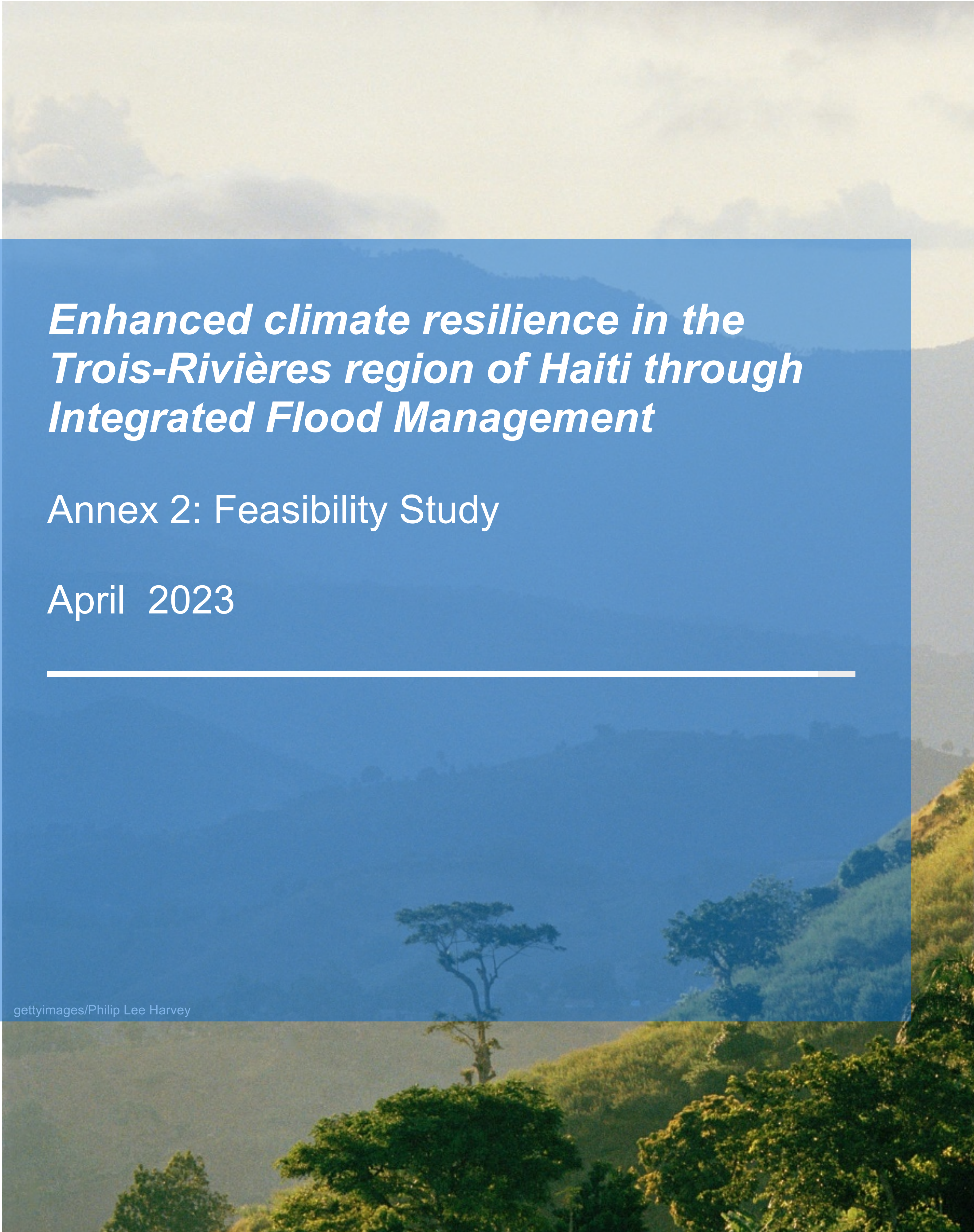
Enhanced climate resilience in the Trois-Rivières region of Haiti through Integrated Flood Management

