FUNDING PROPOSAL TO THE GREEN CLIMATE FUND

CLIMATE CHANGE: THE NEW EVOLUTIONARY CHALLENGE

FOR THE GALAPAGOS

ANNEX 2. FEASIBILITY STUDY

September 2021

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1. Introduction

Climate change represents one of the main threats to the conservation and sustainable use of marine and terrestrial biodiversity worldwide (Mantyka-Pringle et al. 2012). Oceanic islands are especially vulnerable to this global climatic driver due to the fragility of their ecosystems, which are the result of complex evolutionary, geological, and environmental processes (Harter et al. 2015). The geographic isolation of oceanic islands, in combination with the long-term stability of the environmental conditions and natural selection, has promoted high levels of endemic and native species (Jansson 2003; Fordham and Brook 2010). Thus, evolutionary processes shaping island communities have originated insular species with unique behavioral and life-history traits, and ecological relationships suited to stable conditions. Insular species exhibit intrinsic characteristics that make them susceptible to habitat disturbance, including narrow ecological niches, natural restricted distributions, reduced competitive ability and predator awareness, and behavioral or habitat specializations (Cronk 1997; Fordham and Brook 2010; Sodhi et al. 2004). These ecological features make island ecosystems highly vulnerable to invasive species, whose colonization after natural or human-induced disturbances is facilitated by the absence of predators and low levels of interspecific competition (Vilà et al. 2011; Harter et al. 2015).

Climate change in combination with invasive species will exacerbate the degradation of island ecosystems (Keener et al. 2012; Hernández-Delgado 2015; Braje et al. 2017). Physical (e.g., rising air temperature, sea-level rise) and chemical changes (e.g., ocean acidification, O2 concentration declines) can affect both the composition and biodiversity of insular communities and the various functions of the ecosystem, transforming their structure (Keener et al. 2012; Ferreira et al. 2016; Harter et al. 2015). For example, rising sea surface temperature (SST) will result in increased rainfall that affects both low- and highland ecosystems, which likewise will alter plant growth and community structure, promote erosion, and provide better conditions for invasive species (Trueman and D'Ozouville 2010; Larrea Oña and Di Carlo 2011).

Climate change is occurring faster than expected by the scientific community (IPCC 2014; Smith et al. 2015), potentially exceeding the adaptive capacity and resilience of island ecosystems. This is happening in a context, in which most of these unique ecosystems are already degraded by a growing number of drivers of change, increasing the vulnerability of native and endemic species to climate change (Fordham and Brook 2010; Smale et al. 2019; Castrejón and Charles 2020).

1.1 Justification

The Galapagos Islands are located in the Eastern Tropical Pacific (ETP), 960 km west of mainland Ecuador (Fig. 1). This volcanic archipelago is located in the confluence of three major seasonally varying warm and cool water oceanic current systems, and it is strongly affected by El Niño-Southern Oscillation (ENSO), whose main influence area is the Equatorial Pacific Ocean (Liu et al. 2013; Glynn et al. 2018). Hence, the singular location of Galapagos makes it a particularly vulnerable to the potential impacts of climate variability on the demography and life history traits of Galapagos biota.

The larger differences in oceanographic conditions across the archipelago have produced broad-scale and marine biogeographical patterns not observed in other parts of the world (Edgar et al. 2004a; Riegl et al. 2019a; Schiller et al. 2014). These unique features have made the Galapagos a nature-based tourism destination that the local economy depends on (Mathis and Rose, 2016). It generates annual revenues of USD 450 million, representing ca. 20% of Ecuador's tourism gross domestic product and ca. 80% of the local economy (Pizzitutti et al., 2017). However, tourism has produced adverse effects on the Galapagos natural environment, including the introduction of new invasive species, an increasing amount of waste, and growing use of limited local resources, mainly drinking water (Toral-Granda et al. 2017; Epler 2007; Larrea Oña and Di Carlo 2011; Pizzitutti et al. 2017). Besides the increasing number of tourists and invasive species, the Galapagos Islands face several other drivers of change, such as marine pollution, overfishing, and illegal fishing (Schiller et al. 2014; Alava et al. 2014; Salinas-De-León et al. 2020). All of these drivers of change can interact at multiple temporal and spatial scales with ENSO and climate change (Crain et al. 2008; Mantyka-Pringle et al. 2012; Harvey et al. 2013; Graham et al. 2011; Genner et al. 2010; Mouillot et al. 2013), exacerbating their impacts and threatening even more an already fragile system.

Climate change in Galapagos is already evident today. Droughts have heavily impacted the agricultural sector, and 28% of its area is already covered by invasive species, spreading further with climate change. High Ecological Value Areas (HEVAS) from the National Park and the Marine Reserve are also at risk because of invasive species which are much more resilient to climate variability and humidity changes than endemic species. Fisheries have also been impacted, as evidenced during the 2015/16 El Niño event when significant changes were observed in catch composition. These climate change-related effects, in combination with unsustainable tourism, marine pollution, IUU fishing, and overfishing, will impact local human communities, whose livelihoods are dependent primarily on the ecosystem services provided by the unique terrestrial and marine ecosystems of the Galapagos Islands, including nature-based tourism, fisheries, and agriculture.

Further, climate scenarios for Galapagos show that by the 2040s will further alter marine and terrestrial ecosystems. Climate risks include higher sea surface temperatures, ocean acidification, and sea-level rise. On the terrestrial areas, changes expected include the increase of average annual temperatures and rainfall seasonality. Future scenarios also suggest stronger ENSO events (refer to sections 4 and 7 of this document, for details).

In addition, like other islands globally, Galapagos food security is highly dependent on food imports from mainland Ecuador. In 2014, Galapagos consumed 25,000 tons of food, of which 76% was imported, and 24% was locally produced (Sampedro et al. 2018). Most of the imported goods (4500–5000 tons per month) are transported from mainland Ecuador by maritime and air cargo, with predictions rising to 95% by 2036 (Pizzitutti et al., 2017). As Galapagos islands' energy is based on diesel imported from mainland Ecuador, the increasing transport of food from mainland Ecuador to Galapagos will increase the contribution of GHG emissions, decreasing the probability to mitigate the social-ecological impacts expected by climate change.

Finally, the COVID-19 pandemic has revealed the profound vulnerability of the Galapagos economy and food system to global systemic shocks (Castrejón et al., 2021). However, it also has revealed the vital role that the small-scale fishing and agriculture sectors have played to sustain the food security and economy of the Galapagos province in times of need. The economic crisis caused by the pandemic has forced local fishers, farmers, and consumers to adapt their harvesting, marketing, and trading strategies, and consumption patterns. As a result, new opportunities have emerged to promote a systemic transformation of the Galapagos food system to increase its resilience to future crises caused by new pandemics, climate change, and other anthropogenic drivers of change (Castrejón et al. 2021).

The high vulnerability of Galapagos' primary livelihoods to global environmental changes highlights the need to increase the adaptive capacity and resilience of Galapagos and the ecosystem services it provides to Ecuador and the rest of the Eastern Tropical Pacific (Moreira et al. 2018; Cuesta et al. 2017; Fajardo et al. 2014; Kareiva et al. 2011). Adaptation to climate change will demand effective and enforceable regulations to reverse ecosystem degradation and reduce GHG emission and economic and market incentives to ensure the adoption of sustainable and socially responsible practices in the agriculture, fishing, and tourism sectors. All these actions will require political will, as well as financial and human capital. However, if well-targeted, the investment made to help local communities adapt to climate change will yield direct and ancillary benefits in the short and long term, resulting in positive returns on investment and ''win-win'' situations for the coastal communities unique terrestrial and marine ecosystems of the Galapagos.

In this context, the financial resources provided by the Green Climate Fund (GCF) will be fundamental to take advantage of the opportunities created by the COVID-19 pandemic to increase the adaptive capacity and resilience of Galapagos food system and livelihoods, while reducing GHG emissions by adopting a low-carbon development pathway thanks to the implementation of efficient and renewable energy systems.

1.2 Objective

The Development Bank of Latin America (CAF), World Wildlife Fund (WWF) and United Nations Food and Agriculture Organization (FAO), together with Ecuador's Ministry of Environment, Ministry of Agriculture and Livestock, Ministry of Energy and Non-Renewable Resources and the Galapagos Special Regime Governing Council, have submitted to the GCF a proposal for the creation of a five-year program called "Climate Change: The New Evolutionary Challenge for the Galápagos.

The main goal of this Program is to contribute to a transformational change towards a self-sufficient island system in which local livelihoods are developed based on a low-carbon model and enhanced capacity to adapt to climate change. The Program will help overcome barriers related to access to finance, lack of capacity of Galapagos institutions to drive transformational change, lack of technical knowledge on adaptation and mitigation technologies and actions, market barriers from livelihoods, and lack of public awareness and commitment to climate change. It will address mitigation and adaptation with cross-cutting approaches such as behavioral change and ecosystem-based adaptation approaches. Using a combination of funding sources, including loans, grants, and equity, the Program will conduct activities across three main components:

1. ***Energy matrix change in the Galápagos archipelago*****:** this component will increase low-emission energy access and reduce the Galapagos livelihoods' energy consumption by promoting renewable energy generation and energy efficiency investments of the Galapagos livelihoods public and the private sector. The Program targeted the tourism sector because it constitutes a driving force for climate actions based on its significance in the local economy.
2. ***Building climate resilience of the Galapagos' livelihoods***: this component will strengthen Galapagos farmers and small-scale fisheries' adaptive capacity to increase local food production by adopting sustainable land and fisheries practices and restoring key marine and terrestrial ecosystems that sustain Galapagos livelihoods, including tourism.
3. ***Sustainability mechanisms for climate resilience and low emissions livelihoods*****:** this component will strengthen the response of local livelihoods and population through educational and communicational programs and increasing capacity of key institutions by empowering their decision making by mainstreaming climate change into policy instruments.

The Program will be implemented in the four populated islands of the Galapagos (Santa Cruz, San Cristobal, Isabela, Floreana) and the protected areas of the archipelago, including the High Ecological Value Areas (HEVAS) from the Galapagos National Park and the Galapagos Marine Reserve (GMR).

The Programme complements governmental efforts led by the National Government and by the Governing Council of the Galapagos related to climate change, agriculture, water, and energy in the country, notably the NDC and the National Strategy of Climate Change and in particular the recently approved Galapagos 2030 Plan, which was developed in close coordination to this funding proposal. In can be affirmed that the proposed programme will constitute one of the main instruments to help accelerate the achievement of the Plan's objectives.

The main direct stakeholders are the local governments (Government Council of the Special Regime of Galapagos (CGREG) and the Galapagos National Park Directorate (GNPD), the tourism sector (hotels, restaurants, operators), the agricultural sector (farmers), small-scale fisheries and the education sector (schools and universities).

More than 470 beneficiaries from the tourism sector will have access to finance for investing in energy-efficient technologies and distributed renewable energy generation. A total of 624 farmers or UPAS (1,872 persons) and 1,000 fishing households (3,000 persons) will benefit from the implementation. The Program will enhance climate resilience in 19,000 hectares of agricultural areas, 1,500 hectares of Scalesia forests and 138,000 km2 of marine ecosystems. The indirect beneficiaries of the Program are the total population (approx. Thirty-three thousand residents) and the more than 270,000 annual tourists, as distributed power generation will make the electricity from each island's grid cleaner and inclusive. In this way, all the inhabitants of Galapagos will mitigate their activities, become more resilient by reducing their overall energy dependence on diesel imported from the mainland, and enjoy better air quality by reducing electricity generation from thermoelectric plants.

The Programme will lead to an estimated emissions reduction from agriculture, forestry, and other land use (AFOLU) and energy investments of 73,517 tCO_2e per year, about 361,859 tCO_2e during the 5 years of implementation of the Programme, and 1.59 million tCO_2e during its lifespan - 20 years lifetime in the case of AFOLU and 25 in the case of energy investments-.

The Programme will have a total volume of USD 117.59 million. This includes USD 30.54 million from GCF reimbursable funding, USD 25.23 million in senior loans from CAF, USD 23 million from equity from the Conolophus PV plant bid winner Gransolar-Total Eren, USD 3.88 million from equity from the final beneficiaries of the GCCL; USD 33.07 million in grants from the GCF, USD 1.66 million in grants for Programme Management and a USD 0.21 million grant from CAF.

A portion of the reimbursable funding from the GCF and CAF will fund the centralized energy project through a trust fund and another portion will be channeled through intermediated credit managed through the public development bank Corporación Financiera Nacional (CFN) and local banks present in Galapagos. This scheme will serve to overcome current barriers to accessing credit for mitigation and adaptation investments in energy, nature-based tourism, agriculture, fisheries, and ecosystems to reach a wide range of beneficiaries. In addition, the grant portion will be used primarily for supporting the placement of the loans, for investments in enhancing ecosystem resilience, and for technical assistance, knowledge management, and awareness-raising activities.

The Program will be implemented by CAF as the Accredited Entity and will co-work with the Executing Entities WWF, FAO, and CFN. The Government Council of the Special Regime of Galapagos (CGREG), Galapagos National Park Directorate (GNPD), Ministry of Agriculture and Livestock (MAG), Ministry of Energy and Non-Renewable Natural Resources (MEyRNRNR), and Ministry of Tourism (MinTur) are the Governmental partners. The Programme will be led by the Ministry of Environment, Water and Ecological Transition (MAATE) as the NDA.

2. Methodological approach

This feasibility analysis was developed by an interdisciplinary and interinstitutional group of national and international researchers and consultants from the Development Bank of Latin America (CAF), Food and Agriculture Organization of the United Nations (FAO), World Wildlife Fund (WWF), Mentefactura, Universidad de las Americas (UDLA), Universidad San Francisco de Quito (USFQ), Charles Darwin Foundation (CDF), Ecology Project International (EPI) and the Behavioral Insights Team (BIT). It was built on an extensive review of the gray and scientific literature available on the impact of climate variability and change on the terrestrial and marine ecosystems of Galapagos, and the economic activities on which the economy and food security of the local population depend on, and the conceptual and methodological approaches available to promote adaptation and mitigation to climate change. The main economic activities (livelihoods) evaluated included agriculture, fishing and tourism. In addition, the energy matrix of Galapagos was evaluated to determine the level of greenhouse gases emissions (GHG) generated by the human population of the archipelago, including estimations about the potential impact of alternative renewable energy sources on the mitigation of GHG.

The sources of information consulted included:

1. National and international laws, regulations and agreements associated with mitigation and adaptation to climate change.
2. Scientific publications and technical reports regarding the impact of ENSO and climate change on terrestrial and marine ecosystems, agriculture, and fisheries
3. Local and national strategies or action plans associated with mitigation and adaptation to climate change.
4. National and international conceptual frameworks and methodologies to address climate change mitigation and adaptation.
5. Available statistics on energy, agriculture, fisheries, and tourism.
6. Recent diagnoses on the Galapagos food system, including market analysis and value chains on agriculture and fisheries.
7. Management and operational plans of the Directorate of the Galapagos National Park (DPNG) and the Governing Council of the Galapagos Special Regime (CGREG) and decentralized autonomous governments (GAD).
8. Existing local and national projects or initiatives to strengthen the fight against climate change.

The sources of information described were complemented with diverse quantitative and qualitative analyses to determine the potential impact of climate change on Galapagos terrestrial and marine ecosystems, livelihoods, food security and economy under different expected scenarios. Based on the sources of information consulted and the results of the analysis conducted, a series of intervention actions, or ecosystem-based adaptation measures (EBA), were proposed to increase the adaptive capacity and resilience of Galapagos to climate change.

The research carried out for the elaboration of this feasibility analysis produced several technical reports, which are integrated into this report as appendices. The 13 appendices elaborated are grouped into five thematic groups. The content of this report was built on these appendices. Therefore, please refer to each of them to delve into the logic and details of each of the proposed interventions described along this report. The list of appendices developed is the following:

1. Appendix Energy Matrix Change
- 1.1. Appendix Energy
- 1.2 GHG emissions reductions calculations
- 1.3. Innovative Climate Change Challenge_Final Report_KORBA

2. Appendix Livelihoods Resilience
- 2.1 Appendix Agriculture
- 2.2 Appendix Fisheries
- 2.3 Appendix Marine Restoration
- 2.4 Appendix Terrestrial Restoration

3. Appendix Sustainability Programme
- 3.1 Appendix - Ecotourism certification

The appendixes 5.1 and 5.2 correspond to two peer-review papers produced specifically for the development of this feasibility study. WWF-Ecuador and FAO provided the funding needed for research and publication. Their reference is the following:

Escobar-Camacho, D., Rosero, P., Castrejón, M., Mena, C., Cuesta, F. (2021). Oceanic islands and climate: using a multi-criteria model of drivers of change to select key conservation areas in Galapagos. Regional Environmental Change 21:47.

Paltan, H., Benítez, L., Rosero, P., Escobar-Camacho, D., Cuesta, F., Mena, C. (In press.). Climate and Sea Surface Trends in the Galapagos Islands. Nature Scientific Reports.

The purpose of this document is to guide the content of the feasibility studies carried out for each of the sectors. Therefore, it presents a summary of the appendices and peer-review papers elaborated. It is organized in 17 sections. Section 3 provides a general description of Galapagos marine and terrestrial ecosystems and the economic activities on which local population's livelihoods depend on. Section 4 provides an analysis of recent historical climatic observations and future projections available specifically for the Galapagos Islands. Section 5 provides a description of the level of greenhouse gases emissions (GHG) generated by the human population of the archipelago, including estimations about the potential impact of alternative renewable energy sources on the mitigation of GHG. Section 6 explains how different drivers of change, including unsustainable tourism and local population growth, overfishing and illegal, undeclared, and unregulated (IUU) fishing, and invasive species, interact with climate-based drivers such as El Niño Southern Oscillation (ENSO) at multiple temporal and spatial scales, exacerbating their negative impacts on already fragile ecosystems and the socioeconomic system of the Galapagos. Section 7 explains the methodological framework used to identify high-ecological value areas (HEVAs) with high sensitivity and exposure scores to environmental drivers of change. The HEVA represent priority areas for implementing EBA aimed at increasing the resilience and adaptation capacity of the Galapagos Islands. Section 8 explains in more detail the socioecological impacts generated by climate variability and climate change, and other anthropogenic drivers of change, reported by the available scientific studies over different ecosystems, species, and human activities. Section 9 includes a summary of the mitigation opportunities of the Programme. Section 10 describes the intervention actions and EBA prioritized through a multi-criteria analysis methodology that considers potential impact, feasibility level, and potential paradigm shift. Section 11 describes the theory of change of the program proposed to increase the resilience and adaptation capacity of the Galapagos Islands to climate change. Section 12 describes the description of the program, including the rationale behind each intervention action proposed. Section 13 describes the Galapagos' Credit Line channeled through CFN and local banks in Galapagos. Section 14 explains the institutional arrangements for the implementation of the program, while Section 15 describes the governance structure of the program. Section 16 describes the monitoring, reporting and verification (MRV) framework of the program. Finally, Section 17 includes the list of references.

3. Intervention area

3.1 General aspects

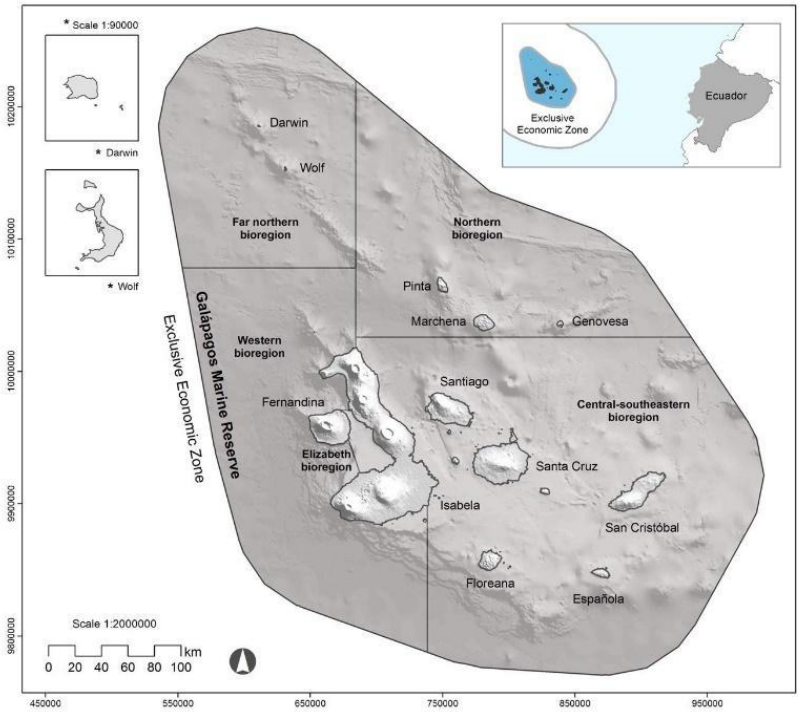
The Galapagos Islands are part of the Republic of Ecuador. They lie about 960 km from the Ecuadorian coast in the Pacific Ocean. Galapagos comprises approximately 234 islands, islets, and rocks with a total land area and coastline of ca. 7,985 km and 1667 km (DPNG, Dirección del Parque Nacional Galápagos, 2014), which are enclosed in a multiple use area (MPA) of nearly 138,000 km^2, the Galapagos Marine Reserve (GMR) (Fig. 1) (Heylings et al. 2002). Nearly 77 percent (7,733 km^2) of the total land surface area is designated as National Park and the remaining 3% (263 km^2) is destined to urban (4%) and rural areas (96%), hosting a population of about 33,000 people (INEC, 2020). Most of the Galapagos territory is protected (97% terrestrial and 100% marine). Galápagos was declared a Natural Heritage Site by UNESCO in 1978.

The archipelago is divided into five marine bioregions, referred to as Far-Northern, Northern, Central-Southeastern, Western, and Elizabeth (Fig. 1) (Edgar et al. 2004a). Each bioregion has distinctive reef fish and macro-invertebrate assemblages, which are unique combinations of species derived from Indo-Pacific, Panamanian, Peruvian, and endemic source areas (Edgar et al. 2004a). The abundance and distribution of these communities are strongly affected by the confluence of warm currents from the north and cool waters from the southwest (Riegl et al. 2019a). The western and central- south bioregions are characterized by colder upwelling conditions (Edgar et al. 2004a), while the northern bioregions exhibit higher SST than the central archipelago.

The GMR encompasses a variety of ecosystems, ranging from coral reefs, coral communities, and mangroves along the shorelines (Glynn et al. 2018; Moity et al. 2019; Tanner et al. 2019) to rocky reefs and newly discovered kelp-forests on seabeds through- out the archipelago (Buglass 2018; Buglass et al. 2017; Eddy et al. 2019; Graham et al. 2007; Okey et al. 2004; Tompkins and Wolff 2016).

The GMR provides habitat for over 2900 fish species, aquatic invertebrates, and marine mammals, 20% of which are endemic (Schiller et al. 2014). The marine diversity in the GMR ranges from emblematic pelagic megafauna species such as whale sharks and mantas to endemic corals, groupers, and coral reef fish (Acuña-Marrero et al. 2014, 2018; Edgar et al. 2004a; Glynn et al. 2018; Hearn et al. 2014). Ecosystems within the GMR are important in the lifecycle of top predators that support shark diversity, shark nurseries, and other demersal ray-finned fishes (Hearn et al. 2010; Llerena et al. 2015; Salinas-De-León et al. 2015; Peñaherrera-Palma et al. 2017). The marine ecosystems of the GMR also provide important services to humans. This occurs mainly through fish productivity, where species such as red spiny lobster, sea cucumber, and demersal serranids are particularly exploited by artisanal fisheries (Hearn and Toral-Granda 2007, Hearn et al. 2005; Castrejón 2011).

Figure 1. Map of the Galapagos Islands with inset showing location of the archipelago relative to continental Ecuador. Surrounding lines denote the Galapagos Marine Reserve with its five bioregions as described by Edgar et al., 2004a: Far-Northern, Northern, Central-southeastern, Western and Elizabeth.



Among the terrestrial environment, islands and islets exhibit a deserted landscape rather than a tropical forest typical of equatorial latitudes. Plants depend mostly on sporadic rain from December to June. However, islands higher than ~ 200m can permanently have a dense fog (Porter 1979). The spatial variation of rainfall with altitude creates a vegetation zonation pattern of three main regions in the Galapagos Islands: (1) the dry lowlands, also referred as the arid zone, which occupies the majority of the archipelago (83% of total land area); (2) the transition zones; and the (3) humid zone or the highlands (Larrea Oña and Di Carlo 2011).

Regarding plant community assemblages, up to seven vegetation zones can be recognized from lower to higher altitudes: (1) litoral, (2) arid, (3) transition, (4) Scalesia, (5) Brown, (6) Miconia, and (7) fern sedge zone. The plant biodiversity in each vegetation zone is adapted to the existing micro-climate conditions (Hamann 2001; Porter 1979). Smaller and lower islands typically have only littoral and arid/dry zones; seven of the islands are high enough to support humid zone ecosystems (Tye and Francisco-Ortega 2011). The Galapagos Islands harbor over 600 plant species, of which 30% are endemic (Galapagos-Conservancy 2021) and mostly in the arid zone (Porter 1979). The humid zone has higher productivity due to its higher rainfall, which provides habitat for many native and endemic species (Larrea Oña and Di Carlo 2011). However, the humid zone is mostly degraded on inhabited islands due to land use and invasive plant species impacts (Laso et al. 2020; Watson et al. 2009). Protected land areas are managed by the Galapagos National Park (GNP), which covers 97% of the land area in the archipelago (GNP, 2021).

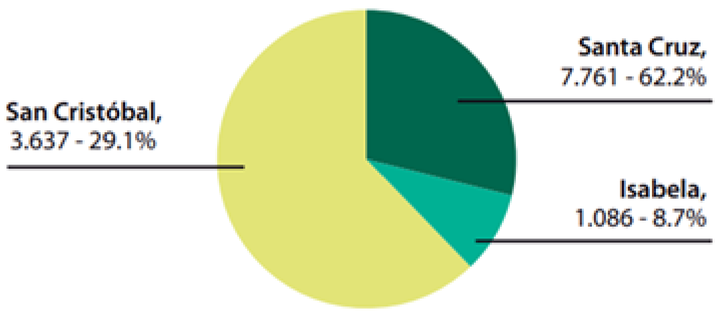
3.2 Demography

According to INEC projections to 2020, the population of Galapagos is 33,042, distributed 61% in Santa Cruz, 9% in Isabela, 29% in San Cristóbal and 1% in Floreana (Figure 2). Based on tourism growth, the number of local residents is likely to increase to between 48,000 and 105,000 people by 2035 (Sampedro et al 2019).

According to the 2015 Census, the population of the Galapagos Islands is mostly young; 68.2% of its inhabitants are between 15 and 60 years of age, and of this age range, the majority are between 25 and 39 years old. There are more men than women of reproductive age because, due to the characteristics of the islands, there is high immigration that is linked to productive activities in which male participation prevails (Desarrollo Sustentable y Ordenamiento Territorial del Régimen Especial de Galápagos, 2016).

The Population and Housing Census (2010) indicated that in 2010 the Working Age Population (WAP) in Galapagos is 17,055 people (67.9% of the total for the province); 73.2% of this corresponds to the Economically Active Population (EAP) and the remaining 26.8% to the Economically Inactive Population (EIP). Of the provincial EAP, 60.2% corresponds to men and 39.8% to women. The Santa Cruz canton concentrates more than 62% of the EAP of the territory. San Cristóbal, where the provincial capital is located, has at least 30% of the provincial EAP. (CGREG 2016, 57).

Figure 2. Distribution of the EAP by canton



Source: INEC, 2020 Population Census. Elaboration: CGREG.

The three main occupations at the provincial and cantonal levels in Galapagos are: service workers and salespersons (20.3%); elementary occupations (14.3%); and tradesmen, workers, and artisans (12.4%).

The Galapagos population is mainly composed of immigrant mestizo population, indigenous people, Afro-Ecuadorians, and a significant percentage of foreign population. An important part of the population are immigrants from provinces such as Guayas, Tungurahua, Manabí, Pichincha, Loja, and others in the Amazon region. The resident population has very diverse characteristics because they have come to the islands from different ecological levels on the continent, mostly from the coast and highlands. There is also an important percentage of the floating population, who come to the islands due to the productive and subsistence dynamics of the islands.

The level of education in both urban and rural areas of Galapagos shows that there is a low level of professionalization of the population, with 2,677 people in urban areas and 263 in rural areas with higher education, while the rest of the population has primary, secondary or no education at all.

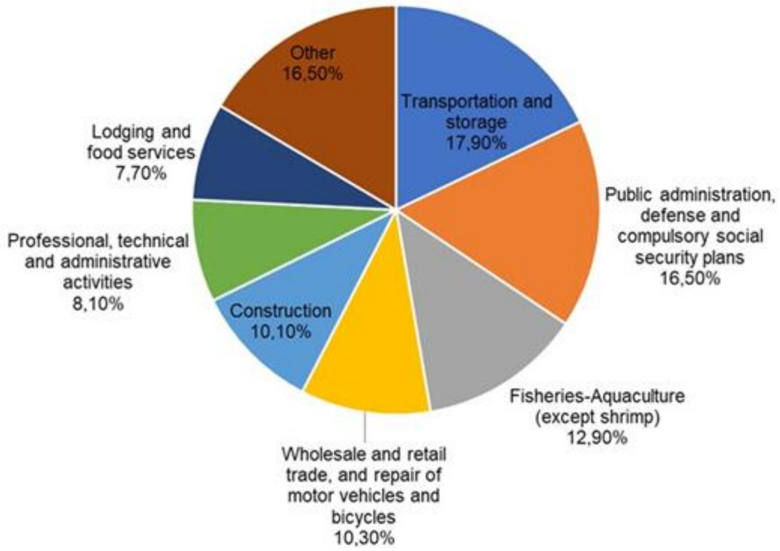
Poverty based on unsatisfied basic needs (UBN) is an analytical approach that allows to highlight the dynamics of poverty and is based on an approach of access to basic services and is more frequently used by developing countries (CGREG, 2010, 5). This method uses specific indicators to show the "satisfaction of household needs". Galapagos is the province with the third lowest poverty rate nationally, followed by Pichincha and Azuay. All provinces share the main reason for poverty, which is limited access to the public water network and deficient excreta disposal systems (CGREG, 2012, pp11).

According to the Living Conditions Survey (INEC, 2009/2010), 52% of the population of Galapagos is living in UBN poverty, meaning that 520 out of every 1,000 people do not meet all their basic needs. At the national level, the number of poor people is 601 per thousand people. If a distinction is made between rural and urban areas, we note that poverty rates are always higher in rural areas, this is because the dispersion of the population hinders the coverage of basic services. In the country, there are 802 people living in poverty per thousand people, while in Galapagos the situation is slightly less critical, with 780 poor people per thousand people.

The economic environment of Galapagos reflects the impact of the main activities on the economy of the islands and their importance in the local gross domestic product, reflecting the high dependence of tourism on the generation of foreign exchange, sources of employment and investment in the archipelago.

Local sales and exports according to data from the Internal Revenue Service (period 2016 - 2020) show that in 2019, 318.1 million USD are generated, which means a growth of 13.7% compared to the previous period in which revenues of 279.8 million USD were generated, however, in 2020, revenues in Galapagos due to the COVID-19 pandemic has a drop of 72.9%, reaching 86.2 million USD. The predominant economic activities in the province, in terms of the annual value added they generate, are presented in the figure below.

Figure 3. Contribution to the provincial GDP of Galapagos by economic activities (2010)



Source: Ecuador Central Bank

As expressed in the Plan for Sustainable Development and Land Use Planning of the Special Regime of Galapagos 2015-2020, there is no balance between the productive sectors that generate the most value added, such as agriculture, fishing and artisanal value added, such as agriculture, fishing, and artisanal activities, because these are the ones that have the least participation in the economic system, contrary to what happens with trade and tourism. The large imports of goods and products from the Ecuadorian mainland added to the increase in tourism and the disincentives and limitations to develop agricultural and fishing activities that were originally the main activities of the islands, have been determining factors for the population to move towards tourism and trade that offer greater opportunities for development and income.

The participation of tourism activity within the overall economic and productive activities of Galapagos reflected in a share of 55.92% in 2019, 56.89% in 2018, 55.88% in 2017 and 56.46% in 2016. Although the economic situation of the tourism industry has reflected a significant drop in sales and visitor arrivals in the Galapagos Islands due to the pandemic, the World Tourism Organization predicts that revenues will return to the same levels as in 2019 as of 2024, reflecting the need to reactivate the companies and businesses that are part of the tourism value chain, the World Tourism Organization forecasts that the islands will return to the same income levels as in 2019 as of 2024, reflecting the need to reactivate the companies and businesses that are part of the tourism value chain.

Tourism does not have the full participation of residents in the entire chain of operation and commercialization, since most of the benefits produced are absorbed by continental companies (national and foreign) that manage tourism operations by providing lodging, food and tourism services. This has generated conflicts and permanent dissatisfaction among local operators and merchants (Salcedo A., 2008). However, while land-based tourism has increased significantly in the last decade and has generated clear and strong links with the local economy, it is developed mainly by national tourists who have a lower average expenditure than foreign visitors.

Another element that has played a decisive role in shaping this model, which is highly dependent on the exterior, is the supply system. Until now, very little attention has been paid to the relationship that should exist between production and consumption of locally generated products, which has a negative impact on the living conditions of the population and the fragility of the island's ecosystem, since it depends on maritime cargo transport for its subsistence (Development and Territorial Management Plan - Galapagos 2030).

3.3 Agriculture

This section puts into context the characteristics and conditions of the food-agriculture system in Galapagos (please refer to Appendix 2.1 Agriculture for details).

3.3.1 Agricultural zones

The agricultural area extends over 2.4% of the island’s territory (19,010 ha.), distributed in 755 farming units, of which 63% are family farms (less than 5 ha.) and 30% are managed by women. All four inhabited islands of the Galapagos, Santa Cruz, San Cristobal, Isabela, and Floreana, have a zone in the humid highlands that has been designated for agricultural use. Farmers represent 5.5% of the economically active population at the provincial level. If the comparison is made at the cantonal level, Isabela is the island where 8.8% of the population is dedicated to this activity, followed by San Cristóbal with 7.3% and finally Santa Cruz with 4.3%. Agriculture in the Galapagos is developed in a defined geographic space, under a special political regime, where there are no opportunities for fair competition with imported products that come from the continent, which are highly subsidized and produced with a lower cost of labor and inputs. Inhabitants of the highlands of the Galapagos use their land for three general activities: cattle ranching (bovine, poultry, pork), crop production (permanent and annual crops), and tourism activities.

From 755 farms surveyed on the four inhabited islands, located in Santa Cruz (357), followed by San Cristobal (260), Isabela (127), and Floreana (11). There is an increase of farms from 604 in the year 2000 to 755 farms in the year 2014 (CGREG, 2015), indicating a process of farm subdivision since the area for agriculture is fixed and has not increased during this time period. The farms are made up of diversified farming and breeding systems, most producers combine crops with livestock, pig farming, and poultry. Thanks to their varied livelihoods, farmers can optimize agricultural income, which is why in Galapagos there are no specialized farmer groups. The raising of hens is common for most farms as a constant source of income. In San Cristobal 61% of San Cristobal farms are dedicated to crop production, 17% to livestock and about 7% keep a mix production. In Santa Cruz about 37% of the farms keep a crop production system, while 26% for livestock activities. In Isabela, crop, and livestock production accounts for 37% and 36%, respectively, while about 16% of the farms are dedicated to mix production. Finally, in Floreana about 36% of the farms have mixed production, 45% of the agroecosystems are dedicated to crop production, and only 9% produce livestock. The coffee production is centered in San Cristobal (26%) and Santa Cruz (74%).

Due to the higher overall humidity and lower average temperatures and solar radiation throughout the year, these areas also record higher productivity and plant diversity when compared to the dryer lowland ecosystems of the Galapagos (Itow, 1992). The continuous influence of atmospheric and climate factors, such as temperature, precipitation, wind and radiation, over highland areas have gradually weathered the islands' volcanic rocks, creating a patchwork of nutrient-rich soils of variable depths and textures (Chiriboga, Fonseca, & Maignan, 2006). - Isabela's agricultural soils are likely easier to cultivate due to their low bulk density, while the coarse texture provides good drainage. These characteristics, along with their high Soil Organic Carbon (SOC) contents, high pH and relative abundance of base cations make the soils of Isabela Island well-suited to agriculture. Many of the soils of San Cristóbal Island are clayey, have low pH values and are largely depleted of their nutrient reserves, which poses challenges to agricultural management. Soils in Santa Cruz Island have intermediate conditions that change with elevation (See appendix 2.1 Agriculture, for details).

The altitude gradient that exists in the Galapagos Islands produces drastic biophysical conditions in a relatively short range in the agricultural areas of the Galapagos. From 100 meters above sea level, the bioclimate ranges from semi-arid to semi-humid. When altitude increases humidity increases with a high presence of drizzle and fog, mainly in cold seasons. These conditions give rise to, different, humid ecosystems favoring the agricultural development of different traditional crops across the gradient (Allauca et al., 2018):

1. Low elevation (150 to 250 m.a.s.l), crops include musaceous (e.g., banana, edible plantain), coffee, vegetables, fruit trees, pineapple, among others.
2. Mid elevation (251 to 450 m.a.s.l), crops include vegetables, corn, potatoes, grasses, among others.
3. High elevation (above 451 m.a.s.l): include grasses, potatoes, and citrus (less quantity).

From the perspective of agricultural activities, the alternation of warm and cold seasons allows the production of both tropical-weather crops and temperate-weather crops on the same altitudinal level. This contributes to the diversification of agricultural production, which is key to the resilience of the system.

There are two distinct sources of food in Galapagos: products imported from the mainland and locally produced. The growing human population in Galapagos, from 18,640 in 2001 to 25,244 in 2015, has increased the demand for food, which has led to most food products being imported from the mainland, generating a cascade of impacts from the abandonment of agricultural lands to the increasing the risk of introducing invasive species to the archipelago.

The consumption per capita of vegetables and livestock food in Galapagos is higher than the Ecuador national average: 0.3119 tons/year/person for agricultural products, which include fruits and vegetables; and 0.1319 tons/year/person for livestock products, which include meat, eggs, and milk, while the national average is 0.2825 and 0.0973, respectively. In general, the main consumption rates correspond to residents who meet their basic needs consuming more than 92% of agricultural products and 98% of livestock (Sampedro et al 2019). The population of the Galapagos Islands depends nearly exclusively on imported food through sea and air cargo because local agricultural production is not able to meet the population's demands for agricultural products with a deficit of 47%. Sampedro et al (2019) calculates that about 75% of agriculture food supply was transported from the continent in 2017 and this will increase to 95% by 2036 if there are not changes in food policies.

The Galapagos consumption behavior has a direct impact on social, economic, and environmental systems through the increased use of resources including agricultural products and livestock production. This requires more land, water, and energy resources, and raises the carbon footprint because of food's transportation (Pizzitutti et al. 2016). Consequently, the expenditures for the population and local authorities also increase (Llive 2016).

3.3.2 Water

As a result of the seasonality of the hydro climatological process, having enough water to sustain human, agricultural, and economic activities has been identified as a major challenge of the Islands. Of the major populated Islands, only San Cristobal has sufficient freshwater sources as it has a series of perennial streams and networks of aquifers which result in water springs and surface water bodies. Santa Cruz and Isabela are dominated by brackish water, characterized by basal aquifers at lower elevations and deep boreholes at higher elevations where water is fresher (Violette *et al.* 2014). Brackish water at lower elevation in Santa Cruz Island results from both seawater intrusion and aquifer overexploitation and it is contaminated with both organic (Liu and d'Ozouville 2013) and inorganic matter (López and Rueda 2010). At higher elevations, water is less saline since it is extracted from deep boreholes (Violette *et al.* 2014). Floreana on the other hand depends on small-outflow springs that have become depleted over the years (d'Ozouville 2007). Thus, across the islands, the water available to sustain various uses and needs is generally deemed as scarce (d'Ozouville 2007). While the main inhabited Islands have diverse characteristics, in various cases they share similar problems. Across Santa Cruz, San Cristobal, Isabela, and Floreana, the lack of universal coverage (or even the total absence) of water systems forces people to store locally water in tanks (Grube *et al.* 2020). An important problem, related to agriculture and cattle ranching, and in general related to human-induced practices, are the impacts to water quality. In general, the contamination by solid wastes, organic wastes, fertilizers and pesticides, garbage thrown and accumulated, affects the superficial freshwater resource in streams or gullies, and in the waters that drain in the subsoil or in the water table.

In Galapagos, water for irrigation is scarce (d'Ozouville 2007, CISPDR 2015). Only 30% of the farms have access to irrigation. In general, the Island of Isabela has access to irrigation by 39%, San Cristobal by 27% and Santa Cruz by 29%. In terms of farm size, small-scale farms have access to irrigation by 30%; and contain high salinity concentrations making it unsuitable for long term use. When dry seasons are intense, or there are poor wet seasons, farmers need to rely on rainfall collection and paid municipal water tanks (CISPDR 2015). In Isabela, freshwater can be found in natural pools and crevices which are rainfed. However, water with sufficient quality can be just found shallowly since brackish and salty water can already be found just a few meters deep (Violette et al. 2014). In this Island, there is no water distribution system for the agricultural and livestock sectors, so farmers here completely depend on the Ministry of Agriculture and Livestock (MAG) and private water tanks (CISPDR 2015). Floreana Island depends on water tanks due to an absence of a distribution system.

3.3.3 Land Use

San Cristobal has the largest area of abandoned farms, representing 46.3% of the total Galapagos agricultural area and 29.5% of the total Island´s agricultural area. Based on 2019 land cover classification using high resolution satellite images (Laso et al., 2020), the agroecosystems in Galapagos show a high landscape heterogeneity, where invasive plants cover most of the surface area (28%), mostly dominated by Psidium-guava reaching nearly 5,000 ha (see section 8 for details) (Table 1). Pastures for raising cattle cover 22% of the agricultural zones and food crops of different kinds cumulatively cover 18% of the surface area. Inside of the agricultural areas, almost 19% of the surface were identified as Native vegetation, mainly located in San Cristobal (2,535 ha). About 12% of the agricultural landscape is covered by vegetation that could not be clearly identified as either native or invasive vegetation. Currently, invasive species cover the largest fraction of the non-active farms ranging from 33.86% in Santa Cruz to 76.19% in Isabela (Laso et al., 2020), being *Psidium guajava* the alien plant with most presence in the area (on average, covers 55%). On the other hand, native vegetation (native forest and pioneers), on average, covers 29% of these areas, where San Cristobal is the only island with a significant cover of native vegetation (42%).

Table 1. Land use in 2014 and 2019 in the Galapagos

Land Cover Class	Land Cover 2014 (Agricultural Census)		Land Cover 2019 (Laso et al., 2020)			
	Active farms		Active farms		Active and abandoned farms	
	Ha	%	Ha	%	Ha	%
Permanent crops	1,517	8	3,171	16	3,913	15
Transitory crops	330	2	587	3	698	3
Pastures	11,126	59	5,117	26	5,618	22
Invasive species	934	5	4,964	25	7,080	28
Pioneer and forest	4,622	24	5,479	28	7,630	30
Other Uses	482	3	169	1	307	1
Total	**19,010**	**100**	**19,488**	**100**	**25,246**	**100**

Food Value Chain

Food availability in the Galapagos depends largely on the extent on food and agriculture inputs (e.g., labor) imported from the mainland, despite recent regulations promoting the local production. However, imports facilitate the introduction of pests and invasive species, imbalance in competitiveness, and consequently affecting the profitability of local production (Viteri and Vergara, 2017), decreasing the resilience to external shocks, including climate change. Based on data from the 2014 Agricultural Census, Granda (2017) shows that local agricultural production in 2014 was 7,085 MT/year, while the entry of products from the mainland was 19,066 MT/year

(MAG, 2018). According to Guzmán (2018), only tomato and cabbage had a local supply greater than the products coming from the mainland in 2009, from the local production 2,939 MT/year corresponds to permanent (81%) and short-cycle (19%) crops. In 2019, Barrera et al. (2019) reported that the crop production increased to 5,359 MT/year, where 84.8% (4,545 MT/year) of the production is destined for sale in the local markets, the remaining for family consumption. In cattle production, 65% of the farms are dedicated to meat production and 35% to milk production. In the Galapagos there is an "intermediary system", which does not differentiate between local and imported foods, which means that everything is sold at the same price, depending on perceived quality, decreasing local product profitability. The diminished returns from selling local produce at markets are driving many landowners to seek a future in the tourism industry and therefore abandon agriculture. On the other hand, local meat production supplies 100% of the local and tourist demand for "fresh meat" due to the laws that prohibit the import of fresh meat to the islands, strengthening this sector. In terms of processed meats (smoked, frozen, among others), local production supplies almost 68% of the demand of the locals and the tourism industry (Espinoza, 2017). There are links (chains) between in the wider economy of the islands through the service industry. In this process, there are also leaks of different types of capital, which allows resources to escape to suppliers who are located outside the area (CEPAL, 2002). In Galapagos, there is a weak articulation within the tourism chain, strong dependence on intermediaries and imported inputs from the continent, with strong potential for leaks in the system, and leakages of profits, services, utilities, and other to the mainland, which impacts the local economy.

The promotion of the local agricultural system is, therefore, a fundamental link to strengthen the food chain, in addition, to developing adaptive agricultural systems in the face of climate change. The destinations of its products are multiple: most are fresh products, consumed by families or sold as raw materials within the local environment. The differences in production costs between the mainland and the islands, regular availability (lack of supply) and limited access of healthy and fresh foods, vulnerability to transportation issues make it difficult for local products to be competitive in local markets. Institutional frameworks, such as transportation subsidies for products from the mainland, which promote the importation of food are negative factors for local production (Viteri and Vergara, 2017). In addition, local agriculture is also impacted by the low degree of association among producers and lack of efficient technologies.

In the Galapagos Islands, producers are grouped through unions, associations, and cooperatives. According to data from the SPMSPC (National Secretary for People, Social Movements and Citizen Participation) in 2012, 41% of active social groups were in San Cristobal, 67% in Santa Cruz and 46% in Isabela. The Institute of Popular and Solidarity Economy, also registered in 2015 a total of 13 community organizations, associations, cooperatives, and integration organizations (CGREG, 2020). Coffee production has been promoted by a cooperative COPGALACAF, which encompass coffee farmers from the 4 inhabited islands and have strong relationships with the community. Current Situation of the main local products

Global trends in agriculture are applicable in the Galapagos as well. Most agricultural lands (58.9%) are extensive pastures for cattle ranching which employ few or no technologies for optimizing resource use. About 224 cattle (equivalent to 80,088 pounds of meat) are slaughtered every month across the entire province and over 91% of the meat is sold on the local market. Santa Cruz supplies 69% of the total meat sales, while San Cristobal provides 25%, and Isabela contributes the remaining 6% (MAG, 2018). Furthermore, local pig and poultry production satisfies approximately 84% of the demand of the resident and tourist populations. Importing unprocessed meat into the Galapagos is prohibited by law due to biosafety and quarantine standards, so local farms are usually the only beef suppliers for local consumption. However, the entry of frozen tenderloin has been allowed for the tourism sector because tourists demand a greater quantity of quality products than what local markets can provide (see appendix 2.1 Agriculture, for details).

3.4 Fisheries

This section puts into context the general characteristics and conditions of the food-fisheries system in Galapagos (please refer to Appendix 2.2 Fisheries, for details).

3.4.1 Fishery resources, fishers, and governance

Approximately, 68 marine species are commercially exploited in Galapagos (Castrejón, 2011), being the most relevant yellowfin tuna (*Thunnus albacares*), wahoo (*Acanthocybium solandri*), swordfish (*Xiphias glaudius*), sailfin grouper (*Mycteroperca olfax*), mottled scorpionfish (*Pontinus clemensi*), snapper (*Lutjanus argentiventris* and *L. novemfasciatus*), almaco jack (*Seriola rivoliana*), white-spotted sandbass (*Paralabrax albomaculatus*), misty grouper (*Hyporthodon mystacinus*), octopus (*Octopus oculifer*), slipper lobster (*Scyllarides astori*), spiny lobsters (*Panulirus penicillatus* and *P. gracilis*), among other finfish and shellfish species (Haro-Bilbao and Salinas-de-León, 2014; Schiller *et al.*, 2014; Castrejón and Moreno, 2018). The brown sea cucumber (Isostichopus fuscus) is also harvested, but this fishery has remained closed since 2015. However, at least three other species (Stichopus horrens, Holothuria kefersteini, and H. atra) are illegally caught (Toral-Granda 2008).

The small-scale fishing sector is a strategic sector to sustain the food security and economy of the Galapagos human population (Castrejón, 2011). In 2014, the estimated gross annual revenue generated by the entire Galapagos small-scale fishing sector was US$4.35 million (Lynham *et al.*, 2015). There are 1100 fishing license holders and 333 vessels registered by the Galapagos National Park Directorate (GNPD), which are distributed in three main fishing ports (Baquerizo Moreno, Puerto Ayora, and Villamil; Fig 1). However, only 36.4% and 44.1% of fishers and vessels registered by the GNPD remain active in the fishing activity (Castrejón and Charles, 2020). Small-scale fishers are organized into five fishing cooperatives: COPROPAG, ASOARMAPESBAY, COPESAN, COPESPROMAR, and COPAHISA. The Law of Cooperatives and its associated regulations regulate fishing cooperatives at the national level. The maximum decision-making authority within a cooperative is the General Assembly, which is composed of all its members.

Currently, the Galapagos artisanal fishing fleet is made up of two types of vessels: (1) mother vessels up to 18 m in length and 50 gross registered tons; and (2) small vessels up to 12.5 m in length. According to the current legal framework, the only fishing gears allowed for the fishing of large pelagic fish include the trawl line with lure or bait, locally called trolling; rod with or without reel, and hand-line.

Ecuadorian industrial fisheries are prevented from fishing within the borders of the GMR and are only allowed to operate within the exclusive economic zone (EEZ), an area that extends from outside of the GMR border to 320 km. The most important target species caught by the Ecuadorian industrial and artisanal fishing fleet are the skipjack, yellowfin, and bigeye tuna (*Katsuwonus pelamis*, *Thunnus albacares*, and *Thunnus obesus*, respectively) and mahi-mahi (*Coryphaena hippurus*) (Schiller et al. 2014; Castrejón 2020a).

Before the industrial fishing fleet was prohibited in the GMR, the contribution of Galapagos tuna landings to the Ecuadorian tuna industry was approximately 24.3% (Bustamante, 1999). It is estimated that at the Ecuadorean tuna industrial fleet captured a total of 12 410 t of yellowfin tuna, 11 428 t of bigeye tuna and 5 872 t of skipjack tuna in Galapagos between 1995 and 1997. These catches represented, respectively, 28%, 38% and 7% of the total catch per species registered at national level (Bustamante, 1999). In contrast, the total landing of yellowfin tuna recorded in Galapagos during 2016 (131.3 t) contributed only 0.002% to the total catch of this species recorded in Ecuador (57 747 t) during that same year (Castrejón and Moreno 2018).

The Galapagos National Park Directorate (GNPD), in collaboration with non-environmental organizations (NGO) and other strategic allies, has taken concrete actions to prevent and eradicate the impacts of overexploitation and illegal, undeclared and unregulated (IUU) fishing and to ensure the sustainability of Galapagos small-scale fisheries. The most relevant has been the creation of the GMR, through the approval of the Galapagos Special Law (GSL) in march 1998 (González et al. 2008; Castrejón 2011). The GMR ensures the conservation of this immense natural wealth and guarantees sustainable economic development for the island's population. Since then, several fisheries management measures have been implemented to shift from an open-access to a common property regime in fishery resources (Heylings and Bravo 2007; Castrejón 2011). Some of the most important included the prohibition of industrial fishing inside the reserve, the allocation of exclusive use rights to local fishers, in the form of licenses and fishing permits, a moratorium on new entrants, and the adoption of an ecosystem-based spatial management (EBSM) approach. The latter was implemented through the adoption of marine zoning, a spatially explicit management tool that was designed and implemented through a consensus-based participatory process between 1999 and 2006 (Heylings et al. 2002; Castrejón and Charles 2013). As a result, ca. 18% of the Galapagos coastline were declared as no-take zones (Fig. 1), whose individual size ranged from small offshore islets to a 70 km span of coast, with no offshore boundaries legally established (Heylings et al. 2002; Castrejón and Charles 2013).

Unfortunately, the effectiveness of Galapagos marine zoning to improve the governance and sustainability of SSF has been limited by the biased location of no-take zones in areas of low abundance of the most lucrative fishery resources (e.g., sea cucumbers and spiny lobsters), in combination with a lack of effective enforcement and a high rate of non-compliance (Edgar et al. 2004b; Viteri and Chávez 2007; Castrejón and Charles 2020). The sea cucumber fishery collapsed in 2006 (Wolff et al. 2012b; Defeo et al. 2016), while the Galapagos grouper, the white-spotted sand bass, and the olive grouper (*Epinephelus cifuentesi*) show signs of overexploitation (Usseglio et al. 2016; Eddy et al. 2019). Despite these failures, spiny lobster stocks showed an unexpected and remarkable recovery after a period of overexploitation, probably caused by the combined effect of market forces and the ENSO rather than no-take zone implementation (Defeo et al. 2013b; Defeo et al. 2016; Szuwalski et al. 2016; Castrejón and Charles 2020). Nevertheless, overfishing and IUU fishing of sea cucumbers, groupers, and sharks has substantially decreased their ecological role on marine ecosystems, triggering cascading effects with profound effects on the whole food web (Ruiz and Wolff 2011; Eddy et al. 2019).

As ENSO and climate change are likely to exacerbate the effects of overexploitation and IUU fishing, it is fundamental to comprehend how fishery resources, and people that depend on them, will be affected by climate stressors in the coming decades. This is a research and management priority relevant for sea cucumbers, sailfin grouper, and many other Galapagos shellfish and finfish fisheries, whose exploitation status is overfished or unknown (Schiller et al. 2014; Usseglio et al. 2016). Based on this knowledge, policies aimed at building resilience of Galapagos marine ecosystems must be implemented by the GNPD and the Galapagos Governing Council to increase the resilience and adaptive capacity of fishery resources, fishing communities, and institutions to cope with and adapt to climate change. However, even though climate change and variability are currently attracting the most attention, the socioeconomic disruptions caused by overexploitation and IUU fishing, and their ecological impacts on targets species, critical habitats, and ecosystems, should not be neglected (McCay et al. 2011; Defeo et al. 2013b; Castrejón and Charles 2020).

3.4.2 Value chain and market analysis

Before the COVID-19 pandemic, the annual demand for fish was approximately 871.3 t, of which 31% was consumed by the local community (271.8 t), while the remaining 69% was consumed by tourists (599.5 t) (Berman et al. 2018). It is estimated that 14% of the fish consumed in the Galapagos, before the pandemic, was yellowfin tuna (122 t). The remaining 86% (749.3 t) corresponded to the fish species that make up the whitefish fishery, locally known as "pesca blanca", being the Galapagos sailfin grouper the species in greatest demand, particularly during the Easter season. Approximately 70% of tuna landings (138.5 t) were consumed in Galapagos, while 30% were shipped to mainland Ecuador (58.3 t) (Berman *et al.*, 2018).

Furthermore, before the COVID-19 crisis, a significant proportion of seafood consumed by tourists in the Galapagos occurred in cruise ships. Approximately 197.2 t of fish and 51.4 t of shellfish were consumed annually in cruise ships (Haro-Bilbao and Salinas-de-León, 2014). Most of the fish (75.3%) was sourced locally, while shellfish was mostly procured in mainland Ecuador (91.9%). The most common species sourced outside Galapagos, either frozen or canned, include shrimps (*Penaeus sp*.), squid (*Loligo sp.*), octopus (*Octopus sp.*), snake eel (*Ophichthus sp.*), Nile tilapia (*Oreochromis niloticus*), Atlantic salmon (*Salmo salar*), corvina (*Cynoscion sp.*) and South Pacific hake (*Merluccius gayi*) (Haro-Bilbao and Salinas-de-León, 2014). Tuna is also imported to satisfy the local demand for canned seafood, despite this species is available fresh or frozen in Galapagos. In consequence, the food security of the Galapagos is highly dependent on food imports from mainland Ecuador. In 2014, 25 000 t of food were consumed in the Galapagos, of which 76% was imported and 24% was locally produced (Sampedro *et al.*, 2018). Most of the imported goods (4500–5000 tons per month) are transported from mainland Ecuador by maritime and air cargo (Pizzitutti *et al.*, 2017). About 70% of the food imported is processed and dry food, 38.7% are seafood, and 38% are fresh fruits and vegetables (Viteri, 2017).

A growing number of value chain and market analysis studies have been conducted since 2014 to identify business opportunities that contribute to increasing the economic value of the tuna fishery, without the need to increase catch levels. However, the efforts associated with this management approach have been, in most cases, short-term, isolated, and without adequate and sustained institutional and financial support to ensure the creation of the necessary enabling conditions to take advantage of the business opportunities offered by the Galapagos small-scale tuna fishery. Velasco et al (2014) provides an overview of the profitability of the Galapagos fishery value chain (demersal, pelagic, lobster and sea cucumber fisheries), describing the revenues of the main stakeholders participating in the supply chain, such as boat owners and fishers. This study also highlights the differences among stakeholders specialized in one or several fish products. The second study, Haro-Bilbao y Salinas 2014, estimates the demand of fish products by the tourist cruise ship fleet in Galapagos, based on surveys applied to a sample equivalent to 80.2% of the passenger capacity of the whole cruise ship fleet. The third study by Berman et al. (2018), is based on an in-depth analysis of the local tuna market, and on interviews of numerous stakeholders of the GMR, such as fishers, boat owners, seafood stores, restaurants, and cruise ships.

Based on the above analyses, several inefficiencies in the supply chain that hinders the creation of additional value within the tuna fishery have been identified, together with a set of potential business opportunities that could increase the profitability of the Galapagos tuna fishery. The most pressing value chain inefficiencies associated with the Galapagos tuna fishery are highlighted below (Viteri et al. 2018):

- The market for Galapagos tuna is unsophisticated and poorly coordinated. As in many fishery supply chains, the movement of tuna in Galapagos relies on long standing personal and disparate business relationships between many boat-owners and distributors, particularly in the early stages of the supply chain.

- The lack of coordination between fishers has led to the emergence of numerous intermediaries in the local market who extract significant value from the tuna fishery. As a result, Galapagos fishers only capture 27% of the value created in the local market, and just 21% of the value in the export market (Berman et al. 2018).

- Fishers have limited negotiating power relative to the single export market buyer. The latter is due to limited buyer competition, as well as the limited local capacity to qualify the quality of tunas.

- There is not a differentiation of tuna prices according to tuna quality.

Therefore, the value of the tuna fishery could be improved through the following strategies:

- Increasing the quality of the tuna caught, rather than their quantity.
- Implementing adequate harvest and post-harvest techniques to improve and maintain tuna quality.
- Developing value-added seafood products (e.g., smoked tuna, tuna burgers and sausages, etc.). Strengthening the organizational and entrepreneurial capacity of fishers to link them directly with markets that offer them a better price for their catches.

3.5 Tourism

Tourism is the main driver of change behind increasing demands for natural resources and population growth in the Galapagos, leading to an unsustainable development model that is fundamentally incompatible with the long-term conservation interests. In less than 10 years, the number of tourists that visit Galapagos has grown 417%, from 65,000 to 271,238 between 2000 and 2019 (Fig. S8A). Nature-based tourism is the primary economic engine of the Galapagos and generates annual revenues of USD 450,000,000 (Pizzitutti et al. 2017). This represents close to 20% of Ecuador's tourism Gross Domestic Product (GDP) and almost 80% of the local economy (Pizzitutti et al. 2017). The international representation of the Galapagos has transformed the islands into a world-class nature-based tourist destination, receiving a staggering 271.238 visitors in 2019 (DPNG 2019).

The tourism industry has promoted demographic and economic growth for the Galapagos, resulting in ca. 30, 000 residents (Epler 2007; Walsh and Mena 2016) that depend both directly and indirectly on the tourism industry (Fig. S8B). The population growth rate in the islands is three times higher than on the Ecuadorian mainland (Pizzitutti et al. 2017), while the economy is one of the fastest-growing economies in the world. In response, the Ecuadorian Government has implemented restrictive migratory measures to avoid immigration into Galapagos. However, the resolution of this problem is more difficult than expected due to a complex intersection of economic, cultural, social, and political realities associated with the human development of inhabited islands (Brewington 2013; Epler 2007). Exponential rates of tourism arrivals have also negative feedbacks to local population, especially indirect effects on public health, as flux of migrants put increase pressure to the weak health systems, potable water network and pressure over food security (Walsh and Mena 2016; Thompson et al. 2020; Nicholas et al. 2019; Houck et al. 2020).

3.6 Energy

Nowadays, electricity generation is highly dependent on imported fossil fuels, grids are inefficient, distributed renewable energy generation is not the mainstream, and there is important room to promote the adoption of energy efficient appliances. With a lower impact, a change in land use practices by the agriculture sector can also bring benefits in GHG emissions reductions.

The electric power generation system has four isolated grids, thermoelectric plants are the main source of power generation (Table below). The energy sector consumed a total of 3,5 million gallons of diesel (ELECGALAPAGOS, 2019), in addition to consumption associated with ship transport to the islands, represented emissions worth 35,415-ton CO_2eq/year. The fuel used for electricity generation is shipped from mainland Ecuador 1,000 km away; this constitutes additional GHG emissions associated with transport and adds to the environmental and social risks associated with diesel transport to the islands upon ecosystems and species.

Table 2. Characteristics of the Galapagos' current generation park

System[1]	Customers 2019 [#]	Peak Load [MW]	Diesel Power installed [MW]	Wind power installed [MW]	Solar Power installed [MW]	Energy Storage [MWh]	Diesel Consumption 2019 [Gal.]
Santa Cruz-Baltra	7770	6.65	13.9 (11 units)	2.25 (3 units)	1.567	4 LA[2] 0.268 LI	2.31 million
San Cristobal	3792	3.39	8.4 (8 units)	2.5 (3 units)	-	-	1.11 million
Isabela	1417	1.37	1.62 (5 units)	-	0.922	0.258 LI	0.383 million
Floreana	94	0.078	0.283 (4 units)	-	0.021	0.19 LA	0.023 million

Source: ELECGALAPAGOS, 2020

In 2007 under the "Zero Fossil Fuels in Galapagos Islands," introduced the first renewable energy power plants. Additionally, the renovation of the thermoelectric plants conducted in previous years, allowed a reduction of diesel consumption by 1.1 million gallons in 2016 (Ministerio de Energía Eléctrica y Renovable, 2017a). Since 2007, solar and wind projects have been developed proving their effectiveness in Galapagos. Other renewable generation technologies have been analyzed, finding limitations to their development in the short and medium term, such as the case of geothermal energy available only where there is no electrical demand (MEER, 2010), or tidal energy limited by the environmental impact to the marine protected areas (Rodríguez-Santos & Chimbo-Campuzano, 2017).

The 2017-2026 Ecuador Electricity Masterplan (PMEE) included the Plan for Generation Expansion in the Galapagos Isolated System (PEGSAG 2018), which seeks to shift the current energy generation composition of the islands (85% diesel, 11% wind, 4% solar) towards 60% renewables penetration (Ministerio de Electricidad y Energía Renovable, 2017b). As a non-interconnected system, it faces challenges in terms of control, reliability, and stability. It is critical to improve efficiency considering the 11% of energy losses in the distribution system and electricity consumption of auxiliary equipment.

Specific for Santa Cruz, the 2018 PEGSAG proposed a set of wind farm, PV plant and ESS projects for the short-term and a similar set for the medium-term.

The government endorsement of the private initiative PV project for this island, called PV Conolophus project started on June 6, 2020, and has already finished the tender process and the concessionaire Gran Solar-Total Eren are the bid winners. At the moment (July 12, 2021) the Ministry of Energy has to sign the resolution.

In a public act transmitted via telematics, June 12th, 2021, the economic offer (envelope no. 2) scheduled for the public selection process for the Conolophus Renewable Energy Project, located in the Galapagos Islands, was opened. This project proposes the installation of 14.8 MW of

1 Energy Balance 2019, ELECGALAPAGOS

2 LA: Lead acid battery; LI: Lithium-ion battery

photovoltaic generation with 40.9 MWh batteries on Santa Cruz Island. A private investment of 45 million dollars is estimated.

The Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources presented a reserve price of 565.41 dollars per MWh, while the offer of the association Gransolar/Total Eren was 458.88 dollars per MWh. Of the five companies authorized in August 2020, only the group submitted a technical offer, so in April, the Technical Commission signed the Evaluation and Qualification Act of the Technical Offer (envelope No. 1), in which it resolved enable the Gransolar/Total Eren consortium for the next phase of the PPS corresponding to the opening of the economic offer.

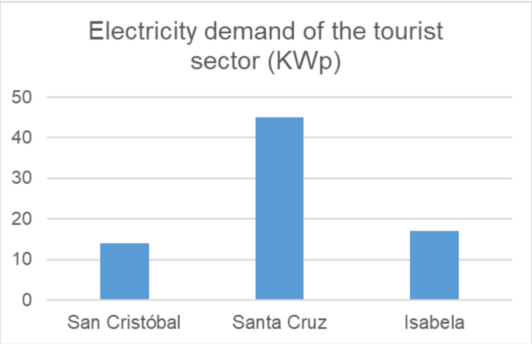
The great weight of tourism in the islands' emissions profile

Tourism contributes to anthropogenic global climate change through the emission of greenhouse gases (GHG) related to accommodation, activities, and transport (Moreno & Amelung 2009). Tourism has grown at almost the same rate as electric power demand in Galapagos, with an annual average growth rate of 7.7%, representing more than half of the total electric consumption, thus suggesting a direct driver for associated emissions (Ministerio de Energía Eléctrica y Renovable, 2017b).

Tourism can be separated into boat-based (48% accommodation growth/ 75% occupation rate) and land-based tourists (324% accommodation growth/ 20% occupation rate) (Ministerio de Turismo, 2016). Boat- based spends the main part of their tourism experience on-board, while the land-based tourists rely almost completely on local products, services, and labor. As the major economic engine, tourism --in all its forms-- is the main driving factor behind increasing demands for natural resources and population growth (IUCN & UNESCO, 2006), leading to an unsustainable development model, fundamentally incompatible with long-term conservation interests. Economic growth is encouraged by government subsidized fuel, electricity and transportation of people and goods from the continent (CDF, GNP, 2010).

The electricity demand and the number of tourism businesses in Galapagos are as shown in the figures below.

Figure 4. Electricity demand of the tourism sector (left). Number of tourism businesses in Galapagos (right).



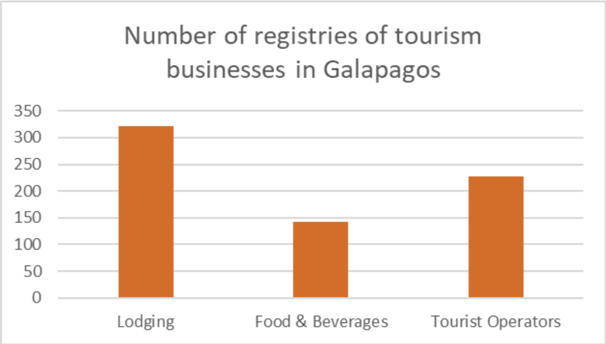
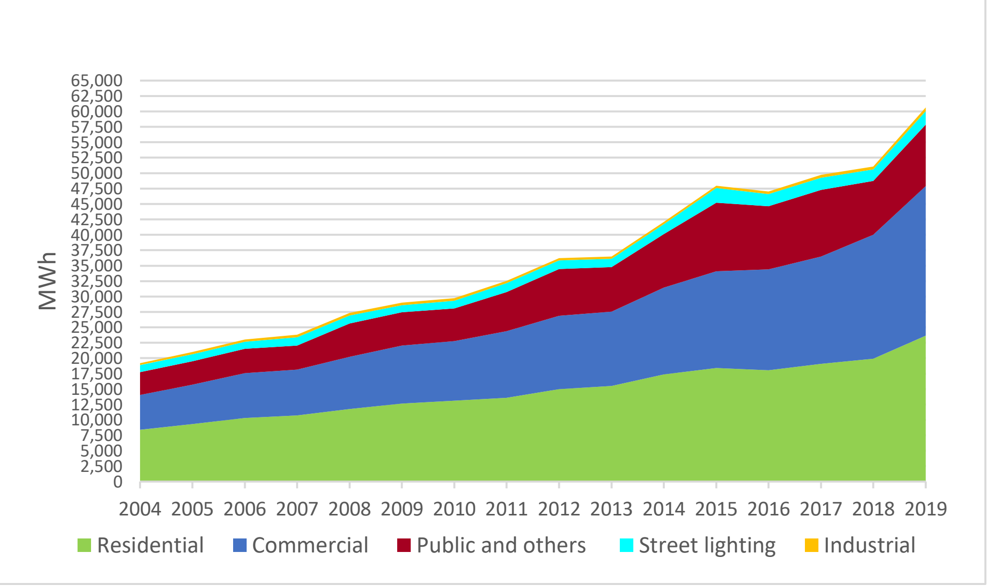


Figure 5. Historical demand by sector shows how the commercial/tourist sector's demand has increased in the last years, being the main source for the growing total demand (growth rate: 41%).



3.7 Institutional framework

The Programme is aligned and consistent with the Republic's Constitution, guaranteeing nature's rights and recognizing special regimes for planning and development. It explicitly states that the government will promote the use of clean and alternative energy sources, in addition to energy efficiency, while providing access to public services, preserving the environment, and maintaining food and water security.

The project´s institutional framework is formed by the following national, regional and local institutions whose capacities, competencies and legal mandates are fundamental for the implementation of this program.

- *The Government Council of the Special Regime of Galapagos / CGREG[3]:* Public law entity created by constitutional mandate, responsible for administration, planning, land management, citizen security, resource management and the organization of activities in the province of Galapagos to ensure the conservation of the natural heritage of the State and good living.
- *Galapagos National Park Directorate / GNPD*: Responsible for the conservation of the ecological integrity and biodiversity of the island and marine ecosystems of the archipelago's protected areas, as well as the rational use of the goods and services they generate for the community.
- *The Ministry of Agriculture and Livestock / MAG*: Governing institution and executor of public agricultural policies. We promote productivity, competitiveness, and health of the

3 All Acronyms correspond to the names in Spanish.

sector, with environmental responsibility through the development of technical, organizational, and commercial capacities of agricultural producers at the national level, with emphasis on small, medium, and family farming, contributing to food sovereignty.

- *Ministry of Energy and Non-Renewable Natural Resources / MEyRNRNR*: Promotes the development and sustainable use of energy and mining resources, with social and environmental responsibility, through the formulation, implementation, monitoring, and evaluation of public policies, applying principles of efficiency, transparency, and integrity in its management.
- *Ministry of Tourism / MinTur:* governing body that plans, manages, promotes, regulates, and controls sustainable tourism in Ecuador.
- *Empresa Eléctrica Provincial Galápagos / Elecgalapagos*: Entity responsible for generating, distributing, and commercializing quality electric power and public lighting services, complying with the current legal framework; with the continuous improvement of internal processes, promoting energy efficiency and environmental care in Galapagos.
- *The Galapagos Biosecurity Regulation and Control Agency* is the Galapagos' health authority and oversees reducing the risk of introducing exotic species to the islands that may affect the islands' biodiversity, people's health, and the productive sector.

3.8 Legal framework

The political and legal environment of Galapagos is subject to a set of regulations that directly influence the political and institutional management of the archipelago, the most important of which are described below.

3.8.1 National

- **Constitution of the Republic of Ecuador**

The Political Constitution of the Republic of Ecuador, in Article 14, Title II, Chapter Two, states that: "The right of the population to live in a healthy and ecologically balanced environment that guarantees sustainability and good living, Sumak Kawsay, is recognized".

On the other hand, Article 284 states among the objectives of the economic policy: "To encourage national production, systemic productivity and competitiveness, the accumulation of scientific and technological knowledge, strategic insertion in the world economy and complementary productive activities in regional integration" (National Constituent Assembly, 2008).

Likewise, in reference to the province of Galapagos, due to its unique characteristics, Article 258 provides that: "It shall have a special regime government. Its planning and development will be organized in strict adherence to the principles of conservation of the State's natural heritage and good living, in accordance with the law" (National Constituent Assembly, 2008).

- **National Development Plan 2017 - 2021 - Toda una Vida (A Whole Life).**

The "National Development Plan 2017-2021" is a national planning instrument whose objective is to strengthen the decentralized territorial planning system and contribute to the progressive fulfillment of constitutional rights and the objectives of the development regime through the implementation of public policies, projects and interventions that are framed on two pillars which are environmental sustainability and equitable territorial development, highlights policy 9.4 which proposes: Position and enhance Ecuador as a mega diverse, intercultural and multiethnic country, developing and strengthening the national tourism offer and cultural industries; promoting inbound tourism as a source of foreign exchange and employment, within a framework of protection of natural and cultural heritage.

- **Organic Code of Territorial Organization Autonomy and Decentralization**

The Organic Code of Territorial Organization, Autonomy and Decentralization COOTAD establishes the political-administrative organization of the Ecuadorian State in the territory; the regime of the different levels of decentralized autonomous governments and special regimes, in order to guarantee their political, administrative and financial autonomy.

- **Organic Law of the Special Regime of the Province of Galapagos**

The LOREG establishes a set of measures to regulate the special regime of the province of Galapagos and establishes the administrative legal regime to which they are subject, within the scope of their powers, both from the Governing Council of the Special Regime of the province of Galapagos, and from the Decentralized Autonomous Governments and agencies of all State functions, as well as from all natural and legal persons, national and foreign that are within or that perform activities in the province of Galapagos, based on a strict adherence to the principles of conservation of the natural heritage of the State and Good Living.

3.8.2 Climate change

In recent years, Ecuador has taken important steps towards developing a legal framework for climate change mitigation and adaptation under the leadership of the MAATE. The country's National Climate Change Strategy (2012-2025) establishes the strategic and institutional basis for the generation of national climate change plans in prioritized sectors for mitigation and adaptation. The present proposal is coherent with the spirit of the strategy and particularly the action lines related to: Conserve and sustainably manage the natural heritage and its terrestrial and marine ecosystems to contribute to their capacity to respond to the impacts of climate change; Identify and incorporate appropriate practices to mitigate climate change in the agricultural sector, which can also strengthen and improve its productive efficiency and competitiveness; Strengthen the implementation of measures to promote energy efficiency and sovereignty, as well as the gradual change of the energy matrix, increasing the proportion of renewable energy generation, thus contributing to climate change mitigation.

Ecuador is in the final stages of developing its National Adaptation Plan (NAP), which is expected to be completed between late 2021 and early 2022. This proposal is aligned with the main areas of activity of the NAP, related to strengthening the technical and institutional capacity of planners and decision makers, improving information on climate vulnerability at the territorial and sectoral levels, and contributing to monitoring, reporting and verification of adaptation.

The National Climate Change Mitigation Plan (PLANMICC) is currently in its initiation phase. This Plan is one of the climate change management instruments in accordance with the Organic Code of the Environment and its Regulations and aims to reduce greenhouse gas emissions and conserve and increase carbon sinks, in accordance with national capacities and circumstances, without harming the competitiveness and development of the different sectors. The Plan will establish the measures and actions to mitigate climate change, as well as the mechanisms and instruments for their implementation and coordination.

Climate change adaptation and mitigation have also been addressed through national policies since 2009 via Executive Decree 1815, and through the Inter-institutional Committee on Climate Change established in 2010, via Executive Decree 495. Furthermore, Ecuador has adopted the 2030 Agenda for Sustainable Development as a national policy through Executive Decree 371 from April 2018.

The Programme falls within the NDC presented by Ecuador in March 2019, in which the energy sector is vital in emissions reduction and development of adaptation measures in strategic environmental areas in Ecuador. The present proposal contributes to the following NDC’s lines of action and initiatives: boost the use of renewable energy, strengthen energy efficiency by supporting equipment replacement; promote sustainable livestock development; develop and implement sustainable agro-productive systems, and strengthen sustainable forest management. In adaptation, it will contribute to the following measures and goals:

- Natural Heritage: improvement of the public policy instrument for natural heritage including ACC, implementation of sustainable practices for the use of natural resources in areas of influence.

- Water Heritage: incorporation of climate change criteria and national and sectoral strategies and plans of the water sector, inclusion of climate change variables in technical feasibility and in the regulation and control of water resources and control of water resources. and implementation of its management plans to ensure, in the future, water in quantity and quality; and design and implementation of actions that contribute to increasing the adaptive capacity of hydraulic infrastructure (existing and new) for multiple use.

- Creation and strengthening of capacities on climate change, management of natural heritage and water resources.

- Implementation of communication, dissemination and capacity-building programs that allow the awareness of actors in the agriculture and water sector about the effects of climate change.

The Programme is in line with the “Galapagos Zero Emissions”, which intends to gradually reduce the use of fossil fuels in vehicles, vessels, and thermoelectric energy generation, as well as to progressively replace conventional vehicles with electric vehicles in the Galapagos archipelago, initiative for the decarburization of the tourism sector.

On the education and participation activities side, the Programme is aligned with the Paris Climate Change Agreement and the 2030 Agenda for Sustainable Development that “unanimously recognize the importance of education and public awareness in the drive towards sustainable development”, and in particular with the Action for Climate Empowerment (ACE) contained in article 6 of the United Nations Framework Convention on Climate Change and in article 12 of the Paris Agreement. ACE has six interdependent and interrelated elements: education, training, public awareness, public participation, public access to information, and international cooperation. They all play a fundamental role in accelerating adaptation and mitigation actions regarding climate change. At the National level, these activities are aligned with several local initiatives, the National Adaptation Plan Project (PLANACC), and the National Strategy of Environmental Education for Sustainable Development 2017 2030 (ENEA) and the “Tierra de Todos” programme, promoted by the MAAE in collaboration with the Ministry of Education (MINEDUC), to contribute to climate and environmental literacy in Ecuador.

Additionally, the Programme is aligned with the Environmental Organic Code, sanctioned in 2018, and includes climate change measures in local planning strategies.

The proposed Programme was developed in close consultation with national and local authorities representing all stakeholders involved in the different activities, allowing appropriation and alignment to contribute to relevant state policies by strengthening capacities and competencies of key national and local institutions. The Stakeholder Engagement Plan sets the guidelines for an effective engagement of the different actors related to the Programme’s initiatives.

3.8.2 Energy

- Regulation to the Organic Law of the Electric Energy Public Service - August 20, 2019.
- Regulation of Concessions, Permits and Licenses for the Provision of Electric Energy Services - March 31, 1998.
- Electricity Master Plan 2016-2025.
- National Electric Energy Plan 2016-2035.

- Plan for Sustainable Development and Land Management of the Special Regime of Galapagos 2030.

3.8.3 Ecosystems

Applicable regulations:

- Organic Code of Production, Commerce and Investments Official Gazette No. 351 of December 29, 2010.
- Organic Environmental Code Supplement to Official Gazette No. 983 of April 12, 2017.

Planning Instruments:

- Proposed PDSOT 2030
- Galapagos National Park Management Plan

Proposed Climate Change chapter for the National Park Management Plan.

3.8.4 Tourism

- Tourism Law

Article 3 defines the principles of tourism activity, literal b) The participation of provincial and cantonal governments to promote and support tourism development, within the framework of decentralization. On the other hand, regarding tourism promotion, Art. 76.- Promotion, states that the Ministry of Tourism "will dictate the policies and the referential framework in order to position the country as a tourist destination, the management of tourism promotion corresponds to it in conjunction with the private sector. The means of promotion and marketing will be conventional channels such as fairs, workshops, familiarization trips, journalists' trips, congresses, expositions, among other non-conventional means such as tourist information services, internet and promotional material, etc.".

- (Within) Regulations of the Organic Law of the Special Regime of the Province of Galapagos

This regulation, in Title IX, Chapter I, Art. 50, states that "sustainable tourism shall be understood as a model that responds to the current needs of tourists and the province, while protecting and improving opportunities for the future. It is focused on the adequate management of all resources, so that they satisfy economic, social and conservation needs; within the framework of respect for cultural integrity, essential ecological processes, biological diversity and life support systems". Similarly, Article 51 establishes that tourism in the province of Galapagos is based on "the principles of sustainability, environmental limits, conservation, public use, safety, and quality of tourism services".

- Special Regulations for Tourism in Natural Protected Areas RETANP

The RETANP establishes a set of policies for the regularization and control of tourism activities in the State's Natural Areas Heritage, highlighting the development and promotion of sustainable tourism; as well as citizen participation in the cultural, social, educational and economic benefits generated by the exercise of tourism activities in the State's Natural Areas Heritage; as well as the conservation of ecosystems and their resilience to the impacts of climate change and the sustainable use of natural resources; and the minimization of the negative impacts resulting from the exercise of tourism activities in the State's Natural Areas Heritage.

Other regulations applicable to the sector:

- Organic Code of Production, Commerce and Investments Official Gazette No. 351 of December 29, 2010.
- Organic Administrative Code Official Gazette Supplement No. 31; of July 7, 2017.
- Organic Code of Planning and Public Finances Official Gazette Supplement No. 306; of October 22, 2010
- Organic Environmental Code Official Gazette Supplement No. 983; of April 12, 2017

3.8.5 Agriculture and water

Relevant regulations:

- Organic Code of Production, Commerce and Investments Official Gazette No. 351 of December 29, 2010.
- Organic Administrative Code Official Gazette Supplement No. 31; of July 07, 2017
- Organic Code of Planning and Public Finances Official Gazette Supplement No. 306; of October 22, 2010
- Organic Environmental Code Official Gazette Supplement No. 983; of April 12, 2017.
- April 12, 2017
- Rural Lands and Ancestral Territories Law Official Gazette Supplement No. 711; March 14, 2016
- Organic Law on Water Resources, Uses and Development of Water.
- Official Gazette Supplement No. 305; August 6, 2014.
- Organic Law of the Food Sovereignty Regime Official Gazette Supplement No. 583; May 5, 2009.
- Law for the Creation of the Public Company National Storage Unit, Official Gazette No. 16; June 17, 2013.

Planning Instruments:

- AM 068 Strategic Plan 2017-2021.
- Proposed National Agricultural Plan.
- Proposal to update policies for Ecuadorian agriculture.
- Proposal for a Sustainable Agriculture Plan for Galapagos.
- Proposed PDSOT 2030 for Galapagos.

3.8.6 Fisheries

Applicable regulations:

- Organic Code of Production, Commerce and Investments Official Gazette No. 351 of December 29, 2010.
- Organic Environmental Code Supplement to Official Gazette No. 983 of April 12, 2017.
- Law of Fishing and Fishing Development (1974)
- Special Regulations for Artisanal Fishing Activity in the Galapagos Marine Reserve (REAPRMG; 2003).

Planning Instruments:

- Fishing Calendar (2016-2021).
- Management Plan for the Galapagos National Park Marine Reserve.

3.8.7 International

- United Nations Framework Convention on Climate Change (UNFCCC)
- Nationally Determined Contributions (NDCs)
- United Nations Convention to Combat Desertification (UNCCD)
- Sustainable Development Goals 2030
- Chengdu Declaration on Tourism and Sustainable Development Goals
- Universal Declaration of Human Rights (UDHR)
- American Convention on Human Rights 1969
- Additional Protocol to the American Convention on Human Rights in the Area of Economic, Social and Cultural Rights (Protocol of San Salvador) (1988)
- Sustainable Development Goals

- Convention on the Elimination of all Forms of Discrimination Against Women (CEDAW)
- Eight core ILO Conventions
- ILO Convention no 169
- United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)
- Convention on Biological Diversity (CBD)
- National Biodiversity Strategies and Action Plans (NBSAPs)

3.9 Financial system

3.9.1 Financial supply (green financing baseline)

According to the Ecuadorian Bank Association, by the end of November 2020, the balance of the loans portfolio granted by private banks reached a value of USD 29,184 million. Of the total financing awarded, USD 17,349 million were granted to production credit. The credit for productive sectors, housing and microenterprise is 59% of the total portfolio. On the other hand, credit for consumption was 41% of the total which is USD 11,834 million. The balance in the commercial loans reached USD 12,891 million at the end of November 2020, Galapagos reported a total credit volume bordering USD 8 million during the same period. The default rate of all private banks at the end of November 2020 was 2.8%, while in Galápagos it is 0,4% lower than the national average. Default by segment closed in November at 0.8% for the commercial segment, 4.5% for consumption, 4.8% for mortgages and 4.2% for microcredit.

The total of green credits allocated in the financial system compared to the total loan allocation is minimal (less than 0.4%). Out of 26 banks are allowed to operate in Ecuador, only 15% offer this type of credit and the amount is minimal compared to the total credit allocation. Since the lack of financing supply is substantial, the GCF loan will not disturb the market money costs. In fact, it is the opposite, it will supply the financing necessities of an industry with an unsatisfied demand, therefore, it can be concluded that requesting funds to the GCF in the form of concessional loans and grants is justified. According to data from Asobanca, since 2016 the bank Produbanco has disbursed $142 million in this type of product. Procredit more than $ 72 million (since 2012). Banco Pichincha started in 2018 and to date has placed $ 150 million. The requirements and conditions to access this financing are basically the same as for a traditional credit, but these are added to the environmental standards, certification and MRV schemes. Interest rates respond to the segments set by the Superintendency of Banks, the ranges are differentiated by the customer segment, which can be corporate, business, SME, or microcredit. In general terms, the green credit is on average 2,0% lower than the normal interest rate.

Please see the complete assessment in Appendix 4.1 - Market Study of the Ecuadorian Financial System.

3.9.2 Financial demand

An analysis of the demand for credit in each of the sectors has been carried out. Please refer to Section 12 " Programme Description", subsections "Market Study" for each of the Outcomes where applicable: Outcome 1.1. Centralized energy and renewable energy; Outcome 1.2 Energy efficiency; Outcome 2.1 Agriculture and fisheries; and Outcome 2.2. Ecosystems.

4. Galapagos climate, trends and future scenarios[4]

The Galapagos Islands is one of the major vulnerable global hotspots to environmental and climatic change (Hobday & Pecl, 2014; Escobar-Camacho *et al.*, 2021). This is due to their unique location, which causes them to be exposed to various oceanographic and climatological variations and affects the distribution of marine species and habitats across the archipelago (Trueman and D'Ozouville, 2010). The influence of currents and winds is governed by interactions of the Inter-Tropical Convergence Zone (ITCZ) and the El Niño Southern Oscillation (ENSO) (Houvenaghel, 1974; Sachs and Ladd, 2010). Specifically, the ITCZ migration influences the main bi-seasonal characteristics of currents and winds of the Islands, whereas ENSO regulates yearly decadal fluctuations (Hamann, 1979, 1985; Hartten and Gage, 2000).

The seasonality of the ITCZ combined with the topography of the archipelago gives rise to the two seasons in Galapagos: a warm and rainy season, from January to May, and a cool and dry season extending from June to December (Hamann, 1979; Itow, 2003, Colinvaux, 1972). During the warm and rainy season evaporation due to high sea surface temperature (SST) leads to orographic rainfall that increases with altitude, thus, lowlands only receive a fraction of the annual rainfall and stay dry (except in El Nino years) (Trueman and d'Ozouville 2010; Snell and Rea, 1999). Contrastingly, during the cool season the air is cooled by the ocean surface and creates condensation because of being trapped below masses of warmer air. This condensation occurs above 250 m altitude and creates heavy mists and horizontal precipitation, that are blown inland from the ocean and are shifted upwards by the mountains and consequently cooled resulting in more intense rainfall in the highlands (Hamman, 1979, Trueman and d'Ozouville 2010; Sachs and Ladd, 2010).

The Tropical Eastern Pacific (TEP) exhibits inter-annual SST variability that is dominated by the ENSO cycles (Wang and Fiedler, 2006). El Niño (warm phase) events are characterized by high SST, a lack of west-to-east thermal gradient across the surface of the Pacific and a weakening of the easterly trade winds (Snell and Rea, 1999). El Niño (warm phase) effects in the Galapagos include high air temperatures, sustained high SST, increased rainfall, and a longer than usual warm season, whereas La Niña (cold phase) events result in abnormally cold conditions and drought (Sachs and Ladd, 2010). Past strong el Niño events (1975-76, 1982-3, 1993-4 and 1997-8) (Martin et al., 2017; Trueman and D'Ozouville, 2010) triggered dramatic effects on both marine and terrestrial ecosystems (Snell and Rea, 1999). Coral reefs suffered intensely during this period, with 98% of corals being wiped out by coral bleaching (Glynn, 1994, 1990; Lessios et al., 1983; Robinson, 1985) followed by a significant decrease in marine species diversity (Edgar et al., 2010; Stein Grove, 1985). During El Niño events the bottom of the food chain is also impacted by ENSO, as phytoplankton concentrations can decrease substantially (33-46%) because of high

4 This section is based on a peer-reviewed paper that is currently under revision in the Journal Nature Scientific Reports: Paltan, H., Benítez, L., Rosero, P., Escobar-Camacho, D., Cuesta F., Mena C. Climate and Sea Surface Trends in the Galapagos Islands. This study was developed specifically for the design of this proposal and it was funded by the Food and Agriculture Organization of the United Nations – Ecuador Program and WWF-Ecuador.

temperatures in the archipelago, leading to community-level reductions in biomass (Wolff et al., 2012).

The impact of ENSO events also extends to terrestrial ecosystems and communities. Heavy rainfalls characteristic of El Niño can trigger massive increases in herbaceous plants, which can then stimulate increased abundances of exotic invasive species and vines (Larrea Oña and Di Carlo, 2011). Over-flooding can also result in increased mortality for resident species, such as for arboreal plants (Aldaz and Tye, 1999; Tye and Aldaz, 1999) that have trunks smothered by vines (Hamann, 1985; Tye and Aldaz, 1999) and giant tortoises that die due to injury or drowning in flooded ravines (Marquez et al., 2008). Land birds (e.g. finches) can also be negatively affected by El Niño events due as to the intensity of perturbations and because high rainfall triggers more intense parasitism (Dudaniec et al., 2007; Fessl and Tebbich, 2002; Grant et al., 2000). Despite the occurrence of ENSO events in the Galapagos for thousands of years, strong El Niño events are unusual. However, evidence suggests that El Niño events have increased in intensity and frequency over the last two decades due to warmer SSTs (Conroy et al., 2010, 2008; Rustic et al., 2015; Thompson et al., 2017).

Apart from influencing the Islands' biological and ecosystem diversity, the climate —and its land-ocean impacts— also has repercussions on local socioeconomic conditions and overall human welfare (Sachs & Ladd, 2010). For instance, oscillations in Sea Surface Temperature (SST), due to changes in primary productivity, are often linked to fish abundance and distribution(Wooster & Hedgpeth, 1966; Houvenaghel, 1978; Chavez & Brusca, 1991; Witman & Smith, 2003; Palacios, 2004). Such changes affect artisanal fisheries that harvest at least 68 fish species and several marine invertebrates for domestic consumption and overseas exports(Toral-Granda, 2008; Schiller *et al.*, 2015; Zimmerhackel *et al.*, 2015).

However, despite the clear role played by climate in the Galapagos Islands, little is known about the region's present and future climatic trends(Sachs & Ladd, 2010). This is of particular relevance for the islands of Santa Cruz, San Cristobal, and Isabela, since they are home to over 99% of the Islands' population(Instituto Nacional de Estadística y Censos (INEC), 2015a). There is also an overall lack of understanding of current SST trends. A failure to acknowledge climate and SST changes may, in turn, severely undermine our ability to understand the extent of the fragility of human populations and ecosystems (along with their diversity) on the Islands.

The main aim of this section is to provide an analysis of recent historical climatic observations and future projections available specifically for the Galapagos Islands. Its objectives are threefold: first, we describe the recent trends (1981-2017) for key terrestrial land surface climatological variables (precipitation and temperature) for the two Islands with sufficient hydrometeorological records (Santa Cruz and San Cristobal). To expand our understanding of key climatic variables during this period, we also include re-analysis products and satellite sources (as given by CHELSA, MODIS, ERA5, and CHIRP products; see Materials and Methods for details) to detect these trends in the region. We the estimate climatological values for Isabela. Second, we report historical SST trends for the Galapagos Marine Reserve (GMR) as read by MODIS products. Third, by examining climate projections derived from both Ecuadorian (Ecuadorian Ministry of Environment, or MAE, for its acronym in Spanish) and international climatological repositories (as given by the CHELSA projections) we shed light on the future evolution of the terrestrial-climate variables. Our analysis also seeks to provide an initial diagnostic on the dispersion of climatological datasets, highlighting the lack of sufficient observational records available.

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4.1 Methodological considerations

Precipitation and historical observations of temperature were first obtained from the five active weather stations publicly available on the Islands, which have information spanning three decades or more. These stations are managed by the Ecuadorian National Meteorological and Hydrological Institute (INAMHI, for its acronym in Spanish) with the collaboration of the Charles Darwin Research Station (CDRS). They are divided as follows: four principal climatological stations, and one precipitation-only station.

We obtained observations from the four stations located on both San Cristobal and Santa Cruz islands, since they have recorded data for a period of 30 years or more. We should note that three stations, M0192, M0191, and M0221, provided both precipitation and air temperature readings, whereas M0508 records only rainfall. The meteorological station in the coastal region of Santa Cruz (M0191) has kept records since 1965, whereas the station in the highlands of the same island has been recording data since 1988. To maintain temporal consistency between stations and ensure an adequate comparison across time, we have used the data from the 1980s onwards.

We also acknowledge the existence of other meteorological stations owned by NGOs, individuals, and private institutions. However, they are not publicly available, or lack the temporal extension required for a robust multi-year analysis. For example, the station at Isabela (M0194) began its readings in 2002, and the recorded data is only available until 2004. As such, meteorological stations on Isabela are not functional for the purpose of this study. The Universidad San Francisco de Quito's Galapagos Science Center likewise manages five stations on San Cristobal, but their temporal availability ranges from two to six years. The lack of sufficient observations, combined with the complex topography and habitat diversity in the islands, thus prevented us from following traditional extrapolation exercises.

We also used an altitude threshold of 250 m.a.s.l. to differentiate between coastal (low) and highland regions. This threshold is first given by the estimated altitude at which condensation (and thus drizzle and heavy mist) occurs and has been identified in previous research(Hamann, 1979; Sachs & Ladd, 2010). This threshold has been applied for past studies, principally in the agricultural, agrodiversity, and food security sectors on the inhabited islands (Allauca Vizuete *et al.*, 2018). We acknowledge that this threshold may reflect variation if spatial variability within specific islands is accounted for. However, we believe that this altitude sufficiently captures the climatological and other physical dynamics that serve to differentiate between high and lowlands for the multi-island comparison analyses.

Next, we enriched the meteorological records from INAMHI by including available satellite observations, as well as climatological reanalysis products. As such, we first evaluated how satellite products describe temperature and precipitation patterns in the islands analyzed. To carry this out, we used the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) (Funk *et al.*, 2015) and MODIS (Wan *et al.*, 2015) satellite products for precipitation and temperature analysis, accordingly. We also then evaluated ERA-Interim or ERA5 (Hersbach *et al.*, 2020) temperature and precipitation products for the region.

CHIRPS is a land-only daily rainfall dataset available since 2014. Compared with all other existing precipitation databases, the principal characteristic of this dataset is the high resolution of the available data (0.05 degrees ≈ 5km). As with MODIS, we use the Land Surface Temperature and Emissivity (MOD11C3) product, which provides high spatio-temporal data for the "skin" temperature at 0.05 degree of resolution. ERA5, on the other hand, is a recent product that provides gridded records of precipitation and air surface temperature at high temporal resolution and with somewhat finer spatial resolutions than other gridded data products of climate variables. This product has been developed by the Copernicus Climate Change Services and the European Centre for Medium-Range Weather Forecasts (ECMWF) with a 0.1° grid resolution. The time range of the datasets used here spans a 38-year period (1981-2017) except for MODIS data, which is available from 2000 until the present.

We also acknowledge that while the products used here are already calibrated against local observations, more local applications and studies would be benefit from additional data manipulation and correction techniques. Similarly, the differing degree resolutions of the various products used should be recognized. While the cross-product comparison occurs at the grid level, our findings may be also biased by physical and climatological processes that are not captured or are oversimplified at the sub grid level.

To understand the potential impact of climate change on the Galapagos Islands, we examined temperature and precipitation from: i) the official estimates from the MAAE, to downscale climate projections from four selected CMIP5 and; ii) climate outputs from the CHELSA effort. The MAE climate projections consist of the dynamically downscaled outputs of four GCMs: CSIRO-Mk3-6-0, GISS-E2-R, IPSL-CM5A-MR, MIROC-ESM. The final spatial resolution of this product is 10km. For more information see (Ministerio del Ambiente (MAE)., 2017).

CHELSA is a high resolution (30 arc sec, ~1km) dynamical global climate dataset for land surface areas, which is hosted by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)(Karger *et al.*, 2017). Here we use a collection of 13GCMs that have been reported to better represent and capture the Eastern-Pacific ENSO dynamics(Kim & Yu, 2012; Bellenger *et al.*, 2014), and thus are relevant for the Galapagos Islands. The GCMs used here are: CNRM-CM5, CSIRO-Mk3-6-0, FGOALS-g2, GFDL-ESM2G, GFDL-ESM2M, GISS-E2-H, GISS-E2-R, HadGEM2-CC, HadGEM2-ES, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM, and NorESM1-M. Climate conditions were characterized for the reference or baseline periods 1979-2013 and 1981-2015 for CHELSA and MAE data, respectively. Overall, the CHELSA and the MAE efforts provided us with a total of 55 climatic scenarios.

Changes in extreme precipitation and temperature conditions was calculated from the ensemble of models used here. This is from the total 55 scenarios combining climate trajectories and modelling efforts. Extreme anomalies (very hot, very warm, very cool, and very dry conditions) are obtained from the 90^{th} and 10^{th} percentile estimates for the total of ensembles. For each ensemble, change was calculated from the difference between the future projections and their historical reference periods (979-2013 and 1981-2015 for CHELSA and MAE data, respectively).

Lastly, to assess SST variation, we used the NASA annual SST MODIS L3 satellite product for 2002 – 2018 with a spatial resolution of 4 km. For this, we ran a simple linear regression model between the annual mean SST of the entire Galapagos Marine Reserve (GMR) during the observed period, which provided an estimation of the increasing trend of inter-annual SST variability. Then, we estimated SST anomalies using a reference mean surface temperature of 25 °C, calculated for the GMR for the year 2002. The differences between the reference temperature and the grid values for each year were calculated. Finally, we estimated the mean anomaly for the 2002-2018 period. For this, the spatial and temporal patterns observed in the SST anomalies and trends, respectively, were analysed by a Mann-Kenndal following (Pohlert, 2016).

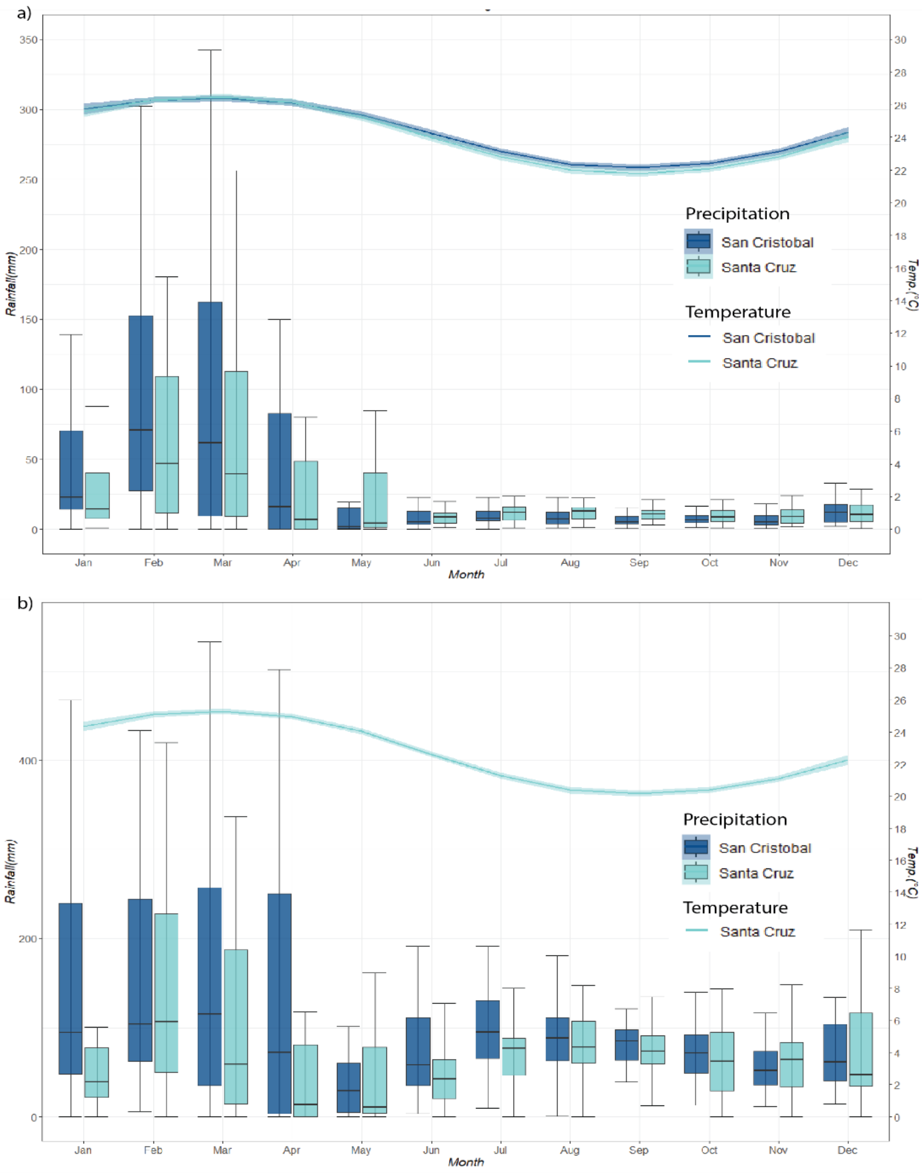
The test for SST was conducted independently for the five Marine Bioregions (Edgar *et al.*, 2004) using the mean SST of the GMR per year. Because there were differentiated spatial patterns and increasing trends for each marine bioregion, we built two models of exposure to sea currents for the GMR: first, we modelled exposure to warm and cool currents with intervals of 20 km; second, we assessed the combined effect of multiple environmental variables in explaining SST trends for the observed time period through a multiple regression analysis using standard least-squares for fitting a model with annual SST values as the dependent variable. This analysis was implemented with all the SST data for the GMR. As predictive variables, time period, the exposure to warm currents, and longitude were used. Before the regression analysis was carried out, we conducted a Pearson correlation analysis between all the variables to exclude strongly correlated (Pearson correlation, $r < 0.6$) explanatory variables. We selected the best model by minimizing the residual mean square, the Akaike information criterion (AIC), and maximizing r2.

4.2 Current and observed temperature trends

We find that mean annual land surface temperatures over the last 35 years (1981 – 2017) ranged from 22°C to about 26°C as read by the meteorological stations in Santa Cruz and San Cristobal (Figure 6). Over this period, we note that mean land surface temperature has increased by approximately 0.6°C in the lowlands (regions with altitude less than 250 meters above sea level (m.a.s.l). Here the increase in mean annual temperature is approximately 0.02°C/year, sd ±0.4). In the highlands (regions with an altitude above 250 m.a.s.l.), mean land surface temperature has increased by approximately 0.21°C (0.02°C/year, sd ±0.2). It is of particular note that, in the highlands, this increase responds mainly to higher observed temperatures during the dry/cold season (Jun-Nov). In the coastal region, or lowland areas, the pattern is reversed: here, the rate of mean temperature increases is higher during the wet/warm season (Dec-May).

We also find that the MODIS-LST satellite product seems to significantly overestimate observations. ERA-5 re-analysis data seems to merely approximate observed meteorological values, and solely in the Coastal zone of Santa Cruz, while CHELSA historical temperature estimates seem to detect seasonality and magnitudes better. We also found that, on this dataset, temperature distributions show a lapse rate of 0.55 °C per 100 meters. The thermal amplitude ranges from a mean air condition of 24°C at sea level to as cold as 15°C at 1600 m.a.s.l., at the highest, mountainous regions of the islands. Also, as read by CHELSA, it can be observed that over the recent decades, mean temperatures in the coastal region of Isabela were around 22.7 (sd ±0.3), whereas in the highlands, they were around 19.8 (sd ±0.7).

Figure 6. Mean annual precipitation and temperature values as observed by the meteorological stations in Santa Cruz and San Cristobal between 1981-2017 for: a) Coastal Regions, b) Highland Regions. Error bars are shown for precipitation and confidence intervals (95%) for temperature.



4.3 Current and observed precipitation trends

4.3.1 Temporal trends

As for precipitation, during the 1981-2017 period, mean annual rainfall in Santa Cruz and San Cristobal was about 500mm (sd ±185 in the coastal-arid regions, concentrated primarily in the wet/warm season (Figure 6). During the dry/cold season, mean rainfall was around 130 mm (sd ±65). On the other hand, in the highlands the mean annual rainfall ranges from about 1050 mm and 1670 mm—the difference between wet/warm and dry/cold is not as accentuated as in the coastal/low areas. During the dry/cold season, water vapour from the ocean surface rises and condenses at higher altitudes, and this condensation creates fog and heavy mists in the highlands (referred to locally as *garúa*)(Sachs & Ladd, 2010; Trueman & d'Ozouville, 2010). In the highlands, this *garúa* may account for nearly 35% of total rainfall in July and August on the island of Santa Cruz.

Our results also show that precipitation is highly variable, particularly during the wet season. This mainly corresponds to the influence of the El Niño years (1982-83 and 1997-98) on island climate (See Supplementary Figure 1 in Appendix 5.1): these years were almost three times wetter than non-El Niño years (about 3000mm of mean annual precipitation for El Niño years vs 1100mm for non-El Niño years).

Over the period analyzed, we notice a decreasing trend in the mean annual precipitation values across the Islands. Indeed, our analysis finds a significant decreasing rainfall trend for both San Cristobal and Santa Cruz over the last decade (Table 3). This is mainly caused by significant reductions in precipitation during the wet season, which could be as high as about 140mm (in the highlands of Santa Cruz, or 27% of seasonal rainfall). We also find that the dry season in Santa Cruz over the last decade has shown a positive wetting trend, particularly in the highlands (about 43mm or 9% of seasonal rainfall, or 4% of the region's total annual rainfall). However, a slightly wetter dry season may not be sufficient to compensate for the wet season losses. In fact, when compared with the 1981-2000 period, both islands were on average 45% drier during the first two decades of this century.

It is nonetheless important to recognize the influence of strong El Niño events in these trends. When we remove the 1982-83 and 1997-98 events from the time series, various of the drying trends described above are reversed. For instance, without ENSO events, rainfall in fact increases by over 40% during the last decade in the highland of San Cristobal. Trends may thus be biased by the influence of unusual and very wet ENSO events during the 1982-1983 and 1997-1998 periods.

Table 3. Precipitation Trend Analysis for San Cristobal and Santa Cruz Islands for the 1981-2018 period. Trends were obtained from a Modified Mann-Kendall's Test (MMKT) to investigate the presence of monotonic trends (upward or downward) (Sen, 1968). Results of trend tests are reported at a 90% confidence interval. Marked cells correspond those where a significant trend was found. Light red cells mark periods where a drying trend is observed, whereas those colored light blue mark where a wetting trend is detected.