Annex 2: Feasibility Study

April 2023



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List of acronyms

AE	Accredited Entity
AO	Administrative Officer
CARICOM	Caribbean Community
CIAT	Inter-ministerial Committee for the Management of the Territory
CSO	Civil Society Organisations
DIINEPA	National Directorate for Water Supply and Sanitation
DRR	Disaster risk reduction
EbA	Ecosystem-based Adaptation
EE	Executing Entity
EU	European Union
EWS	Early Warning System
FAO	Food and Agriculture Organisation of the United Nations
FPO	Financial and Procurement Officer
GCCA	Global Climate Change Alliance +
GCF	Green Climate Fund
GDP	Gross domestic product
GEF	Global Environment Facility
GHGs	Greenhouse gases
GoH	Government of Haiti
HTG	Haitian Gourdes
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IMCAWA	Integrated Management of Watersheds and Coastal Areas
IPCC	Intergovernmental Panel on Climate Change
IT	Information Technology
IWRM	Integrated Water Resources Management
LDCF	Least Developed Countries Fund
M&E	Monitoring and Evaluation
MARNDR	Ministry of Agriculture and Natural Resources
MoE	Ministry of Environment
MoP	Ministry of Planning and External Cooperation
MPW	Ministry of Public Works
NAP	National Action Plan
NAPA	National Adaptation Programme of Action
NEAP	National Environmental Action Plan
NDC	Nationally Determined Contribution
NGOs	Non-governmental organisations
PC	Project Coordinator
PM	Project Manager
PMC	Project Management Committee
PMU	Project Management Unit
PO	Programme Officer
SIDS	Small Island Developing States
SDPH	Strategic Development Plan for Haiti
ToRs	Terms of Reference
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
US	United States
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organisation

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Executive summary

A Feasibility Study has been prepared to support the proposed GCF project, entitled *"Enhanced climate resilience in the Trois-Rivières (TR) region of Haiti through integrated flood management"*. The objective of the project is to implement an integrated approach to land and water resources management to manage the impacts of climate change-induced flooding. This approach is underpinned by a strengthened institutional framework that will create the enabling environment for the sustainable uptake and scaling up of climate-resilient flood management interventions in Haiti. The following sections of the Feasibility Study describe the baseline situation of the country, as well as provide technical analyses and support of the proposed project interventions presented in the GCF Funding Proposal.

1.1. Geography, demographics and socio-economic context

1.1.1. Geography

Located in the Caribbean archipelago, Haiti occupies the western end of the Hispaniola Island while the Dominican Republic occupies the eastern end. With an area of 27,750 km^2, Haiti has 31 watersheds, ~160 major rivers and a predominantly rugged terrain, with ~80% of the total land area being mountainous. More than half of the country's land is on a slope of 40% or greater, while less than a quarter of the country is on a slope of 10% or less. Other major types of landscapes include river valleys and coastal flatlands, with these lowland plains occupying the remaining 20% of the total land area (~550,000 ha)[1]. The Hispaniola Island lies along the border of two large tectonic plates — the North American and Caribbean plates — and two major fault lines run through Haiti, the Enriquillo-Plantain Garden and the Septentrional faults. This geological placement makes Haiti vulnerable to earthquakes and aftershocks, with consequent negative effects on its population further compounded by a limited capacity to respond and adapt to natural disasters[2].

1.1.2. Population

Haiti has a population of ~11 million people (~55% women), with an annual population growth rate of ~1% and a projected increase to ~14 million people by 2050. In 2017, the average population density was ~392 people per km^2, with 60% (~6.5 million people) living in urban areas along the 1,535 km coastline[3]. The 2018 Climate Risk Index listed the country as the most affected by hydrometeorological disasters in the world[4], with 96% of Haitians at risk of natural hazards[5]. Climate vulnerability is exacerbated by a high incidence of poverty, with ~59%[6] of the population living below the national poverty line[7]. Poverty across the country is highest in isolated rural areas, increasing the vulnerability of communities to extreme weather events by constraining their adaptive capacity[8]. Additionally, approximately one in three Haitians require food assistance[9], with food insecurity having subsequent negative public health impacts such as an increased likelihood of contracting diarrheal diseases.

[1] The World Factbook: Haiti. N.d. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/ha.html
[2] USGS. N.d. Significant Earthquakes on a major fault system in Hispaniola, Puerto Rico, the Virgin Islands, and the Lesser Antilles, 1500–2010: Implications for Seismic Hazard Available at: https://www.usgs.gov/centers/whcmsc/science/significant-earthquakes-a-major-fault-system-hispaniola-puerto-rico-virgin?qt-science_center_objects=0#qt-science_center_objects
[3] Index Mundi. 2019. Haiti Demographics Profile 2019. Available at: https://www.indexmundi.com/haiti/demographics_profile.html
[4] Germanwatch. 2018. Global Climate Risk Index 2018 – Who Suffers Most from Extreme Weather Events? Weather-related Loss Events in 2016 and 1997 to 2016. Available: http://germanwatch.org/files/publication/20432.pdf
[5] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions.
[6] UNDP. N.d. Haiti: Human Development Indicators. Available at: http://hdr.undp.org/en/countries/profiles/HTI
[7] World Bank. 2020. The World Bank in Haiti. Available at: https://www.worldbank.org/en/country/haiti/overview
[8] World Bank. 2010. Disaster Risk Management in Latin America and the Caribbean Region: Country Notes – Haiti. Available at: https://www.gfdrr.org/sites/default/files/publication/drm-country-note-2010-haiti.pdf
[9] World Food Programme. N.d. Haiti. Available at: https://www.wfp.org/countries/haiti

Urbanisation in Haiti is increasing due to climate change impacts — such as an increased frequency and intensity of floods — which are forcing farmers into urban areas in search of alternative livelihood options[10]. This contributes to an increased vulnerability of Haiti's population to natural disasters as the number of people living in flood-prone areas, often in informal settlements, is increasing[11] — with ~65% of the urban population residing in informal settlements[12].

1.1.3. Economy

Haiti is the only Least Developed Country (LDC) in the Western Hemisphere, with an annual GDP per capita of ~US$1,810 in 2018[13]. It is a free market economy, with agriculture being one of the largest contributors to the country's GDP (at ~22%, behind services and industry sectors at ~58% and 20%, respectively) and much of the agricultural workforce — particularly women — undertaking small-scale subsistence farming[14]. The Artibonite Department, which is part of the proposed project's target area, is known as Haiti's 'breadbasket' because of its high agricultural output. However, the agriculture sector has already been affected by climate change across the entire proposed project area, the impact of which is expected to be exacerbated in the future.

1.2. Climate profile

Haiti has a year-round hot and humid tropical climate with an average annual temperature of 24.4°C, and temperatures reaching as low as ~15°C and ~35°C in winter and summer, respectively[15]. Average annual rainfall in Haiti ranges between 1,400–2,000 mm, with uneven distribution across the country. This is because rainfall levels differ according to the island's varied topography, meaning central, mountainous regions receive more rainfall than the northern and western regions that are characterised by lowland plains. Annual precipitation in mountainous areas averages 1,200 mm, while in the plains it is as low as 550 mm[16]. The North-West, Artibonite, North-East, and Central Departments frequently experience repeated droughts caused in part by unpredictable rainfall patterns[17]. Because of its small size, the entire country is situated within a hurricane belt, with severe storms routinely occurring from June to October — often leading to widespread flooding resulting from concentrated precipitation events[18]. Several climatic factors contribute to Haiti’s vulnerability to flooding, including: i) changes in the variability of rainfall and extreme weather events; ii) intense seasonal rainfall; and iii) storm surges in coastal zones. This vulnerability is exacerbated by the country’s generally fragile soil conditions and unsustainable land-use practices (e.g. charcoal production), which reduces forest cover and increases the incidence of flooding in Haiti, particularly in watershed areas.

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[10] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti. *Oxfam Research Reports.* Available at: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/314540/rr-climate-change-resilience-haiti-260314-en.pdf;jsessionid=EC22CC2F0C14C211175539E5EB3FF87C?sequence=1
[11] Singh, R.J., and Barton-Dock, M. 2015. *Haiti: Toward a New Narrative.*
[12] UNDP. 2013. MDG Report – Haiti: A New Look. Available at: https://www.latinamerica.undp.org/content/rblac/en/home/library/mdg/HaitiMDGReport2013/
[13] World Bank Data. N.d. GDP per capita, PPP (current international US$) - Haiti.
[14] Index Mundi. 2019. Haiti Economy Profile 2019.
[15] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf
[16] USAID. 2015. Climate Change Information Fact Sheet: HAITI. Available at: https://www.climatelinks.org/sites/default/files/asset/document/Haiti%20Climate%20Info%20Fact%20Sheet_FINAL.pdf
[17] World Bank Group. 2019. Climate Knowledge Portal: Haiti Country Context. Available at: https://climateknowledgeportal.worldbank.org/country/haiti/climate-data-historical
[18] World Bank. 2011. Climate risk and adaptation country profile: Haiti. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_HTI.pdf

1.3. Climate rationale

As a Caribbean Small Island Developing State (SIDS) and Least Developed Country (LDC), Haiti is one of the most vulnerable countries in the world to climate change, including increases in the frequency and intensity of flooding, hurricanes and tropical storms. The impacts of climate change-induced flooding, in particular, are already adversely affecting Haiti's economy, with the associated negative impacts having severe consequences for several of the country's major economic sectors, including agriculture.