COAST

		Annual		Wet Season		Dry Season	
	Period	Q	p-value	Q	p-value	Q	p-value
SAN CRISTOBAL	1981 - 1990	4.6	0.70	14.5	0.17	-2.1	0.37
	1991 - 2000	-6.9	0.85	-2.6	0.80	6.3	0.45
	2001 - 2010	-1.3	1.00	-7.5	0.72	**-5.0**	**0.00**
	2011 - 2018	**-76.5**	**0.01**	**-70.8**	**0.01**	**-4.4**	**0.01**
SANTA CRUZ	1981 - 1990	**-35.9**	**0.06**	-10.6	0.34	-2.5	0.25
	1991 - 2000	-26.2	0.48	-23.8	0.43	-1.7	0.70
	2001 - 2010	5.2	0.25	8.4	0.27	**-3.2**	**0.00**
	2011 - 2018	**-58.6**	**0.00**	**-61.2**	**0.00**	**5.9**	**0.00**

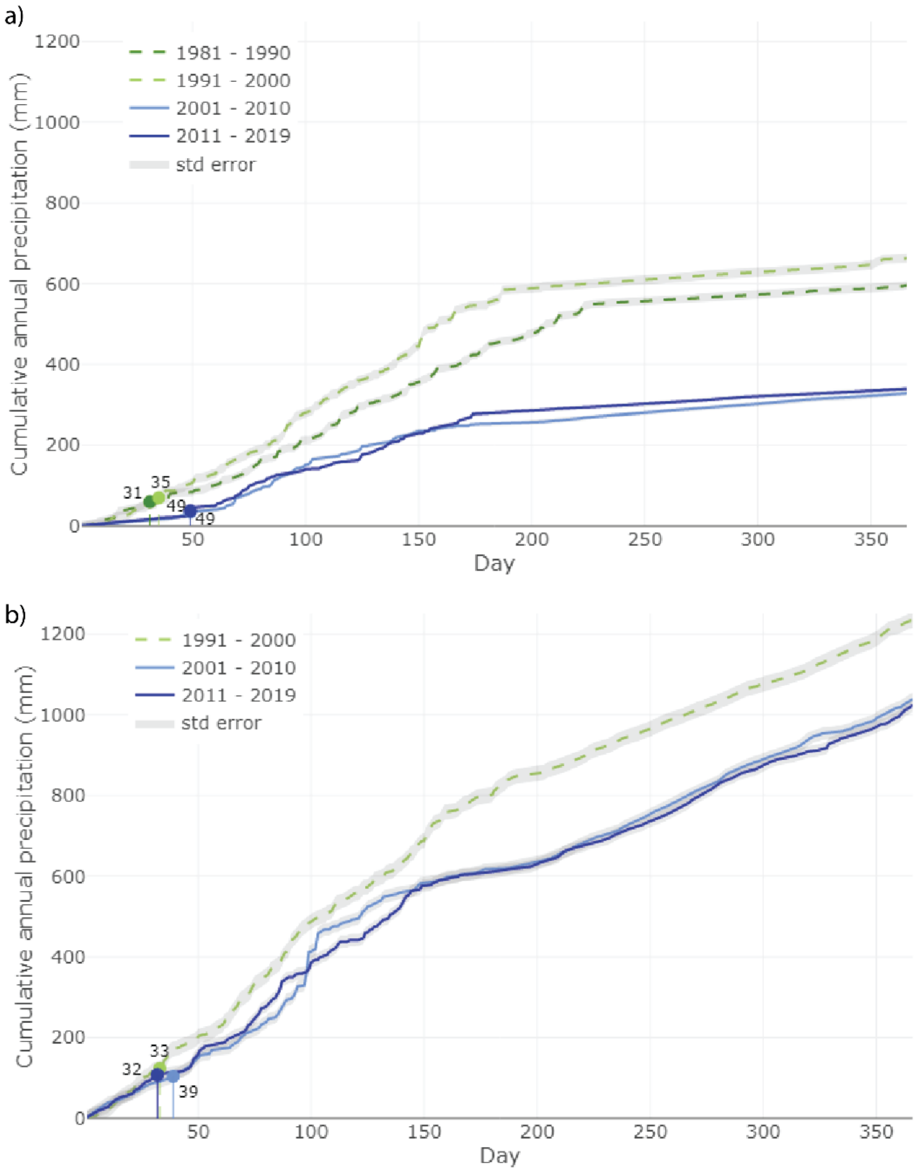
HIGHLANDS

		Annual		Wet Season		Dry Season	
	Period	Q	p-value	Q	p-value	Q	p-value
SAN CRISTOBAL	1981 - 1990	-47.6	1.00	25.7	0.64	-20.1	0.36
	1991 - 2000	-40.5	0.70	14.8	1.00	10.0	0.20

	2001 - 2010	13.3	1.00	25.5	1.00	0.6	0.58
	2011 - 2018	**-132.7**	**0.00**	**-39.2**	**0.07**	**-75.5**	**0.00**
SANTA CRUZ	1981 - 1990	-	-	-	-	-	-
	1991 - 2000	**-55.1**	**0.09**	-34.5	0.42	-6.4	0.64
	2001 - 2010	**-6.2**	**0.10**	7.0	1.00	**-27.0**	**0.00**
	2011 - 2018	-95.5	0.30	**-138.1**	**0.03**	**43.4**	**0.04**

This is particularly important since the wet season seems to be typically responsible for up to 75% and 55% of annual precipitation in the coastal and highland regions, respectively, of Santa Cruz. We can also identify a decreasing trend at the beginning of the rainy season (Figure 7) in Santa Cruz. In fact, we find that over the past two decades, a delay of almost 20 days can be observed in the rainy season onset in the coastal region. This is more acute if we also consider the extension in the number of days it presently takes to reach the 10% of accumulated precipitation, which was usual in the final decades of the 20th century (around 80mm). While in the 1980s and 1990s it took only around 35 days to reach this threshold, the 2000's it has taken over 70 days. In the highlands, the delay in reaching 10% of the annual accumulated precipitation is currently about 7 days (32 days vs 39). However, the number of days it takes to achieve 10% of the annual precipitation common in the 1990s (32 days) at present takes about 45 days. However, we also find that current precipitation in the dry/cold season (from approximately day 180 onwards) and especially in the highlands —where the *garúa* maintains humidity levels— has decreased in magnitude compared to the 20th century, confirming the drying trends described above. These results also suggest that the rainy season is both becoming drier and starting later.

Figure 7. Onset of the rainy season over the a) Coastal and b) Highland Regions of Santa Cruz. The onset of the rainy season is defined as the day since December 1st (theoretical beginning of the rainy season) when the cumulative 10% precipitation of the total annual rainfall was achieved. Dots show the day where the 10% of the mean total annual precipitation for a given decade is achieved. Shaded areas represent standard error.



4.3.2 Spatial trends

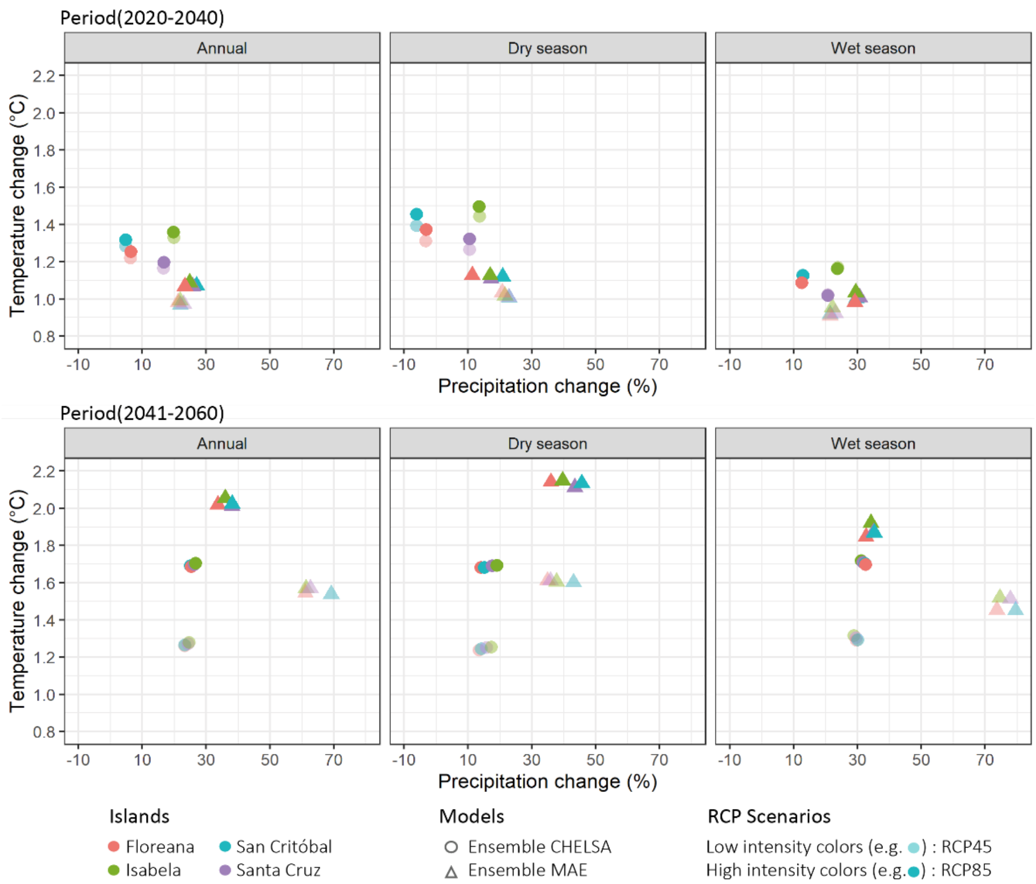
We find that the reanalysis precipitation from ERA5 product (See Appendix 2, Supplementary Figure 2) better approximates those read by the meteorological stations in Santa Cruz and San Cristobal. Nevertheless, this dataset seems to underestimate precipitation estimates in San Cristobal and appears to overestimate precipitation in the coastal areas of Santa Cruz. On the other hand, when comparing the meteorological precipitation observations with the CHELSA historical datasets and CHIRPS satellite observations, we find that these two sources do not adequately capture annual mean precipitation magnitudes and seasonality. The later seems to adequately detect seasonality, yet its magnitudes are largely underestimated. In Isabela, ERA5 estimates that total annual precipitation in the highlands typically ranges from about 565mm to about 855mm, while on the coasts, it ranges from about 580mm to about 740mm.

4.3 Future climate

In terms of future climatological patterns for the Islands, in general, the Ecuadorian, MAE, and CHELSA climate projections suggest a consistent future warming trend and wetting conditions on the three main islands studied, which is consistent across the Galapagos Islands (Figure 8, and Supplementary Figure 5 in appendix 5.1). The MAE multi-model ensembles project increases in average annual precipitation of between 30% and 45% across the Islands by 2050, suggesting a wetter future. Spatially, estimated increases in annual rainfall are accentuated on San Cristobal. As for temperature, we find that the total ensemble of climate projection estimates increases between 1.4 and 1.9 °C by the 2050-time horizon for RCP 4.5 and RCP 8.5, respectively.

However, the specific magnitude of the projected changes differs across modelling efforts, scenarios, and decades. Conservative estimates (typically RCP 4.5) project an increase in mean annual temperatures of just 0.5°C for the next two decades (both MAE and CHELSA projections, when compared with the historical reference period) (Figure 8). Meanwhile, the most extreme climate projections (RCP 8.5) suggest that temperatures may increase up to 2.5°C in the period from 2040-2060. The MAE's output typically simulates these extreme future conditions, while CHELSA projections estimate a maximum temperature increase of just about 1.8°C by said time period. Likewise, as expected, the RCP 8.5 scenarios lead to greater levels of warming than CP 4.5, a difference which would be accentuated during the 2040-2060 decades.

Figure 8. Summary of climate projections for projected average temperature and precipitation changes relative to the historic baseline as simulated by the MAE and CHELSA modelling efforts. Temperature on the y-axis represents absolute change in temperature. The x-axis represents percentual changes in precipitation. Circles represent outputs from the CHELSA modelling projections used here, and triangles represent those from the MAE experiments. The saturation of colors determines the RCP climate scenario; low color intensities represent RCP4.5, while high color intensities represent RCP8.5.



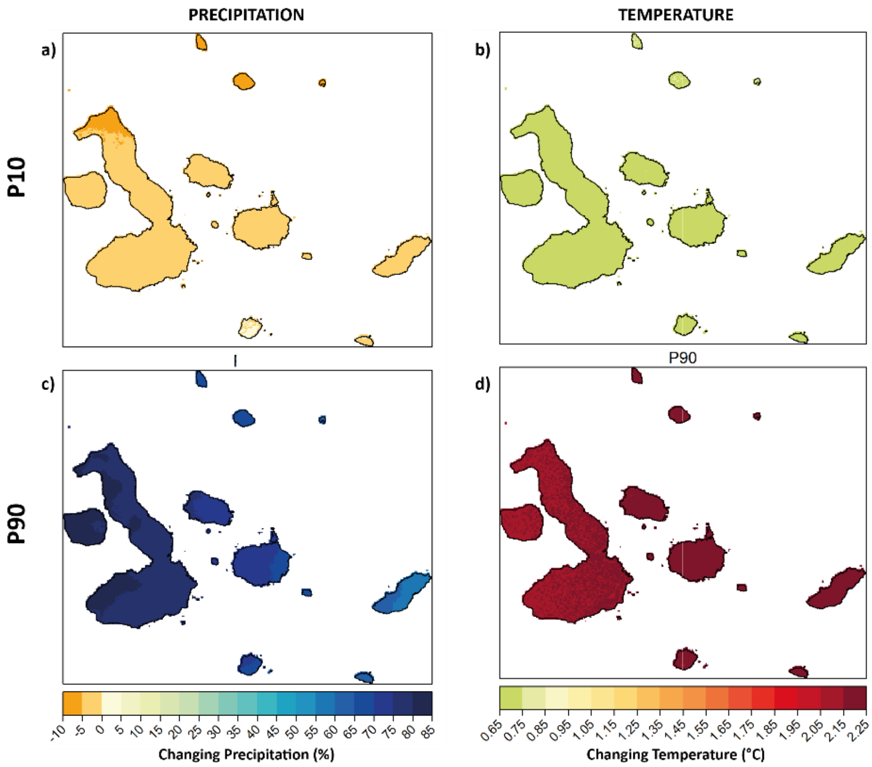
As with temperature, precipitation projections differ across models. We find that the multi-model mean annual precipitation over the next two decades would increase between 5% and around 25% across the three islands evaluated, and indeed, throughout the overall region (Figure 8). In general, MAE estimates for the future appear to be at the higher end of the overall ensembles, whereas CHELSA precipitation increases seem to be more conservative. This pattern seems to result from an intensification of the wet seasons, since relative increases increase in accordance with the annual estimate (in contrast to the dry season, where some scenarios even project a reduction in precipitation). For the decades between 2040 and 2060, precipitation may increase even more: climate projections suggest that rainfall in the Galapagos may increase between 20 and 70% (Figure 5). Similarly, MAE projections generally estimate a wetter future, particularly for RCP 4.5 scenarios (as opposed to RCP 8.5 scenarios). According to these projection subsets, by the end of the century, wet season conditions may intensify by up to 80%.

Lastly, we also calculate changes in extreme conditions in the islands (Figure 5). Temperature anomalies indicate that for the lower percentile (10th percentile) of the ensemble of scenarios and models used here, temperature increases range from 1°C and 1.5°C (Figure 5b). This result suggests that cooler days in the Galapagos Islands may become hotter. In the case of the upper percentile (90th percentile, Figure 5d), the estimations show an increase in temperature between 1.5°C and 2.5°C, meaning that warm days would become hotter. Overall, these results suggest the more frequent occurrence of abnormally hot conditions, which could then translate into more common heatwaves.

Magnitudes of extreme wet anomalies (90th percentile) increase between 60% and 85% for the 2040-2060 period (Fig. 9c). This is particularly evident on Isabela, where extreme precipitation may typically increase by about 70%. As for extreme dry conditions (10th percentile, Fig. 9a), we find that the low precipitation is likely not to significantly change (percentual changes between -5% and +5%). However, we note that the northern parts of the three islands analysed here, and indeed the Archipelago, extreme dry anomalies would become at least 5% drier.

While we acknowledge the existence of other more sophisticated techniques and metrics to calculate extreme precipitation and temperature characteristics, our objective here is to provide an initial overview of these types of hydrometeorological conditions.

Figure 9. Multi-model ensemble changes in extreme wet and dry anomalies in the Galapagos Islands for the 2040-2060 period. Upper panels show multi-model changes in precipitation (a, %) and temperature (b, oC) for the 10th percentile (P10, extreme dry and cool anomalies). Lower panels show multi-model changes in precipitation (a, %) and temperature (b, oC) for the 90th percentile (P90, extreme wet and hot anomalies).

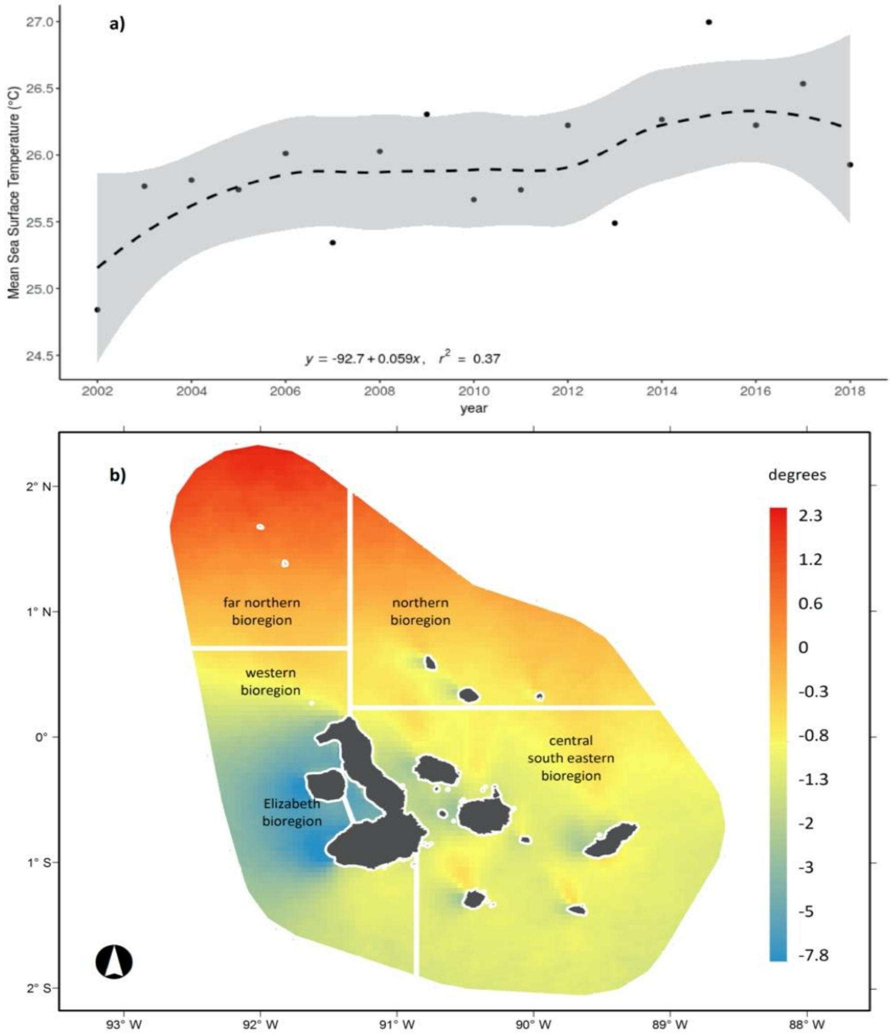


4.4 Current and observed sea surface temperature trends.

In the Marine Reserve area, our results show that SST has increased at a rate of 0.06 °C per year over recent decades (Figure 10a). For the 2002-2018 period there was an overall increase of 1.2°C. We also observed high spatial and temporal heterogeneity in the SST throughout the Galapagos Marine Reserve (GMR). The Western, Central and Southern regions of the GMR showed cooling anomalies over the last two decades, whereas the Northern, the far Northern and some coastal areas of the Eastern and Central regions showed warming anomalies for the year 2002 (Figure 10b).

Figure 10. (a) Mean Sea Surface Temperature (SST) in the Galapagos Marine Reserve (GMR) derived from the SST MODIS L3 product for 2002-2018. Line represents the fitted linear regression between observed mean SST in the GMR for each year. The shaded area represents the 95% confidence interval (b) Mean

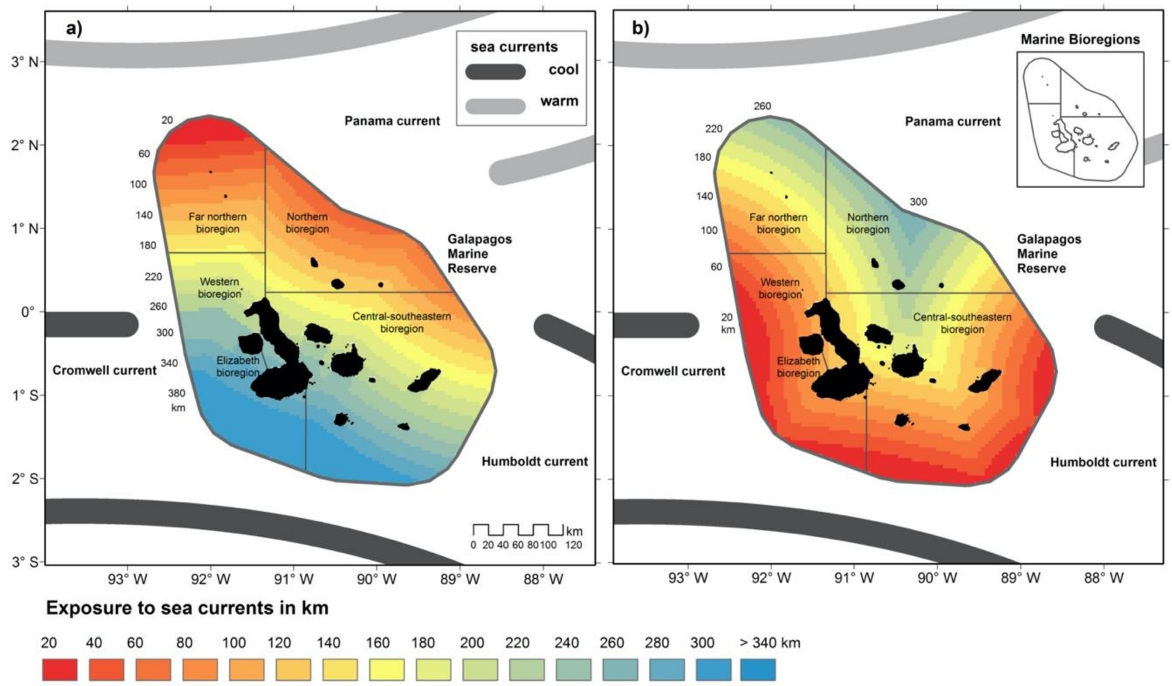
annual anomalies of Sea Surface Temperature (SST) in degrees for the period 2002-2018. White lines represent the five marine bioregions of the GMR (Edgar et al., 2004).



Likewise, the interannual changes observed in satellite-derived patterns showed both the spatial and temporal variability between cool and warm zones (Supplementary Figure 6). Our analysis revealed warmer SST transitions for the periods 2002-2003, 2007-2008, 2010-2011, 2013-2014, and 2016-2017, demonstrating that the gap between cooling and warming phases has decreased over the observed period. Indeed, we find that following the warming peak registered in 2015 and La Niña of 2016, a widespread warming trend was observed in the Central-South-Eastern region for the remaining of the period studied (See Appendix xx, Supplementary Figure 6).

Simultaneously, the Mann-Kendall test confirms different warming trends in the GMR bioregions (See Appendix 5.1, Supplementary Table 2). We notice that the far Northern, Northern and Central-South-Eastern bioregions exhibited significant warming trends (tau = 0.362, P-value = 0.048; tau = 0.362, P-value = 0.048; tau = 0.368, P-value = 0.044, respectively), whereas the Elizabeth and Western bioregions reported no significant warming trends (tau = 0.185, P-value =0.32; au = 0.309, p-value =0.091). These results demonstrate the influence of exposure to warm and cool currents on differentiated warming trends among the GMR (Figure 11). Multiple regression analyses show that SST in the GMR could be explained by the time period (year), the spatial distribution of SST (longitude), and the exposure to warm currents (See Appendix 5.1, Supplementary Table 2).

Figure 11. Annual exposure of the Galapagos Marine Reserve (GRM) to warm (a), and cool (b), currents. Black lines represent the five marine bioregions of the GMR as defined by Edgard et al. (2004)(Edgar et al., 2004).



4.5 Implications for the Galapagos islands

Our results explain the recent historical and future climatic trends on the Islands of San Cristobal, Santa Cruz, and Isabela. We first find that a warming trend over recent decades is accompanied by a decrease in precipitation values across these islands (particularly during the wet season). Indeed, a registered increase of about 0.6°C is accompanied by a reduction of around 45% of total precipitation, compared to the 1980s. This situation becomes more acute considering that we also found a delay of about 20 days in the onset of the rainy season over the last decade. Drier islands will naturally have repercussions on regional water-dependent systems, but the extent to which drier conditions may affect water supply, irrigation, and overall water and food security for the settled and floating human populations on the Islands requires further investigation. A further factor to take into consideration is that sectorial competition for water in the Islands would, in turn, impact natural systems. At present, human decisions on the Islands are thought to play the largest role in shaping the regional ecosystems and landscape dynamics (Restrepo *et al.*, 2012).

However, the drying trends found here may be biased by the fact that, during the final decades of the 20th century (as compared to the previous four centuries) El Niño events were unusually strong in the Eastern Pacific(Freund *et al.*, 2019). The decrease in Eastern Pacific El Niño activity during this century may explain the detected drying trends. In fact, our results found that if the El Niño years are not considered in our calculations, these drying trends are attenuated, or even reversed. Unusual wet periods during the late 20th century may result in biases when seeking to understand future climatic trends: *wetter than usual* baseline conditions may in turn lead to overestimate water availability across the Islands.

Our results also provide an understanding of the future climatic conditions that may characterize the Islands. The CHELSA and MAE models consistently agree on a wetting and warming trend across the region. In fact, precipitation is projected to increase between 20 and 70% and temperature may even increase up to 2.5 ºC, in comparison with the last four decades. These increments will be accompanied by augmenting hot and wet extremes, which would ultimately translate into more severe heatwaves and floods in the region.

These extreme conditions will, in turn, have significant impacts on natural and human systems. For example, increase in rainfall conditions as a result of ENSO events can trigger a substantial growth of herbs and vines and change the community structure of arid ecosystems, making them more susceptible to colonization by invasive species(Hamann, 1985). The increase in the prevalence of pathogens and parasites during rainy conditions can also lead to bird populations (e.g. finches and mockingbirds) being overwhelmed, resulting in lower breeding and fledging success(Cimadom *et al.*, 2014). Likewise, wetter conditions may alter plant growth and community structure, accelerate soil erosion rates, and provide better conditions for invasive species(Trueman & d'Ozouville, 2010). Also, previous extremely wet conditions in the Galapagos (from past El Niño events), have led to economic losses, damages to infrastructure, damages to cropland, and impacts on human lives and ecological richness, including coral disturbances and biodiversity loss (Glynn, 1990; Tye & Aldaz, 1999; Vos *et al.*, 1999). Subsequent efforts will need to account for the present and future vulnerability levels of natural and social systems (including food, water, and infrastructure) to these types of extremes.

Nonetheless, these future estimates may be constrained by the ability of General Circulation Models (GCMs) to represent climate change in the equatorial Pacific (Hourdin *et al.*, 2017). In the case of the Galapagos region, major discrepancies have been reported between GCMs and observed tropical Pacific SSTs trends. These discrepancies result from the deficiencies of CMIP5 experiments in adequately capturing the Equatorial Pacific cold tongue (Coats & Karnauskas, 2017). As a result, GCM outputs for the Galapagos region are thought to overestimate the warming and wet trend(Seager *et al.*, 2019). In fact, the projected warmer and wetter future contradicts the recent drying trends (described previously). More importantly, if the unusual wet decades in the late 20th century and the overestimation of future precipitation in the Galapagos Islands are not carefully addressed, this will lead to misinterpretations regarding the Islands' water availability and hydrological processes. Further efforts should thus investigate future changes of specific drought and flood-metrics in the Islands as well as shifts in key sub-regional hydrological processes such as future highland mists (*garúa*) conditions, while cautiously addressing these constrains.

We likewise found that over the past two decades, SST within the GMR had a mean absolute increase of 1.2°C from 2002 to 2018. This approximation is higher than the mean warming estimates for the Equatorial Pacific over the last 40 years (0.4º-0.8º)(Hartmann *et al.*, 2013), and, critically, greater increases are expected in this region due to greenhouse warming(Cai *et al.*, 2018). Rising SST will in turn result in increased rainfall, which would intensify the natural and human disturbances discussed previously. Previous extreme climatic events have seriously affected productive habitats in the GMR, coral reefs, and coral and macroalgae communities, as well as oceanographic features(Glynn *et al.*, 2015; Karnauskas *et al.*, 2015). Higher SST will also have variable effects on fish species: for example, positive changes in temperature are expected to yield more variable tuna and yellowfin biomass(Dueri *et al.*, 2014; Senina *et al.*, 2018). As a whole, climatic changes will aggravate the already significant degradation of marine ecosystems caused by anthropogenic pressures (Hoegh-Guldberg *et al.*, 2007; Escobar-Camacho *et al.*, 2021). Despite this, the response of fisheries in the Galapagos to climate change, and its consequences for regional economic activities and food security, remain poorly understood.

We also found a heterogenous warming and cooling pattern in the GMR. This, in turn, may respond to the associated convergence of the three major current systems in the Galapagos Archipelagos (the Panama, Humboldt, and Cromwell currents). While ENSO events are thought to temporarily disrupt these currents, the extent to which global warming may also affect these processes is not clear(Wang & Fiedler, 2006; Wolff *et al.*, 2012). Ultimately, the formation of a micro region of upwelling cold water in the Western and Elizabeth bioregions of the GMR would also lead to enhanced phytoplankton concentration, thus determining marine diversity(Wolff *et al.*, 2012).

Our results highlight the general warming trend observed in the Islands in both surface air temperatures and SSTs. This has been accompanied by a drying trend, which may be reversed given that climate projections show a hotter and wetter future. However, considering the major reported uncertainties in GCMs, such estimates should be carefully examined. At the same time, we also acknowledge other limitations and uncertainties in understanding climatological and SSTs patterns in the Islands'. They include, among others, the lack of a comprehensive, publicly available network of instruments to capture the entire geographical diversity of the Archipelagos. As such, we also emphasize the need to incorporate uncertainty and climate risk-based approaches as the bases for planning strategies in the water, food, conservation, and other climate-connected sectors in the Galapagos Islands. These strategies must be both robust in the face of a wide range of potentially uncertain climate conditions, as shown in this study, and flexible, allowing the Islands to adapt to future climatic and non-climatic scenarios that are less than uniform.

5. Greenhouse emissions

5.1 Current situation

Galapagos livelihoods are not only affected by climate change, but they also contribute to global GHG emissions. The small-scale fisheries sector does not represent a heavy load in the balance: their contribution is mainly related to the use of fossil fuel-based energy (boats, refrigeration). Nevertheless, agriculture and tourism can significantly contribute to emissions reductions. Agriculture can have a significant impact by changing land use practices, livestock and manure management and the use of fossil fuel-based energy (machinery, refrigeration). Also, the tourism sector (hotels, restaurants, other tourism operators) is key for reducing emissions related to energy consumption: not only through a more efficient use of energy and the deployment of renewable energy, but also because an important part of the fuel that is nowadays being imported will no longer have to be transported from mainland, with its consequent associated emissions.

5.2 Future scenarios

The scenario without programme implementation involves a conversion towards meeting the PEGSAG targets, but at a much slower speed. At the same time, electricity demand will continue to increase, see Appendix 2.1 sections 2.4 and 2.5 for an understanding of the current and projected electricity demand situation. Therefore, without the project, the Galapagos energy system would continue for more years to emit greenhouse gases from longer fossil fuel-based electricity generation.

Without the project, farmers would not receive an impetus to change their practices to lower carbon practices, which have a large impact, if one looks at the estimates of a with-project scenario.

The with-project scenario shows that emissions could be reduced by

1. The investments of the Programme will lead to an estimated reduction of 73,815 tCO2e/year and more than 1.4 MtCO2e over lifespan5.

Table 4. Estimated GHG emissions reductions from the Programme investments.

Sector	tCO_2e/year	tCO_2e in 5 years (Programme implementation)	tCO_2e in 20 years (lifetime of technology / ecosystem equilibrium reached)
Energy	23,443.18	111,104.19	468,863.57
Land Use	50,372.00	251,860.00	1,007,440.00
Total	**73,815.18**	**362,964.19**	**1,476,303.57**

Please refer to section 9. Mitigation opportunities, for the expected results in GHG emissions reductions and avoidance by the Programme activities.

6. Additional drivers of change

The Galapagos Archipelago, like many tropical islands, is a system highly sensitive to human impacts (Fordham and Brook 2010) and is affected by climate dynamics (Grant and Grant 2006). The intrinsic sensitivity of the Galapagos has increased in recent decades because of the following drivers of change: (1) climate change; (2) unsustainable tourism and local population growth; (3) overfishing and illegal, undeclared, and unregulated (IUU) fishing; and (4) invasive species (Defeo et al. 2013; Castrejón and Charles 2020; Salinas-De-León et al. 2020). These drivers can interact with climate-based drivers such as El Niño Southern Oscillation (ENSO) at multiple temporal and spatial scales, exacerbating their negative impacts on already fragile ecosystems and the socioeconomic system of the Archipelago. Throughout this section, we refer to drivers of environmental change as any natural or human-induced stressor that causes a change in ecosystems (Nelson et al., 2006; Carpenter, et al., 2006). The combined impacts of these drivers pose an unprecedented threat to the Galapagos system (Salinas-de-León et al., 2020; Escobar-Camacho et al. 2021).

5 In the case of the energy investments, the emission factors of each isolated system have been calculated (Baltra-Santa Cruz, San Cristobal, Isabela and Floreana), applying the CDM methodology TOOL07 (IRENA, 2021). The emissions from fuel transport have been calculated in accordance with the Guidelines for Measuring and Managing CO2 Emission from Freight Transport Operations (ECTA CEFIC, 2011). PUNA ship transports fuel to the islands, which transports 2,400 tons of diesel. Emission reduction calculations from land use were performed using the EX-ACT tool (FAO, 2021).

6.1 Unsustainable tourism

Human development has aroused several problems that threaten natural resources, such as with oil spills inside the marine reserve (Snell 2002), water contamination and wastewater mismanagement (Alava et al. 2014; Ragazzi et al. 2016; Wikelski et al. 1996), destruction of native ecosystems (Brewington 2013; Laso et al. 2020), touristic sites and trails overuse (Brewington 2013; Self et al. 2010), and plant and animals disturbance (Denkinger et al., 2013; French et al., 2010; Wikelski et al. 1996). One of the most pervasive byproducts of tourism is the introduction of invasive species (Nash 2009; Pizzitutti et al. 2017) (Fig. S8C), which have increased over time positively correlating with the increasing number of tourists (Toral-Granda et al. 2017). The effects of tourism have been so severe that UNESCO (United Nations Educational, Scientific and cultural Organization) added the Galapagos Islands to the list of "World Heritage in Danger" in 2007, listing uncontrolled development and mismanagement of tourism and growth in the human population as main reasons (Nash 2009). Additionally, the Galapagos conservation assessment by the IUCN was evaluated as of "significant concern" by the 2017 World Heritage Outlook, with tourism, invasive species and climate change being the significant current threats (IUCN, 2017). Galapagos is a prime example of a protected area suffering an environmental crisis that has been generated by the over-exploitation of natural resources (Pizzitutti et al. 2017).

Overall, while the appealing combination of unique flora-and-fauna and beautiful landscapes in the Galapagos has helped boost the local economy and allowed the GNP to gain funds for its management and conservation initiatives, it has also brought problems to the archipelago. Climate change and tourism are interrelated drivers of change, as tourism contributes to climate change through the emission of greenhouse gases (GHG) related to accommodation, activities, and transport (Scott et al. 2008) and climate change disrupts ecosystem processes and the abundance and distribution of endemic species, which impacts the tourism industry. Thus, climate change scenarios in the Galapagos should be aligned with the tourism industry to mitigate the impacts and identify adaptation measures to increase both ecosystem and tourism industry resilience.

6.2 Invasive species

Invasive species have been introduced into the Galapagos both deliberately and by accident, including the introduction of farm animals and plants and the accidental introduction of rats, fire ants, and the parasitic fly (Philornis downsi) (Toral-Granda et al. 2017; Gardener et al. 2013; Larrea Oña and Di Carlo 2011). Until 2017, there were 1575 alien species across the archipelago (Toral-Granda et al. 2017). Among these, there are ca. 870 introduced plant species, of which 16% are invasive species and 3.3% transformers species, leading to plant communities structure modification (Buddenhagen and Tye, 2015; Trueman and D'Ozouville 2010). Invasive plant species not only impact native and endemic species abundance through competition and by transforming plant communities but can also be incorporated into the diet of native animals, aiding expansions in their distribution (Blake et al. 2012, 2015; Ellis-Soto et al. 2017). Invasive insects and vertebrates also cause negative impacts on native and endemic species decimating their populations. The larvae of the parasitic fly (P. downsi) feeds on the blood of chicks from native and endemic birds, causing high mortality rates (Deem et al. 2008; Jiménez-Uzcátegui et al. 2007; Lawson et al. 2017).

Invasive fire ants predate on a variety of Galapagos wildlife, including reptiles, birds, and invertebrates (Causton et al. 2006; Herrera and Causton 2008; Wauters et al., 2016, 2017, 2018). Introduced mammalian species, mainly goats, rats, cats, and dogs, have decimated the abundance of diverse plant and animal species through predation and competition for the same ecological niches (Wiedenfeld and Jiménez-Uzcátegui 2008; Heleno et al. 2012; Renteria et al. 2012b). The ecological impacts produced by invasive species can be exacerbated by climate oscillations that result in favorable conditions for these species (e.g., longer rainfall periods).

ENSO increases rainfall season, which triggers massive growth of herbs and vines, changing the community structure of arid ecosystems and making them more susceptible to colonization by invasive species (Hamann 1985). In consequence, invasive plants have transformed entirely the composition of plant communities in the farmlands and pastures, located in the highlands of Galapagos inhabited islands (Laso et al. 2020; Watson et al. 2009) (Table S1). The increasing prevalence of pathogens and parasites during the rainfall season increases the mortality rates of bird populations, particularly of Galapagos finches and mockingbirds, by reducing their breeding and fledging success (Cimadom et al. 2014). This problem is exacerbated by rats and mice, which prey on native and endemic birds and whose abundance increases during the rainfall season.

The eradication of invasive species is extremely challenging and expensive (Renteria et al. 2012a), and projects aiming to eradicate invasive species in the Galapagos often meet a series of challenges, mainly with a lack of economic support for institutions, the denial by landowners to conduct fieldwork, or overly ambitious projects (Gardener et al. 2010).

Despite these obstacles, plant eradications are feasible, realistic, and justifiable if well-known criteria are met. Buddenhangen and Tye (2015) have reported an up to 38% success rate for eradication programs in the Galapagos. In addition, several invasive vertebrates like goats, pigs, pigeons, rats, dogs, tilapia, and donkeys have been successfully eliminated from some of the islands or even from the entire archipelago (Carrion et al., 2007, 2011; Cruz et al. 2005; Phillips et al., 2012a, b). The removal of these harmful species has immediate positive results on the recovery of endangered native species (Carrion et al. 2011; Donlan et al. 2007).

However, the eradication of invasive species is just one of several steps in being able to restore the terrestrial ecosystems of the Galapagos Islands (see Atkinson et al. 2008, Carrion et al. 2011). Finally, although the impacts of invasive species have been extensively studied in Galapagos terrestrial ecosystems, very little is known about marine invasions in Galapagos and the magnitude of their impacts on marine ecosystems. At least 53 introduced marine invertebrates and 33 cryptogenic invertebrates, algae and halophytes, have been reported for Galapagos, most of them were probably brought by ships (Carlton et al. 2019; Keith et al. 2015). Given that research on marine alien species in Galapagos is relatively recent and that only a subset of habitats has been assessed, this suggests that marine alien species and their impacts are substantially underestimated. Therefore, regulating institutions should implement measures to study the advancement of alien species, reduce invasion risk, and minimize their impacts.

6.3 Overfishing and IUU fishing

Sharks are caught incidentally in the tuna and mahi-mahi fishery and, together with IUU fishing, represent one of the main threats for shark conservation (Castrejón 2020b). The legal framework of Ecuador prohibits shark finning and commercial exploitation of sharks nationwide. In mainland Ecuador, the landing and trading of sharks are permitted only in those cases when these species are caught incidentally and as long as they are landed whole (fins and body). In contrast, the capture, landing, and trading of sharks are prohibited in the GMR, even if they were caught incidentally. Despite these measures, thousands of sharks are landed annually on the main fishing ports of mainland Ecuador, suggesting the existence of a fishery within the Ecuadorian EEZ that targets sharks illegally, including the GMR (Carr et al. 2013; Alava et al. 2017; Alava and Paladines 2017). Hence, the estimated landings of sharks very likely represent only a fraction of the total landings for this region (Schiller et al. 2014).

The Galapagos Marine Reserve is a sanctuary for heavily exploited fish like tuna and sharks, which migrate consistently to and from the reserve (Hearn et al. 2016; Acuña-Marrero et al. 2017; Boerder et al. 2017). The maintenance of the GMR is beneficial for both industrial and artisanal fisheries, as it increases fish productivity both outside and inside the reserve (Boerder et al. 2017; Bucaram et al. 2018). However, the overexploitation, incidental catch, and illegal fishing, produced by Ecuadorian and foreign industrial and artisanal fisheries established along GMR's boundaries (Boerder et al. 2017), reduce the effectiveness of the GMR to ensure the recovery of these commercial and protected species (Alava et al. 2017; Alava and Paladines 2017; Castrejón 2020b).

To mitigate the impacts of human activities on the GMR and to ensure the sustainability of Galapagos small-scale fisheries, marine zoning plan was implemented (between 2000 and 2006) in combination with a co-management regime, and the allocation of exclusive fishing rights to local small- scale fishers (Heylings et al. 2002; Castrejón and Charles 2013). Approximately, 18% of the Galapagos coastline were declared as no-take zones, whose individual size ranged from small offshore islets to a 70-kmspan of coast, with no offshore boundaries legally established. However, the biased location of no-take zones in areas of low abundance of the most lucrative fishery resources (i.e., sea cucumbers and spiny lobsters), combined with a lack of effective enforcement and a high rate of non-compliance, severely limited the effectiveness of Galapagos marine zoning to improve the governance and sustainability of small-scale fisheries and the conservation of Galapagos marine biodiversity (Bucaram et al. 2013; Bucaram and Hearn, 2014; Defeo et al. 2014; Edgar et al. 2004b; Moity 2018).

The sea cucumber fishery collapsed in 2006 due to overfishing (Hearn and Toral-Granda 2007; Hearn et al. 2005; Toral-Granda 2008), while large apex-level fish such as the Galapagos grouper (M. olfax), the white-spotted sand bass (Paralabrax albomaculatus), and the olive grouper (Epinephelus cifuentesi) show signs of overexploitation (Danulat and Edgar, 2002; Schiller et al. 2014; Usseglio et al. 2016). Groupers and sand basses exhibit decline in landings and catch size compared to previous estimates, even in no-take zones (Burbano et al. 2014; Zimmerhackel et al. 2015; Usseglio et al. 2016). As a result, the catch composition has changed over time. Fish species previously with no economic value now are commercially exploited, including mullets (Xenomugil thoburni and Mugil galapaguensis), wahoo (Acanthocybium solandri), and pomfret (Seriola rivoliana) (Castrejón 2011; Danulat and Edgar 2002).

Furthermore, the rate at which sharks are being extracted illegally from Galapagos is among the highest of any EEZ in the world (Schiller et al. 2014). Fishery assessments and genetic studies suggest that sharks in the ETP show signs of overexploitation (Carr et al. 2013; Pazmiño et al. 2017), and thus, urgent attention to illegal and incidental catch of sharks within and around the GMR is required.

Intensive fishing coupled with the reduced distribution of several Galapagos marine species (e.g., Galapagos grouper) makes them very susceptible to extinction (Schiller et al. 2014). Overexploitation of top predators, such as groupers or sand basses, can trigger cascading effects in the trophic chain, declining Galapagos marine diversity (Ruttenberg 2001; Ruiz and Wolff 2011). Furthermore, given the ecological role of sea cucumbers as nutrient recyclers (Purcell et al. 2011), the depletion of this species probably degraded the function and structure of Galapagos marine ecosystems. The reduction of spiny lobster stocks could be linked to an increasing presence of sea urchins (e.g., Eucidaris galapagensis) in the subtidal zone, leading to bioerosion and detriment of coral communities (Banks 2007; Glynn et al. 2015). However, this hypothesis is uncertain considering that, after a period of overexploitation, spiny lobster stocks have shown clear signs of recovery (Defeo et al. 2014; Szuwalski et al. 2016).

7. High-ecological value areas (HEVA)[6]

Human-based drivers of change (see section 6) can interact with climate-based drivers such as El Niño-Southern Oscillation (ENSO) at multiple temporal and spatial scales, exacerbating their negative impacts on the ecosystems and the socioeconomic system of the Archipelago. Therefore, we developed and applied a spatial impact assessment model to identify high-ecological value areas (HEVAs) with high sensitivity and exposure scores to environmental change drivers. The impact assessment model was constructed based on a literature review of scientific published literature from 1945 to 2020 and local and global climate databases (see section 6) to analyze drivers of change in the Galapagos.

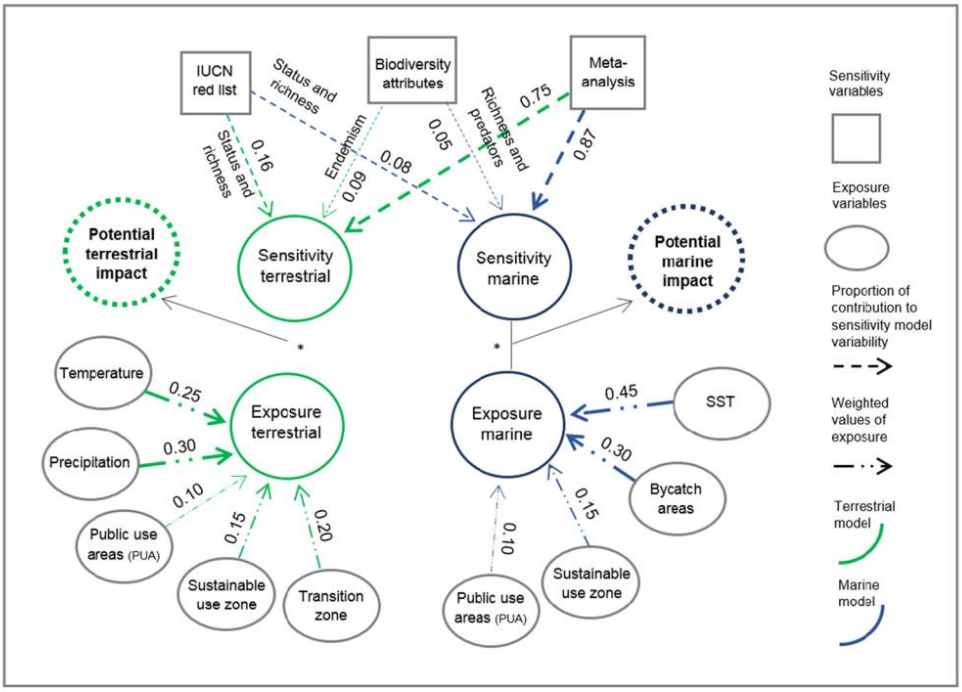
To select priority areas for the implementation of EBAs in the Galapagos (Colls et al. 2009), we built a spatially explicit model for impact assessment (Figure 12). We used the concept of vulnerability for the identification of areas that would be highly sensitive and exposed to multiple drivers of change. The interaction of multiple drivers can result in additive, synergistic, or antagonistic outcomes with varying degrees of negative impacts (Crain et al. 2008). However, the outcomes of multiple drivers' interactions in Galapagos' ecosystems remain unknown. Therefore, we used a simple additive model approach, where the impact of drivers' interactions is the product of their cumulative effects (Crain et al. 2008), and the magnitudes of exposure are differentiated and ranked. Our model does not pursue the precise estimation of the magnitudes of interactions but poses an approximation to the spatial distribution of different drivers and their heterogeneous and overlapped occurrence among the Galapagos Islands. The combined magnitudes of sensitivity and exposure sub-models were used to identify areas of potential impacts (i.e., areas of biotic and abiotic importance where multiple drivers of change co-occur) (Fig. 12, Eq. 1). To this end, we used methods of multicriteria and algebraic spatial modeling (Chakhar and Mousseau 2007; Dunčková et al. 2019; Greene et al. 2011; Lin 1998).

Eq. (1) Potential Impact = Sensitivity * Exposure

The magnitude of sensitivity was obtained by a literature review derived from the Galapagos-related scientific literature about the impact of climate change on terrestrial and marine ecosystems. The magnitude of exposure was obtained by combining environmental online databases (i.e., CHELSA, NOAA, land cover maps) with anthropogenic variables, such as terrestrial and marine public tourist use areas, reported targeted fishing and bycatch areas, and land use management status. The resulting impact model represents a hypothetical trajectory of potential environmental change-related impacts on a sensitive ecological system, assuming the absence of adaptation measures (Füssel and Klein 2006). Finally, it is not within the scope of this study the quantitative validation of the model, but to illustrate the spatial occurrence of the multiple drivers of change described in our literature review. However, the results of our impact assessment model were qualitatively validated by local management authorities and stakeholders through workshops and work meetings. For further detail on the sensitivity and exposure models please refer to Appendix 5.2, section Projected impacts of environmental change, page 10.

Figure 12. Diagram showing the development of the impact assessment model for the Galapagos Islands. Drivers of change and submodels that were used for estimating impacts are shown in green and blue denoting terrestrial and marine ecosystems, respectively.

6 This section is based on a peer-reviewed paper published in the Journal Regional Environmental change: https://link.springer.com/article/10.1007/s10113-021-01768-0 This study was developed specifically for the design of this proposal and it was funded by WWF-Ecuador.



7.1 Drivers of change in the Galapagos Islands: current and future impacts

Our impact assessment model identified current and future potential impacts of diverse drivers of change throughout the Galapagos Archipelago, based on the intrinsic sensitivity and degree of exposure of different bioregions, ecosystems, and islands (Figures 13 and 14). The areas with higher impact scores were classified as high-ecological value areas (HEVA), which are defined as areas highly sensitive and exposed to drivers of environmental change. These areas are key for environmental service provision including freshwater, fisheries, and nature- based tourism activities. HEVA with the highest impacts were concentrated on the biggest and most inhabited islands, with a clear trend towards the highlands: the Miconia and Scalesia zones containing nearly 40% of all of the HEVA (Figures 13a and 15). The island of Santa Cruz exhibited the highest impact, followed by San Cristobal, Floreana, and Isabela (Figure 13a). Our impact assessment also identified a high concentration (ca. 20%) of HEVA in the transition and arid zones of different islands. The skewed spatial distribution of the HEVA towards the inhabited islands is related to the ecological importance of the humid forested ecosystems and the high endemism from the arid zone. This is coupled with a projected variability in climate and the effects of the zoning in 2016 of the highlands on the inhabited islands, which are primarily used for farmlands, pastures, and tourism, resulting in an increased concentration of invasive species and a constantly increasing demand for natural resources.

Although HEVA were widespread throughout marine ecosystems in our results, there were specific regions that concentrated uneven proportions of HEVA (Figure 14). High impacts were clustered in the Far-Northern, Elizabeth, and the Central-Southeastern bioregions (Figures 14a and 16). In the Western bioregion, HEVA were identified in the north and south boundaries of the Bolivar Channel and the central part of the archipelago (a marine corridor connecting Isabela, Santiago, Santa Cruz, Pinzon, and Rabida) (Figures 16). The remaining HEVA were distributed along the islands' shorelines, whose ecological importance relies on several ecosystem services, including nature-based tourism and fisheries. Among marine macro-habitats, shark nurseries showed the highest impacts, followed by corals and the habitats of hammerhead and tiger sharks (Figures 14b). The distribution of endemic species and macro-habitats in areas with high sensitivity, coupled with the rise of SST throughout the GMR, might explain the high score impacts for sharks and corals.

Figure 13. Magnitudes of impact for (a) islands and (b) terrestrial ecosystems. Impact scores were built for each island and terrestrial ecosystem based on the weighted values of sensitivity and exposure. Frequency denotes the number of hexagons, the minimum unit of analysis (3.46 km2).

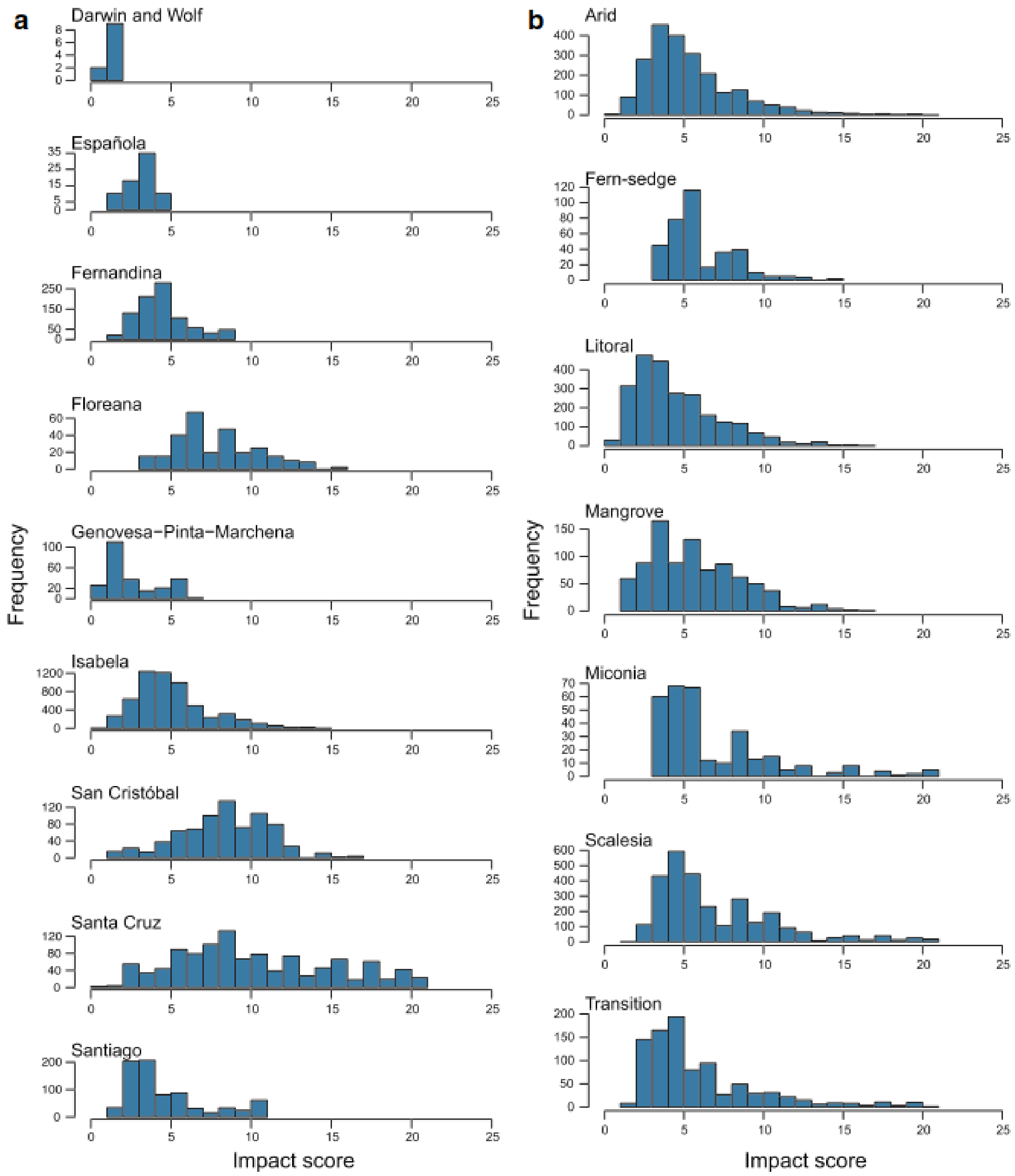


Figure 14. Magnitudes of impact for (a) bioregions and (b) marine macro-habitats. Impact scores were built for each bioregion and marine macro-habitat based on the weighted values of sensitivity and exposure. Frequency denotes the number of hexagons, the minimum unit of analysis (3.46 km²)

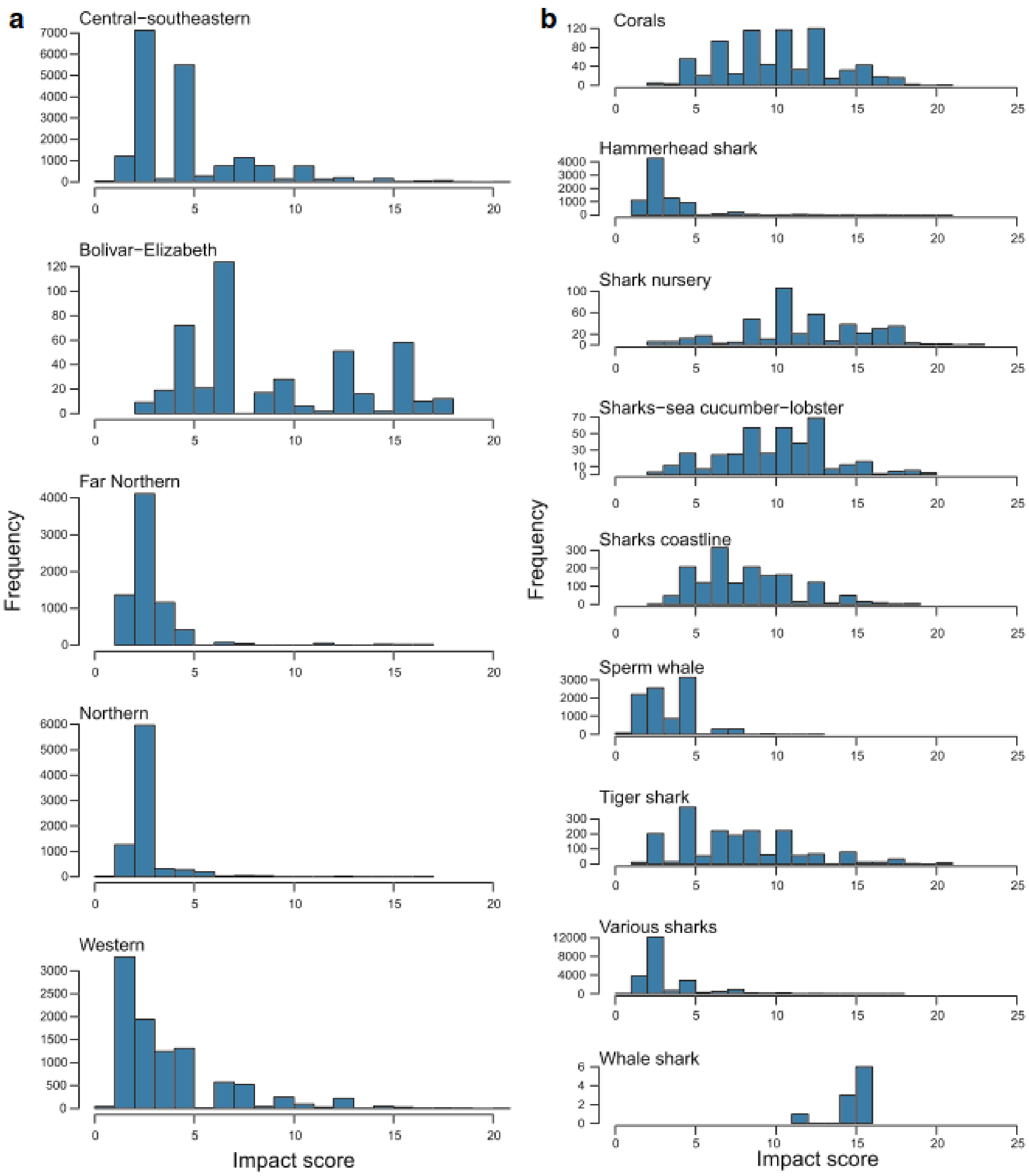


Figure 15. Projected impact on Galapagos' terrestrial ecosystems by drivers of change. Spatial analysis units are hexagons of 3.46 km2.

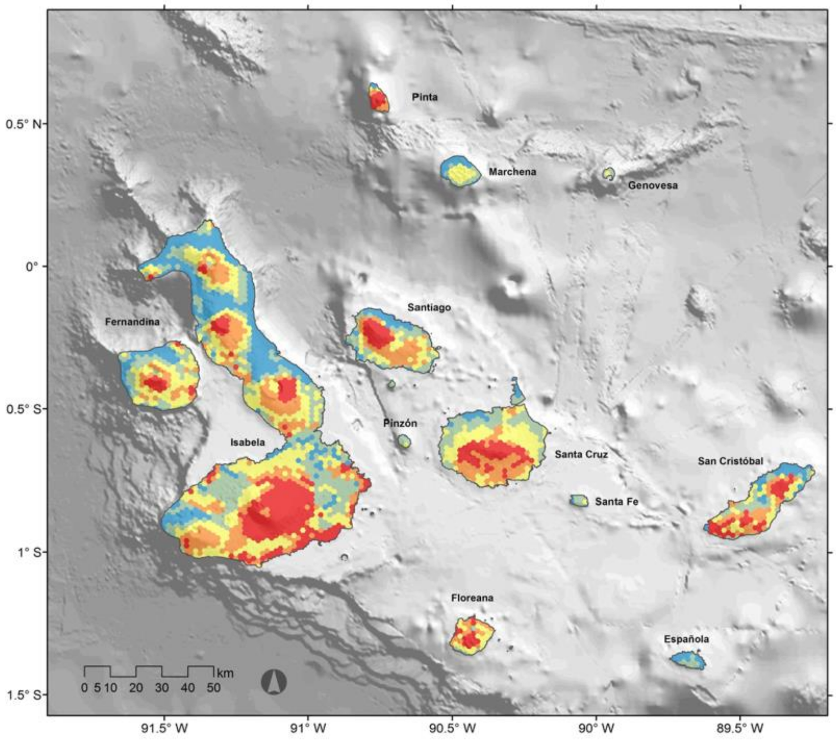
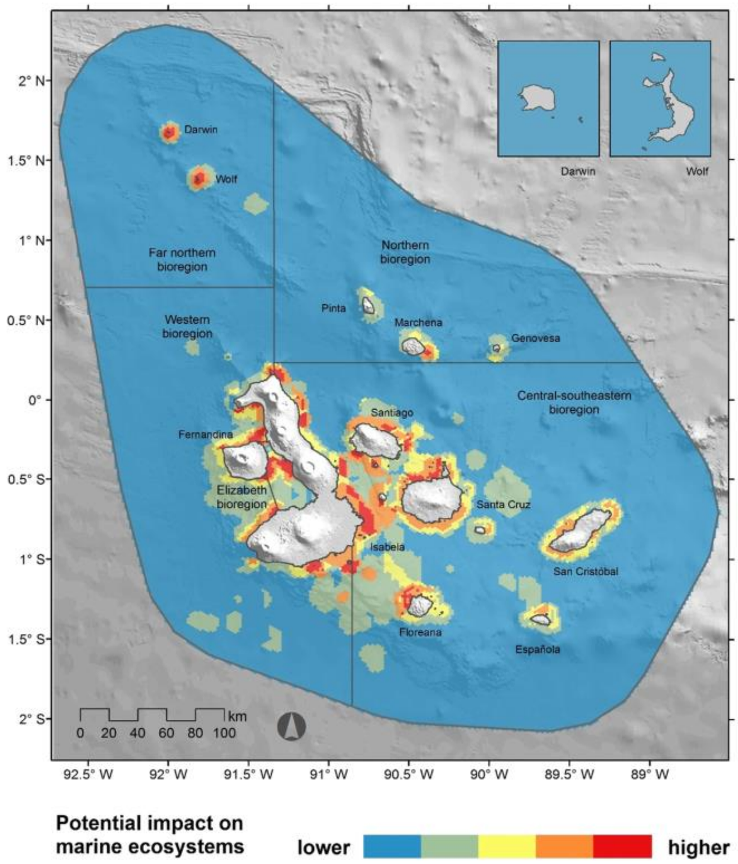


Figure 16. Projected impact on Galapagos' marine ecosystems by drivers of change. Spatial analysis units are hexagons of 3.46 km2.



7.2 Priority high-ecological value areas and stakeholder's validation

To select HEVA that should be prioritized for implementing ecosystem-based adaptation measures (EBAs) aimed at increasing the resilience and adaptation capacity of the Galapagos Islands, we cross-validated our results with the assistance of technical staff and directors of the GNP during a 2-day workshop held in Santa Cruz, Galapagos, in February 2020. In this workshop, we used the results of our impact assessment models as inputs and chose 13 HEVA with terrestrial and marine ecosystems (Table 5, Fig. 17). Overall, the HEVA host endemic, vulnerable, and critically endangered species or ecosystems with limited distribution; comprise spawning zones, shark nurseries, and nesting sites for sea turtles and birds; harbor resilient coral reefs and communities; and are characterized by a high influx of tourists. Some HEVA report high diversity and biomass of marine species from different tropic guilds, are feeding grounds of multiple marine and terrestrial species, and could be considered potential climate change refugia. Moreover, some terrestrial ecosystems within the HEVA are buffering areas around the agricultural zone, register an increasing incidence of invasive species, but also include the last remnants of the Scalesia forest in the humid highlands. Finally, these areas are of prime importance for local livelihoods, especially for small-scale fisheries, but some of them are highly exposed to overfishing (for details of selected HEVA, see Appendix 5.2, section Supplementary material, Table S8). Each HEVA is characterized by the following criteria: (1) expected climatic variability given by the spatial distribution of terrestrial future climate models; (2) representativeness, measured as HEVA distribution among bioregions; (3) habitat connectivity across the elevation gradient (i.e., number of terrestrial macro-habitats occurring on each HEVA); (4) marine habitat diversity (number of marine macro-habitats); and (5) HEVA relevance for environmental service provision (e.g., tourism, fishery, freshwater provision). The HEVA selected comprise 22.7% (14,715 km2) of the Galapagos Archipelago, distributed in 2.77% (3,835 km2) of the GMR and 19.9% (1,592 km2) of the GNP (the terrestrial protected area; Table 5).

Based on the above-listed criteria, the HEVA were ranked for prioritizing the implementation of EBAs to confront climate change. Four HEVA had the highest priorities: (1) Corridor Sierra Negra Volcano Isabela South; (2) Conservation area Santiago-Santa Cruz; (3) Corridor Wolf Volcano, Punta Albermarle, and Cape Marshall; and (4) The Bolivar Channel and Elizabeth South (Fig. 17). These four areas comprise more than half of the marine priority HEVA and one-third of the terrestrial priority HEVA (Table 5). Overall, the selected priority HEVA constitute relevant areas for the distribution and life cycle of critically endangered and endemic species and relict ecosystems (e.g., Scalesia forest), which are interconnected by marine and terrestrial corridors. Furthermore, the prioritized areas are fundamental to sustain water, agriculture, and fishery provision for local inhabitants and the nature-based tourism industry.

To show the impact of nature-based tourism on the islands, we overlaid the priority HEVA with the estimated potential visits of public use areas (PUA) Reck et al. (2010)). We calculated the average ratio between the admitted capacity of visitors (CAV, for its Spanish acronym) and the average annual visits registered in five PUA (i.e., Puerto Ayora, Puerto Baquerizo Moreno, Puerto Chino, Puerto Villamil, and Sierra Negra) for the period 2016–2019. Then, we estimated the number of visits for not monitored PUA given their actual CAV multiplied by the calculated average ratio (actual PUA CAV * 0.05). This approximation to the potential visits that PUA with no data may receive (given their actual CAV and the available data from highly visited areas) adds to a maxi- mum capacity of up to 526,080 annual visitors in the entire GNP. Specifically, the priority HEVA exhibited an estimated capacity of up to 383,200 annual tourists, equivalent to more than half of the potential total annual tourists the Galapagos Islands could receive (Fig. 9). HEVA with the highest capacity were (6) Conservation Area Santiago-Santa Cruz (110,400), (11) Corridor El Junco and Southern seabeds (67,520), (3) Corridor Sierra Negra Volcano Isabela South (55,200), and (7) Floreana and Islets (44,160). This estimation outweighs the number of tourists registered in 2019 (Fig. S8) for the regulated tourist sites. Our estimations suggest that the high influx of tourists could be affected by drivers of change, especially in marine-related touristic activities. Besides, the estimated maximum capacity should be reevaluated concerning sustainable ecosystem capacity, as many visitors that arrive directly to the inhabited islands visit nearby tourism attractions that are not recorded in the PUA/CAV statistics (GNP, personal comment). There is a lack of records regarding tourist visits and only five PUA out of 66 keep visit records. According to our estimations, more than 200,000 visits may account for the non-monitored/regulated tourism in the islands, which may exceed the sustainable ecosystem capacity.

Figure 17. Priority high-ecological value areas (HEVA) for the development of adaptation measures against climate change. Priority HEVA are denoted as colored areas, where orange and red correspond to the fourth and fifth quintiles of the impact model score, respectively. The numbers next to the HEVA represent the estimated annual tourists at each HEVA. Stripped areas denote the admit- ted capacity of marine tourism sites (PUA) within HEVA. The estimated number of visitors was calculated by the ratio between the admitted capacity of visitors (CAV) and the average annual visits registered in 5 PUA (Puerto Ayora, Puerto Baquerizo Moreno, Puerto Chino, Puerto Villamil, and Sierra Negra). This may overestimate or underestimate the magnitude of visits in some areas but is an approximation of the average visits that PUA (with no data) may receive, given their actual CAV and the data in highly visited areas. Priority HEVA are as follows: (1) Corridor Wolf Volcano, Punta Albermarle, and Cape Marshall; (2) The Bolivar Channel and Elizabeth South; (3) Corridor Sierra Negra Volcano Isabela South; (4) Corridor Cartago Bay—San Luis sea- bed; (5) Santiago highland; (6) Conservation Area Santiago-Santa Cruz; (7) Floreana and Islets; (8) Marchena coral remnants; (9) Corridor la Galapaguera—Punta Pitt; (12) León Dormido (Kicker's rock); (11) Corridor El Junco and Southern seabeds; (12) Española and Gardner islands; and (13) Darwin and Wolf islands

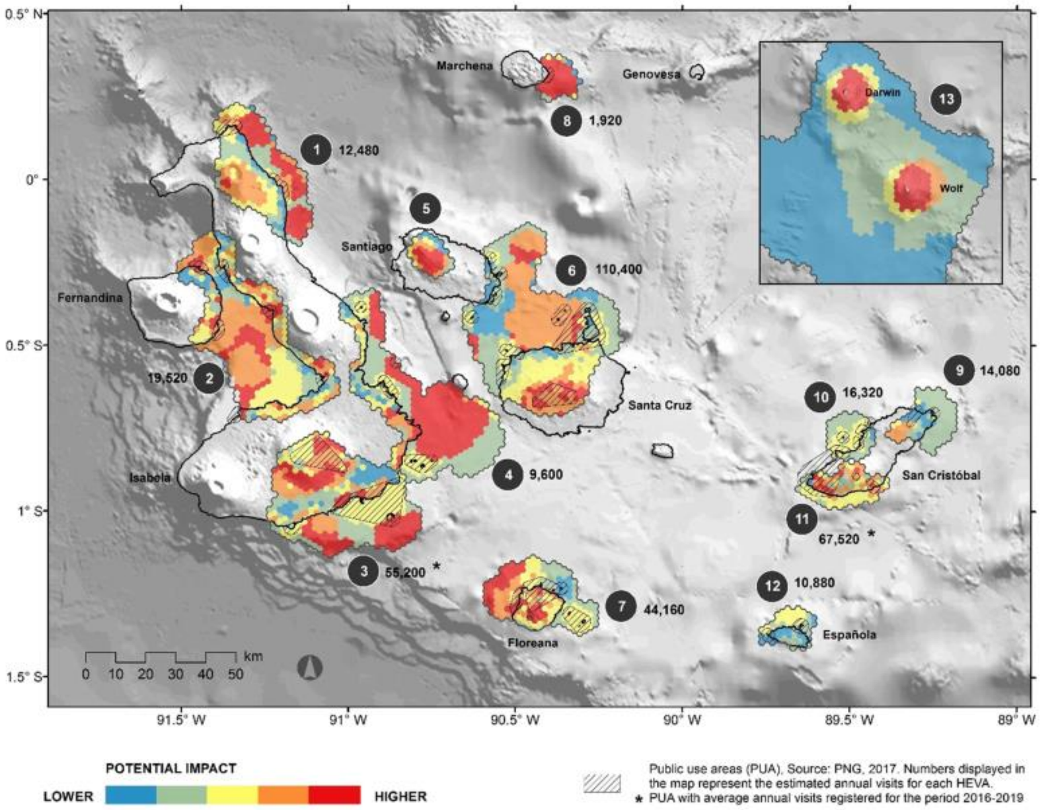


Table 5. Terrestrial and marine priority high-ecological value areas (HEVA) of the Galapagos Islands. A. Prioritized HEVA validated by the Galapagos National Park and chosen as areas of indirect intervention. b4th and 5th quintile of the potential impact model (orange and red areas

in the map) from the priority HEVA chosen as direct intervention areas for EBAs. Priority HEVA are as follows: (1) Corridor Wolf Volcano, Punta Albermarle, and Cape Marshall; (2) The Bolivar Channel and Elizabeth South; (3) Corridor Sierra Negra Volcano Isabela South; (4) Corridor Cartago Bay—San Luis seabed; (5) Santiago highland; (6) Conservation Area Santiago-Santa Cruz; (7) Floreana and Islets; (8) Marchena coral remnants; (9) Corridor la Galapaguera—Punta Pitt; (10) León Dormido (Kicker's rock); (11) Corridor El Junco and Southern seabeds; (12) Española and Gardner islands; and (13) Darwin and Wolf islands

Site ID	Total HEVA (km^2)	Marine HEVA (km^2)[a]	Total area of GMR (%)[a]	4th and 5th quintile of priority HEVA (km^2)[b]	Total area of GMR (%)[b]	Terrestrial HEVA in (km^2)[a]	Total area of islands (%)[a]	4th and 5th quintile of prioritized HEVA (km^2)[b]	Total area of islands (%)[b]
1	915.80	477.8	0.35	366.30	0.26	438	5.48	154.2	1.93
2	1617.95	990.35	0.72	617.43	0.45	627.6	7.85	280.26	3.50
3	1448.65	657.05	0.48	489.70	0.35	791.6	9.90	388.67	4.86
4	1502.80	1189.5	0.86	633.65	0.46	313.3	3.92	121.74	1.52
5	159.35	n/a	n/a	n/a	n/a	159.35	1.99	100.34	1.25
6	2006.40	1330.4	0.96	719.15	0.52	676	8.45	283.93	3.55
7	669.25	496.95	0.36	245.70	0.18	172.3	2.15	114.18	1.43
8	156.48	156.48	0.11	141.90	0.10	n/a	n/a	n/a	n/a
9	318.05	204.55	0.15	n/a	n/a	113.5	1.42	38	0.48
10	213.90	153.9	0.11	76.12	0.06	60	0.75	n/a	n/a
11	311.03	138.33	0.10	117.80	0.09	172.7	2.16	110.7	1.38
12	193.75	132.9	0.10	51.90	0.04	60.85	0.76	n/a	n/a
13	5201.26	5201.26	3.76	375.34	0.27	n/a	n/a	n/a	n/a
Total	14715	11130	8.05	3835	2.77	3585	44.83	1592	19.91

These results are important for guiding the design and implementation of adaptation measures aimed at increasing ecosystem resilience and human adaptive capacity in the face of global environmental change. Overall, these results will be valuable in their application for preserving Galapagos biota, securing the provision of vital ecosystem services for resident human populations, and sustaining the nature-based tourism industry.

7.3 Implications for ecosystem-based adaptation measures

This research presents the first study evaluating the current and potential ecological impacts of major drivers of change that threaten terrestrial and marine ecosystems of the Galapagos Islands, including climate change, unsustainable tourism and local population growth, IUU fishing, and invasive species. Our literature review, coupled with the spatial impact assessment model, identified 13 areas of high- ecological value area (HEVA) distributed across the Archipelago, equivalent to ca. 23% (14,715 km2) of the marine and terrestrial habitats. These HEVA represent areas most vulnerable to climate-based and human drivers of change that threaten the conservation and sustainable use of Galapagos' marine and terrestrial biodiversity. They also constitute important areas for the distribution and life cycle of critically endangered and endemic species and relict ecosystems (e.g., Scalesia forest).

Our impact assessment model demonstrated that current and potential impacts over HEVA are likely to concentrate on the four inhabited islands' highlands due to their prolonged periods of transformation. Projected changes are expected to increase invasive species encroachment, potentially impacting endemic Galapagos biodiversity and freshwater availability. In contrast, areas of higher impact for marine ecosystems concentrate along shorelines of most Galapagos islands, which could profoundly affect food security and livelihoods for Galapagos artisanal fisheries and the nature-based tourism industry. The four HEVA with the highest priority to focus ecosystem-based adaptation measures are (1) Conservation Area Santiago-Santa Cruz; (2) Corridor Sierra Negra Volcano Isabela South; (3) Corridor Wolf Volcano, Punta Albermarle, and Cape Marshall; and (4) The Bolivar Channel and Elizabeth South.

Based on these results, we recommend creating strategic alliances to design, agree upon, and implement a set of ecosystem-based adaptation (EBA) measures. These EBAs need to ensure the well-being of local livelihoods and the conservation of Galapagos' unique marine and terrestrial ecosystems by increasing the resilience and adaptation capacity of the Archipelago against current and future threats. Specifically, it is urgent to implement the following EBA measures: (1) restoring the humid highland ecosystems of the four inhabited islands as a means to increase freshwater provision, se- cure agricultural production, and reduce exotic species invasions; (2) improving the design and effectiveness of Galapagos marine zoning, through an adaptive co- management of the Galapagos Marine Reserve to reduce IUU fishing and protect the most suitable areas to ensure commercial stocks recovery, based on climate change risk assessment; (3) strengthening marine biosecurity pro- grams for invasive species; (4) restoring selected coral reef habitats through experimental coral breeding and exclusion areas; (5) reducing the impact of diving, anchoring, and pollution related to tourism operations in select- ed marine HEVAS; (6) strengthening ongoing ecological and socioeconomic monitoring programs to produce the scientific data required to understand how climate change will interact with other non-climatic drivers and how they will impact the Galapagos Islands. This will support the design of scientific-sound base adaptation measures and the evaluation of their effect on increasing ecosystem resilience and human adaptive capacity.

8. Socioecological impacts (hazards) and expected scenarios

This section explains the socioecological impacts of climate variability and climate change and other anthropogenic drivers of change, reported by the available scientific studies over different ecosystems, species, and human activities. In some cases, different types of environmental, oceanographic, or population models were built to quantify the potential impact of those climatological and oceanographic variables under different scenarios associated with climate change. In other cases, when scientific data were not available, different expected scenarios were built based on the qualitative analysis of the information available. The details of the methodology and results described in this section are found in appendices 2.1, 2.2, 2.3 and 2.4.

8.1 Terrestrial ecosystems

8.1.1 Impacts

The unique humid highland ecosystems of the Galapagos Islands have undergone massive losses of their original distribution and biodiversity due to their transformation into pastures and agricultural lands in the past (Watson et al. 2009). The remaining fragments are exposed to progressive degradation due to the synergistic effects of the invasion of alien species and climate change (Trueman et al. 2010). Below, we provide an overview of each of these drivers of change and present a case study for the spread of the highly invasive guava under climate change scenarios in the highlands of Santa Cruz, San Cristóbal and Isabela, which serves as a proxy for the anticipated spread of other invasive plants, especially that of blackberry.

The analysis of Watson et al. (2009) revealed that 5% (37,833 ha) of the Galapagos Archipelago's main inhabited (or previously inhabited) islands had been disturbed by human activities. While this disturbed land represents a small fraction of the total land area, it has experienced a substantial human impact over the last 100 years (Watson et al. 2009). The total area of degraded land per vegetation zone shows that the naturally bare, the littoral and arid vegetation zones have been subject to minimal human impact (~ 1% modification), whereas 29 and 45% of the humid and very humid zones have been altered, respectively (Table 6). Degradation of vegetation zones is not evenly distributed among inhabited islands. For example, 94 and 100% of the humid and very humid zones have been degraded on San Cristóbal, and 88 and 76% of the humid and very humid zones on Santa Cruz. Overall, the humid and very humid vegetation zones of the main islands have been heavily impacted by land conversion and invasions by four of the most prevalent alien plant species (*Psidium guajava*, *Rubus niveus*, *Cinchona pubescens* and *Syzygium jambos*), with major effects on Santa Cruz, San Cristóbal and Isabela (Table 6).

Table 6. Total area (ha) and percentage of degraded land (in parenthesis) of the six vegetation zones on the five inhabited or formerly inhabited (Santiago) islands of the Galapagos Archipelago.

Vegetation zone	Floreana	Isabela	San Cristóbal	Santa Cruz	Santiago	Total
Naturally bare	0	406 (0.4)	15 (0.5)	0	0	421 (0.2)
Littoral	0	8 (0.4)	NDA	0	NDA	8 (0.3)
Arid	54 (0.5)	162 (0.2)	888 (2)	319 (0.4)	0	1,423 (0.4)
Transition	72 (2)	2,185 (4)	1,015 (24)	3,121 (25)	10 (0.2)	6,403 (5)

Humid	1,170 (38)	8,173 (21)	5,552 (94)	8,381 (88)	23 (0.5)	23,299 (29)
Very humid	NA	2,460 (29)	2,078 (100)	1,765 (76)	13 (1)	6,316 (45)
Total	1,296 (8)	13,394 (5)	9,548 (17)	13,586 (14)	46 (0.1)	37,870 (4.4)

Source: adapted from Watson et al. (2009)

NDA = No data available

One ecosystem type that is severely being affected by land-use change (conversion to agricultural areas) and invasive species is the Scalesia forest. *Scalesia* is one of the seven endemic plant genera (15 species with 21 taxa) of the Galapagos Islands (Eliasson 1974). Some species occur on several islands while others are endemic to a single island. Most are shrubs that established in the arid and transition zone, but three species: *S. pedunculata*, *S. cordata* and *S. microcephala* are trees that used to occur in the highlands and used to form dense forests as the dominant species in the past (Eliasson 1974; Hamann 2001).

On Santa Cruz, San Cristóbal, Floreana, and Santiago, this forest is comprised of the giant endemic and vulnerable daisy-tree, *Scalesia pedunculata*. Today, remnants of this forest can only be found in the protected areas and hardly any *Scalesia* trees are left on San Cristóbal (Mauchamp and Atkinson 2010). The forest on Santa Cruz is now estimated to cover an area less than 1% of its original extent (Mauchamp and Atkinson 2010) and remnants are invaded by non-native plants, especially by blackberry and guava (Rentería et al. 2012, Rivas-Torres et al. 2018a). Ironically, agriculture has proved to be only marginally viable as an economic activity and hence much of this land now lies fallow and increasingly infested with non-native species (Watson et al. 2009). On Isabela, it is estimated that only about 300 trees of the endangered *Scalesia cordata* remain at Cerro Azul and Sierra Negra volcanoes (Jaramillo and Chávez 2002; Jäger, unpubl. data). All Scalesia forests are very species-rich and house many endemic species, like the Darwin's finches, which are currently in dramatic decline (Dvorak et al. 2012). There are eleven endemic invertebrate species registered for *Scalesia pedunculata* (Boada 2005), some of them feeding exclusively on *Scalesia*, especially some Lepidoptera species (Roque 2006). Together with the *Scalesia*, loosing these species species would result in a drastic decline of the local biodiversity. Biodiversity-poor ecosystems are more vulnerable to the establishment of invasive species and less resilient to climate change (Trueman et al. 2010). For example, in forest fragments where the understory is dominated by blackberry, mortality rates of adult *Scalesia* trees is high and recruitment of saplings and young trees is limited, leading to forest degradation (Rentería et al. 2012, Jäger et al. 2017). In addition, being an evergreen endemic tree in the otherwise naturally treeless highlands (Jäger et al. 2007), *Scalesia pedunculata* offers a permanent surface to capture additional water from the characteristic mist (*garúa*) of the highlands in the cool season (Pryet et al. 2012). Studies in Hawaii have shown that the canopy water storage capacity was twice as much at the native site compared to the site invaded by the introduced strawberry guava (*Psidium cattleianum*, Takahashi et al. 2011) Thus, conserving the last fragments of this critically endangered ecosystem, and implementing restoration efforts so that it can eventually recover, will enhance the resilience of terrestrial ecosystems in Galapagos to climate change, while supporting the livelihoods of the local farmers..

The terrestrial ecosystems of Galapagos have evolved within the unique climate of the archipelago and are therefore susceptible to changes in the climatic regime (Di Carlo et al. 2010). Due to the natural rainfall variability associated with ENSO events, there is some intrinsic resilience in terrestrial organisms and communities (Trueman et al. 2010, Restrepo et al. 2012). However, the two strong El Niño events in 1982–83 and 1997–98, marked by anomalous warming of the sea surface temperature, air temperature and extreme precipitation, resulted in substantial impacts in the terrestrial ecosystems, like increased growth of herbaceous plants (proxy for increase in invasive species growth) and mortality of arboreal plants (Escobar-Camacho et al. 2021). These observations help us understand the vulnerability of species and ecosystems to potential future changes to the climate in Galapagos. These insights are key to be able to develop and apply management measures to increase the resilience of threatened species and ecosystems to climate change, like the different *Scalesia* species that form these unique forests. *Scalesia pedunculata* may be particularly affected by ENSO, since it exhibits a natural stand-level dieback and regeneration that appears to be linked with El Niño and La Niña events (Hamann 1985). Scalesia forests are highly susceptible to extreme precipitation events, leading to high tree mortality, since these get water-logged (Hamann 1985). In the past, the initial high tree mortality triggered by El Niño was usually followed by a mass recruitment of *Scalesia* through seed germination during the following La Niña event (Hamann 1979). However, due to the invasion of the understory by blackberry, the light-demanding *Scalesia* seeds cannot germinate in the dense thicket and the forest is not able to regenerate as it used to (Rentería et al. 2012; Jäger et al. 2017). Higher precipitation, as predicted for Galapagos, could threaten the humid zone ecosystems by changing vegetation growth rates and forest structure (Trueman et al. 2010). Additionally, increasing temperatures could cause species, like the *Scalesia* species, to shift their ranges to higher elevations (Larrea and Di Carlo 2011). This, combined with the short life expectancy of the *Scalesia* species (an estimated 15 years, Hamann (2001)), makes them more vulnerable to long-term disturbances (Hamann 2001) and to invasive species (Jäger et al. 2017). Climate change impacts, including warming temperatures and changes in CO_2 concentrations, are likely to increase opportunities for invasive alien species because of their adaptability to disturbance and to a broader range of biogeographic conditions (Burgiel and Muir 2010).

The mean annual temperature in Galapagos has increased by ~0.6°C over the last four decades across the islands (Escobar-Camacho et al. 2021). Future scenarios detected by General Circulation Models (GCMs) suggest warmer and wetter trends for the Galapagos Islands. Annual precipitation is projected to increase between 20-70%, with major changes in the highlands, while mean annual temperature is expected to rise between ~1.1 and 2.0 °C (Paltan, under review). Under these new climatic conditions, the increase, distribution and impacts of invasive species may directly or indirectly be accelerated (Hulme et al. 2017, Essl et al. 2020). Many invasive species are pre-adapted to take advantage of disturbed areas (e.g. native ecosystems stressed by climate change), mainly by extreme events such as ENSO, creating new opportunities for introduced species to establish and thrive (Beaury et al. 2020, Shackleton et al. 2020). A good example is the case of the guava (*Psidium guajava*) and blackberry (*Rubus niveus*), the most invasive plants in Galapagos (Jäger et al. 2017, Shackleton et al. 2020, Appendix 2). Preliminary evidence suggests that guava is drought and shade tolerant, resistant to temporary water-logging, grows well in a wide range of soil pH and has the capacity to intercept fog water via stemflow (Walsh et al. 2008, Takahashi et al. 2011). These characteristics, coupled with the high rainfall and several droughts associated with El Niño and La Niña respectively, is expected to facilitate the spread of guava and blackberry after dieback of native species (e.g., *Scalesia spp.*) and the progressive degradation of agroecosystems in Galapagos (Tye 2006, Jäger et al. 2019, Schmitt et al. 2018, Laso et al. 2020).

In addition, residents from the farming zone migrate to coastal towns to work on tourism related activities, which leads to the abandonment of agriculture and cattle ranching. The proportion of the population residing in rural areas has decreased from 42% in 1974 to just 17% in 2010 (Sampedro et al. 2018). This leaves the lands vulnerable to the invasion of alien species (Barona and Mena 2014) and further exacerbates the desertion of the highlands and a low food production. According to the Agricultural Census, the total productive area had been reduced from 23,426 ha in 2000 to 19,010 ha in 2014, representing a decrease of 19% (Sampedro et al. 2018). According to Laso et al. (2020), guava is the most common invasive plant inside the agricultural area, covering about 6,836 ha (27%) of the area, of which 73% corresponds to areas dominated by guava and the rest corresponds to areas covered by mixed forest, which is a mixture of native vegetation and invasive species (mainly blackberry). However, in a representative survey of 20% of the farmers on Santa Cruz, 85% of interviewees said that blackberry was the most problematic invasive species on their land, followed by guava with 67% (Jäger et al. 2019). Moreover, previous studies carried out in the GNP suggested that about 2-5% of the protected area had been severely modified by the spread of invasive species from the adjacent agricultural area (Rivas-Torres et al. 2018b). Current studies indicate that almost USD 3,000,000 are invested in Galapagos annually to fight invasive species in the agricultural area, of which about USD 1,000,000 correspond to investments in family labor force (Viteri and Vergara 2017). This represents a substantial investment by local farmers that consequently leads to higher costs for agricultural and livestock production. These increased costs discourage farmers from agricultural production, which leads to an increase in the likelihood of abandonment of the activity, when farmers are not able to recover the investment due to droughts, pests, and diseases.

Invasive species do not only have to be controlled in the agricultural areas. Over more than 20 years, the GNPD has been controlling alien plants by applying manual and chemical control (Toral-Granda et al. 2017). Results from an experimental removal of blackberry in the Scalesia forest showed a spectacular natural regeneration of *Scalesia*. Only 5 months after the last herbicide application, up to 280 *Scalesia* seedlings were encountered in an area of 10 m × 10 m. In the adjacent, blackberry-invaded area, not a single seedling emerged from seeds during that same time (Jäger et al. 2017). The study showed that without blackberry control, the Scalesia forest will not be able to regenerate on its own. However, an initial reduction in the number of invertebrates and breeding success of the green warbler finch (*Certhidea olivacea*) was also observed right after control measures were applied, but only two years later, these where not detectable anymore in the subsequent monitoring (Cimadom et al. 2019).

Therefore, anticipated negative impacts from control actions have to be counteracted by a subsequent restoration approach to increase the number of native and endemic species and the species' cover, as well as suppressing the regeneration of invasive plants. Given the current trend of abandonment in the agricultural sector in Galapagos (Laso et al. 2020) and the ability of guava and blackberry to persist under ENSO conditions, which will likely become more frequent and extreme under future climate change (Cai et al. 2015), guava and blackberry propagation could be faster than ever before (Schmitt et al. 2018). Studies have shown that restoration of plant diversity may greatly increase carbon capture of degraded agricultural lands (Yang et al. 2019). Thus, integrating invasive species management into the Galapagos climate change mitigation and adaptation programs, will help to maintain and restore native ecosystem integrity, safeguards livelihood benefits and thereby increase resilience of the protected and agricultural ecosystems to climate change.

8.1.2 Expected scenarios

The development of models that capture the future spatial distribution of invasive species is essential to facilitate effective management actions, such as prevention of spread and opportunities for eradication (Bellard et al. 2013). For this analysis, a Cellular automata-Markov chain (CAMK) simulation model was implemented to understand the current distribution pattern and quantify the dispersion of invasive plant species under different climate change scenarios in Galapagos by 2030. Understanding the role of plant invaders in an ecosystem, as well as interactions between and among species, is important and can significantly affect the outcome of restoration programs (D'Antonio and Meyerson 2002). This case study aims at identifying areas that would be highly susceptible to the expansion of invasive plant species under climate change. The modelling focuses on the guava invasion in ecologically important areas that have to be protected, preserved and restored and serves as a proxy for other invasive plant species, like blackberry. The reason we are using guava as the model species is the fact that we have more and also more reliable data for guava for Santa Cruz, Isabela and San Cristóbal than we have for blackberry. As a mainly understory shrub, blackberry is hard to distinguish from shrubby or arboreal vegetation in satellite or drone images, so that an accurate modelling of its distribution would be difficult. However, we know from experimental plots that guava and blackberry are similar in their invasion behavior and that that they often occur together in invaded areas (Jäger et al. 2009, Jäger, unbubl. data). Thus, we feel confident that the modeling of the guava invasion gives us a reliable proxy for the blackberry invasion. Since blackberry forms monospecific stands that displace most species except for some fern species, whereas guava trees do not completely block the passing of light and are even seen as partially beneficial by some cattle farmers (Renteria et al. 2012, Jäger et al. 2017, Rivas-Torres et al. 2018a). Consequently, the target species to control in the proposed intervention is mainly blackberry, with guava being controlled where it occurs together with blackberry. It is important to mention that guava is seen as partially beneficial by cattle farmers but not by agricultural farmers, who mentioned guava as being the second most problematic species on their farms, with blackberry being the most problematic (Jäger et al. 2019). Based on the modeling for guava, this project contemplates supporting a restoration program over ~1,500 ha, which will provide direct impacts on the protection of natural resources.

8.1.2.1 Modelling of *Psidium guajava* spread under climate change.

Occurrence data

Psidium guajava or guava is an evergreen small tree (8 m tall), native to the tropical regions of America and introduced to the Galapagos Islands in the late 19th century (Walsh et al. 2008). It is now recognized as one of the most aggressive invasive plants in the archipelago, where both the agricultural area and the protected area of the GNP are seriously infested (Rivas-Torres et al. 2018b, Urquía et al. 2019). Occurrence data for guava were obtained from the most recent initiatives to map land use and land cover in Galapagos for the reference years 2016 and 2018 [(Rivas-Torres et al. 2018b, Laso et al. 2020, Carrión, unpubl. data), Table 7]. The invasion pattern of guava was analyzed in the shared area of these studies. The land cover categories selected for this analysis are those related to guava-dominated vegetation (> 50%) (Figure 18).

Table 7. Current efforts to map land cover in the Galapagos Islands.

Source	Sensor	Spatial Resolution	Years images acquired	Study area	Interest categories
Rivas-Torres et al. (2018b)	Landsat 8	15 m	2015/2016	GNP	*Psidium guajava*
	SRTM	30 m	2015		
Laso et al. (2020)	PlanetScop	3 m	2018	Agricultural area and surrounding protected area	*Psidium guajava*
	Sentinel-2	10 m	2017/2019		
	SIGTIERRAS-DTM	10 m	2009		
Carrión (unpubl. data)	Worldview 2	0.46/1.84 m	2015/2018	GNP	Guava Dominant

Based on previous studies (Jacobi and Warshauer 1992, Barona and Mena 2014), data availability and multidisciplinary experts' knowledge, a list of 15 drivers for guava invasion was compiled and analyzed. Multi-collinearity among variables was tested using Pearson's correlation and variance inflation factors (VIFs) (Sokal and Rohlf 2011). Variables with a Pearson correlation > 0.65 and VIF > 5 were dropped to reduce multicollinearity. In addition, climate variables were prioritized in the previous analysis due to their importance in the construction of growth and spread guava scenarios under future climate change. Finally, the remaining five variables: distance to guava patch, soil moisture, wetness index, precipitation, and temperature, were selected as relevant predictors to model current a future guava distribution (Table 8). These variables represent the physical characteristics of the local land (suitability) and the spatial variation in climatic conditions. Selected variables were processed and spatialized via GIS functions and gridded with a 15 m spatial resolution to match the lower resolution of the available land cover maps (Table 8). The values of all variables were standardized into a 0-1 range.

Table 8. Summary of the key driving factors for the guava growth and spread in Galapagos.

Variable	Description	Data Source
Dist_guava	Distance (meters) from the cell to guava patch inside of agricultural area, based on the least-accumulative cost over a DTM (cost surface).	Galapagos land use map 2018 (Laso et al. 2020). SIGTIERRAS orthophotos 2010 (10 m)
Soil moisture (SM)	Monthly soil-moisture storage (mm), which is the moisture retained in the soil column based on land use categories, elevation, and micro-watershed.	Galapagos Water Balance 2020
Wetness Index (H)	Humidity was represented as a wetness index through the follow equation: $H = \ln\left(\frac{AD}{\tan(\beta)}\right)$ Where, AD is the drainage area and β is the slope in degrees. The index values range from 0 to 15 where values closer to 15 represent higher humidity.	SIGTIERRAS orthophotos 2010 (10 m) Micro-watershed map
Precipitation (Pr)	Annual precipitation value of the cell (mm)	CHELSA project (1 km) (Karger et al. 2017)
Temperature (Tm)	Mean temperature value of the cell (°C)	CHELSA project (1 km) (Karger et al. 2017)

To observe the response of guava to the near-future reference period of 2030 under climate variation, we used: (i) the official downscale climate projections from four selected CMIP5 models at 10 km of resolution (CSIRO-Mk3-6-0, GISS-E2-R, IPSL-CM5A-MR, MIROC-ESM) (MAE 2017) and; (ii) the only two available GCMs (CMCC-CM, MIROC5) from CHELSA dataset (Karger et al. 2017) for this period. The CHELSA project is a high resolution (30 arc sec ≈ 1km) climate dataset for the earth land surface areas. The guava future distribution was examined under moderate and extreme climate change scenarios based on two Representative Concentration Pathway trajectories, RCP 4.5, RCP 8.5 (IPCC 2013). RCP 4.5 is a medium-low stabilization scenario that assume emissions peak around 2040, then decline. For the study area, in this scenario, the predicted temperature increases 1.1 ± 0.3°C by 2030 and the project precipitation increases by about 13% on average by 2030. On the other hand, the RCP 8.5 is a high-emission scenario in which emissions continue to rise throughout the 21st century. In this case, the temperature is predicted to increase in 1.2 ± 0.4°C and the average predicted precipitation is about 14% by 2030 for the study area (Table 9).

Table 9. Projected anomalies in Precipitation (Pr) and Temperature (Tm) under RCP 4.5 and RCP 8.5 scenarios on three islands of Galapagos.

Island	RCP 4.5	RCP 8.5
San Cristóbal	Pr: 12% | Tm: 1.1°	Pr: 14% | Tm: 1.2°

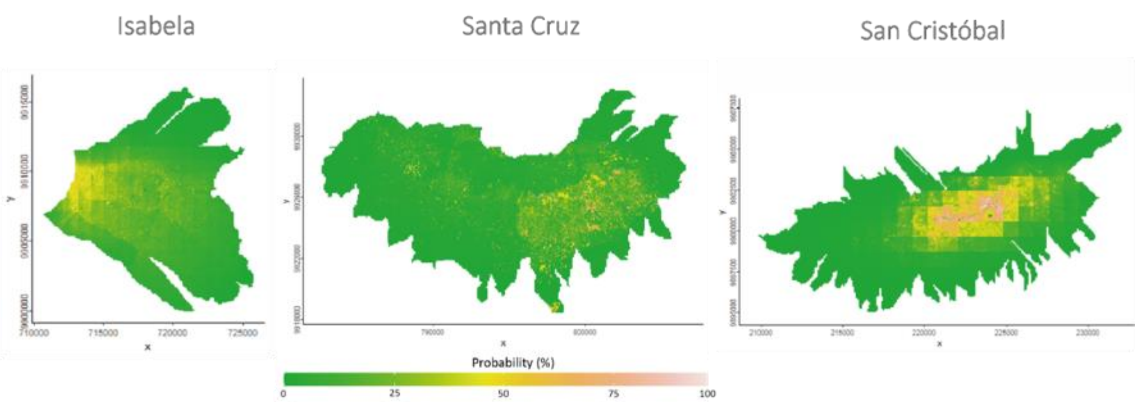
Santa Cruz	Pr: 13% | Tm: 1.1°	Pr: 15% | Tm: 1.2°
Isabela	Pr: 13% | Tm: 1.1°	Pr: 14% | Tm: 1.2°

Species distribution modelling

Several species distribution algorithms have been developed in the field of spatial modelling to represent and capture many complex ecological responses within the natural system (Elith et al. 2010). However, as a single modelling algorithm does not provide the best predictive accuracy, a combination of Cellular automata and Markov chain (CAMK) modelling (Keshtkar and Voigt 2016) was used to characterize the dynamic of invasive plant growth and spread in the Galapagos highlands. The hybrid model proposed combines the stochasticity provided by Markov chain technique (Losifescu 2014) with a probabilistic synchronous from Cellular Automata (CA) approach. This model allows to predict the future status of an ecosystem based on its pre-existing status (Rimal et al. 2018).

The success of the CA model to capture the local and regional dynamic is the optimum determination of the CA transition rules. It was built and calibrated using: (i) a conventional logistic regression based on driving factors; (ii) a neighborhood model using a moving window of 5 × 5 cells (150 m × 150 m), estimated from the cumulative allocated development of the previous period; (iii) a random model that describe the inherent variation associated with the system (stochastic factor); and (iv) the growth and spread constraints (water bodies and built environments). According to the conditions of each island, different transition rules were configured to produce transition potential maps (habitat suitability) (Fig. 18), which differs in regression coefficients. Highest values represent better conditions for the development of this species.

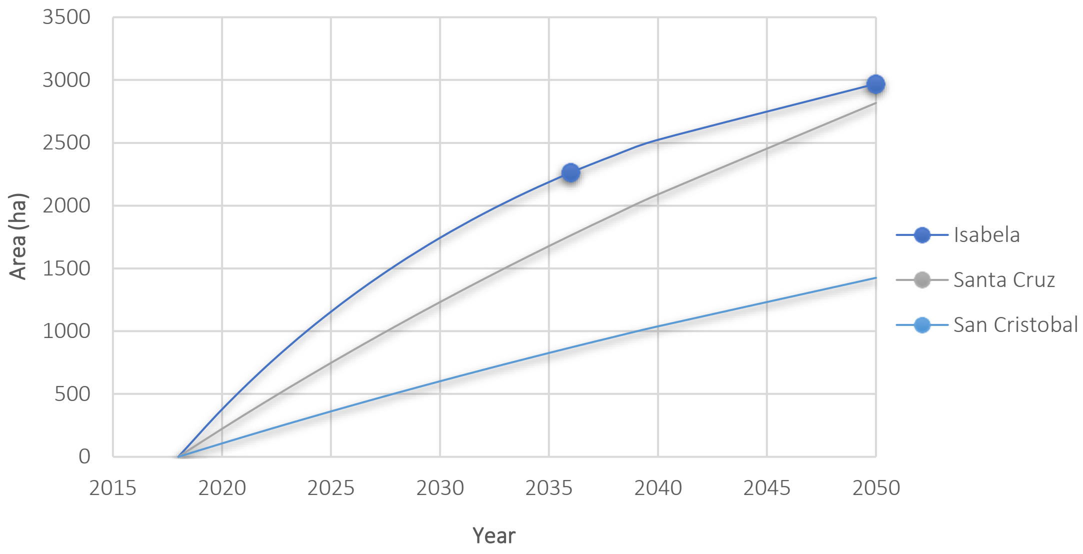
Figure 18. Potential transition maps (habitat suitability) for Psidium guajava development



In the absence of land cover data for a third period in the study area, landscape metrics (spatial validation) were used to evaluate the ability of the model to simulate future changes by comparing the observed *Psidium guajava* map of 2018 with the simulated map of the same year.

Finally, the map based on observed data for guava for 2018 was set as the base map and the transition probabilities (demand) of change in guava growth from 2016 to 2018, calculated through Markov chain technique, were used to forecast the guava growth map of 2030 (Figure 19). These data were used as input in the annual interactive CA modelling where, for each year, the highest potential pixels are selected and converted in guava land until de demand is filled.

Figure 19. Psidium guajava growth area on the three islands, calculated based on Markov chains projections.



Restoration/Rehabilitation criteria

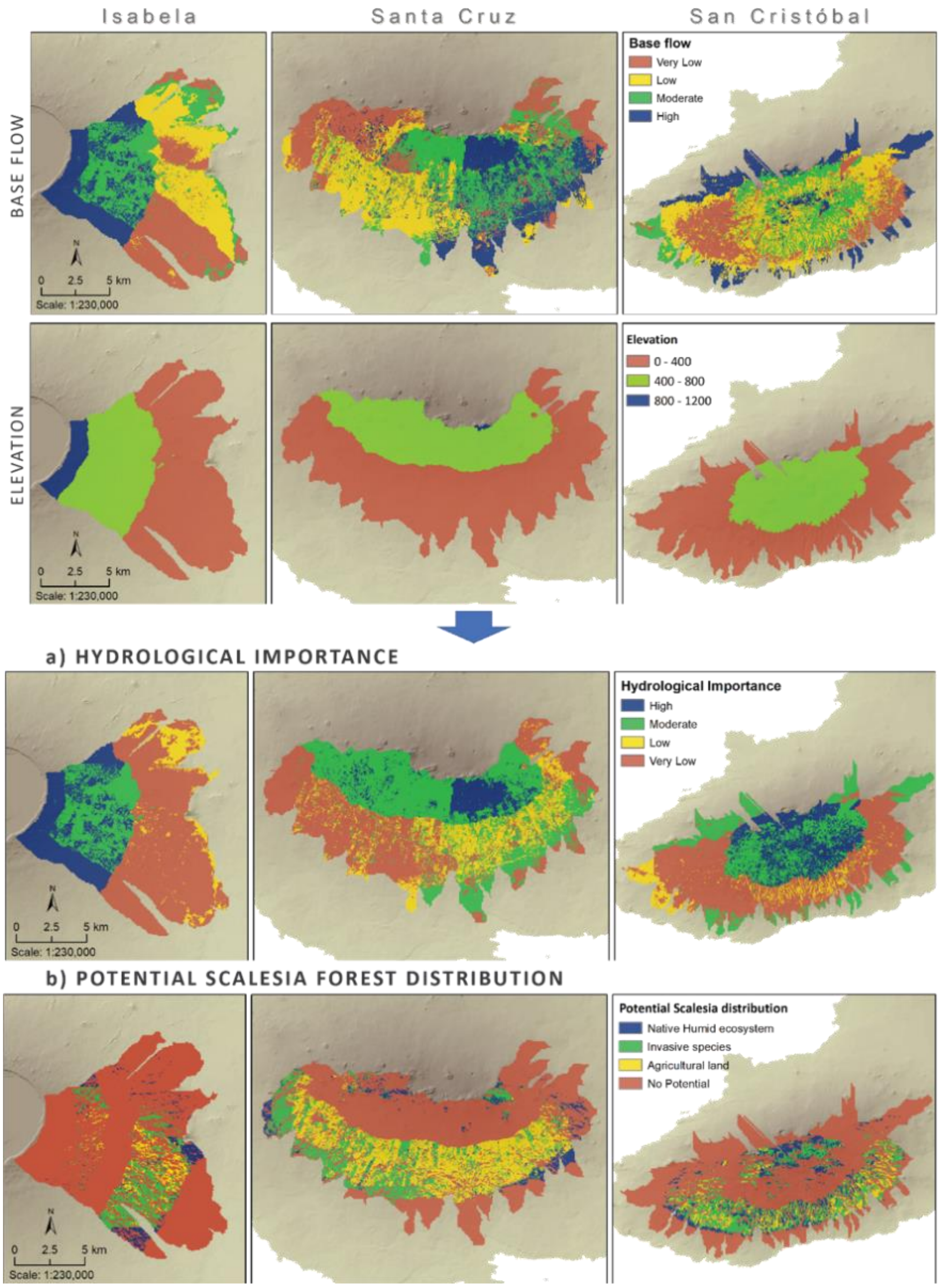
A multi-criteria evaluation (MCE) was performed to define the areas with high ecological and hydrological importance in the Galapagos highlands. This method allowed us to evaluate land use based on expert knowledge in order to support land use and environmental planning and management (Feizizadeh and Blaschke 2012, Barona and Mena 2014). Expert knowledge was included in the model based on focal groups meetings with restoration scientists in Galapagos, where restoration criteria were defined. The application of MCE process involves: (i) identification of criteria or factors that contribute to identify areas with ecological and hydrological importance; (ii) determination of the relative importance (weighting) of each factor based on "*experts' opinions*"; (iii) aggregation of the criteria weights and check model consistency; and (iv) an overall evaluation of the suitability model.