The agricultural sector is highly vulnerable to frequent extreme weather events and natural disasters[19]. For example, frequent flooding has impacted agricultural productivity as floods result in crop losses and degradation of agricultural soils through erosion[20]. Following Hurricane Jeanne, hillside erosion caused by flooding also led to crop reductions as gravel flooded the farmers' fields, making cultivation difficult afterwards. These losses have led to considerable impacts on economic activity across the Artibonite Department in recent years. This department is a major food-producing region in North-West Haiti that is particularly vulnerable to the impacts of climate change-induced flooding. Such impacts will be exacerbated by climate change — particularly the increased frequency and intensity of flooding, hurricanes and tropical storms combined with increased rainfall variability. A further example of the impacts of climate change on agriculture is the changes in rainfall variability which have already shifted the growing season, impacting the suitability of certain crops[21]. Under future climate change conditions, both small-scale subsistence farming and larger, commercial agricultural operations are likely to be increasingly impacted by climate change. For example, the resulting climatic conditions are not appropriate for the cultivation of corn. Furthermore, climate change will negatively impact the economic viability of export agriculture, decreasing Haiti's competitive advantage in the global trade of crops such as coffee and cacao, as well as the amount of productive land available for growing them[22]. The impacts of rainfall variability are particularly challenging for rural farmers in the Artibonite, Nord (hereafter 'North') and Nord Ouest (hereafter 'North-West') Departments who rely on rainfed agriculture as they lack access to irrigation and depend predominantly on climate-sensitive crops such as corn and tubers as a source of income[23;24]. If average annual rainfall declines, temperatures continue to rise, and storms intensify, as predicted, the yields of subsistence farmers will likely decrease, adversely affecting nutrition and the resilience of agricultural livelihoods[25,26].

The above-mentioned adverse impacts of climate change on the livelihoods of vulnerable communities are already being experienced frequently in Haiti. During the period 1993–2012, Haiti experienced 31 floods[27], 10 of which were directly attributed to hurricanes and a further 16 attributed to extreme rainfall events since 2000[28]. During this period, these floods caused the deaths of ~2,870 people and adversely affected ~9 million people in total through livelihood losses and personal damages. In 2004, Hurricane Jeanne alone caused flooding in the northern part of Haiti that resulted in more than 2,800 deaths, ~US$41 million in damages and the need to remove ~592,000 m^3 of mud that clogged drainage networks and infrastructure

[19] Index Mundi. 2019. Haiti Economy Profile 2019.
[20] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[21] FAO. 2017. FAO/WFP Crop and Food Security Assessment Mission to Haiti. FAO, Rome.
[22] Centro Internacional de Agricultura Tropical. 2013. Prediction of the impact of climate change on coffee and mango growing areas in Haiti. Available at: http://dapa.ciat.cgiar.org/wp-content/uploads/2014/03/CC_impact_coffee-mango_Haiti_CRS-CIAT_final.pdf
[23] Singh, B., and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[24] https://geonode.wfp.org/layers/geonode%3Ahti_pop_livelihoodzones_fewsnet2014_geonode_20170417
[25] World Bank. 2011. Vulnerability, Risk Reduction, and Adaptation to Climate Change: Haiti. Available at: http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_HTI.pdf
[26] USAID. 2017. Climate Risk Profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf
[27] The World Bank. 2018. Resilient Productive Landscapes in Haiti (P162908).
[28] which are directly attributed to hurricanes and tropical storms.

across the country[29]. Furthermore, Hurricane Matthew, the Category 5 hurricane that struck Haiti in 2016, caused intense flooding across the country and resulted in an estimated US$8–14 billion in damages and economic losses[30].