In this feasibility assessment, we combined agricultural livelihoods needs with ecological and hydrological criteria for identifying intervention areas for the restoration of Scalesia forest ecosystem and rehabilitation of ecosystem services in the Galapagos highlands. These criteria included the following thematic information: (i) areas of high hydrological importance based on the baseflow (mm) of each island; (ii) the potential *Scalesia* forest distribution; and (iii) altitudinal range (m) (Figure 20).

Areas of high hydrological importance are referred to those with the highest water yield. To identify these areas, a water balance for the highlands was developed to determine the current water production on the three major inhabited islands (see Appendix 2 of the 2.1 FS Agriculture Water balance). The water balance analysis focused on three main flow subcomponents: (1) surface runoff, (2) interflow and (3) baseflow. In general, these three types of flows inform us about the speed of the water, the capacity of soil water regulation and water demands based on current land use (see below). Areas of high ecological importance are referred to those where the potential distribution range of the *Scalesia* forest were predicted to occur, before human intervention modified the landscape (Escobar-Camacho et al. 2021).

Activity 2.1.1.1 includes trainings through the Farmer Field Schools (FFS) and Soil Doctors Program (SDP) approaches and topics include hydrology, irrigation and decision making based on early warnings. Extension agents that participate in the capacity building program for government technical staff will be required to design a training program and provide extension services to farmers accompanying the FFS and SDP as a requirement to obtain a diploma on climate change impacts and management in agriculture. (Please see further information in Section 12.5, in Output 2.1.1 description).

Figure 20. Thematic variables used to build sustainable areas for Scalesia forest restoration.

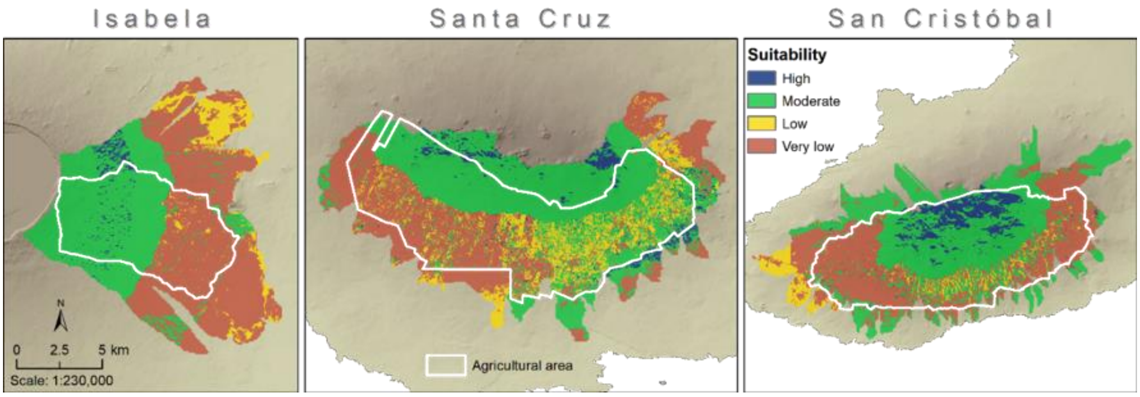


Each thematic criterion, mentioned above, was categorized according to the degree of restoration suitability. The baseflow data was grouped into four-category quantile, elevation data was classified every 400 m intervals and the potential *Scalesia* distribution map was categorized based on their land use coverage. Each suitability classes were subsequently ranged according to their relative importance on a 1 to 4 scale, where 1 represent a very low restoration suitability and 4 a high restoration suitability. As previously mentioned, the relative importance was assigned based on expert´s opinion (see above). All variables and indicators were aggregated through a weighted overlay using GIS spatial analyses tools. A particular criterion weight was determined for each resulting combination. The details of weights used for the evaluation criteria are listened in Table 10. The weights were assigned based on restoration as a constraint to invasive plants spread, where 0 represent a high constraint to guava spread and 1 represent no-constraint to invasive spread (Fig. 21).

Table 10. Detailed weights and ranges for the criteria for restoration and invasive plant spread.

Suitability	**Factor**	**Criterion**	**Weight**
High	*Scalesia* potential distribution	Over agricultural areas and invasive and native vegetation	0.25
	Baseflow	Highest values (4th Quantile)	
	Altitude	Over 400 m asl	
Moderate	*Scalesia* potential distribution	Over agricultural areas and invasive and native vegetation	0.5
	Baseflow	Moderate and High values (3rd and 4th Quantiles)	
	Altitude	0 - 800 m asl	
Low	*Scalesia* potential distribution	Over agricultural areas and areas with no *Scalesia* potential distribution	0.75
	Baseflow	Low and Moderate values (2nd and 3rd Quantiles)	
	Altitude	0 - 800 m asl	
Very low	*Scalesia* potential distribution	Over agricultural areas and areas with no *Scalesia* potential distribution	1
	Baseflow	Lowest values (1st Quantile)	
	Altitude	0 - 400 m asl	

Figure 21. Suitable areas for Scalesia forest restoration in the Galapagos highlands



Driving forces of Psidium guajava invasion in Galapagos

In this study, a logistic regression analysis allowed us to understand and statistically quantify the relationship between guava growth and its driving factors. All the variables selected as driving forces in guava growth were significant at $\alpha < 0.001$ (Table 11).

Table 11. Cellular Automata parameters generated by logistic regression.

	San Cristóbal		Santa Cruz		Isabela	
Variable	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	-8.83	<0.001	-8.91	<0.001	-6.81	<0.001
Dist_Guava	-7.39	<0.001	-1.03	<0.001	-7.89	<0.001
SM	1.73	<0.001	9.39	<0.001	6.02	<0.001
H	4.05	<0.001	2.89	<0.001	3.11	<0.001
Pr	7.82	<0.001	2.26	<0.001	3.62	<0.001
Tm	-6.55	<0.001	-1.75	<0.001	-2.12	<0.001

The results show that there is a positive correlation between guava growth and factors associated with water availability (i. e. precipitation, humidity, and soil moisture; Table 11). Thus, access to water plays an important role in the interaction between native and invasive species (Guo et al. 2020), where introduced plants have shown to be better competitors than native plants. For this analysis, higher values of precipitation, humidity (wet index) and soil moisture represent better conditions for guava growth and spread. Of these three variables, soil moisture showed a higher significance in the guava growth process with an estimated coefficient that ranges from 2 to 9 depending on the islands (Table 11). This means that when resources increase (high soil water storage), it will increase the probability of the invasion success of guava into a native plant community and its presence will not be affected by water scarcity due to its drought tolerance (Binggeli et al. 1998; Schmitt et al. 2018). Climate projections suggest a wetter future, promoting the increase and spread of invasive species outside of their current distribution.

Finally, the remaining two variables (distance to guava patch and temperature) showed a negative correlation with guava growth on the islands (Table 11). As was expected, guava invasion is more likely to occur in proximity of actual guava-dominated patches that currently are located within agricultural areas. This could be associated with the dispersion of seeds by local animals such as finches, giant tortoises, and lizards, because these species have included guava fruit into their diets, facilitating their establishment and spread (Blake et al. 2012, Heleno et al. 2013). Furthermore, the results show that guava is more successful in areas with low temperature, becoming a strong competitor with the native forest species in the Galapagos highlands (Table 11).

Future spread under Climate Change

We explore two opposing scenarios of how the *Psidium guajava* invasion will develop in the next decades under climate change based on simulation models. The first shows a “Business as usual” (BAU) scenario, where extensive areas of agricultural land are abandoned, causing the fragile Galapagos agroecosystem and the adjacent protected areas to be more vulnerable to the expansion of invasive plants (Laso et al. 2020, McCleary 2013). Currently, the agricultural area of Galapagos houses a higher number of invasive plant species, which cover 28.5% of its surface (Guézou et al. 2010; Laso et al. 2020). These exotic plants not only threaten agricultural systems but also the remaining fragments of native ecosystems that still exist within farms, as well as the native ecosystems in the adjacent GNP.

The second scenario is based on a project intervention scenario, where areas of high hydrological and ecological importance are selected to implement ecosystem-based activities. Rehabilitation and passive restoration activities will be promoted to implement agroforestry systems within active and abandoned farms, in conjunction with protection strategies that support natural succession and improve the quality of the forest fragments to enhance sustainable agroecosystems. This will be complemented through the implementation of methods to control invasive species and enrich native ecosystems by means of planting native/endemic species like *Scalesia pedunculata* in degraded areas within the GNP. To ensure the continued success of a restoration/rehabilitation project, a long-term monitoring program is necessary to evaluate the success of invasive species control methods and results, like the potential impacts on non-target species.

Two possible scenarios were considered in the project intervention. For the first scenario (R1), active and passive restoration activities are implemented in about 1,500 ha inside regions with high and moderate suitability for ecological restoration (Fig. 22). The 50% (750 ha) of areas that would be restored are in protected areas and the remaining half (750 ha) within farms. The second scenario (R2) considers the reactivation and strengthening of the Galapagos agricultural sector through climate-resilient activities. These activities include forestry practices, such as bio-diversification and silvopastoral systems, which will allow the agroecosystem to control of invasive species, conserve remnants of forest fragments, protection of water resources, among others.

After process simulation, no significant difference was observed in the resulting maps under RCP4.5 and RCP8.5 scenarios. This could be explained by the minimal difference in the temperature and precipitation anomalies among both scenarios in a near-term future (Table 12) over the study area. For this reason, the results of this study are only presented under RCP 4.5 scenario.

According to the analysis, 15.7% of the study area was occupied by *Psidium guajava* in 2018 (Table 13), which will increase to 23.6% by 2030 under a BAU scenario. If restoration and rehabilitation activities were implemented in both protected and agricultural areas, this increase could be reduced to 17.5% and 16.4% under R1 and R2 scenarios, respectively. The results also showed that the rapid expansion of guava is mainly concentrated in Isabela, where the increment could range from 23.3% to 70.3% under BAU and project implementation scenarios, respectively (Table 13). The observed large expansion of guava in the highland vegetation of Sierra Negra volcano on Isabela (Fig. 22) are consistent with the agricultural abandoning process recorded since the 1980s (Laso et al. 2020), leaving the agricultural production concentrated in the lowest section of the agricultural zone.

Furthermore, we noted an important decline of guava on San Cristóbal (Table 13), if an intervention project was implemented (loss of 0.49% to 23.8%). On this island, the guava growth and spread were mainly concentrated in the agricultural area (Fig. 22), showing an effective control of invasive plants propagation under climate-resilient practices, supported by landowners and the GNPD. In addition, passive restoration practices on farms would help in the prevalence of native ecosystems within the agricultural area of San Cristóbal, where 30% of the agricultural area was categorized as native vegetation (Laso et al. 2020).

Santa Cruz has the most extensive pastures of the Galapagos agricultural area, where guava trees are used as shade trees for cattle in the silvopastures systems. Under rehabilitation activities and the protection of forest fragments, the guava spread could mainly be controlled in the protected area, where it could be reduced between 13% to 27%, compared to the BAU scenario (Table 14).

Table 12. Psidium guajava area (in ha) and percentage of change for 2018-2030 under Business as usual – BAU scenario and two project intervention scenarios (R1, R2).

Island	Initial stage, 2018	Scenario, 2030			Change in Guava distribution for 2030		
		BAU	R1	R2	Δ% 2018-BAU	Δ% 2018-R1	Δ% 2018-R2
Isabela	2478	4221	3556	3056	70.3	43.5	23.3
Santa Cruz	2424	3656	3183	2683	50.8	31.3	10.7
San Cristóbal	2139	2740	2128	1628	28.1	-0.5	-23.9
Total	**7041**	**10617**	**8867**	**7367**			

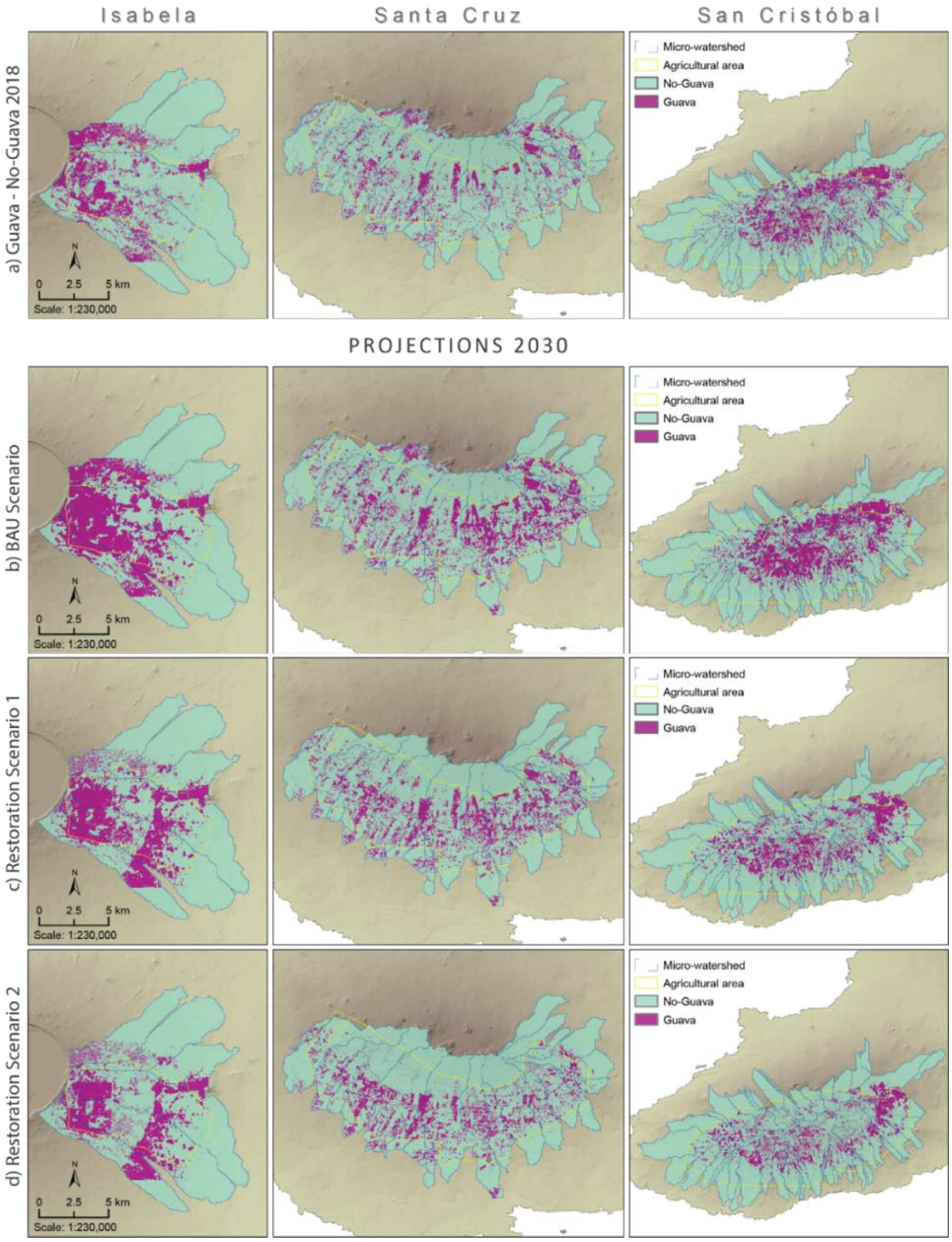
Considering the actual land use in the study area, the projected expansion of guava under a BAU scenario would be accompanied by an important decline of cultivated land area (loss of 21%), followed by pastures (loss of 10%) and native vegetation (loss of 6%) (Table 13). This pattern threatens food security in the islands, and the conservation and integrity of the native ecosystems will be heavily affected.

Table 13. Loses (in percentage) in land use categories (native vegetation, crop land and pastures) by Psidium guajava expansion by 2030 under different scenarios.

Island	Scenario	Native Vegetation	Crop's land	Pastures
Isabela	BAU	10.9	27.4	22.3
	R1	5.8	30.4	20.2
	R2	4.3	25.1	16.0
Santa Cruz	BAU	2.0	25.5	5.3
	R1	0.4	29.8	3.6
	R2	0.5	29.4	3.9
San Cristóbal	BAU	6.6	5.9	14.5
	R1	2.9	13.7	15.2
	R2	1.7	12.4	11.7

Figure 22 illustrates the fact that guava tends to spread over agricultural areas. Although spatial patterns may be affected by the growth rate used for modelling, which is not affected by restoration/eradication efforts, it is expected to see a significant reduction in both the rate of growth and spread with the implementation of control strategies for invasive species, which will be key for improving resilience in agroecosystems.

Figure 22. (a) Actual Psidium guajava distribution map, 2018; and simulated growth maps by 2030 under (b) BAU scenario and (c, d) Project intervention scenario (R1, R2).



8.2 Agriculture

8.2.1 Impacts

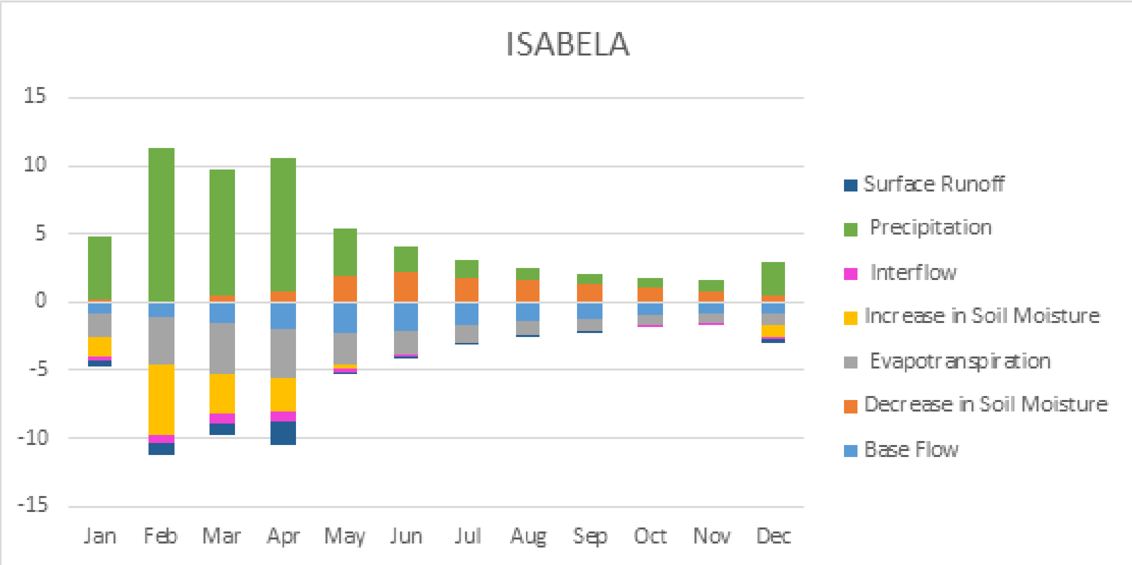
Agriculture has a high degree of sensitivity to both short-term weather changes and long-term seasonal changes. The expected changes in the climate will have a negative impact on agricultural sector, including a greater dispersion of invasive species (see section 8.1), effects on the aquifer recharge process that provide water for agriculture, loss of soil's capacity to retain nutrient and water, greater evapotranspiration and changes in water availability. In general, climate change impacts work in synergism with other endogenous factors (e.g., local population growth, unsustainable agricultural practices, policies, etc.) and other exogenous drivers (e.g., tourism growth, imported products, etc.) to stress a food production system. Consequently, these impacts can further reduce the productive capacity of the agricultural and livestock sector disturbing development processes and food security.

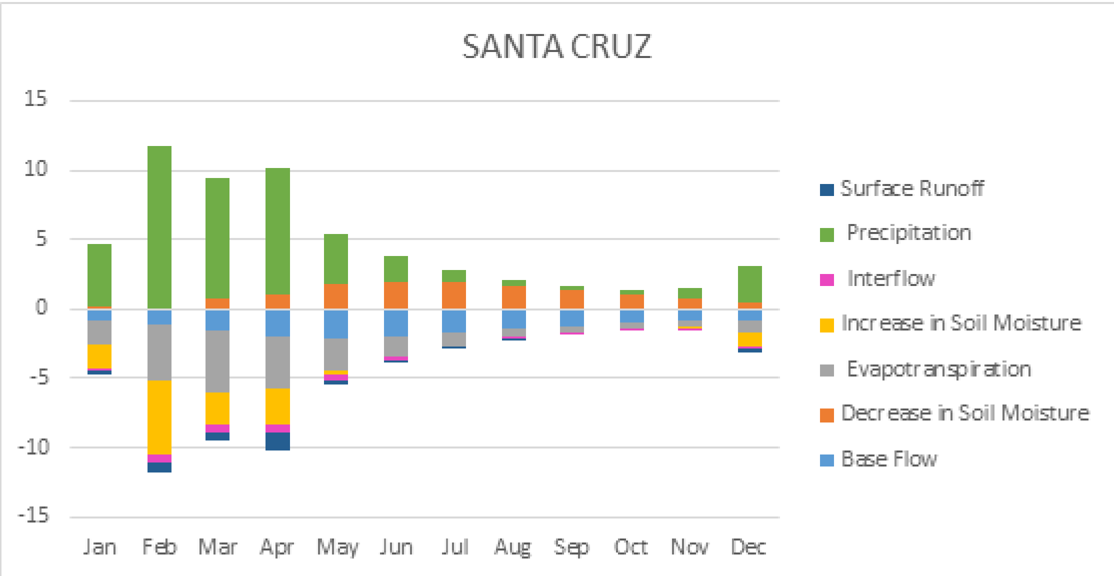
Water Deficit

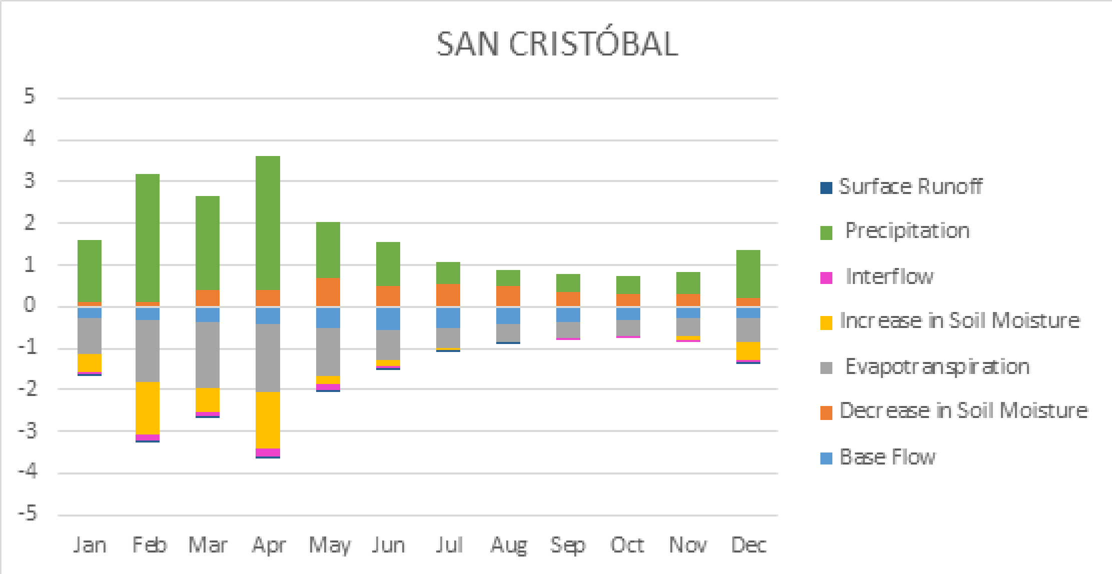
This proposal has generated a water balance for Santa Cruz, San Cristobal and Isabela Islands using a Water Evaluation and Planning System (WEAP) model as our main tool, see 2.1 Appendix Agriculture (water balance) for details. Briefly, for the Galapagos Islands the model is set up by using a range of available data, which includes climatological data from the ERA5 reanalysis effort as well as direct observations from available meteorological stations, soil parameters (A Pryet, 2011) as well as a Digital Elevation Model (Lehner et al., 2008) at 3 arc-second spatial resolution. This model generates as output the following variables: evapotranspiration, surface runoff, subsurface flow, base flow, and changes in soil humidity.

This balance cannot be validated by observed flows because of the lack of discharge information. This is the reason why one of the proposed practices/activities include a monitoring system of discharges in the islands. intend to build a robust balance by evaluating the different flows such as the aquifer recharge flow and identify specific zones to intervene because of their hydric importance. This balance can be a guide to know if the model represents in a good way the fluxes in the ground (Figure 23). Also, the hydrological model was set up in a way that makes easy the input of new variables such as climatic and hydrological values for future projects.

Figure 23. Hydrological balance in Isabela, Santa Cruz, and San Cristobal islands

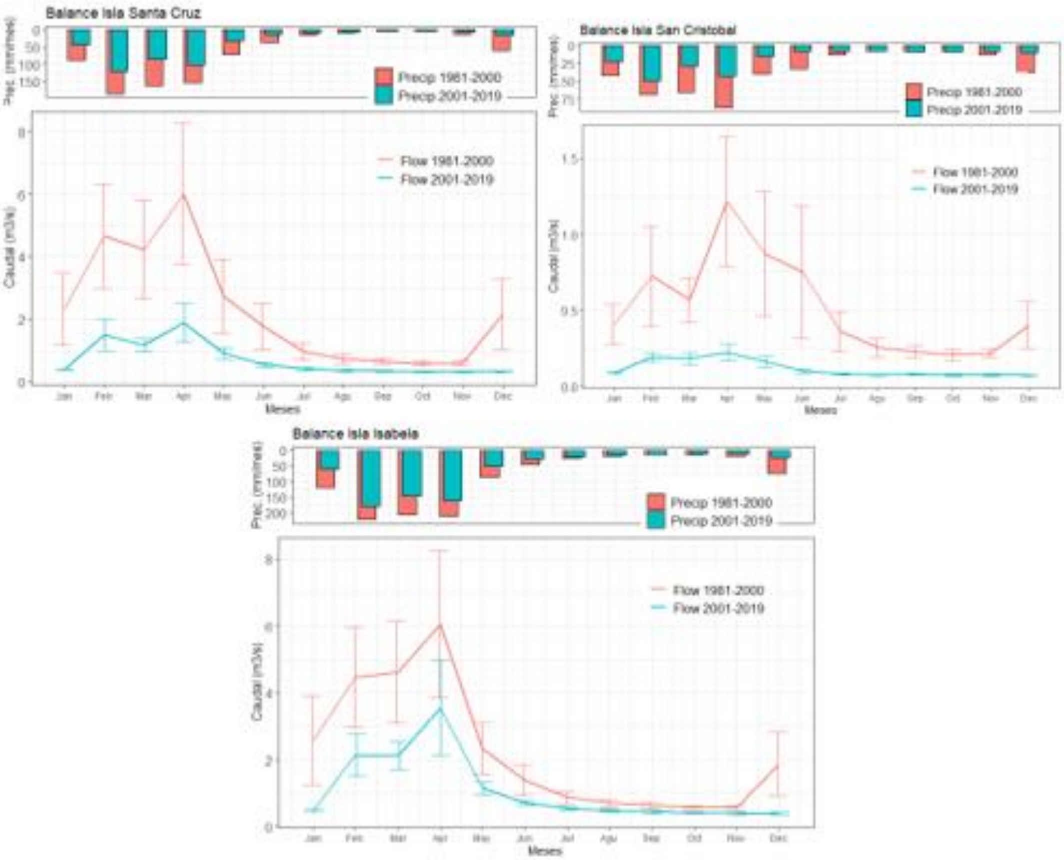






This modeled water balance shown here depicts the mean average flow for two time periods: 1981-2000 and 2001-2019. The first period represents a wet one where El Niño events (1982-1983 and 1997-1998) were relevant and caused vast damage in native ecosystem and anthropogenic infrastructure in the region. Conversely, the most recent period represents one with more apparent dryness and characterized by the presence of La Niña events. The results show a notable decrease in surface flow between these historical baselines (Figure 24), mainly in the wet season. The flow variability in the dry season is not significant in the two periods.

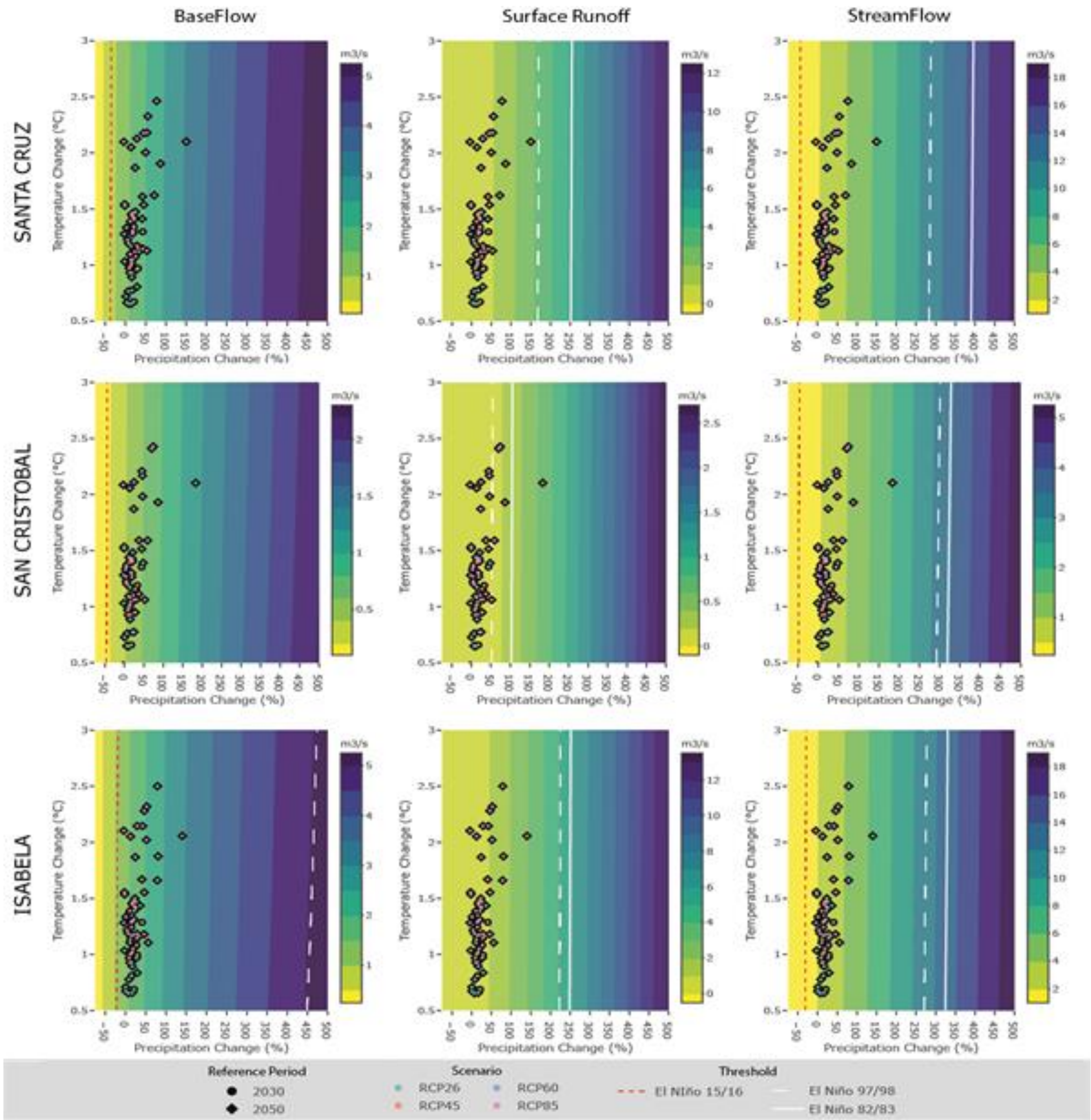
Figure 24. Water balance for the Galapagos Islands - Historical Conditions (precipitation and surface flow). Bars represent standard error.



Moreover, the study also estimates how land-hydrological variables may be affected by climate change. This is done by utilizing mean annual hydrological results of our sensitivity analysis, which are then plotted in surface response maps (showing the increases in temperature and precipitation, and their resulting output variable) against the CMIP5 climate projections. For reference, we also delineate the hydroclimatic conditions of El Nino 1982-1983, 1997-1998 and the dry conditions of 2015-2016. The first two caused important damages and losses in the Islands as result of severe floods. The recent dry conditions led to local authorities to decree a regional state of emergency due to severe impacts that droughts caused on society. As such, we first note that none of the projected climate scenarios estimate that the mean annual drought conditions in 2015-2016 would not be repeated (or intensified) in the upcoming decades. This is the case for the three variables used here: base flow, surface runoff, and streamflow. While this result may provide a sense of robustness and certainty of Galapagos water systems, it is important to once again, highlight the general pluvial tendency of existing GCMs in the Islands; this in turn contradicts recent observed drying trends, as discussed above.

In line with this, we also note that in general, and across the Islands, the future climate projections estimate *normal* mean annual hydrological conditions for the upcoming decades. This can be observed as mean annual projected changes in the three hydrological variables do not reach the mean annual levels experienced in 1982-1983 and 1997-1998. An exception to this can be observed in San Cristobal where various scenarios project that mean annual surface runoff conditions would resemble those El Niño years, and even one scenario projects conditions *more* intense than those observed in the mentioned periods. Yet, it is important here to note the discussed deficiency of GCMs to project general climatological variability in the area. Similarly, this analysis is based on mean annual conditions and does not include changes in seasonality.

Figure 25. Surface response maps for the sensitivity analysis of mean annual conditions of key hydrological variables (baseflow, surface runoff, and streamflow) to changes in precipitation and temperature. Colors represent the mean annual hydrological output when combinations of temperature and precipitation are run. Those ranges of change (scenarios for the sensitivity experiment) are reflected on the x and y axis for precipitation and temperature, respectively. Dots represent climate projections from the CMIP5 experiment. White lines show mean annual conditions of El Niño events of 1982-83 and 1997-98; the red line shows drought mean annual conditions of the drought 2015-2016.



Crops and yield reduction

In terms of the effects of climate change in water availability and their consequences in the productive systems, the study shows different types of crops and its water demand. The actual evapotranspiration (ETA) value is an output of the WEAP model that is based in crop coefficients (Kc) methodology (Allen et al., 2006) and potential evapotranspiration (PET) calculated by the Penman-Montheith method (Monteith, 1985). Crop coefficient values had to be corrected because of the type of climate in Galápagos. These corrections are based on the relative humidity, precipitation depth and wind velocity. The process shows an increase in the crop coefficient values and therefore in the evapotranspiration values. Results show a considerable difference between water supply and demand, Table 14 illustrates it for the month of October (dryer month), which show higher demands of water for all crops modeled. For detailed information please refer to 2.1 Appendix Agriculture (water balance).

Table 14. Water demand by crop in October

CROPS	Eto (WEAP)	Modified crop coeficient Kc			Crop evapotranspiration daily demand (m3/ha)			Daily water supply-October (m3/ha)			Daily water demand-October (m3/ha)		
	mm/day	Crop season			Crop season			Scenario			Scenario		
		Initial	Develop	Late	Initial	Develop	Late	Dry	Mod	Wet	Dry	Mod	Wet
Alfalfa	3.70	0.40	1.22	1.17	14.80	44.40	43.3	2.2	3.77	5.19	42.2	40.6	39.2
Porotón	3.70	0.40	1.03	0.63	14.80	37.00	23.1				34.8	33.2	31.8
Morera	3.70	0.40	1.03	0.63	14.80	37.00	23.1				34.8	33.2	31.8
Leucaena	3.70	0.40	1.03	0.63	14.80	37.00	23.1				34.8	33.2	31.8
Café	3.70	0.90	0.99	0.99	33.30	35.15	36.7				32.9	31.3	29.9
Pasto Gramínea-leguminosa	3.70	0.40	1.08	0.88	14.80	38.85	32.4				36.6	35.0	33.6
Cedro	3.70	0.50	1.14	0.69	18.50	40.70	25.6				38.5	36.9	35.5
Maize	3.70	0.40	0.84	0.74	14.80	29.60	27.2				27.4	25.8	24.4
Fréjol	3.70	0.40	1.20	0.40	14.80	42.55	14.6				40.3	38.7	37.3
Cítricos	3.70	0.50	0.54	0.49	18.50	16.65	18.2				14.4	12.8	11.4
Aguacate	3.70	0.60	0.92	0.82	22.20	31.45	30.3				29.2	27.6	26.2
Sandía	3.70	0.45	0.78	0.78	16.65	27.75	28.6				25.5	23.9	22.5
Yuca	3.70	0.30	1.13	0.53	11.10	40.70	19.7				38.5	36.9	35.5
Papa	3.70	0.00	1.17	0.67	0.00	42.55	24.9				40.3	38.7	37.3

CROPS	Eto (WEAP)	Modified crop coeficient Kc			Crop evapotranspiration daily demand (m3/ha)			Daily water supply-October (m3/ha)			Daily water demand-October (m3/ha)		
Tomate	3.70	1.15	0.92	0.62	42.55	33.30	23.0				31.1	29.5	28.1
Pimiento	3.70	0.60	1.03	0.78	22.20	37.00	28.7				34.8	33.2	31.8
Banana	3.70	1.00	1.29	1.19	37.00	44.40	44.1				42.2	40.6	39.2
Maracuja	3.70	0.55	0.99	0.74	20.35	33.30	27.3				31.1	29.5	28.1
Pina	3.70	0.50	0.32	0.32	18.50	11.10	11.9				8.9	7.3	5.9
Sugar cane	3.70	0.40	1.34	0.84	14.80	46.25	31.0				44.0	42.4	41.0
Papaya	3.70	0.50	1.19	1.09	18.50	40.70	40.2				38.5	36.9	35.5
Mani	3.70		1.22	0.67	0.00	42.55	24.6				40.3	38.7	37.3

Table 15 shows the threshold temperature and rainfall requirement of the main groups of crops cultivated in the islands. Responses to temperature and water requirements differ among crop species throughout their life cycle (Hatfield and Prueger, 2015). Increases of temperature significantly impact productivity of vegetables, grains, ornamentals and some roots and tubers crops. While the reduction of precipitation can mainly impact pastures and fruit trees. On the other hand, the occurrence of heavy rains and increased precipitation influences the occupation and possible expansion of invasive plants that threaten local agricultural productivity and are responsible for the degradation of critical habitats and ecosystems in the protected areas located in the upper and humid parts of the island (FIC-LAVOLA-UTPL, 2019).

Table 15. Temperature thresholds and rainfall requirement of the main groups of crops cultivated in Galapagos (INIAP, 2019).

Crop	Weather	Minimum Temperature °C	Maximum Temperature °C	Precipitation mm/cycle
Vegetables	Tempered	10	22	400
Grains	Tempered	12	24	400
Tree Fruits	Warm	18	30	1000
Roots and tubers	Cold	6	18	700
Roots and tubers	Warm	12	30	700
Medicinal and aromatic	Tempered	10	24	500

Grassland and forages	Warm	15	28	1000
Ornamental		5-8	28-30	600

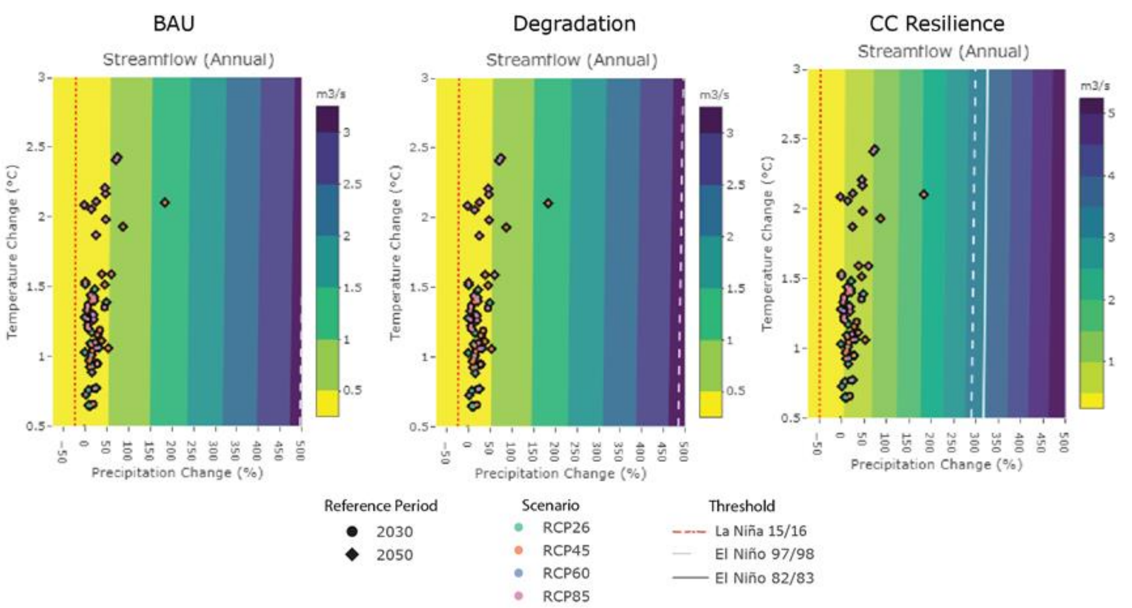
8.2.1 Expected scenarios

8.2.1.1 Future scenarios of water availability in the agricultural areas

It is important to also note that the orographic characteristics of the islands distinguish between coastal and highlands sub-climates. The agricultural area, for example, exhibits important humidity as well as drizzles during the cold season. Our results find that in average, the drizzles or *garúas* contribute to about 30% of the cold-season rainfall over the highlands. As for temperature, observations estimate that mean annual values have increased by ~0.6°C over the last four decades across the Islands. This research suggests that by the mid-century mean annual temperature is expected to rise by ~1.1 and over 2.0°C when compared to the historical baselines. These changes will be more acute during the dry season. Thus, subregional as well as seasonal differentiations should also be considered when refining past and future hydroclimatic conditions in the Islands. For detailed information please refers to 2.1 Appendix Agriculture (water balance).

This section shows the results of a land-hydrological model. Figure 26, which shows how surface "stream flow" is affected by climate change. This is done by utilizing mean annual hydrological results of our sensitivity analysis, which are then plotted in surface response maps (showing the increases in temperature and precipitation, and their resulting output variable, stream flow) against the CMIP5 climate projections. For reference, the study also delineated the hydroclimatic conditions of El Niño 1982-1983, 1997-1998 and the dry conditions of 2015-2016. The first two periods of El Niño caused important damages and losses in the Islands as result of severe floods. The recent dry conditions led to local authorities to decree a regional state of emergency due to severe impacts that droughts caused on society.

Figure 26. Surface "stream flow" affected by climate change



The proposal first shows that none of the projected climate scenarios estimate the mean annual conditions of 2015-2016 (drought) would not be repeated (or intensified) in the upcoming decades. While this result may provide a sense of robustness and certainty of Galapagos water systems, it is important to highlight the general wetting tendency of existing GCMs once again in the Islands; this in turn contradicts recent drying observed trends, as discussed above. Also highlights the current vulnerability to droughts of the Galapagos productive systems.

Additionally, this proposal presents the results of streamflow, with projections of land use change in agricultural areas (Table 16). Agricultural areas have been modeled in detail in Sampedro et al 2018 and in this feasibility study we create three scenarios of land change, and related to the land management options, including strategies for land use adaptation to climate change.

Table 16. Land Use Scenarios used to model the impacts of the climate change resilient strategies on streamflow temperature.

Land Use Scenario Year 2035 (based on Sampedro et al 2018)	Scenario Description
Business as Usual (BAU)	▪ ~50% of agricultural area covered by pastures. ▪ Decrease ~10% of crop area ▪ ~28% of area covered by invasive species. ▪ Loss of ~90% of area covered by native vegetation
Land Abandonment Scenario	▪ ~40% of area covered by invasive species. ▪ Loss of 90% of area covered by native species. ▪ 10% reduction of productive areas (pasture + crops)
Climate Change Resilience Scenario	▪ Native vegetation within agricultural areas is conserved. ▪ There is an increase of 5% area covered by agriculture and cattle ranching (crops and pastures) with climate resilience practices including silvopastoral practices, integrated soil management, and conservation of key hydro-ecological areas. ▪ Reduction to 26% of area covered by invasive species

Results show the water availability (streamflow) increased by almost the double under a scenario of Climate Change Resilience. Moreover, BAU and land abandonment scenarios put GCMs results close to conditions of drought as experienced in the Galapagos (Figure 18, red line). The Climate Change Resilience scenario moves away from those drought conditions.

Surface response maps for the sensitivity analysis of mean annual conditions of streamflow to changes in precipitation and temperature. Colors represent the mean annual hydrological output when combinations of temperature and precipitation are run, for three different land use management scenarios.

INIAP (Instituto Nacional de Investigaciones Agropecuarias) has generated a dataset of crop tolerance to temperature and precipitation for different agricultural products in the Galapagos Islands. We have taken these tolerances to create agricultural product suitability according to our climate change scenarios (see section 4 and appendix 2.1 Agriculture).

Models used in this study show how agricultural products or crops will be drastically affected. Grains and vegetables across all seasons will be strongly affected with temperature change, but more importantly affected by rainfall decrease, especially during the dry season. This is probably the most important implication of climate change in agricultural products. Pastures will be seriously affected by the decreased precipitation, especially during the dry season. Fruit trees and roots and tubers are cultivars that will have higher tolerance to climate change, although affected in minor degree.

It is expected that with climate resilient activities and sub-activities, described below in Section 12. Programme, there will be an improvement of the conditions, for example, in terms of productivity, crops will increase productive within the first year of the project. Table 17 shows a comparison of performance with current practices versus estimated future performance with resilient practices, in Tons/Hectare. Future performance is estimated for 24 crops used in the agricultural areas of Galapagos. In all cases, there are improvements that range from 2.6 to 69.6%, including pasture, cassava, peanut, and others with the highest improvement in productivity.

Table 17. Estimated Impact of project activities in a year of project.

performance with current practices *vs* estimated future performance with resilient practices (Tons/Hectare)					
CULTIVOS	Current Practices	Climate Resilient Practices	Crops	Current Practices	Climate Resilient Practices
Limón	9	9.6	Naranjas	9	11
Café	1	1.2	Papaya	14	15
M-plátano	8.5	10	Papa	11	16
M-banano	9	11	Pimiento	6	7.5
M-orito	2	4	Piña	14	15.5
Yuca	16	33	Tomate	14	15
Caña	75	77	Maní	1	2
Fréjol	1.6	2.2	Maracuyá	20	30
Hortalizas	5.5	6.5	Aromáticas	0.4	0.6
Maíz – choclo	7	11	Medicinales	0.5	0.75
Maíz – ensilaje	15	22	Pastos	11.2	19
Mandarina	11	12	Forrajes	21.8	33.2

Invasive species and agriculture

Most invasive plant species are also found in the humid highlands, where agricultural lands are established, and biotic conditions are more suitable for invasion. Currently, these biotic conditions are changing due to shifts in climate conditions and have become more favorable for the spread of invasive plants (Watson et al. 2009).

The results of dispersion analysis of invasive species in Galapagos, mainly focused on Psidium guajava (see section 8.1 and Appendix 2.4 Terrestrial Restoration) and below in the section impacts of climate change on terrestrial ecosystems) show that there is a positive correlation between guava growth and factors associated with water availability (precipitation, humidity, and soil moisture). Thus, access to water plays an important role in the interaction between native and invasive species (Guo et al., 2020), where introduced plants have shown to be better competitors than native plants. For this analysis, higher values of precipitation, humidity (wet index) and soil moisture represent better conditions for guava growth and spread. This means that when resources increase (high soil water storage), it will increase probability of the invasion success of guava into a native plant community/abandoned agricultural lands and its presence will not be affected by water scarcity due to its drought tolerance (Binggeli et al., 1998; Schmitt, 2018). According to the analysis, 15.7% of the entire study area was occupied by Psidium guajava in 2018, which will increase to 23.16% by 2030 under a BAU scenario. If restoration and rehabilitation activities (resilient practices) were implemented in both protected and agricultural areas, this increase could be reduced between 16% and 18% under program implementation scenario.

8.2.1.2 Farmers adaptive capacity

As ecosystem and terrestrial ecosystems, water availability, crops, livestock, and land become affected by climate change as explained in the previous sections, direct impacts will be felt within the human society, from both economic and quality of life perspectives. In 2016, a severe drought generated losses for the agricultural sector by more than USD 15 million (Ministerio de Agricultura y Ganadería, 2018a), affecting products associated with the basic food basket (BFB), accounting for the nutritional balance of the resident population and tourists. All of this will have negative economic repercussions within Galapagos society and potentially for Ecuador. The current conditions in the communities of Galapagos, including poor healthcare, sanitation, water quality, and little to no urban planning, will exacerbate these risks and make farmers vulnerable to climate change.

The socio-ecological integrity of the Galapagos and its food system are increasingly vulnerable due the constraints its “island condition” but are raised by several other forms of human–related pressures such as invasive species, spontaneous development, constrained infrastructure, lack of regulation of imported agricultural products, and changes in the local food consumption preferences, which may alter importation trajectories and compromise conservation on the island. Central to these pressures over the food system within Galapagos are two emergent and synergistic drivers: tourism and climate change.

There are two distinct sources of food in Galapagos: products imported from the mainland and locally produced. The growing human population in Galapagos, from 18,640 in 2001 to 25,244 in 2015, has increased the demand for food, which has led to most food products being imported from the mainland, generating a cascade of impacts from the abandonment of agricultural lands to the increasing the risk of introducing invasive species to the archipelago.

The consumption per capita of vegetables and livestock food in Galapagos is higher than the Ecuador national average: 0.3119 tons/year/person for agricultural products, which include fruits and vegetables; and 0.1319 tons/year/person for livestock products, which include meat, eggs, and milk, while the national average is 0.2825 and 0.0973, respectively. In general, the main consumption rates correspond to residents who meet their basic needs consuming more than 92% of agricultural products and 98% of livestock (Sampedro et al 2019). The population of the Galapagos Islands depends nearly exclusively on imported food through sea and air cargo because local agricultural production is not able to meet the population's demands for agricultural products with a deficit of 47%. Sampedro et al (2019) calculates that about 75% of agriculture food supply was transported from the continent in 2017 and this will increase to 95% by 2036 if there are not changes in food policies.

There is consistent evidence of the impact of food insecurity in the islands, which is pushed forward by the lack of availability and quality of fresh produce, as well as easy access to industrialized processed and ultra-processed foods (Freire et al. 2018). In a recent study, most women (55%) reported food insecurity and 60% reported limited availability of fresh produce due to an unreliable food supply shipped from mainland Ecuador (Pera et al. 2019). More important, in Galapagos, there is the prevalence of the dual burden nutritional disease, where: (1) overweight and noncommunicable disease risk factors and (2) undernutrition and infectious disease symptoms are present within individuals and households. In Galapagos, 16% of children, 33% of adults, and 90% in households, food insecurity was positively associated with the risk of dual burden at the household level (Thompson et al. 2020).

Galapagos undergoing a nutritional transition, drastic changes in diet and lifestyle that lead to obesity and chronic diseases (Waldrop et al. 2016). There is consistent evidence of the impact of food insecurity in the islands, which is pushed forward by the lack of availability and quality of fresh produce, as well as easy access to industrialized processed and ultra-processed foods (Freire et al. 2018). In a recent study, most women (55%) reported food insecurity and 60% reported limited availability of fresh produce due to an unreliable food supply shipped from mainland Ecuador (Pera et al. 2019). More important, in Galapagos, there is the prevalence of the dual burden nutritional disease, where: (1) overweight and noncommunicable disease risk factors and (2) undernutrition and infectious disease symptoms are present within individuals and households. In Galapagos, 16% of children, 33% of adults, and 90% in households, food insecurity was positively associated with the risk of dual burden at the household level (Thompson et al. 2020). In terms of water security, in rural areas of Galapagos, being higher income in rural settings is significantly protective of water quality and increasing household size is associated with reduced water access (Nicholas et al. 2020), which can be interpreted as the poor rural households as the most vulnerable for water insecurity.

Although a multicomponent intervention is needed in the Galapagos to solve the nutritional problems (Ocampo 2017), it is clear that the availability of fresh healthy food is strongly needed. There are two complicating and related factors: (a) the growing need for food linked to increased number of tourists and (b) the lack of local agriculture due farm abandonment and uncertainty to farming conditions, including climate change. Assuming that the importation of more food is extremely difficult due the lack of ports, ships, and the excessive financial and environmental costs, it is necessary to improve the local food production and generate a climate resilient farming system.

In a socioeconomic survey carried out in February 2020, 196 farms' households were interviewed about socioeconomic, environmental and climate change, as related to agricultural activity. A vast number of farmers, 98%, reported climate change as a change already present in their farms, which is consistent with climatic historical observations and climate modeling. Of those farmers, 41.5% already report negative effects in their production. There are relatively minor differences across island and farm sizes. In terms of negative events suffered because of climate change, farmers report a diversity of types, being droughts the type of climatic events that have caused more damage.

For the Galapagos in general, according to the 2014 Census, the percentage of people with "basic needs not satisfied" is 25,01%. Newer household surveys indicate different dimensions of poverty. As indicated before, in terms of nutrition, most women (55%) reported food insecurity and 60% reported limited availability of fresh produce. About 39.4% of households sampled in the Galapagos think that they live in a "poor" household and that conditions have worsened through the years. Lack of formal employment is more than double for women (7.2%) than for men (3.0%), despite that woman are slightly better educated than men (average years of reduction, 9.4 for men and 9.61 for women). Only 55% of the population have access to the National Institute of Social Security (IESS – Instituto Nacional de Seguridad Social) and only 11% have access to prepaid private medicine. These numbers are set to be amplified in rural households, where no official numbers exist. Although the conditions of poverty are not extreme like other provinces of the Ecuadorian continent, 10.4% of people in Galapagos live below 50% of the average income. 51.3% of the population is in poverty due to unsatisfied basic needs (INEC, 2016). The gross employment rate is 74.5% (INEC, 2017). 85% of economic activity depends directly or indirectly on tourism. Galápagos had 275,000 tourists in 2019, and there was a 75% decrease in 2020.

In terms of the farming system, there is a large diversity of types of farms across islands. Appendix 2.1 Agriculture (Tables 12 through Table 16) show detailed information for Galapagos and each of the islands, in terms of size and main agricultural activity.

In terms of demographic variables, household size in the farms of Galapagos is, on average 3.0, which is significantly lower than the national average. Table 18 shows the distribution of people by age groups (< 5 years old, 6 – 18 years old, 19– 60 years old and > 60 years old). This table also shows the low number of young people (6-18 y.o) that live in the farms (Table 19).

Table 18. Percentage of people, across different age groups in farms by Islands and farm size

	% of people within the farm			
Island	< 5 y.o.	6 – 18 y.o.	19 – 60 y.o.	> 60 y.o.
Isabela	6	15	61	17
San Cristobal	3	18	49	30
Santa Cruz	1	15	59	25
Farm size				
Small-scale farms	5	15	59	22
Medium-scale farms	4	21	50	25
Large-scale farms	1	13	52	34
Total	**3**	**16**	**54**	**26**

Among the key socioeconomic characteristics of these farms, and the households who manage them, are labor, access to credit, and production costs. As expected, these farms have differences, in terms of labor according to their size. Small farms are worked mostly as family units, 58% of the small farms have family as the main labor force. In contrast, large farms have mostly hired labor as a workforce. Men are primarily workers at the farms of Galapagos, but 29% of the small farms are managed by women. Figure 27 shows details for all the Galapagos farms. In terms of off-farm employment, 49% of the owners also have additional economic activities outside of the farms.

In terms of access to loans, in general, less than 45% of the farms had access to credits to improve their production (Table 19). San Cristobal is the island with less access to loans.

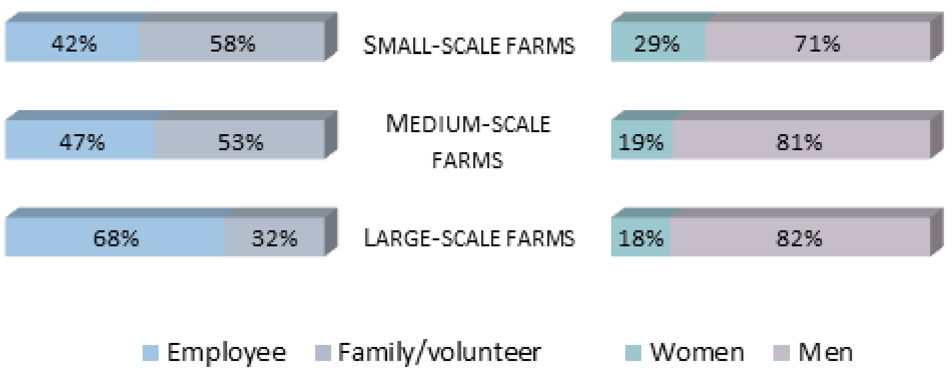
Table 19. Access to loans by farms in the Galapagos Islands

	Farms that had access to loans in the last 5 years (%)	
Island	No	Yes
Isabela	47.37	52.63
San Cristobal	59.76	40.24
Santa Cruz	53.95	46.05
Galapagos	55.10	44.90

In terms of the cost of production, defined here as the dollar value of all on-farm inputs for growing a specific or several crops in each period. This exploratory indicator estimates costs for seeds, irrigation water, fertilizer and pesticides, machinery time, purchase/maintenance of small farm tools, and labor, all reported by farmers. The annual hired labor was determined from total daily workers, daily wage, and an assumption of 180 labor days.

Results show that the average cost of production on-farm was approximately $7,000 in 2019. San Cristobal has the lower production cost in the islands, mainly since San Cristobal is the only island with natural freshwater sources, reducing the irrigation water cost. On the other hand, as expected, large-scale farms double annual production costs (~$12,000) compared to the small and medium-scale farms ($5,000), see Figure 27.

Figure 27. Agricultural production costs by farm size and Islands



Given the number of agroecosystems and their main household characteristics, the potential beneficiaries, which will be managed under climate-resilient practices proposed in this component, was selected based on farm type (scale) and agricultural activity. Thus, with these factors in mind, we determined that each practice will be adopted in at least 41% of the productive farms in Galapagos, covering approximately 8,500 ha of productive lands across the four populated islands (see Appendix 3).

The adverse effects of climate variability and climate change have a high impact on the agricultural sector and have become increasingly evident in recent years. For example, the major events experienced by the agricultural sector in Galapagos are described below:

- 1997/98 ENSO (El Niño event): during this period surface temperature and rainfall increased drastically over much of the Pacific. Farmers reported losses of 100% of total harvest of crops such as plantains, banana, cassava, and vegetables due to excess water.
- 2016 ENSO (La Niña event/Drought): it was a period of extreme drought from January to November 2016, which severely affected 56.5% of land for agricultural use (10,740 hectares) according to information provided by the National Agrarian Authority (MAGAP, 2016), causing economic losses and environmental in the agricultural sector, unrecoverable to date in Galapagos. As a result, 45.9% of the grassland were affected, as well as 49.7% and 74% of the short-cycle and perennial crop land, respectively. It is estimated that the loss of the agricultural and livestock sector was over USD 15 million, with the most affected products being cassava, maize, tomato, banana, melon, orange, as well as milk production. All these items are part of the basic food basket and provide a nutritional balance for the population. Additionally, the reduction in milk (55.9%) and beef production threatens quarantine policies that have already been established in this territory to prevent the entry of bovine diseases and boost the local dairy products industry (MAG, 2018).

8.3 Marine ecosystems

8.3.1 Impacts

The marine ecosystem services within Marine Protected Areas (MPAs) have been extensively assessed, described and characterized from the economic, social and environmental standpoints, as critical in the maintenance of ecological processes, functions, structures and human livelihoods. Ecosystem services are provided by several ecosystem functions and contribute to a wide range of benefits that human populations can use in a variety of ways (Costanza et al. 2014, de Groot et al. 2010, Lau et al. 2019). Two of the most important sectors that depend upon these ecosystems, and whose sustainability is linked to them, at global scale, are tourism and small-scale fisheries (FAO 2020). And in Galapagos Marine Reserve, this situation is not the exception.

According to this reasoning, the way we look at these key ecosystems in the Galapagos Marine Reserve (e.g., rocky reefs with coral patches) includes a comprehensive format of socio-ecological systems that are interdependent and deeply linked. Additionally, from the social perspective we highlight here: first, the importance of these ecosystems, as livelihood supporter for the tourism industry in the Galapagos Islands, and second, the relevance these spaces provide to the small-scale fisheries sector in Galapagos. The varied restoration initiatives proposed in this research thus focus on the integrative approach to ensure marine ecosystems conservation and livelihood viability in Galapagos.

The accelerated rate of anthropogenic climate change poses a great challenge for species, who must adapt to keep pace with such changes. The persistence of species will depend on how rapid they can adapt to novel conditions, which does not seem very optimistic, especially for the most vulnerable species, including long-lived species (Zhang et al., 2019; Bisbing et al., 2021). On the other hand, these changing conditions, also create ideal circumstances for some species to move out of their home ranges, even between regions, and eventually become invasive. Consequently, climate change facilitates the dispersion of non-indigenous species (NIS) and creates opportunities for them to become invasive (Canning-Clode et al., 2011).

Preventing NIS is the single most cost-effective action to ensure long-term sustainability of island biodiversity and avoid costly eradications (Faulkner et al, 2020). In the context of bioinvasions, EDRR protocols are a series of sustained and coordinated actions to predict, monitor, report and verify the presence of NIS before the species becomes established and spreads, continued by a rapid response process to eradicate the species before it establishes and spreads to the point where eradication is no longer feasible (Reaser et al., 2020). These protocols would not only safeguard the environment and human well-being form NIS impacts, but also potentially save billions of dollars that would otherwise have to be spent on repairing the damage caused by the NIS along with control measures that could go on indefinitely (Meyers et al., 2020; Reaser et al., 2020). EDRR protocols present a critical framework for preventing, limiting, and mitigating the spread of NIS to islands not only to Galapagos but to other islands in the ETP.

To design effective ecosystem-based adaptations (EBAs) to adequately manage, govern, and conserve marine ecosystems in the GMR, it is important to be able to predict ecosystem-wide ecological responses to climate change and other anthropogenic stressors (Ellison et al. 2005; Trifonova et al. 2019). To achieve this, ecosystem-based models can be developed to understand the often-complex relationships between biotic and abiotic factors in marine systems (Helmuth et al. 2006). Ecosystem-based models have already been successfully applied to a variety of ecosystems to address a wide range of questions. For example, models have allowed us to better understand how climate change affects different trophic levels of marine pelagic communities in temperate regions (Edwards & Richardson 2004), to predict species distributions (Moya et al. 2017), to prioritize areas that should receive protection due to their ecological importance (Yates et al 2016), and to estimate changes in primary production due to climate change (Brown et al. 2010; Schlenger et al. 2019). These studies demonstrate that it is possible to develop an 'ecosystem-based modelling framework' that evaluates the vulnerability of marine systems in the GMR to ecosystem-wide changes, brought on by anthropogenic threats and exacerbated by climate change. Based on these exercises, strategies can be designed to implement measures that increase response capacity and reduce the risk of impact on marine systems.

The Charles Darwin Foundation (CDF) has over fifteen years of baseline data (2004 – 2020) on marine biodiversity of the GMR, which is product of the long-term subtidal ecological monitoring program on rocky reefs (Banks et al. 2016). The sample unit consists of a 50m transect parallel to the coast at two different depths 15m and 6m at any given site. This methodology focuses primarily on recording data on three major groups of macro fauna: fish, macro invertebrates and sessile organisms (Banks et al. 2016; Edgar et al. 2004). There are 380 sites from which a minimum of 64 diagnostic sites, within the GMR that are monitored on a yearly basis (Figure S1). This effort assesses species richness, diversity, abundance and size of marine communities, as well as their distribution, composition and structure. The subtidal ecological monitoring also assesses the environmental impacts and anthropogenic disturbances that affect these ecosystems, due to natural and anthropogenic events (Table S3). Analyses this long-term assessment show that rocky reefs dominate more than 80% of the subtidal habitat at less than 40m, and that these are the areas with the highest exposure to interactions with users of the GMR (Banks et al. 2016; Edgar et al. 2004; Edgar et al. 2008; Edgar et al. 2009) (Figure S1).

The 2004 – 2020 subtidal dataset was used to identify the drivers affecting key marine ecosystem services. Ecosystem-based models were developed to predict the ongoing and potential future negative impacts of climate change and anthropogenic pressures for rocky reef ecosystems within the GMR. The Remote Ocean Modelling System (ROMS) (https://www.myroms.org/) was used to predict the oceanographic conditions under different Representative Concentration Pathways (RCPs) up to the year 2040. The ROMS model uses the Hadley Centre Global Environment Model version 2 (HadGEM2-ES), which uses the ORCA tripolar grid (Madec & Imbard, 1996; https://www.metoffice.gov.uk/research/approach/modelling-systems/unified-model/climate-models/hadgem2) to generate the future climate and atmospheric forcing, and the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/climate-forecast-system-version2-cfsv2) to estimate current and past climate and atmospheric data.

Currently, the Synthesis Report of the IPCC Fifth Assessment Report (AR5) describes four RCPs that represent a range of emissions (IPPC, 2014). For this study, RCPs 4.5 and 8.5 will be used because RCP 4.5 is the scenario that Ecuador and the GNPD would aim for if the average temperature trend continues until the end of the century (DPNG, 2019). On the other hand, RCP 8.5 is considered a pessimistic scenario, which will illustrate what would happen in the GMR if no mitigation measures would be taken against climate change. The outputs from ROMS of the GMR and the surrounding ocean created in 2014 were used to create graphs and maps comparing RCPS's 4.5 and 8.5 regarding temperature and currents at two depths (5 and 15m) during the hot season (December to May). This season was chosen because it experiences the most variability during these months, most likely affecting coral populations. The resolution of the ROMS model was 5/88° by 5/88°. Each month modelled had a period of 30 days and 12 months were modelled for each year. The model was run under RCPs 4.5 and 8.5 from 2020 to 2040. MATLAB® was used to extract the outputs from their netCDF format files. These were then averaged over the 30 days of each month to get the monthly mean values for temperature and oceanic currents. Temperature variability was plotted for each month across the years, followed by a best fit polynomial using polyval and polyfit functions, to attain the coefficients and to fit the curve respectively. Currents were plotted using the quiver function which plots arrows, which represent the horizontal and vertical vectors of velocity. This was overlayed on a high-resolution bathymetry map of the GMR to clearly show the trajectories of currents around the islands.

The data for the bathymetry used, was obtained from the Pacific Marine Environmental Laboratory provided by NOAA, it was created by merging various bathymetric grids of the archipelago (Chadwick, 2007). Furthermore, a particle tracking model was developed for two reef-building coral species in the GMR (*Pavona gigantea and Porites lobata*) to predict larvae dispersal under RCP 4.5 and 8.5 climatic scenarios. This model would provide a link between the data collected from the Subtidal Ecological Monitoring program and the ROMS model projections for oceanographic and climate change within the GMR over the following 40 years. The particle tracking model was run at 5-year intervals during the warm season in the Galapagos (January to May), at depths of 5 m and 15 m, which are based off the Subtidal Ecological Monitoring depths (Banks et al. 2016) and well within the common depth limits for both species. (Glynn et al., 2016). The larvae within the particle tracking model had 7 starting islands based on the locations at which these species have been found during the most recent years of the Ecological Monitoring project. These islands are Española (-89.6 -1.365) (blue), Floreana (-90.37 -1.237) (green), Santiago (-90.52 -0.3243) (red), Darwin (-91.99 1.646) (cyan), Wolf (-91.81 1.389) (black), Genovesa (-89.98 0.3243) (white), and Marchena (-90.51 0.3003) (magenta). Each starting location is marked by an X of the colour listed previously (Figure S9). Twenty particles were released per site for each month and their movement was recorded every minute, although the current data is only daily, an interpolation of this across the days at 6-hour intervals with a velocity recording every minute allows for more accurate movement of the larvae. Each movement step for each particle included a random displacement in the x and y plane of 15 m to replicate the movement by the larvae themselves swimming or small currents and eddies, which the model cannot simulate. The pelagic larval duration (PLD) of both species has never been empirically determined however it is thought to be between 20 and 50 days. For simplicity, at this stage of the model the larvae were suspended in the water for 30 days. The final location of each larva was marked by a circle with the same colour as its starting location marker.

Further analysis can be done to evaluate the impacts of changing temperatures on the abundance of these species, as well as others, however, further work on the model is required to reach that point. The species spread can be recorded over the course of several months with each new site populated able to produce further larvae and any larvae unable to reach a location of suitable depth and temperature within their PLD killed off. However, this process is very computer intensive and time consuming so it would need longer time frames to be completed. In addition, the rapid depth-drop along the coast of each island makes it difficult to record the correct depth along the coastline without a higher resolution bathymetry across the GMR. For the islands of Darwin and Wolf it would be more useful to have a model covering a larger area north of the islands because the current maps show strong evidence of circular currents occurring, which would drag the larvae north. then back east, before looping back into the north-eastern islands of the archipelago. These results act as an example of the work that can be done through particle tracking for native species expansion and self-recruitment within the GMR, as well as the spread of and high-risk areas associated with invasive NIS.

The use of an offline particle tracking model, combined with a three-dimensional hydrodynamic model, in this case a ROMS model's outputs, has repeatedly shown to be able to successfully recreate or predict the spread of NIS throughout a marine ecosystem due to larval transport (Robins et al., 2013; Simons et al., 2013; Brickman, 2014; Wood et al., 2021). Predicting the arrival of NIS to Galapagos due to climate change is the first step in creating the EDDR framework for the archipelago. In regards to the dispersal of larvae and potential movement of species population sites across a marine ecosystem, be they native or introduced, the main external drivers are currents and thermal gradients (Garciá Molinos et al., 2017). These have been shown to either positively or negatively affect the movement of species, depending on their directional agreement, with greater directional agreement accelerating the movement of species driven by climate change and vice versa (Garciá Molinos et al., 2017). As can be seen from the ROMS outputs, the temperature and currents within the GMR increase and vary respectively, with the more extreme RCP 8.5 scenario showing more drastic effects. This change in surface current directions, caused by climate change, has the ability to create new vectors for NIS spread, as previously unconnected islands become so, particularly the increased current movement into the Elizabeth bioregion between Fernandina and Isabela which up until now has been a mostly isolated area (Edgar et al., 2004). Changing surface currents across the ETP could also become new vectors for introduction from outside the GMR, carrying marine debris with species attached from new regions to the GMR. The changes in temperature across the different bioregions also increases the risk of invasive species spread, since they are often better adapted to changing conditions unlike native species which may die back and struggle to recover with more competition for light and nutrients. Furthermore, previously uninhabitable (for introduced species) regions, particularly in the West could become more vulnerable to invasion as their yearly average temperature increases. The offline particle tracking model, in combination with the information about larval dispersal as well as barriers or accelerators such as climate change and directional agreement, has the potential to be an incredibly useful tool in predicting the future spread of introduced species around the GMR and, if expanded to the entire ETP, any external invasions from the continent. In addition, it can aid in showing the sites from which native species, such as corals, can recover and receive larvae from due to the connectivity of specific islands through sea-surface currents.

The tourism sector could also be affected by climate change as the species and ecosystems on which it depends and are of high value to this sector, are vulnerable to the impacts of climate change. The tourism sector in Galapagos should amplify its commitment to the conservation of the islands by promoting activities that contribute to increase the resilience of the Galapagos' ecosystems and reduce its vulnerability to climate change.

8.3.2 Expected scenarios.

8.3.2.1 Changing oceanic currents.

Changing oceanic current systems have large impacts upon the ecology of a marine system such as changes in larvae dispersal (Cetina-Heredia *et al.*, 2015), reduced levels of nutrients received in certain areas (Nishino *et al.*, 2015) and the appearance of new vectors for NIS to arrive at previously unaffected areas (Heyligers, 2007). Therefore, it is important to analyze the future modelled currents within the GMR during the warm season to attempt to foresee any major alterations to these patterns, product of changing climate. From January to March, at 5 m depth, (Figures S5, S6 and S7) the movement of currents across the archipelago is mostly uniform, flowing from east to west and splitting once they reach the eastern coast of Isabela. This creates an area of lower current magnitude directly to the west of Isabela during these months. The current directions mean that most particles would flow from the eastern islands towards the western ones, excluding the effects of some inner currents between the main islands, as well as a lack of connectivity between Fernandina and the western coast of Isabela with the other islands. The main change by 2040 during these months is a stronger pull to the south within the southern hemisphere, particularly under RCP 8.5, which is most evident in the map for January 2039 (Figure S5), where the currents originate from the north-east and flow southwards over the eastern islands of the archipelago. This would create new vectors for transport since normally larvae from islands such as Genovesa would not be able to reach an island such as Floreana during this month. Up until 2034 the currents in April follow much the same pattern as the previous months and continue to do so under RCP 4.5 to 2040 (Figure S8). However, after that, under RCP 8.5, the currents at 5 m begin to originate from the north-west, which allows for a flow of particles from Darwin and Wolf down to the main islands of the archipelago as well as introducing a flow onto Fernandina. By 2039 these changes, with a gyre forming as these south-easterly flowing currents, hit the westward flowing currents and this would allow particles to be cycled through the islands to the east of Isabela (Figure S8). In May once again RCP 4.5 currents mostly maintain a westerly flow across the islands which would have no great impact on the usual movement of particles, but RCP 8.5 shows much larger variations (Figure S9). In 2020 and 2029 there is a strong eastward flow which splits as it hits the western coast of Isabela, this leaves a low current magnitude zone among most of the main islands, which could be good for self-recruitment, although it is a problem for the connectivity between populations. These changes, particularly under RCP 8.5, show the importance of mitigating the effects of uncontrolled climate change within the GMR because it is very likely they could disrupt the oceanographic workings of the marine ecology.

At 15 m depth most of the current flow across the islands is similar to 5 m for the months of December to March (Figures S10, S11 and S12). One of the main new interesting features at this depth is a pull-back-in towards Fernandina and Isabela of the currents, which flow over the northern tip of Isabela. This introduces a vector not seen before at 5 m which allows particles from the main islands to reach Fernandina. The southern pull in 2039 during January is even further seen with the currents pulling towards the south-east under RCP 8.5 (Figure S10). February also shows a much greater connectivity between islands such as Marchena and Darwin and Wolf under RCP 8.5 (Figure S11). At this depth by April and May the east be moving currents are already present under both RCP scenarios by 2029 and the interactions as these clash, with the westward flowing ones, creates some unique current patterns within the archipelago (Figures S13 and S14). This once again reinforces the point that more extreme climate change will lead to greater changes within current systems in the GMR even at greater depths.

8.3.2.1 Expected impacts on coral ecosystems from particle movement and temperatures.

Most coral species present within the GMR, such as *Porites lobata* and *Pavona Gigantea*, show the same responses to temperature change as most corals worldwide, with an upper temperature limit of 30°C before bleaching begins. Regarding temperature variations, at 5 m the average sea temperature within the GMR reached 30°C in April 2033 under RCP 8.5, and looking at the projections for RCP 8.5 the average temperature in March and April will surpass that threshold. This is a big worry for shallow coral populations which will be at risk, in addition to the extra stresses associated with climate change such as increased CO_2 which can also lead to bleaching. Fortunately, at a depth of 15 m the temperature increases under both scenarios are not yet close to threshold for most warm months under both scenarios.

The particle tracking aspect allows for further visualization of the connectivity between islands due to larval dispersal. The main connections between islands at both depths and under both RCPs are Genovesa to Marchena and Pinta, Santiago to western Isabela and Santa Cruz, and Española to Floreana. At a depth of 5 m for both RCPs there is a clear drop-off by 2039 in the connectivity between populations of coral species among the main islands, excluding April (Figures S16, S17, S18, S19 and S20). This is likely due to increased current magnitude which drags the larvae out of the reserve into the open ocean, preventing them from settling. At 15 m (Figures S21, S22, S23, S24 and S25) the connectivity to Fernandina and the west coast of Isabela can particularly be seen during the month of December. As the years progress for other months, the movement of larvae becomes more chaotic at this depth. Connectivity between isolated populations is essential for growth as well as recovery from natural phenomena, like El Niño, which greatly reduce numbers, so a change in these usual patterns would likely disrupt the survivability and future growth of coral populations in the GMR. The impact is a reduction in recruitment rates due to changes in the circulation systems of the currents, together with a loss of connectivity between the populations of the different islands. It is therefore once again imperative that action be taken to mitigate these effects and preserve the incredible biodiversity of this marine reserve.

8.4 Fisheries

8.4.1 Impacts

A growing number of empirical studies have shown that climate variability, represented mainly by the ENSO and coupled with anthropogenic drivers, has affected Galapagos marine ecosystems, fishery resources, and fisher´s behavior. Climate change research related to the Galapagos Islands has mostly focused on evaluating the observed effects of ENSO on landings, fishing effort and CPUE of several fisheries. In contrast, few studies have evaluated the ecological impact of ENSO on fishery resources and the consequences of climate variability on Galapagos' small-scale fishers and coastal communities.

Considering that ca. 68 species are commercially exploited in Galapagos (Castrejón 2011; Schiller et al. 2014), then there is empirical information about the impact of ENSO for less than 6.1% of Galapagos fishery resources. This a matter of great concern, as some species, particularly pelagic and demersal finfish species, are fundamental for the economy and food security of Galapagos human population.

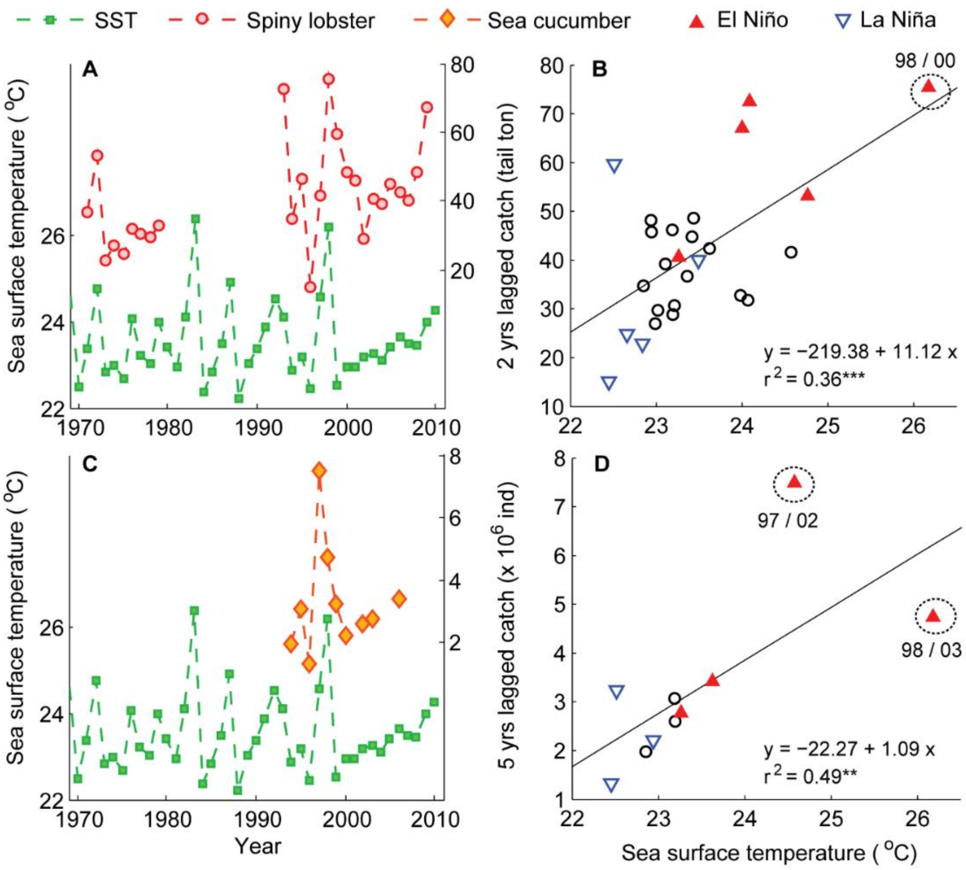
In consequence, the GNPD lacks information to guide and prioritize decisions about investments and initiatives needed for climate change mitigation and adaptation in the small-scale fishing sector.

8.4.1.1 Spiny lobster and sea cucumber fisheries

The spiny lobster is the Galapagos small-scale fishery on which most information about the impact of ENSO exists. However, even in this case study, there is uncertainty about the observed impact of the ENSO and climate change. According to Defeo et al. (2013b) the production (landings) of the spiny lobster and sea cucumber fisheries could be related to variations in sea surface temperatures (SST) in general, and particularly during El Niño events. Two and five years after the 1997/98 El Niño event, the spiny lobster and sea cucumber registered maximum historic production levels (Fig. 28). Furthermore, Wolff et al. (2012a), based on a trophic mass balance model for the Bolivar Channel ecosystem, suggest that lobsters biomass increased following the 1997/98 El Niño event.

The increased production levels registered for the sea cucumber SSF in 2002 are suggested to be product of the combined result of two main factors (Hearn et al. 2005; Castrejón 2011; Wolff et al. 2012a): (1) a strong recruitment pulse triggered by the 1997/98 El Niño that led to unusually high stock densities during years 2000-2003; and (2) an increase in fishing effort that resulted from the opening of the sea cucumber artisanal fishery in 1999 (Fig. 28) (Hearn et al. 2005; Castrejón 2011; Wolff et al. 2012a). Furthermore, the same factors, combined with a low predator abundance (e.g., demersal fish) and high prey abundance (e.g., sea urchins) after the 1997/98 El Niño, could explain the high production of spiny lobsters in 2000 (Bustamante et al. 2000; Hearn and Murillo 2008; Wolff et al. 2012a). However, Szuwalski et.al (2016) determined that the ENSO did not affect the biomass and recruitment of red spiny lobster stocks between 1997 and 2011.

*Figure 28. Time series and linear regressions between mean annual sea surface temperature (SST in situ, Santa Cruz Island) and lagged annual catch of spiny lobster (Panulirus penicillatus and P. gracilis; A, B) and sea cucumber (Isostichopus fuscus; C, D) in the Galapagos Islands, Ecuador. Catch series from 1995 to 2011 were linearly detrended and the residuals added to the mean, to account for the effect of fishing. Encircled triangles in B and D indicate the positive effect of 1997/98 El Niño over spiny lobster (2000) and sea cucumber (2002–2003) catches. El Niño and La Niña events were defined based on the Oceanic Niño Index (ONI) estimated by the National Oceanic and Atmospheric Administration (NOAA). **: P <0.05; ***: P <0.001. Catch and SST time series were provided by Galapagos National Park and Charles Darwin Foundation (2012). Source: Defeo et al. (2013).*



Although El Niño events caused a positive effect in shellfisheries, the sea cucumber fishery collapsed in 2006 due to overexploitation (Wolff et al. 2012b; Defeo et al. 2016). Apart from their economic importance to Galapagos fishers, sea cucumbers are also important in marine ecosystems due to their key role as nutrient recyclers (Purcell et al. 2016). Sea cucumbers excrete inorganic nitrogen and phosphorus, enhancing the productivity of benthic biota. This form of nutrient recycling is crucial in ecosystems in oligotrophic waters such as coral reefs. Feeding and excretion by sea cucumbers also act in increasing seawater alkalinity which contributes to local buffering of ocean acidification (Purcell et al. 2016). As the ocean is absorbing a large proportion of atmospheric CO2 derived from anthropogenic activity, the seawater carbonate chemical equilibrium is shifting towards lower pH, i.e., more acidic waters and lower calcium carbonate saturation states (Manzello et al. 2017). These changes impact many calcifying species, e.g., shell-forming marine organisms, but also probably the physiology and respiration of fishes, especially the more vulnerable early life stages. However, the ecological impact generated by the overexploitation and collapse of sea cucumbers stocks on the regulation of seawater carbonate chemical equilibrium in the Galapagos is unknown.

Unlike the spiny lobsters and sea cucumbers, no studies have been conducted to evaluate the impact of ENSO over slipper lobster and other benthic species, such as octopus. This is a matter of concern because slipper lobsters and octopus are important for the economy and food security of Galapagos.

8.4.1.2 Galapagos sailfin grouper and other demersal fish species

The Galapagos artisanal finfish fishery referred locally as "pesca blanca", target benthic and demersal fishes, being the most relevant the sailfin grouper (*M. olfax*), the endemic white-spotted sandbass (*P. albomaculatus*), mottled scorpionfish (*P. clemensi*), and the misty grouper (*H. mystacinus*). According to Schiller et al. (2014), 26 500 t of finfish were caught within the economic exclusive zone of the Galápagos Islands between 1950 and 2010. Of these catches, approximately 25.3%, equivalent to 6700 t, was consumed by Galapagos human population, including tourists, while the remainder 74.7%, equivalent to 19 800 t, was exported to mainland Ecuador.

Some studies have recently evaluated the impact of the ENSO and climate change on the sailfin grouper. Research evaluating the effect of El Niño 2015/16 over the landings composition of the Galapagos artisanal finfish fishery showed how catch composition changed during the 2016 El Niño event. Larger size individuals and uncommon demersal and benthic predatory fish species, like the Grape eye seabass (*Hemilutjanus macrophthalmos*) and Pacific dog snapper (*Lutjanus novemfasciatus*) were caught during this event (Marin and Salinas de León 2020). It is believed that the 2015/16 El Niño event probably decreased prey biomass by reducing primary productivity, leading to demersal and benthic predatory fish species into a starvation state. Thus, the catchability of these species probably increased, as they were more likely to be attracted to the bait offered by artisanal fishers. According to Marin and Salinas de León (2020), the increased catchability of larger individuals, caused by El Niño, could exacerbate the overexploitation of the Galapagos sailfin groper. In consequence, these authors proposed the implementation of management actions, including minimum legal size, catch limits, and spatiotemporal closures, to promote the recovery of this endemic and vulnerable species across the archipelago.

Furthermore, studies examining the impact of fishing on the biomass and ecosystem role of Galapagos sailfin grouper, during both normal and El Niño years, suggests that the ecosystem role of groupers, as top predators, has greatly diminished with overexploitation, which has depleted the stock by ca. 85% compared to unfished levels.

Reduction of groupers biomass decreases their ecosystem role as a keystone species[7], hence, their removal produces cascading effects with profound effects on the whole food web, during

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7 Keystone species are those which have an extremely high impact on a particular ecosystem relative to its population.

both normal and El Niño years. Grouper's overexploitation has triggered large changes (increase and decrease) in the biomass of many functional groups, and with covariations during El Niño years. If the Galapagos sailfin grouper stocks were rebuilt to at least half of unfished biomass, their role in the ecosystem would be partially restored and more fish would be caught (Eddy et al. 2019).

On the other hand, Monnier et al. (2020) indicate that under business-as-usual scenario (RCP 8.5) SST in Galapagos would increase 3.9 °C by the end of this century. This means that by the year 2100 the SST in Galapagos would be, on average, 30.9 °C in the worst-case scenario. According to Kaschner et al. (2016) the preferred sea temperature of the sailfin grouper ranges between 14.5 °C and 23.7 °C, thus, this species would be outside of its thermal range under an RCP 8.5 scenario in Galapagos. In fact, Monnier et al. (2020) indicate that the sailfin grouper is already outside of its preferred temperature range in Galapagos and predicts that this species will be severely impacted by sea water warming, even in the case of the IPCC strong mitigation scenario (RCP 2.6). These authors also estimate that the sailfin grouper's ecosystem biomass will be reduced 8.3% and 10.8% by 2030 under RCP 2.6 and 8.5 scenario, respectively. Such reduction in biomass will be higher by 2100 (8.0% and 15.6% for RCP 2.6 and 8.5 respectively).

Another potential impact of climate change on groupers are the expected changes in oceanic circulation patterns as a result of rising water temperatures (Kennett & Ingram, 1995). It has been demonstrated that anthropogenic global warming will change oceanic circulation patterns around the Galapagos archipelago in the time span 2025 and 2050, and will affect bioregions differently (Liu *et al*., 2013). These changes in ocean circulation are expected to have consequences on the larval stage of fish species (Kendall *et al*., 2016). Although information on the sailfin grouper larvae and its actual transport mechanism is still unknown, changes in the oceanic currents surrounding the archipelago could result in larvae transported away from highly productive habitats, ultimately resulting in poor recruitment.

Furthermore, groupers are known to have ontogenetic habitat use differences in the GMR. Adult sailfin groupers are mainly found in rocky reefs and *bajos* (shallow seamounts), while juveniles are mostly found in mangrove fringes (Aguaiza, 2016; Fierro, 2017). As such, adaptations measures for sailfin groupers should consider all grouper's habitats. Climate change will also impact species through sea level rise, negatively affecting mangrove ecosystems in the Galapagos. While mangroves could keep pace by migrating landward (Alongi, 2002), this will depend on water rising at a sufficiently slow rate to allow mangrove migration to occur (Gilman et al. 2008). The combined effect of rising temperatures and sea level rise will affect adults and juveniles respectively. can have devastating effects on the already threatened Galapagos grouper.

Since mangroves provide critical habitat for a suite of economically important species, including the sailfin grouper EBA measures must identify and conserve, through no-take areas, those mangrove forest patches with the highest structural complexity and with the possibility to migrate inwards to keep pace with rising waters. These patches will act as climate change refuges for the juvenile stages of the sailfin grouper and other commercially important species that are expected to be fundamental in the recovery of the species.

A recent analysis based on the abundance of this species measured in coastal waters across the archipelago (all bioregions) for a time span of 20 years (1994-2014), shows no statistically significant linear patterns with regard to temperature measured on-site (linear regression, $p=0.18$, $n=520$) nor with average Oceanic Niño Index (ONI) values (Ramírez-González et al. 2020). However, visual inspection suggests that normal conditions (i.e., neutral ONI values) are those with the highest sailfin grouper abundances (Fig. 3). This analysis also shows that the effects of temperature anomalies have different responses according to bioregion (Fig. 4-5). The Western and Central south-eastern bioregions seem to have lower abundancies in the extremes, i.e., with ONI values above and below 0.5, corresponding to El Niño and La Niña respectively. For the Far Northern and Northern bioregions the pattern is less clear.

Figure 29. Abundance of bacalao (mean per site along a 250m2 transect) versus Oceanic El Niño Index (n=972). Colors indicate El Niño phase [3 month running mean of ERSST.v5 SST anomalies in the Niño 3.4 region (5oN-5oS, 120o-170oW)], E= El Niño (red), L=La Niña (green), N=Neutral (blue. (Ramírez-González et al. 2020).

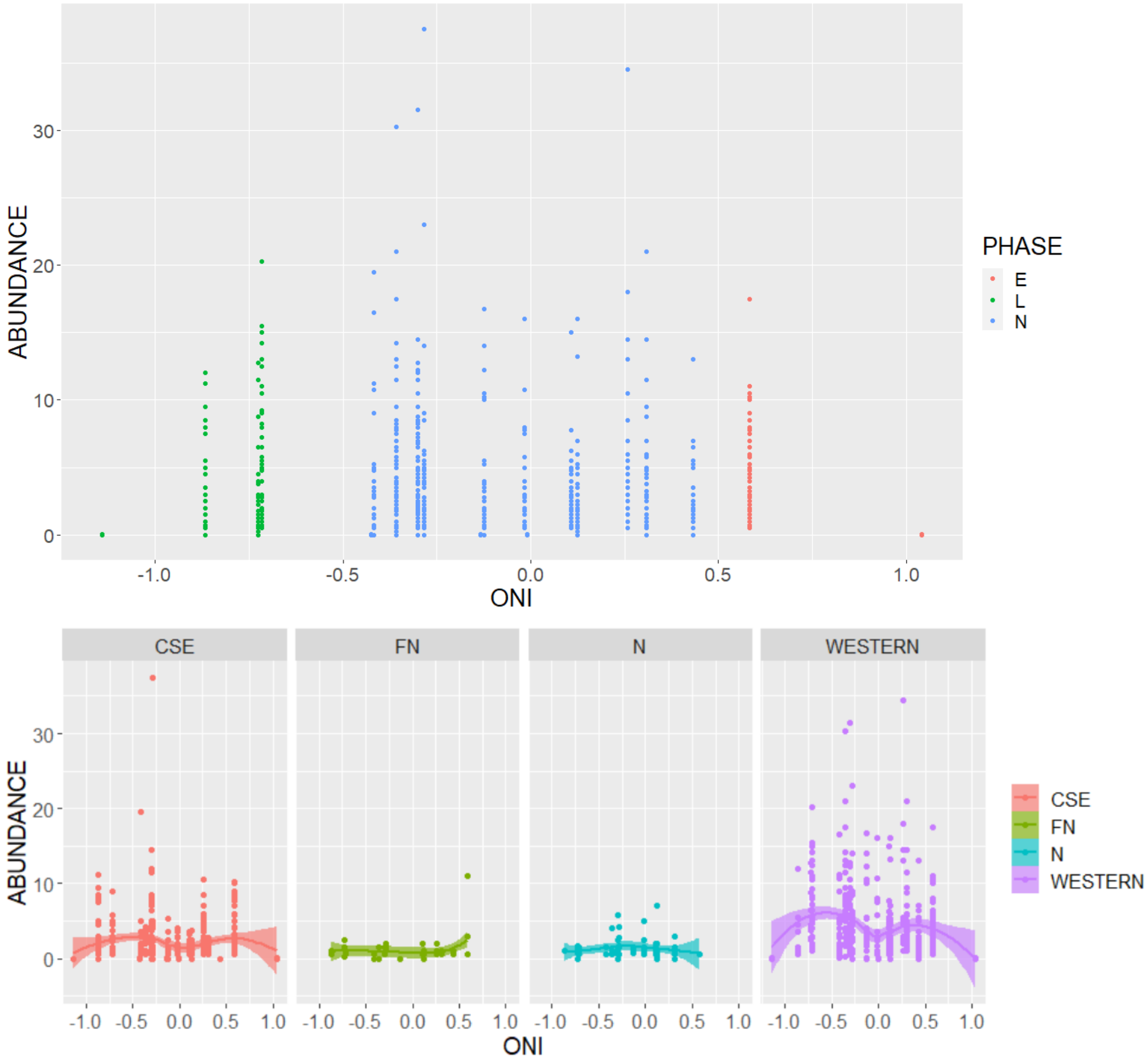
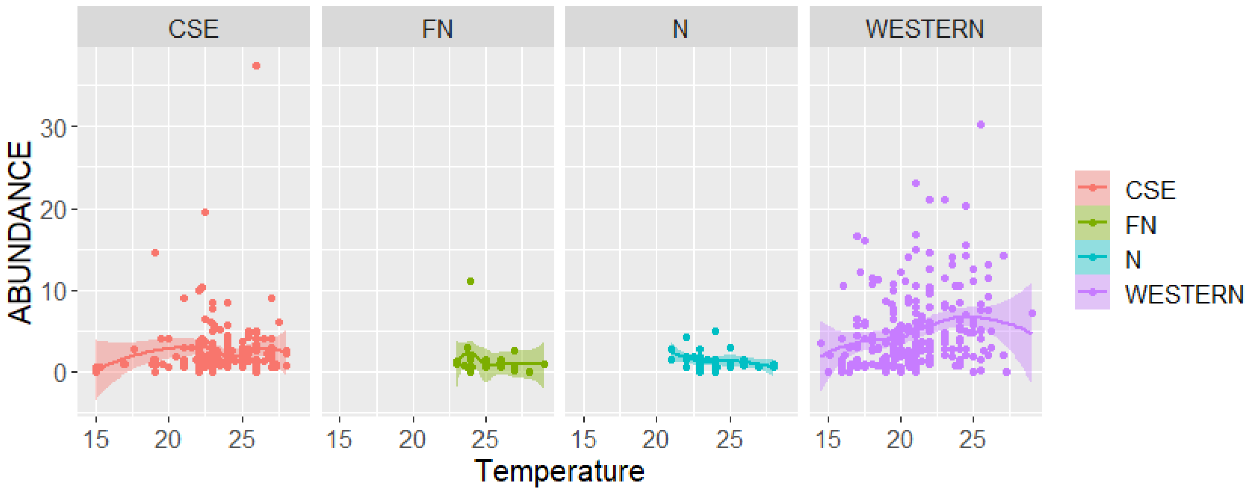


Figure 30. Abundance of bacalao (mean per site along a 250m2 transect) versus temperature measured on-site in (C) (n=520). Colors indicate bioregion, CSE=Central southeaster, FN=Far North, N=North and Western. (Ramírez-González et al. 2020)



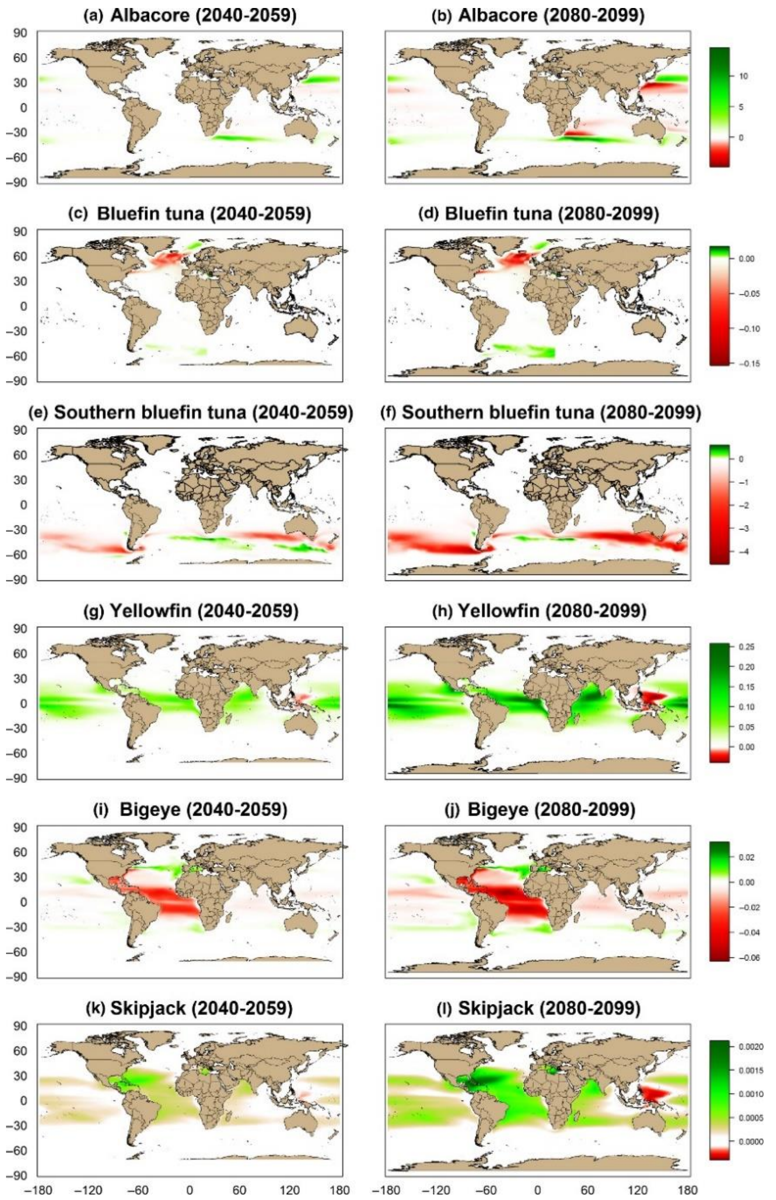
Although recent efforts have studied the sailfin grouper fishery and biology, no information exists for other commercial finfish species in Galapagos, including the mottled scorpionfish (Table 1). This is a matter of great concern because several demersal finfish species are important for the economy of the SSF and tourism sectors of Galapagos.

8.4.1.3 Yellowfin tuna

In Galapagos, the harvest and consumption of tuna have increased gradually since 2006 due to the increasing number of tourists, residents, restaurants and hotels. Between 1997 and 2017, yellowfin tuna landings increased by a factor of nearly five, from 41.1 to 196.8 t per year (Castrejón and Moreno 2018). According to the DGNP statistics, approximately 70% of the tuna catch (138.5 t) is consumed in Galapagos, while 30% is shipped to mainland Ecuador (58.3 t) (Berman et al. 2018). Thus, the increasing importance of yellowfin tuna highlights the need for adaptation measures against climate change for this specific fishery.

Tuna are characterized by dynamic distribution patterns that respond to climate variability and long-term change (Erauskin-Extramiana et al. 2019). These highly migratory and transboundary species are of particular importance in Eastern Tropical Pacific, as they contribute significantly to the livelihoods, food and economic security of Ecuador, Panama, Costa Rica and Colombia (Castrejón 2020). However, changes in water properties and circulation will impact on tuna larval dispersal, preferred habitat distributions and the trophic systems that support tuna populations throughout the region (Ganachaud et al. 2013).

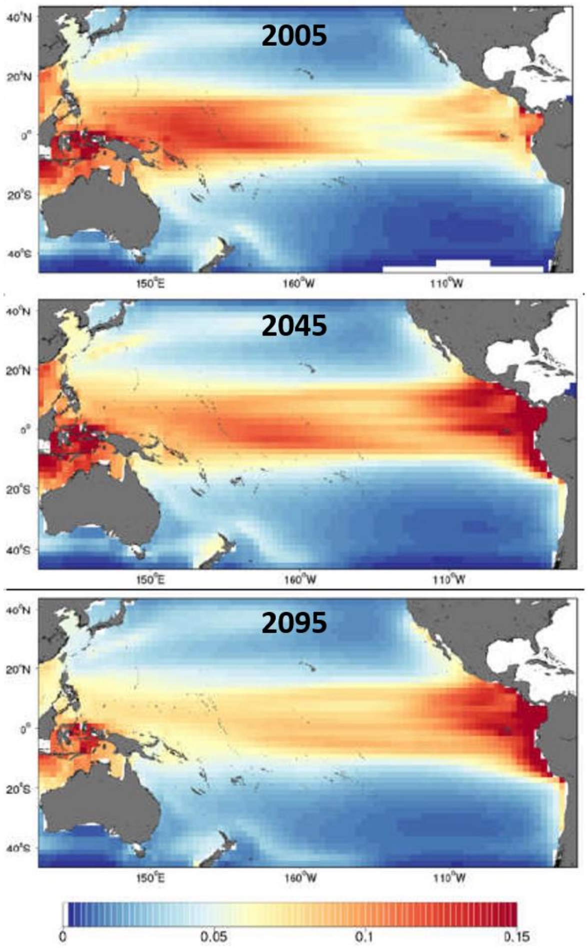
Figure 31. Gains and losses of abundance (in tons per 1,000 hooks, except for southern bluefin tuna, in number of individuals per 1,000 hooks) for mid- (left column, a, c, e, g, i and k) and end-of-the-century (right column, b, d, f, h, j, l). Source: Erauskin-Extramiana et al. (2019).



In the Eastern Tropical Pacific, the yellowfin tuna (*T. albacares*), bonito (*Sarda chilensis*), and dolphin fish (*Coryphaena hippurus*) stocks are expected to move into the coastal waters from northern Chile to northern Peru–south Ecuador due to the ENSO, increasing the availability of these species to fishers in this area (Bertrand et al. 2020). This suggests that yellowfin tuna abundance, within the Galapagos Marine Reserve could decrease, as well as their catchability, due to changes in the migratory movements.

In contrast, Erauskin-Extramiana et al. (2019) projected that skipjack and yellowfin tunas will become more abundant in tropical areas as well as in most coastal countries' exclusive economic zones (EEZ) at the end of the century (Fig. 31).

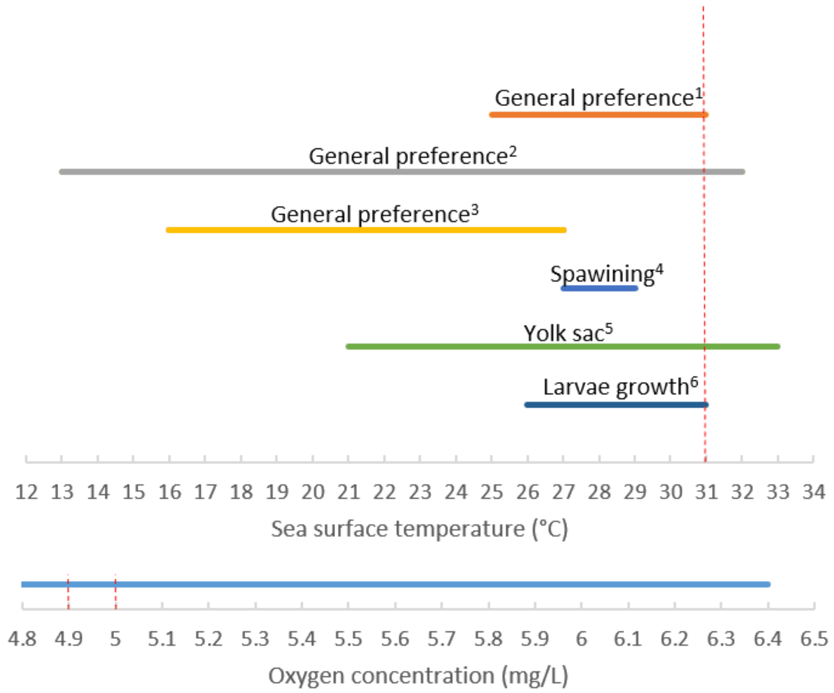
Figure 32. Projected mean distribution of yellowfin tuna biomass across the Tropical Pacific Ocean under IPCC-RCP 8.5 climate change scenario for 2005 and from the decades centered on 2045 and 2095. Modified from Senina et al. (2018).



Similarly, Senina et al. (2018) projected a clear shift from the western to the central and eastern Pacific (Fig. 7), with a biomass increase above 50% in the International Water Eastern Pacific Ocean-Central, without considering the fishing impact in the past and future. In addition, when Senina et al. (2018) included the effects of fishing in the climate change models under the RCP 8.5 scenario, they projected an increase in catches (52-107%) of yellowfin tuna in the ETP by the end of this century. However, it is important to consider that larval mortality, due to ocean acidification, shows a strong effect in the ETP yellowfin abundance, leading to a 20% decline in biomass, which could increase 10% to 15% by 2100.

Analyses based on sea temperature and oxygen as the main variables that explain the distribution of yellowfin tuna (Arrizabalaga *et al*., 2014) partially support the hypothesis of an increase in biomass of yellowfin tuna in Galapagos under the climate change RCP 8.5 scenario. By the end of the century, Galapagos would meet favourable yellowfin tuna conditions for oxygen concentration, general SST, yolk sac and larval growth development (Senina *et al.* 2018) but will not meet ideal conditions for optimal spawning (Wexler et al 2011) (Fig. 33).

Figure 33. Sea surface temperature and oxygen preferences for yellowfin tuna and projections of these parameters (red dotted vertical lines) under IPCC-RCP 8.5 climate change scenario by the end of this century in Galapagos. Own elaboration from Monnier et al. (2020), CPPS (2018), 1Arrizabalaga et al. (2014), 2Senina et al. (2018), 3Kaschner et al. (2016), 4Wexler et al. (2011).



8.4.1.4 Influence of climate and anthropogenic drivers on fisher's behaviour

Only two studies have evaluated the consequences of climate variability on Galapagos' small-scale fishers and coastal communities. Bucaram et al. (2013) and Castrejón and Charles (2020) found that climatic variables, in combination with economic and oceanographic conditions, influence fisher's behavior regarding how and where to fish. Travel distance from vessels' home ports to fishing grounds and expected revenues are the most important factors affecting the spatial allocation of fishing effort in Galapagos spiny lobster fishery (Bucaram et al., 2013). Furthermore, fishing effort increased during El Niño events, which could be caused by the redistribution of spiny lobster stocks from inshore to deeper waters, making them inaccessible to hooka divers, who in response increased search times and diving hours per fishing trips (Castrejón and Charles, 2020; see Appendix 2.2 for details).

8.4.1.4 Synthesis of the impact of ENSO on fish and fishers and coping strategies.

The social-ecological impact of ENSO on the six most important fishery resources within the limits of the GMR are summarized in Table 20. For more details see Appendix 2.2.

In summary, scientific studies has focused on evaluating the observed effects of ENSO on spiny lobsters, sea cucumbers, sailfin groupers, and most recently, on the yellowfin tuna fishery, mostly in relation to landings, fishing effort and CPUE (Table 20). In contrast, few studies have evaluated the ecological impact of ENSO on fishery resources (Table 20).

No impact of ENSO on the biomass, recruitment, and spawning stock biomass has been reported for the spiny lobster fishery (Szuwalski et al. 2016), while for the sailfin grouper fishery the proportion of sexually immature individuals in catch composition has been reported to increase during El Niño event (Nicolaides and Murillo 2001).

Furthermore, positive impacts of ENSO have been reported for sea cucumbers, spiny lobsters and sailfin groupers for landings and CPUE (Nicolaides and Murillo 2001; Defeo et al. 2013b; Marin and Salinas-de-León 2018), although this study shows no impact of El Niño on CPUE for the spiny lobster fishery. For this fishery, landings have been reported to decrease during the 1997/98 El Niño, while two years later they increase (Defeo et al. 2013b; Defeo et al. 2016). Therefore, positive and negative effects have been reported for the same indicator (Table 20). In contrast, negative impacts of ENSO on landings and CPUE in the yellowfin tuna fishery are expected to occur in Galapagos due to changes in the migratory patterns of this species due to climate change (Bertrand et al. 2020). Therefore, the impact of ENSO on the socio-economic well-being of fishers will vary, temporally or permanently, depending on the type of impact produced by ENSO on landings and CPUE (Table 20).

Decreasing landings and CPUE of yellowfin tuna likely will decrease catchability and increase search times. Similar trends have been reported for the spiny lobster fishery during the El Niño event, including increasing fishing hours per trip (Castrejón and Charles 2020). In contrast, the impact of ENSO on the sailfin grouper is uncertain as some studies report that catchability increase during El Niño (Marin and Salinas-de-León 2018), while others report a decrease of this fishery-related variable (Nicolaides and Murillo 2001).

Finally, it is important to highlight that for the slipper lobster and mottled scorpionfish fisheries there is no information at all for any ecological or social indicator (Table 20). This is a matter of concern, as both fisheries are important for the economy of the small-scale fishing and tourism sectors of Galapagos.

Table 20. Social-ecological impacts of ENSO reported for Galapagos small-scale shellfisheries. Type of impact: green (increase), red (decrease), yellow (no impact), blue (uncertain), grey (no information). SC: sea cucumber; SL: spiny lobster; SLL: slipper lobster; YT: yellowfin tuna; SG: sailfin grouper; MSF: mottled scorpionfish; OCT: octopus.

Impacts	**SC**	**SL**	**SLL**	**YT**	**SG**	**MSF**	**OCT**
Ecological							
Biomass							
Recruitment							
Spawning stock biomass							
Sexually immature individuals							
Social							
Landings							
CPUE							
Catchability							
Socio-economic well-being (temporal or permanent)							
Coping strategies							
Search times							
Fishing hours per trip							

8.4.2 Expected scenarios

8.4.2.1 Effect of ENSO over Galapagos spiny lobster fishery

For the purpose of this feasibility study, fishery monitoring data collected by the Participatory Fisheries Monitoring and Research Program (PIMPP, Spanish acronym) from 1997 to 2018 were analyzed to determine the effect of the ENSO over the spiny lobster fishery. Three fishery-related indicators were used for this analysis: (1) annual total catch, (2) annual total fishing effort, and (3) catch per unit effort (CPUE). Fishery-related data were collected by interviewers and fishery observers at the three main ports of Galapagos (Puerto Ayora, Baquerizo Moreno, and Villamil) on a daily-basis along each fishing season. Annual CPUE was calculated as kilograms of lobster tails captured per diver each fishing day (kg tail diver^{-1} day^{-1}). Total fishing effort was calculated diving total annual catch (in kg) by annual CPUE. Estimation of CPUE was restricted to those fishing trips conducted in small vessels (fiberglass and wooden made) by one or two hooka divers, where the number of effective fishing days ranged from one to four.

Climate variability was evaluated through the annual average of the Oceanic Niño Index (ONI), which is one of the primary indices used by the National Oceanic and Atmospheric Administration (NOAA) to monitor the ENSO (Dahlman 2009). This oceanographic index is calculated by averaging sea surface temperature (SST) anomalies in an area known as Niño 3.4 region, located in the east-central equatorial Pacific Ocean (5S to 5N; 170W to 120W). To isolate variability closely related to the ENSO phenomenon a 3-month time average of the SST is calculated. ONI values equal to or higher than +0.5 indicate El Niño conditions, meaning that the East-central tropical Pacific is significantly warmer than usual. In contrast, La Niña conditions are denoted by ONI values equal to or lower than -0.5, indicating that the region is cooler than usual (Dahlman 2009). Finally, ONI values between -0.5 and 0.5 mean ENSO-neutral conditions; that is neither El Niño nor La Niña has prevailed. Data were obtained from the NOAA Climate Prediction Centre, accessed on Abril 25th 2020 at

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_change.shtml

Autocorrelation analysis determined that catch, fishing effort, and CPUE were not stationary; i.e., a flat looking time series, without trend, in which the mean, variance, and autocorrelation structure do not change over time. In consequence, the observed time series were de-trended by using first-order differencing (Shumgay and Stoffer 2011). Then, to determine the associations between ENSO and fishery-related variables from 1997 to 2018, cross-correlations were calculated between ONI and annual estimates for the catch, fishing effort, and CPUE. This analysis was used to identify lags of the independent variable (ONI), which might be a useful predictor of dependent variables (catch, fishing effort, and CPUE). Cross-correlations were calculated using ONI lagged 0 to 6 years to investigate whether fishery-related variables were affected by El Niño some years after the conclusion of this extreme climatic event. Finally, multiple regression models were used to explain the relationship between dependent variables (catch, fishing effort, and CPUE) and past lags of the predictor variable (ONI) (Shumgay and Stoffer 2011).

The results obtained showed that eight El Niño events and ten La Niña events occurred in Galapagos between 1997 and 2018 (Table 21). The strongest El Niño events, denoted by ONI values equal or higher than 2.3, were represented by El Niño 1997/98 and El Niño 2015-2016. In contrast, the strongest La Niña events, denoted by ONI values equal to or lower than -1.5, were represented by La Niña 2007/08 and La Niña 2010/11 (Table 21).

On the other hand, catch, fishing effort and CPUE decreased substantially between 1997 and 1998 (Fig. 2). Declining trends in catch and CPUE could be caused by the redistribution of spiny lobster stocks from inshore to deeper waters due to reproductive migration associated with warmer sea surface temperatures, making spiny lobster inaccessible to fishing by hooka diving (Castrejón and Charles 2020). In response, fishers increased search times for spiny lobsters, leading to increasing diving hours per fishing trip (fishing effort) in 1997 (Castrejón and Charles 2020), then fishers reduced their fishing effort, in terms of the number of effective diver fishing days, in 1998 (Fig, 2), probably due to low levels of catch.

However, after 1997/98 El Niño, catch, fishing effort and CPUE increased, until reaching a peak between 2000 and 2001 (Fig. 2B, C, D). According to Castrejón and Charles (2020), the re-opening of the sea cucumber fishery, one year after the creation of the GMR in March 1998, caused severe overcapitalization of the entire Galapagos small-scale fishing sector, with fishing capacity increasing not only in the sea cucumber fishery but also in the lobster fishery. Only a moratorium on new entrants in 2002 stopped the exponential growth in the number of fishers and vessels registered in Galapagos, that had occurred between 1997 and 2000 (Castrejón and Charles 2020).

The overcapitalization of the small-scale fishing sector caused the overexploitation of the sea cucumber and spiny lobster fisheries (Defeo et al. 2016; Castrejón and Charles 2020). For this reason, catch, fishing effort, and CPUE gradually decreased after 2001, until reaching minimum historical values between 2009-2010. CPUE decreased 52.7% between 2000 and 2005, while catch decreased by 75.4% between 2000 and 2009 (Fig. 34). The fishing effort showed a similar trend, decreasing 70.7% between 2000 and 2010 (Fig. 34).

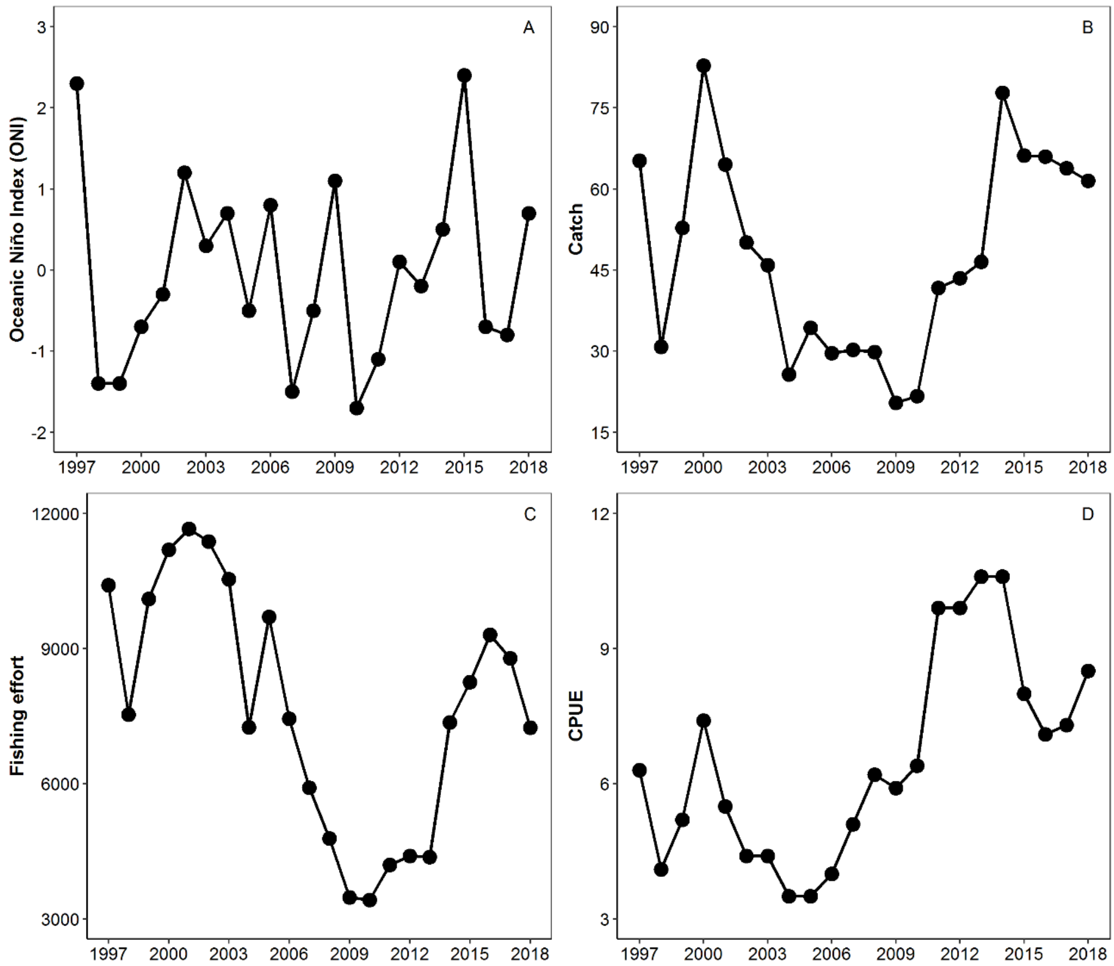
After 2005, the spiny lobster fishery began to show signs of recovery. CPUE steadily increased until reaching a maximum peak in 2014. During this period, CPUE increased 202.9%, from 3.5 to

10.6 kg tail diver-[1] day[-1] (Fig. 2). After 2009 and 2010, catch and fishing effort increased until reaching second maximum peaks in 2014 and 2016, respectively. During this period, catch increased 281%, from 20.4 to 77.8 TM, while fishing effort increased 172.1%, from 3419.2 to 9304.4 diver fishing days (Fig. 34). After 2014, CPUE has decreased, although it remains comparably higher than CPUE values observed at the end of the 1990s. Catch and fishing effort also showed similar decreasing trends during the same period (Fig. 34).

Table 21. The annual average of the Oceanic Niño Index (ONI) from 1997 to 2018. ONI values equal or higher than +0.5 indicate El Niño conditions, while La Niña conditions are denoted by ONI values equal to or lower than -0.5. Finally, ONI values between -0.5 and 0.5 mean ENSO-neutral conditions; that is neither El Niño nor La Niña has prevailed. Source: NOAA Climate Prediction Centre, accessed on Abril 25th 2020.

Year	ONI	ENSO
1997	2.3	El Niño
1998	-1.4	La Niña
1999	-1.4	La Niña
2000	-0.7	La Niña
2001	-0.3	ENSO-neutral conditions
2002	1.2	El Niño
2003	0.3	ENSO-neutral conditions
2004	0.7	El Niño
2005	-0.5	La Niña
2006	0.8	El Niño
2007	-1.5	La Niña
2008	-0.5	La Niña
2009	1.1	El Niño
2010	-1.7	La Niña
2011	-1.1	La Niña
2012	0.1	ENSO-neutral conditions
2013	-0.2	ENSO-neutral conditions
2014	0.5	El Niño
2015	2.4	El Niño
2016	-0.7	La Niña
2017	-0.8	La Niña
2018	0.7	El Niño

Figure 34. Time series for the Galapagos spiny lobster fishery (Panulirus penicillatus and P. gracilis) from 1997-2018. A: Oceanic Niño Index (ONI); B: catch (lobster tails TM); C: fishing effort (diver fishing days); D: CPUE (kg tail diver-1 day-1).



According to Defeo et al. (2016), the recovery of spiny lobster stocks could be attributed to the substantial reduction in fishing effort, together with the combined effect of market forces and favorable environmental conditions, probably caused by El Niño. This hypothesis is partially supported by Szuwalki et al. (2016), who found that spiny lobster estimated biomass started to increase in 2007, probably due to large previous recruitment events and remarkable reduction of fishing effort mortality. However, these authors did not find evidence that spiny lobster stocks recovery was caused by El Niño. This last result is supported by the cross-correlations analysis conducted in this report, which revealed that catch, fishing effort, and CPUE were not significantly affected by ONI between 1997 and 2018.

No lagged effects were detected in the Auto Correlation Function (ACF) plots (Fig 35), which are a visual way to show a serial correlation in time series data. These results suggest that the recovery of the spiny lobster fishery was caused mainly by a remarkable reduction of fishing effort, while the impact of favorable environmental conditions produced by the ENSO on such recovery is uncertain.

Finally, results of the cross-correlations analysis were supported by multiple regression models, which did not find any statistically significant relationship between dependent variables (catch, fishing effort, and CPUE) and past lags of ONI, even in those cases in which correlation values were higher than 40 (Fig. 36-38).

Figure 35. Cross-correlations of ONI vs catch, fishing effort and CPUE. ACF: Autocorrelation function.

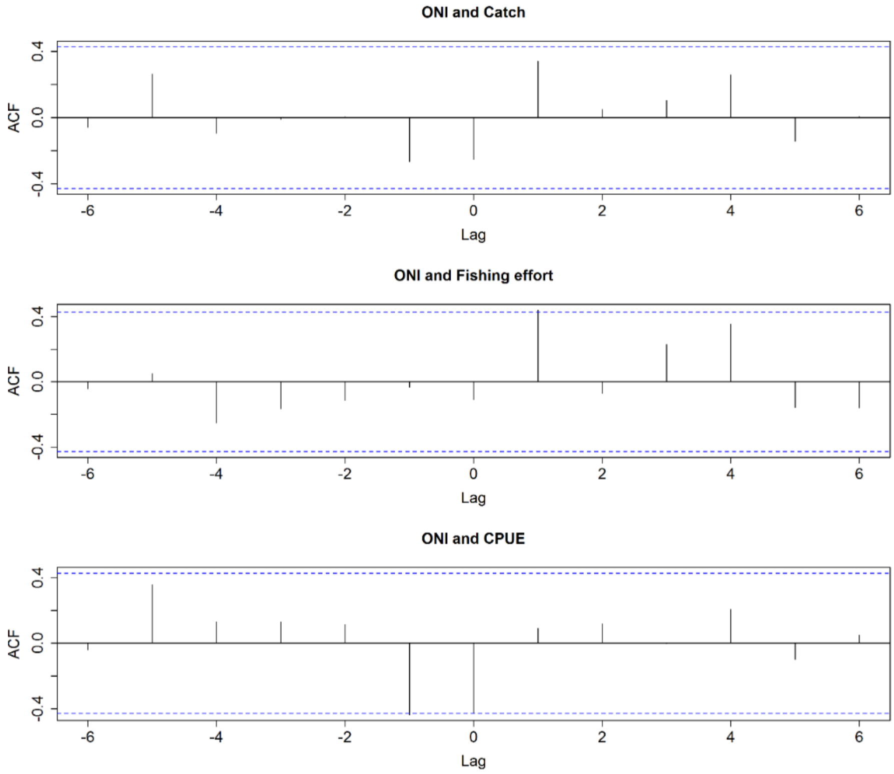


Figure 36. Scatterplots between time series of stationary catch and ONI past lags from 0 to 8. In each plot, the independent variable (StationaryCatch) is on the y-axis and a past lag of ONI is on the x-axis

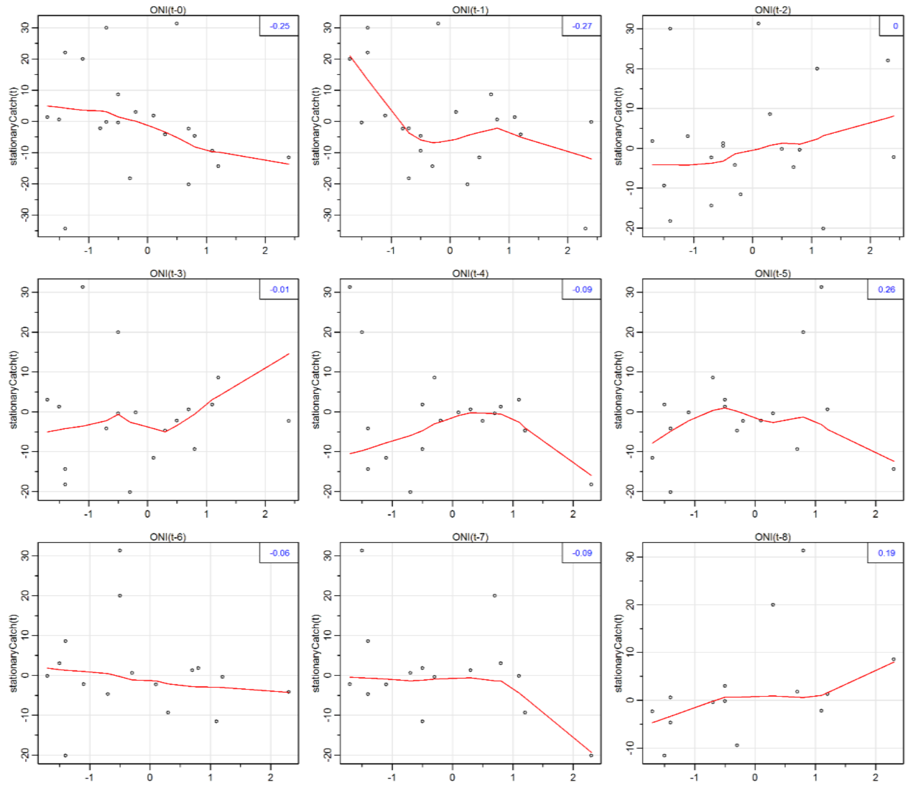


Figure 37. Scatterplots between time series of stationary fishing effort and ONI past lags from 0 to 8. In each plot, the independent variable (StationaryEffort) is on the y-axis and a past lag of ONI is on the x-axis. Correlation values are given on each plot.

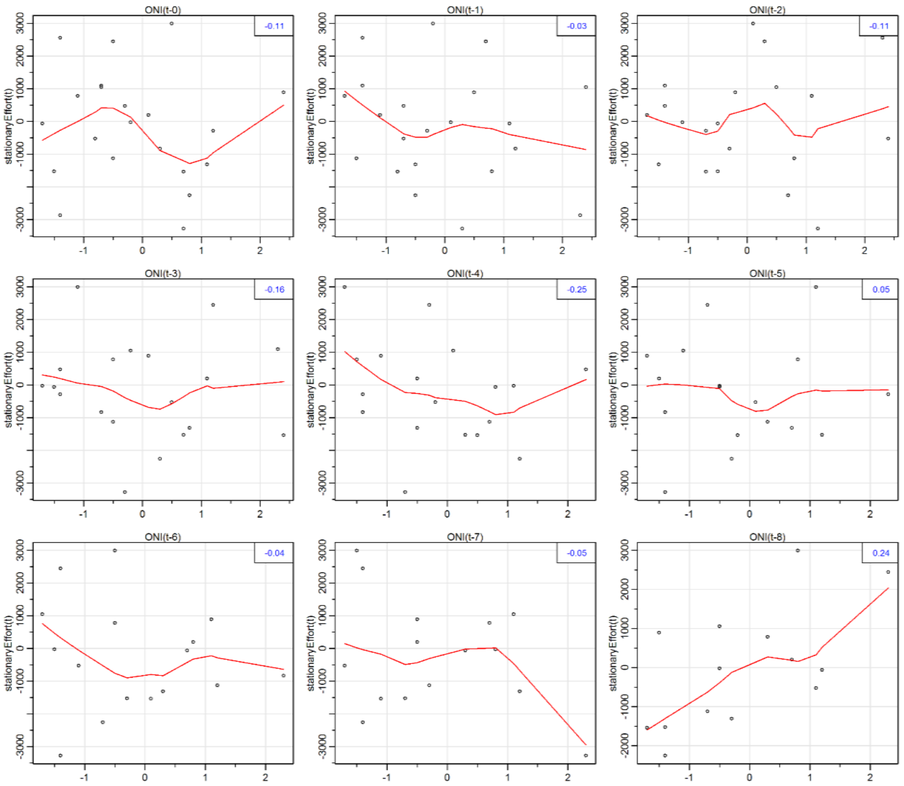
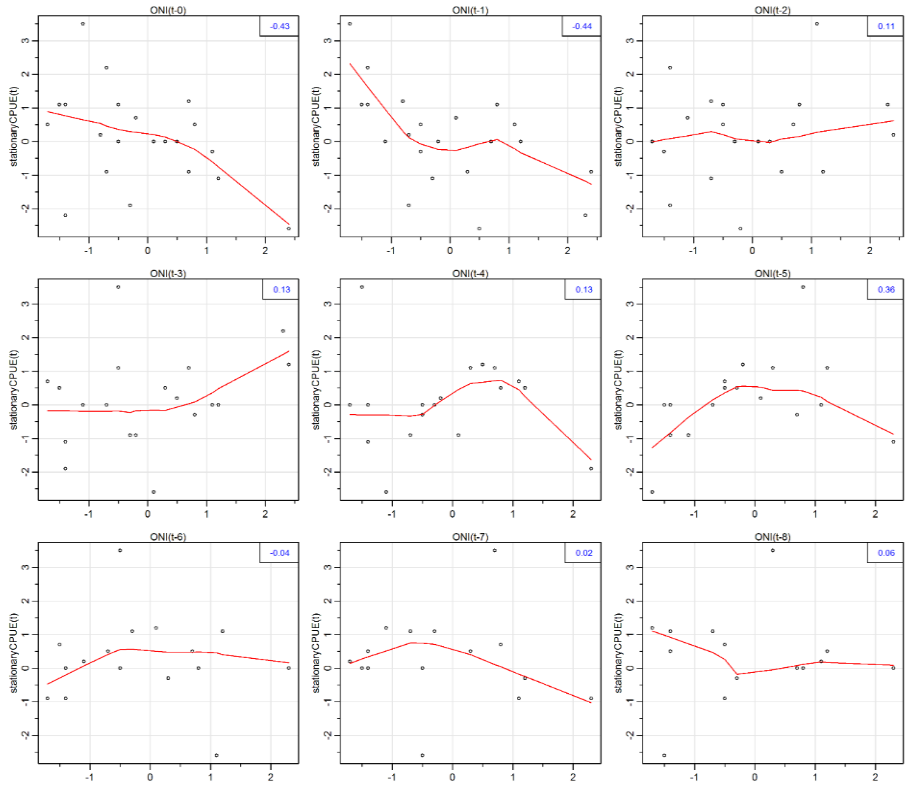


Figure 38. Scatterplots between time series of stationary CPUE and ONI past lags from 0 to 8. In each plot, the independent variable (StationaryCPUE) is on the y-axis and a past lag of ONI is on the x-axis. Correlation values are given on each plot.



The results of this analysis showed that, even in the case of spiny lobsters, which is the Galapagos small-scale fishery on which most information about the impact of ENSO exists, there is uncertainty about the observed impact of El Niño. In Section 8.4.1, Defeo et al. (2013) suggests that spiny lobsters landings are positively impacted by El Niño, particularly during extreme El Niño events, while Wolff et al. (2012), based on a trophic mass balance model for the Bolivar Channel ecosystem, suggest that lobsters biomass increased following the 1997/98 El Niño event. In contrast, the study of Szuwalski et.al (2016) suggests that El Niño does not affect the biomass and recruitment of red lobster stocks, while the cross-correlation analysis presented in this section did not find any influence of El Niño on spiny lobsters catch and CPUE from 1997 to 2018.

The uncertainty about the observed impact of El Niño over the spiny lobster fishery could be associated with variations on the intensity of this climatic event. According to (Bertrand et al. 2020), no two El Niño events are alike, nor are the resulting ecological responses. In consequence, these authors have identified five ENSO events that occur at a global scale:

1. Extreme El Niño events: intense warming over most of the equatorial Pacific with the strongest oceanic signature located in the eastern part of the basin.
2. Moderate Eastern Pacific (EP) El Niño events: modest warming over most of the equatorial Pacific with the strongest oceanic signature located in the eastern part of the basin.
3. Moderate Central Pacific (CP) El Niño events: modest equatorial Pacific warming located near the dateline with weak oceanic signature along the west coast of South America.
4. Coastal El Niño events: warm conditions along the west coast of South America, but normal or cool conditions elsewhere in the Pacific.
5. Strong La Niña events: large-scale cooling over most of the equatorial Pacific with the strongest oceanic signature located in the central part of the basin.

Based on a global synthesis about the impact of the variety of ENSO events on fisheries and aquaculture in the context of a changing climate, Bertrand et al. (2020) concluded that El Niño impacts on the southeast Pacific, area that includes the Galapagos Islands, considerably differ between El Niño types. They found that while CP El Niño events do not significantly impact the Humboldt Current System (HCS) and related fisheries, strong and coastal El Niño events lead to warm ocean temperatures, heavy rain, floods, and heavy river discharges in northern Peru that can impact SSF infrastructure. Therefore, while extreme El Niños have the greatest impact, the response strongly differs from one event to the other, with the extreme El Niño of 1982/83 producing a much larger impact than that of 2015/16. As a result, Bertrand et al. (2020) conclude that the strength of the impact depends on the type of event. Extreme El Niños have by far the most relevant effect, followed by the EP El Niños, while the impact of strong La Niña events is usually opposite to those of extreme and EP El Niños, but with fewer consequences.

As Galapagos is located in the main influence area of ENSO, it is expected that small-scale fisheries from this archipelago will be strongly impacted by future ENSO events, particularly during extreme and EP El Niños (Bertrand et al. 2020). As the strength of the impact depends on the type of event, this helps to explain why different impacts have been observed in the Galapagos spiny lobsters fishery from 1997 to 2018.

Another source of uncertainty that limits the capacity to predict the observed impact of El Niño on the Galapagos spiny lobsters fishery is the influence of overfishing, which is an anthropogenic driver that exacerbates the effects of climate stressors (Defeo et al. 2013). The results presented in this report, and other studies (Defeo et al. 2016; Castrejón and Charles 2020), showed that fishing effort varied remarkably between 1997 and 2018, contributing to the overexploitation and subsequent recovery of the spiny lobster stocks. In consequence, the resilience and adaptive capacity of these species probably increased since the recovery of the fishery, counteracting the impacts of El Niño events that occurred after this period. However, it is uncertain how spiny lobster stocks will respond to future El Niño events, particularly to the extreme El Niño events, if fishing effort is not regulated.

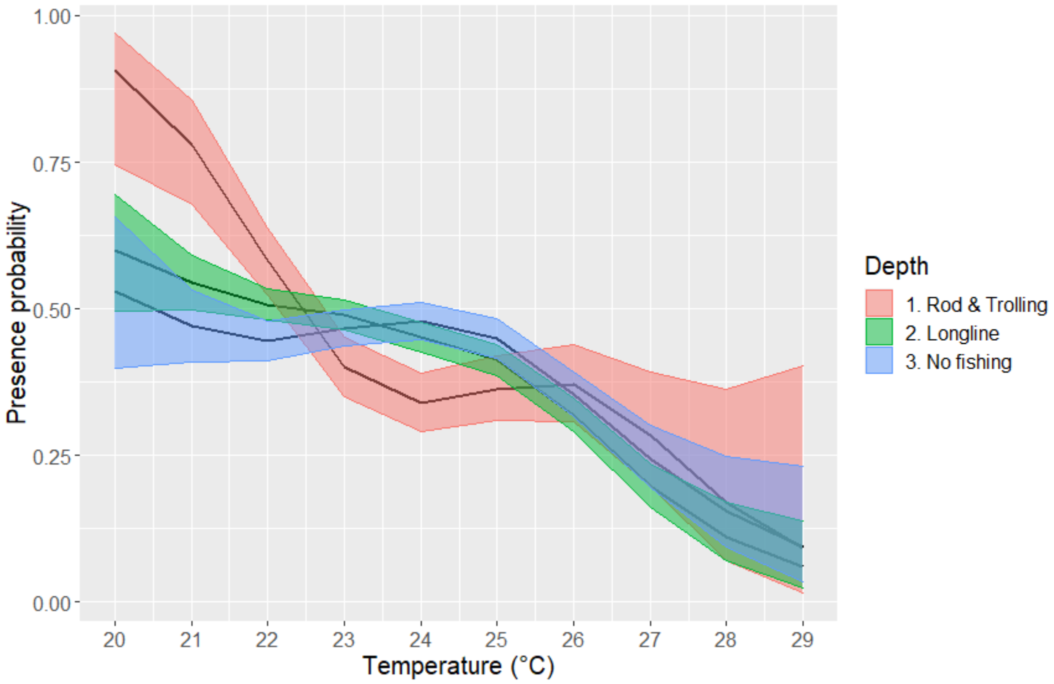
The spiny lobster fishery is a case study that demonstrates that the influence of climatic and human-induced factors over the dynamics of fishery resources and SSF is difficult to disentangle. Therefore, climatic and anthropogenic drivers must be taken into consideration to formulate management strategies that contribute to increasing the resilience and adaptive capacity of SSF to climate variability and change.

8.4.2.2 Effect of sea surface temperature on yellow-fin tuna bathymetric distribution

For the purpose of this feasibility report, the influence of sea surface temperature (SST) and other environmental variables on the presence of yellowfin tuna in the GMR, was analysed. Such an analysis was based on data from echosounders (Satlink ELB3010) attached to four fish aggregation devices (FADs) located across the archipelago. This analysis predicted a significant and negative relationship between the probability of presence of yellowfin tuna in the FADs and SST and depth. For more details about this analysis please refers to Appendix 2.2.

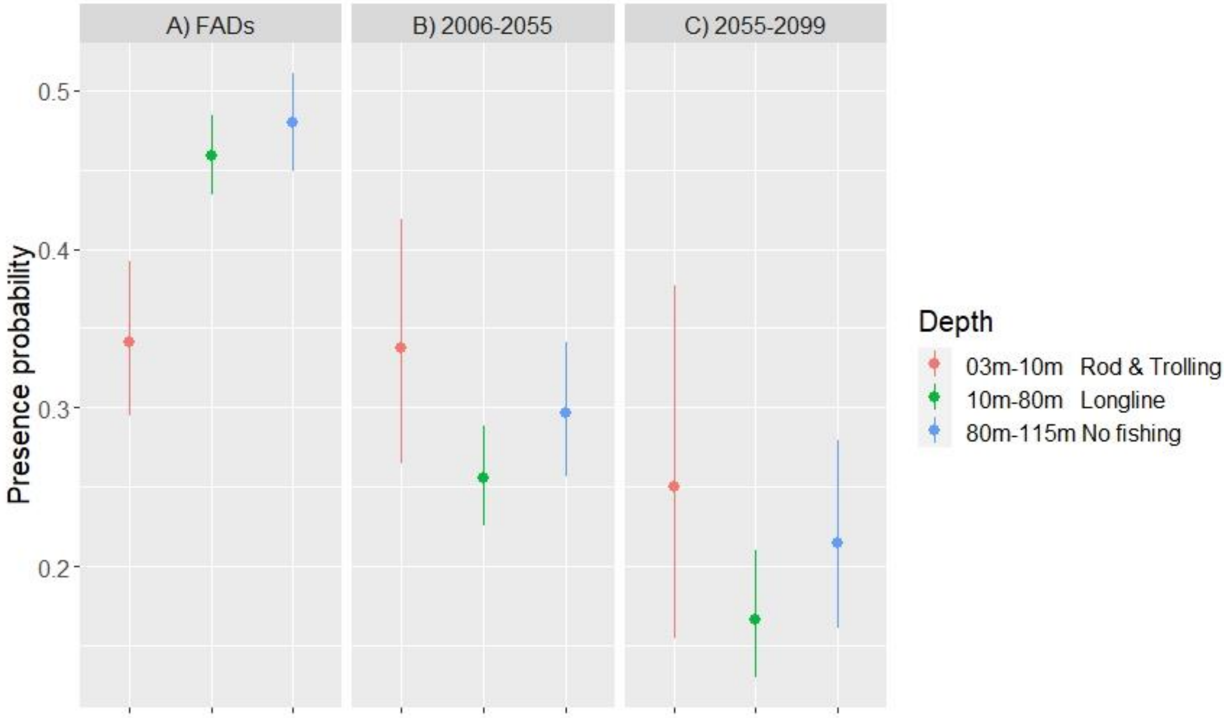
Figure 39 shows the interpretation of a Bernoulli (presence – absence) model of the echosounders data. The model indicates that the higher the SST, the lower the probability of yellowfin tuna presence in the rod and trolling depth (3m-10m), longlines (vertical and horizontal) depth (10m-80m) and depths where small-scale fishers usually does not fish (80m-115m).

Figure 39. Bernoulli model (with 95% confidence intervals) of the FADs data with relationships of the probability of yellowfin tuna presence and SST at different fishing depths.



This model was used to predict the probability of yellowfin tuna presence around seamounts (including shallow seamounts locally known as 'bajos') of the GMR for the periods 2006-2055 and 2055-2099 under RCP 4.5 climate change scenario. This was done by calculating the average SST around seamounts of the GMR for each period based on changes projected in the oceans by coupled climate models' CMIP5 experiments. The average SST values obtained for these future time-periods were used to predict the probability of yellowfin tuna presence on seamounts using the Bernoulli model mentioned above. The results indicate that the probability of yellowfin tuna presence in the seamounts of the GMR will decrease in both periods at all depths. This decrease is clearer in the longlines and no-fishing depths (Figure 40).

Figure 40. Probability (with 95% confidence intervals) of yellowfin tuna presence by depth in three scenarios: A) average SST of FADs (23.8ºC); B) average SST in seamounts (26.5ºC) in the period 2006-2055 under climate change scenario RCP 4.5; C) average SST in seamounts (27.3ºC) in the period 2055-2099 under climate change scenario RCP 4.5.



Combining these projections with those of Erauskin-Extramiana *et al.* (2019) and Senina *et al.* (2018), it is possible to envisage that with climate change, yellowfin tuna populations will move from west to east in the Pacific Ocean, but its probability of presence in the GMR will decrease along the water column, meaning that its populations will move down vertically.

It is important to mention that, currently, the only fishing gears permitted for catching yellowfin tuna in the GMR is the rod, trolling and the vertical longline with 3 to 5 hooks, the latter of which is not used by the fishers because of the great physical effort and fuel cost that it represents. Another important fact is that, according to Galapagos fishers' knowledge, the largest tuna that have the highest quality and price in the market are found at longlines (vertical and horizontal) fishing depths. This is one of the reasons why the fishers in Galapagos are constantly asking the authorities to allow the use of horizontal longlines, which is currently prohibited in the GMR.

This is important because with the predictions of our model, under climate change scenario 4.5, fishers are expected to be less likely to catch large, good quality, highly priced tuna. This translates into a decrease in the catchability and an increase in the number of hours spent searching for tuna and fishing hours per trip, decreasing the fishers' socio-economic well-being.

8.4.3 Socioeconomic implications

Despite the information described in the previous sections, no study has predicted yet how climate change will affect fishery resources and fishers, including the socio-economic significance of this impact. This is a simple question, whose answer requires not only a prediction of impacts of atmospheric warming on climatic, hydrological, oceanographic and ecological processes, through coupled physical-ecosystem models, but an understanding of the social and economic dynamics of fishing fleets and fishing communities, and their capacity to adapt to change (Allison et al. 2009). This integrated prediction approach is beyond the current frontiers of knowledge in Galapagos.

However, potential future climate change scenarios can be elaborated qualitatively, based on the scientific information available and with the assumption that future ocean conditions will shift toward an El Niño-like ocean state, meaning that sea surface temperature will increase, while primary productivity will decrease, possibly forever. In this context, the worst climate change scenario possible would be the collapse of all Galapagos fishery resources due to unfavorable ocean conditions caused by El Niño-like ocean state, while the best scenario would be the recovery of overfished fishery resources due to favorable conditions caused by this global climatic driver. Nevertheless, based on the scientific information available, the most probable scenario could be one on which different species will show variations in their availability and/or accessibility (or catchability) due to gradual or sudden changes in their abundance or distribution as ocean conditions shift towards El Niño-like ocean state. For example, the accessibility to spiny lobsters and yellowfin tuna stocks could decrease in an El Niño-like ocean state, probably due to changes in their distribution, which will make them inaccessible to Galapagos small-scale fishers. However, the availability of predatory finfish species, such as sailfin groupers, could also be reduced due to higher natural mortality rates caused by bottom-up effects on marine ecosystems, as suggested by Wolff et al (2012) and Eddie et al. (2019). In both cases, fishers' livelihoods and food security of coastal communities probably will be negatively affected, as fishery resources probably will be unavailable and/or inaccessible due to unfavorable ocean conditions caused by climate change.

Therefore, to determine the potential socio-economic impact of climate change on Galapagos small-scale fishing sector and coastal communities, five aspects were evaluated during the elaboration of this feasibility assessment:

9. The multiplicative effect of seafood trading along the value chain,
10. The influence of climate change on food security of Galapagos human population
11. The economic dependence of fishing.
12. The implications of climate change on the recovery of overfished fisheries.
13. The adaptive capacity of local fishing communities to cope with and adapt to climate change.

The potential socioeconomic impacts of climate change on Galapagos small-scale fishing sector and coastal communities is discussed in the following subsections, considering the five aspects mentioned above. This analysis was built on a climate change scenario in which the availability and accessibility of spiny lobsters, yellowfin tuna and sailfin groupers stocks decrease due to permanent changes on their abundance and distribution caused by El Niño-like ocean state, which it is expected to exacerbate the effect of fishing on fishery resources and marine ecosystems. In this scenario, it is assumed that the sea cucumber fishery did not recover due to persistent illegal fishing and the negative impact of climate change, remaining closed to fishing in the coming decades. Besides, as sea cucumbers are not traditionally consumed in Galapagos, as in the rest of Ecuador and Latino America, no impact is expected on the food security of Galapagos coastal communities. Therefore, sea cucumbers are not considered relevant in the climate change scenario described and analyzed below. However, an ecosystem-based adaptation measure for the recovery of sea cucumbers stocks is proposed as part of an ecosystem-based fisheries management strategy to restore the contribution of this species to climate change impact and to help to diversify fisher's livelihoods (see Section 12.5 on this document and refer to Appendix 2.2 for details).

8.4.3.1 The multiplicative effect of seafood trading along the value chain

As fisheries represent a small percentage of the Galápagos gross domestic product (< 4 %), it is expected that negative or positive climate change impacts on fisheries will have limited implications for Galapagos' economy (Bertrand et al. 2020). However, this hypothesis does not consider the multiplicative effect of seafood trading along the value chain.

The total gross revenue is the main economic indicator used to estimate the contribution of small-scale fisheries to the Galapagos gross domestic product (GDP). This indicator is estimated multiplying the annual total catch by the annual average ex-vessel price, i.e., the price that fishers receive for their catch, or the price at which fish are sold when they first enter the seafood supply chain. However, the GDP did not take into consideration that Galapagos fishers only capture a small proportion of the total value created along the value chain, both in the domestic and export markets. For example, according to Berman et al. (2018), Galapagos small-scale fishers only capture 27% of the total value created by the tuna fishery in the domestic market, while 61% and 12% is captured by restaurants and intermediaries, respectively. In the export market, the situation is worse. Fishers captured only 21% of the value created, while intermediaries, restaurants, and exporters capture 15%, 26%, and 38%, respectively. The spiny lobster fishery provides another example. Fishers capture 18% of the net earnings generated by the value chain, while 82% is capture by intermediaries (Castrejón 2012). These estimates highlight that a high proportion of the contribution to the tourism sector to Galapagos' GDP depends indirectly on small-scale fisheries.

Based on the two examples above, the negative or positive impacts of climate change will probably have strong implications on Galapagos economy, as it will affect all economic agents involved in small-scale fisheries' value chains, including fishers, intermediaries, restaurants, exporters and final consumers.

8.4.3.2 Influence of climate change on food security of Galapagos human population

Because of its importance in Galapagos households, the decrease in catchability of yellowfin tuna could have a severe impact on the food security. For example, tuna has been the main species consumed by local communities, before and during the lockdown established by the Ecuadorian government to avoid the spread of COVID-19 in the archipelago (M. Castrejón – unpublished data). After yellowfin tuna, shrimps, octopus, mottled scorpionfish, wahoo, and sailfin grouper are the most important species consumed by Galapagos coastal communities, thus, the collapse of any fishery targeting these species will also geopardize food security in Galapagos.

8.4.3.3. Economic dependence of fishers on Galapagos fishery resources

The socioeconomic impact of climate change on the small-scale fishing sector will depend on the level of economic dependence of fishers on Galapagos fishery resources. The greater a fisher's dependence on fishery resources, the greater the economic impact of climate change on their livelihoods. Castrejón (2011) evaluated the level of economic dependence of fishers on the spiny lobster and the finfish ("pesca blanca") fishery. According to this study, more than 64% of Galapagos fishers are highly dependent on the spiny lobster and finfish fisheries to sustain their livelihoods. Highly dependent means that between 70 and 100% of fishers' monthly income comes from these two fisheries. Therefore, the greater the number of commercial species negatively affected by climate change, the greater the economic impact on the Galápagos fishing sector.

Based on this information, the collapse of the spiny lobster fishery is expected to have a significant impact on fishers' livelihoods, particularly during lobster fishing seasons (August/December). Similar impacts could be expected if the finfish fishery collapsed. However, it is unlikely that the finfish fishery entirely collapses because it targets a high diversity of pelagic and demersal fish species. If the abundance and catchability of one or two demersal finfish species decrease or collapse, then probably fishing effort will shift to other demersal or pelagic species. Such changes in fishing patterns probably could mitigate the impact of climate change on fisher's livelihoods, but fishing pressure will increase over finfish species whose exploitation status is, in most cases, unknown.

8.4.3.4 Implications of fisheries collapse due to climate change on the recovery of overfished fisheries.

The collapse of certain commercial species due to climate change could lead to the redistribution of fishing effort towards other species, increasing their risk of overexploitation. For example, the reduction in the catchability of yellowfin tuna across the archipelago could result in changes of fishing patterns, in order to continue satisfying seafood consumption in the domestic market. As a result, fishing effort will likely switch to mottled scorpionfish, wahoo, and sailfin grouper leading to their renewed overexploitation and thereby compromising their population recovery. It is therefore our opinion that the sustainable management of the yellowfin tuna is fundamental to promote the recovery of all coastal overexploited fisheries and diversify fishers' livelihoods.

Before the creation of the GMR, the large-scale fishing fleet caught 29 710 t of tuna, equivalent to 24.3% of total tuna landings at the national level (Bustamante, 1999). Nowadays, the small-scale fishing fleet catch less than 300 t of tuna annually (Castrejon and Moreno, 2018). Therefore, the impact of the local fishing fleet over yellowfin tuna stock is minimal, eliminating the risk of overexploitation. The annual demand for fish, including the tuna and whitefish fishery before the COVID-19 pandemic was approximately 871.3 t, of which 31% was consumed by the local community, while the remaining 69% was consumed by tourists (Berman et al. 2018). Therefore, even if the Galapagos finfish fishery collapsed and fishing effort turn entirely to the tuna fishery, the risk of overexploitation of yellowfin tuna stocks by the local fishing fleet will continue to be minimal for this species.

9. Mitigation opportunities

The major opportunities to reduce GHG emissions in Galapagos are related to sustainable land use and to the adoption of renewable energy generation and energy efficiency technologies.

9.1 Agriculture, Forestry and Other Land Uses (AFOLU)

Agriculture, Forestry and Other Land Uses (AFOLU) contribute around 23% of total net global anthropogenic emissions of GHGs, primarily through deforestation, livestock emissions and soil and nutrient management. These activities accounted for around 13% of CO_2, 44% of methane (CH_4), and 82% of nitrous oxide (N_2O) emissions during 2007-2016. When emissions associated with pre- and post-production in the global food system are included, the food system accounts for up to 37% of total net emissions (IPCC, 2019).

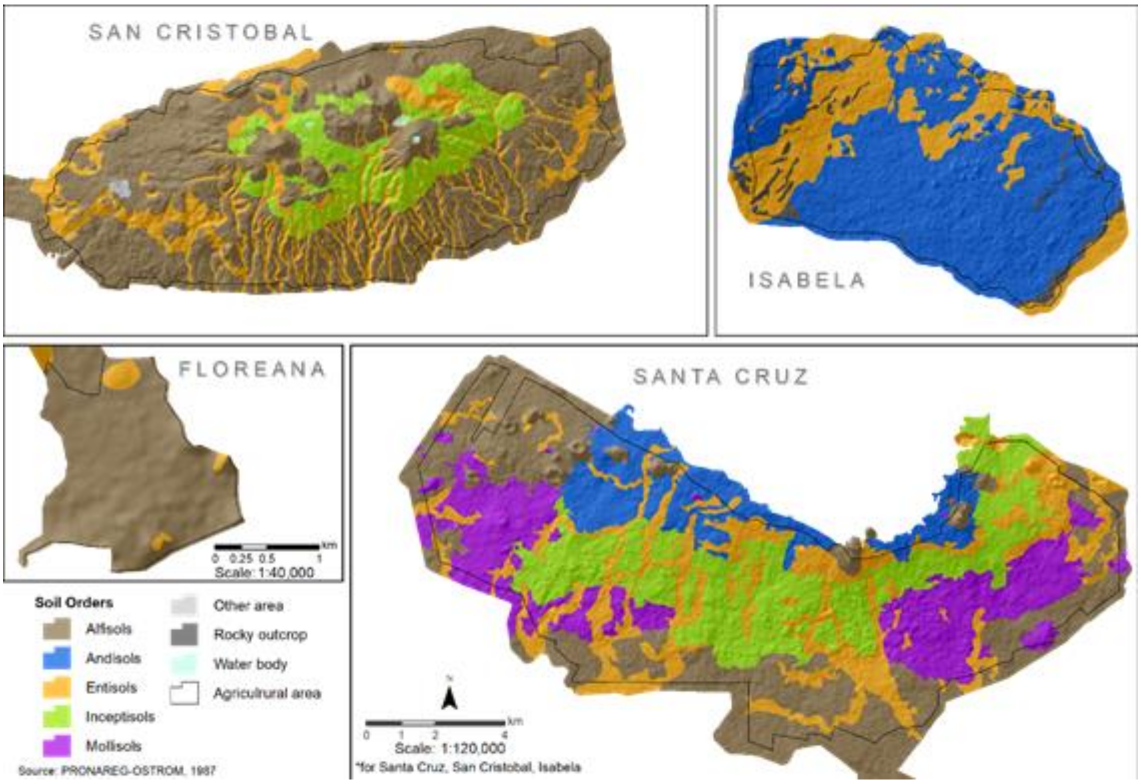
The agriculture sector can significantly contribute to the GHG emissions reductions. 44% of the Galapagos farms keep a conventional production system that includes monocultures, intense tillage, the use of synthetic fertilizers and chemical pesticides imported from mainland Ecuador, among others. All these activities increase the GHGs emissions from the agricultural sector in Galapagos. The resilient farm model includes restoration/improvement of ecosystem services through invasive species control and native/endemic planted forest interventions, adoption of improved cropland management, improvement of silvopasture systems, adoption of agroforestry and incorporating new technologies to waste management and reduction of emissions derivative of agriculture.

Ecuador does not have baselines or GHG inventories at the provincial level, therefore it is not possible to have a baseline for this sector in Galápagos. However, the proposed resilient practices will also have mitigation benefits that have been calculated with the FAO Ex -ACT and Ex -ACT methodology and system. The EX-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by the Food and Agriculture Organization of the United Nations (FAO) providing ex-ante estimates of the impact of agriculture, forestry and fishery development projects, programmes and policies on the carbon-balance. Detail information will be found in Appendix 2.1 Agriculture - Carbon Balance).

EX-ACT is a land-based accounting system, measuring C stocks, stock changes per unit of land, and CH_4 and N_2O emissions expressed in t CO_2-e per hectare and year. The main output of the tool is an estimation of the C-balance that is associated with adoption of alternative land management options, as compared to a 'business as usual' scenario. The tool helps project designers to estimate and prioritize project activities with high benefits in economic and climate change mitigation terms. This is why it is widely used by World Bank investment projects and has already been used in the preparation of GHG analysis for various green climate fund projects. EX-ACT has been developed using primarily the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), complemented by other existing methodologies and literature reviews of default coefficients associated with agricultural/forestry production systems, farm operations and inputs acceptable to the scientific community.

The agricultural regions are within the humid highland of the Galapagos, and in comparison, to the lowland, they receive nearly three times as much rain. Although its volcanic origin, the severe seasonal temperature and precipitation fluctuations of highland areas have gradually weathered the islands' volcanic rocks, creating a patchwork of nutrient-rich soils of variable depths and textures where can grow both tropical-weather crops and temperate-weather crops (Tabodad et al., 2015; Chririboga et al., 2006). Based on studies conducted by PRONAREG-ORSTOM-INGALA (1987), in the older islands (Santa Cruz, San Cristobal and Floreana), where weathering and soil formation is more advanced, the highland area is dominated by soils of the order Alfisols, Inceptisols and Mollisols, being categorized by the IPCC as soils with High Activity Clay (HAC) minerals. On the other hand, the highland area on Isabela is dominated by soils of the order Andisols (Figure 41). These types of soils are categorized by the IPCC as Volcanic soils, showing a lower degree of weathering as compared with HAC soils.

Figure 41. Soil distribution in the Agricultural area of Galapagos Islands



Business-as-Usual Scenario (Without project)

Extensive areas of agricultural land in Galapagos have been abandoned in the last decades, making this fragile and iconic agroecosystem vulnerable to the expansion of invasive plants (McCleary et al., 2013; Laso et al., 2019). Currently, the agricultural area of Galapagos records a higher number of invasive plants, which cover 28.5% of its surface (Guézou et al., 2010; Laso et al., 2020). These plants not only threaten agricultural systems but also the remaining patches of native ecosystems that still exist in the non-protected area. On the other hand, the uncontrolled spread of invasive plants in the agriculture zone is a latent threat to the local native/endemic biota located in the adjacent protected humid highlands.

The species considered highly invasive in Galapagos is the guava (Psidium-guava), which is often used in silvo pastures (wooded pastures). In 1987, 1310 ha of guava forest were recorder in the agricultural area of San Cristobal (Villa and Segarra, 2010), while in 2019 the area covered by this invasive species was 1952 ha (Laso et al., 2020), corresponding to a natural increase of 49% of guava in the last 30 years.

If business-as-usual continues in the farmers activities, guava forest would be expected to increase by 32% (~1500 ha) in the next 20 years, considering that it currently occupies 4,958 ha of the agricultural land in Galapagos. In addition, 44% of the farm still keep conventional production systems that include monocultures, intense tillage, the use of synthetic fertilizers and chemical pesticides imported from Ecuador continental, among others. All these activities increase GHG emissions from the agricultural sector in Galapagos.

Proposed Agriculture Practices (With project)

The resilient farm model proposed in this component includes four climate-resilient agricultural practices described in Output 2.2.1. These practices promote food security on the Islands, reducing dependency on imported agricultural inputs, food and fossil fuels from continental Ecuador. Improving field productivity, adapting production patterns to be climate change resilient and adding value to local agriculture activity. Details of the proposed practices are in the next chapter or in the appendix, but in summary are: 1. Community-based Seed Bank, Integrated climate resilient Crop Management System, Silvopastoral System, and 4. Implement a water management system.

Timeframe

The EX-ACT tool differentiates between two times periods; one for the implementation phase, where the climate-resilient practices are carried out, and another for the capitalization phase, where the benefits of the program are still occurring due to the changes induced by the adoption of the practices.

Given the typology of the practices proposed under this program, the analysis considers a 20-year period, which is in line with IPCC recommendations for considering the timeframe between transition states of natural systems and the period necessary to reach a new equilibrium for carbon stocks. Therefore, the program consists of five (5) years for the implementation phase and the sequestration will continue to capitalize for 15 more years to reach the 20-year period. In addition, the analysis assumes a linear dynamic of chance (from “without project (BAU)” to “with project) over the duration of the program.

Areas considered for this analysis.

This analysis considers that each practice will be adopted in at least 54% of the productive farms in Galapagos, considering the agro-production activity and farm size. The water management system will be implemented to cover at least 500 new hectares of agricultural land with improved water management practices. This project proposes to cover at least 41 ha. of fodder areas (2500 m2 per farm) with sprinkler irrigation, supplying irrigation facilities to at least 164 farms. Additionally, 459 ha. of the agricultural farms that will include an adequate integrated crop management (404 farms), will be covered with drip irrigation according to their identified needs. Based on 2014 Census data analysis, in Galapagos there are 375 farms that are used by crop production, 185 farms that are concentrated in livestock production and 64 farms that have adopted both types of production (crop+livestock).

Restoring native ecosystems in the agricultural landscapes will be focused in a passive restoration in farms that still conserve native forest fragments and with potential hydrological importance. These areas are usually located into inactive farms and farms categorized as “Other”. Furthermore, agroforestry practices proposed in the program, will also allow the agroecosystems restoration incorporating native/endemic species in the agricultural landscape.

Considering the potential implementation farms and using the area covered by different land uses in each multidimensional category, the intervention area by practice is: Community based seed bank: 4508 ha, integrated crop management: 3146 ha, silvopastoral systems: 5497 ha and water management: 500 ha. Total area: 8643 ha These values were key to model the net carbon balance in the upgrade process of each farm category. The modules, emission factor and, characterization of the analysis in the Ex-Act tool detailed data are in appendix 3.

The carbon balance from program implementation is estimated to be about -1 million of tCO2-eq of avoided emissions and increased carbon sequestration over 20 years analysis in 8,643 ha. This translates into -131 tCO2-eq per hectare over 20 years or -6.5 tCO2-eq per hectare per year. The principal contributions for this balance are the CO2 sequestration from Biomass (-632,514 tCO2-eq) and Soil (-344,815 tCO2-eq) through the resilient-practices implementation proposed in this program. Improvements in feeding practices and the implementation of biodigesters help generate an absorption from enteric methane (-11,895 tCO2-eq).

Results

The carbon balance from program implementation is estimated to be about -1 million of tCO2-eq of avoided emissions and increased carbon sequestration over 20 years analysis in 8,643 ha (Table 22). This translates into -131 tCO2-eq per hectare over 20 years or -6.5 tCO2-eq per hectare per year. The principal contributions for this balance are the CO2 sequestration from Biomass (-632,514 tCO2-eq) and Soil (-344,815 tCO2-eq) through the resilient-practices implementation proposed in this program. Improvements in feeding practices and the implementation of biodigesters help generate an absorption from enteric methane (-11,895 tCO2-eq).

Table 22.. Summary of net carbon-balance for program implementation

<table>
<tr><td colspan="2">RESILIENT FARMS</td><td colspan="2">tCO2-eq per year</td><td>tCO2-eq in 5 years (project implementation)</td><td>tCO2-eq in 20 years (ecosystem equilibrium reached)</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">-50,372</td><td>-251,860</td><td>-1,007,440</td></tr>
<tr><td colspan="6">Greenhouse gases contribution (tCO2-eq)</td></tr>
<tr><td></td><td colspan="3">CO2</td><td rowspan="2">N2O</td><td rowspan="2">CH4</td></tr>
<tr><td></td><td>Biomass</td><td>Soil</td><td>Inputs</td></tr>
<tr><td>Total</td><td>-632,514</td><td>-344,815</td><td>-8,254</td><td>-2,962</td><td>-11,895</td></tr>
<tr><td>Per ha per year</td><td>-4.2</td><td>-2.2</td><td>-0.1</td><td>0</td><td>-0.1</td></tr>
</table>

These results indicate that the Galapagos food system component can have an important contribution in mitigation which complements the adaptation and resilience objectives sought by the program. It will be important to closely monitor the assumptions made during program implementation to truly assess the impact of the program on the ground (Appendix 2.1 Agriculture - Carbon Balance).

9.2 Energy

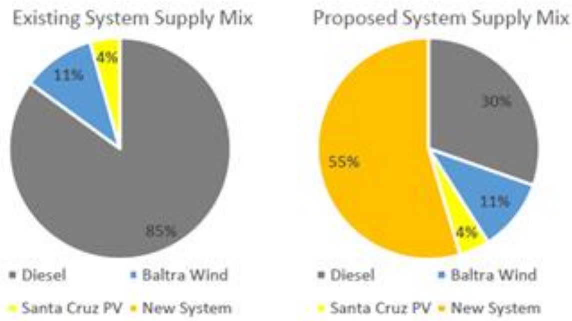
The energy investments of the Programme will lead to an estimated reduction of 23,443.18 tCO_2e per annum. The emissions reductions during the 5 years of implementation of the Programme will be about 111,104.19 tCO_2e (considering that the Galapagos' Credit Line will start providing credits in year 2). Over the 20-year lifespan of the technology, emissions reductions will reach 468,863.57 tCO_2e.

Table 23. Estimated annual GHG emissions reductions from energy investments.

	Annual power generation / energy saved (GWh)	Annual diesel displaced ('000 liters)	Annual GHG reductions from RE generation / avoided from EE investments (tCO_2e)	Annual GHG avoided from diesel transportation (tCO_2e)	Annual GHG reductions from Component 1 activities (tCO_2e)
Centralized ER	22.94	6,339.82	18,975.35	26.91	**19,002.26**
Distributed ER	4.50	1,071.83	3,116.69	4.55	**3,121.24**
Energy Efficiency	1.69	466.46	1,351.14	1.98	**1,353.12**
Total	**29.13**	**7,878.11**	**23,443.18**	**33.43**	**23,476.61**

2. The expected increase in the renewable generation share of the Santa Cruz island due to the centralized PV project will have a great impact. The figure below shows the forecasted monthly share.

Figure 42. Santa Cruz energy mix with PV Conolophus project



Source: MERNNR, 2020

10. Analysis of alternatives

The intervention options have been prioritized through a multi-criteria analysis methodology that considers potential impact, feasibility level, potential paradigm shift. This assessment is summarized below for each of the sectors, and further described in the corresponding appendixes.

10.1 Energy

The evaluation of projects to be prioritized within the financing proposal is carried out using the methodology shown in the multi-criteria evaluation methodological manual for programs and projects. 8

After identifying the projects that contribute to the objective of the Program (Table 24), they are evaluated according to the following criteria:

Potential Impact: To first assess the potential impact of the identified projects, a quantitative evaluation according to the power to be installed.

Feasibility Level: The level of feasibility available studies for each project is considered. The technical, legal, and environmental feasibility available in public and private institutions that developed project studies are analyzed.

Potential paradigm shift: The transformative capacity in the energy performance of the islands is analyzed, taking as a key point the involvement of society as key actors in the transformation and contributes to the environmental sustainability of the islands.

The matrix of projects to be evaluated is the result of the analysis of the available studies and government plans regarding the change of the electrical energy matrix in the Galapagos Islands, shown above.

Table 24. Projects to be prioritized.

Nro.	Projects	Detail/ Phases
1	**San Cristobal (PEGSAG)**	• *Second Phase San Cristobal Wind Farm* • *Energy Storage System* • *PV Plant San Cristobal Project*
2	**Santa Cruz Baltra (PEGSAG)**	• *Second Phase Baltra Wind Farm* • *PV Plant Santa Cruz* • *Energy Storage System Santa Cruz* • *Third Phase of Baltra Wind Farm, PV Plant Santa Cruz Projects, and Second Phase ESS Santa Cruz Project*
3	**Isabela (PEGSAG)**	• *PV Plant Expansion of Hybrid Isabela Project* • *BESS Expansion of Hybrid Isabela Project* • *Second Phase of PV Plant Expansion of Hybrid Isabela Project* • *Second Phase of BESS Expansion of Hybrid Isabela Project* • *Third Phase of PV Plant and BESS Expansion of Hybrid Isabela Project*
4	**Floreana (PEGSAG)**	• *PV Plant Foreana Project* • *BESS Floreana* • *Second Phase PV Plant Foreana*

8 Multi-criteria evaluation methodological manual for programs and projects. CEPAL (2008)

5	***Centralized renewable energy generation (Conolophus)***	• *Baltra PV Project* • *BESS Baltra* • *Hybrid control* • *Transmission line*
6	***Smart Grid implementation in distribution system***	• *Santa Cruz Smart Grid project*
7	***Renewable distributed power generation projects in the tourism/commercial sector***	• *PV distributed micro power generation Santa Cruz.* • *PV distributed micro power generation San Cristóbal.* • *PV distributed micro power generation Isabela.* • *PV distributed micro power generation Floreana.*
8	***Energy Efficiency (replacement of equipment)***	• *Replacement of refrigerators and air conditioners*
9	***Sustainability standards applied to construction.***	• *Efficient construction standards*

Source: Mentefactura, 2021

The objective to fulfil within the prioritization of projects will be: Maximize the contribution to the change of the energy matrix in the Galapagos Islands, by incorporating renewable sources and optimizing the use of energy.

The objective is to establish a maximization of emission reduction in the generation of electrical energy necessary to supply the demand. the reduction potential is evaluated by the power evaluated as feasible.

Prioritization results

After applying the criteria shown in this section, on each of the options considered, the following prioritization was obtained, which will be developed in the proposal below:

Table 25. Results of energy projects prioritization

Nro.	Project	General Results
1	Centralized renewable energy generation (Conolophus)	High potential impact. Availability of feasibility studies. High potential paradigm shift.
2	Renewable distributed power generation projects in the tourism/commercial sector	Medium potential impact. Availability of technical pre-feasibility and legal feasibility studies. High potential paradigm shift.
3	Energy Efficiency (replacement of equipment)	Medium potential impact. Availability of government plans. High potential paradigm shift
4	Centralized renewable energy generation Santa Cruz Balta (PEGSAG)	High potential impact. No feasibility studies are available. High potential paradigm shift.
5	Centralized renewable energy generation San Cristobal (PEGSAG)	Medium potential impact. No feasibility studies are available. High potential paradigm shift.
6	Centralized renewable energy generation Isabela (PEGSAG)	Small potential impact. No feasibility studies are available. High potential paradigm shift.

7	Centralized renewable energy generation Floreana (PEGSAG)	Small potential impact. Low availability of feasibility studies High potential paradigm shift.
8	Smart Grid implementation in distribution system	Low potential impact No feasibility studies are available. Medium potential paradigm shift
9	Sustainability standards applied to construction.	Low potential impact No feasibility studies are available. Medium potential paradigm shift

Source: Mentefactura, 2021

From the results obtained, the three best rated projects are prioritized for development, as they have the characteristics that guarantee the fulfilment of the objectives. The projects that are not prioritized have high potential to contribute to the energy transition of the islands, after the feasibility studies are available that will guarantee their execution.

The prioritized projects are developed in the section "12. Programme description", where the available information, the contribution in reducing emissions and technical characteristics is specified as part of the studies developed.

10.2 Ecosystems

To design the most pertinent and cost-effective EBAs to promote the adaptation of Galapagos ecosystems, the following activities were performed:

1. Selection of priority areas for the implementation of EBAs in the Galápagos, already explained in section 7 of this document
2. Cross-validation and consultation with technical staff and directors of the GNP.
3. Selection and design of EBAs with Galapagos scientists.

We cross-validated our results with the assistance of technical staff and directors of the GNP during a two-day workshop held in Santa Cruz, Galapagos in February 2020. In this workshop, we used the results of our impact assessment models as inputs and chose 13 HEVA with terrestrial and marine ecosystems (Table 4, Fig. 17). Overall, the HEVA hosts endemic, vulnerable and critically endangered species or ecosystems with limited distribution; comprise spawning zones, shark nurseries and nesting sites for sea turtles and birds, harbor resilient coral reefs and communities, and are characterized by a high influx of tourists. Some HEVA report high diversity and biomass of marine species from different trophic guilds, are feeding grounds of multiple marine and terrestrial species, and could be considered as potential climate change refugia. Moreover, some terrestrial ecosystems within the HEVA are buffering areas around the agricultural zone, registering an increasing incidence of invasive species, but also include the last remnants of the *Scalesia* forest in the humid highlands. Finally, these areas are of prime importance for local livelihoods, especially for small-scale fisheries, but some of them are highly exposed to over-fishing (For details of selected HEVA see Appendix 5.2, Table S8). Each HEVA is characterized by the following criteria: (1) expected climatic variability given by the spatial distribution of terrestrial future climate models, (2) representativeness, measured as HEVA distribution among bioregions; (3) habitat connectivity across the elevation gradient (i.e., number of terrestrial macro habitats occurring on each HEVA), (4) marine habitat diversity (number of marine macro habitats), and (5) HEVA relevance for environmental services provision (e.g., tourism, fishery, freshwater provision). The HEVA selected comprise 22.7% (14,715 km^2) of the Galapagos archipelago, distributed in 2.77% (3,835 km^2) of the GMR and 19.9 % (1,592 km^2) of the GNP.

Based on the above-listed criteria, the HEVA were ranked for prioritizing the implementation of EBAs to confront climate change. Four HEVA had the highest priorities: (1) Corridor Sierra Negra Volcano Isabela South, (2) Conservation area Santiago-Santa Cruz, (3) Corridor Wolf Volcano, Punta Albermarle and Cape Marshall, and (4) The Bolivar Channel and Elizabeth South (Fig. 17). These four areas comprise more than half of the marine priority HEVA and one-third of the terrestrial priority HEVA. Overall, the selected priority HEVA constitute relevant areas for the distribution and life cycle of critically endangered and endemic species and relict ecosystems (e.g. *Scalesia* forest), which are interconnected by marine and terrestrial corridors. Further, the prioritized areas are fundamental to sustain water, agriculture and fisheries provision for local inhabitants and the nature-based tourism industry.

Lastly, the selection and design of EBAs with Galapagos scientists entailed a discussion of the most relevant EBA measures according to the selected priority areas, the technical complexity to implement those actions (simpler EBA measures were rated with higher scores), The analysis was based on the cost and its relationship with ongoing local efforts. As a result, the following EBAS were proposed (Table 26). Later on, on a second interaction each leading scientist for the marine and terrestrial ecosystem designed in detail each of the selected EBAS (see appendix 2.3 and 2.4).

Table 26. Evaluation and prioritization of EBAs for the Galapagos ecosystems

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Improvement livelihoods economy	Tangible results in a 5 - year period	Implementation of related actions in place	Total Score
Marine ecosystems							
1	Update the zoning of the GMR with climate change considerations that allows: (a) Create migration corridors free of fishing between different habitats.	2	2	2	2	2	10
2	Include within the maximum protection areas, species' nurseries, sensitive to environmental stressors.	2	1	1	1	1	6
3	Fill information gaps on abundances, life cycles, temporal and spatial distribution patterns of species of high ecological value that constitute tourist attractions (e.g. sharks, turtles, corals).	2	2	2	2	1	9

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Improvement livelihoods economy	Tangible results in a 5 - year period	Implementation of related actions in place	Total Score
4	Design / update management plans for focal species of high ecological value that constitute tourist attractions (e.g. sea turtles, sea lions, marine iguanas, hammerhead sharks, cod etc.)	1	2	1	2	2	8
5	Mark priority coral reefs and shallows to limit fishing and tourism activities.	2	2	1	2	2	9
6	Strengthen the GMR control mechanisms focused on conservation (eg, control the condition of the boats' engines to reduce pollution), within the framework of the current management plan.	2	2	1	2	1	8
7	Change the fossil fuel-based energy system of boats to renewable energy (e.g., solar energy).	2	1	1	2	2	8
8	Wastewater treatment and its discharge into mangroves located in areas of public use.	2	1	1	1	1	6
9	Change of technologies for diving practices in sensitive sites (e.g., use of low impact anchorage, geolocation systems).	2	2	2	2	2	10
10	Responsible diving practices with no impact on the marine ecosystem.	2	2	2	2	1	9

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Improvement livelihoods economy	Tangible results in a 5 - year period	Implementation of related actions in place	Total Score
11	Technological improvements for the control of priority invasive species in climate change scenarios (e.g., Philorni downsii fly, and black rat, Rattus rattus) in mangrove areas.	1	2	1	1	1	6
12	Implement experimental coral restoration measures: (a) planting corals, (b) removal of species that limit regeneration and accelerate degradation (e.g erizo de Galápagos, Eucidaris galapagensis, y el alga pétalo, Chaulerpa chetnitzia).	2	2	2	2	1	9
13	Fill knowledge gaps on the adaptive capacity of different mangrove and coral species in climate change scenarios, including the carbon cycle.	2	2	1	2	1	8
				Terrestrial ecosystems			
14	Technological improvements for the control of priority invasive species in climate change scenarios (e.g. Philorni downsii fly, and black rat, Rattus rattus) in mangrove areas.	1	2	1	1	1	6
15	Implement native revegetation actions and sustainable land management actions (MST: agroforestry, silvopastoral systems) that restore or increase connectivity and water supply in agricultural or public use areas.	2	2	2	2	2	10
16	Modeling land cover and land use changes in climate change scenarios with particular emphasis on high priority invasive species and the provision of water resources.	2	2	1	2	2	9

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Improvement livelihoods economy	Tangible results in a 5 - year period	Implementation of related actions in place	Total Score
17	Transplants / translocation of native species (e.g. Scalesia, (Z. fagara and C. scouleri) to different islands that promote ecological restoration and succession.	1	1	1	2	1	6
18	Strengthen programs for the reintroduction and restoration of native herbivores (e.g. giant tortoises), to manage the landscape of the islands..	1	1	1	1	1	5
19	Development of a management plan for pathogens that includes: (a) experimental studies that allow modeling the response of pathogens to controlled conditions, as well as identifying more effective population reduction mechanisms. The management plan should also include a long-term monitoring component with a focus on: (1) epidemiology of pathogens and animal diseases under climate change scenarios; (2) monitoring the change in the distribution range of vectors under future climate scenarios.	1	2	1	1	1	6
20	Build and implement an agenda of research priorities focused on filling knowledge and information gaps that support the design of adaptation strategies and measures.	2	2	1	1	2	8

10.3 Agriculture

The main objective of this component is to strengthen the islands' food system, resulting in increased availability of local food to supply for visitor and resident populations, while simultaneously addressing the provision of fundamental ecosystem services, such as water as well as healthy ecosystems and emblematic species to sustain nature-based activities. In order to achieve these proposed objectives and indicators while accounting for the uncertainties and limitations (described in the previous sections), the proposed measures/practices are robust and no regret.

The proposed adaptation measures for component 2 are framed within the "Ecosystem Based Adaptation (EbA)" approach. The goal of EbA is to protect, maintain, and restore ecosystem functioning in order to achieve long-term sustainability of marine and terrestrial ecosystems and the human communities that depend on them (Guerry 2005, McLeod et al. 2005, Rosenberg and McLeod 2005). As such, EBA focuses on the benefits humans derive from biodiversity and ecosystem services, and how these benefits can be utilized in the face of climate change. Consequently, EBA is a people-centric concept, but one that acknowledges that human resilience depends critically on the integrity of ecosystems. Yet ecosystem health alone does not guarantee human resilience, so EBA is best implemented as an integrated element of a broader adaptation strategy. EBA approaches are accessible to the rural poor in developing countries and can be cost-effective. Examples of EBA measures include, for example, marine habitat restoration, agroforestry, livelihood diversification, and sustainable forest management interventions that use nature to reduce vulnerability to climate change.

Within the framework of this approach, the selection of the EbA measures proposed in the program for component two were based on specific variables and criteria for each sector, as explained below:

The main objective of component 2 of this programme is to strengthen the islands' food system, resulting in increased availability of local food to supply for visitor and resident populations, while simultaneously addressing the provision of fundamental ecosystem services, such as water as well as healthy ecosystems and emblematic species to sustain nature-based activities. In order to achieve these proposed objectives and indicators while accounting for the uncertainties and limitations (described in the previous sections), the proposed measures/practices are robust and no regret.

There are a variety of adaptation options that allow for increasing the productivity of the agricultural system, improving its resilience to climate stress, and reducing greenhouse gas emissions under a concept of sustainability (CGIAR, 2013; Khatri-Chhetri, et al., 2017). These options have been defined as climate-resilient practices (FAO, 2010), which integrate traditional and innovative practices that are relevant for a specific location to adapt to climate change (CIAT, 2014; FAO, 2013). These practices are mainly focused on the sectors of agricultural production: crop production, livestock production and forestry; and in a climate-resilient use of natural resources: water; soil and genetic resources; in addition to considering energy management and value chains of the food system (FAO, 2018). Examples of these practices include the use of diverse varieties and species of seeds tolerant to climate stress, in addition to hybrid seeds, efficient irrigation programs with low energy consumption, sustainable cattle raising (i.e., silvopastoral practices); tree integration in the agricultural system; restoration of degraded lands; improvement of fertilizer use and soil quality, energy solutions for agro-processing; organic waste management, including the use of anaerobic biodigesters (World Bank, 2016; Lipper et al., 2014); among others.

The main steps were considered in designing and prioritizing the climate change mitigation and adaptation measures are detailed below:

- Assessment of the food systems and consultation process with key stakeholders
- Selection of climate resilient agricultural and livestock practices based on decision scaling approach for the resiliency of agro-ecosystems.

Consultation Process

To carry out all this study and analysis of the last 2 chapters, information about the current state of the food system was obtained through consultations with farmers and key institutions of Galapagos. A household survey was conducted, during February of 2020 on 344 households, randomly selected from the 744 Unites of Agricultural Production (Farms), distributed on the three major inhabited islands: San Cristobal, Santa Cruz, and Isabela. A long-form questionnaire was previously designed, which include questions about demographic characteristics, socio-economic conditions, social organization, gender, agricultural practices and outcomes, crop and livestock management, irrigation, and climate change. 119 farm households were surveyed in San Cristobal, 168 in Santa Cruz and 57 in Isabela. At the moment of this report, descriptive and cross-tabulations analysis were performed. Additionally, a semi-structured, open ended questionnaire was applied to key stakeholders from public and private institutions, community leaders and farmers, to understand their role and opinion about the Galapagos Food System.

Interviews with farmers, technical staff and authorities were performed between March and December 2020, by telephone and via email, due restrictions created by the COVID19 pandemics.

Selection of resilient agricultural and livestock practices based on decision scaling approach for the resiliency of agro-ecosystems.

Based on the assessment of the food system (with the climate and non-climate drivers) and the classification of agroecosystems, this analysis selected resilient agricultural and livestock practices that contribute to the transition from conventional agriculture to an agriculture that is resilient to climate change. This selection has an agroecological focus, emphasizing the harmonic relationships of stabilizing processes and their functionality, as well as the system's capacity to tolerate different disturbances of different magnitudes, natural or anthropogenic.

The biggest challenge for climate change adaptation of the agricultural sector is the lack of data necessary to establish robust planning activities. For example, there are discrepancies between the historical and future modeling in precipitation for this proposal, showing a high uncertainty and also showing the influence of the climatic variability and non-climate drivers; therefore, decisions must be robust enough for both conditions or "no regret".

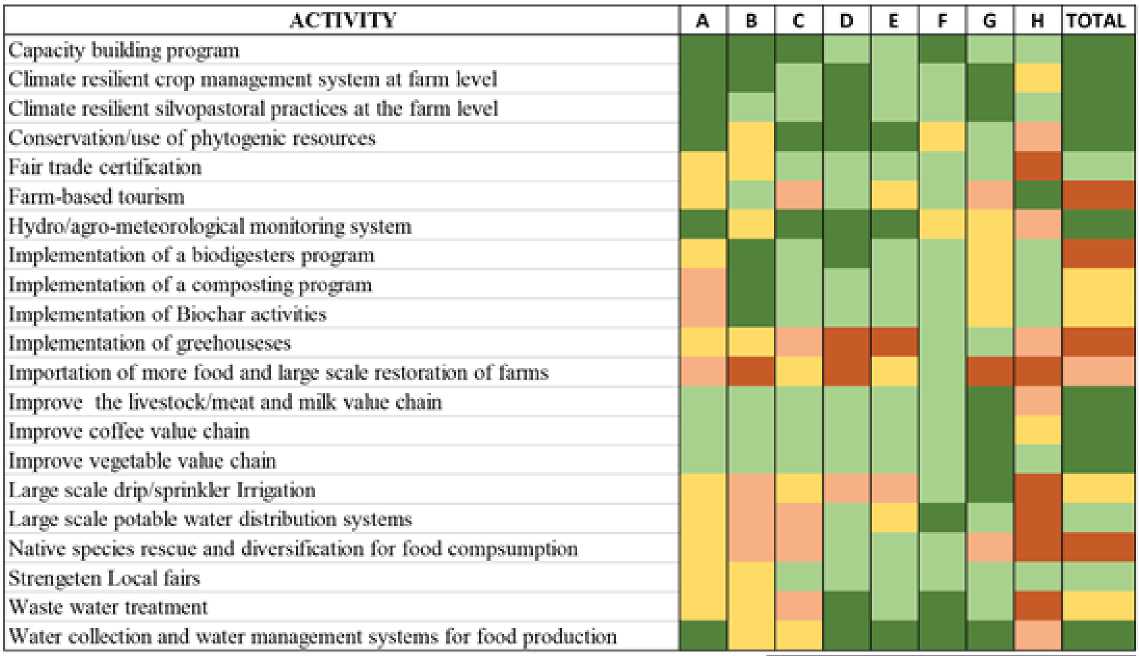
This analysis therefore sought alternative methods for a process to design and implement adaptation activities. Among the various approaches that exist, for this proposal we followed a decision scaling approach (also known as the Climate Informed Decision Analyses, CIDA or the Decision Tree Framework by the World Bank) (Brown et al., 2012). Here, the level of complexity as well as the resources needed to inform decisions is scaled (adjusted) according to the unique characteristics of the food and water systems, as well as the issues and decisions that may arise in the process that are generated by stakeholders. This approach consists of two main stages, which are herein, briefly described:

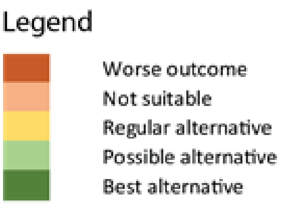
Phase 1. Diagnostic and Formulation. This phase corresponds to the understanding of the general characteristics of the resources system and the formulation of objectives and intervention strategies. In this stage it is represented and described the physical, infrastructure, uses, stakeholders and others which characterize the system. This physical characterization includes the examination of the relationship between climatic parameters and land parameters (e.g., soil, runoff, river flow, recharge, etc.). At this point, it is also possible to estimate elasticities of key variables to shifts in climatic, and other, conditions. The characterization of the system then includes the definition of the metrics upon which a system, or investments, may be deemed as successful. Once these relationships and characteristics are understood, this stage finalizes with the listing of intervention strategies, which would be used to improve the metrics already described.

Phase 2. Stress Test. The next stage corresponds to a deeper examination of the climatic and no climatic vulnerabilities of the analyzed food and water systems. Acknowledging the uncertainties that such systems may face, in this phase, risk is exhaustively evaluated and detected by testing a large set of possible scenarios which may occur. This stage principally makes use of tools such as stochastic generators of time series which in the case of climate change, correspond to weather generators, synthetic time series, and others. So, a wide number of plausible scenarios of climate, demand, land use, and others are used to evaluate how the indicators and metrics of such food and water systems respond under those scenarios and their combinations.

A decision matrix was built to identify the best alternatives for the resilience of the agro-ecosystems in Galapagos. The alternatives were weighted according to their grade of suitability considering climate, environmental, social, and economic dimensions (Figure 43).

Figure 43. Decision matrix for resilient agricultural practices selection





	DIMENSION	WEIGHT
A	CC Adaptation Potential	1
B	CC Mitigation potential	0.8
C	Uncertainty of uncertainty	0.8
D	Environmental Feedback	0.8
E	Broad Conservation objectives	0.7
F	Broad Development objectives	0.7
G	Socially accepted	0.7
H	Economic Considerations	0.7

In this context, this program promotes the adoption of practices and technologies resilient to climate change that are tailored to the needs of each production system present on the Islands. The practices will be oriented to maintain and conserve agrobiodiversity through rural development, training and awareness, mainly with the participation of women and focus on agro-ecological approaches. It is so important to mention that the selected practices have also been used in other FAO projects at the regional level and some have already been carried out in the islands; but not efficiently.

10.4 Fisheries

Coping and adaptive responses to ENSO and climate change will vary depending on their positive or negative effect on fishery resources and their fisheries along the supply chain (Bertrand et al. 2020). However, the magnitude of the impact will also depend on the adaptive capacity of fishers to climate change.

According to Cinner et al. (2018), adaptive capacity could be built across five key domains: (1) the assets that people can draw upon in times of need; (2) the flexibility to change strategies; (3) the ability to organize and act collectively; (4) learning to recognize and respond to change; and (5) the agency to determine whether to change or not. Altogether, fishers' adaptive capacity will vary according to diverse factors, including the portfolio of fisheries in which a single fisher depends on to sustain their livelihoods, the level of diversification of their fishery products, markets, and livelihoods, as well as their economic condition, social network, and willingness and entrepreneurial capacity to change and improve their socio-economic condition.

For example, a fisher will be more vulnerable to the negative impacts of climate change if they specialize in a single fishery (e.g., spiny lobster fishery), if their monthly income depends entirely on fishing, if they don't add value to their fishery products (e.g., individual fishers sell tail lobsters instead of whole or live lobster whose market price is higher), and if they rely upon one market or client to sell their products (e.g., export market and intermediaries). Their vulnerability will also be aggravated if they have a huge number of debts and no savings, if they do not have family or friends who provide support in times of crisis, and if they don't have the willingness to face adversity and the entrepreneurial capacity to take advantage of crisis as opportunities to change their livelihoods or create new ones.

According to Quiroga et al. (2010), Galapagos fishers have a moderate adaptive capacity to climate change because they can shift to alternative fisheries and livelihoods, have access to credit, and strong social and institutional networks. However, most fishers also have low levels of education and computational skills, and few speak other languages besides Spanish, which reduces their adaptive capacity to shift to other economic activities, such as tourism or experiential fishing, during times of adversity. Unfortunately, no additional studies about the adaptive capacity of the Galapagos small-scale fishing sector have been conducted since Quiroga et al. (2010). Consequently, policymakers lack updated information to design policies aimed at enhancing the adaptive capacity of fishing communities and institutions to cope with and adapt to climate change.

On the other hand, according to Bertrand et al. (2020), successful adaptation in the fisheries and aquaculture sector must be based on three non-mutually exclusive areas: institutional adaptation; livelihood adaptation; and risk reduction and management for resilience.

Institutional adaptation comprises the actions of public bodies, that address policy, legal and institutional issues including public investments and incentives, including planning and management of fisheries and aquaculture following the ecosystem approach to fisheries or the ecosystem approach to aquaculture (Bertrand et al. 2020). Livelihood adaptation includes a mix of public and private activities, within or among sectors, most commonly through diversification strategies within or outside the sector to reduce vulnerability. Finally, risk reduction and management for resilience include a mix of public and private activities that promote early warning and information systems, improve risk reduction strategies, and enhance response to shocks. For these three areas of intervention, Bertrand et al. (2020) provide a set of adaptation measures relevant for fisheries and aquaculture in the context of ENSO.

To increase the resilience and adaptive capacity of the Galapagos small-scale fishing sector in the face of climate change, a first set of 35 intervention measures were proposed (Table 28). These measures were built on the measures proposed by Bertrand et al. (2020) and the five domains of adaptive capacity proposed by Cinner et al. (2018). Furthermore, the recommended interventions were contextualized, based on the impacts and expected scenarios described in Section 8.4.

The proposed measures were evaluated and prioritized by a broader group of specialists and representatives of the Galapagos National Park Directorate, using the following criteria:

- Political, technical, and institutional viability that includes criteria to evaluate barriers and risks for a successful implementation and sustainability of the measure. Political will of key stakeholders was the first aspect considered in the analysis. The technological and methodological requirements to implement each measure were also evaluated. Finally, the current legal context as well as institutional capacities to implement the measure were analyzed. This analysis allowed us to preliminarily identify the gaps in each of these aspects that the program must have to address to create enabling conditions.
- Impact on the conservation of biodiversity**.** Considering all documented direct effects (positive and negative) of the proposed measure in the conservation of the GMR ecosystems and species.
- Improvement of small-scale fishers' economy**.** Based on the last Galapagos small-scale fisheries census (GNPD, 2019) the analysis focused on identifying possible affectations of each measure to the fishers' income sources,
- Tangible results in a 5-year period. The possibilities of obtaining concrete and high impact results considering the Programs' implementing period, were analyzed.
- Articulation with other program outputs. Complementarity among different program outputs is essential to potentiate impacts and reduce costs. The measures were analyzed considering synergies and trade-offs with actions proposed for the restauration and adaptation of marine ecosystem and agriculture (see Output 2.2.1, 2.1.2, and 2.1.5 in Section 12.5).

Each of these criteria were rated from 0 to 2; where 0 represents a negative feedback, 1 a neutral effect or unknown scenario, and 2 a positive feedback. The results of this analysis are presented in Table 27 below. The measures that obtained the highest scores (9 to 11) are the following:

1. Adopt an adaptive co-management to address ENSO-related events.

2. Agreed upon the design of the new Galapagos marine zoning and support its implementation, monitoring, and enforcement.

3. Risk-based zoning and siting through risk analysis to protect key biodiversity areas particularly vulnerable to climate risks and selecting the most suitable areas to ensure commercial stocks recovery.

4. Diversify fishing patterns regarding species exploited, location of fishing grounds, or fishing gear used.

5. Improve post-harvest techniques to improve the quality of seafood products.

6. Promote ecolabelling to promote responsible fishing practices and fair trade.

7. Adopt a circular economy to reduce waste and create new sources of income.

8. Rebuild sea cucumbers stocks through small-scale aquaculture in combination with the experimental allocation of Territorial Use Rights for Fishing (TURFs).

9. Diversify markets and fish products and help fishers to get access to higher-value markets.

10. Access to credit with low-interest rates to implement good practices (EBAs).

11. Redistribution of no-take zones to protect critical habitats and promote the recovery of overfished species.

12. Marine zoning and area co-management.

13. Protect key biodiversity areas and promote the recovery of degraded ecosystems.

The 13 measures selected were integrated into three main EBA. Each EBA was further developed, complemented, and fine-tuned based on specific climate change projection analysis, additional literature review, financial analysis, interviews with fishers and extensive consultation with the Galapagos Governing Council de National Park Directorate (See Appendix 2.2).

The three EBA proposed are:

1. The combined effect of climate change, overfishing and IUU fishing is prevented and mitigated through an adaptive co-management of the Galapagos marine zoning (see Section 12.5.1.4).

2. The ecological role of shellfish and finfish stocks are restored, and livelihoods diversified, through the adoption of climate-smart small-scale fisheries and aquaculture approach (see Section 12.5.1.5)

3. Upgraded and more efficient value chains for climate-smart seafood products, potentiated with links to new markets (see Section 12.5.1.6)

The general objective of these EBA is to increase the resilience and adaptive capacity of Galapagos small-scale fisheries against climate change to help safeguard one of most the important biodiversity and climate change hotspots in the world. If successfully implemented, the three EBA measures proposed will help local fishing communities to adapt to climate change and will yield direct and ancillary benefits in the short and long-term, resulting in positive returns on investment and ‘‘win-win’’ situations for coastal communities and marine ecosystems. However, their implementation will demand effective and enforceable regulations and economic incentives, all of which will require the political will of the GNPD and Galapagos Governing Council, as well as adequate financial and human capital.

In Section 12.5, the rationale for each EBA is described, together with their objectives, outcomes and outputs associated, including a description of their impact on the resilience and adaptive capacity of the Galapagos marine ecosystems and fishers’ livelihoods, and other relevant information.

Table 27. Evaluation and prioritization of EbA measures for the Galapagos SSF.

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Impact on the conservation of biodiversity	Improvement of small-scale fishers’ economy	Tangible results in a 5 - year period	Implementation has initiated	Total Score
4	Adopt an adaptive co-management to address ENSO-related events.	2	2	2	2	1	2	**11**
5	Set-up interinstitutional and intersectoral mechanisms of coordination.	2	2	1	1	1	1	**8**
8	Determine the adaptive capacity of the Galapagos small-scale sector and develop a strategy to enhance it.	0	2	1	2	1	2	**8**

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Impact on the conservation of biodiversity	Improvement of small-scale fishers' economy	Tangible results in a 5 - year period	Implementation has initiated	Total Score
9	Consider ENSO/climate change in management practices e.g. the ecosystem approach to fisheries (EAF) including adaptive fisheries management and co-management.	1	2	2	1	1	1	**8**
10	Agreed upon the design of the new Galapagos marine zoning and support its implementation, monitoring, and enforcement.	2	2	2	1	2	2	**11**
11	Risk-based zoning and siting through risk analysis to protect key biodiversity areas particularly vulnerable to climate risks and selecting the most suitable areas to ensure commercial stocks recovery.	2	2	2	2	2	1	**11**
12	Adapt fishing seasons according to the potential impact of different types of ENSO.	1	1	2	2	1	0	**7**
13	Spatiotemporal fisheries management measures to rebuild commercial stocks during periods when the climate is favorable, or to avoid exacerbate overfishing when environmental conditions are unfavorable.	1	1	2	2	1	0	**7**
14	Transboundary stock management to take into account future changes in the distribution of yellowfin tuna stocks.	2	1	1	2	1	0	**7**
15	Diversify fishing patterns regarding species exploited, location of fishing grounds, or fishing gear used.	1	2	2	2	1	1	**9**
16	Improve post-harvest techniques to improve the quality of seafood products.	2	2	1	2	2	2	**11**
17	Promote ecolabelling to promote responsible fishing practices and fair trade.	2	2	2	2	2	2	**12**
18	Adopt a circular economy to reduce waste and create new sources of income.	2	2	2	2	2	1	**11**
19	Rebuild sea cucumbers stocks through small-scale aquaculture in combination with the experimental allocation of Territorial Use Rights for Fishing (TURFs).	2	1	2	2	2	0	**9**

#	Adaptation measures	Articulation with other program outputs	Political, technical, and institutional viability	Impact on the conservation of biodiversity	Improvement of small-scale fishers' economy	Tangible results in a 5 - year period	Implementation has initiated	Total Score
20	Diversify markets and fish products and help fishers to get access to higher-value markets.	2	2	1	2	2	1	**10**
25	Get access to market information to anticipate price/market variability.	1	2	0	2	2	0	**7**
27	Set up risk insurance schemes for the fishing sector.	0	1	0	2	2	0	**5**
29	Access to credit with low-interest rates to implement good practices (EBAs).	2	2	1	2	2	0	**9**
30	Social protection and safety nets for the most vulnerable.	0	2	1	2	2	1	**8**
31	Redistribution of no-take zones to protect critical habitats and promote the recovery of overfished species.	2	1	2	2	2	1	**10**
32	Marine zoning and area co-management.	2	2	2	2	1	2	**11**
33	Ensure the implementation of VMS and AIS to ensure safety at sea.	0	2	1	1	2	2	**8**
35	Protect key biodiversity areas and promote the recovery of degraded ecosystems.	2	2	2	2	2	1	**11**

10.5 Summary of the links between climate and non-climate threats, impacts, adaptation measures and HEVAs

Table 28 below summarizes key climate and non-climate threats, associated socioecological impacts, adaptation measures needed for the ecosystems in Galapagos and High Ecological Value Areas where those measures are proposed to be implemented.

Table 28. Key climate and non-climate threats, associated socioecological impacts, adaptation measures needed for the ecosystems in Galapagos and High Ecological Value Areas where measures are proposed to be implemented.

Key climate change and other non-climatic threats	Major socioecological impacts	Adaptation measures	HEVA in which EBAs measures will take place
Increases in air temperature and precipitation will favor invasive species expansion (e.g., guava, blackberry), resulting in Scalesia forest degradation	Nature-based tourism: • Loss of highland ecosystems key for conspicuous endemic species that constitute important tourism attraction. Farming systems: • Loss of crop yield due to competition with invasive species encroachment and enhanced evotranspiration. • Loss of Scalesia forest capacity to intercept to capture additional water from the characteristic mist (*garúa*) of the highlands in the cool season, leading to possible water shortages. Ecosystems: • Changes in ecosystem productivity that can possibly affect carbon sequestration	• Strengthen control programs for invasive plant species, especially blackberry, in protected and agricultural areas, based on projected dynamics of their expansion under climate change scenarios. • Restore key remnant forest fragments in protected and agricultural areas to enhance ecosystems adaptive capacity and provision of environmental services.	Conservation area Santiago-Santa Cruz Corridor Sierra Negra Volcano Isabela South Corridor Wolf Volcano, Punta Albermarle and Cape Marshall, The Bolivar Channel and Elizabeth South
Increases in Sea Surface Temperature (SST) and stronger ENSO events coupled with increasing tourism numbers	Nature-based tourism: • Coral habitats degradation due to bioerosion and bleaching events • Reduction in coral´s recruitment rates due to changes in the circulation systems of the currents, together with a loss of connectivity between the populations of the different islands.	• Restore high ecological value coral reef areas through coral planting and exclusion area. • Reduce the impact of diving, anchoring and pollution related to tourism operations in selected marine HEVAs, to enhance ecosystems resilience and adaptive capacity to the effects of climate change.	Darwin and Wolf islands Marchena coral remnants The Bolivar Channel and Elizabeth South Conservation Area Santiago-Santa Cruz
Increases in Sea Surface Temperature (SST) coupled with increase in marine traffic due to an upsurge in annual visitors	Nature-Based tourism: • increase the number of new marine bio invasions due to non-indigenous species (NIS) leading to a reduction of the functional diversity of the resident species assemblages by removing key organisms, which may have overall implications for ecosystem function, including productivity. • Substantial losses to nature-based tourism by expanding uncontrollably, forming dense	• Strengthen marine biosecurity programs in the GMR, to prevent and control climate driven introductions and invasions by Non-Indigenous Species (NIS)	The GMR as a whole

Key climate change and other non-climatic threats	Major socioecological impacts	Adaptation measures	HEVA in which EBAs measures will take place
	beds that cover recreational sites becoming a problem for boating, swimming, and diving.		
Increase in air temperature together with sea level rise coupled with an increase in marine traffic	Nature-based tourism: • Loss of green turtles nesting and feeding habitats due to sea-level rise and erosion • Feminization of sea turtle populations	• Improve surveillance and control measures for adequate sea turtle nesting and foraging in the GMR, to counteract potential effects of climate change in their reproductive success.	The Bolivar Channel and Elizabeth South Corridor Sierra Negra Volcano Isabela South Conservation area Santiago-Santa Cruz
Increased SST will promote spatial and bathymetric changes of spiny lobsters and yellowfin tuna stocks.	Small-scale fisheries: • Climate change will exacerbate the impact of IUU fishing and marine pollution. • Reduction of the accessibility of spiny lobsters and yellowfin tuna in the long-term will increase fishing variable costs, reducing fishers' livelihoods, and put in risk the economy and food security of local coastal communities.	• Reduce fishing effort over spiny lobsters through the sustainable development of the tuna small-scale fishery. • Improve the design and effectiveness of Galapagos marine zoning to ensure the sustainable development of the spiny lobster fishery. • Strengthen management conditions of small-scale tuna fishery to reduce its ecological impact over secondary and endangered, threatened and protected (ETP) species. • Improve surveillance and control measures to reduce IUU fishing. • Promoting a blue circular economy through new sustainable and social responsible seafood enterprises.	The Bolivar Channel and Elizabeth South Corridor Sierra Negra Volcano Isabela South
Increased SST will increase the natural mortality rates of Galapagos sailfin groupers stocks.	Small-scale fisheries: • Climate change will exacerbate the negative impact caused by overfishing of Galapagos sailfin groupers. • Reduction of the availability of Galapagos sailfin groupers will reduce fishers' livelihoods and food security of coastal communities.	• Reduce fishing effort over Galapagos sailfin grouper through the sustainable development of the tuna small-scale fishery. • Strengthen management of sailfin groupers fishery to mitigate climate change impacts while restoring the species ecological	The Bolivar Channel and Elizabeth South Corridor Sierra Negra Volcano Isabela South Conservation area Santiago-Santa Cruz

Key climate change and other non-climatic threats	Major socioecological impacts	Adaptation measures	HEVA in which EBAs measures will take place
		role by improving the design and effectiveness of Galapagos marine zoning and adopting a climate-smart small-scale fisheries approach. • Diversify fishers' livelihoods by enhancing climate change resilient local value chains to improve Galapagos seafood system access to markets. • Improve surveillance and control measures to reduce IUU fishing.	
Acidification of the ocean increased due to lack of the regulation of seawater carbonate chemical equilibrium by sea cucumbers	Small-scale fisheries: • More acidic waters will impact many calcifying species, e.g., shell-forming marine organisms, but also probably the physiology and respiration of fishes, especially the more vulnerable early life stages.	• Implement small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs), to rebuild the ecological role of sea cucumber stocks and diversify fishers' livelihoods. • Strengthen management of sea cucumber fishery to mitigate climate change impacts while restoring the species ecological role by improving the design and effectiveness of Galapagos marine zoning and adopting a climate-smart small-scale fisheries and aquaculture approach. • Improve surveillance and control measures to reduce IUU fishing.	Conservation area Santiago-Santa Cruz The Bolivar Channel and Elizabeth South Corridor Sierra Negra Volcano Isabela South
Increased average annual temperatures	*At farm level:* • Increasing water needs at farm level on dry season.Loss of crops yields and income reduction. • Increase of plagues and diseases on crops • Changes in water humidity on soil Increase of invasive species *Agriculture livelihoods:*	Strengthening institutional capacities for monitoring agro climatic variables under climate change scenarios. • Ensure provision of climate information for decision making for farmers and stakeholders. • Local farmers use climate information for planning crops and land	Agricultural zones of the islands Santa Cruz, San Cristobal, Isabela and Floreana

Key climate change and other non-climatic threats	Major socioecological impacts	Adaptation measures	HEVA in which EBAs measures will take place
	• Farms abandonment • Increase food insecurity and malnutrition • Farmers capacity to produce food is reduced.	use at farms enhancing ecosystem services provision.	
Increased rainfall seasonality		Support farmers in developing and adapting ICM and silvopastoral systems in farms for using water more efficiently. Increasing water availability for agriculture through reservoirs and irrigation infrastructure Increasing food production and availability for improving food security of local communities and consumers. • Improving carbon organic soil content with best managing practices • Improve crops and grassland management with efficient water use • Strengthen management of invasive plant species, especially blackberry, in agricultural areas, based on projected dynamics of their expansion under climate change scenarios. • Increase of carbon stocks on soils and aerial biomass with silvopastoral systems	Agricultural zones of the islands Santa Cruz, San Cristobal, Isabela and Floreana.
More intense ENSO events		• Enhance agriculture value chains based on resilient production. • Improved access to credit to maintain food chain products and improving local livelihoods. • Diversify and improve farmers' livelihoods by enhancing agriculture climate change resilient local value chains access to markets (local	Agricultural zones of the islands Santa Cruz, San Cristobal, Isabela and Floreana.

Key climate change and other non-climatic threats	Major socioecological impacts	Adaptation measures	HEVA in which EBAs measures will take place
		consumption and for tourist). •	

11. Theory of change

The core problem

Today, Galapagos main livelihoods (agriculture, small-scale fishing, tourism), are highly vulnerable to climate change and present significant opportunities to reduce GHG emissions”. In other words, the main Galapagos livelihoods, which are heavily dependent on ecosystem services, need to increase their resilience to climate change; and at the same time, they are the main actors through which the Galapagos islands can find a low-carbon development pathway.

The context of these three main livelihoods is complex, given their dependence on:

- The marine and terrestrial ecosystems, in terms of food, water, and touristic attractive (before COVID, nature-based tourism was the most important driver of the local economy, around 80%, and now it has dropped dramatically, showing that resiliency should be achieved also by diversifying the local economy).
- Food and fossil fuel imports from mainland Ecuador (75% of the food is imported nowadays, with predictions raising to 95% by 2036 – 85% of the energy is based on diesel imported from the mainland).

As described in Section 4, climate risks severely exacerbate the threats posed by the drivers of environmental change that are intrinsic to the development of the Galapagos economy. These magnified impacts will directly affect the Galapagos livelihoods: agriculture production, water deficit, pests, loss of environmental services of native ecosystems and agroecosystems, changes in fish species distribution and availability, and general impact on the ecosystems that are the main attraction for the nature-based tourism sector.

Galapagos' livelihoods also contribute to global GHG emissions, as described in section 5.

The goal

This Programme has the goal of promoting a transformational change towards a self-sufficient island system in which livelihoods are developed under a low-carbon model and greater capacity to adapt to climate change. For reaching this objective, the Programme has designed a set of activities to overcome the barriers described below.

Programme goal statement: “IF financial, technical and institutional barriers are removed for the investments in renewable energy, energy efficiency, and resilient and low-carbon agricultural and fishing practices; restoration and conservation of key ecosystems; institutional strengthening; and education and mobilization of the civil society with a behavioral change approach, THEN Galapagos will be able to effect its transformational change towards a self-sufficient, low carbon and resilient island system, BECAUSE livelihoods and local governments will understand the importance of undertaking a low-carbon and resilient pathway; investments will be made to effectively change technologies and practices of the tourism, agriculture and small-scale fisheries sectors; investments in restoration will enhance key ecosystems services needed to cope with climate change; and sustainability mechanisms will be in place for the actions driven by the programme”.”.

According to the logic of the proposed intervention, changes in the **energy** system would be achieved through the provision of concessional financing for investments in centralized and distributed renewable energy generation systems and energy efficiency technologies, as well as technical assistance for the preparation of energy projects, primarily in the tourism sector, but also in the small-scale agricultural and fishing sectors and for the evaluation and monitoring of such projects by local banks. In this way, these interventions would help reduce the vulnerable livelihoods’ dependence and that of the entire Galapagos system on external sources and reduce greenhouse gas emissions through a reduction in fossil energy consumption and an increase in the generation of cleaner energy (Outcomes 1.1 and 1.2).

Through the improvement of institutional capacities for climate-resilient **planning and development**, the Programme expects to break down several barriers related to the weakness of local institutions to address the challenges of climate change in the tourism, energy and food sectors and the field of ecosystem management. The Programme expects to achieve this goal by providing technical assistance and capacity building to governmental staff, to improve their climate information management and understanding, and their knowledge on the specificities of the challenges faced by the three sectors, not only in technical aspects but also their capacity and financial needs. This will contribute in a cross-cutting manner to all the expected outcomes of the Programme.

The Programme strategy addresses key financial and technical barriers faced by **farmers and small-scale fishers** by providing concessional credit, technical assistance, and capacity building to change their current practices to resilient and low carbon practices. This way, farmers will be able to access these facilities to improve water management, means to conserve and use phytogenic resources, and implement integrated climate-resilient crop management systems, silvopastoral practices, and agroecosystem restoration. It is expected that, by giving impulse to these activities, the trend of increasing farming land abandonment will be reversed, the rural population will find in this activity a reliable source of income and, consequently, other problems will be avoided, such as the spread of invasive species due to the abandonment of these plots and enhanced by the increase in the frequency of rainfall events and tree mortality worsened by ENSO events. Farmers will not only contribute to emissions reductions through the aforementioned access to renewable energy investments but also through the improved farming practices promoted, which have a very large contribution to GHG avoidance and sequestration. On the other hand, the program support will allow small-scale fishers (SSF) to adopt a climate-smart fishing and aquaculture approach, strengthening the management conditions of small-scale tuna and sailfin groupers fisheries, and rebuilding sea cucumber stocks to diversify livelihoods. This approach will be framed and reinforced through an adaptive co-management of the Galapagos marine zoning to overcome the lack of regulations for evidence-based management of overfished fisheries. Working with farmers and fishers will not only contribute to the outcome of the resiliency of the Galapagos foods system (Outcome 2.1), but also to the expected outcome of marine and terrestrial ecosystems under effective restoration schemes (Outcome 2.2).

The fact that the small-scale fisheries are centered around few and overexploited species, that there are limited links between farmers and fishers with the Galapagos tourism value chain, that willingness to pay for sustainable Galapagos food products is not reflected in the value chains, that there is a lack of climate-smart infrastructure to guarantee the quality of products needed to reach the markets and that farmers and fishers lack of financial resources to face the change of their practices to climate-resilient ones, makes that the Programme needs to propose strategies to overcome important market, knowledge and financial barriers. The Programme assumes that by providing technical assistance and concessional finance to improve the different agriculture and seafood value chains and promoting a blue circular economy, along with the capacity building to governmental staff described above, this baseline situation will be transformed. As a result, upgraded and more efficient value chains for climate-smart seafood and agriculture products would be potentiated with links to new markets such as tourism, ultimately contributing to the climate resiliency of the Galapagos' food system (Outcome 2.1).

The underlying principle of the entire Programme is that the health of **marine and terrestrial ecosystems** is critical to the resilience of the archipelago's livelihoods. While the ecosystems will benefit from the activities described above, related to improving agricultural and fishing practices, it is necessary to actively work on their restoration as well. Therefore, adaptation measures to adequately manage, restore, and conserve key marine and terrestrial ecosystems in the face of climate change, will be promoted through technical assistance, concessional funding for innovative technologies, information, and capacity building to strengthen the Galapagos National Park Directorate and other local institutions, in collaboration with the private sector. The Programme will implement strategic restoration of terrestrial ecosystems changing the current paradigm towards a landscape-scale approach, that integrates the agricultural and Galapagos National Park areas in a single common vision to face climate change impacts. Control programs for invasive plant species will be strengthened, especially blackberry, in protected and agricultural areas, based on projected dynamics of their expansion under climate change scenarios, and key remnant forest fragments in protected and agricultural areas will be restored to enhance ecosystems adaptive capacity and provision of environmental services. In the GMR, the risks of expansion of invasive species due to climate change are not included in current biosecurity programs, therefore the program will implement improved marine biosecurity and Early Detection and Response (EDRP) protocols. The lack of active restoration approaches in current coral conservation practices will be addressed through experimental coral planting and exclusion areas. The lack of a climate change adaptation approach for the management of sea turtles will be overcome by promoting adequate sea turtle nesting and foraging sites. Finally, with the involvement of the tourism sector, the impact of diving, anchoring, and pollution related to tourism operations will be reduced in selected marine high-ecological value areas. These measures will benefit not only the fishing sector but also the tourism sector by ensuring the good health of the marine ecosystems and species that generate a high level of visitor interest. Programme resources spent on active restoration, biosecurity, monitoring, and control programs, working with tourism operators, and strengthening governmental staff will be key to bringing marine and terrestrial ecosystems under effective restoration schemes, ultimately increasing the resilience of the Galapagos' livelihoods (Outcome 2.2).