While most of Haiti is at risk to the impacts of climate change, the country's Trois-Rivières (TR) watershed (which extends across the Artibonite, North and North-West Departments) has been identified as particularly high-risk[31]. Although the Three Rivers watershed is not the largest watershed in the country, its population — located in six cities and three departments — is highly vulnerable to the impacts of climate change. TR watershed is prone to frequent flooding in the municipalities it crosses, with adverse effects particularly on poor communities who do not have sufficient resources to adequately respond. The rural areas of Trois-Rivières — such as Marmelade, Plaisance, Pilate, Gros-Morne, Bassin Bleu, Chansolme, and Port-de-Paix — are home to 80% of Haiti's population of extremely poor people. These areas have an extreme poverty rate of 40%, which is almost twice the national average of 23.9%, and much higher than any other area (for comparison, Port-au-Prince has an extreme poverty rate of 4.9%). In addition to the high rate of poverty, which inhibit communities from adapting and responding to climate impacts, the impacts of extreme climate events are being compounded by ecosystem degradation caused by unsustainable agricultural practices such as the increasing area under crop cultivation, and particularly the practice of leaving soil bare and exposed to extreme weather for most of the year. During intense rainfall and storm events that cause flooding, the limited ground cover leads to increased surface runoff and consequently exacerbates soil erosion in the watershed. This erosion is compounded by extensive deforestation in the mountainous parts of the watershed, primarily linked to charcoal production. The demand for charcoal in Haiti is high because of its use as a primary source of fuel to meet household energy demands. This demand is unlikely to decrease in the foreseeable future, with many farmers in the TR watershed resorting to charcoal production as an alternative livelihood in response to low yields, crop failure or unexpected expenses (particularly in extremely wet or dry years). As a result, most of the native forests have been harvested, with minimal effort towards reforestation activities[32]. These practices have radically changed the TR watershed's natural landscape, where the large-scale removal of tree cover has decreased infiltration capacity of the soil and contributed to increased surface runoff during heavy rainfall events. This, in turn, has considerably increased flood frequency and intensity in the TR watershed, with floods washing away fertile soils and causing sedimentation of riverbeds and blocking drainage infrastructure. Given the near-complete absence of embankments and levees in the watershed, this cycle then intensifies the next round of flooding, leading to the destruction of crops, farmland and agricultural infrastructure, as well as the loss of livestock and human lives[33]. Vulnerable communities that depend on agriculture for their livelihoods will be particularly affected by the increased flooding, exacerbating the adverse economic, environmental and social conditions already being experienced in the area.

While frequent and intense flooding, soil erosion and sedimentation of rivers have considerable adverse impacts on the landscape and agriculture in the TR watershed, they also have severe consequences for water resources and human health. The erosion of riverbanks and sedimentation build-up in rivers caused by flooding considerably decreases water quality in the watershed, with multiple impacts on freshwater and marine biodiversity as well as increasing the risk of waterborne diseases in surrounding communities. Women and girls are particularly at risk as their household duties — including cooking and cleaning —

[29] Gaspard G. 2013. Flood Loss Estimate Model: Recasting Flood Disaster Assessment and Mitigation for Haiti; The Case of Gonaives. Available at: https://pdfs.semanticscholar.org/b32b/d0ccdce15f58b07a70f5b1bd5d570baf7f79.pdf.
[30] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions.
[31] according to four different studies and assessments (including Oxfam's).
[32] World Bank. 2017. Charcoal in Haiti. A National Assessment of Charcoal Production and Consumption Trends. World Bank, Washington. Available at: http://documents.worldbank.org/curated/en/697221548446232632/pdf/134058-CharcoalHaitiWeb.pdf.
[33] OXFAM, Welt Hunger Life, NATHAT, and Cap-Haitien.

involve the highest level of exposure to potentially contaminated food and water[34]. The adverse health risks of diarrheal diseases are exacerbated by flooding, which further extends the spread of water pollutants, disrupts water supply and increases the potential of exposure to contaminated water. The TR watershed is particularly vulnerable to waterborne diseases given the area's exposure to flooding. For example, ~19,100 diarrhoea cases were reported in the watershed in 2018, accounting for ~35% of all cases of diarrhoea in the country at that time. The TR watershed is classified as one of the "priority" watersheds for development by the World Bank and the Inter-American Bank based on the area vulnerable to flooding and potential for loss of life and property[35]. Therefore, the TR watershed is an area of strategic interest for the country, both on a socio-economic and ecological level[36]. The interest in developing actions in this watershed lies in: i) the protection of downstream area of this watershed — particularly coastal ecosystems such as mangrove which are important for protecting fishing villages such as Haut Fourneau from flooding and serves as a privileged space for fishing and the protection of biodiversity; ii) the protection of the national road #5, the main road connecting the North-West and Artibonite; iii) the conservation and development of water upstream of a very degraded watershed inhabited by many people for whom the land is the only resource for their livelihood; and iv) the pooling of two very complementary approaches which are Risk and Disaster Management (RMD) and Integrated Water Resources Management (IWRM) in a territory where the mountain-sea links between the communities are inseparable.