Without **sustainability strategies**, the actions and results of the Program would be at risk of not being maintained over time once the implementation period is over and GCF funding is withdrawn. Therefore, three lines of action have been proposed - which will be grouped under Component 3 - to support the sustainability of all actions aimed at the transformation of the Galapagos in all the sectors mentioned above. The Program is based on the logic that if it establishes financial tools and mechanisms to perpetuate the investments promoted in the 5 years of implementation if it acts in the areas of formal and non-formal education and communication to mobilize the population towards collective climate action, and if it strengthens the regulatory and institutional frameworks for climate-responsive planning and development, the sustainability of the program will be guaranteed (Outcome 3.1).

This Theory of Change shows the high level of the interrelationship between barriers, activities, outputs, and outcomes, and how the program components then need to reinforce each other to achieve real change in the islands. The diagram below helps to visualize that to achieve transformational change in Galapagos, it is necessary to act comprehensively in all of the strategic areas identified.

Link of specific activities proposed by the Programme and barriers to overcome.

As can be inferred from the above, the barriers that are common to the whole Programme are related to access to accessible finance, to the low capacity of the Galapagos institutions to drive transformational change, insufficient technical knowledge for implementing adaptation and mitigation solutions, market issues regarding competence with imported products, and lack of public awareness and engagement. The following table shows the barriers identified and how they will be addressed by the Programme.

Table 29. Key barriers to climate resilient and low-carbon development in Galapagos and how the Programme addresses them.

Actor/sector facing barrier	Barrier type	Barrier	How barrier will be addressed by the Programme
Private energy investors, public administration	Financial	Lack of access to concessional sources of funding for centralized renewable energy	• **Activity 1.1.1.1.** Centralized renewable energy generation and storage project.
Tourism, commercial, farmers, small-scale fisheries	Financial	Lack of accessible financing for investing in distributed renewable energy, energy efficiency.	• **Activity 1.1.1.2.** Distributed renewable power generation projects. • **Activity 1.2.1.1.** Efficient energy consumption of the Galapagos' livelihoods
Banks, private energy investors, tourism, commercial, farmers, small-scale fisheries	Knowledge	Lack of knowledge for the development of mitigation projects, and to comply with the ESMS and MRV requirements.	• **Activity 1.2.2.1** Technical Assistance facility for energy investments
Local governmental agencies, farmers and producers' organizations, INIAP	Knowledge and institutional capacity	Weak institutional and technical capacities to address climate change in the Galapagos food system.	• **Activity 2.1.1.1.** Implement a capacity building program for governmental staff with practical information, knowledge and training about climate change and climate resilient agricultural practices. • **Activity 2.1.1.2.** Install a hydro/agro-meteorological monitoring system to inform and tailor the information to the needs of vulnerable smallholder farmers.
Farmers, public institutions	Financial and Knowledge	Vulnerable farmers lack knowledge and access to low-carbon, climate resilient agriculture approaches and technological packages. Farming lands abandonment, becoming contagious and dispersion sources of invasive species towards natural areas.	• **Activity 2.1.2.1.** Develop a physical and knowledge network for conservation and use of phytogenic resources. • **Activity 2.1.2.2.** Implement an integrated climate resilient crop management system at farm level. • **Activity 2.1.2.3.** Implement silvopastoral practices at the farm level.
Farmers, public institutions	Financial and Knowledge	Limited knowledge and access to technological solutions to collect and store water during the rainy season for use during the dry season	• **Activity 2.1.2.4.** Develop and implement water collection and water management systems for climate-resilient food production
Fisheries, public institutions	Knowledge, institutional capacity	Lack of evidence-based management regulations for overexploited fisheries.	• **Activity 2.1.3.1** Improve the design and management effectiveness of Galapagos marine zoning, based on conclusive scientific evidence

		Key marine ecosystems with projected exacerbated degradation processes currently outside no take zones. Weak monitoring capacities on the impact of climate change on fishery resources, marine biodiversity and fishers' livelihoods Lack of integration of subtidal monitoring information into decision-making by key stakeholders Low quality information on CC impacts on ecosystems and lack of monitoring systems to assess impacts of adaptation action	on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods. • **Activity 2.1.3.2** Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning. **Activity 2.1.3.3** Strengthen the current decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve.
Fisheries, public institutions	Knowledge, institutional capacity, financial resources	Lack of evidence-based management regulations for overexploited fisheries and climate change impacts. Lack of traceability systems for key fisheries species Lack of knowledge and financial resources for the sustainable management of the fishery resources.	**Activity 2.1.4.1** Management conditions of small-scale tuna fisheries, strengthened to reduce the ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species. **Activity 2.1.4.2** Management of sailfin groupers fishery strengthened to mitigate climate change impacts while restoring the species ecological role. **Activity 2.1.4.3** Small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs) implemented to rebuild sea cucumber stocks and diversify fishers' livelihoods.
Agriculture, fisheries, tourism, public institutions	Knowledge, institutional capacity, financial resources	Weak institutional and technical capacity to address climate change in the Galapagos food system. Limited links between farmers and fishers with the Galapagos tourism value chain By-products from fishing activity are not incorporated into the value chain. Lack of climate smart infrastructure to guarantee the quality of products needed to reach the markets.	**Activity 2.1.5.1** Implement strategies to improve the livestock/meat and milk value chain. **Activity 2.1.5.2** Implement strategies to improve the Galapagos coffee value chain. **Activity 2.1.5.3** Implement strategies to improve the Galapagos vegetables value chain. **Activity 2.1.5.4** Promotion of a blue circular economy through new sustainable and socially responsible seafood enterprises

		Willingness to pay for sustainable Galapagos food products is not reflected in the value chains.	**Activity 2.1.5.5** Put in place a long-term financing mechanism to improve sustainability and competitiveness of Galapagos small-scale fishing sector.
Marine ecosystems managers, users, and dependent livelihoods (Fisheries, tourism)	Knowledge, institutional capacity, financial resources	Lack of innovative approaches to control and eradicate invasive species	**Activity 2.2.1.1** Strengthen marine biosecurity programs in the GMR, to prevent and control marine bioinvasions by Nonindigenous Species (NIS) that could proliferate due to the effects of climate change.
Marine ecosystems managers, users, and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Ongoing coral reef conservation practices do not incorporate active restoration approaches.	**Activity 2.2.1.2** Restore high ecological value coral reefs through coral planting and exclusion areas, to enhance their ecological role in the GMR.
Marine ecosystems managers, users, and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Business as usual tourism operations lack best practices to reduce their impacts on CC highly sensitive marine ecosystems.	**Activity 2.2.1.3** Reduce the impact of diving, anchoring and pollution related to tourism operations in selected marine HEVAs, to enhance ecosystems resilience and adaptive capacity to the effects of climate change.
Marine ecosystems managers, users, and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Current marine turtle management measures do not consider the impacts of climate change on the species	**Activity 2.2.1.4** Improve surveillance and control measures for adequate sea turtle nesting and foraging in the GMR, to counteract potential effects of climate change in their reproductive success.
Terrestrial ecosystems managers, users, and dependent livelihoods (Agriculture, tourism)	Financial and knowledge	Farming lands abandonment, becoming contagious and dispersion sources of invasive species towards natural areas. Lack of climate change approaches to restore native forests and control and eradicate invasive species. Low quality information on CC impacts on ecosystems and lack of monitoring systems to assess impacts of adaptation action	**Activity 2.2.2.1** Strengthen control programs for guava and blackberry, in areas inside and outside the GNP, based on their projected dynamic expansion under climate change scenarios. **Activity 2.2.2.2** Restore key remnant forest fragments inside and outside the GNP, to enhance ecosystems adaptive capacity and provision of environmental services. **Activity 2.2.2.3** Monitor success and impacts of invasive species control and restoration measures.

Tourism sector, public institutions	Financial, knowledge and institutional capacity	Lack of financing lines with special conditions to access both the certification scheme and its implementation, which stopped many operators in the sector from accessing certifications in the past. Lack of efficient management model and marketing strategies to ensure the sustainability of certification schemes. Lack of financial instruments to scale-up the adoption of low-carbon and climate-resilient practices.	• **Activity 3.1.1.1** Implement an ecotourism certification scheme to adopt best practices across the tourism value chain.
Local educational community	Knowledge and institutional capacity	Efforts to integrate climate change education into the existing programs are not articulated. There is no mechanism by which the information on mitigation and adaptation initiatives promoted by the Programme could reach the local educational community. Education programmes are not prepared for addressing the local demand of Galapagos livelihoods in the face of climate change and post-COVID-19 context.	• **Activity 3.1.2.1** Strengthen the educational system to provide quality education to face climate change and promote sustainable development. • **Activity 3.1.2.2** Create non-formal education and outreach opportunities, to encourage local communities' interest and active involvement in addressing climate change. • **Activity 3.1.2.3** Implement a Programme communication and dissemination strategy
	Knowledge and institutional capacity	Regulatory frameworks do not address ecosystem degradation and biodiversity loss. Lack of evidence-based management regulations for overexploited fisheries.	• **Activity 3.1.3.1** Mainstream climate change into regulatory frameworks and planning instruments.

Assumptions.

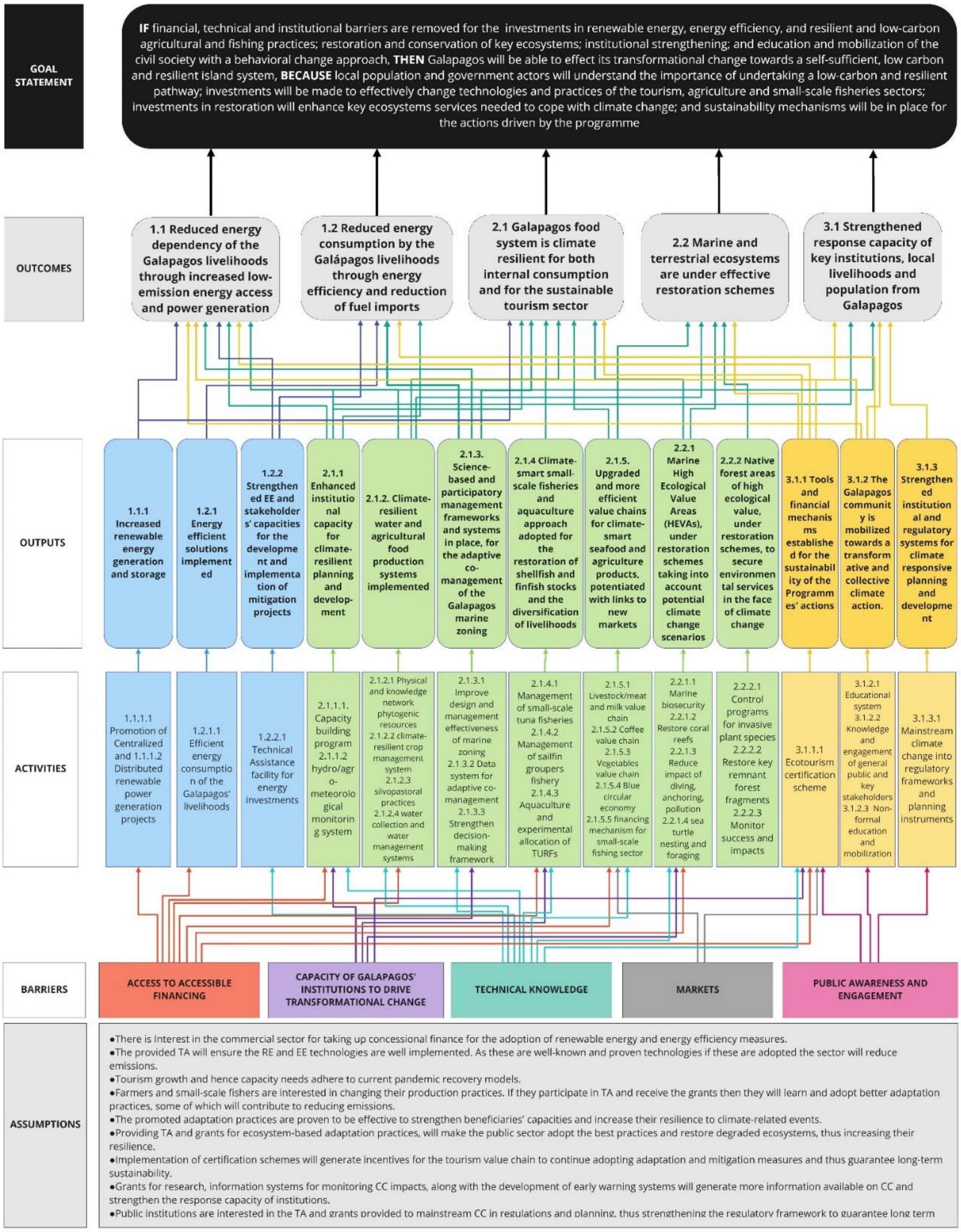
The following are the necessary conditions for change, or the "underlying conditions or resources that need to exist for planned change to occur":

- There is Interest in the commercial sector for taking up concessional finance for the adoption of renewable energy and energy efficiency measures.
- The provided TA will ensure the RE and EE technologies are well implemented. As these are well-known and proven technologies if these are adopted the sector will reduce emissions.
- Tourism growth and hence capacity needs adhere to current pandemic recovery models.

- Farmers and small-scale fishers are interested in changing their production practices. If they participate in TA and receive the grants then they will learn and adopt better adaptation practices, some of which will contribute to reducing emissions.
- The promoted adaptation practices are proven to be effective to strengthen beneficiaries' capacities and increase their resilience to climate-related events.
- Providing TA and grants for ecosystem-based adaptation practices, will make the public sector adopt the best practices and restore degraded ecosystems, thus increasing their resilience.
- Implementation of certification schemes will generate incentives for the tourism value chain to continue adopting adaptation and mitigation measures and thus guarantee long-term sustainability.
- Grants for research, information systems for monitoring CC impacts, along with the development of early warning systems will generate more information available on CC and strengthen the response capacity of institutions.
- Public institutions are interested in the TA and grants provided to mainstream CC in regulations and planning, thus strengthening the regulatory framework to guarantee long term sustainability of the results achieved.
- People participate and change their knowledge and behavior through the proposed communication / education activities, thus ensuring long-term sustainability.
- Commitment and endorsement of Ecuador and Galápagos' highest authorities throughout the implementation.
- Effective implementation and relationship between executing entities and CGREG, MAE, MAG, MinTur and MEyRNNR.

The figure below shows a simplified version of the Theory of Change diagram of the Programme.

Figure 44. Theory of Change of the Programme



12. Programme description

12.1 Objectives

The Programme has the **goal** to achieve a transformational change towards a self-sustaining island system in which livelihoods are developed under a low carbon and climate-resilient model. The main livelihoods of the Galapagos need to increase their resilience to climate change; and at the same time, they are the main channels through which the Galapagos Islands can find a way to significantly reduce their GHG emissions.

The Programme has the **objective** of providing financial and non-financial resources to help reduce barriers to investment in mitigation and adaptation actions and to foster behavioral change by the agriculture, fisheries and tourism sectors that currently have insufficient access to credit and a significant lack of knowledge about climate change impacts and possible solutions to increase the resilience of productive systems and reduce GHG emissions. The Programme aims to mobilize the Galapagos community towards a transformative climate action and to establish mechanisms such as certification schemes and financing strategies, for the sustainability of the Programme actions in the long term.

To achieve the expected outcome, the Programme will use a combination of funding sources, including loans, grants, and equity, through three mutually reinforcing and interlinked **components**: **(1)** Energy matrix change in the Galapagos Archipelago, **(2)** Building climate resilience of the Galapagos' livelihoods, and **(3)** Sustainability mechanisms for climate resilience and low emissions livelihoods.

Territorial and programmatic approach of a cross-cutting proposal: This proposal is a comprehensive programme for the transformation of Galapagos. As such, it seeks to have an impact on various sectors and with various strategies, under the same umbrella of a climate approach. It is critical to understand the proposed territorial approach in such a particular area as a small archipelago far from the mainland: there, in this small group of islands, everything is interconnected: the way energy is generated and used influences urban and rural areas almost equally; everything that changes in one sector, in one terrestrial or marine area, changes in the others, since everything inhabits the same territory, and all economic activities are interdependent. Therefore, the Government of Ecuador is proposing a programme with activities that transform all sectors and strengthen ecosystems, while mobilising the population to achieve a real transformation. This programme is cross-cutting because it actively seeks to reduce GHG emissions (energy and land use sectors) and increase the resilience of communities and ecosystems. It is also transversal in the use of loan and grant resources, as described throughout sections B.3 and B.4 and as shown in Figure 3.

Given the need to create an enabling environment that catalyzes resilient and low-carbon investments in tourism, agriculture, and fisheries, the Programme proposes to structure the **Galapagos' Climate Facility** to channel credit to these sectors through the national development bank (CFN) and local banks through the **Galapagos' Climate Credit Line (GCCL)**; establish the **Conolophus Centralized Power Generation Trust Agreement** between CAF, the Ministry of Energy and the private sector to boost investment in centralized renewable energy; and provide **Non-Reimbursable Resources** channeled by WWF, FAO and CAF for investments in ecosystem rehabilitation and technical assistance and awareness for all actors involved in implementation, including final beneficiaries. Please refer to section 13 for further details on the GCCL and the Trust to be established.

The Programme activities have been prioritized through a **multi-criteria** analysis methodology that considers potential impact, feasibility level, and potential paradigm shift. Please refer to Section 10 "Analysis of alternatives".

The Programme has also been designed based on a **market study**. Please refer to Appendix 4.1 for details on the green financing baseline and the financial demand in Galapagos. Also, section 12 includes the market studies along with the description of the activities.

12.2 Structure

Components and outcomes are structured as shown in the figure below. They are further described in the following sections. For further details, refer to the appendixes of this document.

Figure 45. Summary of Components and outcomes of the Programme

Component 1 - Energy matrix change in the Galápagos archipelago.

Outcome 1.1: Reduced energy dependency of the Galapagos livelihoods through increased low-emission energy access and power generation

Outcome 1.2: Reduced energy consumption by the Galápagos livelihoods through energy efficiency

Component 2: Building climate resilience of the Galapagos' livelihoods.

Outcome 2.1: Galápagos food system is climate resilient for both internal consumption and for the sustainable tourism sector**.**

Outcome 2.2: Marine and terrestrial ecosystems are under effective restoration schemes.

Component 3: Sustainability mechanisms for climate resilience and low emissions livelihoods

Outcome 3.1: Strengthened response capacity of key institutions, local livelihoods, and population from Galapagos.

12.3 Beneficiaries

The indirect beneficiaries of the Programme are the more than 270,000 tourists visiting the island every year, which are considered as resource users (energy, water, food, ecosystems). The direct beneficiaries are 33,000 people, corresponding to the total population of Galapagos will become more resilient and will be part of a low-carbon development, based on the actions of the Programme, and More than 470 beneficiaries from the tourism sector will have access to finance for investing in energy-efficient technologies and distributed renewable energy generation, a total of 624 farmers or UPAS (1,872 persons), and 1,000 fishing households (3,000 persons) will benefit from the adaptation measures implementation; the Programme will enhance climate resilience in 19,000 hectares of agricultural areas, 1,500 hectares of Scalesia forests and 138,000 km2 of marine ecosystems.

The types of direct beneficiaries of the Programme resources are summarized in the table below. Please refer to section 3 for the characterization of the sectors and section 8 for the description of the climate impacts they face. Their eligibility is defined in the description of each activity.

Table 30. Programme beneficiaries

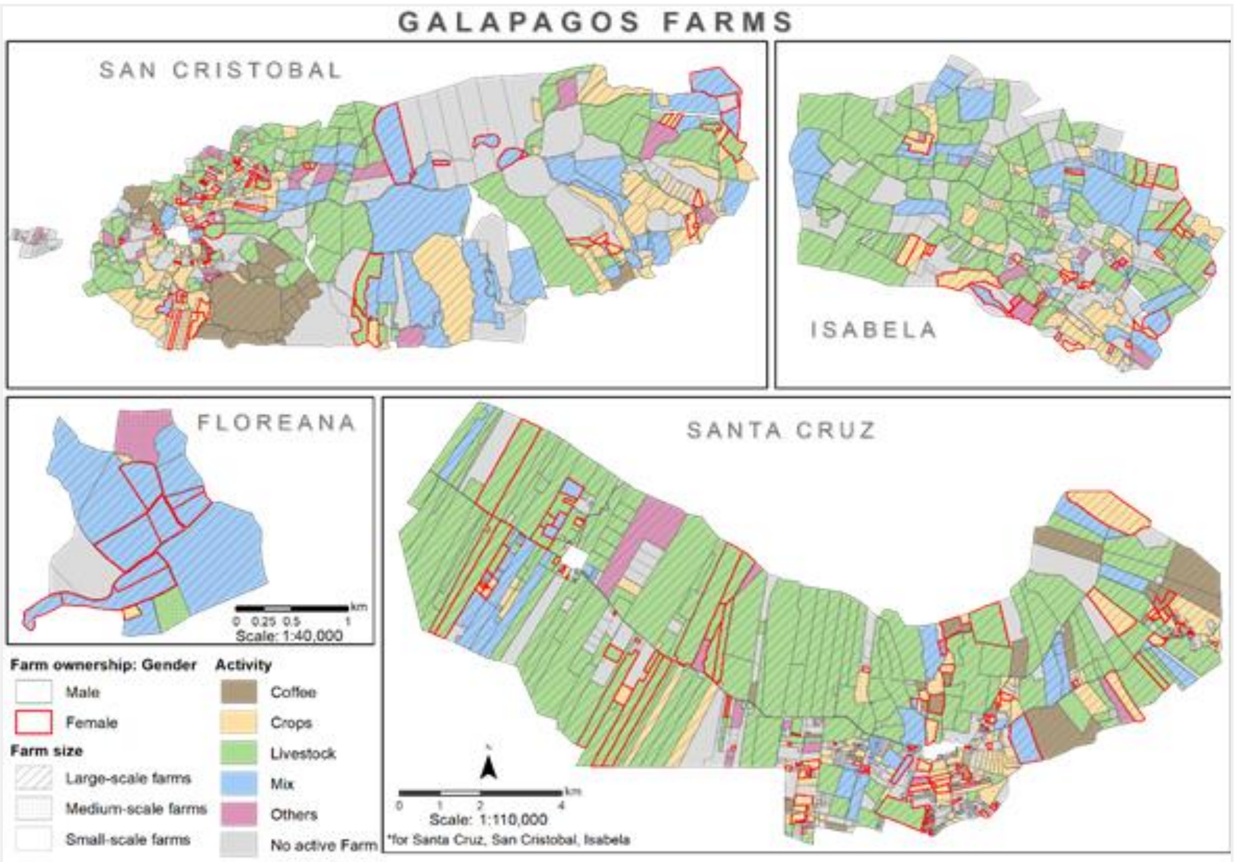
Component 1	Component 2	Component 3
1. Galapagos population *2. Galapagos Livelihoods* • *Tourism value chain (hotels, restaurants, boats, logistics operators, commercial, services).* • *Agriculture* • *Small-scale fisheries* *Other:* *Educational and sport centers*	*1. Galapagos Livelihoods* *Agriculture* *Small-scale fisheries* *Tourism (hotels, restaurants, boats, logistics operator).*	*1. Main governmental institutions.* *2. Galapagos Livelihoods* • *Agriculture* • *Small-scale fisheries* • *Tourism (hotels, restaurants, boats, logistics operator).* • *Education sector (youth, schools, universities).*

Office, residential and private buildings *3. Local Financial Institutions* *4. Conolophus tender winner; Gransolar/Total Eren consortium (beneficiary of the Trust)*		

Beneficiaries - Agriculture

The beneficiaries of this component related with agriculture are families managing 755 farms located in the Galapagos Islands. These farms cover an area of 19,000 hectares, containing 228 large-scale farms (> 20 hectares), 202 medium-scale farms (5-20 hectares), and 325 small-scale farms (< 5 hectares). Figure 46 shows the spatial location of the farms across different agricultural zones. The map also indicates whether the farm is mainly managed by male or female farmers and the main activity within the farm, including if it is mainly devoted to coffee, crops, livestock, mix (crops+livestock) or other, which include native or invasive vegetation. This map also indicates the location of non-active (abandoned) farms. Only for the output 2.1.2, It is estimated that a total of around 624 farmers will benefit directly from the project (about 187 female and 437 male farmers). The average family size is 3 per household, thus, the number of total beneficiaries is estimated to be around 1,872 persons.

Figure 46. Map of the beneficiary farms in the agricultural areas of the Galapagos Islands



Characteristics and details of the activities, characterization of the farms and beneficiaries are in Appendix 2.1 Agriculture.

Beneficiaries - Fisheries

There are three main fishing ports in Galapagos (1) Baquerizo Moreno (San Cristóbal), (2) Puerto Ayora (Santa Cruz) and (3) Puerto Villamil (Isabela) (Fig. 1). Fishers are organized into four fishing cooperatives, most with low levels of organization, social cohesion, and leadership. There are 1084 license holders and 416 vessels registered in Galapagos, although only 37% of them remain active (Castrejón and Charles 2020). Each fishing license provides to its owner the right to fish any type of shellfish and finfish species commercially permitted. Approximately 97% of active vessels are smaller than 9.6 m long (fiberglass or wooden made) and equipped with outboard engines (15–200 HP). Only 13% consist of large wooden boats (8 to 18 m long) equipped with inboard engines (30-210 HP). Large boats are used as storage, resting and towing units for up to four small vessels. Most harvesting activities usually last one or two days, although large boats are able to operate for a maximum of 12 days.

Approximately, 68 shellfish and finfish species from 27 families are commercially harvested by ca. 400 small-scale fishers (Castrejón 2011; Schiller et al. 2013; Castrejón and Charles 2020). The most important fishery resources, after the collapse and total closure of the sea cucumber (Isostichopus fuscus) fishery occurred in 2006 (Defeo et al. 2016), are spiny lobsters (Panulirus penicillatus and P. gracilis), slipper lobsters (Scyllarides astori), yellowfin tuna (Thunnus albacares) and several benthic and demersal fish species, including the Galapagos sailfin grouper (Mycteroperca olfax), the mottled scorpionfish (Pontinus clemensi), the whitespotted sandbass (Paralabrax albomaculatus), and the misty grouper (Hyporthodon mystacinus) (Castrejón 2011; Schiller et al. 2014; Defeo et al. 2016; Marin and Salinas-de-León 2018).

Beneficiaries - Tourism

The project will generate direct and indirect benefits to 1.663 actors of the tourism value chain, 874 are active business while the remaining 789 are individual tourist guides (27% female, 73% male). By providing access to concessional loan facilities, investing in renewable energy and improving overall resilience capacity of the tourism value chain, the project is expected to have an overall impact in the Galapagos as a tourist destination, therefore benefiting an economic sector currently employing 7,888 people, out of which 61% is concentrated in terrestrial and marine lodging. Beneficiaries are spread across four inhabited islands, 52% are concentrated in Santa Cruz, 25% in San Cristóbal, 21% in Isabela and 2% in Floreana. A tourism certification scheme and its associated capacity building opportunities will be targeting at least 30% of the actors of the tourism value chain.

12.4 Component 1: Energy matrix change in the Galapagos archipelago.

Component 1 will reduce energy dependency of the Galapagos livelihoods through increased low-emission energy access and power generation and will reduce energy consumption by the Galápagos livelihoods through energy efficiency.

Drawing on behavioral science literature and evidence, we will set out some techniques to remove barriers and leverage enablers to reach behavioral goals associated with the activities related to this component and the different factors that influence the problem of energy dependency and consumption. Please refer to Appendix 3.4 for an illustrative example where behavioral goals and potential techniques were identified to promote efficient energy consumption of the Galapagos´ livelihoods (Activity 1.2.1.1), as well as a detailed description of the methodology in order to illustrate how we will apply the behavioral science approach in practice.

12.4.3 Outcome 1.1 Reduced energy dependency of the Galapagos livelihoods through increased low-emission energy access and power generation.

12.4.3.1 Output 1.1.1: Increased renewable energy generation and storage.

Activity 1.1.1: Promotion of Centralized renewable energy generation

The Program will finance high impact centralized energy projects. Initially, it will support the development of the Conolophus solar photovoltaic power generation project. Due to its level of progress - at the time of writing this proposal, it is in the bidding phase - and its high impact, the Conolophus project has been prioritized over the other projects to be promoted in Galapagos, as established in the Generation Expansion Plan of the Galapagos Isolated System (PEGSAG).

The Conolophus PV project

The project tendering includes a 14.8 MWp PV plant, a 40.9 MWh battery energy storage system, a switching station at 34.5kV, 49 km of sub-transmission line, and a centralized automatic control system for all the power plants in the island. By the end of 2018, the Ministry of Energy and Non-Renewable Natural Resources issued a declaration of public interest for this private initiative.

The dispatchable PV+BESS power plant and substation will be located in a WWII decommissioned runway in Baltra island, following the recommendation of the territory development plan issued by Galapagos Government Council (CGREG). The centralized automatic control system will have its main equipment in Baltra while a backup will be placed in Santa Cruz diesel power plant.

The PV solar production study for the site using PVSYST software projected a yearly generation of 23.60 GWh at P90 and 25.47 GWh/year (P50) as average energy production. The feasibility studies included modelling of the demand and supply with the purpose of identifying the suitable while keeping electrical stability. Considering that by 2019 the renewable energy penetration accounted for 14.4%, the RV Conolophus Project should provide the remaining amount to the recommended 70% participation of renewables in the Santa Cruz Island, at the first whole year of its operation. Please refer to Annex 2 and appendix 1 for further details on the technical feasibility that includes description of the equipment, expected share of energy mix, and characteristics of the centralized automatic control system.

The technical concept of this project tackles specific aspects such as the intermittent nature of the renewable energy sources, the stability and reliability of electric grid operation, and the optimization and renewable sources priority in the generation dispatch. All of them have been main constraints for the expansion of power plants based on renewable energy technologies in the small and isolated Santa Cruz – Baltra island electric grid.

This project becomes the cornerstone for achieving high penetration of renewable energy in Santa Cruz – Baltra and provides the technical means for future generation projects' integration.

Emissions reductions: this activity is expected to reduce:

- An average of 18,893 tCO2e/year, 95,647 tCO2e during the 5 years of implementation and 472,323 tCO2e in 25 years due to avoided diesel-based generation.
- An average of 26. 791 tCO2e/year, 135.62 tCO2e during the 5 years of implementation and 670 tCO2e in 25 years due to avoided transportation of diesel from the mainland.

The project model refers to a public-private partnership where the private organization builds, owns, operates, and transfers the facilities after a 25-year concession period. Further details on contractual and legal aspects are described in Section 14 Implementation arrangements.

Activity 1.1.1.2. Distributed renewable power generation projects.

Distributed energy generation will be increased by opening the Galapagos' Credit Line in CFN and the Local Financial Institutions for channeling funding for the tourism and commercial sectors, although the agricultural and fisheries sectors are also eligible for accessing these credit lines. These interventions are structured in the three subactivities described below.

Beneficiaries will self-generate reducing its dependence on the power grid and creating systemic benefits such as decrease in diesel consumption for power plants, CO2 emissions cuts, fewer large investments in centralized power plants, defer investments in electrical distribution system upgrades extending lifetime of lines and transformers, among others. At the same time, the beneficiaries become sustainable tourism champions at energy use, which aligns with the campaigns for a sustainable touristic sector.

The electrical system of the islands will also profit on the distributed generation projects by decreasing the demand curve at noon and early afternoon, also likely reducing some technical losses at distribution level, and by delaying expansion of the power plants and the sub-transmission system (in the case of Santa Cruz – Baltra). Please refer to Annex 2 appendix 1 for further considerations about the stability of the grid and the regulations requirements.

An intermediation scheme will allow granting loans to beneficiaries of the tourism/commercial, agriculture and fisheries sectors to invest in Micro distributed PV generation through the Galapagos' Credit Line that will be managed by the Public Bank CFN through local banks present in Galápagos. The tourism sector will be targeted in three of the inhabitant islands and will focus on the hotels with the largest energy consumption; Floreana island was not considered because it does not have a commercial sector that impacts on the electricity demand.

This activity expects to reach at least 200 beneficiaries of the tourism/commercial sector (50% in Santa Cruz, 25% in Isabela and 25% in San Cristobal).

Emissions reductions: this activity is expected to reduce:

- An average of 3,116.69 tCO_2e/year, 10,469.30 tCO_2e during 5 years of Programme implementation (assuming loans are provided from year 2 onwards) and 78,773 tCO_2e in 25 years due avoided diesel-based generation.
- An average of 4.55 tCO2e/year, 15.28 tCO2e during 5 years of Programme implementation and 115 tCO2e in 25 years due avoided transportation of diesel from mainland.

Eligibility conditions: The eligibility conditions for accessing loans for distributed RE generation are listed in the table below.

Table 31. Eligibility conditions for accessing loans for distributed RE generation.

Condition	Description
Beneficiaries	a) Ecotourism value chain such as hotels, restaurants, and boat operators. b) Farmers (individuals, cooperatives, associations, MSMEs). c) Small-scale fisheries.
Eligible investments	• Small scale solar PV systems
Minimum objectives	80% GHG emissions reductions 80% reduced Energy consumption
Financing thresholds	From USD 5,000 to 40,000
Minimum co-financing by the beneficiary	20%
E&S category	B or C (category A is not eligible)
Other conditions	Must be proven RE technologies. Micro distributed PV generation must comply with the current regulation on equipment specifications and protection requirements.

12.4.4 Outcome 1.2: Reduced energy consumption by the Galápagos livelihoods through energy efficiency and reduction of fuel imports.

12.4.4.2 Output 1.2.1: Energy-efficient solutions implemented.

Activity 1.2.1.1 Promotion of efficient energy consumption by the Galapagos' livelihoods

An intermediation scheme will allow granting loans to beneficiaries of the tourism/commercial sector through the Galapagos' Credit Line that will be managed by the Public Bank CFN through local financial institutions present in Galápagos. This activity will implement the Second Phase of the Government's Program for Renewal of Inefficient Energy Consumption Equipment. The objective is to optimize the electrical energy consumption in the acclimatization and refrigeration areas, with replacement of 3.200 units (1900 Refrigerators and 1300 A/C) in the tourist/ commercial sector. This replacement would obtain savings of 2,279.5 MWh/year (1,357.2 MWh/year from refrigerators and 922.3 MWh/year from A/Cs).

Emissions reductions: this activity is expected to reduce:

- An average of 1,322.90 tCO2e/year, 4,988.39 tCO2e during 5 years of Programme implementation (assuming loans are provided from year 2 onwards) and 33,072 tCO2e in 25 years due avoided diesel-based generation.
- An average of 1.94 tCO2e/year, 7.31 tCO2e during 5 years of Programme implementation and 48 tCO2e in 25 years due avoided transportation of diesel from mainland.

Table 32. Eligibility conditions for accessing loans for energy efficiency investments.

Condition	Description
Beneficiaries	a) Ecotourism value chain such as hotels, restaurants, and boat operators.
Eligible investments	• Air conditioners. • Refrigerators.
Minimum objectives	Air conditioners: • 20% GHG emissions reductions • 20% reduced Energy consumption Refrigerators: • 15% GHG emissions reductions • 15% reduced Energy consumption
Financing thresholds	From USD 300 to USD 10,000
Minimum co-financing by the beneficiary	20%
E&S category	B or C (category A is not eligible)
Other conditions	Equipment rated A in energy consumption. Split air conditioners. Inverter technology.

12.4.4.3 Output 1.2.2 Strengthened Executing Entities and stakeholders' capacities for the development and implementation of mitigation projects.

Activity 1.2.2.1: Technical Assistance facility for energy investments

The objective of the activity is to facilitate the implementation of the Programme by increasing knowledge on climate change and low carbon energy investment projects, supporting local financial institutions, actors of the touristic, agricultural and fisheries sectors, and technical service providers to strengthen their capacities, as well as ensuring the dissemination of lessons learned and general learning throughout the Programme. These activities are structured in the sub-activities described below.

The beneficiaries of this activity are:

- Financial institutions providing loans under the program.
- Technology and technical assistance providers.
- Stakeholders in the tourism, agriculture, and artisanal fisheries sectors.

Matchmaking events to facilitate development of mitigation projects.

The objective is to contribute to building a relationship of trust between TSPs, local banks and stakeholders in the tourism, agricultural and artisanal fishing sectors. One of the main barriers identified for the adoption of these technologies is the lack of knowledge of the banks and potential beneficiaries in the tourism, agriculture, and artisanal fishing sectors. Matchmaking events will be held between local banks and technical assistance providers to facilitate project development. Through this activity, the participation of more than 200 people (40% women) is planned, through the organization of workshops during years 1, 2 and 3.

Technical Assistance for Local Banks

Aimed at local banks that grant loans under the program to strengthen the capacity of officers, executives and staff involved in the Programme to identify potential clients, evaluate potential beneficiaries and projects based on eligibility criteria, and determine potential bankable projects. The following types of training will be offered:

- Renewable energy, energy efficiency and sustainable building project evaluation.
- EE and RE contractual agreements between clients and suppliers.
- Strengthening for environmental and social risk management of projects.
- Technical support for the definition of GHG baseline and MRV.

Through this activity, the participation of around 40 people (40% women) is planned, through the organization of training sessions in years 1, 2 and 3.

Technical Assistance for Final Beneficiaries

The objective is to strengthen capacity and provide technical support to beneficiaries in the tourism, agricultural and artisanal fisheries sectors and technical service providers for effective project development and implementation of mitigation projects. Technical assistance will address:

- Training in mitigation project preparation and management: how to structure bankable projects, environmental and social safeguards, understanding contractual agreements between clients and suppliers.
- Training for women at the head of companies in the sector to bridge identified gaps related to knowledge on green business.
- Pre-investment activities: will include feasibility studies for the identification of RE, EE and sustainable construction development opportunities, environmental and financial assessments, support for business plan development, and other advisory activities necessary for the effective implementation of climate investments.
- Technical support for the definition of baseline and MRV.

Through this activity, the participation of more than 1,800 people (20% women) is planned, through the organization of training activities in years 1 to 4.

12.4.4.1 Market studies

12.4.4.1.1 Renewable energy.

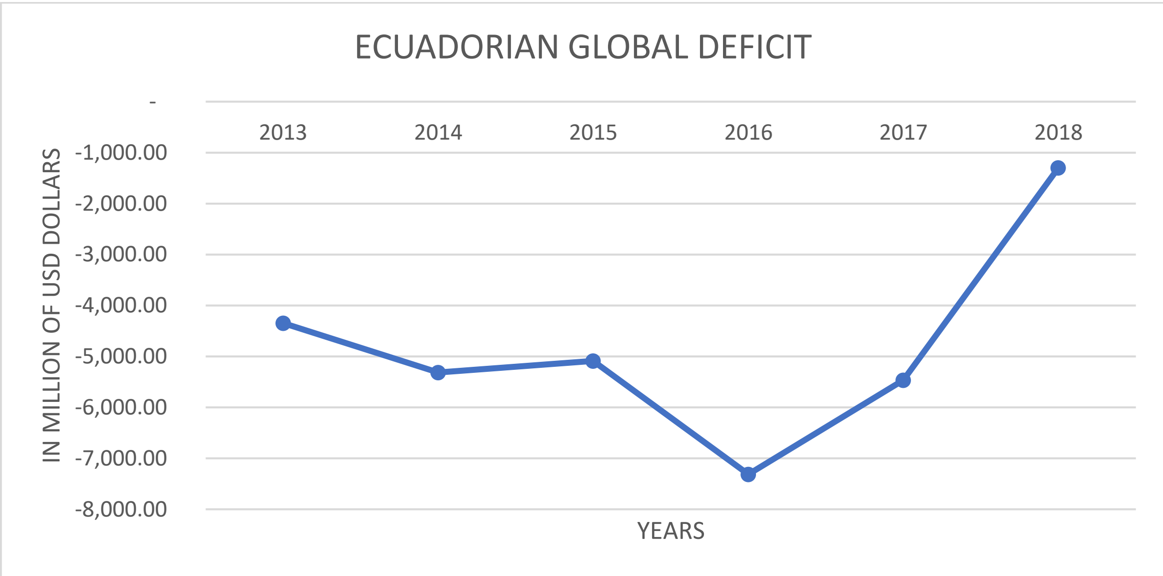
A market study was performed to determine for the market appetite of the tourism/commercial sector for the renewable energy products. Please refer to Annex 2 appendix 1 for further details on demand, energy consumption, demand willingness to purchase the product via credit and payment capability. The information sources are surveys (primary source) and secondary sources such as banking system public information, official data bases, and massive consumption methodology.

12.4.4.1.2 Centralized renewable energy

Ecuadorian Deficit

Since 2007, the government began an aggressive process of building hydroelectric and thermoelectric plants (Observatory for renewable energy in Latin America and the Caribbean, 2011). As a result, Ecuador's continental energy demand is completely satisfied, however, the cost of this process for the national treasury was high. According, to the Ecuadorian Observatory of Fiscal Policy, in eight years 20% of the current GDP was assigned to the construction of hydroelectric and petrochemical (Observatory for fiscal policy, 2019). During this decade Galapagos was not able to realize its intention to replace fossil fuel for RE generation, and nowadays the government's current fiscal budget presents a deficit status, making it impossible to engage in new RE investments.

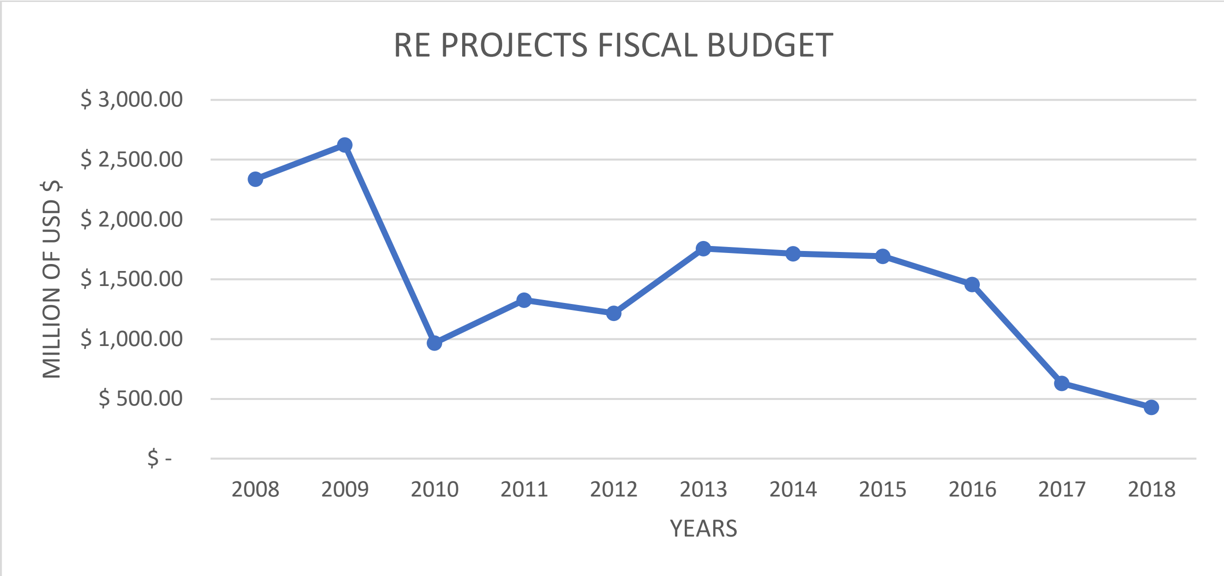
Figure 47. Ecuadorian Deficit



Source: Ecuadorian Observatory for fiscal policy, 2019

Moreover, the Ecuadorian government has a specific account assigned for this kind of projects, whose trend is presented in the previous Figure.

Figure 48. Trend of fiscal account for RE projects



Source: Ecuadorian Observatory for fiscal policy, 2019

As shown, the fiscal budget for RE projects for 2018 was less than $500 million, whereas in 2009 was $2,623 million, which means an 84% decrease. For 2019, the fiscal budget for renewable energy is almost nonexistent as stated in the official financial plan9.

It can be stated that the government does not possess the necessary capital resources to develop RE projects in Galápagos. Therefore, the government has started to promote the private sector enrolment in RE projects; for instance, a key government energy project such as "El Aromo" has been opened to private investors10. The execution contract of this new modality is that the government lets the private sector construct the RE projects and after a period of time the ownership of this project passes to the government.

Private Companies

The private sector declared its intentions to aid the government's plan by investing in RE in Galapagos. This interest was verified during the launching event of this funding proposal for GCF held in Quito 5/06/2019 (El Comercio, 2019).

During the last ten years, the government classified the energy sector as "public interest", which means that all energy plants have a great deal of government intervention (Ministry Coordinator of Strategic Sectors, 2016). Due to this, the private sector had minimal involvement in the energy industry.

According to the latest sectoral analysis of Superintendence of Companies (2014), the electricity production industry shows the following return on equity (ROE).

Table 33. Energy Industry return on equity data

Average	Maximum	Minimum	Standard Deviation
19%	30%	-5%	1,43

Source: Superintendence of Companies

9 Ecuadorian fiscal budget account #421: https://www.finanzas.gob.ec/wp-content/uploads/downloads/2018/11/13-CN_Por-Entidad_Gastos.pdf

10 Press note on "El Aromo": https://www.eluniverso.com/noticias/2019/07/26/nota/7442706/proyectos-energia-se-licitan-cuatro-dias

An investor should expect at least the average return on equity (investment) of the Ecuadorian electricity industry, which takes into account the sovereign risk of the country (Emerging markets bond index), which as September 3th, 2019 is 6,93%[11].

Distributed Renewable Energy

PRODUCT DESCRIPTION

A photovoltaic (PV) module or solar electric panel is the smallest replaceable unit in a PV array. The module is an integral unit that provides support for a number of PV cells connected electrically and protected from the elements. The electrical output of the module depends on the size and number of cells, their electrical interconnection, and, of course, on the environmental conditions to which the module is exposed. Solar electric panels come in all shapes and sizes and may be made from different materials. However, the most commonly used module is a "glass-plate-sandwich" that has 36 PV cells connected in series to produce enough voltage to charge a 12-volt battery. The purpose of the structure is to provide a rigid package and protect the inter-cell connections from the environment. Plus (+) and minus (-) connectors are located on the back of the module for interconnection. The modules may have an individual metal frame or be protected by a rubber gasket and intended for installation in a larger mounting system designed to hold several modules.

The industry standard against which all PV modules are rated and can be compared is called Standard Test Conditions (STC). STC is a defined set of laboratory test conditions which approximate conditions under which solar panels, or PV modules, might be used. Although there are other standards that offer better real-world approximations, STC offers the most universal standard. The same standard is also used to evaluate potential installation locations, since it is the basis for values. STC includes three factors:

1. Irradiance (sunlight intensity or power), in Watts per square meter falling on a flat surface. The measurement standard is 1 kW per sq. m. (1,000 Watts/m2)

2. Air Mass refers to “thickness” and clarity of the air through which the sunlight passes to reach the modules (sun angle affects this value). The standard is 1.5.

3. Cell temperature, which will differ from ambient air temperature. STC defines cell testing temperature as 25 degrees C.

The aim of this study is to commercialize entire kits of self-production of energy, not just the solar panels. Thus, pole Mount (where necessary), controller, cable and support are included. More specifically, the solar panel kits come complete with multicrystalline solar panel, side of pole/wall mounts, PWM Charge Controller and outdoor rated 12AWG cable. Technical assistance is included.

Average Price

The following list describes the main Ecuadorian solar panels kits providers and their retail price for one KWp. It is important to mention that not many suppliers of this energy can be found in Ecuador since electric energy is state subsidized.

Table 34. Solar panels kit suppliers

Supplier name	**Price per KWp**

11 Ecuadorian Central Bank, EMBI information: https://www.bce.fin.ec/index.php/informacioneconomica

Proviento	$1826
Enercity	$1995
Renova Energía	$1900
Solergy	$1881
Ecohit	$1947

Source: Mentefactura and suplliers

The average price is $1910.

Prices in Galapagos

It is important to mention that prices in the Galapagos vary substantially from the prices in the mainland. The reason is that the islands are located 1,000 kilometers from the mainland, so many food and products have to get there by boat or by air, which significantly increases the cost of goods. In fact, the National Institute of Statistics and Censuses (INEC) has developed a price index exclusively for Galapagos.

The last update of this index, which is a joint work between the INEC and the Ministry of Labor and the Government Council of Galapagos, showed that the results of the calculation of the Galapagos Space Consumer Price Index (IPCEG) is located at 1,803, that is, the price level of the archipelago (cost of living) is 80% higher than in the rest of the country.

It is important to mention that on June 11, 2015, the Special Law of Galapagos was published in Official Gazette No. 520, established that the salaries of Galapagos workers will be paid with an increase that will be calculated by multiplying the Consumer Price Index (CPI) annual with respect to the prices of continental Ecuador.

The previous Law established that the salaries of public officials must have an increase of 100% with respect to those of Continental Ecuador, while for private workers it established a 75%.

However, after talking to solar panels kit suppliers, the price of the product will not increase in 80% but 30% for this type of products. Therefore, the average price for solar panels kits in the islands is $2500.

Energy Demand

According to the technical feasibility document of this funding proposal, the demand for energy in KWp of tourism business goes as following.

Table 35. Electricity demand

Island	Demand in KWp
San Cristóbal	14
Santa Cruz	45
Isabela	17

Source: Mentefactura

BENEFICIARY STATISTICS

The following data was collected between august and November 2020 via surveys and focus groups. The survey technical analysis is the following.

Sample Calculation

The sample size calculation for this study is based on Yamane[12] sample size formula. The aim of the calculation is to determine an adequate sample size which can estimate results for the whole population with a good precision.

Yamane's formula to calculate a representative sample is the following:

$$n = \frac{N}{1 + N(e^2)}$$

Where, N is the population size and e is the desired level of precision.

The level of confidence for this study will be 95%, which means that out of 100% independent samples from the same population, then 95 out of the 100 samples will provide an estimate within this percentage precision. The degree of precision is the margin of permissible error between the estimated value and the population value. In accordance with the level of confidence of this study, the degree of precession was set to +/- 5%.

The sample size the survey cannot be calculated as a total, since the properties of each surveyed vary considerably. However, the universe can be divided into categories, which are: Hotels, Businesses, Restaurants and Vessels. According the Galapagos Tourism Observatory[13] the total registered tourism businesses in the islands are:

Table 36. Total Businesses Universe.

	Lodging	Food & Beverages	Tourist Operators
Number of Registries	321	143	227

Since the program aims to provide financing to these business via public financial institutions, a segregation of each category was performed according to financial requirements of local public banks.

In the food and beverages category, the population data was segregated to restaurants and cafeterias with eight or more tables. According to the economic national census[14] an establishment with less than eight tables does not pursue financing.

Regarding the lodging industry, the hostels and hotels with more than 10 rooms were considered for the sample calculation. According to the economic national census a lodging establishment with more than 10 rooms has an acquired financing.

The tourist operators population data considered were the businesses with more than four employees. According to the National Association of Banks[15], a business with less than four employees tends to receive a microcredit loan, which is not the target of this program.

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12 Calculation of the sample size (Yamane, 1967)

13 Galapagos Tourism Report May 2019. https://www.observatoriogalapagos.gob.ec/wp-content/uploads/2019/05/Estad%C3%ADsticas_turismo_Gal%C3%A1pagos_2018_V1.pdf

14 Ecuadorian National Census and Statistics Institute https://www.ecuadorencifras.gob.ec/hoteles-restaurantes-y-servicios/

15 National Association of Banks Credit Report. https://www.asobanca.org.ec/publicaciones/estudios-especiales

The results of the data segregation are the following:

Table 37. Segregated Population.

	Lodging	Food & Beverages	Tourist Operators
Number of Registries	122	89	23

In order to achieve sample calculation precision, Table 2 was categorized according to the island it operates as follows:

Table 38. Segregated Population by Island.

	Lodging	Food & Beverages	Tourist Operators
Floreana	2	2	0
Isabela	28	26	3
San Cristobál	31	23	4
Santa Cruz	64	40	16

Sample Size Calculation

For Floreana:

Lodging:

$$n_h = \frac{2}{1 + 2\,(0.05^2)}$$

$$n_h = 2$$

Food & Beverages:

$$n_h = \frac{2}{1 + 2\,(0.05^2)}$$

$$n_h = 2$$

For Isabela:

Lodging:

$$n_h = \frac{28}{1 + 28\,(0.05^2)}$$

$$n_h = 26$$

Food & Beverages:

$$n_h = \frac{26}{1 + 26\,(0.05^2)}$$

$$n_h = 25$$

Tourist Operators:

$$n_h = \frac{3}{1 + 3\,(0.05^2)}$$

$$n_h = 3$$

For San Cristobál:

Lodging:

$$n_h = \frac{31}{1 + 31\,(0.05^2)}$$

$$n_h = 29$$

Food & Beverages:

$$n_h = \frac{23}{1 + 23\,(0.05^2)}$$

$$n_h = 22$$

Tourist Operators:

$$n_h = \frac{4}{1 + 4\,(0.05^2)}$$

$$n_h = 4$$

For Santa Cruz:

Lodging:

$$n_h = \frac{64}{1 + 64\,(0.05^2)}$$

$$n_h = 55$$

Food & Beverages:

$$n_h = \frac{40}{1 + 40\,(0.05^2)}$$

$$n_h = 36$$

Tourist Operators:

$$n_h = \frac{16}{1 + 16\,(0.05^2)}$$

$$n_h = 15$$

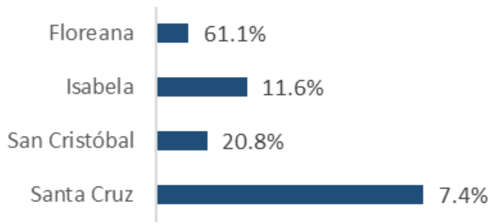
The following table is the summary is the sample calculations.

Table 39. *Sample Size by Island*

	Lodging	Food & Beverages	Tourist Operators
Floreana	2	2	0
Isabela	26	25	3
San Cristobál	29	22	4
Santa Cruz	55	36	15
Total	**112**	**85**	**22**

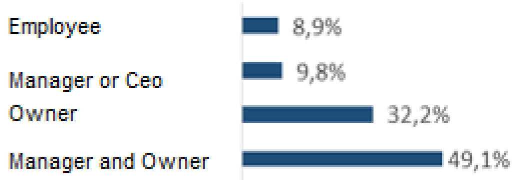
Results Overview

Surveyed businesses



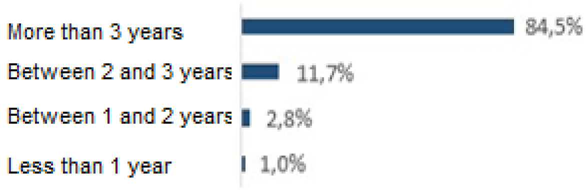
The total of valid surveys adds up to 218 surveys (sample 219), distributed as follows: 132 correspond to Santa Cruz, 25 San Cristóbal, 45 Isabela and 16 Floreana.

Job title of the surveyed



49.1% of the interviewed indicate being Owner Manager and 32.2% corresponds to Owner.

Company Age and Number of Employees



A company that has been operating for a short time is usually not susceptible to receive a loan. Companies that are less than one year old do not have the necessary information to generate a projected cash flow. With 3 or more years of operation the requirement is met.

Regarding the years of operation of the companies, 84.5% of the interviewees mention that the operations exceed 3 years of operation.

The arithmetic mean of employees that are men is 3.7, for women is 2.7

Product Acceptance

For 60.1% of the interviewees, they are interested in installing equipment that produces energy from renewable sources as long as there is financing and for 56.8% they are interested as long as the investment made reduces fixed costs.

Financial aspects of the beneficiaries

The financial aspects of the beneficiaries were collected via questions in the survey mentioned above. These questions are shown in this section.

On average, how many tourists hire the services of your company annually?

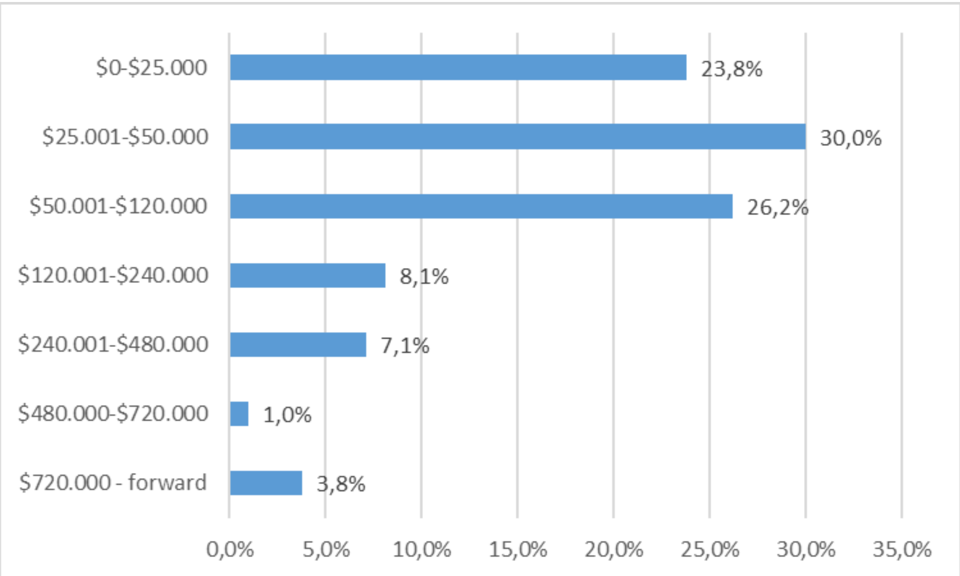
Note: In a later question, the amount of sales is asked, considering this information for the number of customers, the average sale price can be obtained. This data informs us of the average equilibrium point. A question of ranges was not asked because the answers can be very varied between restaurants, businesses, and hotels.

Result: The number of tourists who hire the services of your company annually corresponds to a total of 1500 and 2000 annually.

What was the approximate annual sales amount in 2019?

Note: The monthly sales amount is key to determining the amount of credit that can be granted. The sales ranges were established according to the sales records in Galapagos published in the Superintendency of Companies.

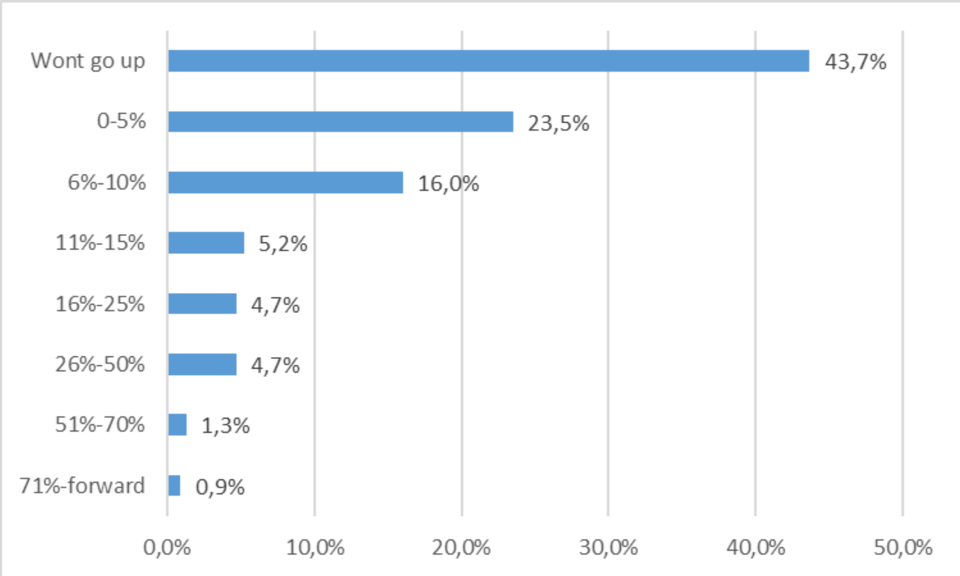
Results:



30% of the interviewed indicate a sales range between 25,001 and 50,000 US dollars.

In what percentage range do you think your sales will increase in 2022 compared to 2019?

Results:

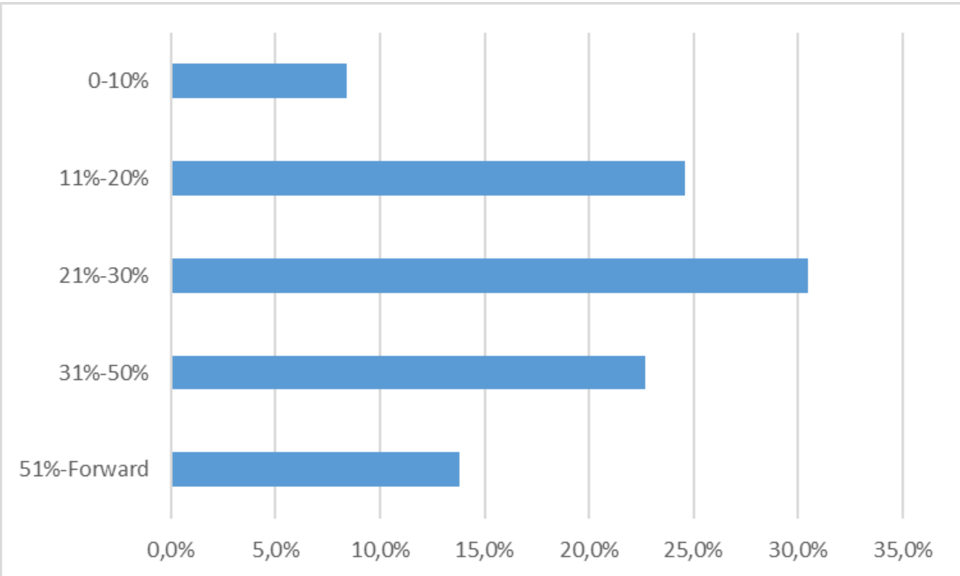


43% of those interviewed consider that their sales will not increase in 2022 compared to 2029 and 23.5% of those interviewed consider that they will increase between 0 and 5%.

What was the approximate weight of fixed costs in relation to annual sales for 2019?

Note: This question measures the guarantee to face the debt.

Results:

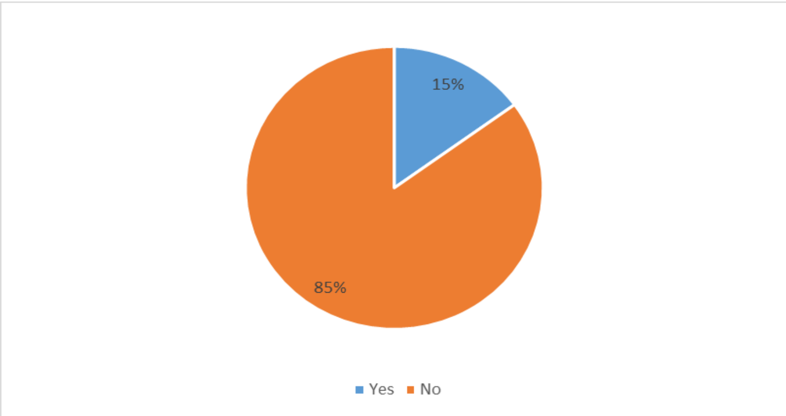


31.5% consider that the approximate weight of the fixed costs in relation to the annual sales of 2019 corresponded between 21% and 30%.

Did you report financial losses to the IRS last year (2019)?

Note: The most recent profitability is an essential indicator to establish the ability to pay a loan.

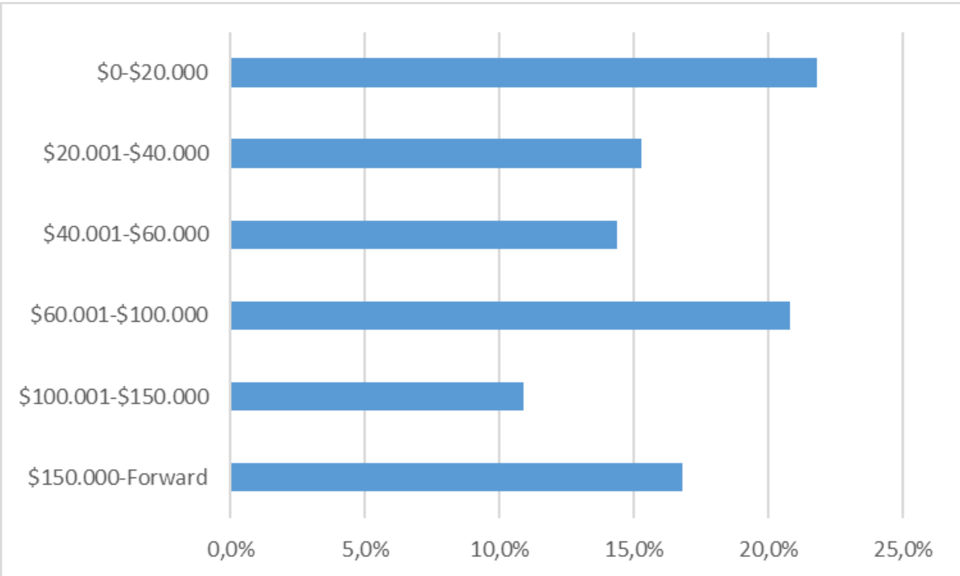
Results:



Approximately what is the amount of fixed assets of your company?

Note: One of the characteristics that classifies a company within the microenterprise, SME, corporate, etc. ranges is the value of fixed assets. The type of credit changes according to its category

Results:

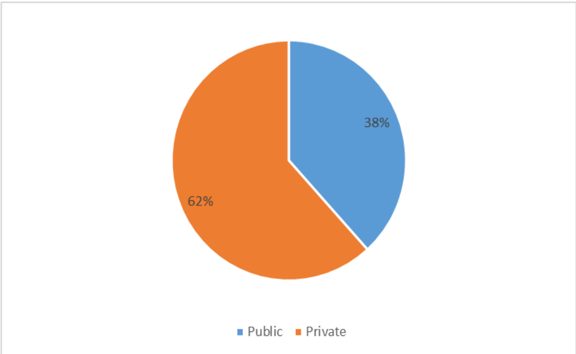


21.8% indicate that the total amount of fixed assets of their company fluctuates between 0 and 20,000 US dollars and for 16.8% of the interviewed is 150,000 US dollars or more.

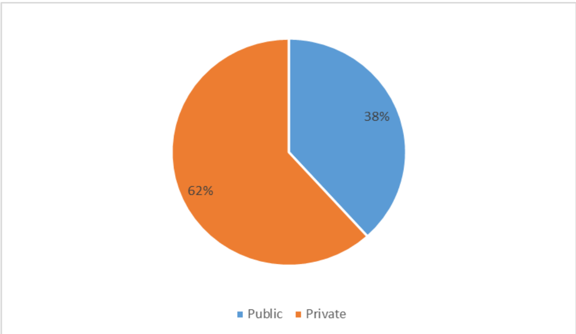
Do you have a debt with a financial institution?

Note: Pre-existing debts affect the solvency of the company. But above all the relevance of this question is to determine if the company has a credit record.

Results:



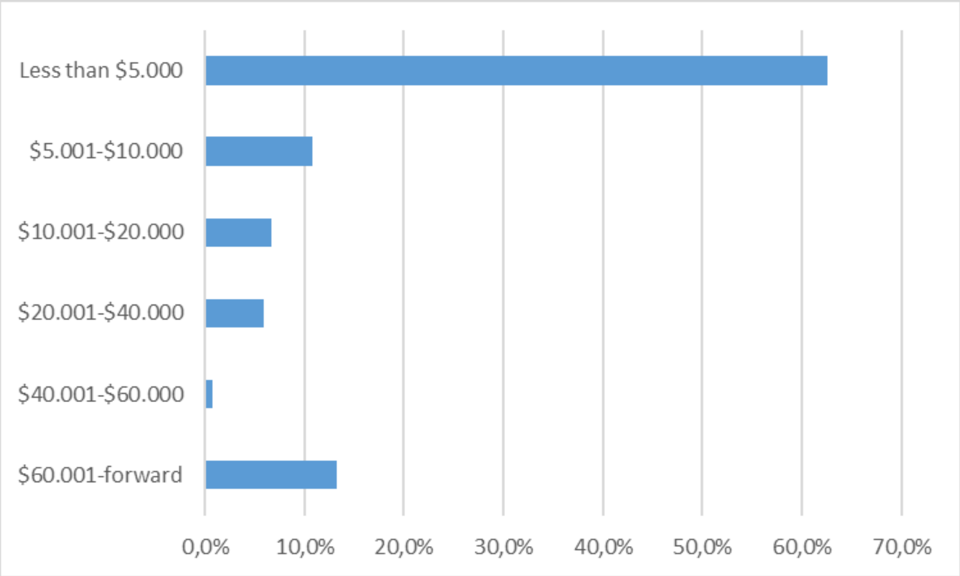
If you answer yes to the previous question, was the financial institution private or public?



Approximately what is the amount of the debt in monthly installments?

Note: This question helps to measures the monthly free cash flow

Results:

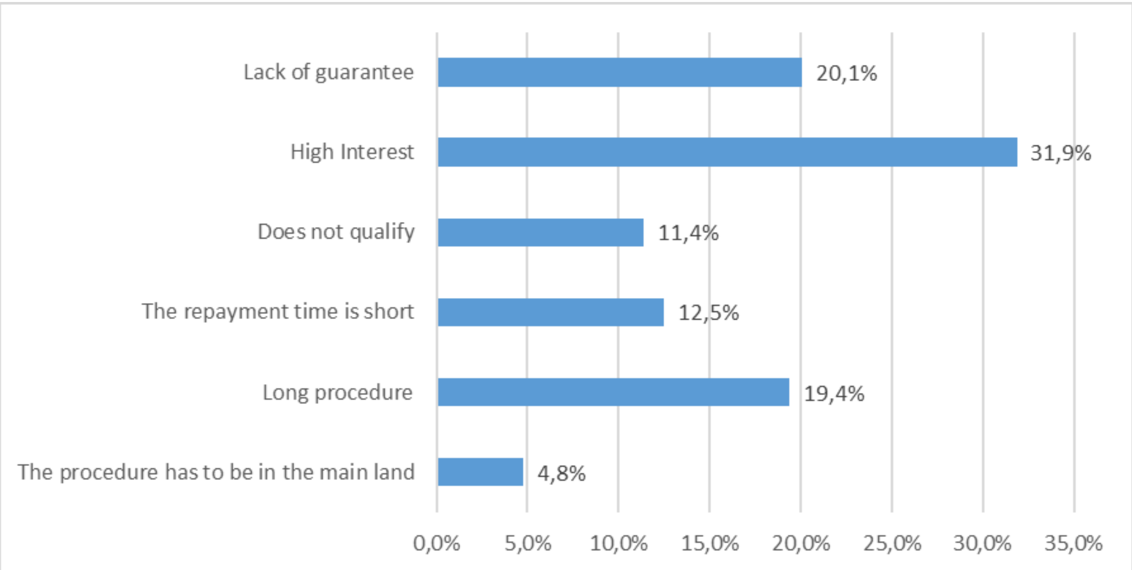


For 65.5%, the monthly amount of the debt is less than $ 5,000. While for 13.3%, the monthly dividend exceeds 60,001 US dollars.

In your opinion, what are the main obstacles to obtain a credit?

Note: This question helps to establish the characteristics of the financial product.

Results:



31.9% consider that one of the main obstacles to accessing a loan is high interest.

In your opinion, what is the main financial need at present for the reactivation of the business?

Results:

74.9% consider that the main financial need at present for the reactivation of the business is to access loans for working capital. 44.9% indicate that it is credit to cover labor obligations and 28.5% for technical advice.

In 2021, what are your non-reimbursable technical cooperation needs so that your business is directed towards the sustainable development of the sector?

64% of the individuals consider that training is required, and 46.9% assistance for promotion and marketing and 37.9% access to certifications related to sustainability.

CONCLUSIONS ON POTENCIAL MARKET

Considering the potential accommodation market for which we have the information of installed capacity and the price of KWp. Also, considering the finances of potential clients.

There is a potential market of **$ 6.514.525,00**.

The previous statement is backup by the following calculation.

Assumptions and data		
A	Total Universe Isabela	52
B	Total Universe San Cristobal	52
C	Total Universe Santa Cruz	100
D	KWp Isabela	394,27
E	KWp San Cristobal	394,7
F	KWp Santa Cruz	1816,84
G	Financial Capacity	55%
H	Market acceptance	60%
I	Average price by KWp	2.500,00

Market calculations Isabela		
J	Potential business in KWp (D)	394
K	Potential business in $ (J*I)	985.675,00

Market calculation San Cristobal		
M	Potential business in KWp (E)	395
N	Potential business in (M*I)	986.750,00

Market calculation Santa Cruz		
P	Potential business in KWp (F)	1.817
Q	Potential business in $ (P*I)	4.542.100,00

Total market distributed energy	
Potential Market (K+N+Q)	**$ 6.514.525,00**

12.4.4.1.3 Energy efficiency.

A market study was performed to determine for the market appetite of the tourism/commercial sector for the energy efficiency products. Please refer to Annex 2 appendix 1.1 for further details on demand, energy consumption, demand willingness to purchase the product via credit and payment capability. The information sources are surveys (primary source) and secondary sources such as banking system public information, official data bases, and massive consumption methodology.

PRODUCT DESCRIPTION FOR RESIDENTIAL HABITANTS

The emphasis of this study is the RENOVA program. The implementation of the Program of Refrigerators Renewal – RENOVA – which was performed in a first phase (2012 – 2016) at national level, 95.645 units were replaced, processing in consequence 6.012,72 tons of scrap metal and recovering 2.733 kg of refrigerant gases (2.557,945 kg of CFC12 and 175,1 kg of R134a)16.

The goal in Galápagos was the replacement of 1.109 refrigerators, mainly in Santa Cruz Island, considering the biggest residential sector, reaching a saving of approximately 430 MWh/year.

The Secretary of the Government has considered that for the next phase of the Program the impulse to the replacement of inefficient equipment must continue in Galapagos, because the use of fossil fuels remains in almost 90% and also due this is an isolated system having reduced electrical generation from renewable sources, which results in a subsidy provided from the Government for the provision of the service.

In addition, it had been established that the sectors registering the greater electricity consumption are the residential and commercial ones, where it is important to strengthen the energy efficiency policy, emphasizing in the main uses of the energy in the province: refrigeration and acclimatization.

Objective of the Program for Renewal of Inefficient Energy Consumption Equipment Second Phase: Optimize the electrical energy consumption in the acclimatization and refrigeration areas, with replacement of 3.200 units (1900 Refrigerators and 1300 A/c) in the tourist commercial sectors of the Province of Galapagos with the purpose to reduce the amounts invested by the Government in the electrical generation of that intervention zone.

Baseline

- Refrigeration Equipment

The national market began the commercialization of refrigeration and acclimatization equipment of domestic use with a best efficient level, with average saving ranges between 250 and 450 kWh/year, corresponding to the A, B and C types, regarding the Ecuadorian Technical Regulation - RTE 035-2009.

- Air-conditioning Equipment

Recent referential data provided by national suppliers report the sales distribution of air-conditioning units in the insular region, with 53% of units of 12.000 BTU/h of Split type. Additionally, there are 25% of window type units, and the remaining units are Split type for the total of the surveyed sample for the two sectors.

16 RENOVA report of first phase, January 2017. Ministerio de Electricidad y Energía Renovable.

Expected results due the replacement of equipment.

Based on the results obtained for the first phase, it is expected to continue with the energy saving via the replacement of old equipment by other with most efficient technology, and below the data and suppositions considered for the next calculations are detailed:

Table 40. RENOVA Second Phase results (Energy Saving)

Equipment to replace	**Saving in Electricity (MWh/year)**
1300 Acclimatization	922,3
1900 Refrigeration	1.357,2
Total	2.279,5

It is expected to obtain an energy consumption saving of 2.279 MWh, which will permit to achieve an economical saving of USD 899.006,00 considering the generation and distribution cost for the electrical utility of 39 cents/kWh (real cost of electricity generation).

After to complete the Project, the total of replaced equipment yearly will generate a saving of 2.279 MWh/year.

Regarding the power demand it is estimated to obtain 447 kW (5% respect the maximum demand), which permits to have an economical saving of USD 365.774,48 considering the cost of 818.49 USD/installed kW for thermal generation.

Product characteristics

According to the RENOVA plan, the characteristics of these are air conditioners of 9000 “British Thermal Units” (BTU) and 12000 BTUs. Refrigerators must be nationally produced Ri 365 models.

Average Price

The following list describes the mainland Ecuadorian household electric appliances market leaders their retail price for air conditioning and refrigerators. These providers do not have much presence in Galapagos. However, they represent a optimal benchmark for Galapagos.

Table 41. Suppliers of household appliances

Supplier name	**Price per refrigerator Ri365 models**
Comandato	$400
La Ganga	$390
Almacenes Japon	$400
Sukasa	$410
Supplier name	**Price per air conditioning 9000 BTU**
Comandato	$359
La Ganga	$349
Almacenes Japon	$355
Sukasa	$365

Source: Mentefactura and suppliers

The average price for refrigerators is $400 and for air conditioning is 357.

Prices in Galapagos

It is important to mention that prices in the Galapagos vary substantially from the prices in the mainland. The reason is that the islands are located 1,000 kilometers from the mainland, so many food and products have to get there by boat or by air, which significantly increases the cost of goods. In fact, the National Institute of Statistics and Censuses (INEC) has developed a price index exclusively for Galapagos.

The last update of this index, which is a joint work between the INEC and the Ministry of Labor and the Government Council of Galapagos, showed that the results of the calculation of the Galapagos Space Consumer Price Index (IPCEG) is located at 1,803, that is, the price level of the archipelago (cost of living) is 80% higher than in the rest of the country.

It is important to mention that on June 11, 2015, the Special Law of Galapagos was published in Official Gazette No. 520, established that the salaries of Galapagos workers will be paid with an increase that will be calculated by multiplying the Consumer Price Index (CPI) annual with respect to the prices of continental Ecuador.

The previous Law established that the salaries of public officials must have an increase of 100% with respect to those of Continental Ecuador, while for private workers it established a 75%.

However, after talking to local citizens of Galapagos, the price of the product will not increase in 80% but 40%, which is in accordance to the distributed market study. Therefore, the average price for refrigerators is $560 and for air conditioning is $499.

POTENTIAL MARKET FOR RESIDENTIAL HABITANTS

Taking into account the RENOVA forecast of efficient appliances sales and the current prices the potential market in USD for acclimatization appliances is $649.740 while for refrigerators is $1.082.050. This means that the total market for residential habitants is $1.731.790

PRODUCT DESCRIPTION FOR TOURIST BUSINESS

Baseline

- Refrigeration Equipment

The national market began the commercialization of refrigeration and acclimatization equipment of domestic use with a best efficient level, with average saving ranges between 250 and 450 kWh/year, corresponding to the A, B and C types, regarding the Ecuadorian Technical Regulation - RTE 035-2009.

- Air-conditioning Equipment

Recent referential data provided by national suppliers report the sales distribution of air-conditioning units in the insular region, with 53% of units of 12.000 BTU/h of Split type. Additionally, there are 25% of window type units, and the remaining units are Split type for the total of the surveyed sample for the two sectors.

BENEFICIARY STATISTICS

This section is the same as the beneficiary statistics of the distributed market study.

POTENTIAL MARKET

Every business in the potential market has the financial strength to respond for a loan of $ 1,040 to make a replacement of two refrigeration equipment (average).

Likewise, considering an average replacement of 3 airs of $ 464 each and taking into account the growth in purchasing power, there is a potential market of $ 643,708 of customers willing to change equipment.

The previous statement is backup by the following calculation.

Assumptions and data		
A	Total Universe	335
B	Acceptance to change appliances	79%
C	Average number of refrigerators per business	2
D	Average number of air conditioning per business	3
E	Average price of refrigerators	$ 400
F	Average price of air conditioning	$ 357
G	Price increase in Galapagos	40%

Calculation of the refrigerators market		
H	Business market (A*B)	265
I	Average number of refrigerators per business (C*H)	529,3
J	Price adjustment (E*(1+G))	560
K	*Potential market in $ (J*I)*	*296.408,00*

Calculation of the air conditioning market		
L	Business market (A*B)	265
M	Average number of air conditioning per business (L*D)	793,95
N	Price adjustment (F*(1+G))	499,8
O	*Potential market in $ (M*N)*	*396.816,21*

Total market		
Potential market (O+K)	**$**	**693.224,21**

It is crucial to mention that according to the surveyed business, the change of refrigerators and air conditioning appliances occurs every 10 years since the extensive use depreciates the equipment in an accelerated manner. Because of this reason, the potential market is USD $1.386.448,42 since the program maturity is 10 years in which one appliances replacement would be made.

12.5 Component 2: Building climate resilience of the Galapagos' livelihoods.

As described in previous sections, the food system of the Galapagos Islands, as in other oceanic islands of the Eastern Tropical Pacific, is affected by disturbances generated by an increasing and a diverse number of drivers of change, which act simultaneously at different spatial scales. Some of the most relevant include invasive species, unsustainable tourism, IUU fishing, overfishing, marine pollution, climate variability and change, and more recently, the COVID-19 pandemic. Previous sections explained how these drivers affect the sustainability and resilience of food systems and thus their ability to provide the food on which the Galapagos population depends on sustaining their economy and food security.

The vulnerability of the Galapagos food system to the COVID-19 pandemic has made it clear that a transformation of this system is required to strengthen its sustainability and resilience in the face of future crises, including new pandemics the intensification of climate change, or other anthropogenic drivers of change. To this end, the Program proposes the implementation of ecosystem-based adaptation measures (EBA). In other words, the adoption of measures designed to simultaneously reduce poverty, protect biodiversity and ecosystem services, and mitigate GHG emissions. Therefore, an EBA integrates the use of biodiversity and ecosystem services through a comprehensive strategy to improve the sustainability and resilience of food systems, thus helping to improve the ability of humans to adapt to the adverse impacts generated by climate variability and change.

Therefore, Component 2 will promote the implementation of EBA to increase the resilience of Galapagos ecosystems, food systems and livelihoods to climate change while reducing the dependence on food imported from mainland Ecuador, and therefore contributing to reduce GHG emissions related to goods transportation. In the case of agriculture, the Program will increase the adaptive capacity of farmers through achieving participatory and integral farm planning with producers, technical assistance and concessional credit for the application of climate change adaptation measures, adequate materials and equipment. Income diversification opportunities for resilient climate production will create new market channels with the tourist industry and the local population. The integration of farming and seafood products into the tourism value chain (Output 3.3) will increase the consumption of local food products and improve the Galapagos' food self-sufficiency.

Furthermore, the Program will implement three main EBA to improve the resilience and adaptive capacity of the Galapagos small-scale fisheries in the face of various drivers of change, including climate change. The first EBA proposes improving the design and management effectiveness of the new Galapagos marine zoning to reconcile conservation and fishery management objectives. The effective implementation of the new marine zoning, combined with a co-management regime, long-term ecological and fisheries monitoring programs, coupled with an advanced information system, and a structured decision-making framework, will promote the adaptive co-management of the GMR. The successful implementation of this ecosystem-based management approach is expected to be an effective solution for rebuilding depleted marine populations, conserving HEVAS, and increase the resilience of marine ecosystems, fishery resources and fishers to climate change. The second EBA proposes restoring the ecological function of overexploited populations and diversifying the livelihoods of the fishing sector and local community through a climate-smart approach to small-scale fishing and aquaculture. In other words, through a management approach based on an ecosystem approach to fishing and aquaculture, through which productivity and economic income are increased sustainably, greenhouse gases generated by fishing activity are reduced and strengthen the resilience of fishing systems to climate variability and change. Finally, the third EBA will diversify fishers' livelihoods based on four pillars: innovation and technology, circular economy, public-private investment and the sustainable development of the Galapagos tuna fishery.

In the same line, the Program seeks to increase the resilience capacity of critically threatened ecosystems to sustain nature-based tourism, the agricultural production and the small-scale fisheries of the Galápagos. The Program will implement two main EBA, one centred in the Scalesia forests of the inhabited islands, to preserve and restore critical habitats for endemic threatened species that constitute important attractions for inland tourism while controlling invasive species to guarantee agricultural productivity production. The second EBA focuses primarily on conserving and restoring coral formations and seabeds that constitute the biggest attraction for diving tourism and constitute critical habitats for many overfished targeted fishes.

Specific behavioral maps will be developed for each component/sector, and these will guide how we target our interventions -the behaviors that our implementation strategies should aim to change. For this component, through a behavioral map, we will prioritize and select target behaviors based on the extent to which they contribute to increasing local food systems and livelihoods´ resilience to climate change, and how likely it is that we have a meaningful impact through behavior change interventions.

Drawing on behavioral science literature and evidence, we will develop potential solutions to reach Component 2 outputs, addressing the barriers or building on the enablers identified for behavior change. Please refer to Appendix 3.4 for an illustrative example where behavioral goals and potential techniques to promote behavioral changes for a blue circular economy through new sustainable and socially responsible seafood enterprises (activity 2.1.5.4) and to put in place a long-term financing mechanism to improve sustainability and competitiveness of Galapagos small-scale fishing sector (activity 2.1.5.5.), are identified.

The following sections describe each outcome, output and activities of Component 2, including a description of targets, beneficiaries and estimated costs. Figure 49 summarizes outcomes and outputs of Component 2.

Figure 49. Summary of Component 2 outcomes and outputs

Outcome 2.1: Galápagos food system is climate resilient for both internal consumption and for the sustainable tourism sector.

Output 2.1.1. Enhanced institutional capacity for climate-resilient planning and development.

Output 2.1.2. Climate-resilient water and agricultural food productions systems implemented

Output 2.1.3. Science-based and participatory management frameworks and systems in place, for the adaptive co-management of the Galapagos marine zoning.

Output 2.1.4. Climate-smart small-scale fisheries and aquaculture approach adopted for the restoration of shellfish and finfish stocks and the diversification of livelihoods.

Output 2.1.5. Upgraded and more efficient value chains for climate-smart seafood and agriculture products, potentiated with links to new markets.

Outcome 2.2 Marine and terrestrial ecosystems are under effective restoration schemes.

Output 2.2.1 Marine High Ecological Value Areas (HEVAs), under restoration schemes taking into account potential climate change scenarios.

Output 2.2.2 Native Forest areas of high ecological value, under restoration schemes, to secure environmental services in the face of climate change.

12.5.1 Outcome 2.1 Galapagos food system is climate resilient for both internal consumption and for the sustainable tourism sector.

The COVID-19 pandemic has revealed the key role that the agriculture and small-scale fishing play to sustain the food security and economy of the Galapagos province in times of need. The economic crisis caused by the pandemic has forced local fishers, farmers and consumers to adapt their harvesting, marketing and trading strategies, and consumption patterns. As a result, new opportunities have emerged to promote a systemic transformation of the Galapagos food system to increase its resilience to future crises caused by new pandemics, climate change, and other anthropogenic drivers of change (Castrejón et al. 2021).

Therefore, the main objective of this outcome is to take advantage of the COVID-19 pandemic to strength the food security and resilience of the Galapagos food system by enhancing the adaptive capacity of ecosystems, fishery resources, fishers, farmers, and institutions, while reducing significantly GHG emissions.

This outcome consists of five outputs. Outputs 2.1.2, and 2.1.5 will be implemented in all the farms of the agricultural area in Galápagos. Activities these Output will be financed through the Galapagos' Credit Line. Direct beneficiaries of these outputs are families managing 755 farms. These farms cover an area of 19,000 hectares, containing 228 large-scale farms (> 20 hectares), 202 medium-scale farms (5-20 hectares), and 325 small-scale farms (< 5 hectares).

Please refer to Appendix 2.1 Agriculture (intervention plan) for further details about the characterization of beneficiaries in each of the islands (location, type, scale, agricultural activity, socioeconomic characteristics). Furthermore, at least 400 fishers and their families will benefit from this outcome, including Galapagos seafood consumers (local residents and tourism sector).

Activities under Output 2.1.2. Output 2.1.5 will be financed through the Galapagos' Credit Line.

Table 42. Eligibility for accessing loans for investment in sustainable land use.

Condition	Description
Beneficiaries	Farmers (individuals, cooperatives, associations, MSMEs).
Eligible investments	• Silvopastoral systems • Storage, distribution, use • Value chains - machinery, equipment, working capital (seed fund, seed capital to start the process)
Eligibility of beneficiaries	• Placed in most vulnerable zones subject to changes in water availability. • Lower income and small farm size will be prioritized. • Participation on farming field schools.
Minimum objectives	30% of the farming area
Financing thresholds	From USD 5,000 to USD 100,000
Minimum co-financing by the beneficiary	20%
E&S category	B or C (category A is not eligible)
Other conditions	Those who have previously participated in technical assistance activities and capacity building processes will be favored. No purchase of additional livestock, no expansion of the agricultural frontier.

12.5.1.1 Market study of food system

12.5.1.1.1 Agriculture

According to the assessment of access to loans by the farmers, less than 45% of the farms had access to loans to improve its production. San Cristobal is the island with less access to loans. San Cristobal has the lowest production cost in the islands, mainly because San Cristobal is the only island with natural freshwater sources, reducing the irrigation water cost. On the other hand, as expected, large-scale farms double annual production costs (~$12,000) compared to the small and medium-scale farms ($5,000). Please refer to Annex 2 - appendix 2.1 for further details.

12.5.1.1.2 Fisheries

Approximately 70% of Galapagos residents planned to keep their new seafood consumption patterns after the lockdown, including the same suppliers and information channels (Castrejón et al., in prep.). This creates business opportunities to adapt fishers' livelihoods by diversifying markets and products to add value to the seafood supply chain.

Therefore, in order to take advantage of the business opportunities created by the COVID-19 crisis and enhance the adaptive capacity of small-scale fishing sector, we suggest putting in place a participatory process that involves fishers, tourism operators, retailers, intermediaries, chefs, managers, and consumers to define a more sustainable and financially viable seafood system for Galapagos. This new food system will be based on fair and equitable value chains that come from profitable and environmentally friendly SSF (outcome 3.1), as well as from new financially viable business models based on principles of sustainability and social responsibility (outcome 3.2). The successful implementation of the new system will require residents to change their consumption patterns, fishers to adopt responsible fishing practices, and government agencies to adopt cutting-edge technology and effective regulations to reduce IUU fishing and marine pollution.

To this end, Castrejón et al (in prep) suggest putting in place several actions to help reactivate the economy and adaptive capacity of Galapagos coastal communities. These include (a) increasing the consumption of pelagic species, like tuna, rather than demersal species with signs of overexploitation (e.g. sailfin grouper); (b) support the development of sustainable and socially responsible seafood enterprises, which will help to improve food security by reducing reliance on imported food; (c) improving monitoring, traceability, and trading of fisheries with state-of-the-art technology to reduce IUU fishing and promote fair trade, and, finally, (d) promoting a blue circular economy to diversify products and markets, reduce waste and add value to the small-scale fisheries. These actions will enable conditions for the development of a new seafood system more sustainable, equitable and financially viable that will enhance the adaptive capacity of Galapagos against climate change and other future crises.

It is important to highlight, that the World Bank, in collaboration with the Charles Darwin Foundation and Conservation International, will put in place during 2020 a one-year project called "Ecuador Coastal Fisheries Initiative Challenge Fund". The objective of this project is to provide technical assistance to the Government of Ecuador in developing a new "seafood system vision" for Galapagos and a set of "prototypes" to implement such vision. A seafood system comprising fair and equitable value chains from a wide diversity of small-scale fisheries, investable enterprises, and holding to key principles of sustainable seafood, depends upon a myriad of behaviors from multiple actors - from consumers changing their diets and fishers adopting sustainable fishing practices, to public sector agencies developing and enforcing effective regulations to curtail overfishing and illegal practices.

The goal of prototypes is to help reactivate the economy and the resilience-adaptive capacity of Galapagos coastal communities by supporting the development of sustainable and socially responsible seafood enterprises. These enterprises will help to improve food security by reducing reliance on imported food, with buy-in from the local community and the tourism sector, and will diversify products and markets, improving the monitoring and traceability of fisheries, reduce IUU fishing, and promote fair trade.

The Challenge Fund project will identify key gaps/risks/issues that will need to be addressed, including risks resulting from weak governance, poor infrastructure, a lack of investable enterprises, and other capacity issues that could prevent these prototypes from becoming the new reality. Strategies to overcome these risks will be developed and implemented to the extent possible, along with assessments of the investment readiness of specific enterprises wishing to operate as part of the new seafood system. For more advanced enterprises, investment prospectuses will be developed to aid in their efforts to secure financing.

Therefore, the fisheries component of the GCF has been elaborated to create strong synergies with the Challenge Fund project to ensure the scalability, replicability, and impact of both initiatives. The Challenge Fund will provide the technical assistance needed to make seafood enterprises (prototypes) investable, while the GCF will provide, hopefully, the investment required for such enterprises to consolidate their development and ensure their success, according to the new Galapagos seafood vision that will be defined thanks to technical support provided by the Challenge Fund project.

To this end, this EBA proposes the creation of a Blue Incentives Program, whose main objective is to promote a blue circular economy through the financial inclusion of fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices, in exchange for receiving financing for the development of enterprises with principles of sustainability and social responsibility. The intention is to provide soft loans, through the GCF or other financial entities, to those enterprises that show bankable business plans or investment prospectus, which would be developed or consolidated with technical assistance provided by the GCF, through a "Galapagos Virtual Innovation Lab". Both outcomes of this EBA are complementary and will contribute to improve the productivity, competitiveness and social inclusion of Galapagos small-scale fishers and entrepreneurs in the financial system, based on criteria of sustainability and social responsibility. In the next sections, both initiatives are described in detail, together with the outcomes, outputs associated to their implementation.

12.5.1.2 Output 2.1.1. Enhanced institutional capacity for climate-resilient planning and development.

The activities proposed in this output will improve the knowledge of Galápagos' government staff and vulnerable farmers on climate change issues and climate-resilient agricultural best practices. In addition, the improvement of generation and access to hydro-meteorological information for decision-making in a changing climate will be strengthened, and consequently decision-makers and farmers will act against climate change. These activities will enhance the adaptive capacity of farmers and allow climate change adaptation planning to be sustained beyond the activities proposed in this component and program. Uncertainty about short- and long-term climatic conditions does not allow investment on agricultural lands, promoting agricultural land abandonment. In this context, this package of activities is built into the assumptions that local, on-time, information, accompanied by suitable training, are key for any adaptation activity or program in the agricultural sector. It also assumes that one of the pillars of sustainability of this program is the knowledge accumulated and shared by agricultural extension programs[17] and applied by farmers through Farmer Field Schools (FFS). The extension program will take in account local knowledge, practical and technical demands from farmers, and Galapagos agroecosystems conditions based on ongoing monitoring. Additionally, it builds on FAO's FFS methodology, an approach used for over 30 years in over 90 countries (FAO 2019a); the proposed programme includes a gradual scalation strategy that requires that farmers initially targeted share resources with other farmers. This approach will contribute to guarantee the sustainability of the program.

[17] Agricultural extension is how new knowledge and ideas are introduced in rural areas in order to generate changes and improve the quality of life of farmers and their farmers. This agricultural extension program is coordinated and implemented by the Ministry of Agriculture and Livestock.

Activity 2.1.1.1. Implement a capacity building program for governmental staff with practical information, knowledge and training about climate change and climate resilient agricultural practices.

This activity will develop a capacity building program to strengthen key local governmental agencies (MAG, INIAP and CGREG) with technical knowledge, so they are capable to develop or improve their extension program for farmers and their families about climate change agricultural adaptation practices based on local knowledge and conditions to guaranty sustainability of the activities of this program.

This activity will be the base for the implementation and the sustainability for climate-resilient agricultural practices (Output 2.2.1) at the farm level in Santa Cruz, San Cristobal, and Isabela Islands. Fifteen specialists from the MAG, INIAP, CGREG, and three Municipalities will receive formal training, for 4 months, in topics related to climate change, the effects of climate change in Galapagos, the technical aspects of climate resilient agricultural practices and crosscutting dimensions. The trained participants will be the base of a long-term extension program -based on the Farmers Field Schools (FFS) model- about the agricultural practices based on local conditions to improve resilience in the agricultural areas of Galapagos.

It is important to mention that each organization will carry out the implementation of activities and training for farmers according to their competencies and using the agricultural extension program. Human capital development is key for the agricultural sector to adapt to climate change (Mustapha et al 2012) and it is imperative for achieving a climate resilient food system in Galapagos. Knowledge acquisition and co-creation and sharing among government agencies and farmers will be key for long-term adaptation action beyond this program and key for long term climate resilience of the food system of the Galapagos Islands.

This activity includes the following sub-activities.

a. Develop a training program of 4 modules for governmental staff in Galápagos.

A set of 4 educational modules will be taught to 15 local government staff members (MAG, INIAP, municipalities, and CGREG), with a duration of 80 hours synchronous and 160 hours of complementary work. The proposed contents for the modules are: 1. The scientific basis of climate change, 2.Climate change and the agricultural systems in the Galapagos , 3. Exposure, vulnerability, risk, and adaptive capacity of the agricultural areas in the Galapagos , 4. Climate resilient agricultural practices : silvopastoral systems, vegetative Species diversification, integrated crop management, soil management (based on FAO's soil doctors programme), agroecological principles (based on FAO's Tool for Agroecology Performance Evaluation), use of genetic resources, other on farm actions: biodigester, composting, biochar, climate smart value chains, best practices in irrigation water management, water technologies maintenance, hydrometeorological and irrigation, hydrology, decision making and business skills, use of Tool for Agroecology Performance Evaluation (TAPE), information interpretation, diffusion and decision making; crosscutting themes: gender mainstreaming, youth incorporation in agriculture, implementation of extension and rural advisory services, monitoring and evaluation (for technical staff) and other topics to be refined based on technical and practical needs and demands from farmers.

The training will be endorsed by the organizations that will implement this component and the program; and the endorsement of an educational center will also be sought, to grant a diploma to technicians trained. The participants will be selected based on their institutional functions which will be related with the training program. The training will be implemented in a periodicity coherent with the crop cycles in the region during the five years of the implementation program.

b. Development of the framework for extension and rural advisory services for farmer's climate change adaptation for its implementation in Farmers Field Schools (FFS).

This component will be developed by the staff already trained (sub-activity a). Five technical staff will work in each island and will be divided as follows: 2 MAG staff members for agricultural services, 1 INIAP staff member for phytogenetic resources (seed management, agrobiodiversity conservation), 1 CGREG staff member for water management, 1 person for each Municipality for climate resilient productivity (agricultural value chain)18.

These training frameworks will be the base for the Farmers Field Schools (FFS) implementation, which are deemed both an extension service as well as an agricultural innovation platform. FFS build on concepts of non-formal education, and has a strong hands-on, experiential learning component. The FFS will rely on the guidance from the trained technicians who will have developed the competent knowledge and skills to carry out this capacity building process. The group meets regularly during the growing season, carries out experimental participatory research, by which farmers identify production problems, brainstorm potential solutions and compare with improved practices, ensuring the co-creation of knowledge and avoiding failed top-down strategies.

FFS have been widely documented around the world as a suitable strategy to scale up knowledge and practice adoption based on the solid development of human capital (FAO 2016c). The FFS approach has been proved to enhance the understanding of complex agroecosystems, and can contribute significantly to the monitoring and development of sustainable systems among smallholder in the face of climate change (APAARI 2018) and extreme weather events (Holt-Giménez 2002).

Due to the hands-on requirement of FFS, activities will be done directly on the farms of lead farmers, considering a culturally sensitive schedule and gender and youth participation. The practices that are initially set up as part of the FFS become a “technological showcase”, this is, physical demonstrations where farmers can exchange information and results about the practices implemented (IICA 2014). The lead farmers (both male and female) that emerge from the FFS are critical c. Farmer Field Schools (FFS)19 and Soil Doctors Programme (SDP)20 for farmer-farmer learning, faster adoption and scalability.

This activity aims at supporting a farmer-farmer networking with a focus on strengthening farmer capacity for adopting and scaling up of the program. These are producers, chosen by their social characteristics and committed to dissemination of climate resilient agriculturaland sustainable land management practices. TheyFFS are an adult education training methodology and will be an integral part of theinclude workshops, training and extension cycle by sharing their knowledge (therefore escalating extension services through knowledge dissemination) and sharing resources (inputs that are produced in their farms) with other farmers, whether these are targeted or non-targeted.

As part of a gradual scalation strategy, it will be required that farmers targeted in the FFS interventions use some of their own resources for practice implementation, as well as share back resources after they produce inputs; examples of these could befield days according to a curricula developed by technicians from MAG and INIAP trained in practices a. and b. (M&E of FFS results will also be performed by technicians from MAG and INIAP trained in practices a. and b.). Training through the FFS will include topics such as climate resilient and sustainable land management

18 Extension agents that participate in the capacity building program for government technical staff will be required to design a training program and provide extension services to farmers accompanying the Farmer Field Schools (FFS) as a requirement to obtain a *diploma* on climate change impacts and management in agriculture.

19 Farmer Field Schools (FFS) are an adult education training methodology. A detailed description of this approach is available on: FAO. Farmer Field Schools- Guidance Document. Rome, 2016. http://www.fao.org/publications/card/en/c/d7d4db1f-826f-4d81-b097-44292ff7eeca

20 Global Soil Doctors Programme (SDP) – FAO. Platform: http://www.fao.org/family-farming/detail/en/c/1288031/ Manual: http://www.fao.org/publications/card/en/c/CA7492EN/

practices; the use of Tool for Agroecology Performance Evaluation (TAPE); irrigation and water management; hydrology; decision making and business skills. Technicians from MAG and INIAP, trained in practices a and b. will obtain the diploma after having trained all the farmers (from both genders, including youth) on the same topics that they have been provided and tailoring the capacity building program to the needs and conditions of farmers. It will be required that farmers targeted in this activity share back resources after inputs are produced: seeds, fodder banks materials, seedlings, other reproductive vegetative material, biofertilizers. Sharing back these materials with farmers initially non-targeted farmers will allow a cascading effect and scaling the potential of the project, and offsetting in this way, the extension costs.

Along with the training curricula to be developed by technicians, the FFS process will build, for some topics, on training materials already developed by FAO,. Champion farmers (both male and female chosen by their social characteristics and committed to dissemination of climate resilient agricultural practices) will also have their knowledge enhanced with tools such as the Soil Doctors Programme, a FAO-led programme based on farmer-to-farmer training which provides capacity building on the principles of sustainable management, and the Tool for Agroecology Performance Evaluation (TAPE), which will support the multidimensional assessment of practices. The use of these well proved educational materials will ensure the successful learning and knowledge co-creation, as well as providing sustainability for the implementation.

The sustainability of the. Finally, in this activity, the program will also support farmers with technical assistance to access loans to scale-up the activities in their farms. This tailored capacity building program will be also supported by monitoring provided by the trained technicians from MAG and INIAP, in coordination with consultants and staff hired by the events over the 4 years of project. MAG and INIAP have agreed to ensure that the professional staff trained will have time lifetime, allocated in their regular work schedule to guarantee the functioning of the trainings. After the project is over, MAG and INIAP have committed to mainstreaming this program into their regular activities for farmers, revisiting and delivering with their own resources on the way forwardwith a periodicity that is suitable to local crops, and with the continuous commitment of the champion farmers. Technicians that are trained from MAG and INIAP will be in charge of practices monitoring, as well as knowledge transfer monitoring in coordination with the consultants and technicians hired by the program. Monitoring of field activities will also include the use of TAPE. An agreement will be done with the MAG, INIAP and local government institution for maintaining a long-term monitoring program.

Benefits- Co-benefits:

Local knowledge co-generation and sharing for greater resilience of ecosystem and agroecosystem services to climate change at the agricultural landscape scale, sustainability and protection of the crops, protection of water sources, control of the expansion of invasive species, and increase of natural pollinators.

Increased adaptive capacity of farmers, strengthening women and youth participation in climate knowledge co-creation. Additionally, by building capacities in key government agencies, and the commitment that these have already expressed, the program supports the sustainability of the climate-resilient agricultural practices on the long term.

Beneficiaries:

Direct: 15 technical staff members of the Ministry of Agriculture (MAG), Ecuadorian Institute of Agricultural Research (INIAP), the Galapagos Government Council (CGREG), and three Municipalities; 1.872 farmers (considering 624 farms with an average of 3 household members per farm).

▪2100 farmers who will be part of the Farmer Field Schools (FFS) training through the program

Indirect: Landowners of active farms where climate resilient practices will be implemented: 260 farms in San Cristobal (5,612.9 Hectares), 357 farms in Santa Cruz Island (9,591.7 Hectares), 127 farms in Isabela (3,575.5 Hectares) and 11 farms in Floreana (229.5 Hectares).

Financial Mechanism

Total Budget: $659,726.1

- GCF Grant: $591,567.8
- Private Sector: $68,158.3

Activity 2.1.1.2. Install a hydro/agro-meteorological monitoring system to inform and tailor the information to the needs of vulnerable smallholder farmers.

Access, generation, and delivery information is critical in the process of enhancing the adaptive capacities of the rural areas to climate change. This action will collect data, produce information, analyze, and interpret, and disseminate information for decision making at different levels, and for the farmers. This activity looks to address the weakness of hydrometeorological monitoring data and analysis in the Islands and strengthen the capacities of local government agencies and scientific organizations to provision "in-time" information and services., which will allow the construction of an early warning system and climatic information for land management decisions. These actions will reduce the uncertainty of drastic hydrometeorological changes and climatological variability. By improving and generating information about hydro-meteorological conditions will also help to understand agricultural productivity through restoration and rehabilitation strategies, look to increment carbon sequestration and create or maintain microclimatic conditions that favor the sustainability of a cropping system. Initially, the Galapagos Science Center (GSC), located in San Cristobal Island will lead the management, analysis, and distribution of meteorological and climatic data in coordination with INAMHI. The GSC is a research center co-managed and co-funded by Universidad San Francisco de Quito and the University of North Carolina at Chapel Hill (USA). GSC in 2019 signed a Memorandum of Understanding with INAMHI to provide technical and logistic support in the Galapagos Islands. For this adaptation activity, GSC will provide in kind support for this action, in the form of equipment, i.e., servers and technical staff for data management. The provision of "in-time" information and services will allow the construction of a climatic information system for land management decisions.

This activity will:

- Collect relevant hydrometeorological and climatic data suitable for land management decisions and climate change adaptation practices.
- Process and distribute, on-time, climate change information to relevant users of different levels, to promote adaptation practices.

The monitoring system will include:

a. Climatological monitoring: This is the base of the input information in water and irrigation planning and operations. Temperature, precipitation, humidity, wind velocity, radiation and cloud fraction are the variables that give the base towards a sophisticated understanding of the water fluxes and dynamics in the Islands. At the same time, as indicated, fog plays a major role in the Galapagos, especially in areas above 400m above sea level. Thus, it is important to also monitor this process and the real contribution that it may have on water offer.

b. Surface hydrology monitoring: Next monitoring surface water variables are useful to estimate water flow levels at the catchment or farm level. Key variables here include surface runoff, interflow, and baseflow. and interflow. Since the Islands do not count with direct observations, at present, these variables are obtained from assumptions or modelling efforts as the one used here.

A comprehensive water resources management initiative should establish a minimum of direct observations and measurements of these variables which in turn support local-level decisions as well as modelling efforts.

c. Groundwater monitoring: similarly, the Galapagos do not count with a system which monitors groundwater levels and dynamics. It is important to note that aquifers and springs are the principal water source specially in Santa Cruz and Isabella. A series of instruments to permanently monitor the conditions of the aquifers and thus inform decisions about recharge levels and its quality.

d Train farmers and government technicians in decision making based on the information generated and disseminated, through capacity building and related training materials. This will be linked to the training for government staff and Farmers Field Schools in 2.1.1.1. for farmers.

Data will be available for different users, at different scales and different platforms, including a dedicated web portal for external users and a radio program, to be built with a participative approach, to disseminate in-time information across farmers. A key component is a training for technical staff in the use of equipment, process of data, troubleshooting, and data distribution. This component is also articulated with Activity 2.2.1.2, which includes the implementation of training for better water management practices for farmers, where the use of information is key.

The practices (sub-activities) to improve the adaptive capacity are:

a. Acquisition, placement, and implementation of sensors capable of measuring climate, water, and agriculture variables. This practice looks to address the strong lack of hydrometeorological data in the Islands through a rigorous study about the current situation of ground and surface water to survey the geophysical, geological, and hydrogeological characteristics of the Islands. The hydrological baseline will be conducted in the first year of the implementation period. Additionally, traditional devices and tools will be acquired to the monitoring program which will record the main hydro-climatic variables mentioned: temperature, precipitation, humidity, wind velocity, radiation, cloud fraction, surface runoff, interflow and baseflow and groundwater levels and dynamics.

b. Develop an information system capable of collecting information, processing and perform data quality/data control activities. This information system will be capable of distributing data in real time, interpreting data for farmers and distributing data to local governments, scientific institutions, and external users. Data interpretation, modelling and forecasting capacity building will be tailored to different stakeholders: decision makers, farmers, and communities. Data will be available for different users, at different scales and different platforms, including a dedicated web portal for external users, and an app, to be built with a participative approach, and a radio program to disseminate in-time information across farmers. The app and the radio program will be accompanied by the Farmer Field Schools approach (2.1.1.1) and complemented with activities of component 3 on education.

c. Train technical staff for implementation of sensors and management of the information system. Under this sub activity, capacity building for farmers will take place to ensure that protocols are followed by all the key actors. Training sessions will be given by technical staff of INAMHI and GSC.

The Monitoring will be implemented in coordination with MAG, INIAP, INAMHI, PNG, and universities such as USFQ.

Benefits, Co-benefits: by decreasing the uncertainty related to climatic conditions and its hydrometeorological drivers, authorities, and technical staff will be informed on time of potential conditions that could harm their crops, animals, investments and put pressure over the food chain, causing stress to the food security of the islands. Farmers will also benefit from access to more accurate, dependable, and tailored information on weather, climate, and hydrological resources, which will allow them to plan agricultural tasks and manage crops, soil, and water.

These activities and sub activities provide indirect impacts on the protection of natural and water resources. Access, analysis, use and sharing information is a mechanism to act and protect vulnerable areas and maintain local biodiversity. Consequently, it also provides resilience of ecosystem and agroecosystem services at the agricultural landscape level. Lastly, these interventions support the access and analysis of reduction and capture of CO2 information.

Beneficiaries:

Direct: 35,000 local users of the information, Government agencies: MAE, INIAP, CGREG, INAMHI, Universities and ONGs

Indirect: 755 farm households and 19,009. 6 Hectares and 3 Municipalities

Financial mechanism:

Total Budget: $1,682,068.1

- GCF Grant: $1,455,309.9

Private Sector: $226,758.3

12.5.1.3 Output 2.1.2. Climate-resilient water and agricultural food productions systems implemented.

The activities of this output will transform degraded agricultural areas into healthy agroecosystems to enhance climate change adaptation capabilities, optimizing quality in all aspects of agriculture and the environment, by respecting the natural capacity of plants, animals, and the productive landscape, which are key to the Galapagos Islands. These activities will also lead to improved water recharge and productivity and contribute to the population's and ecosystem's increased resilience to climate change, while improving their livelihoods. As one of the impacts of climate change is the scarce availability of water for agriculture, especially in dry seasons, one of the activities will help better access, storage and distribution of water considering the climate variables. Agriculture has a high degree of sensitivity to both short-term weather changes and long-term seasonal changes. Agricultural productivity is impacted by changes in temperature and precipitation as well as infestation by pests, diseases, and weeds (climate rationale). Economically, it has an impact in terms of profitability, prices, supply, demand, and trade. The expected changes in the climate will have a negative impact on the Galapagos agricultural sector, including a greater dispersion of invasive species favored by a warmer and wetter climate. These practices/activities are based on agroecology principles and are also considered "non-regret" practices, considering climate variability and the impacts of climate change in Galapagos.

This output emphasizes on sustainable agroecosystems as a science, a social movement and a practice (Wezel et al. 2009), defined as an integrated approach that applies ecological and social concepts and principles to the design and management of food and agricultural systems (FAO 2019b). Scaling up Agroecology has been identified by FAO as a strategic approach to achieve Zero Hunger and the other Sustainable Development Goals (SDGs), improving the livelihoods of rural peoples. The implementation of agroecological practices, in addition to enhancing environmental aspects, improves other dimensions tightly linked to farmers' livelihoods, such as governance, economy, health and nutrition, and Society and culture (FAO 2019b).

FAO has wide experience in assessing agroecology in a variety of contexts and countries, through a framework that has been iteratively refined: the Tool for Agroecology Performance Evaluation (TAPE) (FAO 2019b). This tool provides a robust methodology for evaluating agroecological systems, including the improvement in farmers' livelihoods, from a multidimensional approach, with strong links to SDG indicators. The core criteria assessed by TAPE are: productivity, income, added value, exposure to pesticides, land tenure, dietary diversity, women's empowerment, youth employment opportunity, agricultural biodiversity and soil health.

GCF resources, combined with CAF co-financing, will be invested in providing Galapagos farmers with the skills, knowledge and technologies they need to manage soils, water and biomass to enhance soil moisture/fertility sufficiently for production of a diversity of climate-resilient crops through agroforestry systems or other climate-resilient practices.

Indicators enabling the assessment of improvement in farmers livelihood will be monitored including include a. Proxy tools for diet diversity; b. amount of agroforestry, fruits, vegetables, dairy products for domestic consumption (ADC); c. Cash flow from the system and, d. Analysis of income at the beginning of the project and during project implementation as part of the M&E system.

Activity 2.1.2.1. Develop a physical and knowledge network for conservation and use of phytogenic resources through in-situ and ex-situ conservation activities.

This activity will allow access to quality seeds in sufficient quantity, as a decisive means of production to increase productivity at the farm level, and therefore the availability of nutritious food. This will enable the farmers to improve their bargaining power in the local agro-food chain through improved access to adapted seeds to dry seasons and high temperatures. By proposing community-based actions to explore, restore, preserve and distribute seeds, this program recovers and promotes the use of existing cultivars resistant to different biotic changes generated by climate change, will decrease the risk of food insecurity due strong climatic events including pests, droughts, and floods. This practice aims to strengthen and value the role of women in agricultural development, agrobiodiversity conservation and traditional knowledge, supporting the seed distribution activity. This activity seeks to support farmers to improve food and nutritional security and, in turn, the agricultural diversification through the restitution of high-quality and climate-adapted seeds; also strengthen the use and marketing of the local seeds to improve farmers income, mainly in women farmers, strengthening their capacities to access and control their agricultural resources. With the support of extension services from INIAP, farmers will explore, find, select the best seeds of different crops in the field. Part of those seeds will go back to the farm/community seed banks. The focus will be on the conservation and use of all the native and endemic diversity of usable plants, including major and minor crops, neglected varieties, medicinal plants, wild relatives, and trees. The promotion and use of a wide assortment of agrobiodiversity will enhance farmers' livelihoods by improving the variety of their diet, a key aspect of quality food security (FAO & IFAD 2020).

This activity includes the following sub-activities that allow to improve the adaptive capacity of the agroecosystems in Galápagos.

a. Implement in-farms conservation activities: collect, conserve, use and distribute the agrobiodiversity existing in Galapagos (community-based seed bank), with special focus on the variety of crops resistant to biotic changes caused by climate change. This component will be implemented in 25 "seed" farms distributed in the four inhabited islands. Seed Farmers capacities will be strengthened through annual training workshops (5 workshops at provincial level) to establish, operationalize, coordinate, and distribute the agrobiodiversity conservation (resilient varieties). The main actions that will be developed are: · Participatory research aiming at identifying and selecting genetic materials that have demonstrated resiliency traits in the field, such as heat and drought tolerance, resistance to winds, etc. This will entail seed collecting campaigns that will be carried out to obtain climate change resilient varieties of seeds of the main usable species that farmers use in their diet (grains, vegetables, fruits, tubers). These procedures will be carried out under protocols within farms, small structures within farms will be built, where seed management will be carried out to carry out multiplication, conservation-storage, and restitution, seed classification, selection, documentation, and sharing procedures will be carried out at the same time, on specialized farmers' fairs, leaded by women organizations and annual technical report where the harvested, stored and returned seed is recorded (kg-units-plants), through a month monitoring. This monitoring will be carried out after the first 6 months of implementation in both "seed" farms and farms that will receive seed capital. Information about other biosecurity issues will be promoted with ABG to facilitate a seed interchange considering the restrictions established for the islands.

The genetic diversification propelled by this activity along with ICM practices, allow for a more efficient system, because it ensures the reduction of losses due to weeds, insects and disease, and make a more efficient use of available resources of water, light and nutrients (Altieri et al 2012). In addition, although some these plants might have lower yield when compared with commercial varieties, they can help produce dry matter that can be ploughed into the soil, improving its properties and ensuring the capitalization of the farm (Gliessman 1998). These agroecological advantages of genetic diversity, that might appear as a short-term tradeoff for the farmers, will be emphasized in the participatory research, training program, and key messages for farmers. Pinpointing and having evidence of the advantages from different dimensions (e.g. environmental, social, economic) at different scales (farm, society, landscape level), and at different timescales (short vs. long term), will ensure that farmers get engaged in the importance of genetic diversification. The use of the Tool for Agroecology Performance Evaluation (TAPE) throughout the project will ensure the assessment of the whole agroecological systems, pointing out the value other key characteristics for farmers resilience improvement.

b. Improvement of existing infrastructure at INIAP, which will work as an agrobiodiversity repository, knowledge center and distribution facility, for long-term conservation. This component will be implemented through the following actions: the operation, production, and maintenance of germplasm in INIAP seed bank, located in San Cristobal Island, will be carried out according to established protocols and under integrated crop management practices, with low use of external inputs. Additionally, the project aims at having an institutional exchange with the International Maize and Wheat Improvement Center (CIMMYT) on protocols for resilient germplasm exchange, materials that that have already been selected by this research center.

This project will improve existing infrastructure, with the provision of a storage room, fridges, and a curator. In close exchange with the community network, climate change resilient germplasm essential for food security (corn, beans, bananas, cassava, potatoes, fruits, medicinal plants, forages) will be collected. As the process advances, it will be possible to work with all usable species present on the islands, related to food and agriculture. Development of protocols for quality control and quality assessment processes, to ensure compliance with the minimum quality standards, in the climate change resilient seed production. And finally distribute seeds stored in the community seed bank to farmers who need them, covering at least 80% of the total Galapagos farmers. Additionally, seed exchange will take place with CIMMYT of seeds that are adapted to climate change conditions, particularly on drought and floods resilient genetic materials that have been already selected by INIAP. Furthermore, this activity is complemented by participatory research aiming at identifying genetic materials that have demonstrated resiliency traits in the field, such as resistance to winds, heat and drought, and floods tolerance, etc. Information about other biosecurity issues will be promoted with ABG to facilitate seed interchange considering the restrictions established for the islands.

Benefits -co- benefits

Improvement and diversification of agricultural production at farm level (biodiverse farms) with climate resilient genetic materials. Strengthening the participation of women in agricultural production, both in their capacities to access and control their agricultural resources. Diversification of the economic income of farmers. Promoting a healthy food environment – including food systems that promote a diversified, balanced, and healthy diet (fruits, vegetables, roots, grains, among others) for both tourists and local population, mainly for children.

With the support of extension services from INIAP, farmers will conduct participatory research to explore, find, select the best seeds of different crops in the field. Part of those seeds will go back to the farm/community seed banks, enhancing the sustainability of the activity. The focus will be on the conservation and use of all the native and endemic diversity of usable plants, including major and minor crops, neglected varieties, medicinal plants, wild relatives, and trees. Seed production with and without the implementation of this component in the program are shown below. Total of hectares without the project is 570,29 (without grassland), the increase in five year of the project is 469,85 ha.

Table 43. Seed production with and without program implementation

Crops	Has without project	Has with Project (1 year)	Has with Project (5 years)
Lemon	9.47	13.97	22.97
Coffee	133	136	142.00
Musacea-plaintain	106.19	110.49	119.09
Musacea-banana	40.93	43.51	48.67
Musasea-orito	0	1.72	5.16
Cassave	71.78	79.78	95.78
Sugar cane	8.67	15.07	27.87
Beans (Fréjol)	12.55	15.28	20.75
Vegetables	17.34	27.34	47.34
Maize	41.94	64.67	110.12
Maize	0	22.73	68.18
Tangerine	11.75	29.75	65.75
Orange	55.34	73.34	109.34
Papaya	8.54	10.54	14.54
Potato	1.49	8.14	21.45
Pepper	7.25	10.25	16.25
Pineapple	26.68	27.47	29.06
Tomato	17.37	23.37	35.37
Peanut	0	0.11	0.34
Passion fruit	0	1.25	3.75

Crops	Has without project	Has with Project (1 year)	Has with Project (5 years)
Aromatics	0	0.05	0.14
Medicinals	0	0.08	0.23
Grassland	11000	11000	11000
Forage	0	12.00	36
TOTAL ha	11570.29	11726.90	12040.14
TOTAL ha (without grassland)	570.29	726.90	1040.14
Increase in hectares in five years	469.85		
Increase in tons per year	625.18		

Beneficiaries

Direct: INIAP seed bank and 25 "seed" farmers distributed in the four islands: 8 in Santa Cruz, 7 in San Cristobal, 8 in Isabela and 2 in Floreana, where plots for efficient production and reproduction of quality seeds will be implemented. Seed distribution will be implemented in 624 farms that include those with crop, livestock, and mixed production. 755 farm households and 19,009. 6 Hectares will be indirectly benefited.

Indirect: 755 farm households, accounting for approximately 2100 inhabitants.

Financial Mechanism

Total Budget: $740,234.9

- GCF Grant: $617,071.8
- Private Sector: $123,163.1

Activity 2.1.2.2. Implement an Integrated climate-resilient crop management system at farm level.

This activity will minimize pest pressure, and maintain soil fertility, creating greater tolerance to droughts, floods and the attacks of pests driven by environmental and climate change. As part of the agroecological approach, Integrated Crop Management (ICM) is a basic strategy that will allow the development of a healthy agricultural system resilient to climate change. ICM will be incorporated into daily management of the production systems, through technical assistance, monitoring and adaptation cycle. The application of agroecological practices, ICM included, will generate greater climate change adaptive capacity to the production system, by: (a) improved soil moisture and nutritional growing conditions, (b) increased agrobiodiversity into the agri-food productive systems, (c) increased the biodiversity and the organic material in soil , reducing pest and disease problems as a consequence of more resilient systems; (d) reduced impact of rainfall variability and droughts on yields and improved rainfall infiltration, minimum runoff, and soil erosion; (e) increased soil carbon sequestration through higher levels of humid and non-humid

SOM and soil biota, and improved aquifer recharge and stream flow. The changes in cropping and land use pattern, soil management, over-exploitation of water storage and changes in irrigation pattern have a mitigating effect by reducing greenhouse gas emissions and increasing carbon sequestration.

This activity includes the following sub-activities that allow to improve the adaptive capacity of the agroecosystems in Galápagos.

a. Implements Soil management practices in farms. Soil comprises a set of components that interact to give the system characteristics of structure and function. The functions that soil perform are the foundation of agricultural, livestock and forestry production systems that provide a wide variety of ecosystem services. Improving the chemical, physical, and biological processes that take place in the soil through sustainable land management practices are essential to improve soil health, increase agricultural productivity, and improve the performance of agroecosystems. Soil management involves minimum soil disturbance, maintaining soil cover through crop residues or other cover crops, placing fertilizer more precisely into the soil to make it more accessible to crops roots, and improve nitrogen use efficiency. FAO has wide experience in the promovion of soil sustainable management and promotion of soil governance through the Soil Doctors Programme (FAO 2020), an initiative that has produced a set of tools for training farmers in their community, testing kits, and has promoted capacity building in this matter through the identification of champion farmers to educate in their community on soil science principles to train on the practice of sustainable soil management. The Soil Doctors initiative has already been successfully tested and trained thousands od farmers.

- Training workshops (2 workshops at province level) and on-site assistance by lead farmers to facilitate farmer-to-farmer learning to scale up implementation, under FAO team supervision, taking advantage of the Soil Doctors initiative. The execution of the training builds on activity 2.1.1.1. and the champion farmers approach. This concept creates a self- sufficient system that ensures sustainability.

- Strengthen knowledge about composting strategies for managing crop residues and other cut invasive species, which are important in the retention of CO_2 and other chemical elements. Also, reflect on the negative effects of the burning or decomposition of these residues for the environment, minimal disturbance of the soil, for example instead of tilling or ploughing the land (conventional agricultural system), farmers plant crops directly into the soil to improve soil porosity, builds up soil organic matter and beneficial soil biota leading to improved soil health and productivity.
- Prepare and execute fertilization plans with compost and other organic components to maintain a permanent organic soil cover (at least 30%), while at the same time adding biologically fixed nitrogen to keep the soil fertile. It would improve the resilience of the agricultural soil (structure and fertilized) in extreme climatic conditions. Implement a Monitoring system for i) biodegradation and CO_2 capture; and ii) use of compost and other organic components for soil resilience. The monitoring process will be carried out after the first 6 months of activity implementation and will conduct six (6) regular monitoring visits monthly to ascertain the progress of activities by lead farmers to facilitate farmer-to-farmer learning to scale up implementation, under FAO team supervision.
- Strengthen knowledge about composting strategies for managing crop residues and other cut invasive species, which are important in the retention of CO_2 and other chemical elements. Also, reflect on the negative effects of the burning or decomposition of these residues for the environment. Minimal disturbance of the soil, for example instead of tilling or ploughing the land (conventional agricultural system), farmers plant crops directly into the soil to improve soil porosity, build up soil organic matter and beneficial soil biota leading to improved soil health and productivity.
- Prepare and execute fertilization plans with compost and other organic components to maintain a permanent organic soil cover (at least 30%), while at the same time adding

biologically fixed nitrogen to keep the soil fertile. It would improve the resilience of the agricultural soil (structure and fertilized) in extreme climatic conditions.

- Implement a Monitoring system for i) biodegradation and CO_2 capture; and ii) use of compost and other organic components for soil resilience. The monitoring process will be carried out after the first 6 months of activity implementation and will conduct six (6) regular monitoring visits monthly to ascertain the progress of activities.

b. Establish crop and pest management practices, including a growing climate resilient seed.

Crop and Pest management refers to the implementation of timely and adequate pre-cultural and cultural practices according to Galapagos agroecosystems conditions. This practice will be focused on farms with crops and mix production and will receive permanent technical support to train farmers to expand food production with a wide variety of drought and food tolerant products to reduce the vulnerability to climate change and improve market balances, through polycultures, association and crop rotation, pest management and the design and implementation of agroforestry systems to improve and restore agroecosystems healthy. The main action that will be implemented are mentioned below:

- Annual training workshops (2 workshops at province level) and on-site assistance by lead farmers to facilitate farmer-to-farmer learning to scale up implementation, under FAO team supervision.
- Strengthen knowledge in: i) proper use of pesticides and in native biological control management, ii) strategies for the protection of species beneficial to agriculture and conservation, and iii) the importance of maintaining the diversity of plant species within their agroecosystems to mitigate the effects of climate change and offer permanent food to the local community.
- Redesign, together with farmers, the farms; considering a sewing system with a diversification of no less than 12 transitory crops, 8 perennial species and 4 forest species (identify species and varieties of crops resistant to pests and diseases and tolerant to climate change), through the integration of an annual planting plan (requirement of seeds from the community-seed bank) and harvesting of transitory and perennial crops plan (maize, beans, plantains, cassava, potatoes, vegetables) with projections of volumes to be offered to the community.
- Promote the use of organic fertilizers, ideally produced on the farm itself, facilitating the process of trophobiosis in crops.
- Integrate live fences for protecting crops, through the integration into agro-ecosystems of natural protective species (endemic/native arboreal plants with medium/high CO_2 capture capacity such as Acacia and Ziziphus) and native legumes of the island (Leucaena leucocephala, Phaseolus mollis, Dalea tenuicaulis, among others,) with the capacity to fix nitrogen in the soil.
- Breaking the cycle of pests by: i) rotating crops, through the identification of the most critical crop´s phases in relation to attack by pests and diseases; ii) management of exogenous weeds to avoid reproduction of pests; and iii) covering the ground to prevent the emergence of insect-pest larvae.
- Implementation of four (4) island nurseries for the production of endemic / native tree species with medium / high CO_2 capture capacity and leguminous species to improve soil fertility.
- Implement a Monitoring system for climate resilience of farms, biological corridors in agricultural areas, and farmers livelihoods enhancement. The monitoring process will be carried out after the first 6 months of activity implementation and will conduct six (6) regular monitoring visits monthly to ascertain the progress of activities. The monitoring tasks will be carried out by staff from MAG, INIAP and local government institutions who will have specific monitoring training from the activity 2.1.1.1.
- Indicators to be monitored as part of this system include for mitigation: soil carbon; for adaptation: improved hydric availability, plagues and diseases regulation, amount of

agroforestry, fruits, vegetables and dairy products for domestic consumption (ADC) (Ambrose-Oji 2003)

- The monitoring of multidimensional performance of these practices will be guided by the TAPE indicators and principles. Complementarily, in order to ensure the improvement of farmers livelihoods that these activities aim indicators such as: a. amount of agroforestry, fruits, vegetables and dairy products for domestic consumption (ADC) b. Cash flow from the system, c. proxy indicators of diet diversity, d. Analysis of income at the beginning of the project and during project implementation, will be collected as part of the Monitoring and Evaluation system.

It is important to highlight that ICM practices require external inputs for their initial design, however, many of the inputs are not required after the initial expense is done. Farmers will provide their own resources and inputs to improve their farms, and the scalation strategy includes the sharing back of resources and the access to loans for their farming activities. **Benefits, co benefits**

The Integrated Crop Management promotes the restoration of the natural ecological balance, the biological processes development until the optimum level, and enhances the relationship between agricultural activities and biodiversity conservation inside farms. It greatly increases the resilience capacity of these agroecosystems in response to adverse effects of climate change. By implementing an ICM System, this project will reduce the need for herbicide and chemical pesticide application by introducing crop rotation and bio-fertilization strategies, which maintain agricultural production, preserve profitability, and reduce water pollution and GHG emissions including those of carbon and nitrogen origin. This practice will replace the use of synthetic fertilizers in at least 25% of the productive area in the implemented farms.

Additionally, the practices would promote food and water security, and a diversified, balanced and healthy diet.

Direct Beneficiaries:

In general, this activity will be implemented in at least 55% of the total Galapagos farms (404 farms), excluding livestock production, distributed in the following way:

- At least four ICM practices will be implemented in medium and small-scale farms, covering 334 farms (1,002 beneficiaries, 30% women).
- At least four ICM practices will be implemented in large-scale farms, covering 70 farms (210 beneficiaries, 30% women)

Mitigation and adaptation indicators:

For monitoring purposes, soil carbon will be assessed as an indication of ICM practices benefits for mitigation. For adaptation, the following indicators will be monitored: i) improved hydric availability, ii) plagues and diseases regulation, iii) amount of agroforestry products for domestic consumption (ADC). A baseline assessment will take place at early stages of the project implementation.

Financial Mechanism

Total Budget: 3,299,036.99

- GCF Grant: $ 2,977,667.39
- Private Sector: $321,369.6

Activity 2.1.2.3. Implement silvopastoral practices at the farm level.

This activity proposes a silvopastoral model for cattle the islands, which integrates an efficient management of invasive plants, mainly Psidium guajava, in the livestock production system (guava-grass-breeding association), since it is considered highly invasive in Galapagos and its eradication is not feasible. For this reason, this activity seeks to control the actual expansion of this particular alien species at lower density at least 49% (Table 44) providing water and shadow facilities in guaranteeing the continuous production of the herd. Additionally, other native trees species will be integrated in the landscape as generators of shade and ecological services.

Table 44. Control of invasive species (Psidium-guajava) under Silvopastoral system implementation

Current guava presence in farms		Guava presence under SPS		Change (%)
Distance between trees	Number of trees	Distance between trees	Number of trees	
8.5 x 8.5	134	12 x 12	69	49%

Besides tree incorporation in the landscapes, this SPS model comprises: i) Farmers training to implement silvopastoral systems (guava-grass-breeding association), ii) fodder banks with shrubs, iii) internal division of paddocks to apply rotational grazing with occupation periods, and iv) manure management through biodigestor. These practices seek to reduce the vulnerability of livestock production to climate change as they stabilize forage availability throughout the year by favoring water infiltration and soil conservation.

This set of actions is based on spatial explicit modeling, see Appendix 2.1 Agriculture and Appendix 2.4 Terrestrial Restoration, where this proposal shows different scenarios of an invasive plant, i.e., guayaba, invasion on agricultural lands, under different scenarios of climate change and with the impact of the project.

This activity includes the following sub-activities that allow to improve the adaptive capacity of the livestock production in Galápagos.

a. Farmers training to implement silvopastoral systems (guava-grass-breeding association). Training workshops (2 workshops at province level) will be carried out for one week every year and should seek to include knowledge about trees incorporation into livestock systems that has the purpose to enhance resilience of the soil to degradation, improve water holding and infiltration capacity of the soil which contributes to the regulation of the hydrological cycle by reducing runoff intensity. The main activities considered in the workshops are:

- Preparation of participatory inventory per farm (rancher, agricultural technicians, interested community students) for the participatory design of a Guava management plan according to the needs of each farm. It is important to determine: i) symbiotic relationships between species, ii) Live Fences, iii) Rotation of Sustainable Paddocks, iv) fodder banks, among others.
- Dissemination of knowledge about silvopasture techniques, the economic benefits and the long-term ecological implications to the livestock sector of the four populated islands.
- Strengthen the knowledge about the contributions of the Silvopasture System in: i) the ecosystem, ii) animal feed and, iii) livestock productivity (milk and meat).
- Transform the guava-pasture-breeding bovine association towards Agroecological Silvopastoral system adapted to the Galapagos conditions. For this action, it is important to improve the guava trees distribution on the pasturelands. In addition, implement a Monitoring System on emerging synergistic management and its effects on the Guava-

Pasture-Breeding Bovine association, with the support of competent institutions (e.g., MAG). The monitoring process will be carried out after the first 6 months of activity implementation and will be conduct a monthly regular monitoring visit to ascertain the progress of activities.

- Introduction of native trees in the design of the Silvopastoral System with the support of a community-seed bank. This design could be structured as scattered trees in pasturelands and windbreaks/live fences to divide paddocks.

b. Implementation of fodder banks. This practice consists in implementing protein banks in farms with over 20 head of cattle. The proposed fodder banks are enclosed areas of 2,500 m2 that include shrubs and native legumes of the island, such as Leucaena leucocephala, Phaseolus mollis, Dalea tenuicaulis, among others, with high protein-containing leaf biomass. Introducing leguminous species is particularly beneficial for fixing atmospheric nitrogen and improving soil fertility.

c. Implement internal division of paddocks to apply rotational grazing through regularly moving livestock between paddocks. Through targeted temporal grazing exclusions, rotational grazing allows for the maintenance of forages at a relatively earlier growth stage. This enhances the quality and digestibility of the forage, improves the productivity of the system and reduces methane emissions per unit of live weight gain. This action would be managed under a pasture/paddock division based on temporal solar powered electric fences in farms with over 20 head of cattle. The paddocks that were built, have been grazed from 12 to 24 hours and 45-day rest periods. The farmers will acquire the machinery through direct loans promoted by the program.

d. Manure management through biodigestor. Biodigestion is a technology that adjusts to an efficient manure management, helping in the capture of GHG (especially N_2O and CH_4), elaboration of bio-fertilizers, avoids the proliferation of insects (especially flies), viruses, bacteria, parasites, filters wastewater, and generates gas, which can be used as alternative energy. This practice will be implemented on 66 livestock farms (dairy and pig cattle) suitable for the adaptation and construction of biodigesters and will be developed through:

- Two training workshops every year (at province level) to strengthen knowledge about the environmental impacts of livestock (manure decomposition process) and the importance of adopting alternative management technologies and practices to reduce GHG emissions from this sector.
- Implement participatory manure management protocols for GHG reduction, with the support of competent institutions (MAG, ABG).
- Build 66 Biodigesters, each with storage and waste handling capacity for at least 20 dairy cattle units and 25 pig units. Include a waste classification system and a reservoir or tank to store the bio-fertilizer (liquid). The farmers will acquire the machinery through direct loans promoted by the program.
- Exploitation of biogas for domestic use and/or for agro-artisan processing. In addition, to strengthen the use of biogas from biodigestion through incentives from public policy.
- Use of biofertilizers from biodigestion to reduce the use of imported synthetic fertilizers.
- Implement a monitoring system to quantify the reduction of GHG, production of domestic biogas and use and quality of biofertilizers. The monitoring process will be carried out after the first 6 months of activity implementation and will be conducted a monthly regular monitoring visit to ascertain the progress of activities.

Benefits, co benefits

The introduction and strengthening of silvopastoral systems in Galapagos, would likely improve environmental quality, both via i) increased C sequestration of the introduction of trees and bushes but also for reducing the need for synthetically produced farm inputs which are carbon-intensive industrial processes; and ii) nutrient removal by improving organic matter to the system as compared to grass monocultures. In addition, Silvopastoral systems (trees introduction) can provide watershed and biodiversity benefits as well. Trees and bushes improve the microclimate below them, reduce evapotranspiration, and protect grasses from strong winds. The natural fall of leaves and pruning helps increase the availability of water, light, and nutrients for all the system components, improving the productivity of surrounding pastures. This feed production unit (forage bank) will provide sources of protein, energy, and fiber for cattle, even during dry spells.

In addition, according to research carried out, a 1.5 was established as the index of increase in milk production in livestock farming under the Silvopastoral System (Flores Estrada, 2014). If we apply the index in the Silvopastoral System implemented in Galapagos, an average daily production of 6.99 liters per Adult Bovine Unit (UBA) is estimated. On the other hand, when implementing the Silvopastoral System in Galapagos, it has been estimated as an increase rate of 3 in meat production. In this sense, each UBA could have a weight of 462 Kg.

Direct Beneficiaries:

Implement an Agroecological Silvopastoral System in 244 farms in medium and large-scale farms mostly devoted for cattle ranching activities (Livestock and mixed farms). Specific activities, such as fodder banks and paddock division, will be implemented on farms with over 20 cows (68 farms). Additionally, in 66 livestock production farms will be implemented Biodigesters: 42 in cattle production farms and 24 in swine production farms.

Finance Mechanism

Total Budget: $2,486,394.7

- GCF Grant: $1,110,869.1
- CAF Loan: $1,014,974.8
- Private Sector: $360,550.7

Activity 2.1.2.4. Develop and implement water collection and water management systems for climate-resilient food production.

This proposed activity will improve the water collection and distribution through the implementation of a water system (Figure 50) that supports the agriculture needs of the islands, mainly in the dry season by including 500 new hectares (Table 45) with climate resilient farms and new water collection, storage, and distribution systems. The new farms will cover certain crops to generate a new harvest in the dry period. These irrigated areas will enhance farmers' profits by adding one more harvest than usual and keeping fodder fresh for livestock consumption. Additionally, the proposed interventions in the water irrigation system aim to increase its diversity and redundancy, both in sources and in operating infrastructure.

Table 45.Baseline and project implementation areas based on irrigation coverage.

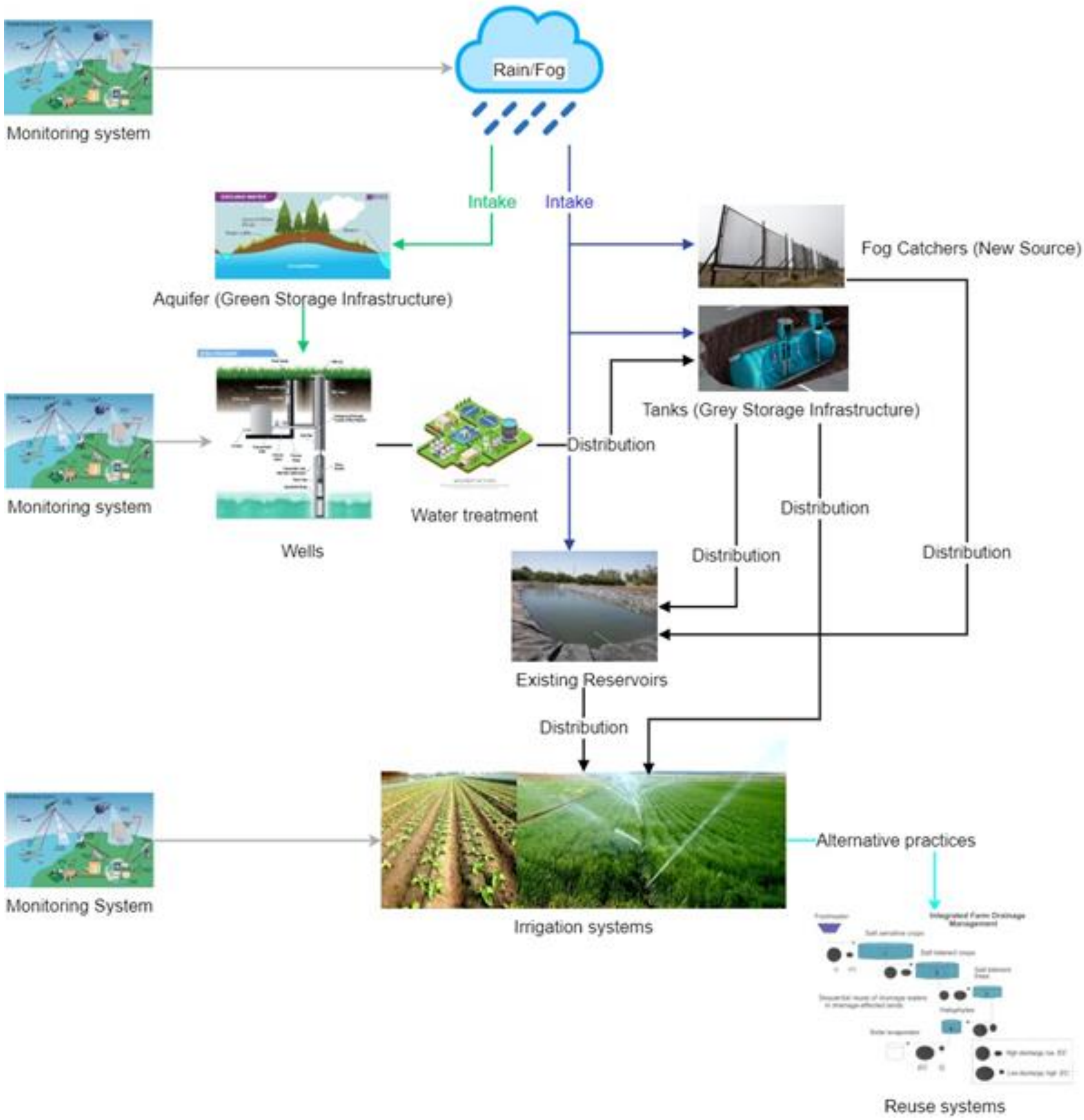
Irrigation and types of crop systems	Hectares baseline	Hectares new practices
Has under irrigation	37 has*	500 has
Has under climate resilient farms	0	500 has
Has under silvopastoral systems	3496 has*	6000 has

*Census 2014

This system will lead to important innovations in the way by which water is traditionally collected in the Islands. The system can be improved by in situ analysis of collecting rates with different net dispositions and locations, and it can be scaled based on the results. This practice could be addressed together with water reuse methods, one of the most popular IFDM (Integrated Farm Drainage Management) used by the National Water Research Center of Cairo, Egypt (SJVDIP, 1999d). Moreover, we also propose to technify the irrigation mechanisms of the system through the use of drip and sprinkle techniques of irrigation which uses water more efficiently and also leads to more agricultural yields.

It is worth mentioning that there is a commitment from the Ministry of Environment and Water, local governments and MAG to provide permanent assistance to monitor and control the work of the irrigation systems, ensuring the sustainability of the actions here proposed.

Figure 50. Flowchart of the practices implemented in the Galapagos water system



This activity includes the following sub-activities that allow to improve the adaptive capacity of the agroecosystems in Galapagos.

a. Water sources, intakes, and storage management that include:

- Rainfall collection: One of the sources to directly fill reservoirs and tanks, and indirectly aquifers is rainfall. For the grey infrastructure (reservoir and tanks) the amount of rain that can be stored depends, apart from the rainfall rates, on the surface of reservoirs and the drainage area around buried tanks. The contribution estimates are calculated assuming the average monthly precipitation rate, free surface of the existing reservoirs and drainage area around tanks. The contribution rates are between 3 – 4 thousand m3/month in the wet period and 2 – 3 hundred m3/month in the dry period. This contribution rate aims to fill all tanks and reservoirs to cover the first months of water irrigation demands, before activating the groundwater system. Their storage capacity is linked with the amount of water that is daily required to satisfy crop needs for each island: 7,220m3 for Santa Cruz, 5,358m3 for San Cristobal, and 3,931m3 for Santa Cruz. The water requirements that are needed, in m3, to satisfy the crop needs are shown below (Table 46). These estimates are also calculated utilizing the sensitivity experiment, in this case, it was used for the results for the dry months of the driest scenario.

Table 46. Daily water demand by crop and scenario. (SX: Santa Cruz, SC: San Cristóbal, Isb: Isabela)

Crop	Proposed area to be increased by year (ha)			Area to be increased in 3 years			Daily water demand (m3/ha)		Total demand for the proposed area (m3/day)					
	SX	SC	Isb	SX	SC	Isb	Scenario		Santa Cruz		San Cristobal		Isabela	
							Dry	Wet	Scenario		Scenario		Scenario	
									Dry	Wet	Dry	Wet	Dry	Wet
Limón	2.7	1.5	1.5	8.1	4.5	4.5	14.5	11.5	39.0	30.9	21.7	17.2	21.7	17.2
Café	1.5	1.5	1.125	4.5	4.5	3.375	33	30	49.4	44.9	49.4	44.9	37.1	33.7
Musáceas	4.5	3	3.75	13.5	9	11.25	42.2	39.2	189.9	176.4	126.6	117.6	158.3	147.0
Yuca	4.5	3	2.25	13.5	9	6.75	38.5	35.5	173.3	159.8	115.5	106.5	86.6	79.9
Caña	3	2.25	2.25	9	6.75	6.75	44.1	41.1	132.2	123.2	99.1	92.4	99.1	92.4
Fréjol	1.35	1.395	0.9	4.05	4.185	2.7	40.4	37.4	54.5	50.4	56.3	52.1	36.3	33.6
Hortalizas	6	4.5	3	18	13.5	9	36.7	33.7	219.9	202.0	164.9	151.5	110.0	101.0
Maíz	15	10.5	6	45	31.5	18	27.4	24.4	411.0	366.2	287.7	256.3	164.4	146.5
Maíz	15	11.25	5.625	45	33.75	16.875	27.4	24.4	411.0	366.2	308.3	274.6	154.1	137.3
Papaya	1.2	0.9	0.6	3.6	2.7	1.8	38.5	35.5	46.2	42.6	34.7	32.0	23.1	21.3
Papa	3	3	2.25	9	9	6.75	40.4	38.8	121.1	116.3	121.1	116.3	90.8	87.3
Pimiento	3	1.5	1.5	9	4.5	4.5	34.8	31.8	104.4	95.4	52.2	47.7	52.2	47.7

Piña	0.45	0.3	0.225	1.35	0.9	0.675	8.9	5.9	4.0	2.7	2.7	1.8	2.0	1.3
Tomate	7.5	4.5	2.25	22.5	13.5	6.75	31.1	28.1	233.3	210.8	140.0	126.5	70.0	63.2
Maní	0.045	0.06	0.03	0.135	0.18	0.09	40.4	37.4	1.8	1.7	2.4	2.2	1.2	1.1
Maracuyá	0.75	0.375	0.375	2.25	1.125	1.125	31.1	28.1	23.3	21.1	11.7	10.5	11.7	10.5
Aromáticas	0.024	0.024	0.018	0.072	0.072	0.054	40.4	37.4	1.0	0.9	1.0	0.9	0.7	0.7
Medicinales	0.0375	0.03	0.03	0.1125	0.09	0.09	40.4	37.4	1.5	1.4	1.2	1.1	1.2	1.1
Forrajes	4.5	4.5	4.5	13.5	13.5	13.5	42.2	39.2	189.9	176.4	189.9	176.4	189.9	176.4
Total per day and per year									2406.5	2189.3	1786.2	1628.7	1310.3	1199.3
Total per year and per 3 years									7219.6	6568.0	5358.5	4886.1	3930.9	3598.0

- New Groundwater Wells and Boreholes: The number of wells is determined by the specific water needs of crops in the driest scenario. In general, we estimate that the daily water needs of the 500 proposed for Santa Cruz, San Cristobal, and Isabela are about 7,220m3, 5,358m3, and 3,931m3, accordingly (supplementary material). Since these requirements are daily, tanks need to be filled in about 12h of continuous extractions and treated for salinity and other parameters found in the groundwater. Ideally, this is to be done during night-time so that water is used during daytime. This process is going to be monitoring as shown in the flow chart. The decision of the amount of groundwater extraction will be taken considering the previous aquifer data collected and the aquifer levels in that moment. The monitoring system plays an important role in the decision making of groundwater extraction due to the over coverage of water demands in some months (Table 47).

Table 47. Daily demand of proposed irrigation areas covered by wells.

Island		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Santa Cruz	Wells extraction m3	7776	7776	7776	7776	7776	7776	7776	7776	7776	7776
	Cover %	400%	197%	122%	121%	111%	114%	112%	107%	104%	112%
San Cristobal	Wells extraction m3	5184	5184	5184	5184	5184	5184	5184	5184	5184	5184
	Cover %	374%	183%	113%	112%	103%	107%	104%	99.7%	98%	104%
Isabela	Wells extraction m3	3888	3888	3888	3888	3888	3888	3888	3888	3888	3888
	Cover %	374%	183%	113%	112%	103%	107%	104%	99.7%	98%	104%

The specific location of these wells is a result from the previous practice which will survey the geophysical, geological, and hydrogeological characteristics of the Islands. The total number of wells proposed are 6 in Santa Cruz, 4 in San Cristobal and 3 in Isabela to cover the total amount of agricultural water demands in the dry season. This practice considers three important points for insurance the aquifer sustainability: i) Data of previous studies and aquifers monitoring, ii) Water treatment before and after irrigation (shared responsibility), iii) Alternative practices of water reuse if reach limit points (Integrated Farm Drainage Management, increase of Fog Catchment coverage)

- Fog Catchers: This option will cover about 1000m2 of croplands; yet it is important to note that the expected amount of water from fog catcher may not fully satisfy crop requirements. Fog Catchers are distributed 20 in Santa Cruz (collecting 7m3 of water), 17 in San Cristobal (collecting 5.5m3 of water) and 10 in Isabela (collecting 3.2m3 of water). In particular, they are to be located in areas over 400 m.a.s.l since in these areas fog reaches its maximum potential to contribute to water yields (Pyret, 2010). The fog catchers proposed here have an area of 40m2 and they, in average, contribute to about 300 l/day. Due to the low contribution in terms of water, the total of fog catchers will be used in the reactivation of the old reservoirs without depending on the water tankers to fill them. This system will be a sustained form of water harvesting showing net benefits after the fourth year of implementation. Today, the water used in the reservoirs has a cost of 3.93 $/m3 in a 7m3 tank truck, the fog collectors will cover the need for 471m3/month or 67 full water tankers per month.

b. Water distribution. The next stage then addresses the distribution of water from the sources and storage elements to the farms. Thus, this corresponds to a series of canals and pipelines which facilitate water transport to local farms. Depending on the natural gradient, these pipelines could be pressurized or free flowing canals. Due to evaporation losses, pipe flow is encouraged. The length would address the distance between the water intake or well to the storage tanks and finally to the farmlands. An estimated length of 25km for Santa Cruz, 20km for San Cristobal, and 15km for Isabela is considered for the distribution network on each Island.

c. Irrigation. This strategy corresponds to the amount of water effectively used by crops. In this proposal, we aim to cover 100% of the needs from croplands. Yet if the system has an excess of water due the benefits of rainfall, the operation decisions in wells and reservoirs can be modified. This could be done to relief extraction rates from the aquifer or to store more water in reservoirs. The number of hectares to be covered by irrigation is the same as those shown in Table 47 above. The mechanisms to irrigate that are proposed are:

- Drip irrigation: Drip irrigation is known for its reduction in losses within irrigation systems. Due to the water scarcity in the islands, this method is the best option to implement an irrigation plan. This type of irrigation has shown a significant improvement in agricultural production in similar areas with water scarce conditions. In spite of these benefits, drip-based systems lose their efficiency when irrigation water is saturated with salt, which is the reality in some places in the Galapagos. This proposal addresses this problem by ensuring that the distributed water is pretreated. Drip irrigation systems were calculated to cover 152.8 Has per year, a total of 458.4 Has in the three years of project development. Furthermore, the characteristics of this system are: i) Pump with 2hp and discharge accessories, ii) 2 inches filter, iii) Fertilization couple, iv) 2 inches principal pipe - 100mts, v) 1-inch secondary pipe - 200mts, vi) 12 valves, vii) 6800 mts dropper tape every 20cm; however, these characteristics will change in function of the crop type.
- Sprinkler irrigation: Sprinkler irrigation is an irrigation method that attempts to balance costs and losses of water in the system. This project proposes to cover the fodder areas with sprinkler irrigation that are going to focus on livestock feeding for driest periods by adding 13.5 has per year up to a total of 40.5 has by the end of the project. One of the benefits of this method is the lack of salt-water treatment, as the pipes and sprinklers do not have clogging problems with it. The characteristics of this system are: i) Pump with 9hp, ii) High pressure pipes, iii) Fertilization couple, iv) 63 millimeters principal pipe -

125mts, v) 50 millimeters secondary pipes - 200mts, vi) 25 millimeters sprinkler pipe - 820mts, vii) 4 valves, viii) 70 sprinklers.

Benefits, co benefits

By implementing the water system described here, this firstly supports adaptive capacity of the population through general food security of the Islands. At the same time, the system in place could be used to enhance water security conditions beyond the agricultural sector. This naturally includes water for human consumption, water risks management (flood and droughts), and others. By proposing new wells as well as fog catchers increases the diversity of places which could effectively supply farms. Similarly, by proposing two types of storage (green infrastructure and new tanks and reservoirs) our strategies also enhance, not just the number of places where water is stored, but also the type of them. As such, if the operation of reservoirs and tanks need to be suspended the Islands could use the natural reservoirs (i.e., groundwater) as an alternative of supply in such circumstances. These conditions could occur when reservoirs and tanks are under maintenance, when intense dry conditions leave high evaporation rates, or other unexpected events.

The inclusion of 500 has of new resilient climate systems and 6000 has of silvopastoral systems (baseline) aims to improve the integrated management of water resources in Galapagos. The monitoring system and previous studies proposed in the first output will allow the understanding of the recharge processes of aquifers, hydraulic regimes, and critical seasons, which is why it seeks to comprehensively improve both agricultural production and the conservation of natural processes by reducing ecosystem alterations to the maximum.

Beneficiaries:

These practices will be implemented in farms of San Cristobal, Santa Cruz, and Isabela islands. By the end of the fifth year, at least 500 new ha. of agricultural land with improved water management practices (1,704 beneficiaries of the water systems, 30% women). So, this broadly refers to the establishment of rainwater collection, water harvesting, treatment, storage, and efficient irrigation systems at a farm scale.

1. Water sources, Intakes and storage:

- The total number of wells proposed are 6 in Santa Cruz, 4 in San Cristobal and 3 in Isabela
- The total number of fog catchers are 20 in Santa Cruz, 17 in San Cristobal and 10 in Isabela
- Grey infrastructure. - the storage capacity calculated for each island to satisfy crops needs is 7,220 m3 in Santa Cruz, 5,358 m3 in San Cristobal and 3,931 m3 in Isabela
- Green Infrastructure. - At present, it is not possible to totally estimate recharge and extraction rates in existing aquifers. These outputs will be explicitly obtained when the monitoring (specially the geophysical, geological, and hydro-geochemical evaluations) phase kicks off.

2. Water distribution: The length would address the distance between the water intake or well to the storage tanks and finally to the farmlands. An estimated length of 25km for Santa Cruz, 20km for San Cristobal, and 15km for Isabela is considered for the distribution network on each Island.

3. Irrigation:

- Drip irrigation systems were calculated to cover 153 Has per year, a total of 459 Has in the three years of project development (209 Has in Santa Cruz, 149 Has in San Cristobal and 101 Has in Isabela).
- This project proposes to cover the fodder areas with sprinkler irrigation by adding 13.5 Has per year up to a total of 41 Has by the end of the project.

Finance Mechanism

Total Budget: $3,462,481.4

- GCF Grant: $2,931,184.4
- CAF Loan: $281,297.0
- Private Sector: $250,000.0

12.5.1.4 Output 2.1.3. Science-based and participatory management frameworks and systems in place, for the adaptive co-management of the Galapagos marine zoning.

There is a growing recognition that MPAs in combination with co-management regimes can be an effective solution for rebuilding depleted marine populations, conserving HEVAS, and increase resilience to climate change (Gutiérrez et al. 2011; Micheli et al. 2012; Edgar et al. 2014; McCay et al. 2014). However, this spatially explicit management approach is not a one-size-fits-all solution effective in all contexts (Castrejón and Charles 2013). This can be observed in cases where MPAs were created using a top-down approach and designed without considering a broad-based and integrated social-ecological approach, which takes into consideration not only the spatial-temporal dynamics of fishery resources and the spatial distribution of HEVAS, but also the dynamics of fishing fleets and fishers' adaptive responses to regulations (Castrejón and Charles 2020).

The resilience of MPAs can be degraded by the impacts produced by diverse climatic and human perturbations, such as climate variability and climate change, overfishing, IUU fishing, marine pollution, market globalization, the establishment of new institutions, regulations or policies, and the boom-and-bust exploitation of new fisheries (Badjeck et al. 2010; Perry et al. 2011; Castrejón and Defeo 2015; Bertrand et al. 2020). Therefore, a comprehensive understanding about how the interaction of these external drivers of change affects the dynamics of resources, their marine environment, and the people whose livelihoods depend on them, is fundamental to develop policies and management strategies to enhance the adaptive capacity and resilience of marine ecosystems, local fishing communities, and institutions to cope with and adapt to change (Castrejón and Charles 2020).

In 2014, the GNPD with the support of international NGO, officially initiated a participatory marine and terrestrial spatial planning process to improve the management effectiveness of Galapagos protected areas. After six years, this participatory process is close to an updated reconfiguration of management areas, including the creation, expansion, or redistribution of no-take zones to improve the protection of HEVAS and to ensure the conservation of at least 30% of all marine macro-habitats (e.g., corals, mangroves, etc.) at each of the five marine bioregions of the GMR.

However, the top-down implementation of a "Marine Sanctuary" in the Far Northern bioregion of the archipelago, in combination with inconclusive scientific evidence about the impact of previous no-take zones on fishery resources and fishers' livelihoods, affected fishers trust and buy-in on the new marine zoning. The resulting socio-political pressure forced the Minister of Environment to postpone the effective implementation of the new marine zoning, approved in March 2016, until GNPD provides scientific evidence about the potential impact of the new network of no-take zones on local small-scale fishers' livelihoods.

A comprehensive understanding about how Galapagos fishery resources and marine biodiversity have been impacted by the interactions of the ENSO, overfishing and IUU fishing, and other drivers of change, is fundamental to determine the effectiveness of the former network of no-take zones over the sustainability of commercial stocks and conservation of marine biodiversity. Based on this knowledge, the GNPD and Galapagos Governing Council will receive a set of recommendations to improve the design and management effectiveness of the new Galapagos marine zoning. To reconcile conservation and fishery management objectives, no-take zones should be strategically re-distributed across the archipelago to ensure the recovery of overexploited fishery stocks and degraded habitats. The new network of no-take zones of the new Galapagos marine zoning will maximize not only the protection of HEVAS, but also the protection of a relevant proportion of fishery resources spawning stocks and critical recruitment and nursery habitats while minimizing its negative impact on fisher's livelihoods. The effective implementation of the new marine zoning, in combination with co-management regime, long-term ecological and fisheries monitoring programs, advance information system, and a structured decision-making framework, will promote the adaptive co-management of the GMR. The successful implementation of this ecosystem-based management approach is expected to be an effective solution for rebuilding depleted marine populations, conserving HEVAS, and increase resilience of marine ecosystems, fishery resources and fishers to climate change.

Therefore, to prevent and mitigate the impact of the ENSO and climate change on marine ecosystems is fundamental to increase the effectiveness and adaptive co-management of the new Galapagos marine zoning, as fishery management and marine biodiversity conservation tool. To accomplish this the program will implement the following activities.

Activity 2.1.3.1 Improve the design and management effectiveness of Galapagos marine zoning, based on conclusive scientific evidence on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods.

The primary objective of the Galapagos marine zoning is to increase the protection of High Ecological Value Areas (HEVAS) and improve ecological representativeness and connectivity through an improved network of no-take zones. However, to reconcile conservation and fishery management objectives, no-take zones should be strategically re-distributed across the archipelago (Edgar et al. 2004b; Castrejón and Charles 2013). To date, there is no conclusive scientific evidence about the impact of the former Galapagos marine zoning on fishery resources, marine biodiversity, and fishers' livelihoods, leading to a lack of trust and buy-in of the local fishing sector on the marine zoning (Castrejón and Charles 2013). Therefore, a comprehensive understanding about how fishery resources and marine biodiversity have been impacted by the interactions of the ENSO, overfishing and IUU fishing, and other drivers of change, is fundamental to determine the effectiveness of the former network of no-take zones over the sustainability of commercial stocks and conservation of marine biodiversity.

To increase the usefulness of marine zoning as fishery management and marine biodiversity conservation tool, the program will integrate scientific and local knowledge about marine biodiversity and shellfish and finfish fisheries with fishery-related socioeconomic information, to suggest improvements to the new network of no-take zones. To this end, complementary fishery-related objectives, criteria and indicators will be set up, based on the scientific literature and international experts' advice, to re-evaluate the distribution of no-take zones across the GMR, including an evaluation of relevant set of human and climatic drivers, on fishery stocks and marine biodiversity across the Galapagos Islands. The efficacy and opportunity cost of the new network of no-take zones in meeting both conservation and fishery goals will be evaluated by software-based simulative and marine spatial planning tools (Klein et al. 2010; Davidson and Dulvy 2017). The results of these studies will provide a set of recommendations to improve the design and management effectiveness of Galapagos marine zoning, to reconcile conservation and fishery management objectives. These recommendations will be the basis for the participatory process that will need to take place for the endorsement of the new marine zoning by the small-scale fishing sector and other relevant stakeholders.

To achieve this stakeholder endorsement and to promote management effectiveness, it is fundamental to fully implement the Consultative Board of Participatory Management (CBPM). This instance of management is responsible for "planning, managing resources, organizing activities carried out in the territory of the province of Galapagos and inter-institutional coordination with State institutions". However, at the time of writing this report, the CBPM has not yet been constituted and put into operation. This has generated confusion regarding the role that local stakeholders will play in generating high-level policies for co-management of the GMR fisheries. Therefore, the first step that the program will give is to provide technical advice and funding to the CGREG and DPNG to create the basic enabling conditions to install the CBPM. The program will then implement a participatory process with the GNPD, CGREG, small-scale fishing sector and other relevant stakeholders so they agree upon and support the process to conclude the fine-tune of the former GMR´s zoning design. Extensive and participatory consultation will be promoted by the program beyond the boundaries of the CBPM through innovative participatory methods that involve not only small-scale fishers but also tour operators, naturalist guides, conservationists, scientists, representatives of local governments, and the general public. At the end of this process, it is expected that the new marine zoning will be endorsed by the small-scale fishing sector and other relevant stakeholders. Such co-management approach will improve the credibility and legitimacy of the new Galapagos marine zoning because it will provide a voice to several members of local coastal communities who have influence or are influenced by the decisions taken concerning the management of the GMR (Castrejón and Charles 2013).

To see details on the proposed activity and justification please see Appendix 2.2.

At the end of the program:

- Conclusive scientific evidence about the impact of the former marine zoning, in combination with other human and climatic drivers of change, on marine biodiversity, fishery resources and fisheries' livelihoods published in at least two peer-review papers.
- The GNPD and Galapagos Governing Council received a set of recommendations to improve the design and management effectiveness of Galapagos marine zoning, contributing to the effective implementation and adaptive co-management of the new marine zoning.
- At least 60% of Galapagos small-scale fishers and 80% of the local community endorse the new marine zoning.
- The new marine zoning has been effectively implemented and protected at least 80% of HEVAS and 30% of all marine macro-habitats (e.g., corals, mangroves, etc.) at each of the five marine bioregions of the GMR, including critical habitats.
- No take zones have been strategically distributed to protect at least 30% of the breeding stock and critical recruitment and nursery habitats for sea cucumbers, spiny lobsters and sailfin groupers.
- The location of traditional fishing grounds and opportunity costs for the small-scale fishing sector were socioeconomic selection criteria used as inputs to adapt the 2000 Galapagos marine zoning.

The new Galapagos zoning system approved in March 2016 offers protection to 32 out of the 38 inshore key biodiversity areas (KBAs) identified by Edgar et al. (2004); i.e., 84% of the KBA are protected. Therefore, it is expected that the same level of protection is established to the HEVA. On the other hand, the new zoning was guided by a set of goals, objectives, and indicators, built in the scientific literature and international marine spatial planning experts' advice, and linked to the vision and principles of the new Galapagos management plan. One of these criteria is "representativeness"; i.e, creating a network of terrestrial and marine protected areas representing at least 30% of the different environmental units existing in Galapagos.

Beneficiaries:	
Direct	• CGREG and GNPD with strengthened capacities for an effective and participatory management of the GMR. • At least 400 fishers and their families will benefit from the recovery of sea cucumbers, spiny lobsters and sailfin groupers stocks.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood. • 100% of tourism operators in the GMR will benefit from healthy nature attractives.

Budget and financing mechanism:	USD 680,395.17 / Grant
Executing entity:	WWF
Governmental partners:	GNPD and CGREG

Activity 2.1.3.2 Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning.

The Galapagos subtidal ecological monitoring program was created in 2004 to evaluate the impact of anthropogenic and climatic drivers, including the implementation of no-take zones, upon marine biodiversity. Based on this information the effectiveness of marine zoning can be determined and adaptations to its design can be developed, following a consensus-based participatory process.

Since 2004, quantitative surveys of fishes, mobile macroinvertebrates, and sessile invertebrates have been conducted at 6 and 15 m at ca. 70 sites by the Charles Darwin Foundation. After ecological monitoring data are physically collected in paper-based logs, they are manually recorded in Access datasets. Manual data recording on paper logbooks has led to issues with data accuracy and reliability due to standardization, transcription, and misreporting problems. Processing and analyzing data are quite slow due to insufficient resources and limited institutional capacity, resulting in a paucity of basic ecological indicators for decision-making. In consequence, subtidal ecological data is subtilized given the prolonged lag between data processing and management interventions.

The adaptive co-management of the Galapagos marine zoning requires better data collection, dimensioned to inform appropriate indicators in a faster and more accessible format for reporting, processing and analysis, that will translate into more effective mechanisms to disseminate results and enable near real-time adaptive responses. However, despite the availability of technological innovations to improve the subtidal ecological monitoring program, the utilization of high-tech advanced data systems has been precluded by limitations of funding and institutional shortcomings.

Therefore, the Program will develop an advanced data system to improve the accuracy, reporting, analysis, and dissemination of subtidal ecological data. Such a system will reduce costs, facilitate adaptive and responsive decision-making procedures, to improve marine zoning management efficiency. An app, a data repository, and a dashboard will be created to collect, store, and analyse annually updated subtidal ecological data. This advanced data system, called the “Subtidal Ecological Monitoring” module, will be created following the transdisciplinary methodology recommended by Bradley et al. (2019). Such a module will be developed in collaboration with the GNP and NGOs, and be integrated into the “Sistema Único de Información Ambiental (SUIA)”, which is the national data repository system for environmental data in Ecuador.

Complementally, local management authorities, scientists, NGO and relevant stakeholders will be trained to facilitate the integration of the information generated by the Subtidal Ecological Monitoring module into GMR management decisions.

The decision-makers will have direct access to the data repository through a dashboard. The same approach has been used for the Fisheries Monitoring Program. The data repository for the “Subtidal Ecological Monitoring" module will be hosted by the Galapagos National Park. The administrative cost will be paid by this institution as it occurs for the “Fishery monitoring module” already created and in place. The data of the “Subtidal Ecological Monitoring" module will be shared with the Charles Darwin Foundation and other interested institutions, based on the signature of memorandums of understanding.

At the end of the program:

- Public data repository and a geographic information system on Galapagos marine biodiversity, oceanography, fisheries, transport, IUU fishing, and marine traffic to support marine spatial planning.
- “Subtidal Ecological Monitoring” module in place and integrated into the “Sistema Único de Información Ambiental (SUIA)”.

- Local management authorities, scientists, NGO and relevant stakeholders trained on “Subtidal Ecological Monitoring" module.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• CGREG and GNPD have strengthened capacities through an innovative data management system to facilitate adaptive and responsive decision-making.
Indirect	• GMR tourist operators and small-scale fishers benefiting from marine ecosystem services (fishing stocks and nature based attractives).

Budget and financing mechanism:	USD 345,999.72 / GRANT
Executing entity:	WWF
Governmental partners:	GNPD and CGREG

Activity 2.1.3.3 Structured decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve.

The effective adaptive co-management of the GMR requires a structured decision-making framework linked to the subtidal ecological and fisheries monitoring program and other monitoring and evaluation systems conducted by the GNPD and Charles Darwin Foundation, which are fundamental to improve the management effectiveness of the marine zoning. Since July 2019, the Lenfest Ocean Program has supported a team of researchers from Arizona State University, to leverage multiple data sources and modelling approaches to improve the adaptive co-management of the GMR, based on scientific criteria. Since then, this research team has worked in collaboration with the GNPD to develop a framework for structured decision-making that involves: (1) refining management objectives and modelling ecosystem behaviour; (2) monitoring ecosystem change and response to management actions; and (3) evaluating spatial management options.

The structured decision-making framework will provide a rigorous framework to GNPD’s managers to assess management zones and actions against specified management objectives. Through this approach, the current monitoring programs in place are being evaluated and enhanced, based on ecosystem indicators, thresholds and scientific modelling to ensure the adaptive co-management of the GMR, based on ecological and socioeconomic information.

At the moment, the research team is working with the GPND to develop management objectives that are measurable. The researchers will then evaluate existing ecosystem indicators to establish thresholds for management decisions. To do this, the researchers will integrate multiple existing data sources into metapopulation models to assess ecosystem change against specified management objectives as well as make projections for key species. The team is employing this approach for three fishery species (yellow fin tuna, wahoo, and sailfin grouper) and three threatened or iconic species (waved albatross, green turtles, and Galápagos sharks), and under three climate scenarios. Species and scenarios has been chosen in conjunction with GNPD technical staff.

The research team is also applying metapopulation models to the revised zoning in three distinct regions: southeast Isabela; between Santiago and Santa Cruz; and southern San Cristóbal and

Española. The aim is to explore the utility of a structured decision-making approach in areas with contrasting zoning rules. New zoning rules for the GMR considers offshore areas for the first time. Thus, the research team is developing a new monitoring protocol for these areas. To align this protocol with existing monitoring programs, the researchers have leveraged existing information on abundance, capture and movement of species (e.g., pelagic fishes and seabirds); have identified information gaps for all study areas; and have integrated existing data streams, and the input of local tour operators as well as other stakeholders.

Finally, through the structured decision-making framework, the research team is evaluating how likely different spatial configurations of zones in the GMR are to deliver on management objectives. The research team is co-developing all previously described modelling and monitoring efforts with the GNPD to facilitate their application across the GMR. By working directly with technical staff and managers, the research team hopes to ensure their efforts are not only robust but useable in a management context and tangible for stakeholders. This project will end on July 2022.

To ensure the effective implementation of the structured decision-making framework, this Program proposes to the GCF to invest in the development of a training program for local management authorities, scientists, NGO and relevant stakeholders. The objective is to facilitate the integration of the structured decision-making framework into GNPD decision-making process and existing monitoring programs.

Furthermore, to financially sustain the structured decision-making framework and the ecological and fisheries monitoring programs required to feed this system in the long-term, we propose to work actively in seeking a cooperation agreement to align the FRMG's priorities with what is proposed in the Programme, and therefore channel FRMG funds to complement and maintain adaptation measures. In other words, no GCF funds will flow from GCF to the FRMG but the objective will be to influence on the FRMG to mainstream climate change in their decision-maiking and obtain an engagement for the funding of this Programme’s activities over time. .

At the moment of writing this proposal, the FMRG is being legally created by the GNPD in collaboration with WildAid and Conservation International. Therefore, the governance structure of the FMRG has not been defined yet. A group of consultants is working on a draft structure, which will be ready for revision and validation at the end of October.

The FRMG would operate as an integral part of the Sustainable Environmental Investment Fund (FIAS)[21]. The original objective of the FRMG is to provide financial sustainability to the monitoring, control and surveillance system of the GMR and its surrounding waters, including all the sub-processes that this requires, including support for the prosecution or execution of legal processes, investments in vehicles and technology to improve patrolling, monitoring and surveillance. However, a group of stakeholders have recommended to extent the original objective of the FMRG to invest in other processes that guarantee an integral adaptive co-management of the marine reserve. This vision is shared by the consultants, who will seek that the governance structure of the FMRG accommodates this integral vision for the management of the GMR. Regarding the financial infrastructure of the FMRG, it is envisaged to have a mixed fund made up of sinking funds and equity funds.

At the end of the program:

- DPNG and CGREG management authorities, scientists, NGO and relevant stakeholders trained for the integration of the framework in decision-making process and existing monitoring programs.

[21] The FIAS is a non-profit organization, with legal identity, governed by the Ecuadorian Civil Code, created on September 6th, 2017 through an executive order. The mission of FIAS is to support the financing of environmental management, protection, conservation and sustainable use of natural resources and biodiversity, as well as actions to mitigate and adapt to climate change and to manage environmental quality in Ecuador.

- DPNG framework for structured decision-making linked and sustained with the financial and technical contribution of the GCF to the “Fondo para la Reserva Marina de Galápagos (FRMG)”.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• CGREG and GNPD strengthened with long term monitoring programs for evidence-based decision making.
Indirect	• GMR tourist operators and small-scale fishers benefiting from marine ecosystem services (fishing stocks and nature-based attractions).

Budget and financing mechanism:	102,000 / GRANT
Executing entity:	WWF
Governmental partners:	GNPD and CGREG

12.5.1.5 Output 2.1.4. Climate-smart small-scale fisheries and aquaculture approach adopted for the restoration of shellfish and finfish stocks and the diversification of livelihoods.

The overexploitation of sailfin groupers and sea cucumber stocks, in combination with IUU fishing and other human drivers of change, has degraded the resilience and adaptive capacity of Galapagos marine ecosystems, making them vulnerable to climate variability and change. Therefore, the project will contribute to restore the abundance and ecological of sea cucumber and sailfin grouper stocks and diversify fishers’ livelihoods by supporting the implementation of community-based fishery improvement projects, together with the implementation of small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs). A TURF is an area-based fishing right that allocate secure, exclusive privileges to fish in a specified area to groups, or in rare cases individuals. Most TURF systems do not grant ownership of fishing areas. They allocate exclusive harvesting rights for one or more marine species in a specified area. TURFs are ideal for species like sea cucumbers that will not move beyond TURF boundaries, but they can be designed for species that are more mobile as well, like spiny lobsters.

The objective of this Output is to restore Galapagos marine ecosystems and improve the socioeconomic condition of the small-scale fishing sector and the food security of the Galapagos coastal communities. It is expected that the effective involvement of local communities in the co-management of strategically placed TURF will contribute to generate a sense of exclusive use and ownership among fishers, promoting the implementation of effective monitoring, control and surveillance procedures, and the accomplishment of objectives for management and conservation.

Activity 2.1.4.1 Management conditions of small-scale tuna fisheries, strengthened to reduce the ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species.

Considering the key role that the tuna fishery plays in the economy and food security of Galapagos coastal communities, there is a consensus between management authorities, fishers and NGOs to promote the development of the tuna fishery to increase the resilience and adaptive capacity of Galapagos coastal fishery resources and small-scale fishing sector against future crises, including climate change. However, the key question is how to maximize the socioeconomic benefits generated by the Galapagos tuna fishery, while minimizing its ecological impact on endangered, threatened, or protected species, such as sharks, mantas, and marine turtles. To answer this question, various institutions and NGOs have developed a holistic, community-based management strategy for the yellowfin tuna fishery, based on principles of sustainability and social responsibility (Castrejón et al. 2019).

Since the mid-2000s, most research and management efforts have focused on increasing tuna catch levels through the experimental use of longline, a fishing gear currently prohibited in the Galapagos Marine Reserve (GMR). This approach has generated considerable controversy due to its potential negative impacts on protected species. An alternative research and management approach, whose relevance has gained momentum in recent years, is to enhance the value of the tuna fishery through capture and marketing strategies. Due to its perceived resilience benefits, we intend to focus on capture strategies that increase the quality of the caught tuna, rather than their quantity, and implementing adequate harvest and post-harvest techniques to improve and maintain tuna quality. Complementary market strategies are addressed in Output 2.1.5, including the development of products with added value (e.g., smoked tuna, tuna burgers and sausages, etc.).

The Program will build from the alliance created by 12 governmental and non-governmental organizations in 2019, to put in place a holistic, community-based approach to improve the Galapagos tuna fishery through the development of a Community-Based Fishery Improvement Project, or C-FIP (Castrejón et al. 2019). Due to lack of funding for the C-FIP action plan for the Galapagos tuna fishery has not been implemented. This activity will build from this initiative to improve the sustainability and governance of the Galapagos tuna fishery through a set of sub-activities: (1) reduce IUU fishing and promote fair trade by implementing an electronic monitoring system that allows the cost efficient collection of catch data in situ, both target and bycatch species, in combination with a blockchain traceability system; (2) increase the quality rather than the quantity of tuna landings by improving post-harvest handling and cold-chain infrastructure, and by designing and implementing a code of good fishing practices and a manual of best practice handling techniques for target and bycatch species.

Finally, the Program will carry out the following research priorities identified by the DGNP and stakeholders to improve the management and sustainability of the Galapagos tuna fishery: (1) determining the impact generated by illegal and incidental fishing of sharks, and other ETP species, generated by the industrial and artisanal fishing fleet, both domestic and foreign, that takes place inside and outside the boundaries of the GMR, taking into consideration the impact of the climatic variability on catch composition; 2) determine the level of impact of ghost fishing and illegal fishing aggregating devices (FADs) on the GMR; and (3) determine the migratory patterns and the genetic and population structure of yellowfin tuna from the GMR. The results of these studies will be used by the GNPD to promote productive, climate-resilient, and low-carbon capture tuna fishery, as well as a strategy to prevent, deter and eliminate IUU and ghost fishing in the GMR. Such action will contribute to increase the resilience and adaptive capacity of Galapagos marine ecosystems by reducing the ecological impact of IUU and ghost fishing over a wide range of commercial and ETP species, including sharks and marine turtles.

Finally, the Program will carry out the following research priorities identified by the DGNP and stakeholders to improve the management and sustainability of the Galapagos tuna fishery: (1) determining the impact generated by illegal and incidental fishing of sharks, and other ETP species, generated by the industrial and artisanal fishing fleet, both domestic and foreign, that takes place inside and outside the boundaries of the GMR, taking into consideration the impact of the climatic variability on catch composition; 2) determine the level of impact of ghost fishing and illegal fishing aggregating devices (FADs) on the GMR; and (3) determine the migratory patterns and the genetic and population structure of yellowfin tuna from the GMR. The results of these studies will be used by the GNPD to promote productive, climate-resilient, and low-carbon capture tuna fishery, as well as a strategy to prevent, deter and eliminate IUU and ghost fishing in the GMR. Such action will contribute to increase the resilience and adaptive capacity of

Galapagos marine ecosystems by reducing the ecological impact of IUU and ghost fishing over a wide range of commercial and ETP species, including sharks and marine turtles.

Finally, based on the analysis of the migratory patterns and genetic and population structure of yellowfin tuna from the GMR, the GNPD will be able to quantify the "spillover effect" that occurs in the boundaries of the reserve (Bucaram et al. 2018). The spillover effect occurs when species located in a marine protected area, where they are protected for a portion of their life cycle and that has allowed them to grow and/or breed, move to adjacent fishing grounds where they are caught, in larger numbers or larger sizes. There is evidence that the catch of commercially important tuna species per fishing set has nearly doubled in the areas adjacent to the GMR (Bucaram et al. 2018). However, the knowledge about the migratory pattern of tuna within and around the GMR is still limited. Therefore, the GNPD has limited information to determine the impact of the GMR over yellowfin tuna stocks and the benefits that large-scale and small-scale fishing obtain from the GMR.

At the end of the project:

- At least 70% of the activities contained in the C-FIP action plan for the tuna fisheries have been effectively implemented.
- The MSC's Benchmarking and Tracking Tool (BMT) reports show that the level of sustainability of tuna fisheries have increased since the inception of the program.
- There is conclusive evidence that the quality of tuna landings has improved thanks to improved post-harvest handling and cold-chain infrastructure.
- At least 100 ship-owners have implemented in their fishing vessels an electronic monitoring system and they are part of a blockchain traceability system.
- At least one fishing organization has designed and implemented a code of good fishing practices and a manual of best practice handling techniques for target and bycatch species.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• At least 308 fisher and their families will benefit from the improvement of the Galapagos tuna fishery. • The GNPD and Ecuadorian Army will improve their control and surveillance capacity. • The entire small-scale fishing sector will benefit from reduction of IUU and ghost fishing.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood.

Budget and financing mechanism:	USD 834,400 / GRANT
Executing entity:	WWF
Governmental partners:	CGREG and GNPD

Activity 2.1.4.2 Management of sailfin groupers fishery strengthened to mitigate climate change impacts while restoring the species ecological role.

Concerns of overfishing, coupled with a lack of fishing regulations and a warmer ocean, have raised concerns regarding the sustainability of the Galapagos sailfin grouper fishery (Usseglio et al. 2016; Marin and Salinas-de-León 2018; Cavole et al. 2020). Based on the relative impact of grouper fishing and environmental factors to changes in simulated ecosystem effects, Eddie et al. (2019) concluded that overexploitation of groupers has produced greater effects over Galapagos marine ecosystems than El Niño events. In consequence, these authors suggest the participatory development of an evidence-based management plan to allow Galapagos sailfin grouper to recover to approximately half of their unfished biomass. This management approach will contribute to increasing groupers' biomass to the maximum sustainable yield (MSY), increasing fishery productivity, and partially restoring the groupers ecosystem role as keystone species.

Usseglio et al. (2016) suggest the need for specific management regulations to rebuild the Galapagos sailfin grouper fishery, including minimum (65 cm total lenght) and maximum (78 cm total lenght) landing sizes, slot limits (64±78 cm total lenght), as well as a closed season during spawning from October to January. It is recognized that these regulations are harsh and will certainly have negative impacts on the livelihoods of fishers in the short term. However, Usseglio et al. (2016) cautions that inaction will likely result in the collapse of this economically and culturally valuable fishery.

Therefore, to rebuild sailfin groupers stocks and restore their ecological role into Galapagos marine ecosystems and based on the successful application of the CFIP for the spiny lobster and tuna fisheries, this activity proposes the design and implementation of a C-FIP for this species. So far, the C-FIP model has contributed to mobilize financial resources from the public and philanthropic sector to improve the management and marketing system of the spiny lobster and tuna fisheries, and the same is expected to occur for the Galapagos sailfin fishery. These public and philanthropic investments have the potential to leverage a cascade of private financial resources to fund innovative projects that increase the efficiency of the fishery sector on all the links of the value chain and reduce the impact of the fishing activity on marine ecosystems, increasing their resilience and adaptive capacity to ENSO and climate change impacts. As a fundamental part of this framework, with this outcome the program will elaborate and adopt a participatory management plan for the sailfin grouper, considering the effects of climate change; this plan will include landing regulations, improve fishing practices and monitoring activities.

The adapted version of the MSC's Benchmarking and Tracking Tool (BMT) developed by Castrejon et al. (2015) will be used to update each fishery diagnostic. The BMT is a key component of the C-FIP model since it represents a comprehensive and standardized analytical framework to measure periodically the progress and impact of C-FIP implementation over fishery improvement. Each of the 43 performance indicators of the MSC+ will be scored annually using the BMT and following the procedures established by the MSC+ standard to determine changes in the sustainability status of the fishery and define key sustainability thresholds. These thresholds correspond to levels of quality and certainty of fishing management practices and their probability of generating sustainability. For more information about the BMT please refer to Activity 2.2 in Appendix 2.2.

At the end of the project:

- A C-FIP action plan for sailfin grouper fisheries is formulated and agreed upon.
- At least 50% of the activities contained in the C-FIP action plan for sailfin grouper fisheries have been effectively implemented.
- The MSC's Benchmarking and Tracking Tool (BMT) reports show that the level of sustainability of sailfin grouper fisheries have increased since the inception of the project.
- Management measures, responsible fishing practices and monitoring activities have been implemented in the sailfin grouper to promote its recovery.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• At least 308 fisher and their families will benefit from the improvement of the Galapagos tuna fishery. • The GNPD and Ecuadorian Army will improve their control and surveillance capacity. • The entire small-scale fishing sector will benefit from reduction of IUU and ghost fishing.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood.

Budget and financing mechanism:	USD 260,600 / GRANT
Executing entity:	WWF
Governmental partners:	GNPFD and CGREG

Activity 2.1.4.3 Small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs) implemented to rebuild sea cucumber stocks and diversify fishers' livelihoods.

The establishment of fishery management measures to ensure the recovery of the Galapagos sailfin grouper will disrupt the socioeconomic condition of the small-scale fishing sector in the short-term. Therefore, Usseglio et al. (2016) suggest that alternative sources of income should be developed in parallel with the establishment of fishing regulations to limit the impact on fishers' livelihoods during the transition to a more sustainable management regime. In response to this call, this activity proposes the development of small-scale aquaculture in Galapagos, in combination with the experimental allocation of Territorial Use Rights for Fishing (TURFs), to rebuild sea cucumber stocks. This will provide an alternative source of income to the small-scale fishing sector and promote the adoption of a rights-based co-management approach. Such management approach will set up the enabling conditions to address the roots of fisheries management failures that led to the overexploitation of the main shellfish and finfish fisheries of the GMR.

The sea cucumber fishery has not shown any sign of recovery, despite the implementation of a total closure since 2015. Empirical evidence of variable natural recovery following fish stock collapses suggests that populations can become "trapped" in a degraded state, possibly owing to multiple factors such as ecosystem effects, genetic deterioration, and modified intraspecific interactions (Lorenzen et al. 2012). Restocking programmes could address some of these issues, helping depleted populations to "break out of the trap" and regain critical mass capacity to increase population size.

Therefore, as the population abundance of sea cucumbers is substantially below carrying capacity because of overfishing, restocking may be the only active management intervention that can boost population recovery. Restocking or stock rebuilding involve temporary releases of hatchery fish aimed at rebuilding depleted populations more quickly than would be achieved by natural recovery (Lorenzen et al. 2012). To this end, a substantial number of sea cucumbers relative to the abundance of the remaining wild stock will be released to significantly accelerate rebuilding. As restocking calls for close ecological and genetic integration of wild and cultured stocks, combined with very restricted harvesting, fishing intensity will be regulated through the experimental allocation of Territorial Use Rights for Fishing (TURF). This management approach will maximize the contribution of wild and released cultured sea cucumbers for population growth. Furthermore, genetic management will be used to maintain the characteristics of the wild population, and developmental manipulations likewise may be carried out to produce “wildlike” sea cucumbers. Therefore, local sea cucumber population will be used as seed stock and larva will be reared locally.

Cultured filter feeders, such as sea cucumbers, do not need external feeds. They can live on carbon and other nutrients in the environment. Therefore, sea cucumber aquaculture can be done with no or minimal GHG emissions and low or minimum environmental impacts.

At the end of the program:

- At least 1 million larvae have been reared locally, and at least 100,000 sea cucumbers have been released in specific TURF to accelerate stock rebuilding across the GMR.
- At least one fishing organization will benefit from the successful allocation of TURF.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• At least 308 fishers and their families will benefit from the improvement of the Galapagos tuna fishery. • The GNPD and Ecuadorian Army will improve their control and surveillance capacity. • The entire small-scale fishing sector will benefit from reduction of IUU and ghost fishing.
Indirect	• At least 25,000 residents will benefit from availability and accessibility to seafood.

Budget and financing mechanism:	USD 434,800 / GRANT
Executing entity:	WWF
Governmental partners:	CGREG

12.5.1.6 Output 2.1.5. Upgraded and more efficient value chains for climate-smart seafood and agriculture products, potentiated with links to new markets.

The lack of integration of vulnerable farmers and fishers to the existing value chains decrease their resilience to onset and drastic events caused by climate change. On the other hand, as a step towards food security of the island’s growing population, there is an increased demand for access to quality products, with higher nutritional value, and of affordable and timely access. In addition, there is a growing demand from consumers for more information about the content, origin, and processing of their food products, including any social and environmental impacts they have. The proposed activities will promote a stronger and more dynamic value chain that will allow actors to address the difficulties of producing and processing, and marketing organic food products more effectively. Food security and the economy of the archipelago could improve remarkably if residents decided to increase their consumption of local products, which would be beneficial for the local small-scale sector and the entire economy of Galapagos. In addition, food imports from mainland Ecuador would be reduced, which in turn would reduce the risk of transporting new invasive species to Galapagos.

Adequate traceability systems Galapagos agroecosystems would guarantee a safe and organic production of at least their staple crops. Some of the products in greatest demand for Galapagos include dairy and meat products, coffee, and vegetables (such as tubers, grains, fruits, and medicinal plants). Within this context, “agro-processing” should be developed within a framework of regulations adjusted to the reality of Galapagos, which should promote a healthy balance between optimization and efficient use of resources, sustainable economic and environmental development, without generating an increase in GHG emissions, in the territory. It is important to recognize the impacts of the dynamics of “agro-processing” as a whole, reflecting the interconnected processes of change at different levels, from production to distribution. In this way, Barret et al. (2001), cited by FAO (2013a), indicate the need to examine the environmental impacts of agro-processes through three different perspectives: i) direct effects on agriculture and on previous supply industries; ii) direct downstream effects on processing, distribution, and related business activities in food supply chains; iii) indirect effects, such as increased income and other structural changes.

Fishers’ adaptive capacity will vary according to diverse factors, including the portfolio of fisheries in which a single fisher depends on to sustain individual fishers livelihoods, the level of diversification of their fishery products, markets, and livelihoods, as well as their economic condition, social network, and willingness and entrepreneurial capacity to change and improve their socio-economic condition. This Output proposes to take advantage of the coping responses used by the fishing sector to face previous emergencies, including the COVID-19 pandemic, as opportunities to enhance fishers’ adaptive capacity and resilience against future impacts, including climate change.

During the COVID-19 pandemic, Galapagos’ fishers diversified their distribution channels and used new marketing strategies to increase their number of clients and sales. On the other hand, consumers changed their consumption patterns during the COVID-19 pandemic, this included shifts in the amount and frequency of seafood consumption, the type of seafood consumed, and the factors that influence their seafood purchase decisions. The oversupply of fresh fish saturated the market, reducing seafood price, which affected the economy of the small-scale fishing sector. Thus, food security and the economy of the archipelago could improve remarkably if residents decided to increase their seafood consumption, which would be beneficial for the local small-scale sector and the entire economy of Galapagos. In addition, food imports from mainland Ecuador would be reduced, which in turn would reduce the risk of transporting new invasive species toward Galapagos (Castrejón et al., in prep.).

In this scenario, this Output will promote the adoption of a circular economy in the seafood value chain through a program of soft loans and the provision of long-term capacity. The objective will be financing the creation, strengthening or expansion of seafood enterprises, based on principles of sustainability and social responsibility. In this way, an alternative long-term financing mechanism will be generated to improve the sustainability of the Galapagos fisheries.

Activity 2.1.5.1 Implement strategies to improve the livestock/meat and milk value chain.

During the study, 80% of cattle ranchers identified slaughterhouses as a bottleneck of the meat value chain (Acebo Plaza & Castillo, 2016). The loss of quality and contamination of meat products tended to occur at this stage. In the case of dairy products, milk processing plants were identified as having inadequate processes that lower quality and raise the price of the final products. The absence of regulatory laws that are specific to the context of Galapagos is another critical area to address before cattle ranching can become an activity that truly contributes towards the resiliency of the region, both in terms of food security and the conservation of the islands.

This activity will strengthen the traceability of dairy and meat products in Galapagos food systems to improve their positioning in the local market and increase their profitability at all stages of the value chain. This activity will:

- At production stage: strengthen farm production processes that have a clear focus on sustainability and climate resilience.
- At processing stage: strengthen processes of manufacturing and adding value to products and foster the use of more efficient technologies that pollute less while increasing their competitiveness in the market.
- Market stage: improve reliability in food product availability and quality and establish local systems for the fair trade between producers and consumers.

This activity includes the following sub-activities that allow to improve the adaptive capacity of the local value chain in Galápagos.

a. Strengthening livestock production systems with environmentally friendly practices that are adapted to the context of Galapagos and help breach the productive gap in farms in terms of quantity and quality.

Annual training workshops (one per island) will be implemented to strengthen the knowledge about the improvement of pastures, animal nutrition/health, and management of genetic resources of livestock and crops. Additionally, these workshops will seek to improve the knowledge, management, and use of highly competitive strategies to empower the local market. In the case of meat products, with the sale of calves that have become safe and genetically adapted to island ecosystems. Furthermore, the program will promote the recognition of farms that integrate sustainable farming practice for raising livestock and delivery of incentives or certificates that promote sustainable practices.

b. Strengthening adequate livestock slaughter and meat processing systems.

Based on rigorous analysis, the program will provide means and alternatives for establishing adequate meat processing infrastructure (slaughterhouses) in San Cristobal, Isabela and Floreana islands considering the supply and demand within the internal market and the environmental and climatic conditions of each island. Additionally, will be integrated a management plan and infrastructure that minimize effluents generated in slaughterhouses. The assurance of a reliable cold transport chain for food products, Isabela and San Cristobal slaughters will be equipped with refrigerated trucks. In the four inhabited islands will be standardized minimum quality and traceability standards though an integrated system for third-party meat vendors.

c. Strengthening of dairy processing plants. The existing processing plants in the four islands will be strengthened adequately and in a timely manner based on a baseline of the economic and social status and installed capacity. Additionally, through the program (CAF loans), direct credit lines will be established for the improvement of the local productive infrastructure, inputs and raw material in San Cristobal, Isabela and Floreana islands. In the four inhabited islands will be standardized product quality and traceability standards, promoting local brands. Finally, the program will support projects relating to technological innovation that contribute to overcome local environmental restrictions and regulations; in an efficient climatic, social and economically sustainable way, in the medium and long term.

d. Positioning of the local market identifies the best inter-institutional and multisectoral strategies for setting prices of food products under the principles of fair trade through an adequate traceability system for dairy and meat production that ensure the food safety of local products by enhancing their preference over the consumer. Additionally, the program will promote economies of scale for the distribution and commercialization of semi-processed and processed meat and dairy products, minimizing the cost of intermediation and promoting and strengthening local brand through advertising campaigns, mainly in San Cristobal, Isabela and Floreana islands

e. Implementing a program to strengthen local capacities. Annual workshops will be conducted in Santa Cruz and San Cristobal to strengthen the: i) meat processing practices in slaughterhouses;

ii) knowledge about production of pasteurized milk, cheese, yogurt, and caramel; iii) local capacities and the culture of consumption, to implement the sale of meat by cuts, promoting greater use of meat to the carcass; iv) Strengthening and raising awareness of the normative, regulatory and health frameworks, to the local reality, so that they facilitate and support the processes of production, processing and commercialization of meat and dairy products and their derivatives.

Benefits, co benefits

GHG emissions reductions will come from: 1) the conservation and efficient use of natural resources like water, soil, and genetic diversity of crops and livestock; 2) a shift away from extensive livestock production strategies with high GHG emissions, in favor of intensive and semi-intensive production systems with lower demands of external farm inputs; 3) an improvement of the manufacturing and processing methods for meat and dairy products with resource-efficient technologies mitigates the impact of pollution sources and the degradation of island ecosystems, providing also adaptation benefits.

Additionally, the activity confers adaptation benefits to the population through the improvement of food security, enhancing the availability and access to diversified food sources of good quality.

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Beneficiaries

The beneficiaries will be the same as those where silvopastoral practices become applied, 244 farms in medium and large-scale farms mostly devoted for cattle ranching activities (Livestock and mixed farms) across all islands.

Financial Mechanism

Total Budget: $4,565,328.23

- GCF Grant: $1,298,400
- GCF Loan: $3,000,000
- CAF Loan: $266,928.23

Activity 2.1.5.2 Implement strategies to improve the Galapagos coffee value chain.

There are 20 farms that produce exclusively coffee (640 Hectares) and 67 farms (3,856 Hectares) of coffee plantations mixed with other corps, distributed across three inhabited islands: Isabela, San Cristobal, and Santa Cruz. This activity will promote the local coffee market by covering the surface of Galapagos agroforestry systems with quality coffee plants. Maintaining and increasing the use of coffee has multiple effects to help adapt agroforestry systems to climate change and environmental deterioration. Coffee plants improve soil structure through roots growth and by adding to the leaf litter. Coffee also establishes a synergy with endemic and native hanging plant species, generating microclimates, and capturing water from atmospheric humidity with their branches. Furthermore, active coffee plantations prevent the expansion of invasive plant species. Coffee production generates a cumulative gross annual income of $923,841, which is equivalent to $1,277 per hectare. If Galapagos coffee could be processed for the local market and sold at the price of high-quality ground coffee ($0.025 per gram), then the average production of 6.5 metric quintals of roasted coffee beans per hectare could fetch about $7,370 per hectare each year.

Permanent labor is required in Galapagos agroecosystems to maintain the coffee plantations. In addition, to avoid the intermediation of parchment coffee and leakage of its conservation value, it is necessary to implement a local coffee agro-processing system with high quality standards and within the framework of the social and solidarity economy (SSE). Why implement an SSE framework? The value of coffee must be redistributed among farmers. Therefore, a solidarity company must ensure not only the quality of locally produced coffee, but also the well-being of the island's farmers. The coffee species to be used in the project include: Bourbón, Typica, Caturra, Catimoro, and Villalobo varieties. In coffee production there are a total of 144 families who are both sources of labor and the owners of their means of coffee production. Engaging this economic sector can open the doors to involving and having a greater impact on subsequent stages of the coffee value chain (labor in processing, restaurants, cafeterias, etc).

This activity will promote the local coffee market by covering the surface of Galapagos agroforestal systems with quality coffee plants, promoting resilient post-harvest practices for different stages for separating the coffee cherry fruit's flesh and skin from the beans, including dry processing and wet processing stage:

For this, it is necessary to:

- Establish the Social Solidarity Economy as an approach that generates social, cultural, and environmental, and economic equity.
- Obtain quality coffee in a cup (with a rating of over 90 points);
- Comply with the Specifications of the Denomination of Origin of the Galapagos Coffee (wet and dry processing);

This activity includes the following sub-activities that allow to improve the adaptive capacity of the local coffee value chain in Galapagos.

a) Harvesting coffee at its optimal ripeness.

An annual workshop will be conducted in the first two years of the program implementation where specialist will strengthen farmers knowledge on coffee post-harvest strategies which include: field inspection for the valuation of the general state of the crop, topographical planning (consideration of altitudinal levels) of coffee plantations to define the sequence for harvesting, harvest planning and available manpower and establishment of biosecurity procedures.

b) Mobilizing production to the local coffee agro-processing center.

An annual workshop will be conducted in the first two years of the program implementation where specialists will strengthen knowledge on mobilization of production with biosecurity measures to prevent contamination and loss of quality of the product. Additionally, each coffee plant (Santa Cruz and San Cristobal), through direct loan lines promoted by the program, will acquire a vehicle for the product transportation which will be equipped with mobile infrastructure to conserve the organoleptic conditions of the coffee.

c) Implementation of a wet processing center.

Based on rigorous analysis, the program will provide strategies and characteristics for the implementation of two coffee processing plants (Santa Cruz and San Cristobal) that meet the needs of each island. The coffee producers (SSE) will acquire the functional infrastructure and equipment to implement a wet processing center through direct loan lines promoted by the program. During the wet processing stage farmers will perform:

· Separation of impurities in crops with o Sieves to classify coffee cherry fruits with imperfections. o Tanks to wash coffee cherry fruits and eliminate grains that have been attacked by coffee borer beetles.

· Mechanical pulping of coffee (according to technical studies)

· Composting: Composting areas for coffee husks.

· Demucilagination (according to technical studies)

· Fermentation, which requires: o Tanks for fermentation, according to the best processes (equipment is required). o Technical advising to improve the fermentation process.

· Washing: requires use of equipment for specialized washing of coffee beans: natural water processing to remove excess minerals from water used for washing, wastewater treatment: Pools for water oxidation (accumulates water from ripe grains, pulped, mucilage, fermented and washed honey), mobilization of washed coffee in containers (drawers) to the drying area.

d) Construction of a dry processing center.

In the same way, coffee producers (SSE) will acquire the functional infrastructure and equipment to implement a dry processing center through direct loan lines promoted by the program. During the dry processing stage, farmers will perform:

· Drying of washed coffee beans (raised beds are required infrastructure). Storage of parchment coffee. Requires: o Storage areas, Special covers for storage and jute bags

· Threshing/cleaning: Requires a threshing machine, screens, and fans to obtain green coffee.

· Tasting of coffee. Requires: Training of local tasters, Equipment for coffee tasting, · Roasting of coffee. Requires: training local roasting specialists, coffee bean toasters and specialized equipment, grinding: Requires specialty grinders for quality coffee

e) Implements a Monitoring system. The implementation institution will conduct monitoring visits in the coffee farms and in the processing plants to control and validate the safety processes on i) post-harvesting and mobilization strategies implemented, and ii) tasting and roasting of coffee. These visits will be carried out each six months.

Benefits, co benefits

Maintaining and increasing the use of coffee has multiple effects to help adapt agroforestal systems to climate change and environmental deterioration. Coffee plants improve soil structure through roots growth and by adding to the leaf litter. Coffee also establishes a synergy with endemic and native hanging plant species, generating microclimates, and capturing water from atmospheric humidity with their branches. Furthermore, active coffee plantations prevent the expansion of invasive plant species such as blackberry and guava. By using a local coffee agro-processing center for wet and dry processing, wastewater and emissions that would normally be released at these stages will be treated or captured on-site. Simultaneously, these treated waters will serve as biofertilizers for coffee plantations.

GHG mitigation co-benefit will be obtained by implementing a wastewater management system that re-captures CO_2 from wastewater through anaerobic processes.

Social benefits

- Agro-processing coffee with high quality standards will lead to increased income for coffee growers, which, in turn, will lead to a renewed interest in coffee production from the wider community, enhancing the local economy. Increased income, additionally, improves food security access (Allee et al 2021) .

- Agro-processing coffee with a Social and Solidarity Economy framework will distribute the economic gains among coffee growers, according to the efforts they have invested to obtain high quality gourmet products.
- The capacities of small and medium-scale coffee growers will be strengthened during harvest, post-harvest, and agro-processing stages.
- The different coffee agro processing stages (wet processing, tasting, roasting) generates direct employment opportunities for the local population.
- The commercialization of Galapagos coffee produced under high-quality agro-processing standards generates indirect employment opportunities for the local population by catering gourmet products and experiences.

Beneficiaries

The aim is to construct one coffee processing center (for wet and dry processing) on each island. Each processing center should be managed by organizations operating under a Social and Solidarity Economy (SSEn) framework.

There are 31 farms that exclusively produce coffee (640 Hectares) and 67 farms (3,856 Hectares) of coffee plantations mixed with other corps, distributed across three inhabited islands: Isabela, San Cristobal, and Santa Cruz. The average size of these farms is 5 ha. This action will include the 31 farms that exclusively produce coffee and 36 farms with mixed crops. In total at least 67 coffee farms will be included in this activity with a total of 201 beneficiaries (30% women).

Financial Mechanism

Total Budget: $548,116.80

- GCF Grant: $256,916.8
- CAF Loan: $291,200.0

Activity 2.1.5.3 Implement strategies to improve the Galapagos vegetables value chain.

This activity will promote the development and/or strengthening of the agro-processing of primary production in order to reduce losses and environmental pollution from waste. In addition to generating new sources of employment and contributing to food security of the population, there will be a greater and more varied offer of local, non-perishable products.

This activity will develop micro-enterprises that add value to potential agricultural products (bananas, plantains, cassava, citrus, medicinal herbs, vegetables, and agrobiodiversity products) from integrated production systems, which in the medium term contribute to strengthening agroecology as an official form of cultivation in the islands. This activity is based on the premise that agroecology rightly represents the most effective and efficient way to achieve climate resilience of agriculture worldwide and especially in island ecosystems highly vulnerable to climate change, such as Galapagos. In this context, it is necessary: i) The implementation of Good Practices of Artisan Agro-processing; ii) Agro-processing plants under strict principles of climate sustainability and social responsibility, with renewable energy sources, waste and waste management, wastewater treatment, production systems that are friendly to the Galapagos ecosystem; and iii) Use of biodegradable containers for storage and packaging of agro-processed products.

a) Agro Processing of Banana, Plantain and Cassava flours and chips.

An annual workshop will be conducted in the first two years of the program implementation where interested local actors with basic knowledge in agro-processing of flours and chips will be identified; and with the support of specialist will strengthen farmers knowledge about technical practices and norms to process flours and chips of banana, plantain, and cassava. Based on rigorous analysis, the program will provide strategies and characteristics for the implementation of two agro-processing plants for flours and medium-capacity chips (Santa Cruz and San Cristobal) that meet the needs of each island. The producers (SSE) will acquire the functional infrastructure and equipment to implement the agro-processing plants through direct loan lines promoted by the program. Each plant will be implemented with the following basic areas: reception, selection, washing, chopping, cooking and drying, pre-grinding, grinding, packaging, storage, construction of Public Policy to position a local Brand of cassava, banana and plantain chips and flours.

b) Agro-processing of preserves and pulps of citrus fruits, pineapple, and tomato.

An annual workshop will be conducted in the first two years of the program implementation where interested local actors with basic knowledge in canned and pulp agro-processing will be identified; and with the support of specialists will strengthen farmers' knowledge about technical practices and norms to process tomato cans and citrus fruit pulps. Based on rigorous analysis, the program will provide strategies and characteristics for the implementation of two agro-processing plants for preserves and pulps (Santa Cruz and San Cristobal) that meet the needs of each island. The producers (SSE) will acquire the functional infrastructure and equipment to implement the agro-processing plants through direct credit lines promoted by the program. Each plant will be implemented with the following basic areas: Reception, Selection, washing, chopping, cooking, packaging, Storage and Construction of Public Policy to position local brand production of preserves and pulps of, at a minimum, pineapple, citrus, and tomatoes.

c) Agro-processing of aromatic and medicinal herbs, and other agrobiodiversity products.

An annual workshop will be conducted in the first two years of the program implementation were interested local actors with basic knowledge in agro-processing of medicinal and aromatic herbs will be identified; and with the support of specialists will strengthen farmers' knowledge about technical practices and norms to process aromatic and medicinal herbs. Based on rigorous analysis, the program will provide strategies and characteristics for the implementation of two agro-processing plants for aromatics (Santa Cruz and San Cristobal) that meet the needs of each island. The producers (SSE) will acquire the functional infrastructure and equipment to implement the agro-processing plants through direct credit lines promoted by the program. Each plant will be implemented with the following basic areas: reception, selection, washing, drying, packaging and storage.

d) Implementing a Monitoring system and Public Policy. The implementation institution will conduct monitoring visits in the farms and in the processing plants to control and validate the safety processes and efficiency achieved in the agro-processing of i) flour and chips; ii) preserves and pulps; and iii) aromatics herbs. These visits will be carried out each six months. Additionally, based on rigorous analysis, a Public Policy will be built to position local brand production of the processed products in the Islands.

Environmental Benefits

Being an undeveloped sector in Galapagos, the agro processing of products, should rather be subject to a sustainable strategic planning according to the environmental requirements and regulations that contribute to the Clean Development Mechanism (CDM), contemplated within the ENCC (National Strategy for Climate Change). Regarding operation, according to the proposal, its operation must be guaranteed under strict principles of climatic and social sustainability, with renewable energy sources, waste and waste management, wastewater treatment, environmentally friendly production systems with the Galapagos ecosystem. By increasing the demand for organic products, as raw material for the supply of small agro-processing companies, an adequate pre- and post-harvest management of crops will be stimulated, generating less contamination due to poor waste management, less contamination of water and soil, and lower risk of proliferation of agricultural pests in the field.

Social Benefits

The increase in the greater variety of products offered by local brands strengthens the territory in terms of food security by providing foods that are available for a longer term and enhancing diet quality through the variety provided by agrobiodiversity inclusion,Furthermore this activity potentiates the generation of jobs, revitalization of the local economy, which contributes to generating greater resilience of the territory towards climate change. Additionally, the implementation of companies within the framework of the Social and Solidarity Economy (SSE) generates direct employment to farmers, personnel in agro-processing, distributors, among others, as well as the dynamization of small-scale local economies.

There are multiple positive impacts that could be generated on the resilience of Galapagos with the strengthening or development of agro-processes. However, in trying to group these benefits into large productive sectors, it is considered:

1. Production systems, as those in charge of supplying the raw material, will be directed towards important processes of productive improvement and optimization of resources, generating climate resilience, since agro-processing "promotes" quality and safety in primary production.

2. Strengthening economies of scale, which help boost local economies by generating new sources of employment aimed at combating poverty in families that currently do not have direct access to means of production.

3. Interinstitutional and multisectoral strengthening of the territory in the face of the adverse effects of climate change, since the Government must create favorable conditions for private investment and innovation (access to credit, policies to support local production, regulations and regulations adapted to the territory).

Beneficiaries

By supplying the agro-processing plants, at least 497 farms (1,491 beneficiaries, 30% women) will be direct beneficiaries. They are distributed in the following way:

- 272 farms in the agro-processing of flour and chips (816 beneficiaries, 30% women)
- 150 farms in the agro-processing of preserves and pulps (450 beneficiaries, 30% women)
- 75 farms in the agro-processing of aromatic herbs (225 beneficiaries, 30% women)

It should be noted, the prices established by the processing plant will be within the framework of the Social and Solidarity Economy and Fair Trade

Financial Mechanism

Total Budget: $470,612.80

- GCF Grant: $325,012.8
- CAF Loan: $145,600.0

General impact mitigation resilient practices in agriculture

The carbon balance from program implementation is estimated to be about -1 million of tCO2-eq of avoided emissions and increased carbon sequestration over 20 years analysis in 8,643 ha (Table 48). This translates into -131 tCO2-eq per hectare over 20 years or -6.5 tCO2-eq per hectare per year. The principal contributions for this balance are the CO2 sequestration from Biomass (-632,514 tCO2-eq) and Soil (-344,815 tCO2-eq) through the resilient-practices implementation proposed in this program. Improvements in feeding practices and the implementation of biodigesters help generate an absorption from enteric methane (-11,895 tCO2-eq).

Table 48. Summary of net carbon-balance for program implementation

RESILIEN FARMS		tCO2-eq per year		tCO2-eq in 5 years (project implementation)	tCO2-eq in 20 years (ecosystem equilibrium reached)
Total		-50,372		-251,860	-1,007,440
Greenhouse gases contribution (tCO2-eq)					
	CO2			N2O	CH4
	Biomass	Soil	Inputs		
Total	-632,514	-344,815	-8,254	-2,962	-11,895
Per ha per year	-4.2	-2.2	-0.1	0	-0.1

These results indicate that the Galapagos food system component can have an important contribution in mitigation which complements the adaptation and resilience objectives sought by the program. It will be important to closely monitor the assumptions made during program implementation to truly assess the impact of the program on the ground.

Activity 2.1.5.4 Promotion of a blue circular economy through new sustainable and socially responsible seafood enterprises.

Previous projects and consultancies have failed in their effort to improve the management and marketing system of Galapagos small-scale fisheries because technical assistance and capacity building processes have been short-term, uncoordinated, and without adequate and sustained institutional and financial support to ensure the creation of necessary enabling conditions, to take advantage of the business opportunities offered by the Galapagos small-scale fisheries (Castrejón et al. 2019).

In response to this problem, this outcome proposes the creation of the “Galapagos Virtual Innovation Lab”, hereafter the G-Lab, to support small-scale fishers, entrepreneurs, and other actors of the local community interested in enterprise development (e.g., farmers). The G-Lab represents the methodological, operational, and institutional framework required for the creation of an inter-institutional and interdisciplinary platform that integrates and coordinates the governmental and non-governmental programs and projects for the promotion and development of sustainable fisheries.

The main objective of the G-Lab is to provide long-term capacity building, knowledge sharing, and technical advice to fishers, cooperatives, associations, seafood companies, and civil society entrepreneurs, in aspects related to social innovation for sustainable development and circular economy. The G-Lab will have two main components. The first one will be a digital repository that will contain relevant publications, data, information, experiences, and relevant and existing resources of interest. The second one will be an online capacity-building component that will contain online training courses/processes on issues associated with the capacity needs identified to implement the Galapagos seafood system vision and new business models (prototypes). This platform will be created to have the capacity for scalability to potentially cover the needs and capacities of other key sectors to guarantee sustainable development for Galapagos, like agriculture and tourism.

Additional funding will be allocated to provide analytical services, capacity building, knowledge sharing, and facilitation services to fishers and entrepreneurs to make their seafood enterprises investment-ready. This includes technical assistance to selected teams of entrepreneurs to help them to test and refine their business models and to develop a business plan. Each business model will be tested and either accepted, improved, and re-examined, or rejected based on customers' experiences.

The G-Lab will include giving technical assistance to fishers and entrepreneurs to acquire the capacity, skills, equipment, and know-how to be able to sell and export tuna without the participation of intermediaries. The Program will hire a tuna grading specialist to help fishers to obtain the capacity to grade the quality of their tunas, which will help them to secure more profits without increasing their current level of catch.

GCF funding will be used to put in place the G-Lab. However, long-term funding it is expected to be obtained from the creation of public-private partnerships, the "Fondo para la Reserva Marina de Galápagos (FRMG)", and the Blue Incentives Program. Furthermore, technical assistance is expected from NGO and universities.

Complementarily a market analysis and a behavioral insights analysis will be conducted to align the needs of consumers with the capabilities of entrepreneurs to develop a product and a story that sustainably fits these needs. Based on this, the best distribution channels, price, and markets to sell Galapagos seafood products will be identified, either at the local, national, or international market, to ensure that such products are profitable, operationally feasible and are based on a business model that can be sustained over time.

Finally, and based on the results of the implementation of the G-Lab, the program will support the creation or consolidation of selected local seafood enterprises, based on principles of sustainability and social responsibility. Technical assistance to local fishers and entrepreneurs will be delivered to comply with all technical, legal, organizational and administrative requirements for the creation or consolidation of new seafood enterprises.

At least three business models or prototypes will be promoted: an export seafood enterprise, a value-added seafood enterprise, and a by-product seafood enterprise. They are not mutually exclusive and can be integrated into a single seafood enterprise. The three prototypes are fully described in Appendix 2.2.

At the end of the program:

- At least 50 entrepreneurs have received sustained institutional and financial support by the G-Lab.
- At least 10 sustainable and socially responsible seafood enterprises have been successfully implemented.
- At least five value added products are offered by the new socially responsible seafood enterprises.
- At least five socially responsible seafood enterprises have obtained access to new markets that pay higher prices for their products.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:

Direct	• At least 400 fishers and their families will have the opportunity to obtain sustained institutional and financial support by the G-Lab
Indirect	• At least 25.000 residents will have the opportunity to obtain sustained institutional and financial support to develop seafood enterprises.

Budget and financing mechanism:	USD 593.567,43 / GRANT
Executing entity:	WWF
Governmental partners:	CGREG

Activity 2.1.5.5 Put in place a long-term financing mechanism to improve sustainability and competitiveness of Galapagos small-scale fishing sector.

One of the main challenges to improve the productivity, sustainability and competitiveness of Galapagos small-scale fishing sector is obtaining long-term financing. To meet this objective, capital is required from several funding sources (i.e., public, philanthropic and private) willing to invest in actions that contribute to improving the profitability of fisheries with principles of sustainability and social responsibility. This could include investments to: (1) improve monitoring programs for target and incidental species, (2) prevent or mitigate ecological impacts produced by fishing activities, (3) implement marketing and marketing-strategies to improve quality and add value to fishery resources, (4) promote fair, equitable trade, and respect of human rights, and (5) comprehensively improve the governance of fisheries through various regulatory actions. Unfortunately, the government budget to invest in all these activities is quite limited.

Consequently, the Program proposes the establishment of a soft credit line for entrepreneurs called the Blue Incentives Program, whose objective is the financial inclusion of fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices in exchange for receiving financing for the development of ventures with principles in sustainability and social responsibility that help improve the productivity, competitiveness and social inclusion of fishers in the financial system.

The intention of the Blue Incentives Program is that the G-Lab, in collaboration with the competent government authorities, announce an annual call to inform that there is financing to invest in seafood enterprises that are sustainable, equitable, financially viable and socially responsible. With the help of an interdisciplinary group of specialists in fisheries, business administration, and enterprise development, the most attractive proposals will be chosen. The selected proposals would receive technical advice from the G-Lab to develop their respective business plans, or market studies, to determine the financial feasibility of success of the business model proposed. Through a selection process, those entrepreneurs who submit the most attractive, innovative business plans and with the greatest probability of generating a positive social and environmental impact would receive soft credits, through the Blue Incentive Program. In this way, it is expected that the G-Lab and the Blue Incentives Program complement each other to improve the productivity and competitiveness of the Galapagos small-scale fishing sector through the principles of a blue and circular economy.

The blue economy promotes the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health. Similarly, a circular economy promotes shifting from a linear take-do-throw-away model to one that keeps products and materials in circulation for as long as possible, minimizing the use of resources and the generation of waste, and reusing products when they reach the end of its useful life to generate more value.

The eligibility conditions for accessing credit for sustainable fishing practices are listed in the table below.

Table 49. Eligibility conditions for accessing credit for investment in sustainable fisheries practices.

Condition	Description
Beneficiaries	Fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices in exchange for receiving financing for the development of seafood ventures with principles sustainability and social responsibility that help improve the productivity, competitiveness, and social inclusion of fishers in the financial system.
Eligible investments	To the extent feasible, business plans for pilot seafood ventures should incorporate and demonstrate their alignment with three principles. • **Economic efficiency:** ensure productivity and profitability of fisheries, particularly a strong value proposition for investment under prospective pilot operations. • **Social equity:** promote positive social welfare outcomes for beneficiaries and effective distribution of wealth from enhanced fisheries, including income and livelihood opportunities, development of value-added products, and market access and diversification, recognizing the key role of women in fisheries value chains. • **Biodiversity conservation and ecosystem health:** reduce the ecological impact of fishing on marine biodiversity and ecosystems by minimizing fishing pressure over commercial and protected species.
Financing thresholds	From USD 10,000 to 60,000
Minimum co-financing by the beneficiary	10%
E&S category	B or C (category A is not eligible)

Other conditions	An investment proposal fulfilling the three principles described should include most of the following conditions: • Demonstrate that the pilot seafood venture creates business opportunities that are attractive from a financial point of view. • Increase seafood consumption at the domestic market to improve food security. • Promote consumption of pelagic species, mainly tuna, rather than species with signs of overexploitation (e.g., sailfin grouper). • Promote the adoption of state-of-the-art technology to reduce IUU fishing, by-catch, habitat destruction, and marine pollution, including emission of greenhouse gasses. • Promote e-commerce and the adoption of blockchain traceability system. • Promote market diversification and development of value-added seafood products. • Increase quality rather than seafood quantity. • Maximizing the use and value of seafood by-products. • Promote mechanisms to adopt appropriate tenure rights to deal with the common pool resource problems and avoid the dissipation of fishery rents. • Propose market-based strategies that maximize net social benefits (profits and social welfare), while minimizing social costs (social negative impacts and environmental negative externalities). • Establish appropriate mechanisms to ensure an effective distribution of wealth from enhanced fisheries, including income and livelihood opportunities, as wider societal benefits.

At the end of the program:

- A soft loan credit program within the Galapagos' Climate Credit Line is established.
- At least 50 seafood entrepreneurs have received financial support by the Blue Incentives program.

To see details on the proposed activity and justification please see Appendix 2.2.

Beneficiaries:	
Direct	• At least 400 fishers and their families will have the opportunity to obtain sustained financial support by the Galapagos' Climate Credit Line.
Indirect	• At least 25.000 residents will have the opportunity to obtain sustained institutional and financial support to develop seafood enterprises.

BUDGET	223,500
Executing entity:	WWF
Governmental partners:	CGREG

12.5.2 Outcome 2.2 Marine and terrestrial ecosystems are under effective restoration schemes.

12.5.2.2 Output 2.2.1 Marine High Ecological Value Areas (HEVAs), under restoration schemes taking into account potential climate change scenarios.

Activity 2.2.1.1 Strengthen marine biosecurity programs in the GMR, to prevent and control marine bioinvasions by Nonindigenous Species (NIS) that could proliferate due to the

Anthropogenic climate and global change are expected to be a major driver in the introduction, establishment, distribution and impact of NIS (Ziska & Dukes, 2014). Climate change is expected to alter the geographic distribution and abundance of many species and increase invasions of NIS in many areas which could lead to species extinction (Chan et al., 2018; Sorte, 2014). It is important to emphasize the impacts of NIS on biosecurity, food security and human health will continue to increase due to global climate change unless steps are taken now to minimize their introduction, establishment and spread (Rahel & Olden, 2008). Changes in temperature and surface currents, are expected to modify both natural and human-mediated species dispersal, enhance survival and establishment of NIS in previously unsuitable localities, and amplify impacts of existing NIS in invaded habitats (Chan et al., 2018). To address these problems changes in the efficacy of mitigation strategies for invasive species need to take place not only in one country but under a global perspective (Funk, 2015). It is important to be able to predict climate change impacts on species distribution and abundance and develop Early Detection Rapid Response (EDRR) protocols to achieve these goals.

It is essential to strengthen the biosecurity program in the GMR in order to prevent and detect climate driven introductions. EDRR is a critical process in preventing, limiting and mitigating the spread and impacts of NIS. EDRR is a key element in addressing NIS issues as it ties in directly with prevention as the most cost-effective way of dealing with a multi-billion-dollar problem. In many cases the impacts of NIS may be uncertain and/or irreversible however, decision makers often react slowly and wait for more information thinking that this would be more cost-effective (Hanley &Roberts, 2019). This was the case with the invasive algae Caulerpa taxifolia that was first observed in 1984 in Monaco, at that time it only covered a few square meters, however there was no rapid control measures put in place for years and now this species covers several thousand hectares. This invasion was a result of the decision makers using the “wait and see” policy, now it would cost governments from several countries billions of dollars to eradicate, additionally, this species has severely impacted the marine ecosystem of this region and altering biological process (Sims & Finnoff, 2013). The “wait and see” policy or the business-as-usual scenario is one that needs to change and a functional alert system with EDRR protocols needs to be implemented in the Galapagos Biosecurity program for climate driven NIS entering the GMR. In the case of Galapagos, a climate driven NIS introduction could cause the extinction of an endemic and native species because at this time only marine traffic associated introductions are considered in the biosecurity plan. If no improvement is made to the biosecurity plan regarding climate driven NIS introduction there is the high risk that species will arrive settle and spread reaching a point of no return costing the local authorities millions in eradication efforts. In a rapidly changing climate, the very concept of invasive species becomes problematic. Increasing temperatures are associated with the increase of species, which has been illustrated in the UK, USA and China (Huang et al., 2011). Controlling NIS arising from climate change is of high importance to safeguard the marine ecosystems of the Galapagos. Investing now in the precautionary principle will allow for the adaptation mechanism to be more effective and more cost-efficient.

The objective of this module is to mobilize invasion science and management solutions to protect, empower, and strengthen the Galapagos biosecurity program, and the public and research institutions involved, to prevent and reduce the expected impacts of marine invasive species related to climate change scenarios.

Invasive species globally produce damages estimated at more than 5% of global GDP, and island and coastal communities are particularly impacted. Invasive species have devastated food production systems around the world, collapsing fisheries (e.g., lionfish) and agricultural systems and impacting food security and livelihoods (Hixon et al 2016). Invasive species also have significant impacts on biodiversity. No place is immune to invasions. Recent research reveals a surprising number of marine species that have invaded marine protected areas, including Galapagos (Carlton, Keith and Ruiz, 2019). Even these critical protected areas are at risk to invasions, which threaten to diminish their high conservation and social value. Preventing the introduction of new alien species through biosecurity is the most cost-effective strategy, rather than managing them once they become established. Thus, effective biosecurity systems are required to minimize the risk of invasive species introductions.

Although marine invasions occur as a result of the unintended transfer of organisms by vessels, aquaculture, fishing, recreation and other human activities, climate change can play a strong role in facilitating invasive species spread and/or aid in their settlement due to favorable conditions (Burgiel and Muir, 2010). Marine organisms can overcome previous existing barriers or be dispersed to arrive at new suitable locations. To prevent marine invasions, it is necessary to reduce the unintentional transfer of organisms combined with a detection and response capability for new incursions. These are fundamental tenets of biosecurity that are well understood but are only partly implemented in marine systems. As a result, the door is still open for new marine invasions in most regions.

Biosecurity protects biodiversity and livelihoods by managing potential pathways that new invasive species may enter, while early detection and rapid response (EDRR) allows for invasive species that pass the filters to potentially be eradicated before they establish (Reaser et al. 2020). Biosecurity is an investment in reducing future costs (e.g., of the need for managing invasive species populations, and costs associated with the impact of invasive species on values such as fisheries and biodiversity). Protocols and training aim to increase the capacity of the responsible public agencies for effectively reducing the risks of invasive species establishing.

We aim to address a major driver in biodiversity loss by (a) creating risk analysis and ranking systems for biosecurity, (b) create effective EDRR protocols to diminish new NIS invasions in the marine environment and (c) create an alert system to announce new incursions of marine invasive species in the GMR. This will allow for rapid detection of threats, improve coordination between local stakeholders and authorities, and will develop both an informal and formal detection network and engaging the public through citizen science.

Risk analysis is often divided into two components: risk assessment and risk management. Risk assessment is the process by which risk is measured and can be conducted before the occurrence of any events that could cause the risk or after the possibility of risk is incurred (Carlton, 2003). Risk assessment systems have been used around the world to try to mitigate NIS arrivals (Brown, 2009). Ranking systems help identify the most problematic NIS in or near the area in question and aid stakeholders in decision-making. Impact assessments can be based on a series of questions: (1) ecological impacts, (2) economic impacts, (3) human health impacts, (4) invasive potential and (5) difficulty of control. Each section gets a score; a high score corresponds to a species that can cause a great impact on the environment. The other part of the assessment deals with the current ability to prevent and take early action, questions related to entry and transport pathways, current distribution, policy and outreach measures already in place are asked to help facilitate prevention or rapid response. (Brown, 2009).

The CDF and the Smithsonian Environmental Research Center (SERC) have been working together since 2015 to advance a regional network along the Eastern Pacific from pole-to-pole and initiated the Coastal Ocean Marine Biosecurity International Network of the Americas (COMBINA) to advance and coordinate marine biosecurity across the Americas, with an initial focus on the Eastern Pacific coast and islands, from Chile to the United States (Alaska). The first meeting and workshop was held in the Galapagos Islands in June 2019, including representatives from 12 Latin American countries and the US. This included resource managers, policy makers, and scientists. To date, this type of regional coordination has been absent, even though all participants faced similar challenges and had many of the same priorities and needs. During the meeting break out groups were formed to discuss the creation of a biosecurity network throughout the region, which resulted in COMBINA whose mission is to provide scientific and management knowledge of non-native species in the region and work together to create high biosecurity standards throughout the South-eastern Pacific region to conserve biodiversity. The networks next steps are to create shared tools, resources, and protocols for application in each of the countries, establish mechanisms to accelerate knowledge exchange on biosecurity approaches and successes, allowing rapid uptake and cross-pollination, including those for management and policy strategies, and finally to expand public engagement and outreach, especially through citizen science to increase detection capability.

At the end of the program:

- A NIS Alert System to mitigate the impact of NIS on marine ecosystems in the GMR developed and adopted by the DPNG and ABG.
- Marine biosecurity protocols, including one early detection and rapid Response (EDRR) protocol, for the GMR developed and adopted by the DPNG and ABG.
- Risk assessments (20) conducted to determine the main pathways for marine invasions into the GMR and the ETP by modelling dispersal mechanisms of potential NIS under climate change scenarios.
- Increased skills and competences of the GNPD park rangers and ABG technicians on NIS identification techniques and biosecurity protocols.

To see details on the proposed activity and justification please see Appendix 2.3.

Beneficiaries:	
Direct	80% technical staff of the Marine and Tourism/recreation Departments of the GNPD are trained and engage in improved marine biosecurity and Early Detection and Response (EDRP) protocols for climate driven NIS. 40% technical staff of the Ecuadorian Navy are trained and engage in improved marine biosecurity and Early Detection and Response (EDRP) protocols for climate driven NIS. 40% technical staff of the Oceanographic Institute of the Ecuadorian Navy - INOCAR are trained and engage in improved marine biosecurity and Early Detection and Response (EDRP) protocols for climate driven NIS. 60% staff members of the Galapagos Governing Council CGREG receive up to date scientific information from the Early Detection and Response (EDRP) protocols for climate driven NIS, to update and improve regulations. 100% of active tour and dive operators, Galapagos Naturalist and Dive guides, in the GMR are trained in improved marine biosecurity and Early Detection and Response (EDRP) protocols for climate driven NIS. 100% of active small-scale fishermen are trained in improved marine biosecurity and Early Detection and Response (EDRP) protocols for climate driven NIS.
Indirect	100% of active small-scale fishermen will benefit from rocky reefs being protected from the arrival of climate driven NIS.

	100% tourists will benefit from rocky reefs being protected from the arrival of climate driven NIS 100% locals will benefit from information regarding the impacts climate driven NIS can have on the GMR and what can be done to prevent their arrival

Budget and financing mechanism:	USD 1,411,583.47 /GRANT
Executing entity:	WWF
Governmental partners:	GNPD and ABG

Activity 2.2.1.2 Restore high ecological value coral reefs through coral planting and exclusion areas, to enhance their ecological role in the GMR.

The objective of this module is to increase the resilience of coral reef ecosystems by restoring corals and strengthening the controls of bioerosion and coral bleaching in critical High-Ecological Value areas (HEVAS) of the GMR.

Since corals are very sensitive to changes in temperature, climate change poses a great threat, particularly to these important communities (Banks et al., 2016). Recent changes in climate have turned many coral reefs into highly endangered ecosystems, reducing their resilience (Riegl et al., 2019b). Persistent temperature increase of only 1-2 oC can result in coral bleaching and mortality. Reduction of corals is widely known to be detrimental for their associated communities (Denkinger and Vinueza, 2014). Therefore, promoting the conservation of coral reefs is fundamental for all marine life but also for people's livelihoods (i. e. income, food and protection; Imtiyaz et al., 2011; Barbier, 2017).

A coral restoration plan will begin with experiments in the marine biology department of CDF determining the feasibility of planting coral and conduct experiments to increase survival rate and reduce mortality rate. Different experimental conditions will be used to measure the optimal temperature, light, and substrate for corals to grow on. Temperature and light can determine the makeup of the initial colonizers while sediment that accumulates on artificial substrate and affect settlement of coral (Spieler, Gilliam & Sherman, 2001). This will be done in close collaboration with technicians from the GNPD and coral experts from the Nova Southeastern University (NSU) in the USA. NSU is one of the leading universities researching coral ecosystems worldwide in order to understand species ecology, improving coral conservation methods, and promoting coral reef restoration and species recovery. NSU has laboratories and coral nurseries which are used to repopulate affected areas in Florida. Knowledge on different techniques and methodologies used by this institution can be applied in the GMR. After initial experiments have been validated using aquariums and a nursery area (1 year), we propose to transplant resilient corals to areas where corals have been degraded in coordination with the GNPD. The area that will be restored will be calculated during the initial assessment of degraded areas (Floreana, Darwin and Wolf). Rearing of coral fragments in nurseries prior to transplantation makes much better use of a given amount of coral source material and provides an opportunity to establish the transplants on substrates that can be readily attached at a degraded reef site. The corals that will be transplanted will be well-adapted to survive at the site as they will be reared under similar environmental conditions. Additionally, control areas will be identified where no active restoration has been attempted in order to provide a clear baseline to be able to evaluate the effectiveness of the transplantation. The rehabilitation of corals will increase the diversity of fish, macroinvertebrates and species functional to the health of the reef. We propose to carry out the proposed EBA, using the Pocillopora, Porites and Pavona corals, which lives naturally in the area where the rehabilitation of the reef patch will be carried out. These species are predominant in the ETP region (Baker, 2004). Furthermore, sea urchins are important herbivores on coral reefs, however, urchins can also have negative impacts on coral reefs where urchin populations reach outbreak densities. Urchins feeding can remove coral recruits, reduce cover of important coralline algae and lead to unsustainable bio-erosion. In order to measure ecological processes that promote resilience this EBA proposes to remove areas of urchins that feed on corals in areas identified during reef assessments to increase survival rates and colonization rates of certain species of coral and use exclusion caged experiments to minimize reef damage and assist recovery of the degraded areas delimited by the GNPD. According to studies conducted in the Seychelles, coral recruitment can increase up to two-fold at sites where urchins have been removed (McClanahan, 1999).

The transplant and rehabilitation actions proposed by this project will promote the conservation of the reef and its biodiversity, on which livelihoods depend on. The areas that will be restored in Floreana, Darwin and Wolf will be identified during the initial reef assessments. This information will be presented to the GNPD who will make the decision on the amount of degraded area the GNPD is comfortable restoring. To avoid degradation and protection of the coral reefs this module will go hand by hand with EBA 5.3 to adopt better diving practices.

In the face of the recovery response of these corals to the increase in sea temperature, finding coral communities that can be resilient to bleaching are increasingly important conservation priorities (Palumbi, et al., 2014). Coral transplants offer us the opportunity to carry out a management intervention and mitigation of impacted areas, using fragments of their colonies through transplantation. For this reason, we propose resilience-based management approach that seeks the conservation of coral environments and the sustainability of the services they offer in a changing global scenario (Hughes et al., 2007).

Restoring degraded coral areas will increase their ability to recover from a disturbance and move towards a coral-rich state, and/or to maintain morphological diversity as opposed to shifting to an algal-dominated state or a single coral morphology. Some of the indicators that show a healthy and resilient reef include, strong coral recruitment, low human impacts and healthy herbivore populations. By intervening on the degraded areas of coral reefs and by monitoring and improving coral conservation programs the coral reefs of the GMR will become more resilient in the face of climate change.

At the end of the program:

- Sensitive areas of degraded and resilient coral formations in High Ecological value Areas (HEVA) of the GMR identified and mapped.
- At least two potential sites for coral transplant in Darwin, Wolf and Floreana, together with a control site selected.
- Effectiveness of transplanting corals to the selected sites validated based on a particle tracking model created to model the coral dispersion under current and future climatic scenarios (RCP 4.5 and 8.5) together with controlled experiments to assess coral species resilience under different environmental conditions.
- At least one degraded coral site in HEVAs of Darwin, Wolf and Floreana under restoration schemes at the third year of the Program with participation of the GNPD.
- At least one small-scale sea urchin removal plan to minimize reef damage and assist recovery of coral reefs in selected HEVAs of the GMR implemented.
- At least one pilot project implemented with the tourism sector to mainstream their participation in coral restoration actions.

To see details on the proposed activity and justification please see Appendix 2.3.

Beneficiaries:

Direct	40% technical staff of the Marine Department of the GNPD trained on techniques and methodologies to grow and transplant corals. 80% technical staff of the and Marine and Tourism/recreation Departments of the GNPD are trained in improved monitoring and coral conservation techniques and engaged in participatory improvement of coral conservation regulations. 40% technical staff of the Ecuadorian Navy engaged in participatory improvement of coral conservation regulations. 40% technical staff of the Oceanographic Institute of the Ecuadorian Navy – INOCAR engaged in participatory improvement of coral conservation regulations. 40% technical staff of the Ministry of Tourism engaged in participatory improvement of coral conservation regulations. 60% staff members of the Galapagos Governing Council CGREG will receive up to date scientific information on coral conservation status, to create new regulations. 100% of active tour, dive operators in the GMR, active Galapagos Naturalist and Dive guides are trained in improved monitoring and coral conservation techniques. 100% active small-scale fishermen are trained in improved monitoring and coral conservation techniques.
Indirect	100% of active small-scale will benefit from coral reefs being restored and protected; species of commercial value will complete their recruitment which in turn benefits livelihoods. 100% of the community will benefit from coral reefs being restored and protected due to increasing revenues related to diving tourism.

Budget and financing mechanism:	USD 1,514,391.47 / GRANT
Executing entity:	WWF
Governmental partners:	GNPD and ABG

Activity 2.2.1.3 Reduce the impact of diving, anchoring and pollution related to tourism operations in selected marine HEVAs, to enhance ecosystems resilience and adaptive capacity to the effects of climate change.

This activity aims to reduce the environmental impacts associated with marine tourism (diving, anchoring and pollution associated with tourism activities).

The slow recovery of coral reefs is particularly alarming since climate change impacts are expected to exacerbate coral habitat loss in the GMR, due to thermal stress. Hence, non-harmful tourism practices on marine ecosystems, and particularly on corals, need to be implemented in order to increase the resilience of coral reefs to natural and anthropogenic impacts.

The specific actions under this activity are: a) Design and implement a conservation categorization system and management protocols for diving visitor sites; b) Development and adoption of Diving Tourism Best Practices Toolkit co-created with dive tourism stakeholders; c) Reinforce the control and monitoring of pollution levels from boats; d) Develop a Decision Support System (DSS) portal for policymakers, with information regarding marine tourism, including impacts from the tourism activities and the health of sites; e) Implement agreements with tourism stakeholders for replacing anchoring procedures and technologies with fixed-mooring buoys signaling and the Digital Positioning Systems (DPS).

For the promotion of the DPS, workshops will be held targeted to diving liveaboard cruises and will derive in an installation plan agreed with DPNG and one third (3-4) of diving cruises operating in the Galapagos selected based on their willingness to engage, DPS specifications and DPS expert advice. Program will assist cruise companies in the access to low interest credits to acquire the technology and will provide technical assistance for the adequate installation of the DPS.

The adoption of these good practices by tourism operators will be linked to the certification program proposed by the program under component 3.

Sub-activities a) to d) will be financed by a GCF grant. With regards to subactivity e) the Galapagos' Credit Line managed by the Public Bank CFN and operated through local banks present in the islands will be part of the Galapagos Climate Facility managed by CAF. The 10 vessels that have expressed interest in an anchoring system have the financial capacity to pay a credit for this system. According to information gathered by WWF, the average price of a DPS is $40,000.00, giving a potential market of $400,000.

Table 50. Eligibility conditions for accessing credit for investment in Digital Positioning Systems.

Condition	Description
Beneficiaries	Diving cruises operating in the Galapagos selected based on their willingness to engage
Eligible investments	Digital Positioning Systems (DPS).
Financing thresholds	From USD 10,000 to 45,000
Minimum co-financing by the beneficiary	20%
E&S category	B or C (category A is not eligible)
Other criteria	Boats meet minimum required engine and electric technological standards. Operators' capacity to finance further maintenance of equipment, and signature of a commitment letter with the GNPD and Navy Operator availability of human and time resources to be trained in related aspects. O&M Plan developed.

At the end of the program:

- Dive sites in HEVAs of the GMR mapped and categorized according to their conservation status.
- Protocols for best diving practices in place and adopted by relevant stakeholders, including the tourism sector.
- Modules for underwater diver behavior and pollution integrated into the Galapagos System of Managing Visitors (SIMAVIS) of the GNPD.
- Participatory design of a fixed-mooring buoys solution, that guarantees its implementation and finds solutions to their maintenance costs.
- Increased skills and competences of dive guides, cruises and GNPD technicians

- Increased awareness of cruises operating in the Galapagos for understanding the operation, benefits, and opportunities to adopt DPS systems.
- Diving operators and diving guides trained and feeding the modules for underwater diver behavior and pollution of the SIMAVIS.
- Control mechanism for pollution levels from the boats in place.
- At least one agreement adopted between tourism stakeholders as a mechanism to enable future co-responsibility in the use of the buoys.
- Voluntary agreement by diving operators to apply the diving tourism Best Practices, designed.
- One third (3-4) of diving cruises operating in the Galapagos adopted the DPS system in agreement with the GNPD.
- Dashboard Decision Support System (DSS) portal for policymakers in place and adopted by the DPNG.

To see details on the proposed activity and justification please see Appendix 2.3.

Beneficiaries:	
Direct	80% technical staff of marine, tourism, and recreation departments of the GNPD with enhanced skills and competences to engage in best practices for low impact diving and cruise operations. 40% Navy INOCAR's technical staff with enhanced skills and competences to engage in best practices for low impact diving and cruise operations. 50% technical staff of the Ministry of Tourism with enhanced skills and competences to engage in best practices for low impact diving and cruise operations. 40% of the technical staff of the Galapagos Governing Council CGREG receiving updated information on impacts from the tourism activities and the health of sites.
Indirect	100% of active small-scale fishers will benefit from critical HEVAS restoration and protection. 100% of the community will benefit from critical HEVAs being restored and protected due to increasing revenues related to tourism.

BUDGET	1,539,911.47
Executing entity:	WWF
Governmental partners:	GNPD, Navy INOCAR, Ministry of Tourism The Army is in charge of reinforcing compliance with maritime regulations in the Galapagos Marine Reserve, including contamination and NIS. The Oceanographic Institute of the Army (INOCAR), through their monitoring platforms, contributes information to the control and regulation role of the Army. The Ministry of Tourism, regulates the commercialization of diving touristic tours through its accredited entities; these

	must comply with established standards and regulations of the tourist services.

Market study: Dynamic Positioning System

Dynamic positioning (DP)[22] is a computer-controlled system to automatically maintain a vessel's position and heading by using its own propellers and thrusters. Position reference sensors, combined with wind sensors, motion sensors and gyrocompasses, provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position. Examples of vessel types that employ DP include, but are not limited to, ships and semi-submersible mobile offshore drilling units (MODU), oceanographic research vessels, cable layer ships and cruise ships.

The computer program contains a mathematical model of the vessel that includes information pertaining to the wind and current drag of the vessel and the location of the thrusters. This knowledge, combined with the sensor information, allows the computer to calculate the required steering angle and thruster output for each thruster. This allows operations at sea where mooring or anchoring is not feasible due to deep water, congestion on the sea bottom (pipelines, templates) or other problems.

Dynamic positioning may either be absolute in that the position is locked to a fixed point over the bottom, or relative to a moving object like another ship or an underwater vehicle. One may also position the ship at a favorable angle towards wind, waves and current, called weathervaning.

AVERAGE PRICE

The main suppliers of DP equipment are shown in the list below.

Table 51. Dynamic Positioning Systems Suppliers

DP main Suppliers
Alphatron Marine
COMEX
Engine Monitor Inc
Guidance Navigation Limited
Kongsberg Maritime
NAUDEQ
Navis Engineering Oy
Praxis Automation Technology

According to WWF, the average price is $40.000 for this type of equipment, which is the base price that would be used for this analysis. It is important to mention that the price increase for the archipelago does not apply here since it is a specific imported product.

DEMAND OF DP

22 The Nautical Institute https://web.archive.org/web/20130125101320/http://www.nautinst.org/en/dynamic-positioning/what-is-dynamic-positioning/index.cfm

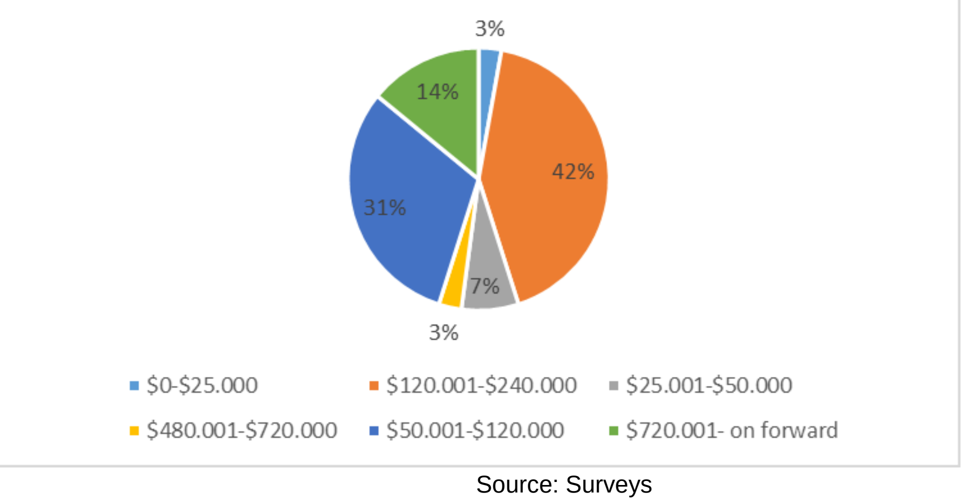
According to a survey conducted by WWF, 10 vessels are interested in purchasing DP equipment. The Universe is quite minor, which implies that all potential demand can be fully identified and studied.

BENEFICIARY FINANCIAL STATISTICS

The following data was collected between august and November 2020 via surveys and focus groups. The survey technical analysis is the following.

Income

Figure 51. Vessels Income



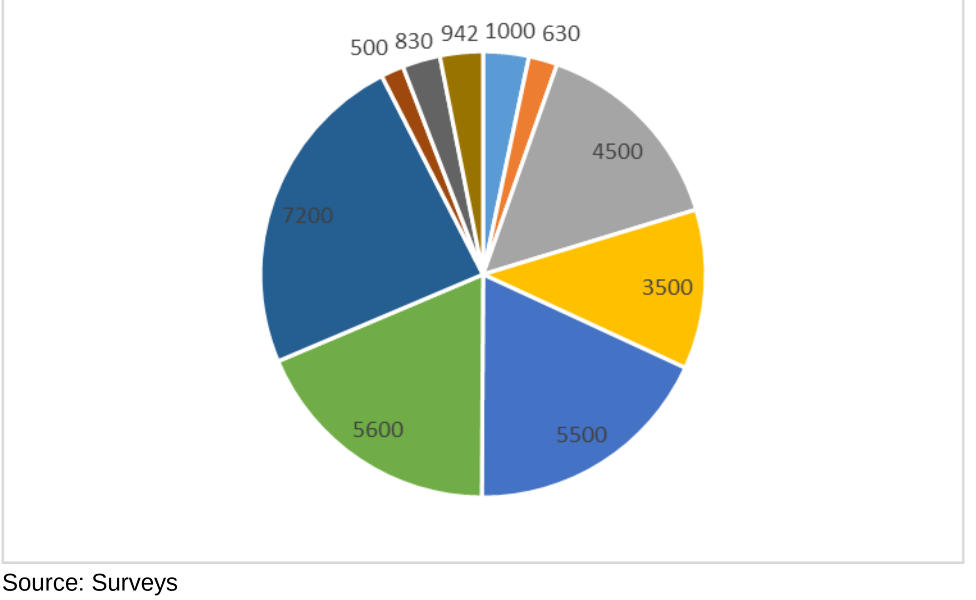
Source: Surveys

Vessels owners were questioned about their financial positions. The target, which were the vessels interviewed by WWF are part of this survey. This segment represents 14% of the universe. These 10 vessels registered an income superior to $720.000 in 2019.

PAX

The average number of tourist that these “10 vessels” served annually are detailed below.

Figure 52. Average number of passengers



Source: Surveys

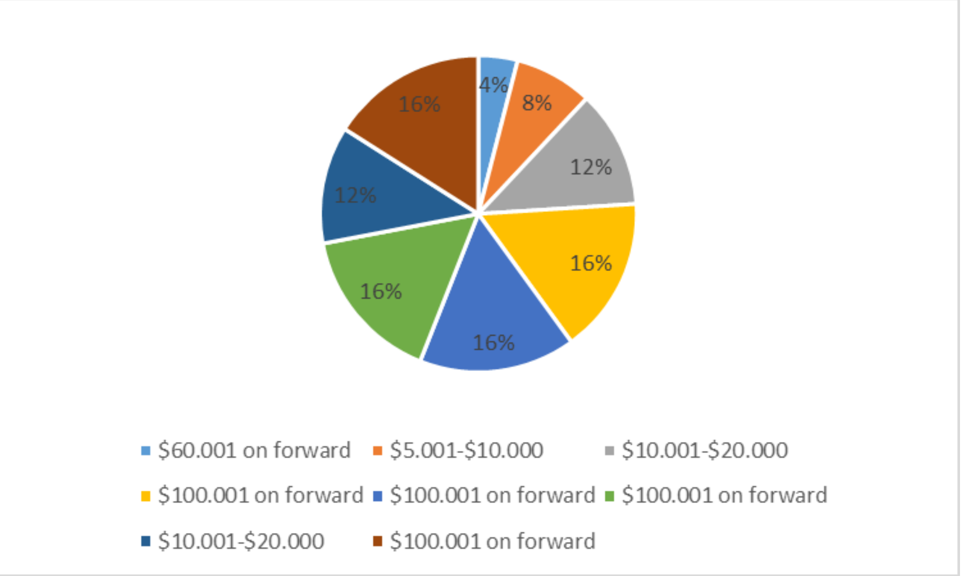
Within the target of the “10 vessels” the average number of pax attended were 3.020, being the minimum amount 500 and the greatest amount 7.200.

Accounting losses reported to the internal revenue services.
None of the 10 vessels reported accounting losses to the internal revenue services.

Debt payment installments

8 of the 10 vessels interviewed reported to have a current loan. The monthly installments are the following.

Figure 53. Monthly debt installments

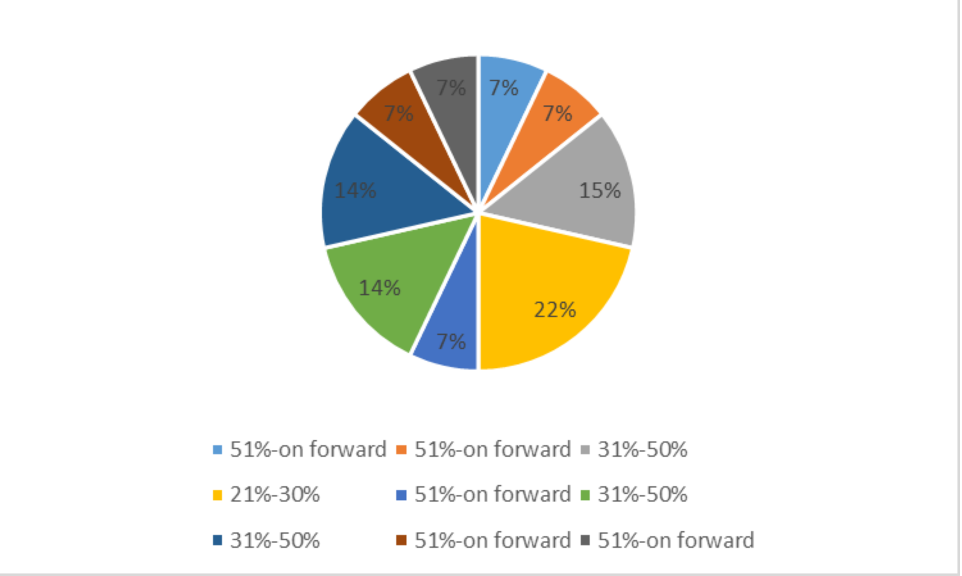


Source: Surveys

Half of the vessels pay a monthly installment of $100.000 or more.
Fixed costs in relation to income

The 10 vessels were asked how much the percentage of their fixed cost compared to their income is. The results are the following.

Figure 54. Fix cost to income



Source: Surveys

On average the ratio fixed cost/income is 42%.

Fixed assets

The 10 vessels alleged that their fixed assets account for more than $150,000.

Potential Market

The potential market is $400.000, which is the result of 10 vessels accepting a loan of $40,000.

Activity 2.2.1.4 Improve surveillance and control measures for adequate sea turtle nesting and foraging in the GMR, to counteract potential effects of climate change in their reproductive success.

The main objective of this activity is to apply mitigation strategies to alleviate climate change impacts on the population of green turtles in Galapagos, by protecting their nests from direct impacts of climate change and reducing other threats of anthropogenic origin that increase the vulnerability of the population.

The vulnerability of sea turtles to potential impacts of climate change has alerted researchers, conservationists and decision-makers all around the world to design strategies to alleviate climate change impacts on their populations. These strategies ranging from (1) directly manipulate nests and habitat to reduce site-specific impacts, (2) increasing their resilience by minimizing mortality due anthropogenic impacts, (3) protecting representative samples of their important habitats, and (4) monitor, management and assess to adequate geographic and temporal scales (Esteban et al., 2018; Hamann et al., 2010). This activity proposes to tackle effects of climate change by (1) directly manipulate turtle's nests to protect them from the direct impacts of erosion and flooding at most important nesting sites of the archipelago, (2) reduce sea turtle mortality due to anthropogenic causes, more specifically boat strikes, and (3) monitor and assess key habitats within the GMR in order to assess the success of the measurements applied.

The proportion of monitored nests at Galapagos nesting beaches affected by wave action and flooding increased from 1.6% during nesting seasons 2002 – 2007 (Zarate et al 2013) to 8.94% during the period 2009 – 2013 (Parra, unpublished data). It is important to highlight that this number of affected nests correspond to monitored nests and not to the total number of nests laid per season/beach. As was mentioned in the previous section, the total number of nests located in the flooding zone is higher. The reason for this difference is explained for the fact that only a sample of nests laid per season, randomly distributed in different areas and zones of the beach is tagged and monitored. This protocol has been applied due to the density of nests in some areas is high then the presence of tags in the nesting area represents obstacles to the nesting females seeking for a site to dig the nest and lay the eggs. Concerning current nests loss, measures can be applied to protect nests located in flooding areas of the beach, by translocating them to areas and zones less exposed to tide effects. To reach this, is crucial to implement a systematic methodology to measure the beach profile, to identify current safer areas within the beaches that can be used for translocation. It is also important to produce data that can be used in advanced modelling to quantify long term nesting habitat loss under extreme scenarios of sea-level rise that could require more drastic interventions. Additionally, consider the thermal conditions of the nesting beaches will be crucial when designing protocols of nests intervention, to avoid sex-ratio biased of nests translocated.

Current sea turtle species have been adapted to historical climate change events that occurred at geological level. However, current acceleration of climate change process due to the human activities and their impacts, change turtles habitats and their environmental conditions at faster rates than species can adapt (Esteban et al., 2018). In addition to changes in their habitats, direct impacts of human activities on sea turtles such as bycatch, direct hunting, collection of eggs and boat strikes, make the population more vulnerable to climate change (Hamann et al., 2010). Therefore, this EBA will address the boat strikes issue reported in Galapagos (Denkinger et al. 2013; Parra et al. 2013; Zarate 2009), by supporting the GNP authorities and the Galapagos Governing Council to design and implement management measurements to reduce sea turtle mortality within the GMR due to boat strikes. By reducing this direct anthropogenic impact, we expect to increase sea turtle population resilience at local and regional due the migratory condition of the species.

Additionally, after 13 years we need to re-assess the feeding sites to detect changes in the sex-ratio composition, identify which sites present a major proportion of males and to extreme protection measures in these sites in order to conserve the male sea turtle population. A constant shortage of males prolonged in time has the potential to eventually cause population extinction, therefore it is crucial to improve conservation efforts to this part of the population at different levels of their life state to ensure a sufficient number of males to maintain populations (Hays et al 2010, Blechschmidt et al 2020). Considering that Galapagos represent the second most important site for the green turtle of the EP, is urgent to understand how climate change is affecting the stability of green turtle key habitat within the GMR as well as the sex ratio of its population to design strategies of conservation and climate change adaptation to assure the conservation of the species at local and regional level.

Sea turtles provide invaluable ecosystem services and by conserving sea turtles, we ensure ecosystem health that is important for local population livelihoods, that directly depend on the ecosystem services obtained through artisanal fisheries and more significantly thought tourism activities. (see section 8 for full details). For example, sea turtles are important in the trophic chain, as a prey at various life history stages (Heithaus 2013). In the Galapagos the nesting beaches are important food resource of native species ranging from small invertebrates such as beetles (Omorgus suberosus) and ghost crabs (Ocypode gaudichaudii) (Zarate et al 2013), to native seabirds such as frigates (Fregata minor, F. magnificens), herons (Ardea herodias, Nyctanassa violacea), gulls (Larus fuliginosus, Larus pipixcan) feeding on eggs and emerging hatchlings (Figure 13) (Zarate 2009) and top predators including tiger sharks (Galeocerdo cuvier) which feed on juveniles and adults specially during the breeding season (Acuña et al 2017). Under this context, given the important ecological role of sea turtles, their protection and conservation within the GMR, it is important to enhance the resilience of key ecosystems of the archipelago such as sandy beaches and coastal ecosystems used by the turtles at nesting and feeding areas during their different life stages.

At the end of the program:

- Four sea turtle’s feeding sites within HEVAs in the GMR assessed, including turtle abundance, sex-ratios, habitat conditions, and boat strikes incidence.
- Thermal conditions during the incubation period of at least two currently monitored nesting beaches assessed.
- Hotspots of boat strikes in turtle nesting and feeding sites in the GMR identified.
- Priority beaches for turtle nesting identified within HEVAs, including those with the lowest risk of flooding and erosion ("safer zones”) due to climate change and density of nests per/zone per beach.
- Increased skills and competences of the GNPD staff on protocols and methodologies of marine turtle´s nests handling and translocations.
- At least one marine turtle's nesting beach selected with the GNPD successfully translocated.
- Monitoring system of marine turtle´s nests translocation in place.

To see details on the proposed activity and justification please see Appendix 2.3.

Beneficiaries:

Direct	80% technical staff members of the Marine Department of the GNPD will be trained on techniques of nests handling and translocation. 80% technical staff members of the Marine Department of the GNPD will be trained on techniques of sea turtles tracking. 80% technical staff members of the Marine Department of the GNPD will be trained on techniques of monitoring beach profile and flooding changes. 100% technical staff members of the Control and Surveillance of the GNPD will be trained to monitor the compliance of the approved marine traffic regulations, adopted by the GNPD. 40% technical staff of the Ecuadorian Navy will be trained to monitor the compliance of the approved marine traffic regulations, adopted by the GNPD. 50% of technical staff members of the Sub-secretariat of Ports and Maritime and River Transport will be participating in workshops to discuss new marine traffic regulations. 50% of technical staff members of the Ministry of Tourism will participate in workshops to discuss new marine traffic regulations. 50% of technical staff members of the Tourism and Recreation Department of the GNPD will participate in workshops to discuss new marine traffic regulations. 40% technical staff members of the Galapagos Governing Council will receive scientific information related to boat strikes on sea turtles and strategies to avoid collisions in order to create new marine traffic regulations.
Indirect	100% active tourist operators with diving and other activities in the GMR are trained in how to compliance new marine regulations. 100% Galapagos active Naturalist and Dive guides are trained in how to compliance new marine regulations. 100% small-scale active fishermen are trained in how to compliance new marine regulations. 100% local schools are involved in outreach activities to learn the importance of protecting sea turtles from climate change and anthropogenic impacts

Budget and financing mechanism:	USD 1,310,077.27/ GRANT
Executing entity:	WWF
Governmental partners:	GNPD

12.5.2.3 Output 2.2.2 High ecological value of native forest areas under restoration schemes, to secure environmental services in the face of climate change.

The following activities seek to increase the resilience of key terrestrial ecosystems through rehabilitation and restoration approaches, while strengthening the ongoing invasive species control program led by the Galapagos National Park Directorate (GNPD). This proposal focuses on the landscapes of the humid highlands of Santa Cruz, San Cristóbal, and Isabela. Specifically, it addresses areas of high hydrological and ecological importance that house the last remnants of Scalesia forests. Overall, the implementation area covers ~45,000 ha in total, with an elevation range from 200 to 700 m a.s.l. Please refer to Appendix xx for further details on the areas included and the ecosystem services they provide.

Activity 2.2.2.1 Strengthen control programs for guava and blackberry, in areas inside and outside the GNP, based on their projected dynamic expansion under climate change scenarios.

This activity addresses urgent actions needed to mitigate ongoing threats to vulnerable species and ecosystems, and to minimize the additive impacts of future climate change. Therefore, the objective of this activity is to contain the spread of invasive plant species in high ecological value forest fragments in the GNP and on selected farms in the agricultural zone. Invasive plant species will be contained through the following approaches: (1) Limiting the distributions and therefore impacts of invasive species on native and endemic species and (2) Preserving remnant forest habitats from further degradation through invasive species control.

For this, priority areas defined as areas with high hydrological and ecological importance, have been identified where invasive plant species control is proposed (see Appendix 2.4) and the area controlled will be a) left to regenerate on its own, allowing ecological succession to take place (passive restoration) or b) restored with native species (active restoration, see Activity 2.2.2.2).

Within the GNP, large areas of the humid zone are invaded by exotic plant species. In the case of Santa Cruz, this applies to more than 55% of the GNP (Trueman et al. 2014). To be able to tackle such a huge challenge, the GNPD needs to apply innovative control measures for invasive plant species. This approach will help to upscale the different restoration projects currently under execution, to increase restoration success, while at the same time reducing the costs. This includes an urgent need to apply easy-to-use and inexpensive solutions to implement restoration to protect native species and recover degraded forest fragments, while improving human livelihoods (Shackleton et al. 2020, Weidlich et al. 2020). Therefore, mapping is an important tool for the management of plant invasions, since it helps the GNPD staff to decide where to prioritize their efforts. The approach taken in this module includes the mapping of the guava distribution in different climate change model scenarios. In addition, estimations will be carried out for the distribution of blackberry, in an area of ca. 750 ha (400 ha on Santa Cruz, 200 ha on San Cristóbal and 150 ha on Isabela). Control of invasive species will be carried out in key areas, stretching over the same 750 ha in the GNP. Blackberry bush will be cut down with a machete to ca. 5 cm off the ground and Combo will be sprayed with a backpack sprayer onto the regrowth after 2 months (Jäger et al. 2017). Combo will be used since it proved to be most effective for the control of guava and blackberry (Yánez et al. 2004; Jäger et al. 2017, Jäger, unpubl. data). Re-growth and seedlings germinating from the seeds will be pulled out by hand.

The management of invasive blackberry requires a long-term commitment, since species resprout readily after control actions and seeds maintain viability in the soil for many years (10 years in the case of blackberry). Through capacity building within GNPD staff, invasive plant species control capacities will be strengthened by monthly meetings on-site, with evaluation of visual impressions, followed up by data-supported results from the monitoring activities (see EBA 3). This way, applied control techniques will be constantly monitored and evaluated to ensure high efficacy, while at the same time minimizing negative impacts on non-target species. In addition, an information system of invasive species will be implemented to support adaptive management of the GNPD invasive species control program (see Activity 2.2.2.3).

In farms, agricultural production faces a set of challenges due to the invasion of crop land by exotic plant species. The impact of invasive plant species on agricultural production has received far less attention than the risk that these pose to the protected areas (Jäger et al. 2019). Food in Galapagos is to a large extent imported from mainland Ecuador, despite recent regulations promoting the local production (Sampedro et al 2018). The local agricultural production in 2014 was 7,085 metric t/year, while the entry of products from the mainland was 19,066 metric t/year (MAGAP 2016). However, these imports facilitate the introduction of agricultural pests and invasive species, decreasing the profitability of local production, since invasive species have to be controlled (Viteri and Vergara, 2017). Sustainable farming production is key for the environmental conservation of the agroecosystems of Galapagos and for ensuring food security for the inhabitants (Sampedro and Mena 2018). These systems are crucial for food security and the control of invasive plants and therefore, this module highlights the importance of practitioners of both conservation and agriculture need to collaborate to pursue a common goal, which is the sustainable restoration and rehabilitation of the Galapagos highlands (Laso et al. 2020). Therefore, in collaboration with the GNPD, the Ministry of Agriculture and Livestock (MAG) and NGOs with ongoing activities and ample experience in improving agricultural production in Galapagos, we propose measures to sustainably control invasive species in the agricultural zone of Santa Cruz, San Cristóbal and Isabela. The GNPD will share their knowledge and expertise on invasive species control in the GNP with the technicians carrying out the control in the agricultural zone, supported by MAG and the NGOs to assure maximum success of control measures applied.

A baseline will be established in the agricultural zone on Santa Cruz, San Cristóbal and Isabela to assess the conservation status of Scalesia forest fragments and the severity of the distribution of invasive species. Since most of the introduced plant species are found in the agricultural zone (Guézou et al. 2010, Laso et al. 2020), it is key to work with the agricultural sector to improve land management practices to protect, conserve and sustain resources, like soil, water and biodiversity. A particular attention has to be paid to limiting the expansion of invasive plants into native ecosystems. Thus, 40 farms within the agricultural area will be included in the restoration process, with an emphasis on strengthening active agricultural practices to control invasive species and establish crops to compete with these. Based on the modeled expansion of guava under climate change scenario and ground surveys, 750 ha will be identified in the agricultural areas of Santa Cruz, San Cristóbal and Isabela. Currently, control methods are limited to manual removal and herbicide application. The same method ("hack-and-squirt"') suggested for the control of invasive species within the GNP will be used here.

At the end of the program:

- Guava and blackberry climate change distribution models are developed and verified based on ground surveys.
- Prioritized areas within the GNP (a total of 750 ha) are under innovative invasive species control schemes.
- Dispersal of invasive species, mainly blackberry, in an area of 750 ha inside the GNP, is contained, with environmental safeguards protocols.
- Protocols for long term control of invasive species under climate change scenarios developed and adopted by the Terrestrial Invasive Species Program of the GNPD.
- Conservation status of 750 ha of Scalesia forest fragments within HEVAs in the agricultural area assessed (400 ha on Santa Cruz, 200 on San Cristóbal and 150 ha on Isabela).
- Areas freed of invasive species that are now available for agricultural production.

To see details on the proposed activity and justification please see Appendix 2.4.

Beneficiaries:	
Direct	• 80% technical staff of the GNPD working in the ecosystem department trained in innovative control techniques. • 100% farmers participating in this project trained in innovative control techniques.

	● 100% farmers obtain land free of invasive plants to carry out sustainable agricultural production. ● 100% of technical workers of farms trained in innovative control techniques.
Indirect	● ABG ● Tourism operators

Budget and financing mechanism:	USD 2,803,002.52 /GRANT
Executing entity:	WWF
Governmental partners:	GNPD, Charles Darwin Foundation, Ministry of Agriculture.

Activity 2.2.2.2 Restore key remnant forest fragments in protected and agricultural areas to enhance ecosystems adaptive capacity and provision of environmental services.

Apart from control of invasive species, restoration actions include active restoration measures in areas where the focal threatened species is not able to regenerate without human intervention (Buddenhagen et al. 2004, Wilkinson et al. 2005). Restoration efforts should be focused on core preservation areas with high conservation values. A connection of these core areas of forest remnants of high conservation values through forest restoration efforts proposed in this activity, will result in larger patches and an increasing community resistance to further invasion by introduced plants (Janzen 1988). These core areas will grow over time, if initial obstacles to restoration are overcome (i.e. mass production of Scalesia seedlings, hesitating participation of landowners, etc.). Once established, these areas will become valuable sources of seed for the restoration of this and other degraded forest fragments (Wilkinson et al. 2005). In areas where there is still a native species seed bank and conditions for a natural regeneration seem optimal (Jäger et al. 2007), active restoration might not be needed (passive restoration). In the case that an active reforestation with Scalesia species is necessary, seeds from as many different sites of that same area will be collected, as widely spread apart as possible, to increase the genetic diversity of offspring. Seeds will then be germinated, and seedlings cultivated at the GNPD nursery greenhouses on Santa Cruz, San Cristóbal and Isabela, using proven successful methods to produce sufficient Scalesia seedlings to support the restoration of sites cleared of invasive plants.

In this context, this activity addresses the preservation of intact habitat and the restoration of degraded native habitats. These approaches will improve forest fragment connectivity, ecosystem services, support biodiversity, enhance productivity and improve resilience against the effects of climate change, such as drought and aridity.

A total of 750 ha in the GNP will be restored with Scalesia and other native and endemic plant species (400 ha on Santa Cruz, 200 ha on San Cristóbal and 150 ha on Isabela). This is the same area that had been previously cleared of invasive plant species. During the first 6 months of the project, a baseline will be established on Santa Cruz, San Cristóbal and Isabela to assess the conservation status of the 750 ha of forest fragments within the GNP. The assessment includes forest structure and composition. This baseline will allow us to prioritize fragments where to concentrate active and passive restoration actions. Further, nurseries of the GNPD on the three islands will be improved and equipped, as well as GNPD staff trained, to be able to mass-produce Scalesia pedunculata (on Santa Cruz and San Cristóbal) and Scalesia cordata (on Isabela), as well as guayabillo (Psidium galapageium), cafetillo (Psychotria rufipes) and uña de gato (Zanthoxylum fagara). Scalesia and the other species will be planted at a distance of 5 m to the next Scalesia or other species, this way, a total of 400 plants will be planted per hectare, totaling 300,000 Scalesia and other native and endemic species for the entire intervention area of 750 ha. On average, one person can plant the 400 plants per hectare in about 2 weeks. Once the 750 ha are planted, continuous follow-up control of invasive species must be carried out, as well as continuous re-planting of dead-off seedlings. Restoration success will be evaluated with the help of permanent plots previously established and a vegetation mapping with drones and high-resolution satellite imagery (resolution of 0.5 m x 0.5 m). The prioritization and planting activity will be carried out in collaboration with NGOs with experience in restoration efforts.

Additionally, the program will seek to integrate active restoration of the remaining fragments of native ecosystems that still exist on farms, as well as agroforestry practices to rehabilitate degraded agricultural areas. These practices will be implemented as a climate change adaptation strategy for increasing forest cover, number of endemic plant species, improving and maintaining the ecosystem services (like pollination, measured by the survey of the invertebrate community) and connectivity between forest remnant patches. The Ministry of Agriculture and Livestock (MAG), NGOs with ample experience in improving agriculture in Galapagos and the farmer's associations will be involved throughout the entire implementation phase of this project.

Furthermore, over the last five years, having small patches of Scalesia forest on the farm has become an important tourist attraction (Jäger, unpubl. data). In addition, more and more farmers have turned to producing "Galapagos" shade growing coffee offering them a lucrative income. In this agroforestry system they use Scalesia and other native species as shade trees (Ortiz and Henderson 2011). In addition, agroforestry systems play an important role in improving water recharge and sustaining productivity, especially during the dry season (Warrier et al. 2012). Therefore, Scalesia trees and other native species on coffee farms will encourage the incorporation of agroforestry systems such as bio-diversification and silvopastoral systems in forestry incentive payment schemes. Furthermore, native trees could also serve as live fences within the diverse matrix of agricultural areas.

This activity will restore and rehabilitate at least ten abandoned or inactive farms within agricultural landscapes into productive areas supporting native ecosystems, with potential biological ecosystem conservation (5 on Santa Cruz, 3 on San Cristóbal and 2 on Isabela).

The specific sub-activities to implement the restoration practices in the selected farms are:

A. Design and implement a conservation categorization system and management protocols for farms on Santa Cruz, San Cristóbal and Isabela.
B. Protecting forest for ecosystem functioning and connectivity (protection of 750 ha). This practice consists of managing the native forest fragments on farms through active restoration actions for conservation/protection of environmental services, like increase in water availability through interception of fog (garúa), pollination, etc.
C. Preparation of projects that will be the object of forest incentives mechanisms promoted by local institutions (MAG, GNPD, among others). These financial mechanisms will provide resources for farmers to facilitate the implementation of appropriate forestry practices to conserve and restore forest cover.
D. Training courses in restoration practices will be held for interested farmers to improve their management skills, who can then be involved in the project activities as qualified workers. Outreach activities will engage with local farmers from the project onset to ensure their support. This will be done through roundtable discussions on the proposed activities and the benefit to them, through workshops and training on *Scalesia* cultivation, as well as field trips to project sites. This strategy will ensure the agricultural community is engaged with the project and supports it, which is key for the success of conservation efforts. In addition to support these communication efforts, leaflets will be produced (digital and in-print) to be distributed, not only to farmers, but also to students, local

authorities, and tour operators, outlining the benefits of the project, not only for biodiversity conservation but also for the local community.

Finally, training courses in restoration practices will be held for interested farmers to improve their management skills, who can then be involved in the project activities as qualified workers. Outreach activities will engage with local farmers from the project onset to ensure their support. This will be done through roundtable discussions on the proposed activities and the benefit to them, through workshops and training on *Scalesia* cultivation, as well as field trips to project sites. This strategy will ensure the agricultural community is engaged with the project and supports it, which is key for the success of conservation efforts. In addition to support these communication efforts, leaflets will be produced (digital and in-print) to be distributed, not only to farmers, but also to students, local authorities and tour operators, outlining the benefits of the project, not only for biodiversity conservation but also for the local community.

At the end of the program:

- Conservation status of 750 ha of Scalesia forest fragments inside the GNP assessed.
- Nurseries of the GNPD to provide native species seedlings to implement restoration activities on the three inhabited islands strengthened.
- In key restoration areas, 300.000 native plants successfully established.
- Priority Scalesia forest fragments (750 ha) within the GNP successfully restored.
- Agricultural land restored (750 ha) with Scalesia spp. and other native tree species, totaling 300.000 planted individuals (400 ha on Santa Cruz, 200 ha in San Cristóbal and 150 ha on Isabela) on at least 10 farms (5 on Santa Cruz, 3 on San Cristóbal and 2 on Isabela).
- Landscape connectivity between key forest fragments on farms increased through restoration actions.
- Farmers trained in restoration practices to be involved in project activities as a qualified labor force.
- Key scientific finds of Scalesia forest restoration disseminated in open-access peer-reviewed scientific journals and with key local and national stakeholders.

To see details on the proposed activity and justification please see Appendix 2.4.

Beneficiaries:	
Direct	• 80% technical staff of the GNPD working in the ecosystem department trained in successful planting of Scalesia and other native and endemic species. • 100% farmers participating in this project trained in successful planting of Scalesia and other native and endemic species. • 100% farmers benefiting from sustainable agricultural production. • 20% farmers with improved coffee production within the Scalesia forest • 100% of technical workers of farms trained in innovative control techniques
Indirect	• Tourism operators from Santa Cruz, Isabela, and San Cristobal. • Coffee producers

Budget and financing mechanism:	USD 2,501,402.52/ GRANT

Executing entity:	WWF
Governmental partners:	GNPD, Charles Darwin Foundation, Ministry of Agriculture.

Activity 2.2.2.3 Monitor success and impacts of invasive species control and restoration measures.

The objective of this module is to inform and improve the management of terrestrial invasive species and restoration actions in the highlands of Isabela, San Cristóbal and Santa Cruz. Predicting future ecosystem dynamics depends critically on an improved understanding of how disturbances and climate change have driven long-term ecological changes in the past (Salinas-de-León et al. 2020). Permanent plots allow for the characterization and modelling of active ecological processes. Since these processes can be spatially autocorrelated (e.g., pathogens, insects, windthrow, etc.), the plots provide the context to analyze how these climate- and human-driven processes are changing vegetation communities and ecosystem dynamics. Long term data from permanent plots can be used to determine how annual climate variation affects each agent of vegetation change, as well as to assess and understand the effect restoration actions over the system.

The Charles Darwin Foundation (FCD) has been monitoring over 180 permanent vegetation plots, ranging in size from 10 m x 10 m to 50 m x 50 m, since 1995 (Tye 2003). Using these long-term data sets allows us to document changes in the vegetation structure, like the distribution and expansion of invasive plant species, but also the efficacy of GNPD restoration efforts. However, to be able to address potential changes and to mitigate climate change impacts, it is indispensable to expand this monitoring and to include a coupled climatological monitoring for the different islands. This requires a better understanding of existing and past climate at a local scale that includes ecosystem complexity and changes along elevational gradients. Therefore, the current system of meteorological weather stations must be expanded, and stations positioned in strategic places.

Monitoring the effects of management practices will prove to be more important the longer the series of permanent plot observations lasts. While it is important to establish new permanent vegetation plots, it is equally important to continue the monitoring of the plots already established. The plots provide crucial long-term baseline data that is essential to be able to address future changes in the vegetation due to interactive effect of climate change and human drivers of change (i.e., invasive species, e.g., Jäger et al. 2009). The data for some of these plots' dates back 20 and more years and correlated with climatological data, will allow for disentangling natural vegetation changes (with and without invasive species) from climate-related changes.

Additionally, assessment of vulnerability and prioritization of management action require an enhanced knowledge of the current spatial distributions of threatened and invasive species. It is critically important to have long-term data on plant community change in the different vegetation zones on different islands to be able to assess negative impacts of invasive species, as well as the vulnerability to climate change. This knowledge will provide science-based advice to the GNPD, MAG, the Galapagos Biosecurity Agency (ABG, acronym in Spanish) and other stakeholders on recommended efforts to mitigate invasive species and climate change impacts.

Through this activity, restoration success will be evaluated with the help of permanent plots previously established and a vegetation mapping with drones and high-resolution satellite imagery (resolution of 0.5 m x 0.5 m, see Activity 2.2.2.2 in this same section of the document), in close cooperation with the GNPD and other relevant stakeholders. Applied control techniques will be constantly monitored and evaluated to ensure high efficacy, while at the same time minimizing negative impacts on non-target species. The information produced through the monitoring program will inform the GNPD via co-implementing monitoring and restoration actions, training, and outreach. In addition, the project will consolidate a data management and information system were all the information will be uploaded. It is envisaged the information system will inform restoration actions based on an adaptive management scheme.

Complementarily, to document restoration success and changes in the plant and animal communities of the forest fragments, a baseline will be established for different species on Santa Cruz, San Cristóbal and Isabela. Prior to the onset of restoration actions, 10 plots on each island will be established to document restoration success and changes in the plant and animal communities, as well as in the composition of agricultural crops.

Additionally, this activity will perform two major tasks: (1) Evaluate current control techniques for invasive plant species, and (2) assess restoration efforts and necessities. For the first task, results from the monitoring of the plant communities in the permanent plots that had previously been controlled or are permanently being controlled, will be used to evaluate the efficacy and impacts of different control techniques for invasive plant species. This includes taking soil and water samples to determine contamination with herbicides. Research has shown that chemical control of invasive plant species can result in an accumulation of herbicide residuals in the soil (Gerzabek et al. 2019). Therefore, soil samples will be taken in at least 10 selected spots in the highlands of Santa Cruz, Isabela, Floreana and San Cristóbal from the top 15 cm and 10 water samples will be collected from natural water drains and grietas. Samples will be transported to the University of the Americas (UDLA) in Quito, Ecuador. Results will help to inform and adjust activities carried out under activity. If residuals of the herbicides Combo are found to be accumulating in the soil, control actions will be stopped immediately. However, based on previous studies, this is not very likely (Zehetner, unpubl. data).

With data obtained from new and already established permanent plots, restoration efforts carried out by the GNPD (e.g., reforestation of key species, and control of invasive species in Santa Cruz) will be evaluated using multivariate statistics such as multiple regression analysis. Evaluating the results from the monitoring work together with the modeling scenarios (see section 4), we will be able to: (a) identify the areas that are in need for active restoration with Scalesia species and other native species, and (b) select areas where a passive restoration is still possible. This distinction is important to be able to allocate scarce restoration funding accordingly.

At the end of the program:

- Control techniques for invasive plant species in the Galapagos highlands, including the identification of the most cost-effective techniques with the lowest environmental risk and major impacts on invasive species, assessed.
- Priority areas to implement active and passive restoration actions identified.
- Data management and information system consolidated and adopted by the GNPD, including an open access, user-friendly, digital platform to readily access information about key species (e.g., invasive species) under a “Social-Ecological System Knowledge Node” format to inform decision-making and strengthen Galapagos local and regional governance.
- Plant and animal diversity in the GNP and on 40 farms to determine the status of biodiversity and to identify priority sites for future conservation and restoration actions.
- Updated assessment of terrestrial biodiversity and ecosystem services focused on ecological information from the highlands to support the implementation of the new zoning format (from 2016) in the GNP.
- Innovative management of terrestrial invasive species in the protected and agricultural areas to protect biodiversity and promote sustainable agriculture in a scientifically validated way, in place.

To see details on the proposed activity and justification please see Appendix 2.4.

Beneficiaries:	
Direct	• 100% of participants in the monitoring program trained in the latest techniques. • GNPD technical staff from the ecosystem department • 100% farmers, from at least 10 farms, benefiting from low impact restoration practices, including invasive species control.
Indirect	ABG

BUDGET	USD 1,129,282.52 / grant
Executing entity:	WWF
Governmental partners:	GNPD, Charles Darwin Foundation.

12.6 Component 3: Sustainability mechanisms for climate resilience and low emissions livelihoods.

This component will strengthen Galapagos farmers and small-scale fisheries' adaptive capacity to increase local food production through the provision of reimbursable and non-reimbursable funds to foster the adoption of sustainable land and fisheries practices, promoting more efficient value chains and a blue circular economy, fostering the protection and restoration of key marine and terrestrial ecosystems that sustain Galapagos livelihoods including tourism, and strengthening the decision-making frameworks related to ecosystem management.

In order to develop resilience to climate change, positive social transformations are required at different levels of the social-ecological framework (individual, interpersonal, community or societal level). These transformations will occur as long as different actors from different sectors of society adopt pro-environmental and pro-climate behaviors, and these are maintained over time. Interventions to change behavior in the short terms should be complemented with strategies in favor of sustaining these behaviors in the medium and long-term (Goldberg et al., 2020). In our context, whether behavioral changes are sustained will depend, to a large extent, on the success of efforts to influence public policies and civil society. We will seek to institutionalize, at different levels, the processes of education (both formal and non-formal), communication and mobilization of community towards climate action in the Galapagos, and leave local capacities installed with the objective of upholding them in the long term.

12.6.1 Outcome 3.1 Strengthened response capacity of key institutions, local livelihoods, and population from Galapagos.

12.6.1.1 Output 3.1.1 Tools and financial mechanisms established for the sustainability of the program's actions.

Activity 3.1.1.1 Implement an ecotourism certification scheme to adopt best practices across the tourism value chain.

The main challenges and opportunities for the adoption of a sustainable tourism certification scheme in the Galapagos Islands have been described in Appendix 3.1.

An ecotourism certification structure will be designed and implemented in compliance with standards for climate-resilient development for the Galapagos tourism sector, based on climate change mitigation and adaptation measures and good tourism management practices, which will contribute to strengthening the competitiveness of the islands' tourism destination. This activity aims to overcome the obstacles faced by the tourism sector related to comply with requirements and to face the cost of the certification. Most of the actors in the tourism sector are small and local family businesses that are suffering from a major economic crisis as a result of the pandemic; in the specific case of the boat operators, most of them have good environmental practices as required by the GNP. However, these practices do not include measures with a climate perspective, e.g., low-emissions solutions.

162.183. Two key aspects of the certification proposed are: 1) it will be sought to be managed by the local authorities and thus it is expected to offer much lower costs to the tourism actors; 2) the technical assistance will include supporting the tourism actors to access loans from the GCCL to fund the costs related to the certification.

The activity will begin by identifying and training local auditors on the concepts, standards, and procedures for ecotourism certification. A socialization will be carried out and finally a certification pilot will be implemented with prioritized companies. This pilot will offer: i) audits; ii) an assistance plan to incorporate improvements and corrective measures with the support of experts and focused on the particular needs and priorities identified for each enterprise; iii) evaluation of results to determine whether the objectives established in the proposed pilot were achieved.

Finally, a final design of the certification program will be achieved, which will establish the standards that will help distinguish and differentiate the ecotourism enterprises established and operating in the Galapagos Islands.

It is expected that this certification will become an original tool endorsed by the agencies that support sustainable development and climate change policies.

12.6.1.2 Output 3.1.2 The Galapagos community is mobilized towards a transformative climate action.

Through the activities in this Output (See Appendix 3.3) we will install local capacities for applying behavioral science to the design and implementation of communication, education, and social participation processes, strategies, and actions. The capacity building program for facilitators will have a special emphasis on developing the knowledge and skills to accompany and support the implementation of the different communications and training processes of the other project components, through a behavioral change lense. On the other hand, through Activity 3.1.2.2 we will develop a comprehensive knowledge management, communication, and outreach program for the Galapagos focused on climate change. Through the sub-activities of this program, the methodological guidelines and basic content on climate change will be provided to effectively guide the awareness-raising, capacity-building, and training actions of the other components, from a behavioral science perspective. We will also develop a behavioral change campaign aimed at consumers of the food system in Galapagos, focusing on those behaviors that can be effectively addressed by communications interventions. For more information on this activity, please refer to Appendix 3.3, Subsection 3.2.2 Description of sub-activities and outputs.

Activity 3.1.2.1 Strengthen the educational system to provide quality education to face climate change and promote sustainable development.

The objective of this activity is to integrate a comprehensive educational approach to climate change within the formal educational system of Galapagos (basic education, high-school, and third-level education), that includes innovative and pertinent education models, approaches, methodologies, and tools.

The limited capacity (knowledge, skills, and pedagogical resources, and time) of teachers to effectively incorporate quality climate change learning experiences into their planning and implementation, the scarce experiential learning opportunities focused on climate literacy integrated into the formal education system, and the fact that technical education opportunities in Galapagos are not connected with local labor market demands and with youth interests, are some of the most important challenges regarding formal education in Galapagos that this activity will address. However, currently in the Galapagos there are enabling national and local frameworks and processes which include, among others, the Galapagos for Education Agreement (AGE) (as its acronym in Spanish) and the process of contextualizing the national curriculum in Galapagos.

Through Education for Sustainable Development (EDS), experiential and place-based education approaches, amongst others, this activity aims to promote and sustain the development of significant teaching-learning experiences to strengthen knowledge, attitudes and skills of children and youth to be better prepared to face climate change and contribute to a resilient and self-sufficient Galapagos system.

Climate change education for sustainable development in the formal field can happen in many ways, and this action will take this perspective into consideration throughout the following five sub-activities, which will be further described in the Appendix ECM.

a) Establish a Board of Education for Climate Change, to articulate the efforts carried out in Galapagos by different institutions and organizations.

Within the framework of the AGE and its Intersectoral Table for Educational Articulation (MIAE), a Board of Education for Climate Change (MECC) (as its acronym in Spanish) in Galapagos will be created to foster articulation, coordination and collaboration between different actors in order to achieve a effective and quality climate change education. Through the MIAE, a promoter committee will be defined, the same that will be in charge of creating the conditions for the constitution of the MECC and its future coordination. This sub-activity puts forward the creation of the 2030 Agenda for Climate Change Education at the provincial level; institutionalize and systematize intersectoral local efforts for climate action in the education system; generate informed dialogues to contribute in the creation of public policies aiming towards a more effective education for climate change; and promote exchange of experiences at a local, national and international level.

b) Integrate quality climate change education into the existing professional development program of the Ministry of Education in Galapagos.

This activity focuses on strengthening teacher professional development in the Galapagos to ensure that they have a deep understanding of the contextualized curriculum components associated with climate change; master the topic of climate change satisfactorily to teach it to their students; and, know how to “translate” the contextualized curriculum, the pedagogical resources, and their understanding of climate change in authentic and meaningful learning activities. To achieve this, the Teacher Professional Development Program with an Education for Sustainable Development approach of the Ministry of Education (Mineduc), with support of the Galapagos Conservancy and the Scalesia Foundation, will be supported through the following actions: intensive training on climate change for all Pedagogical Leaders, integration of the dimensions of climate change during the existing Educational Institutes for teachers, and accompaniment for pedagogical leaders in their roles as advisors with teachers regarding planning and implementation of climate change education.

c) Implement climate-friendly practices in schools to promote pro-climate attitudes and climate literacy.

Complementary with sub activity 1.2, this current sub activity will provide support regarding the design and implementation of pilot projects connected to the new contextualized curriculum for Galapagos. Where the provision of support to Pedagogical Leaders (mentor teachers) is proposed, so they may put into practice their understanding of climate change within authentic and meaningful learning activities for students. Its objective is to strengthen skills, attitudes and generate behavior change intentions among students through the design and implementation of sustainable practices for the mitigation and adaptation to climate change in their schools. Each year one pilot project per island will be selected by the MECC (sub activity 1.1) and will be given technical and pedagogical assistance for its development.

d) Implement community engagement and experiential learning programs for students of basic education and high school, connecting to mitigation and adaptation initiatives promoted by the Program.

The AGE has addressed the importance of experiential education with the creation of a Board of Experiential Education (MEE) (as its acronym in Spanish). Precisely, this sub activity will develop a module entirely dedicated to climate change, which will be inserted in the ecology camps of the GNPD and EPI as part of the Student Participation Program of Mineduc, where learning experiences will be linked to real mitigation and adaptation interventions being carried out on the islands. As well technical assistance and support for generating content and experiential lessons on climate change will be provided to other experiential education programs, such as Galapagos Infinito and Agents of Change. This opportunity will strengthen the practical knowledge and skills of teachers, acquired at the Professional Development Program (ESD Program) under the sub-activity 1.2. described above.

e) Design and implement technical education programs for youth, to address the labor markets local demand in areas related to Galapagos tourism, agriculture, and fisheries value chain, within a climate change and post-COVID-19 context.

To be consistent with the actions to promote sustainable and climate-smart value chains that are proposed within the framework of the Program, the development of four technical education programs focused on sustainable value chains with a strong focus upon climate change is proposed. Two of them aimed at second-level education (technical high school degrees) in close collaboration with Mineduc; and two of them aimed at third-level education (technical degrees) in close collaboration with University San Francisco de Quito. These programs will be designed based on the findings of the assessments that will be carried out regarding the specific labor market needs in Galapagos´ fisheries and agriculture sectors, as well as young people´s specific interests and needs in these areas. A monitoring and evaluation system to strengthen the implementation capacity of these programs and to increase the impact of the expected results in the short and medium terms will be generated, with a focus on the students' post study labor practices.

At the end of the program:

- Institutionalize and systematize intersectoral efforts for climate action in the education system through a Board of Education for Climate Change (MECC) created.
- An Agenda for Climate Change Education at a provincial level is developed and implemented.
- Training modules regarding climate change are designed and implemented for teachers, through intensive training of pedagogical leaders and Education Institutes of the ESG Program.
- Pedagogical resources about climate change are created to implement the contextualized curriculum of Galapagos.
- Pilot projects implemented in a four-year period at different Galapagos educational establishments focused on adaptation and mitigation to climate change.
- Climate-friendly projects replicated successfully at Galapagos educational institutions.

- Immersive and experiential educational experiences on climate change are designed and implemented every year into the educational system.
- Trained teachers co-facilitate real place-based education and experiential learning opportunities on climate change with students.
- Two technical high-school degrees in sustainable food value chains designed with a strong focus upon sustainability and climate change and implemented in close collaboration with the Ministry of Education.
- Two third-level technical degrees sustainable food value chains designed and implemented, with strong focus upon sustainability and climate change, and implemented in close collaboration with USFQ.

To see details on the proposed activity and justification please see Appendix 3.3.

Beneficiaries	
Direct	• 400 teachers in the educational system of the Galapagos • 7.519 students in the educational system of the Galapagos • District Directorate of Education in Galapagos • Organizations that have experiential education models, such as Agents of Change Galapagos Infinito.
Indirect	• Organizations like Galapagos Conservancy and Scalesia Foundation, as well as the Galapagos Government Council and the Galapagos National Park.

Budget and financing mechanism:	USD 1,458,472.72 / GRANT
Executing entity:	WWF
Governmental partners:	EPI, District Directorate of Education in Galapagos, GNPD, MAG, Mintur, CGREG, Galapagos Conservancy and Scalesia Foundation, Galapagos Infinito and Agents of Change.

Activity 3.1.2.2 Strengthen knowledge and foster engagement of public and key stakeholders on climate change impacts and solutions.

This activity aims to facilitate information, practical knowledge, tools, and outreach opportunities, to encourage local community interest, support and active involvement in addressing climate change.

Considering the general lack of accessible, timely, understandable and relevant information about climate change in Galapagos, is a contributing factor to poor climate change literacy among youth and community members and limited evidence-based decision making, as well as the lack of behaviorally-informed climate change communication strategies and interventions, this activity will develop a comprehensive knowledge management, communication and outreach program for the Galapagos focused on climate change.

Through a social and behavioral change approach, climate change communication and social and behavioral change approach (see Appendix 3.3 Behavioral change) will be integral and fundamental to the successful implementation of the Program in the short and medium term and will lay an important basis for promoting deep engagement with climate change adaptation and mitigation actions in the long term.

Climate change communications and social and behavioral change communications can happen in many ways, and this action will take this perspective into consideration throughout the three sub-activities, which will be further described in the Appendix ECM.

a) Develop a knowledge management and outreach digital platform that makes updated and relevant information, knowledge, lessons, and resources regarding climate change in the Galapagos, understandable and accessible to the public and key stakeholders.

An online, web-based platform will be developed for the management of knowledge on climate change in the Galapagos. This will be a collaborative platform that holds a high quality, understandable and timely content, that will facilitate access to information and knowledge, promote exchange, interaction and articulation between stakeholders that produce and use knowledge at a local, national, and regional level, including beneficiaries, practitioners, researchers, managers and policymakers in the public, private and civil society sectors related to this Program. Amongst others, this platform will systematize and make available information on priority aspects on climate change generated by the Program and already available from other projects/partners, develop consultation tools and communication products, generate opportunities for capacity building and showcase the progress of the Program.

b) Develop and implement a communication strategy based on innovative approaches and methods, to strengthen knowledge and foster commitment for the adoption of climate change mitigation and adaptation measures.

Based on the findings of behavioral insights analyses that will be conducted as part of this Program, together with the Behavioral Insights Team (BIT), a comprehensive communication strategy will be developed. The strategy will integrate a diverse variety of innovative behaviorally informed communication techniques, methods, and resources, to facilitate people's awareness, knowledge, attitudes, engagement and empowerment for climate action. As part of this strategy, a cross-cutting content plan will be developed around the overall objectives of the Program, including relevant information and knowledge on climate change, as well of the Program progress, milestones and good practices undertaken by the key stakeholders. In line with the overall Program narrative and content plan, this strategy will encompass a variety of graphic, audiovisual, and written communication resources that will be disseminated through multi-channel and multi-platform approach.

c) *Develop a behavioral change campaign aimed at consumers of the food system in Galapagos, focusing on those behaviors that can be effectively addressed by communications interventions.*

Through the development of social and behavioral change campaigns, we aim to influence upon the consumption choices towards local, sustainable, and climate-friendly food products for consumers in the Galapagos, both of commercial buyers of food products, as well as of the end-users. Based on a nuanced understanding of these consumers´ personal and contextual factors and motivators influencing behavior change, including the cognitive, affective, and unconscious drivers, the campaign will be designed and implemented based on models, frameworks, and tools from behavioral sciences, climate change communication, educommunication, social marketing, and advertising. Through behavior change communication, community mobilization and advocacy, these campaigns will support the transformation of the Galapagos food system towards a greener, sustainable, and climate resilient.

At the end of the program:

- A climate change knowledge management and outreach digital platform that gathers available and relevant information on climate change in Galapagos, is developed.
- A communication and outreach plan, linked to the platform, delivers general communication and education climate change-related materials to key stakeholders.

- A behavioral-informed and comprehensive climate change strategy is designed and implemented, integrating innovative and effective communication approaches, methods and tools.
- A cross-cutting content plan will be developed through a variety of graphic, audiovisual and written communication resources, and disseminated through a multi-channel and multi-platform approach.
- A Behavioral Insight Analysis focused on food consumers in Galapagos, is designed and carried out.
- A social and behavioral change campaign focused on consumers regarding fisheries, agriculture and tourism value chains in Galapagos is designed and implemented in the four populated islands.

To see details on the proposed activity and justification please see Appendix 3.3.

Beneficiaries:	
Direct	• Local community of Galapagos, including decision makers and key stakeholders (farmers, fishers, tourism operators, etc). • Communication staff of management institutions in the Galapagos (specially CGREG and DPNG).
Indirect	n/a

Budget and financing mechanism:	USD 480,582.72 / GRANT
Executing entity:	WWF
Governmental partners:	CGREG and GNPD

Activity 3.1.2.3 Facilitate non-formal education and mobilization opportunities to encourage youth and local community empowerment on climate action.

This activity aims to implement action-based, non-formal educational and outreach experiences to foster youth and community empowerment, engagement, and leadership on climate action, by providing them with practical knowledge, tools and skills, and most importantly, the opportunity and agency to translate those into climate action.

Through lifelong learning, action-oriented and experiential education approaches, this activity addresses challenges in Galapagos regarding the lack of capacity of government officers in to effectively integrate climate change aspects into existing communication, non-formal education and community outreach processes, the limited climate change immersive field-based for community members, and non-formal educational experiences opportunities to foster youth and community-lead initiatives and projects on collective climate action. As a whole, this activity aims to prepare youth and adults for individual and collective action towards climate change by developing the necessary competencies and opportunities for active citizenship.

Deep engagement learning experiences in a non-formal field can happen in many ways, and this action will take this perspective into consideration across the three sub-activities, which will be further described in the Appendix ECM.

a) Develop a capacity building program for non-formal facilitators (government officials, NGOs, community leaders) to increase their understanding and practical application of climate change approach into communication, community outreach and non-formal education interventions.

This sub activity will design and implement a training program aimed at potential facilitators and promoters of local climate action. Through a Project Based Learning (PBL) methodology, the participating facilitators will put into practice the knowledge, skills and tools acquired and strengthened through the training, by developing collective projects integrating innovative and effective communication, education, and outreach strategies, that actively involves the local community, as final beneficiaries of such projects, towards climate action. Considering that the participants of the program are adults, pertinent educational approaches and principles will be integrated in the learning process. At the end of this process, participating facilitators are expected to develop the knowledge and skills to design and implement Environmental Communication, Education and Participation (CEPA) programs, strategies, activities and resources with a focus on climate change.

b) Develop immersive field-based and non-formal educational experiences for different audiences, to connect the local community with the natural environment and climate change mitigation and adaptation initiatives.

Existing experiential and immersive field-based learning opportunities will be strengthened with a climate change focus, as well new ones will be created, aiming to work with multiple audiences of the community in Galapagos, ranging from children to adults of different backgrounds. In order to foster climate literacy through real life experiences, these non-formal education experiences will be connected to the mitigation and adaptation to climate change efforts developed within the Program and coordinated with the distinct institutions working on topics related to climate change locally. These immersive experiences will be implemented through 1) one-day field trips, 2) multi-day educational camps, 3) community monitoring programs and citizen science.

c) Create a permanent working platform that brings together existing organized groups and citizens towards collective climate action, through capacity building and the implementation of pilot youth and community-based projects.

The process developed through this sub activity, aims to work with the multiple civil society and youth groups that already exist in the Galapagos and engage them on a long-term collective training process with a focus on building competencies for climate action, which will be transformed into empowered action through the development of community-based collective projects. Both the establishment of a permanent working group (community) and the training process will happen simultaneously and will integrate a project-based learning and design thinking approach during 8-month cycles. Based on personal and local connections with climate change, individual and collective competencies, as well as the permanent working group, will be developed from a perspective of autonomy and self-determination. In order to ensure long-term commitment, scalability and sustainability of this collective climate action community, interested members will be trained to continue and replicate the process independently. As well, this community will be connected to other WWF Communities in the country as well to regional platforms, raising up the potential of scaling-up climate change solutions at different levels.

At the end of the program:

- A training program for facilitators of communication, non-formal education, and mobilization processes on climate change through a project-based learning methodology, is designed and implemented on Santa Cruz and San Cristobal Islands.
- A training-of-trainers strategy for the replication and scaling of the program, is developed and implemented in the four populated islands.
- At least two immersive field-based experiences regarding climate change, designed and conducted every year in each inhabited island.
- Citizens of the four populated islands, have been trained and are part of the working platform on collective climate action.
- Independent youth and community-based projects or initiatives are initiated and have been successfully completed or are still under development.

- Local community leaders have been trained as facilitators of the working platform and lead their own independent groups towards collective climate action, through on the ground projects and initiatives.

To see details on the proposed activity and justification please see Appendix 3.3.

Beneficiaries:	
Direct	• 40 professionals or technical personnel from government institutions in Galapagos that are working within the framework of the Program (CGREG, DPNG, GADs, MAG, etc.), • NGOs, civil society organizations, community leaders, that in their field of work apply communications, non-formal education, community outreach and social participation. • Community members and experiential education programs such as Galapagos Infinito (ONG) and Explora Galapagos (DPNG). • Multiple civil society and youth groups that already exist in the Galapagos.
Indirect	• Galapagos whole community, ranging from children to adults

Budget and financing mechanism:	USD 990,572.72 / GRANT
Executing entity:	WWF
Governmental partners:	GNPD AND CGREG

12.6.1.3 Output 3.1.3 Strengthened institutional and regulatory systems for climate responsive planning and development.

Activity 3.1.3.1 Mainstream climate change into regulations and planning instruments and define a financial sustainability strategy.

196. This activity will be executed by CAF with its own grant resources. This activity will be developed in three steps:

1) It will begin by strengthening legal instruments in Galapagos for mainstreaming climate change in policies and regulations related to tourism, agriculture, fisheries, and ecosystems. This task will involve conducting a diagnosis of legal tools, developing specific proposals for Galapagos stakeholders, and providing accompaniment and technical assistance to the legal teams of the relevant Galapagos institutions.

2)

The *Climate Action Plan* for Galapagos will be designed in alignment with the actions and lessons learned developed during the implementation of the present Programme. The stages of the design of this plan will include diagnosis, formulation, socialization, and gender-sensitive citizen participation. Having this plan will guarantee the anchoring of resources and state budget.

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3) In this sense, the Financial Sustainability Strategy for the Plan will be developed, which will include the design of financing mechanisms to make it operational and sustain its actions in the long term. A technical accompaniment is foreseen to put it into operation so that in year 3 it starts to be implemented and to collect funds and in year 5, when the Program comes to an end, the

Plan and the mechanism will be fully operational. Through this activity, discussions and working sessions with the Government will be encouraged to mobilize existing or new resources for climate action. It is important to bear in mind that pre-allocation of resources is not permitted in Ecuador under current legislation, and that current policy does not support the creation of a multiplicity of funds throughout the country, but rather promotes the centralization of the management of public funding. However, this Programme will seek the commitment at the central level (e.g., Ministry of Finance) to improve the conditions of financial sustainability of the resilient and low-carbon actions promoted in Galapagos. The technical assistance resources will be used to assess the potential use of the savings obtained with the project (i.e., fuel that will not be imported thanks to the renewable energy investments), to evaluate the channeling of incentives, tariffs, fees (i.e., potential raising of mandatory tourist entrance fees or optional contributions), concessions, opportunities for the carbon economy and the blue economy to design options, and to constantly feed the political-institutional hub that manages the financing mechanisms to influence the allocation of resources. The choice of financing mechanisms will seek to ensure that both private tourism entrepreneurs and tourists contribute financially/compensate or at least cover the subsidy they currently receive from the state. Please refer to section B.6 for further details.

12.7 Summary of activities, barriers, responsible agencies, and timeline

Table 52 below shows the correspondence between activities, subactivities, beneficiaries, type of barriers and specific barriers to adaptation/mitigation, financial mechanism by which each of the activities will be implemented under the Programme, the Executing Entity in charge, the main local stakeholders that will partner for the execution, and the place in the general timetable of the Programme.

Table 52. Summary of activities, barriers, responsible agencies, and timeline

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
Activity 1.1.1.1: Promotion of Centralized renewable energy generation	Installation of Conolophus Solar Photovoltaic Plant and associated storage system	-	Total Santa Cruz population and visitors. Company awarded in public tender	Financial	Lack of access to concessional sources of funding for centralized renewable energy	The Conolophus Centralized Power Generation Trust Agreement	CAF	Winner of the public tender	Year 1	Link
Activity 1.1.1.2. Distributed renewable power generation projects	Increase distributed energy generation by opening the Galapagos' Credit Line	1.1.1.2.a Renewable Energy promoted through the Galapagos' Credit Line	Mainly tourism sector: hotels, restaurants, and boat operators. Agriculture, fisheries, and residential sectors are also eligible.	Financial	Lack of accessible financing for investing in distributed renewable energy, energy efficiency.	1.1.2.a GRANT 1.1.2.b GRANT 1.1.2.c Galapagos' Credit Line	CFN	MinTur CGREG MAATE/Punto Verde	Years 2 to 5	Link
Activity 1.2.1.1 Efficient energy consumption of the Galapagos' livelihoods	Optimize the electrical energy consumption in the acclimatization and refrigeration areas	-				Galapagos' Credit Line	CFN	MinTur PDG/MAG MAATE/Punto Verde	Years 2 to 5	Link
Activity 1.2.2.1: Technical Assistance facility for energy investments	Facilitate the implementation of the Programme by increasing knowledge on climate change and low carbon energy investment projects	1.2.2.1a Fostering an enabling environment for the development of mitigation projects. 1.2.2.1b Technical Assistance for Local Banks 1.2.2.1c Technical Assistance for Final Beneficiaries	Financial institutions providing credit under the program. Technology and technical assistance providers. Stakeholders in the tourism, agriculture, and artisanal fisheries sectors.	Knowledge	Lack of knowledge for the development of mitigation projects, and to comply with the ESMS and MRV requirements.	GRANT	CAF	CFN/Local Banks	Years 1 to 5	Link
Activity 2.1.1.1. Implement a capacity building program for government technical staff for dissemination of practical information, knowledge and training about climate change and climate resilient agricultural practices	Strengthen key local governmental agencies with technical knowledge	2.1.1.1a Develop a training programme of 4 modules for governmental staff. 2.1.1.1b Develop a framework to include climate change in the extension and rural advisory services for farmers	Local governmental agencies, farmers, and producers' organizations, INIAP	Knowledge and institutional capacity	Weak institutional and technical capacities to address climate change in the Galapagos food system.	GRANT	FAO	Provincial Directorate of Galapagos of the Ministry of Agriculture and Livestock (PDG/MAG)	Years 1 to 5	Link
Activity 2.1.1.2. Install a hydro/agro-meteorological monitoring system to inform and tailor the information to the needs of vulnerable smallholder farmers	Collect relevant agro-hydrometeorological and climatic data and Process and distribute, on-time, climate change information to relevant users	2.1.1.2a Acquisition, placement, and implementation of sensors capable of measuring climate, water, and agriculture variables. 2.1.1.2b Develop an information system capable of collecting information, processing and perform data quality/data control activities. 2.1.1.2c Train technical staff for implementation of sensors and management of the information system.				GRANT	FAO	Galapagos Science Center in coordination with the National Institute of Meteorology and Hydrology (INAMHI).	Years 1 to 5	Link
Activity 2.1.2.1. Develop a physical and knowledge network for conservation and use of phytogenic resources through in-situ and ex-situ conservation activities	Improve timely access to quality seeds in sufficient quantity	2.1.2.1a Implement in-farms conservation activities: collect, conserve, use and distribute the agro-biodiversity existing in Galapagos (community-based seed bank), with special focus on the variety of crops resistant to biotic changes caused by climate change. 2.1.2.1b Improvement of existing infrastructure at INIAP, which will work as agrobiodiversity repository, knowledge center and distribution facility, for long-term conservation.	Farmers, public institutions	Financial and Knowledge	Vulnerable farmers lack knowledge and access to low-carbon, climate resilient agriculture approaches and technological packages. Farming lands abandonment, becoming contagious and dispersion sources of invasive species towards natural areas.	GRANT for Technical Assistance On farm investments: Galapagos' Credit Line	FAO	Extension services from the National Institute of Agricultural Research (INIAP)	Years 2 to 4	Link
Activity 2.1.2.2. Implement an integrated climate resilient crop management system at farm level	Strengthen crops through the enhance energy efficiency, minimize pest pressure, and maintain soil fertility, creating greater tolerance to droughts, floods and the attacks of pests driven by climate change	2.1.2.1a Implement soil management practices in farms. 2.1.2.1b Establish crop and pest management practices, including a growing climate resilient seed.	Farmers	Financial and Knowledge		GRANT for Technical Assistance On farm investments: Galapagos' Credit Line	FAO	PDG/MAG	Years 1 to 4	Link

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
Activity 2.1.2.3. Implement silvopastoral practices at the farm level	Implement a silvopastoral system in Galapagos for cattle ranching to improve production efficiency and to integrate the management of the invasive species Psidium guajava (guava) and endemic/native species as associated arboreal species	2.1.2.3a Farmers training to implement silvopastoral systems (guava-grass-breeding association) 2.1.2.3b Implement of fodder banks in farms. 2.1.2.3c Implement internal division of paddocks to apply rotational grazing through regularly moving livestock between paddocks. 2.1.2.3d Implements a manure management through biodigester.	Farmers	Financial and Knowledge		GRANT for Technical Assistance On farm investments: Galapagos' Credit Line	FAO	PDG/MAG	Years 1 to 4	Link
Activity 2.1.2.4. Develop and implement water collection and water management systems for climate-resilient food production.	Improve the water collection and distribution system for the agricultural sector	2.1.2.4a Install water sources and storage. 2.1.2.4b Install water distribution system. 2.1.2.4c Install climate smart irrigation systems	Farmers, public institutions	Financial and Knowledge	Limited knowledge and access to technological solutions to collect and store water during the rainy season for use during the dry season	GRANT for Technical Assistance On farm investments: Galapagos' Credit Line	FAO	PDG/MAG	Years 1 to 4	Link
Activity 2.1.3.1 Improve the design and management effectiveness of Galapagos marine zoning, based on conclusive scientific evidence on the impact of climate change on fishery resources, marine biodiversity, and fishers' livelihoods.	Recommendations to improve the design and management effectiveness of Galapagos marine zoning, to reconcile conservation and fishery management objectives, and effective implementation of the Consultative Board of Participatory Management (CBPM).	2.1.3.1a Assess the effectiveness of former Galapagos marine zoning to protect HEVAS, key target fishing resources and ecosystem processes. 2.1.3.1b Identify HEVAs particularly vulnerable to climate risks and select the most suitable areas to ensure commercial stocks recovery, based on climate change risk assessment. 2.1.3.1c Estimate the cost and potential benefits associated with the implementation of the new Galapagos marine zoning options. 2.1.3.1d Engage stakeholders and facilitate a negotiation process through innovative, extensive, and participatory consultation in the CCPM, to promote their formal endorsement of a new marine zoning.	Fisheries, public institutions	Knowledge, institutional capacity	Lack of evidence-based management regulations for overexploited fisheries. Key marine ecosystems with projected exacerbated degradation processes currently outside no take zones. Weak monitoring capacities on the impact of climate change on fishery resources, marine biodiversity and fisheries' livelihoods Lack of integration of subtidal monitoring information into decision-making by key stakeholders Low quality information on CC impacts on ecosystems and lack of monitoring systems to assess impacts of adaptation action	GRANT	WWF	CGREG GNPD Consultative Board of Participatory Management (CBPM)	Years 1 to 4	Link
Activity 2.1.3.2 Design and implement an advanced data system for the adaptive co-management of the Galapagos marine zoning	Finance a new system that will reduce costs, facilitate adaptive and responsive decision-making procedures, to improve marine zoning management efficiency, and train decision makers on trained to facilitate the integration of the information generated by the Subtidal Ecological Monitoring module into GMR management decisions	2.1.3.2a Design and implement an advanced data monitoring and information system for the Galapagos subtidal ecological monitoring program, including the development of sensitive adaptation SMART indicators. 2.1.3.2b Strengthen capacities of key stakeholders to integrate the information generated by the advanced data information system into GMR management decisions.				GRANT	WWF	GNPD NGOs	Years 2 to 4	Link
Activity 2.1.3.3 Structured decision-making framework to inform the adaptive co-management of the Galápagos Marine Reserve.	Facilitate the integration of the structured decision-making framework into GNPD decision-making process and existing monitoring programs and link them to the Fondo para la Reserva Marina de Galápagos (FRMG) for long term implementation.	2.1.3.3 a Train decision makers and other relevant stakeholders to facilitate the integration of the structured decision-making framework into the GNPD decision-making process. 2.1.3.3.b Link the structured decision-making framework and monitoring programs to the Fondo para la Reserva Marina de Galápagos (FRMG).				GRANT	WWF	GNPD local management authorities, scientists, NGOs	Years 1 to 4	Link
Activity 2.1.4.1 Management conditions of small-scale tuna fisheries, strengthened to reduce the ecological impact of the fishery over secondary and endangered, threatened and protected (ETP) species	Improve the sustainability and governance of the Galapagos tuna fishery	2.1.4.1a Design and implement an electronic monitoring and blockchain traceability system. 2.1.2.4b Promote the adoption of a code of good fishing practices and handling techniques, based on the assessed impact of ghost fishing and illegal fishing aggregating devices (FADs) on vulnerable marine ecosystems. 2.1.2.4c Carry out research priorities to improve the management and sustainability of the Galapagos tuna fishery	Fisheries, public institutions	Knowledge, institutional capacity, financial resources	Lack of evidence-based management regulations for overexploited fisheries and climate change impacts. Lack of traceability systems for key fisheries species Lack of knowledge and financial resources for the sustainable management of the fishery resources.	GRANT	WWF	GNPD	Years 1 to 5	Link

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
Activity 2.1.4.2 Management of sailfin groupers fishery strengthened to mitigate climate change impacts while restoring the species ecological role	Rebuild sailfin groupers stocks and restore their ecological role into Galapagos marine ecosystem	2.1.4.2a Assess current sailfin groupers population status, including projections under climate change conditions and fishing regulations. 2.1.4.2b Elaborate and adopt a climate smart community-based fishery improvement project (C-FIP) for the sailfin grouper.				GRANT	WWF	GNPD, Galapagos Governing Council, small-scale fishing sector, private sector	Years 2 to 4	Link
Activity 2.1.4.3 Small-scale aquaculture and experimental allocation of Territorial Use Rights for Fishing (TURFs) implemented to rebuild sea cucumber stocks and diversify fishers' livelihoods	Rebuild sea cucumber stocks, to provide an alternative source of income to the small-scale fishing sector and promote the adoption of a rights-based co-management approach.	2.1.4.3a Update stock assessment of I. fuscus, including projections under climate change conditions and fishing regulations. 2.1.4.3b Reproduce in captivity and release a substantial number of sea cucumbers into the remaining wild stock, to significantly accelerate rebuilding. 2.1.4.3c Experimental allocation and evaluation of TURF to regulate harvesting and fishing intensity of I. fuscus.				GRANT	WWF	GNPD CGREG	Years 1 to 4	Link
Activity 2.1.5.1 Implement strategies to improve the livestock/meat and milk value chain	Improve the dairy and meat products positioning in the local market and increase their profitability	2.1.5.1a Strengthening livestock production systems with environmentally friendly practices that are adapted to the context of Galapagos and help breach the productive gap in farms in terms of quantity and quality. 2.1.5.1b Strengthening adequate livestock slaughter and meat processing systems. 2.1.5.1c Strengthening of dairy processing plants. 2.1.5.1d Positioning of the local market. 2.1.5.1e Implementing a program to strengthen local capacities.	Agriculture, tourism, public institutions	Knowledge, institutional capacity, financial resources	Weak institutional and technical capacity to address climate change in the Galapagos food system. Limited links between farmers and fishers with the Galapagos tourism value chain By-products from fishing activity are not incorporated into the value chain. Lack of climate smart infrastructure to guarantee the quality of products needed to reach the markets. Willingness to pay for sustainable Galapagos food products is not reflected in the value chains	GRANT for Technical Assistance Investments: Galapagos' Credit Line	FAO (Technical assistance) CFN (Galapagos' Credit Line)	PDG/MAG	Years 1 to 5	Link
Activity 2.1.5.2 Implement strategies to improve the Galapagos coffee value chain	Promote the local coffee market by covering the surface of Galapagos agroforestry systems with quality coffee plants	2.1.5.2a Strengthen knowledge on post-harvest strategies. 2.1.5.2b Mobilizing production to the local coffee agro-processing center. 2.1.5.2c Construction of a wet processing center 2.1.5.2d Construction of a dry processing center				GRANT for Technical Assistance Investments: Galapagos' Credit Line	FAO (Technical assistance) CFN (Galapagos' Credit Line)	PDG/MAG	Years 1 to 5	Link
Activity 2.1.5.3 Implement strategies to improve the Galapagos vegetables value chain	The development of micro-enterprises that add value to potential agricultural products from integrated production systems	2.1.5.3a Implement agro-processing system of Banana, Plantain and Cassava flours and chips. 2.1.5.3b Implement agro-processing system of preserves and pulps of citrus fruits, pineapple, and tomato. 2.1.5.3c Implement agro-processing system of aromatic and medicinal herbs				GRANT for Technical Assistance Investments: Galapagos' Credit Line	FAO (Technical assistance) CFN (Galapagos' Credit Line)	PDG/MAG	Years 1 to 5	Link
Activity 2.1.5.4 Promotion of a blue circular economy through new sustainable and socially responsible seafood enterprises	Create the "Galapagos Virtual Innovation Lab" to support small-scale fishers, entrepreneurs, and other actors of the local community interested in enterprise development	2.1.5.4a Design and develop a G-Lab platform to provide analytical services, capacity building, knowledge sharing and facilitation services to fishers and entrepreneurs to make their seafood enterprises investment-ready. 2.1.5.4b Conduct a market and behavioral science analysis. 2.1.5.4c Provide technical assistance to local fishers and entrepreneurs, to comply with all technical, legal, organizational and administrative requirements for the creation or consolidation of new seafood enterprises. 2.1.5.4d Train fishers and entrepreneurs on tuna grading and production of seafood value added products.	Fisheries, tourism, public institutions	Knowledge, institutional capacity, financial resources	Weak institutional and technical capacity to address climate change in the Galapagos food system. Limited links between farmers and fishers with the Galapagos tourism value chain By-products from fishing activity are not incorporated into the value chain. Lack of climate smart infrastructure to guarantee the quality of products needed to reach the markets. Willingness to pay for sustainable Galapagos food products is not reflected in the value chains	GRANT for Technical Assistance Investments: Galapagos' Credit Line	WWF (Technical assistance) CFN (Galapagos' Credit Line)	GNPD MAATE/Punto Verde	Years 2 to 4	Link
Activity 2.1.5.5 Put in place a long-term financing mechanism to improve sustainability and competitiveness of Galapagos small-scale fishing sector	Soft credit line for entrepreneurs, to foster the financial inclusion of fishers and entrepreneurs from civil society interested in adopting sustainable fishing practices	2.1.5.5a Design, establishment, and administration of a soft credit line for entrepreneurs interested in adopting sustainable fishing practices. 2.1.5.5b Allocate soft loans to those entrepreneurs who submit the most attractive,				GRANT for Technical Assistance	WWF (Technical assistance)	GNPD MAATE/Punto Verde	Years 2 to 4	Link

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
		innovative business plans and with the greatest probability of generating a positive social and environmental impact.				Investments: Galapagos' Credit Line	CFN (Galapagos' Credit Line)			
Activity 2.2.1.1 Strengthen marine biosecurity programs in the GMR, to prevent and control marine bioinvasions by Nonindigenous Species (NIS) that could proliferate due to the effects of climate change	Protect, empower, and strengthen the Galapagos biosecurity program, and the public and research institutions involved, to prevent and reduce the expected impacts of marine invasive species related to climate change scenarios	2.2.1.1a Conduct one regional bioinvasion assessment for each MPA in the ETP region (Galapagos, Cocos, Malpelo, Gorgona, Coiba), considering climate change scenarios. 2.2.1.1b Develop and implement an Alert System for incursions of NIS in the GMR. 2.2.1.1c Adoption and implementation of improved marine biosecurity and Early Detection and Response (EDRP) protocols, by the DPNG and ABG. 2.2.1.1d Implement a regional outreach campaign to showcase and promote the replica of the GMR NIS Alert System and EDRP, in other ETP region MPAs.	Marine ecosystems and dependent livelihoods (Fisheries, tourism)	Knowledge, institutional capacity, financial resources	Lack of innovative approaches to control and eradicate invasive species	GRANT	WWF	ABG GNPD	Years 2 to 4	Link
Activity 2.2.1.2 Restore high ecological value coral reefs through coral planting and exclusion areas, to enhance their ecological role in the GM	Restore coral reef ecosystems and strengthen the controls of bioerosion and coral bleaching in critical High-Ecological Value areas (HEVAS) of the GMR.	2.2.1.2a Produce one update assessment of the abundance and distribution of coral reefs and their associated biodiversity in the GMR considering current and future climate scenarios. 2.2.1.2b Transplant corals from the nursery developed in collaboration with the GNPD, to at least 1 degraded site in each island (Darwin, Wolf and Floreana) 2.2.1.2c Design and implement a removal program for sea urchins to assess vulnerability by conducting experiments. 2.2.1.2d Mainstream the participation of the tourism sector in conservation and restoration programs carried out by the DPNG, in key touristic coral reef sites.	Marine ecosystems and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Ongoing coral reef conservation practices do not incorporate active restoration approaches.	GRANT	WWF	GNPD	Years 2 to 5	Link
Activity 2.2.1.3 Reduce the impact of diving, anchoring and pollution related to tourism operations in selected marine HEVAs, to enhance eco systems resilience and adaptive capacity to the effects of climate change	Reduce the environmental impacts associated with marine tourism (diving, anchoring and pollution associated with tourism activities	2.2.1.3a Design and implement a conservation categorization system and management protocols for diving visitor sites. 2.2.1.3b Development and adoption of the Diving Tourism Best Practices Toolkit co-created with dive tourism stakeholders. 2.2.1.3c Reinforce the control and monitoring of pollution levels from boats. 2.2.1.3d Develop a Decision Support System (DSS) portal for policymakers, with information regarding marine tourism, including impacts from the tourism activities and the health of sites. 2.2.1.3e Implement agreements with tourism stakeholders for replacing anchoring procedures and technologies with fixed-mooring buoys signaling and the Digital Positioning Systems (DPS).	Marine ecosystems and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Business as usual tourism operations lack best practices to reduce their impacts on CC highly sensitive marine ecosystems.	GRANT for Technical Assistance Investments: Galapagos' Credit Line	WWF (Technical assistance) CFN (Galapagos' Credit Line)	GNPD MAATE/Punto Verde	Years 2 to 4	Link
Activity 2.2.1.4 Improve surveillance and control measures for adequate sea turtle nesting and foraging in the GMR, to counteract potential effects of climate change in their reproductive success	Apply mitigation strategies to alleviate climate change impacts on the population of green turtles in Galapagos, by protecting their nests from direct impacts of climate change and reducing other threats of anthropogenic origin that increase the vulnerability of the population	2.2.1.4a Translocation of nests from current flooding areas to safer zones. 2.2.1.4bDesign and implement marine traffic regulations to avoid boat strikes at nesting and foraging sites. 2.2.1.4c Monitoring the impact of climate change on Galapagos Sea turtles and the effectiveness of adaptation measurements applied	Marine ecosystems and dependent livelihoods (Fisheries, tourism)	Financial and knowledge	Current marine turtle management measures do not consider the impacts of climate change on the species	GRANT	WWF	GNPD	Years 2 to 4	Link
Activity 2.2.2.1 Strengthen control programs for invasive plant species, especially blackberry, in protected and agricultural areas, based on projected dynamics of their	Contain the spread of invasive plant species in high ecological value forest fragments in the GNP and on selected farms in the agricultural zone.	2.2.2.1a Strengthen control programs for invasive plant species in an area of 750 ha within the Galapagos National Park, with emphasis on guava and blackberry.	Terrestrial ecosystems and dependent livelihoods (Agriculture, tourism)	Financial and knowledge	Farming lands abandonment, becoming contagious and dispersion sources of invasive species towards natural areas.	GRANT	FAO	PDG/MAG GNPD	Years 1 to 5	Link

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
expansion under climate change scenarios		2.2.2.1b Implement invasive species management and control measures on farms in an area of 750 ha in the agricultural area.			Lack of climate change approaches to restore native forests and control and eradicate invasive species. Low quality information on CC impacts on ecosystems and lack of monitoring systems to assess impacts of adaptation action					
Activity 2.2.2.2 Restore key remnant forest fragments inside and outside the GNP, to enhance ecosystems adaptive capacity and provision of environmental services	Restore and conserve key remnant forest fragments on farms and in GNP areas and raise awareness of the importance of ecosystem services.	2.2.2.2a Restore key remnant forest fragments in an area of 750 ha within the Galapagos National Park. 2.2.2.2b Conserve and restore key remnant forest fragments on farms in an area of 750 ha in the agricultural area. 2.2.2.2c Outreach activities and workshops with local community on importance of ecosystem services and how they benefit livelihoods.				GRANT	FAO - WWF	PDG/MAG GNPD	Years 2 to 5	Link
Activity 2.2.2.3 Monitor success and impacts of invasive species control and restoration measures.	Inform and improve the management of terrestrial invasive species and restoration actions in the highlands of Isabela,	2.2.2.3a Assess ongoing efforts and restoration needs, including evaluating current control techniques for invasive plant species. 2.2.2.3b Establish baselines for plant and animal species in areas under restoration, with a focus on rare species. 2.2.2.3c Monitor changes in plant communities in areas under restoration. 2.2.2.4d Evaluate the impact of restoration by estimating the stored carbon and CO2 sequestration rates of the ecosystems under restoration.				GRANT	FAO - WWF	PDG/MAG GNPD INIAP	Years 2 to 4	Link
Activity 3.1.1.1 Implement an ecotourism certification scheme to adopt best practices across the tourism value chain	Design and implement an ecotourism certification scheme.	3.1.1.1a Design and establish a local certification scheme administered through a public-private partnership. 3.1.1.1b Identify and train local auditors on concepts, standards, and procedures of the ecotourism certification. 3.1.1.1c Information and capacity building of tourism business, on the concepts, standards, and procedures to obtain the ecotourism certification. 3.1.1.1d Design a certification plan for each tourism business from a first set (pilots) of business, inscribed to work towards the certification. 3.1.1.1e Provide technical assistance to pilot business for the compliance of the certification standards. 3.1.1.1f Assist the implementation of audits of compliance to the first set (pilots) of business inscribed to receive the certification.	Tourism sector, public institutions	Financial, knowledge and institutional capacity	Lack of financing lines with special conditions to access both the certification scheme and its implementation, which stopped many operators in the sector from accessing certifications in the past. Lack of efficient management model and marketing strategies to ensure the sustainability of certification schemes. Lack of financial instruments to scale-up the adoption of low-carbon and climate-resilient practices.	GRANT	WWF	MAATE/Punto Verde MINTUR	Years 2 to 4	Link
Activity 3.1.2.1 Strengthen the educational system to provide quality education to face climate change and promote sustainable development	Integrate a comprehensive educational approach to climate change within the formal educational system of Galapagos (basic education, high-school, and third-level education), that includes innovative and pertinent education models, approaches, methodologies, and tools.	3.1.2.1a Establish a Board of Education for Climate Change, to articulate the efforts carried out in Galapagos by different institutions and organizations. 3.1.2.1b Integrate quality climate change education into the existing professional development program of Mineduc in Galapagos for education leaders and teachers. 3.1.2.1c Implement climate friendly practices in schools to promote an eco-friendly culture and strengthen environmental awareness. 3.1.2.1d Implement experiential learning programs for students of basic education and high school, connecting to mitigation and adaptation initiatives promoted by the program. 3.1.2.1e Design and implement a technical education program for youth, to address the labor markets local demand in areas related to	Local educational community	Knowledge and institutional capacity	Efforts to integrate climate change education into the existing programs are not articulated. There is no mechanism by which the information on mitigation and adaptation initiatives promoted by the Programme could reach the local educational community. Education programmes are not prepared for addressing the local demand of Galapagos livelihoods in the face of climate change and post-COVID-19 context.	GRANT	WWF	CGREG MINTUR	Years 1 to 4	Link

Activity	Description	Sub-activities	Beneficiaries	Barrier type	Barrier	Financial mechanism	Executing Entity	Main stakeholders for the execution	When	Eligibility criteria
		Galapagos tourism, agriculture and fisheries value chain, within a climate change and post-covid context.								
Activity 3.1.2.2 Strengthen knowledge and foster engagement of public and key stakeholders on climate change impacts and solutions.	Facilitate information, practical knowledge, tools and outreach opportunities, to encourage local community interest, support and active involvement in addressing climate change.	3.1.2.2a Develop a knowledge management and outreach digital platform that makes updated and relevant information, knowledge, lessons, and resources regarding climate change in the Galapagos, understandable and accessible to the public and key stakeholders. 3.1.2.2b Develop and implement a communication strategy based on innovative approaches and methods, to strengthen knowledge and foster commitment for the adoption of climate change mitigation and adaptation measures. 3.1.2.2c Develop a behavioral change campaign aimed at consumers of the food system in Galapagos, focusing on those behaviors that can be effectively addressed by communications interventions.	Local educational community	Knowledge and institutional capacity	Efforts to integrate climate change education into the existing programs are not articulated. There is no mechanism by which the information on mitigation and adaptation initiatives promoted by the Programme could reach the local educational community. Education programmes are not prepared for addressing the local demand of Galapagos livelihoods in the face of climate change and post-COVID-19 context.	GRANT	WWF	GNPD CGREG MINTUR	Years 2 to 4	Link
Activity 3.1.2.3 Facilitate non-formal education and mobilization opportunities to encourage youth and local community empowerment on climate action.	Implement action-based, non-formal educational and outreach experiences to foster youth and community empowerment, engagement and leadership on climate action, by providing them with practical knowledge, tools and skills, and most importantly, the opportunity and agency to translate those into climate action.	3.1.2.3a Develop a capacity building program for non-formal facilitators (government officials, NGOs, community leaders) to increase their understanding and practical application of climate change approach into communication, community outreach and non-formal education interventions. Sub activity 3.1.2.3b Develop immersive field-based and non-formal educational experiences for different audiences, to connect the local community with the natural environment and climate change mitigation and adaptation initiatives. Sub activity 3.1.2.3c Create a permanent working platform that brings together existing organized groups and citizens towards collective climate action, through capacity building and the implementation of pilot youth and community-based projects.	Local educational community	Knowledge and institutional capacity	Efforts to integrate climate change education into the existing programs are not articulated. There is no mechanism by which the information on mitigation and adaptation initiatives promoted by the Programme could reach the local educational community. Education programmes are not prepared for addressing the local demand of Galapagos livelihoods in the face of climate change and post-COVID-19 context.	GRANT	WWF	GNPD CGREG MINTUR	Years 1 to 5	Link
Activity 3.1.3.1 Mainstream climate change into regulations and planning and define a financial sustainability strategy.	Strengthen legal instruments, design Climate Action Plan for Galapagos and develop sustainability strategy.	-	Local governmental institutions	Knowledge and institutional capacity	Regulatory frameworks do not address ecosystem degradation and biodiversity loss. Lack of evidence-based management regulations for overexploited fisheries.	GRANT	CAF	CGREG GNPD MINTUR INAMHI PDG/MAG INIAP	Years 1 to 4	Link

13. The Galapagos' Climate Facility

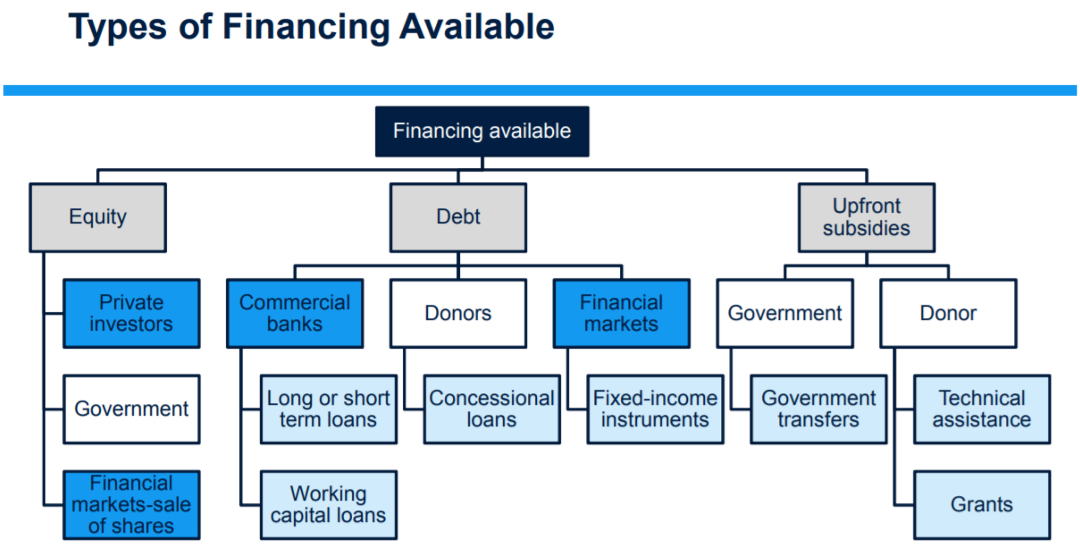
The development of Galapagos' Climate Facility to support investments in renewable energies and energy efficiency as well as in adaptation measures via national development bank, local financial institutions and private investments is an attempt to promote green and circular economy in Galapagos.

With the growing emphasis on mobilizing private capital to accelerate development progress, blended concessional finance (BF) has moved beyond its niche position to become a significant tool for development finance and mobilization. By combining concessional finance from donors or third parties with a National Development Bank normal own-account finance and commercial finance from other Local Financial Institutions, NDBs and LFIs are aiming to mobilize and catalyze private resources, develop private sector markets and in the process advance progress on the Sustainable Development Goals (SDGs)[23].

For this reason, it is important to determine when it is understood that public financing is made under one or other conditions, concessional or not, in order to qualify what is and what is not concessionality. Currently the definition accepted for concessionality is the one offered by the OECD[24] Development Assistance Committee (DAC). It defines the level of concessionality as the measure of "softness" of a loan, that is, the difference that exists between the conditions offered by the market and the conditions offered by the concessional loan. Concessional credits are, then, those that offer advantages or benefits for the borrower –the one requesting the loan– when compared to loans granted under market conditions. A loan or money transfer is understood to be concessional when it includes at least a 25% donation or gratuity element. Consequently, all those financial transfers of public origin that are granted with equal or greater levels of concessionality, are considered within ODA. Any other forms of financing development, no matter how positive they may be for the recipient country, must be differentiated from those properly considered as ODA.

Taking into account the different types of financing available as shown in Figure 55, the previous context for determining concessionality for the proposal, CAF understands to what extent Galapagos' Climate Facility with the GCF's financing is advantageous compared to the rest of a bank's refinancing options. For this reason, the 4.1 Appendix - Market Study of the Ecuadorian Financial System (see Appendix 4.) was carried out.

Figure 55. Map of the Galapagos Islands with inset showing location of the archipelago relative to continental



23 THE WHY AND HOW OF BLENDED FINANCE https://www.ifc.org/wps/wcm/connect/768bcbe9-f8e9-4d61-a179-54e5cc315424/202011-New-IFC-Discussion-Paper.pdf?MOD=AJPERES&CVID=no0db6M

24 CONCESSIONALITY LEVEL - OECD https://stats.oecd.org/glossary/detail.asp?ID=408

During the Funding Proposal structuring, it was confirmed what the I4CE 2017 study presented both economic and financial barriers. In the Economic barriers were identified low risk-adjusted returns for green investments due to weak, unstable, or absent climate and environmental policy, fossil fuel subsidies and in the financial barriers there were high real and perceived risks, large upfront investment needs, high cost of capital for low-carbon investments compared to returns.

In the Market Study of the Ecuadorian Financial System study, for instance, regarding the interest rates for consumption loans, the average interests given by "Banco Pacifico" is 17,05%, while for "Banco Pichincha" is 16,84%.

And for Energy projects, the following summarizes the indicative terms and conditions of the financing strategy for the Base Case:

Funding Indicative Terms	Public Development Banks
Loan period	15 years
Grace period	25 months
Frequency of interest and principal payments	Biannual
Base variable rate	Libor 6M
Margin over base rate	6,50%

The financial premises selected do not necessarily correspond to a midpoint of the range of data obtained in the market reading. These premises were established considering the level to which most of the institutions consulted approached. It is crucial to mention that this feasibility does not consider advantageous conditions in the event that GCF provides a loan.

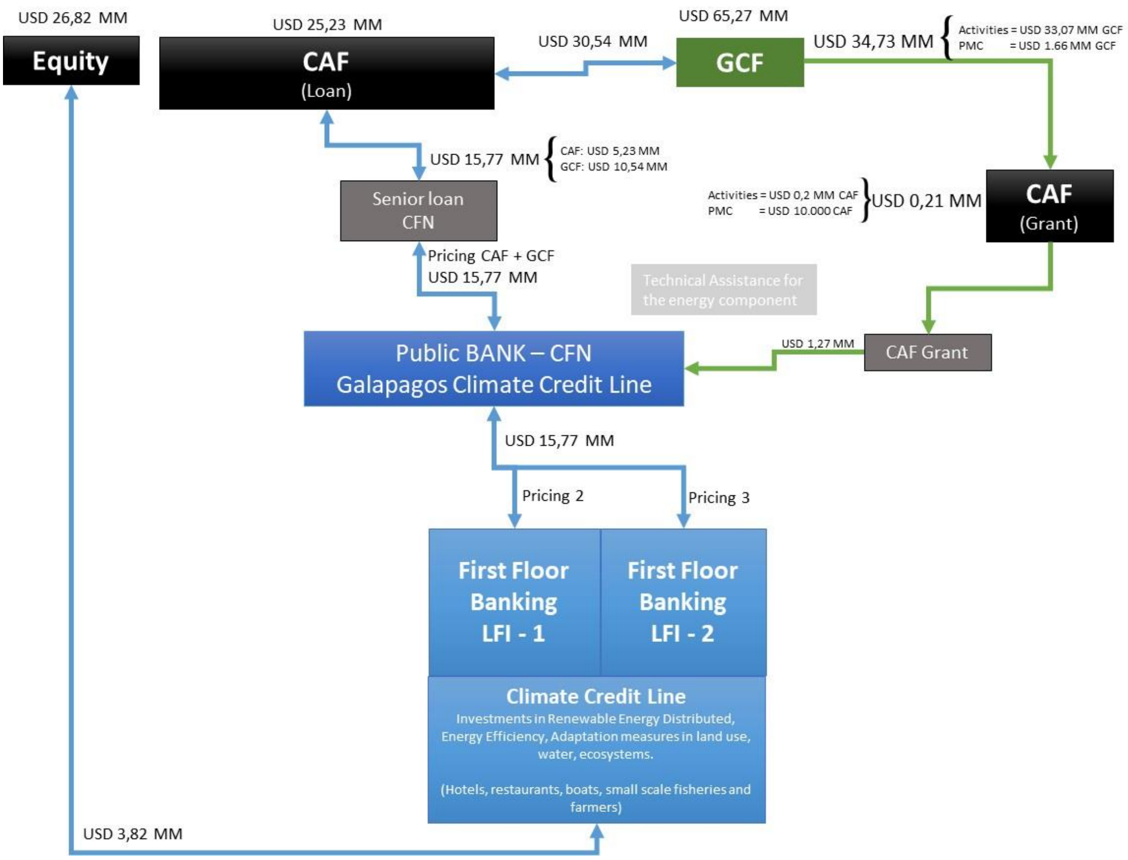
Taking into account the previous, after formulating the necessity of subsidies for the end borrower, the financial instrument (credit line or Trust Fund) should attempt to avoid windfall gains for the local banks. In practice, this will be done by capping the margin banks are allowed to charge on top of the initial costs of the credit line allowing to stay within the already margin used. In the end, it is the margin that matters to the banks, not the costs of the Climate Credit Line provided.

To achieve the preceding, for the Funding Proposal it was important to establish the right balance between incentivizing CFN (rewarding it for its effort to push for green projects) and passing on subsidies to the end-borrowers (if needed) proves to be inherently difficult which was obtained in the financial model given a grant of USD 1 MM.

13.1 The Galapagos' Climate Credit Line

In order to boost investments in decentralized renewable energies, energy efficiency technologies and adaption measures, a Climate Credit Line will be implemented in a five-year financing programme in Galapagos. The main objective of this intervention is to expand the loan portfolio for adaptation and mitigation investments in the fishery, agricultural and tourism sector strengthening their capacities in climate action measures. To this end, CAF-GCF will provide funding via CFN in a 15-year of 16,5 million US dollar credit line. Additionally, technical assistance will be provided, as mentioned in components 2 and 3, to enhance the expertise of the different sectors and facilitate knowledge transfer in the field of climate action measures.

Figure 56. Galapagos' Climate Credit Line Resources Flow



As mentioned in the preceding description of activities, several of the Programme's investments will be implemented through the Galapagos' Credit Line channeled through CFN and local banks in Galapagos. The activities that include investments through this facility are the following:

Table 53. Activities promoting investments through the Galapagos' Climate Credit Line

Activity	Eligible investments
Activity 1.1.1.2 Renewable Energy promoted through the Galapagos' Credit Line.	Small scale solar PV systems
Activity 1.2.1.1 Efficient energy consumption of the Galapagos' livelihoods	High-efficiency air conditioners and refrigerators
Activities under Output 2.1.2Climate-resilient water and agricultural food productions systems implemented.	Silvopastoral systems Water storage, distribution, use Machinery, equipment, working capital (seed fund, seed capital to start the process
Activities under Output 2.1.5. Upgraded and more efficient value chains for climate-smart seafood and agriculture products, potentiated with links to new markets.	
Activity 2.1.5.5 Put in place a long-term financing mechanism to improve the sustainability and competitiveness of the Galapagos small-scale fishing sector.	Business plans and with the greatest probability of generating a positive social and environmental impact
Activity 2.2.1.3 Reduce the impact of diving, anchoring, and pollution related to tourism operations in selected marine HEVAs, to enhance eco systems resilience and adaptive capacity to the effects of climate change.	Digital Positioning Systems (DPS

The conditions of the credit line are listed in the following table.

Table 54. Galapagos' Climate Credit Line Characteristics

Characteristics	Description
Objective Climate Credit Line	To provide a **Climate Credit Line** with adequate financial terms and conditions available to beneficiaries and local businesses from Galapagos in order to finance local distributed renewable energy, energy efficiency,

	Dynamic Positioning Systems (DPS), fisheries activities and land use climate change adaptation and mitigation activities. Loans will be made available to beneficiaries and local businesses to improve or grow their businesses
Resources	The refundable resources available for the **Climate Credit Line** totalize US$16.033.065.98, which include a financial contribution of 70% from GCF and 30% from CAF.
Implementation Period	The implementation period of the Programme is 20 years from the effective date of the FAA. For the case of this, it will be developed in the following manner: ● Period for allocating resources: 5 years. ● Period for recovering resources: 15 years.
Beneficiaries	End beneficiaries of the Programme include beneficiaries and local businesses from specific economic sectors. In order to access the Programme, beneficiaries and local businesses will demonstrate their registration and documentation to prove the fulfillment with eligibility criteria, including the economic sector. beneficiaries and local businesses must be of the following sectors: ● Agroindustry ● Fisheries ● Hotels ● Restaurants ● Tour Operator offices ● Food processing and beverage industry ● Educational and sport centers ● General commerce facilities ● Office, residential and private buildings For further details about the sectors please refer to the Feasibility Study. This credit line will provide specific support to the beneficiaries and local businesses that are headed by women, in alignment to the Gender Action Plan.
Participating Institutions	Local Financial Institutions (LFIs) that have a credit line with CFN, and that comply with the eligibility requirements stipulated by the Programme.
Disbursement Modality	Disbursements will be granted under the credit lines to finance sub-loans granted to Final Beneficiaries. Only sub-loans that have been granted after the FAA enters into force could be recognized. Through this modality, CFN cannot request funds from CAF to recover funds already used in their portfolio. The sub-loans to final beneficiaries will be in US Dollars. Ecuador is a dollarized economy.
Disbursement Operation	CAF will provide funds to CFN, assuring that there is a balanced distribution of the use of the Programme's resources. Then each LFI disbursement request will be funded 30% with CAF's own resources and 70% with GCF resources, with their respective interest rates.
Currency of Disbursements	Disbursements will only be granted in US dollars.
Payments and Amortizations	In general, the method of payment of CFN to CAF, shall be preferably in equal capital quotas, plus interests, with a semiannual periodicity. The method of payment of the final beneficiary to the intermediary will be established in accordance with CFN and the LFI's policies.
Guarantee	CAF requires a Sovereign Guarantee of Ecuador's Government.
Terms of sub loans and grace period for the LFIs	The terms of the sub loans and grace period granted by CFN to the LFIs must be similar to the terms of the loans and grace period granted by CAF to CFN of GCF's and CAF's Proceeds. The terms of the subloans and the grace period granted to the LFIs cannot be contrary to CFN's policies. However, CFN as well as the LFIs neither of them can increase the spread that they normally use.

Interest Rate for CFN	The minimum interest rate applicable to the CFN is determined by CAF's Finance Vice-Presidency and approved by CFN´s President in view of Ecuador ratings and the contracted aspects agreed with GCF and pursuant to CAF's current regulations. CAF's rate depends directly on the Libor+6months plus the rate CAF has established for Ecuador. Therefore, the rate is floating and has to be reviewed every 6 months.
Interest Rate for the LFI	The minimum interest rate applicable to the LFI is determined by CFN's Finance Vice-Presidency and approved by CFN´s President in view of Ecuador ratings, market conditions. Rate is revisable when he rate of the loan from CAF to CFN are reviewed (see previous point).
Prepayment	LFIs can voluntarily prepay the pending capital amount, either in full or partially, at any moment before the end of the term. This prepayment will be subject to CAF's Policy and in agreement to provisions established in the signed FAA.

13.2 The Conolophus Centralized Power Generation Trust

For the structuring of the loan CAF proposes to use Project financing relying primarily on the project's cash flow for repayment.

13.2.1. Settlor Selection

The private company that wishes to become the settlor of the trust fund needs to enter a public RE tender process. Currently, the Ecuadorian government is executing three tendering procedures for RE plants in Ecuador's mainland (Latam Strategic Energy, 2019). Two of them are Eolic, "Villonacos II" and "Villonacos III", while the remaining one, "El Aromo", is photovoltaic. It is assumed that the tendering procedures for RE plants in Galapagos will be very similar. It is important to mention that this process has not been concluded, which implies that is uncertain if the Ecuadorian government has found private investors.

According to the tendering procedures of Ministry of Energy and Non-Renewable Resources (2019 a & b) the government grants to the winning bid the use of the land and a concession for a certain amount of time, in which it pays the company a fixed price per Kwh. The demand is not fix and it varies in accordance with citizen's consumption.

The government selects the company according to experience, technical knowledge, and financial resources. However, a GCF/CAF loan could fill the gap of financial strength making it attractive for the tendering process.

Through the Ministerial Agreement of June 16, 2020, the start of the Public Selection Process was authorized, to exceptionally delegate to private equity companies, national or foreign, the development of the Conolophus Project, for a period of twenty-five 25 years from the signing of the concession contract.

The Conolophus project proposes the installation of a 14.8 MW renewable energy system with 40.9 MWh batteries and a transmission line and electrical substations on the Baltra and Santa Cruz islands.

In a public act transmitted via telematics, the economic offer (envelope no. 2) scheduled for the public selection process for the Conolophus renewable energy project, located in the Galapagos Islands, was opened. This project proposes the installation of 14.8 MW of photovoltaic generation with 40.9 MWh batteries on Santa Cruz Island. A private investment of 45 million dollars is estimated.

The Agency for the Regulation and Control of Energy and Non-Renewable Natural Resources presented a reserve price of 565.41 dollars per MWh, while the offer of the Gransolar/Total Eren was 458.88 dollars per MWh. Of the five companies authorized in August 2020, only the group submitted a technical offer, so in April, the Technical Commission signed the Evaluation and Qualification Act of the Technical Offer (envelope No. 1), in which it resolved enable the

Association Gransolar/Total Eren for the next phase of the PPS corresponding to the opening of the economic offer.

The 8th of September the Ministry of Energy and Non-Renewable Natural Resources notified Gransolar/TotalEren the organization was awarded of the tender.

13.2.2. Project Finance

The term 'project finance' refers to the financing of large infrastructure or energy projects whose initial investment is especially expensive and whose payback period is very long.

By 'project finance' it is understood a structured financing based on the long-term cash flows generated by a company incorporated for an isolated project and taking the assets of this company as collateral. The true differentiating element of a 'project finance' is that it is structured based on the long-term predictability of its cash flows based on a structure of fixed contracts with its clients, suppliers, market regulators, etc.

These characteristics are often linked to companies active in the infrastructure, energy, renewables, utilities, etc. sectors such as the Conolophus Project.

This stability and predictability of income is precisely what makes it possible to contemplate financing structures with a term and leverage outside the scope of a corporate structure with a comparable credit rating. The attractiveness of longer terms and a higher amount of debt outweigh the potential disadvantages of project finance structures such as higher costs and more complex and lengthy closing processes.

As far as financing terms are concerned, they can be extended considerably, even reaching 30 years for the highest quality risks. Likewise, the level of leverage can reach levels that are impossible to match for corporate financing, having in some cases exceeded a Debt: Capital level of 90:10.

Another advantage is that this structure allows the client to associate important blocks of debt with specific subsidiaries, removing them from its corporate balance sheet and therefore not affecting its credit rating or its level of additional corporate indebtedness.

Cost Structure

The Project’s cost structure is around US 63,00,000.00

The largest component is the Engineering, Procurement and Construction work, which represents more than 70% of total costs. It has been deemed reasonable by the Independent Engineer in comparison with similar projects in the region.

Some of the items in the Construction Cost section, particularly the EPC cost, have been revised downwards since CAF’s approval due to improvements in the technology and materials used. Consequently, the Total Investment amount and financing are expected to be lower than those shown in this Funding Proposal. However, those changes will not have any negative impact on the project risks nor its performance. Throughout this document, an asterisk (*) sign has been placed next to figures that may end up being lower than presented.

Sources of Funds

Proposed co-financing will allow the Project to be developed, possibly involving involve local banks despite the recent lack of appetite in financing merchant generation of projects in Chile:

- <u>Senior Debt:</u> [39.5%] CAF -assuming it provides senior debt financing of US$ 24,89 million for **10** years-
- [31.5%] GCF -assuming it provides senior debt financing of US$ 19,85 million for **10** years-

<u>Equity:</u>

- [29% remaining] Sponsor; US$ 18,27
- Gransolar/TotalEren is a strong and well-capitalized company winner of the tender bid the Ecuadorian Government launched in 2020.

- With the proposed financial structure, in which leverage is the 70%, the

13.2.3. Conolophus Centralized Power Generation Trust

The Trust is an independent legal entity and investment vehicle to help to mobilize, blend, and oversee the collection and allocation of financial resources for the implementation of the Conolophus Photovoltaic Project. It is a project-driven solution that facilitates strategic focus, rigorous project management, solid monitoring and evaluation, and high levels of transparency and accountability.

A Trust has two objectives: Meet the Ecuadorian authorities' regulations and legal requirements in order to approve the construction of RE plants in Galapagos and to ensure legal guarantees to funding institutions and shareholders.

A Trust under the Ecuadorian law, a trust fund is a financial mechanism, with the legal figure of a private mercantile trust, under the Securities Market Law of Ecuador (2008). The Trust is a legal entity that holds and manages assets on behalf of another entity (usually the settlor). It is administered by the accredited trustee, which is nominated by the settlor(s) of the trust fund. The main purpose of the trustee is to manage the trust fund in accordance with the trust deed as written by the settlor(s) and to ensure that the assets are used in the best interest of the beneficiaries.

A Trust is the fiduciary relationship when the settlor transfers the ownership of his/her assets to the Trust. The assets are kept in a separate fund from the Trustee's own assets and from the assets of other trusts; legal title to the assets stands in the name of the Trustee while the settlor receives trust fund beneficiary rights. The Trustee has the power, and the legal duty, to manage and dispose of the assets as required by the trust deed and by law. His principal duties are to guard the interests of the beneficiaries, which in this case are the settlor(s).

Under Ecuadorian law, a Trust is a corporate body that has the same rights and obligations as any company. Thus, it pays taxes, can acquire loans, hire personnel, etc. Nonetheless, the Trust has a particularity compared to an ordinary firm, which is that other parties not named in the trust deed cannot seize the trust fund assets. In practice, this means that a trust fund loan payment default does not require going to regular trials; instead, assets are transferred immediately to the unpaid financer.

Once the goals of the Trust Agreement are met, the Trust enters a liquidation process, which consists of returning the settlor's assets and, in this case, returning the land to the government where the RE plants operated in the same state it was given.

A key assumption for this; is that the government grants an operating license of 25 years for RE plants. Although this license is renewable, this model assumes it will end at the end of 25 years. This contract with the energy authorities also establishes the price of USD/KWH that the private company will export to the grid.

13.2.4. Trust Agreement Parties

The parties involved in the trust fund are the following:

- Private Sector: It is the settlor of the trust fund. It transfers the ownership of assets (solar panels, Eolic engines and towers, etc.) to the trust fund. The tender Bid winner (Gransolar/Total Eren)
- Public Sector – Ministry of Energy (grantor): By law, this party cannot transfer ownership of its assets. However, it can provide the Trust the permits to operate in public land and to use the Galapagos power grid. In addition, this party would be the Trust customer (this aspect will be explained in detail in subsequent sections).
- Development Bank of Latin America (CAF): Trust financer.
- RE plants: Energy producers owned by the Trust.

- Implementing and executing agency: Supervises, controls and executes that the RE plants perform optimally and efficiently (this party will be explained in detail in subsequent sections). The trust fund contracts this agency.

Trustee: According to Ecuadorian law, trust funds can be managed only by accredited fiduciaries (Ecuadorian Fiduciaries Association.). These accreditations have been given to a few companies. All of them are registered in Ecuador[25].

The management services of these companies vary in down payment price and monthly prices according to the amount and assets managed in the trust fund. The settlor selects on of these fiduciaries according to its selection policies. Although, CAF is not a settlor, it can suggest the fiduciary in the contract with the settlor.

Figure 57. Trust Fund Flowchart

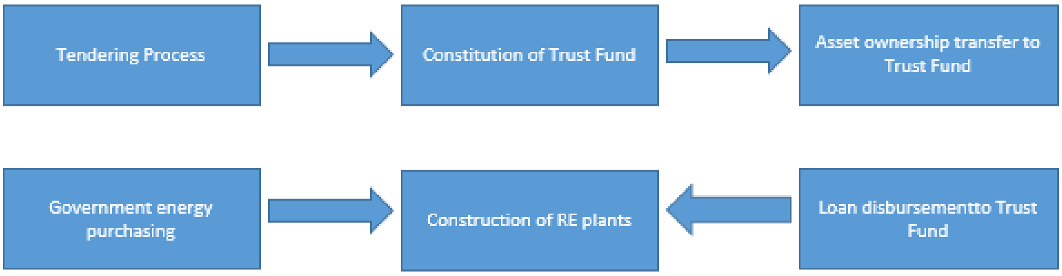


Figure 58. Conolophus Trust Resources Flow

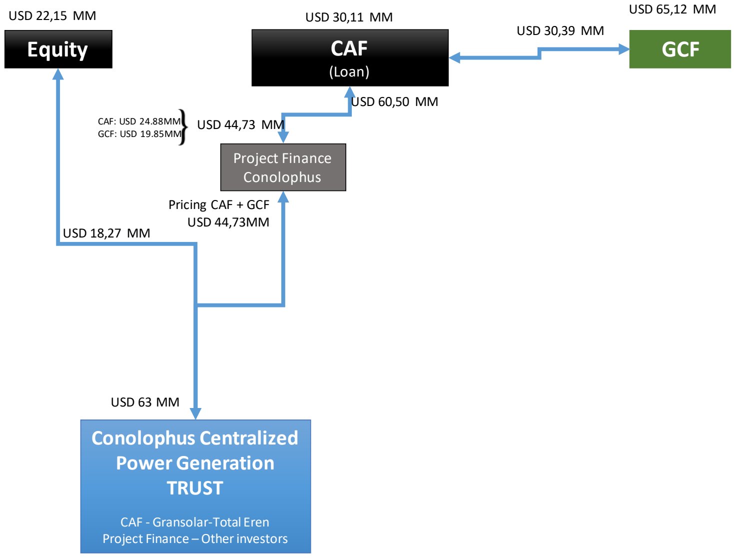
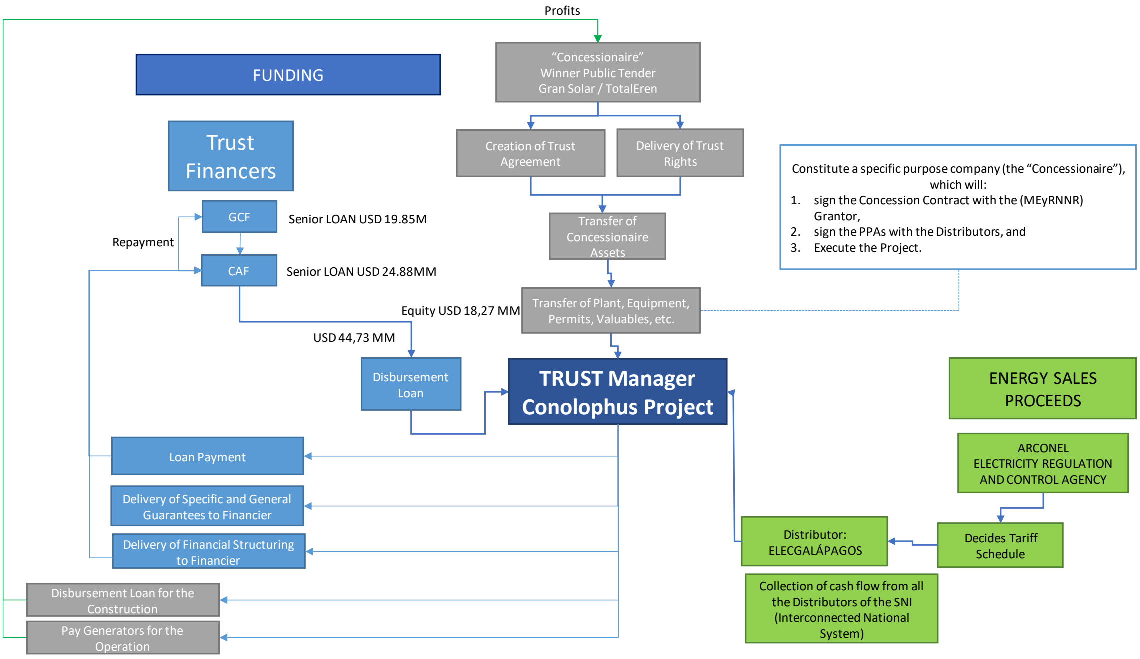


Figure 59. Conolophus Trust Resources Flow

25 National Fiduciaries Association: https://aaffe.ec/



13.3 Grant-Linked Loan Grant Scheme

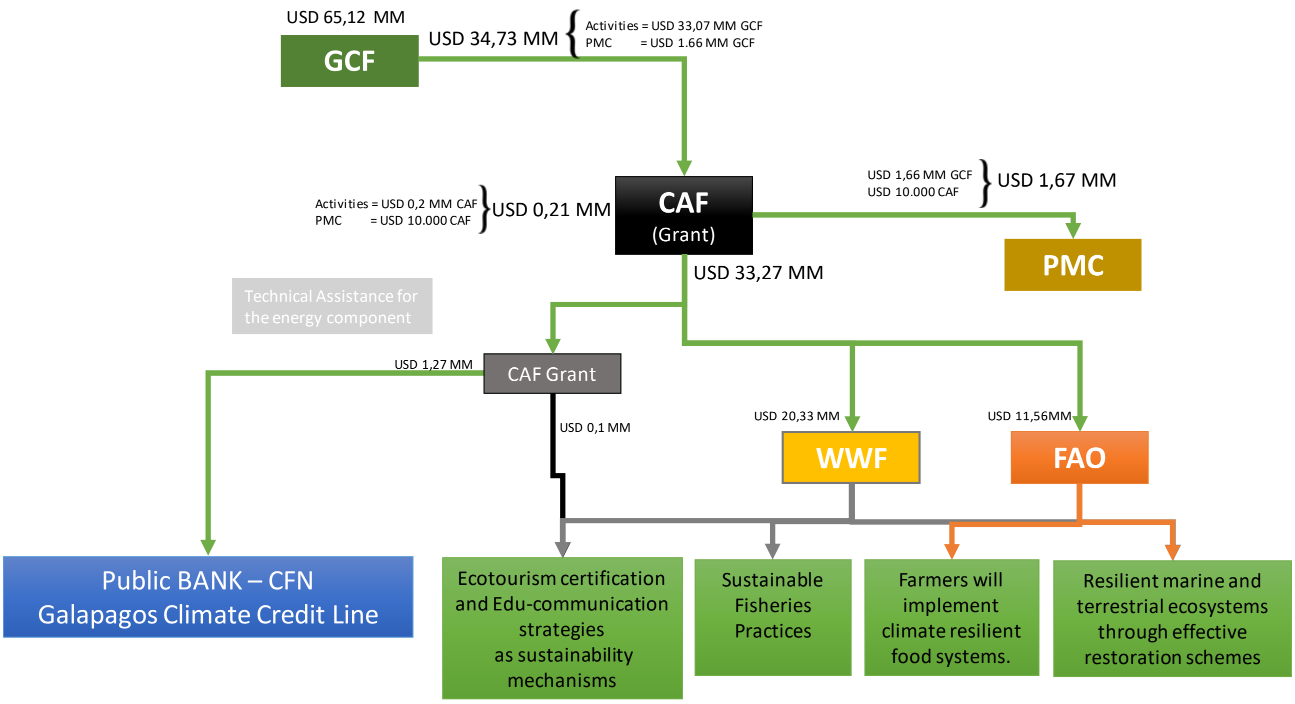
Climate-Linked Loan Grant Scheme, seeks to support climate action activities of all sizes to obtain on one hand climate and green financing by defraying the expenses implementing adaptation and mitigation measures in the agriculture, fishery and tourism sector. The grant also encourages banks to develop green and sustainability-linked loan frameworks to make such financing more accessible to small and medium-sized enterprises.

The grant will enhance agriculture, fishery and tourism sectors ability to obtain climate loans. The grant will cover expenses incurred to engage independent sustainability assessment and advisory service providers to develop sustainability frameworks and targets, obtain external reviews (which includes a second party opinion, verification, certification or rating), and report on the sustainability impact of the loan. With the previous, agriculture, fishery and tourism sector can reach to Eco-tourism Certification Scheme. The previous will be developed with a USD 11,56 MM grant.

Part of the grant (USD 1 MM) will encourage banks to develop frameworks for climate loans. The grant will cover expenses incurred by banks to engage independent sustainability assessment and advisory service providers to develop frameworks, obtain external reviews, and report on the allocated proceeds of loans originated under the framework.

On the other hand, activities from the conservation sector, will be developed also by the grant trench with a USD 16 MM.

Figure 60. Grant Resources Flow


USD 65,12 MM
GCF
USD 34,73 MM
Activities = USD 33,07 MM GCF
PMC = USD 1.66 MM GCF
Activities = USD 0,2 MM CAF
PMC = USD 10.000 CAF
USD 0,21 MM
CAF
(Grant)
USD 1,66 MM GCF
USD 10.000 CAF
USD 1,67 MM
PMC
USD 33,27 MM
Technical Assistance for the energy component
USD 1,27 MM
CAF Grant
USD 0,1 MM
USD 20,33 MM
WWF
USD 11,56MM
FAO
Public BANK – CFN
Galapagos Climate Credit Line
Ecotourism certification and Edu-communication strategies as sustainability mechanisms
Sustainable Fisheries Practices
Farmers will implement climate resilient food systems.
Resilient marine and terrestrial ecosystems through effective restoration schemes

14. Implementation arrangements

CAF will be the Accredited Entity of the Programme, and CFN, FAO and WWF will be the Executing Entities. CAF will also hold the role of EE for three activities: 1.1.1.1, 1.2.2.1 and 3.1.3.1, and in the direct supervision of the loan eligibility of the GCCF. Below, a summary of the experience of the AE and the EEs is presented. Please refer to Annex 2 section 14 for further details on the track record and the capacity of the AE and the EEs to deliver. Please refer to Annex 2 section 12.7 for a summary of the correspondence between activities, financial mechanisms, Executing Entities, and the main local stakeholders that will partner for the execution.

14.1 CAF as accredited entity

CAF is a multilateral development bank created in 1970, and owned by 19 countries, 17 of which are in Latin America, and the Caribbean, Spain, and Portugal, as well as 13 private banks in the region. CAF promotes a sustainable development model through credit operations, non-reimbursable resources, and support in the technical and financial structuring of projects in the public and private sectors of Latin America.

With headquarters in Caracas, Venezuela, CAF has offices in Buenos Aires, La Paz, Brasilia, Bogota, Quito, Madrid, Mexico D.F, Panama City, Asuncion, Lima, Montevideo, and Port of Spain. CAF's mission is to provide sustainable development and regional integration through an efficient mobilization of resources for a timely provision of multiple financial services, with high value added to clients in the public and private sectors of the shareholder countries. CAF is a competitive financial institution, client-oriented, sensitive to the social needs, and supported by a highly specialized staff.

In 2019 CAF's actions have focused on supporting countries' efforts to improve their productive and social infrastructure, as well as institutions for better attention to citizens and more transparent and efficient public action. We financed the construction, improvement, or rehabilitation of 1,294 km of roads; contributed to increased productivity of 23,213 SMEs; financed energy infrastructure benefiting more than 7 million people; established 3,000 new sewerage connections and 52 km of pipelines for drinking water for nearly 3 million beneficiaries; rehabilitated or built 128,164 m2 of educational infrastructure that will benefit 22,680 students; and contributed to a 40,000-ton reduction in carbon emissions. In the financial field, we also made great strides. CAF approved 133 operations with a combined total of USD 13.0 billion. It is also worth noting that the operating profit reached USD 460 million in 2019, the highest in the past decade, and a 48% increase over 2018. Our actions continue to make a significant difference in the lives of millions of Latin Americans, who can see CAF as a tireless champion of their well-being and the realization of their hopes for a better future.

CAF's credit ratings are among the highest of Latin American debt issuers. CAF's long-term credit rating is AA-1 (Fitch Ratings), A+ Standard & Poor's, AA Japan Credit Rating Agency, and Aa3 Moody's Investor Service. CAF's partnerships with public and private sector organizations have allowed it to play an active role in the promotion of projects and programmes that generate environmental benefits and to address climate change impacts.

CAF's Green Agenda fosters the incorporation of development solutions based on nature, credit facilities for low-carbon growth resilient to climate change, and processes supporting virtuous cycles of green financing. Over 28% of CAF's portfolio includes green finance. Such projects have focused on energy efficiency, renewable energy solutions, sustainable transport and climate change adaptation through disaster risk reduction and ecosystem services. CAF is part of the International Development Finance Club (IDFC) through which its members have adopted green finance commitments. CAF has an aspirational target to reach 30% of its portfolio for green finance. In November 2019, CAF completed its first public Green Bonds issuance, EUR 750 million bonds due 2026. This transaction added to the USD 132 million private placements of green bonds completed during 2018. In 2016 CAF signed with the GCF the Accreditation Master Agreement (AMA) as a Regional Direct Access accredited entity.

Capacity of the Accredited Entity to deliver.

A strategic work area of CAF is to support the financial systems of its member countries at three levels (i) regulations, barriers and attracting investments; (ii) coordination at the level of the financial industry; and (iii) financing and advisory at the level of financial institutions. These interventions include a wide range of activities, from regulatory change recommendations to create innovative financial products to providing finance directed to underserved sectors.

In 1997, a vice-presidency for Financial Institutions was created with a portfolio of USD $1.2 billion of financial intermediation, representing 39% of the Bank loan portfolio. Through its successful track record, CAF has developed in-depth knowledge of the financial systems of its member countries, which enabled the establishment of business relationships with key public and private financial institutions in the region.
CAF currently offers its clients from the financial sector financing facilities tailored to its specific needs and to the relevant regulations. In 2019, financing facilities for a total of USD $6.4 billion were approved for financial institutions in CAF member countries.

Moreover, since 2012, CAF has consolidated its Programme for **Environmental and Social Management** for Financial Institutions (PGASIF)[26], as a platform to promote and enhance the management of environmental and social impacts in the financial sector of Latin-America, as well as to transfer knowledge and good practice in environmental and social and Governance (ESG) for the adoption of ESG principles in LFIs. To date, 120 LFIs and more than 3,000 people from 15 countries of the region have received training supported by CAF on environmental and social safeguards, and green finance, including the publication of technical publications and guidebooks. In total, 10 client LFIs have received tailored support for the adoption and enhancement of Environmental and Social Management Systems and the development of green financing products in their portfolio.

With regards to its experience with **Energy projects**, CAF has developed a Programme for Green Business and Energy Efficiency (PNVEE) to stimulate the expansion of green credit lines to its LFIs clients. The Programme includes technical tools to support LFIs in understanding opportunities in green business and EE. Through the PNVEE CAF will provide USD $95 million in co-financing for the recently approved project FP 149 Green Climate Financing Facility for LFIs in Latin-America.

The CAF-GCF Green Climate Financing Facility for LFIs in Latin-America seeks to build upon and scale up, CAF experience and relationship with client LFIs to accelerate the development and volume of local climate change projects in Latin America by helping market actors overcome key financial and knowledge barriers. This will help trigger a transition in the financial sector towards sustainable financing with positive climate change impacts.

CAF has extensive expertise supporting the formulation and implementing of **Land Use projects and programs**. In terms of internal capacity to assess sustainable land use projects, CAF has a Vice-presidency of Sustainable Development with the purpose of promoting and implementing a regional agenda for sustainable and inclusive development in the region, by promoting growth that preserves biodiversity and is low in emissions and resilient to climate change, and which in turn facilitates access for the population to basic quality services in the sectors and / or thematic areas of water and sanitation, urban development, education, health, biodiversity.

This department is composed of four divisions, including Sustainability, Inclusion and Climate Change Division composed of 71 employees. Under this division there are three units: Environment and Climate Change, Green Business and Inclusion and Gender Equity Unit. As part of the team there is 1 executive specialized in land use projects formulation and implementation.

CAF's track record in Sustainable Land Use across Latin America includes work performed with Forest Management, CDM projects for the generation of tCER of forestry activities, evaluation of the Eco Efficiency of the Forest Industry, Development of REDD+ projects in forests and private

[26] More information on PGASIF can be found: www.pgasif.org/

protected areas of Latin America, Agro-master plan, and other projects in the agriculture and agroforestry sector.

CAF in Galápagos

CAF has a relevant track record in Galapagos. To name a few: CAF and the French Development Agency (AFD) supported the development of the "Climate Change Vulnerability Index in the city of Santa Cruz - Galapagos", which aims to identify and prioritize concrete adaptation measures, based on an analysis of climate vulnerability and risk by zones, in order to increase the city's resilience to extreme climate change events and/or climate variability. This study is part of the LAIF program on Cities and Climate Change in Latin America; Technical cooperation for the design of the Roadmap for Sustainable and Safe Integrated Logistics in Galapagos (HdR LISS Galapagos) aimed at identifying, reaching consensus on and formulating the Roadmap for Sustainable and Safe Integrated Logistics in Galapagos. This roadmap will include, among others, an action plan to minimize the risk of invasive species entering the archipelago's ecosystem, optimize the cost and time efficiency of the supply and reverse logistics system to the four inhabited islands; CAF also financed the construction of the sanitary landfill for Santa Cruz; and has demonstrated its interest in supporting climate finance in Galapagos by organizing the forum "Building Sustainable Finance Agreements in Ecuador" on the island of Santa Cruz.

CAF's GCF and Adaptation Fund portfolios.

CAF is an Accredited Entity to the GCF and to the AF. Some of the projects funded are:

- ***Adaptation Fund:***
  - Peru National Project: Ayninacuy - Adaptation to climate change in the alpaca communities of the Sierra de Arequipa.
  - Ecuador National Project: Upper Rio Blanco Watershed. Increased resilience of local communities, ecosystems, and hydropower systems in the upper Rio Blanco watershed.
  - Argentina-Uruguay Regional Project: Uruguay River. Adaptation to climate change in vulnerable coastal cities and ecosystems of the Uruguay River.
- ***GCF:***
  - Readiness projects in Chile (CHL-RS-002, CHL-RS-004), Paraguay (PRY-RS-001), Costa Rica (CRI-RS-001), Panama (PAN-RS-001).
  - FP017 - Climate action and solar energy development programme in the Tarapacá Region in Chile.
  - FP 149 Green Climate Financing Facility for LFIs in Latin-America (includes Ecuador).

14.2 Information on executing entities

CAF, CFN, FAO and WWF will be the Executing Entities of the Programme.

CFN - National Financial Corporation B.P., Ecuadorian Development Bank.

CFN is a public financial institution, whose mission is to promote the development of the productive and strategic sectors of Ecuador, through multiple financial and non-financial services aligned with public policies. The institutional action is framed within the guidelines of the National Government's programs aimed at stabilizing and dynamizing the economy, becoming a decisive agent for achieving the reforms undertaken.

The CFN B.P., during its institutional trajectory, has consolidated its credit activity, reiterating the commitment to continue serving the productive sector with special attention to the micro and small businesses, supporting them additionally in training programs, technical assistance, and the signing of inter-institutional agreements for the promotion of production, seeking to improve and highlight business management as a source of competitiveness in the medium and long term.

FAO

The Food and Agriculture Organization (FAO) is a specialized agency of the United Nations that leads international efforts to defeat hunger. Our goal is to achieve food security for all and make sure that people have regular access to enough high-quality food to lead active, healthy lives.

With over 194 member states, FAO works in over 130 countries worldwide. We believe that everyone can play a part in ending hunger.

The GCF Board has defined key investment priorities, which target many challenges directly relevant to FAO's mandate and work. This includes support for reducing emissions from deforestation and land use and enhancing the resilience of people's livelihoods and food security. FAO is accredited with the GCF as a grant-implementing entity for medium-sized projects (USD 50-250 million) with a medium level of environmental and social risk.

At a global level, FAO provides support to member countries with technical assistance, data, and tools for informed decision-making and in the implementation of programs and projects that facilitate the implementation of integrative approaches for adaptation and mitigation of climate change in the agricultural sector. The Organization's technical assistance focuses on the design of National Adaptation Plans (NAPs), Appropriate Mitigation Actions (NAMAs), and the implementation of national actions prioritized in Nationally Determined Contributions (NDCs). FAO's portfolio related to climate change has expanded to more than 300 programs and projects that address the sector's responses to climate variability and extreme events in the agricultural sector.

As per December 2020, FAO has 13 projects approved by the GCF on adaptation, mitigation, and cross-cutting initiatives.

FAO and the GCF in numbers:

- 17 000 vulnerable families to benefit from the FAO-designed PROEZA project in Paraguay, aimed at combating deforestation, hunger and poverty, and building the climate-resilience of local populations.
- 291 800 vulnerable people to benefit from the IRES project – building climate resilience of rural communities in Cuba.
- 430 000 people to benefit from increased forest coverage and rangeland productivity in Kyrgyzstan.
- 1.1 million tons of CO2 to be reduced through Chile's REDD+ Results Based Payment Funding Proposal.
- 200 000 rural households in Nepal's Churia hills region will build climate-resilient livelihoods through ecosystem restoration and sustainable land-use practices.
- 1.3 million rural people to benefit directly from the FAO-led project in Pakistan's Indus Basin – to improve water management and farming practices and increase climate resilience.
- 17 000 hectares of degraded land to be restored in El Salvador's Dry Corridor.
- 207 rural communities dependent on forests for fuelwood in Armenia's Lori and Syunik provinces will benefit from FAO-led project promoting the use of energy-efficient fuelwood stoves.
- 7 550 smallholder farmers will benefit directly, and another 600 000 indirectly, from Côte d'Ivoire's PROMIRE project for zero-deforestation cocoa.
- 60 000 hectares of forest in Colombia's Amazon region will be managed sustainably, with the active involvement of indigenous peoples, through proceeds from the REDD+ results-based payment pilot programme.

FAO Ecuador

The FAO cooperation program in Ecuador considers as one of the priority areas the strengthening of environmental policy, including strategies for mitigation and adaptation to climate change in the agricultural sector, and thus promoting the transformation and resilience of livelihoods rural. The actions are based on the FAO Strategy on Climate Change. At the national level, FAO advises and develops capacities in government entities, partners and the population in the development, formulation and implementation of agricultural policies, strategies, programs, tools, technologies, and practices that have been developed in various projects in different areas of the country and that have successfully scaled up their practices in other areas.

Among the initiatives that the organization has developed in Ecuador and that have allowed to generate knowledge for the preparation of this proposal, there are four projects focused on the integral management of the landscape with sustainable land management practices, conservation, and restoration practices. forestry in water recharge areas and good agricultural practices for adaptation to climate change (Natural Resource Management in Chimborazo-PROMAREN, Conservation and Good Living in Napo, Sustainable Land Management / KFS-UNCCD, Forest and Farm Mechanism-FFF); in addition to projects focused on the management of plant genetic resources for food and agriculture (Use and Conservation of Agrobiodiversity in High Andean Provinces). Likewise, forestry projects have been designed and implemented (UN REDD, UN REDD Targeted Support and FAO ProAmazonía), and projects focused on the implementation of the climate-smart agriculture approach (Climate-Smart Livestock - GCI and Climate-Smart Cocoa) that have allowed the evaluation technical and economic practices of mitigation and adaptation to climate change, generation of tools, and the provision of evidence for the integration and scaling of these approaches in public policy.

At the national and local level, FAO has a close relationship and cooperation with MAG, MAAE, INIAP, among other entities in the sector, with which actions in the field are coordinated with the Decentralized Autonomous Governments and local actors in the intervention areas of the projects. For the implementation of actions with the different partners, there is a multidisciplinary team of national and international specialists in disciplines related to Sustainable Agriculture, Rural Poverty Reduction, Resilience, Forest Policies and Resources, Climate Change, Biodiversity, among others, who participate in the development and implementation of the project.

Finally, FAO is the United Nations agency responsible for 21 indicators of Sustainable Development Goals (SDGs) 2, 5, 6, 12, 14 and 15. The activities described in the project are related to several of these objectives and targets, including SDG 2 which aims to "End hunger, achieve food security and improve nutrition and promote sustainable agriculture" and its goal 2.4 "ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, help maintain ecosystems and strengthen the capacity to adapt to climate change, extreme weather, drought, floods and other disasters, which progressively improve the quality of land and soil".

FAO has provided technical assistance to Ecuador since 1957. During these years, FAO has implemented hundreds of projects at the national and local level. The main partners of FAO in Ecuador are the Ministry of Agriculture and Livestock and the Ministry of Environment and Water of Ecuador. Additionally, FAO has developed projects on agrobiodiversity and plant genetic resources with INIAP. Also, FAO has direct implementation action with local governments at different levels (province, counties, and parishes).

Ecuador, through the Country Programming Framework (MPP) 2018-2021, has defined the lines of work for FAO technical assistance in the country. The MPP is the planning document that FAO prepares jointly with the national counterparts, which identifies the priority areas of technical assistance that the country requires from the Organization. The prioritized pillars are:

- Priority 1: Food and nutritional security and sovereignty for all and for all through the creation of political, social, and institutional conditions that contribute to the eradication of hunger and encourage the provision and consumption of healthy diets.
- Priority 2: Agriculture and rural development by strengthening farmers' access to rural assets and services for innovation, incorporating a rights, gender, and territorial approach, facilitating the transition to sustainable production and agri-food systems, in a context of climate change.
- Priority 3: Sustainable management of natural resources and resilience against risk through the consolidation of environmental public policy related to the conservation and sustainable management of biodiversity and natural resources, ensuring ecosystem services and the development of strategies for climate change mitigation and adaptation.

The MPP was built jointly with the institutions with which FAO will interact for the program in Galapagos that include Ecuador's priorities for FAO intervention.

WWF

WWF is among the world's leading conservation organizations, with more than a half century of experience and a presence in over 100 countries. These offices are federated under a global non-profit network supported by more than 5 million individual members, with country offices pursuing common objectives, strong collaboration, and active knowledge sharing. WWF was created on April 29, 1961 and since then, has invested $10 billion in more than 13 000 projects around the world. With over five million supporters worldwide, and more than 6 000 employees working in nearly 100 countries, including Ecuador. This global network of professionals gives us the advantage of creating multinational and interdisciplinary teams, which are assembled according to the needs and priorities of each regional, national and local project that we implement.

WWF's work has evolved from saving species and landscapes to addressing global environmental threats and forces that drive them, with people at the center, and organized around six priority areas for improved human welfare through sound environmental management: climate, forests, food, freshwater, wildlife, and oceans. This program takes advantage of WWF's extensive experience in Latin America and success in helping advance innovative conservation programs with a focus on nature-based solutions for climate.

WWF's experience with the GCF is based in its role as an Accredited Entity, whose GCF portfolio under implementation includes Bhutan for Life (BFL, GCF FP050), a US$ 118 Million, 14-year project to guarantee the long-term sustainability of Bhutan's protected areas system that encompass over 50 percent of Bhutan's territory.

WWF in Ecuador

WWF started working in Ecuador in 1962 when it supported the establishment of the Charles Darwin Research Station in Puerto Ayora, Galapagos. Since then, WWF has supported a wide variety of projects with emphasis on Galapagos´ biodiversity conservation and sustainable development. In 1998, WWF provided technical assistance for the adoption of the Special Galapagos Law that created the Galapagos Marine Reserve (RMG). WWF focused its efforts on reducing threats to the Archipelago´s species, habitats, and ecosystems by supporting well-planned and inclusive marine and terrestrial protected area management, bridging the gap between natural conservation and sustainable human development, and supporting the design and implementation of responsible fishing practices, to encourage sustainable use of fishing resources. In collaboration with other institutions, WWF supported the Galapagos National Park Service in an extensive multiple-phase process of planning and social engagement to update a new management plan, that includes integrated management of two protected areas and their link with local communities. Together with the Galapagos National Park Service (GNPS) and fishermen, WWF designed a Galapagos Label for seafood products. Reducing the ecological footprint was also our key priority. We have on the one hand, addressed an ever-increasing tourism industry, by supporting a new tourism model based on best practices and well-versed decision-making; and on the other hand, supported the implementation of an integrated waste management system. WWF-Ecuador has implemented several communications & education campaigns in Galapagos on best practices on ecotourism, efficient energy consumption, waste management, food waste, among others. Currently WWF implements the project "Education for Sustainability: invasive species", whose goal is to promote long-term social commitment to ensure the sustainability of introduced species management efforts through communication, education, and social participation actions.

WWF-Ecuador has evolved into a dynamic organization and since 2014 expanded its work to Continental Ecuador. The growth of WWF's activities in Ecuador has been in direct response to national and sub-regional conservation needs, and at the request of the national and local governments. An important and cross-cutting aspect of our work in Ecuador is the creation of collaboration networks that mobilize key actors to articulate and enhance their efforts.

The organizational structure of WWF- Ecuador on finance and on program areas as well as the competence of the staff, support the projects management and efficient execution. WWF has staff enough in accounting and financial work to ensure the application of adequate controls for the management of the resources allocated within the framework of each project. WWF personnel are evaluated annually based on strategic goals and achievements. WWF will ensure to hire additional efficient staff to develop the program activities and achieve the project goals.

<u>Governmental Partners:</u>

The Governmental Partners are the governmental entities which have been involved during the structuring and formulation of the Funding Proposal and which have presented letter of interest to the proposal. They will be engaged by the EEs (CAF, CFN, FAO, WWF) as procured parties/service providers to implement some of the Activities. The governmental partners will be participating and safeguarding the interests and application of the local government legal framework taking into account that it is a public programme. The governmental partners are part of the Sectoral Technical Committees as shown in figure 60 (*Figure 61. Sectoral Technical Committee).*

- *The Government Council of the Special Regime of Galapagos / CGREG*[27]*.*
- *Galapagos National Park Directorate / GNPD*.
- *The Ministry of Agriculture and Livestock / MAG*.
- *Ministry of Energy and Non-Renewable Natural Resources / MEyRNRNR*.
- *Ministry of Tourism / MinTur:* governing body that plans, manages, promotes, regulates, and controls sustainable tourism in Ecuador.
- *Empresa Eléctrica Provincial Galápagos / Elecgalapagos*.
- *The Galapagos Biosecurity Regulation and Control Agency*.

Technical Advisors: The Programme will work with local organizations which have technical knowledge. They have the technical knowledge and can technically support the development of the Program by virtue of their role in the management and development of knowledge for Galapagos, as well as their technical capacity in hydrological modeling and information generation.

14.3 Information on Direct Beneficiaries of the Trust

Conolophus Tender Winner Gransolar/Total Eren

Gransolar S.A is an Ecuadorian group of investors who believes in the need to generate renewable energy projects. Gransolar S.A aims to develop, direct and execute electricity generation projects through renewable energy sources. We are committed to photovoltaic energy that comes from the sun and its foundation is to transform natural light into electricity. Gran Solar is the developer of the Salinas and Tren Salinas plants with a nominal output power of 2 MW and 999 KW respectively. The plants are 5km from the Salinas Urcuquí highway in Imbabura province. The average irradiation in the project's area of influence is 5.1 kWh / m2 / day.

https://gransolar.ec/

Total Eren. Founded in 2012 by Pâris Mouratoglou and David Corchia, Total Eren develops, finances, builds and operates renewable energy power plants (solar, wind, hydro) representing a gross capacity of 3,500 MW in operation or under construction worldwide. Through partnerships with local developers, Total Eren is currently developing numerous energy projects in countries and regions where renewable energy represents an economically viable response to growing energy demand such as in Europe, in Central and South Asia, in Asia Pacific, in Latin America and in Africa. The objective is to achieve a global gross installed capacity of more than 5 GW by 2022. Since December 2017, TotalEnergies, the major energy company, has been participating as a shareholder of Total Eren.

Total Eren owns 3,500 MW* of solar, wind and hydro energy in operation or under construction supplying electricity to major utilities and large private customers on the five continents

In October 2015, Total Eren – then EREN RE – completed a capital increase of €195 million from a diversified consortium of investors including Bpifrance (12.3% stake in Total Eren in 2021), Next

27 All Acronyms correspond to the names in Spanish.

World Group (4.4% in 2021), Salvepar* and Peugeot Invest (7% combined in 2021) in order to support its growth ambitions in the renewable energy sector.

Thanks to increased financial resources, a common long-term vision and a shared objective of carrying out economically viable projects, Total Eren strengthened its capacity to deploy funds in order to develop and invest in renewable energy projects all over the world, while maintaining the flexibility and agility of a developer that operates on a human scale.

In December 2017, TotalEnergies (formerly known as "Total S.A") invested €237.5 million and acquired an indirect stake in EREN RE to accelerate growth in its production of power from renewable energy sources. Following this strategic alliance, EREN RE was renamed Total Eren.

In April 2019, Total Eren acquired NovEnergia Holding Company ("NHC" or "NovEnergia"), thereby diversifying its project portfolio and strengthening its presence in southern Europe in particular. As part of the transaction, TotalEnergies increased its stake in Total Eren to reach a total of almost 30% (directly and indirectly).

https://www.total-eren.com/en/

15. Governance of the Programme

The program will have two levels of coordination:

- A level of strategic coordination that will include a Steering Committee and three Technical Committee, and
- An operational structure of the program that will be organized according to each of the 3 components, which in turn will meet under a transversal coordination of the program.

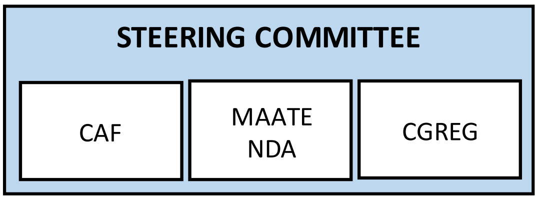
Strategic coordination level

15.1. Programme Steering Committee

Maximum decision-making authority, consisting of high representatives of CAF, the Ecuadorian Ministry of Environment, Water and Ecological Transition and the Governing Council of the Special Regime for Galapagos (CGREG). This Steering Committee will hold meetings every 6 months. It will be in charge of:

1. Verifying compliance of Programme implementation.
2. Reviewing and approving the consolidated Annual Operating Plan.
3. Reviewing and approving the consolidated Annual Procurement Plan.
4. Reviewing and approving the Annual Performance Report (APR) according to the GCF's format.
5. Review and approve the Semi-Annual Performance Report (S-APR)
6. Review and approve Major Changes according to the GCF's Policy on Restructuring and Cancellation
7. Review and approve the mid-term and final evaluations of the Programme, provide comments and recommendations.
8. Be informed on the progress of the APR to be submitted to the Green Climate Fund.
9. Review and approve the TORs of the Programme Management Unit (PMU).
10. Invite WWF, CFN, FAO as observers in the selection process of the Programme Management Unit. Hold face-to-face or virtual meetings at least twice a year on a semi-annual basis. The Steering Committee may be extraordinarily convened by the chair or at the request of any of the members.
11. The Chair of the Steering Committee will alternate annually between the MAATE and CAF through their designated representatives.
12. Decisions of the Steering Committee shall be made in accordance with the rules that ensure management for development results. The decision shall be made by consensus.
13. Arbitrate conflicts that may arise during implementation.
14. Provide strategic guidance aligned with the national climate change policy and local actions.

Figure 62. Programme Steering Committee



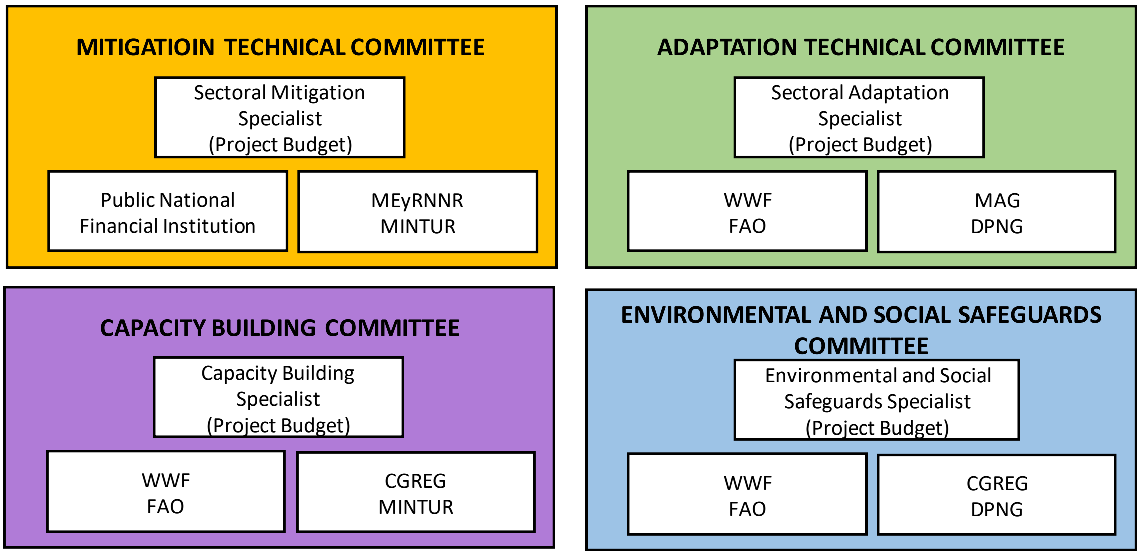
15.2. Sectoral Technical Committee

Committee responsible for presenting execution results to the Steering Committee. The Sectoral Technical Committee is made up of the Climate Change Secretariat at the MAATE, the Management and Promotion Division of Energy Efficiency Projects and the Expansion of the Generation and Transmission of Electrical Energy Division, and Elecgalapagos from the MEyRNNR, the Insular Zonal Division of the Ministry of Tourism, the Planning and management of the territory Division of the CGREG, the Galapagos National Park, the Provincial Agricultural Division of Galápagos of the MAG, the Climate Change Unit of CAF as Accredited Entity of the Programme, the Programme coordinators, CFN, FAO and WWF as Executing Entities.

The Sectoral Technical Committee is in charge of:

1. Delivering the information to consolidate the Annual Operational Plan.
2. Delivering the information to consolidate the Annual Procurement Plan.
3. Delivering the information to consolidate the Semi-Annual Performance Report (S-APR) and provide recommendations.
4. Delivering the information to consolidate the Annual Performance Report (APR)and provide recommendations.
5. Delivering the information in case of requiring Major Changes according to the GCF's Policy on Restructuring and Cancellation
6. Delivering the information of the Programme's performance.
7. Delivering the information required for mid-term and final output assessment.
8. Delivering the information on a semi-annual basis.

Figure 63. Sectoral Technical Committee



CAF as executing entity is part has an active role in the four Sectoral Technical Committees. At the Mitigation and Adaptation Committees the Climate Change Coordination as part of the will act as technical supervisor working hand in hand in the committee. On the Environmental and Social Safeguards Committee two specialists of the Directorate of Sustainability, Inclusion and Climate Change will participate. The person from the Environmental and Social Evaluation and Monitoring Coordination is in charge of giving monitoring the good implementation of the Program safeguarding the Environmental and Social policy of CAF and the GCF. The person of the Social Inclusion and Gender Coordination will be in charge of safeguarding the good implementation of the Gender Action Plan of the Programme. For the Capacity Building Committee there will be a person in charge of the Education Coordination from the Directorate of Analysis and Evaluation Sustainable Development Technique. All of the technical team of CAF are part of the Sustainable Development Vice-presidency.

15.3. Operational structure of the Programme

CAF will hold the role of the Accredited Entity of the Programme, based on its experience of successfully carrying out similar Programme activities in the Latin American region. The existence of a central unit, within CAF's sphere, will allow to guarantee compliance with technical standards and a close monitoring and follow-up by CAF to ensure consistent levels of progress as well as a regular flow of information where progress of activities can be contrasted against the plan. This allows taking corrective actions if necessary, during the Programme's execution, ensuring it is cost-effective.

The external auditing and the incorporation of observations and lessons learned are guaranteed. All execution will be conducted based on an Operations Manual arising from any such agreement as CAF may enter with the GCF, which will respect all understandings reached.

CAF will maintain day-to-day oversight responsibility for Programme supervision and have direct responsibility for fulfilling the duties and obligations of a GCF Accredited Entity. It will be responsible for financial management and accountable for the use of GCF resources under the Programme. It will provide technical and administrative backstopping to the Programme Management Unit or PMU (see below) to ensure results-oriented management and proper administration of funds. It will maintain Programme accounts, monitor resource mobilization of baseline and co-finance. Financial transactions will be subject to annual audits undertaken by internationally certified auditors. The AE functions involve the provision of monitoring and evaluation services as well. CAF will have permanent coordination with Programme staff and dialogue with Programme stakeholders.

15.3.1. The Executing Entities functions

CAF, CFN, FAO and WWF will be the Executing Entities of the Programme.

CAF and CFN will carry out the execution of the activities financed by the Loan trench. The concessional loan for CFN and the project finance loan for the Conolophus Tender Winner – Gransolar/Total Eren. FAO and WWF will ensure the coordinated execution of activities under the Grant trench.

Based on their respective experience, FAO will execute the activities related to agriculture and livestock and WWF will develop the activities related to support fisheries, the restoration and conservation activities in marine and terrestrial HEVAs (in Component 2), and the sustainability activities of the Programme (Component 3).

CAF will carry out the execution of the "Activity 3.1.3.1 Mainstream climate change into regulatory frameworks and planning instruments" taking into account the mainstream of this activity in the Programme. Also, CAF will execute the "Activity 1.1.1.1 Centralized renewable energy generation and storage project".

FAO and WWF will ensure the coordinated execution of activities under Component 2, and WWF will lead the execution of Component 3, working closely with CAF, CFN and FAO especially in this Component with cross-cutting characteristics.

FAO and WWF shall bring technical support at the Mitigation and Adaptation Technical Committees.

CAF, CFN, FAO and WWF shall ensure quality in their operations and are accountable for executing the projects according to the principles and modalities applied to the operations of the Green Climate Fund.

CAF, CFN, FAO and WWF shall ensure appropriate monitoring, independent evaluation, and financial audits of all activities funded by the Green Climate Fund.

15.3.2. The Programme Management Unit (PMU)

The Programme Management Unit (PMU) will be established in Galapagos and will have a dedicated team to guarantee all components and activities are carried out according to the Programme design. It will articulate with the monitoring and evaluation activities (covered by CAF as Accredited Entity) to ensure that all expected results will be achieved on time and within budget.

This PMU will have a Programme Coordinator, a Monitoring and Evaluation Specialist, a Sectoral Adaptation Specialist, a Sectoral Mitigation Specialist, a Capacity Building Specialist, an Environmental and Social Safeguards Specialist and an Accounting Assistant. The latter will be in charge of overseeing the implementation of the ESMF and the Gender Action Plan in liaison with CAF's Coordination of Environmental and Social Assessment and Monitoring (CESAS) and CAF's Gender Coordination. They will report to the Programme Coordinator. The coordinator and the mentioned specialists to be financed by the Programme budget.

The PMU will work closely with the Sectorial Business (private and public) and Administrative (Legal, Procurement, Human Resources, etc.) areas within CAF.

Principal Executives of the Private Sector and Public Sector that are already part of CAF for the management of intermediated programmes, will be assigned for this Programme.

The PMU will ensure that Programme implementation proceeds smoothly through well-written work plans, Terms of Reference and carefully designed administrative arrangements that meet CAF and GCF requirements. PMU's responsibilities will include the following:
1. Follow-up of the achievements of the Programme outcomes, outputs, and objectives.
2. To manage day-to-day implementation of the Programme, coordinating activities by the rules and procedures of CAF/GCF.
3. To provide overall administration, while acting as an independent and unbiased guarantor of cooperation and information exchange.
4. To provide technical input as appropriate to the outcomes.
5. To facilitate staff recruitment and procurement processes.
6. To ensure, together with CAF, to coordinate with the stakeholders and other relevant regional programmes.
7. To oversee the approval of individual projects to be financed by LFIs through CFN.
8. To ensure, together with CAF, to convene quarterly Programme Implementation Meetings (PIMs) to review progress in implementing work plans.
9. To ensure, together with CAF, that specified tasks are outsourced to suitable sub-contracted providers or national and international consultants through competitive bidding processes. PMU's responsibilities in this regard include development of bidding documents and terms of reference and monitoring the overall progress of these processes.
10. To organize Programme-level meetings and workshops, e.g., inception workshop, etc.
11. To monitor financial progress reports and the financial balance provided by CAF's operational systems.
12. Prepare and present the consolidated Annual Operational Plan.
13. Prepare and present the consolidated Annual Procurement Plan.
14. Prepare and present the consolidated Semi-Annual Performance Report (S-APR) including the Technical Committee recommendations.
15. Prepare and present the consolidated Annual Performance Report (APR) including the Technical Committee recommendations.
16. In case of requiring Major Changes according to the GCF's Policy on Restructuring and Cancellation, prepare and present the consolidated request. Prepare and present the consolidated Major Changes requirements.
17. Prepare and present the consolidated Programme's performance.
18. Prepare and present the consolidated required information for mid-term and final output assessment.

19. Planning and monitoring the technical aspects of the Programme, including regular field visits and periodic reporting.
20. Ensuring advanced funds are used following agreed work plans and Programme budget.
21. Preparing and adjusting commitments and expenditures to be authorized by CAF. Guaranteeing timely disbursements, financial recording and reporting against budgets and work plans.
22. Managing and maintaining budgets, including tracking commitments, expenditures and planned expenditures against budget and work plan.
23. Maintaining productive, regular, and professional communication with other Programme stakeholders to ensure the smooth progress of Programme implementation.

Figure 64. The Programme Management Unit (PMU)

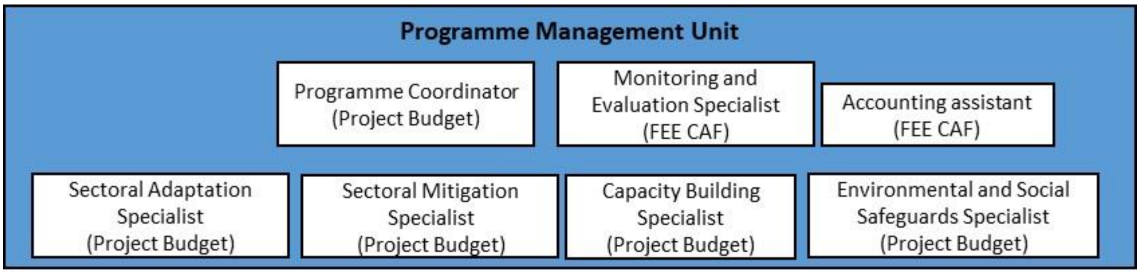
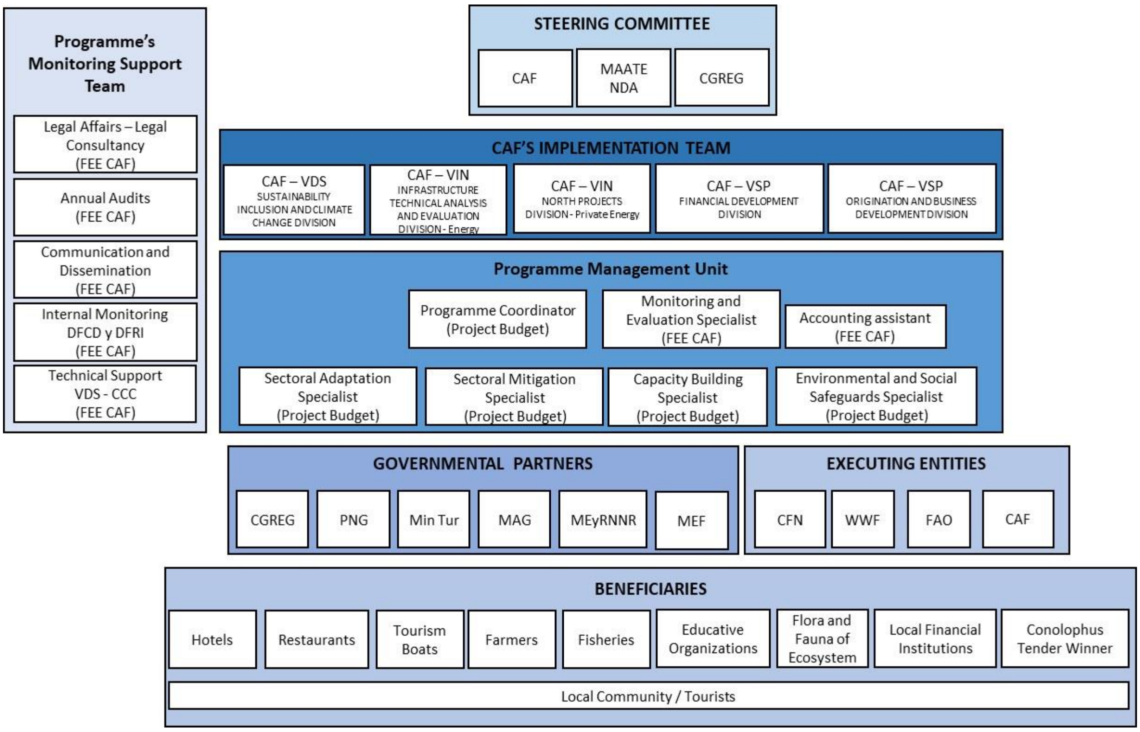


Figure 65. Operational Structure of the Programme



15.4. Anticipated legal arrangements

The anticipated legal arrangements between the GCF, CAF, Executing Entities (CFN, FAO, WWF), Local banks, and beneficiaries include:

- CAF and GCF will enter into a Funded Activity Agreement (FAA) for the Programme in the framework of the Accreditation Master Agreement (AMA). The FAA will outline the sectorial,

technological, and geographical scope (the “Mandate”) of the proposed CAF/GCF Programme.
- During Programme implementation, CAF will be responsible for providing governance, oversight, and quality assurance in accordance with its policies, procedures, and with the FAA and AMA.
- The Executing Entities and the LFIs selected for the Programme have gone through a pre-assessment screening, based on the criteria included in Annex 9– “Know your client”, and in most cases have pre-established financial relations with CAF. An updated and robust due diligence will be in place before CAF approves each IFI under this Programme, where each due diligence will be presented to the CAF investment committee for review.

15.1.1. Galapagos’ Climate Facility

1. The Galapagos’ Climate Facility is not a separate legal entity, but rather the name of the initiative under which the Programme’s will be implemented.

15.1.2. Galapagos’ Climate Credit Line (GCCL) - through CFN and LFIs

1. CAF will enter into loan agreements or amend existing loan agreements with CFN, for the Galapagos’ Credit Line.
2. CAF will establish a methodology to follow appropriate commercial practices and procedures in all operations financed with GCF resources. In the provision of financing, CAF will perform a due diligence of the Executing Entities and the LFIs and carefully assess their ability to meet their obligations under the loan agreement.
3. CAF and GCF proceeds will be lend to CFN, which will in turn on-lend these proceeds to LFIs.
4. The LFIs will use the loan proceeds to fund the loans made under the GCCL.
5. CAF will contractually ensure that the conditions required by GCF are transferred to the GCCL Agreements (thought amendment to those already executed).
6. The loan agreements will make available CAF and GCF financing for investments consistent with the Mandate of the Programme. CAF as per the loan agreement will have the ability to reject a sub-loan. The LFIs screen potential loan recipients (i.e., the final beneficiaries) in accordance with the eligibility criteria and then present a list to CAF for final approval.
7. It will be a requirement in the eligibility criteria and credit rules that refinancing is not allowed.
8. Local banks and CFN will disburse GCF and CAF loans to beneficiaries consistent with the mandate of the Programme. As part of the Programme, CAF teams and technical assistance providers hired by the Programme will provide technical assistance and capacity building to help Local banks and CFN conduct internal procedures to evaluate eligible technologies and/or projects, check compliance with the mandate and put in place monitoring systems. CAF will report to the GCF based on the conditions established in the FAA and AMA. No project may be financed with GCF’s resources if it does not meet the conditions required by the GCF according to the FAA. The Programme Management Unit will review and assess subprojects eligibility. In addition, contractual obligations will be established for both: the IFI and the agreements with Beneficiaries.
9. LFIs agreements will contain AML/ CFT clauses that will be transferred to the Local banks’ Beneficiaries (through the loan agreements between the Local bank and the Beneficiary).
10. Loans will be repaid by the beneficiaries to the Local banks, back to CAF and the GCF. The schedule of repayments is outlined in Annex 3.

15.1.3. The Conolophus Centralized Power Generation Trust

1. CAF will enter into a Common Terms Agreement with the Conolophus tender winner company.
2. CAF will sign an Agreement between creditors. This will regulate the relationships between creditors.
3. CAF will sign a Trust Agreement with the tender winner of the Conolophus Project to finance the construction of the solar power energy plant. Please refer to Annex 2 section 3.6 for further details on the bidding process.
4. The Trust will solely use the loan proceeds to construct the Conolophus PV Project

15.1.4. Grants and Technical Assistance

1. The instrument between CAF and FAO/WWF is a grant. CAF will enter into grant execution agreements with FAO Ecuador and WWF Ecuador.
2. The PMU will enter into contracts with Technical Assistance providers for Component 1 following CAF's contracting procedures, as needed.
3. No project may be financed with GCF's resources if it does not meet the conditions required by the GCF according to the FAA.
4. No further grants will be given to the beneficiaries (i.e., the beneficiaries will not receive cash payments): the grant monies will be used to pay for services and inputs to implement the activities.
5. CAF will not sign any contracts with final beneficiaries.
6. Since FAO and WWF will provide agricultural, educational, environmental inputs and tools, they sign delivery/reception acts, where beneficiaries commit themselves to the proper use of the inputs and maintenance, if required. Acts include name of beneficiary, objective, scope, value, commitments, place of destination, follow up mechanisms, among others

Evaluation and due diligence of Executing Entities.

CAF is responsible for the evaluation of the Executing Entities and the Conolophus Tender Winner.

*F*AO and WWF as direct executing entities of the program based on its standards which cover:

- Basic data of the client or counterparty
- Changes in functional structure
- Documents of incorporation, board of directors, shareholding composition, powers, appointments of their representatives
- Financial Transparency, Audits, Contracts, services and purchases manuals, transparency manual, ethics, others.
- Regulations on Money Laundering, questionnaire on Prevention and Detection of Money Laundering, Declaration of Activities and Legal Assets, Knowledge of Third Parties Authorized to Receive Disbursements.

CAF is responsible for the evaluation of CFN. CAF will:

- Identify the main risk factors of the operation and the client and determine their possible mitigators.
- Analyze the technical, institutional, market, financial, economic, environmental, and social aspects, anti-money laundering, among others, of the operation and the client, in an exhaustive way to determine its viability.
- CAF will complete annually the credit evaluation document. CAF's credit evaluation document is included in Annex 9. (FR-015 Reporte Revisión Adm Créditos Riesgo Soberano)

Evaluation and due diligence of participating LFIs:

The CFN's Responsible Executive will collect information about the operation and the client, ensuring that it allows to know the real situation of the client and their perspectives. To the extent possible, the Responsible Executive will contrast or complement the information it receives from the client with external sources.

CFN is responsible for the evaluation of LFIs. CFN will:

- Identify the main risk factors of the operation and the client and determine their possible mitigators.
- Analyze the technical, institutional, market, financial, economic, environmental, and social aspects, anti-money laundering, among others, of the operation and the client, in an exhaustive way to determine its viability.
- In the case of non-sovereign risk operations, in addition to evaluating the client's ability to fulfill his contractual obligations, paying special attention to the economic-financial situation of the client, his payment experience and the macro-sector environment, as well as to other specific factors of the operation.

Evaluation and due diligence of winner of the tender Project Conolophus:
CAF is responsible for the evaluation of the tender winner Project Conolophus. CAF will:

- Identify the main risk factors of the operation and the client and determine their possible mitigators.
- Analyze the technical, institutional, market, financial, economic, environmental, and social aspects, anti-money laundering, among others, of the operation and the client, in an exhaustive way to determine its viability.
- Evaluate the client's ability to fulfill his contractual obligations, paying special attention to the economic-financial situation of the client, his payment experience, and the macro-sector environment, as well as to other specific factors of the operation.
- CAF will complete the credit evaluation document annually. CAF's credit evaluation document is included in Annex 9 appendix 2.

16. Monitoring, reporting and verification (MRV)

Please refer to Annex 11 - Monitoring and Evaluation Plan, for the extended version of the M&E arrangements and methodologies. Below, the following subsections offer a summary of the different aspects related to the MRV of the Programme.

16.1 Reporting from executing entities to CAF

The Programme will apply the standard procedures established by CAF for monitoring and evaluation of investment operations. Based on the proposed results and a monitoring and evaluation plan to be agreed between CAF and the EEs, the evolution of indicators should be reported periodically during the Programme execution. In coordination with CAF, EEs will compile and maintain all information, indicators, and parameters necessary for the preparation of Programme reports, including annual reports, midterm review and final evaluation.

It will be the responsibility of CFN and local banks, with the technical assistance of FAO and WWF, to ensure that the sub-borrower is eligible for funding from the Programme in accordance with the programme's eligibility criteria. It will be the responsibility of FAO and WWF to ensure that the beneficiaries of grants are eligible for funding from the Programme in accordance with the programme's eligibility criteria. Monitoring of disbursements for eligible expenditures will be reviewed by CAF. In coordination with EEs, CAF may schedule supervision visits to monitor and verify the proper use of resources and compliance with contractual conditions of the Programme with regards to the use of funds.

The monitoring process intends to follow up the execution of the Programme in order to identify the intermediate milestones achieved in each phase and evaluate its outcomes and fulfilment of proposed targets. The indicators to be monitored will be those included the log frame in section E of the funding proposal and reflected in the M&E Plan.

EEs will collect the necessary data for monitoring and present annual reports to CAF. Beneficiaries of the loans will also be trained to be able to contribute with the MRV system and to provide accurate data. In some cases, CAF will make calculations required for some indicators, based on the information provided by the local banks in the annual reports. The EEs' own information systems will undergo a gap assessment by CAF to analyze whether they are sufficient and appropriate for monitoring the proposed indicators.

EEs will deliver these annual reports within thirty (30) calendar days after the end of each year of the Programme´s implementation. The reports will include information regarding the evolution of the indicators, as well as financial information regarding the use of the resources. CAF will be entitled to request additional information, if necessary. In addition to the annual reports and the scheduled activities for monitoring of the operations described above, CAF will contract an independent midterm evaluation within thirty (30) months from the effective date of the loan contract or when 50% of the Programme resources have been disbursed – whichever occurs first. Finally, EEs will present a final report to CAF up to six (6) months after the day of the last disbursement and CAF will contract an independent final evaluation. The EEs' final reports shall contain all relevant information to assess if objectives of the Programme and targets for each indicator have been met. Based on this report, CAF will also prepare a Project Completion Report (PCR), which evaluates the fulfilment of targets, reviews the overall results of the operation, and describes lessons learned, among other relevant aspects.

16.2 Reporting from CAF to GCF

Monitoring, reporting and evaluation arrangements will comply with CAF´s Accreditation Master Agreement and GCF policies, as well as the Funded Activity Agreement (FAA). CAF will provide annual progress reports on the status of the funded activity throughout the relevant reporting period, based on the above-described logical framework, and reporting from Executing Entities to CAF.

CAF will consolidate above described annual, mid-term and final reports from EEs and send them to the GCF within additional thirty (30) days of the above-mentioned reporting periods by EEs to CAF. In addition to these consolidated reports, CAF will report on the indicators defined in Section E of the funding proposal. CAF will deliver numbers in a logframe format a) annually within sixty (60) calendar days after the end of each year of Programme implementation; b) at mid-term within thirty (30) months from the effective date of the loan contract or when 50% of the Programme resources have been disbursed – whichever occurs first; and c) at Programme end up to six (6) months after the day of the last disbursement.

An independent mid-term evaluation will be conducted within thirty months of the effective date of the loan contract or when 50% of the program resources have been disbursed – whichever occurs first. The mid-term evaluation will be based on a participatory and inclusive process, and will involve the following:

- Review of the institutional, technical, environmental, social, economic, and financial aspects of the Programme.
- Review of the progress of activities, planned outputs, expected impacts, cost and financing.
- Review of the achievement of planned impacts and indicators (according to the Logframe).
- Assessment of the need to restructure or reformulate the program.

16.3 MRV framework

In accordance with GCF's MRV requirements, CAF will set up a monitoring framework at Programme level that will apply to all EEs and beneficiaries. The specific MRV actions and steps described below for clean energy, agriculture, fisheries and will be undertaken by the EEs: The envisaged approach to MRV is described in Annex 11.

16.3.1 Energy

For energy efficiency and renewable energy projects, MRV and due diligence processes should be in proportion to the size of the project in order to avoid disproportionately increased costs. Different approaches are recommended for centralized renewable energy projects (medium/large size) and distributed energy and energy efficiency projects (small size).

For small projects, it is recommended that monitoring and evaluation process should primarily be conducted at the local bank level, supported by OT's Mitigation Specialist.

For medium and large projects, a more rigorous process is recommended. The evaluation should be outsourced to experts who would conduct specific studies to determine an appropriate baseline based on the methodology set out below, and verify specified factors including a) the project and technology suppliers capacity to deliver the project, b) correct project installation, c) annual and final monitoring and verification of energy savings / generation compared to the baseline.

The methodology for estimating baselines, energy savings, and greenhouse gas emissions reductions should be based on the International Financial Institutions (IFI) Framework for a Harmonized Approach to Greenhouse Gas Accounting, with the exception of the emission factors that will be used.

The IFI approach for energy efficiency and renewable energy are included in the documents: IFI approach to GHG Accounting for Energy Efficiency Projects and IFI Approach to GHG Accounting for Renewable Energy Projects. These documents set out harmonized approaches for assessing the mitigation benefits, or net GHG emissions reductions for energy efficiency and renewable energy projects. Links to these documents are provided in the feasibility study in Annex II. However, the use of the IFI grid emission factors for MRV purposes would not be adequate because IFI factors generally reflect GEFs for national grids, not for isolated grids such as in the case of the Galapagos islands. Therefore, the IFI methodologies will be used applying, specifically for this project, the emission factors of each isolated system (Baltra-Santa Cruz, San Cristobal, Isabela and Floreana), that will be calculated by IRENA applying the CDM methodology TOOL07. The emissions from fuel transport from the continent, will be calculated in accordance with the Guidelines for Measuring and Managing CO2 Emission from Freight Transport Operations (ECTA

CEFIC, 2011). The emissions have been calculated from maritime transport of fuel to the islands. PUNA ship transports fuel to the islands, which transports 2,400 tons of Diesel.

16.3.2 Agriculture

The EX-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by the Food and Agriculture Organization of the United Nations (FAO) providing ex-ante estimates of the impact of agriculture, forestry and fishery development projects, programmes, and policies on the carbon-balance. EX-ACT is a land-based accounting system, measuring C stocks, stock changes per unit of land, and CH4 and N2O emissions expressed in t CO2-e per hectare and year. The main output of the tool is an estimation of the C-balance that is associated with adoption of alternative land management options, as compared to a 'business as usual' scenario. The tool helps project designers to estimate and prioritize project activities with high benefits in economic and climate change mitigation terms. This is why it is widely used by World Bank investment projects and has already been used in the preparation of GHG analysis for various Green Climate Fund projects. EX-ACT has been developed using primarily the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), complemented by other existing methodologies and literature reviews of default coefficients associated with agricultural/forestry production systems, farm operations and inputs acceptable to the scientific community.

EX-ACT is an easy tool to be used in the context of ex-ante project/programme formulation: it is cost-effective and includes resources (tables, maps) which can help in finding the information required to run the model. It therefore requires a minimum amount of data that project developers can easily provide and is usually collected in the phase of project appraisal. However, it is necessary to prepare this data to determine the adequate modeling of practices/interventions in the tool. This takes into account technical specifications, literature reviews and technical expertise to improve the accuracy of the assessment. All these aspects are discussed below to ensure a clear and transparent understanding of the assessment done for this component.

For MRV proposes it is important to consider the following variables:

- Geographic characteristics
- Business as Usual scenario (without project)
- Proposed agriculture practices (with the project).
- Timeframe.
- Area of intervention.

The net carbon balance will attempt to integrate all the climate-resilient practices above-mentioned and, quantify de CO2-eq emissions or sequestration due to program implementation as compared to a business-as-usual scenario. The first step before modelling is identify which Ex-Act model best fits to evaluate each of the activities proposed under each of the practices as well as the emission factors that will be used either tier 1 (default) or tier 2. The main emission factors per pool used for the assessment are described in Appendix - Carbon Balance

Furthermore, it is cost effective, requires a comparatively small amount of data, and is equipped with useful resources such as tables, maps and FAOSTAT data. While EX-ACT is mostly used at project level it can easily be scaled up to the programme or sector level and can also be used for policy analysis. EX-ACT is based on Microsoft Excel (without macros) and is freely available from the FAO website (www.fao.org/tc/exact).

In the agriculture component, its resilient practices with also mitigation benefits will be financed by different sources: GCF grant, Loan or private sector. Therefore the process for the MRV for the financial loan mechanism with local banks will be different. However, for all cases FAO will provide technical assistance on methodologies and formats Even so as not to discourage access to credit, it could directly provide the bank with basic information on the areas proposed to implement activities.

16.3.4 Fisheries

This program will develop an advanced data system to improve the accuracy, reporting, analysis, and dissemination of subtidal ecological data. Such a system will reduce costs, facilitate adaptive and responsive decision-making procedures, to improve marine zoning management efficiency. An app, a data repository, and a dashboard will be created to collect, store, and analyze annually updated subtidal ecological data. This advanced data system, called the “Subtidal Ecological Monitoring” module, will be created following the transdisciplinary methodology recommended by Bradley et al. (2019). Such a module will be developed in collaboration with the GNP, universities, and NGOs, and be integrated into the “Sistema Único de Información Ambiental (SUIA)”, which is the national data repository system for environmental data in Ecuador.

To ensure the effective implementation of the program actions for the selected fisheries, the program will update annually the fisheries diagnostics for each fishery intervened. The adapted version of the MSC’s Benchmarking and Tracking Tool (BMT) developed by Castrejon et al. (2015) will be used to update each fishery diagnostic. This fishery diagnostic tool represents a comprehensive and standardized analytical framework to measure periodically the progress and impact of a C-FIP[28] implementation over fishery improvement. The MSC+ standard encompasses a set of Principles, Components, Performance Indicators (PIs) and Scoring Guideposts (SG) known as “Default Assessment Tree”, which is used as the basis for assessment of the fishery for compliance with the MSC+ standard (Castrejon et al. 2015). The scoring guideposts incorporate all the scoring elements or scoring issues required at each guidepost.

Each of the 43 performance indicators of the MSC+ will be scored annually using the BMT and following the procedures established by the MSC+ standard to determine changes in the sustainability status of the fishery. Each of the performance indicators will be scored on a graded scale, with levels 60, 80 and 100 defining key sustainability thresholds. A BMT index of 1 means that all performance indicators in the fishery are at least in the 80 level, whereas a BMT score of 0 means that all of the performance indicators are at less than the 60 level. These thresholds correspond to levels of quality and certainty of fishing management practices and their probability of generating sustainability. The final overall score resulted in a “pass” in those cases in which the average score for each principle was greater than or equal to 80, and that each PI was greater than 60; anything below this level resulted in a failure. A fishery can pass with some indicators less than 80, in which case the fishery receives a ‘condition’ requiring improvements so that the score can be raised to an 80 level, normally within a five-year period.

Furthermore, a socioeconomic survey will be designed and implemented, at the beginning and end-of-project, to assess the performance of those seafood enterprises supported by the Blue Action Program and G-Lab, also including the wellbeing of Galapagos small-scale fishing sector. The socioeconomic surveys will be implemented in Santa Cruz, San Cristóbal and Isabela. The aim of the survey will be to establish a baseline and monitor progress of seafood enterprises supported by the Blue Action Program and G-Lab and determine the socioeconomic conditions of small-scale fishing sector using a wider set of indicators.

16.3.5 Ecosystems

For details, please refer to Appendices 2.3 and 2.4.

Marine ecosystems

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28 A C-FIP is defined as an alliance of diverse actors and institutions, including fishers, managers, traders, scientists, private sector, and NGOs, who join efforts to define and agree on an action plan, which specifies the activities that are required to create ecologically sustainable, economically profitable, and socially fair fisheries. This people-centered approach for the improvement of community-based coastal fisheries combines globally recognized ecosystem-based and human rights-based approaches, including the UN FAO’s Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries, and the Marine Stewardship Council Standard (MSC), in combination with blue finance principles, to promote sustainability of coastal community-based fisheries and benefits they provide to humankind.

Risk assessments will be conducted by the GNPD in coordination with the Charles Darwin Foundation (CDF) and ABG to determine the possible pathways for marine invasions and by modelling dispersal mechanisms of potential invasive species, considering variables such as climatic events and oceanographic circulation. A marine Non-native Invasive Species (NIS) dashboard will be created and uploaded to the web-based platform, that will allow dynamic queries and rapid information exchange. This dashboard will be hosted in the CDF DataZone web-based portal and managed by CDFs knowledge management team in collaboration with CDF scientists, GNPD and ABG technicians.

Additionally, eight assessments over 4 years will be conducted of the natural and restored coral ecosystems and their relationship with oceanographic and climatic parameters in the GMR. This will be done over in the warm and cold seasons each year of the project. For the monitoring of coral communities linear transects will be installed to characterize the benthic structure of the area and collect information on the health of the colonies, permanent plots will be established that allow the replication of monitoring over time on a section of the same community. Although the focus of this activity is on the health status of corals, the fish, invertebrates and algae associated with them will be monitored as well because these can be indicators of changes in the coral reef assemblage.

Diving sites will be monitored ecologically and mapped to identify fragile species and areas (e.g., areas with high coral cover). The monitoring will include fish and other macrofauna (sea lions, marine turtles, etc.), macroinvertebrates and benthic cover components. Fixed plots at visitor sites and control sites will be monitored over time for change detection. The sites will be monitored during the duration of the project, but data will be compared before and after the implementation of Diving Best Practices Toolkit, to detect possible changes due to the intervention.

Complementarily, to implement a pollution monitoring plan at marine visitor sites, quantification of the magnitude of the presence of pollutants (heavy metals, organic compounds (hydrocarbons, Benzophenone-2 and 3, micro plastics) will be implemented. Pollutants presence and quantity will be compared between visitor and control sites and relationships between site use and pollutants concentration will be analysed. Each site will be sampled for water, sediment, and representatives of the food chain (fish, gastropods, sea urchins, algae, and corals, three species each). Metals and micro plastics will be analysed in at least 30 sites, organic compounds in 15 sites and organic pollutants (e.g., coliforms) in ten sites. Visitor sites will be chosen by level of use so as to have at least sites with very high and low use (plus control sites with no tourism at all). This sampling design will establish a baseline in pollutants from tourism and evaluate the levels of pollution by comparison between highly visited sites, sites with low visitation and control sites. Also, the degree of impact from pollutants across the marine food chain will be established.

For sea turtles, monitoring of incubation temperatures in nesting beaches of the archipelago through temperature data loggers to collect data of sand temperature during the nesting season in two beaches with potentially different thermal conditions. Monitoring will also be implemented to provide a permanent update on the boat strike incidence on sea turtles at feeding sites. Annual monitoring of the feeding sites will help to monitor the success of the implementation of marine traffic regulations.

<u>Terrestrial ecosystems</u>:

Restoration success will be evaluated with the help of permanent plots previously established by the Charles Darwin Foundation (CDF) and a vegetation mapping with drones and high-resolution satellite imagery (resolution of 0.5 m x 0.5 m, see section 12.5.2), in close cooperation with the GNPD and other relevant stakeholders.

Monitoring of the plant communities will be continued in at least 150 of the currently 180 permanent plots established by CDF, using the line-intercept method (Kaiser 1983). The diameter at breast height (DBH) will be measured from key endemic species (like Scalesia spp) or invasive species (like Psidium guajava or Cinchona pubescens). For example, we will monitor plant communities in the 44 permanent 20 x 20 m plots (established in 1998), representing untouched (e.g. Los Picachos) to manually and chemically controlled plots (e.g. Media Luna, Puntudo and Cerro Crocker) to be able to disentangle climate impacts associated with El Niño from the impacts of invasive species and management control actions. It is widely acknowledged that long term monitoring is the best way to detect population and community responses to climate change, and our long-term plots represent a “gold mine” of information in this regard. Our work will focus on the key species quinine (*Cinchona pubescens*), blackberry (*Rubus niveus*), bracken (*Pteridium arachnoideum*) and Miconia (*Miconia robinsoniana*). Since blackberry has been detected in the plots during the last couple of monitoring, there is a high probability that it will increase and become dominant with increased El Niño rainfalls in the future (see Appendix 2.4). Therefore, long-term data will be analyzed and related to available weather data. Further, during the monitoring of new and established permanent plots, we will determine the dominant (often introduced) insect species, since these are expected to increase in Galapagos due to climate change (Trueman et al. 2010). This also applies to the agricultural zone, where more species have been encountered that adversely affect crops (Cañarte Bermúdez et al. 2020).

Applied control techniques will be constantly monitored and evaluated to ensure high efficacy, while at the same time minimizing negative impacts on non-target species. The information produced through the monitoring program will inform the GNPD via co-implementing monitoring and restoration actions, training, and outreach. In addition, the project will consolidate a data management and information system where all the information will be uploaded. It is envisaged the information system will inform restoration actions based on an adaptive management scheme.

Further, to document restoration success and changes in the plant and animal communities of the Scalesia forest fragments, a baseline will be established for different species on Santa Cruz, San Cristóbal and Isabela. Prior to the onset of restoration actions, 10 plots on each island will be established to document restoration success and changes in the plant and animal communities, as well as in the composition of agricultural crops.

Finally, the program will evaluate the impact of restoration by estimating the above ground stored carbon and CO2 sequestration rates of the ecosystems under restoration. The activities below will be carried out at the beginning of the project and then again just before it ends, to be able to determine significant changes in the restored ecosystem.

- *Measure aboveground plant biomass and nutrient contents*

Aboveground biomass will be mainly measured using remote sensing, by the classification of vegetation cover and the generation of a vegetation type map, that would be calibrated, using regional-scale inputs of basal area and wood density of species in permanent plots (Asner and Mascaro 2014). This will partition the spatial variability of vegetation into relatively uniform zones or vegetation classes, which will be used to extrapolate biomass estimates. In addition, indirect estimation of biomass will be used, like quantitative relationship (e.g. regression equations) between band ratio indices (NDVI, GVI, etc.) and direct radiance values per pixel, with direct measures of biomass and parameters related directly to biomass, e.g. leaf area index, which would need to be assessed by this project. Results obtained will be validated by biomass measurements in the field of the live plant mass aboveground and belowground (using standard estimation methods - allometric and linear regression equations method), as well as the herbaceous layer on the forest floor, including the inert fraction in debris and litter (using standard methods, which include gravimetric and chemical analysis). Plant samples will be transported to the UDLA University in Quito, Ecuador, where analysis of the macro- and the main micronutrients will be conducted.

- *Measure soil and plant carbon and soil nutrients*

SOC stocks will be determined by a regression approach in which SOC densities (mass SOC/area) will be related to a number of auxiliary variables like temperature, precipitation, age class and land-use history. These measurements will be accompanied by a geographic information system (GIS) to calculate SOC densities for each vegetation type from available soil characteristic data and satellite-derived land cover information (Campbell et al. 2008). To validate results obtained, representative soil samples will be collected and transported to the UDLA University in Quito, Ecuador, where analysis of the macro- and the main micronutrients will be conducted.

- *Calculate CO2 sequestration of the ecosystems*

We will estimate the amount of carbon sequestration based on wood density and allometric equations of tree crowns based on DBH were estimated. Crown dry weight will be multiplied by the number of trees of each species in different diameter classes. The trunk weight of trees in different diameter classes is calculated using the wood density and stand volume. The biomass weight of standing trees is calculated by total weight of trunk (trunk biomass) and crown dry weight (crown biomass). The weight of carbon dioxide in the trees will be determined by the ratio of CO2 to C and the weight of carbon dioxide sequestered in the tree by multiplying the weight of carbon in the tree by 3.671 (IPCC 2005).

16.3.6 Behavioral change

BIT uses its bespoke methodology to work with partners through the process of applying behavioral science to achieve social impact goals. This approach—called TESTS, for Target, Explore, Solution, Trial, and Scale—is flexible enough to ensure that, while structured similarly, each project will address a unique challenge and produce tailored solutions. Please refer to Appendix 3.4 for further information on this methodology.

In this sense, in the stage of Trial, together with BIT, we are going to design an evaluation to determine the causal impact of the selected interventions to a high degree of scientific rigor. Whenever possible, we use randomized control trials (RCTs), which are generally seen as the "gold standard" of evaluation. We design our evaluations with the goal of determining whether there is a statistically significant effect, its direction and its magnitude. We also aim to determine what works best, in what context, and for whom, so that the most effective solutions can be scaled up or shared across similar contexts and situations. Although RCTs are BIT's preferred and most common method of evaluating behavioral insights interventions, they are experts in applying other rigorous methods of quantitative evaluation when RCTs are not feasible. In the past, we have used evaluation designs that include difference-in-differences, propensity score matching, coarsened exact matching, regression discontinuity, and instrumental variables.

The evaluation design process that will be used to mainstream the behavioral change approach (Appendix 3.4), not only maximizes the chances of generating valuable evidence on what works, it also seeks to build capacity within our partner organizations to perform rigorous evaluations on their own. BIT together with appropriate stakeholders at WWF, CAF, FAO and local partners, we will also identify a reliable way to randomly allocate participants to treatment and control groups. Based on substantial experience in finding pragmatic yet robust ways of randomizing.

Depending on the number of behavioral change interventions we implement, we will produce one or more trial protocol(s) that will specify exactly how the intervention and the evaluation need to be implemented, our testable hypotheses, and the analysis plan that will be followed. The trial protocol will be shared with and approved by the appropriate source before launch.

For each evaluation, we will focus on the following components to ensure quality and timeliness of delivery:

- Pre-implementation checks and viability testing. Before going live, we will test whether the intervention is being successfully implemented (e.g., checks to see if the randomization is reliable or whether the resulting data is recorded appropriately).
- Implementation period. During the implementation period, we will be in touch with the appropriate partner project lead to make sure that the project goes to plan. We may request intermittent data samples to check that the intervention is being delivered reliably. BIT will assist in implementing the intervention and can provide remote or on-site support, if needed. Furthermore, the BIT project team will make project design adjustments as necessary.
- Data analysis and quality assurance. Once the formal trial period comes to an end, we will request the trial data, appropriately anonymized. These data will be transmitted and stored in line with our data management procedures. Our research team will analyze them according to the pre-specified analysis plan. The results will be written up and undergo our rigorous internal quality assurance process.

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