Given that the frequency and intensity of flooding in the TR watershed is likely to increase under future climate change conditions[37], the impacts of these events on the watershed are expected to become increasingly severe in the absence of urgent adaptation interventions. Further details on the projected changes in rainfall, storm frequency and temperature as well as in the hydrological conditions of the TR watershed are contained in Section 3 of this Feasibility Study.

1.4. Policies and governance

The Government of Haiti (GoH) has established several policy frameworks, strategies and initiatives to increase the resilience of Haiti's watersheds and agricultural sector to climate change impacts, particularly flooding. These strategic documents include: i) the National Adaptation Programme of Action (NAPA) and the Second National Communication on Climate Change to the UNFCCC (SNC). Haiti has also established several other policies and strategies relating to climate change, disaster risk reduction and management (including flooding), agriculture and land use. The proposed project is designed to align with these documents, having been designed in close collaboration with relevant stakeholders in the target sectors. These stakeholders include the: i) Ministry of Environment (MoE); ii) Ministry of Agriculture, Natural Resources and Rural Development (MARNDR); iii) Ministry of Public Works, Transportation, and Communication (MPW); and iv) Ministry of Planning and External Cooperation (MoP).

Best practices and lessons learned at the international, national and regional level during past and ongoing initiatives have been drawn from for the design of the project. These will also be

[34] GBV Sub-Sector Nigeria. 2017. Briefing Note: Integrating Gender in Cholera Prevention and Control Interventions in North East Nigeria. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/briefing_note-gender_in_cholera_response.pdf. Accessed 15/06/2020.

[35] Smucker, Glenn, T. Anderson White and Michael Bannister. Land Tenure and the Adoption of Agricultural Technology in Haiti. CAPRi Working Paper No, 6, 2006.

36 Scot E. Smith and Daniel Hersey., 2008. Analysis of Watershed Vulnerability to Flooding in Haiti. World Applied Sciences Journal 4 (6): 869-885, 2008.

[37] Further details on the projected changes in storm frequency and intensity are contained in Section 3 of this Feasibility Study.

applied to the implementation of the project, as described in Section 7 of this Feasibility Study. Doing so will facilitate adaptive management and ensure that maximum adaptation and flood-reduction benefits are delivered to all project beneficiaries beyond the project lifetime.

1.5. Barriers to addressing climate change impacts

Several barriers to the preferred adaptation solution have been identified for Haiti. These are summarised below and explained in detail in Section 8 of Annex 2: Feasibility Study. The barriers fall broadly in the themes of institutional barriers (Barriers 1, 2 and 3), financial barriers (Barrier 4) and social/psychological barriers (Barriers 5 and 6).

Barrier 1. Limited technologies, resources and knowledge for climate-resilient flood management

Communities in Haiti, particularly farmers, are not informed about current and projected climate change impacts, particularly flooding, on agricultural production, other land-use practices and water resources. There is also limited technical knowledge amongst communities on how to adapt to these changes and increase climate resilience, particularly using Ecosystem-based Adaptation (EbA) solutions. The limited understanding of communities and farmers of the impacts of climate change and how to address them (e.g. through adopting climate-resilient agricultural practices) increases their vulnerability over the long term. This vulnerability is compounded by existing limitations in practical and technical experience to establish and manage local, financially sustainable small-scale tree propagation operations that serve reforestation and agroforestry needs. Community members generally prefer to migrate to urban areas or engage in alternative rural occupations, as these options are perceived to offer more financial stability than tree propagation operations and agroforestry.

Barrier 2. Absence of integrated, climate-sensitive water and land management policy and governance frameworks

Currently, there are no integrated, climate-sensitive water or sustainable land management policy and governance frameworks in Haiti. The country lacks overarching water management legislation, a formal cadaster, a standard practice for land tenure arrangements, or relevant strategies to promote sustainable landscape management. Absence of a regulatory framework and enforcement of sanctions and property rights also reinforces an open-access interpretation of community assets, which is compounded by social barriers (see Barriers 5 and 6) such as the lack of public and private incentives for reforestation. In terms of governance, there are no administrative structures at the catchment or sub-catchment levels, and there are currently no local water resources user associations or other community committees that have the skill and capacity for integrated water resources management (IWRM). This lack of vertical coordination and oversight is evident in line ministries providing weak or minimal support to local communities, which leads to limited support for farmer associations to implement changes in conservation or to manage water resources. Constraints in these policy and governance frameworks — as well as the limited integration of lessons learned — has produced three major concerns, namely: i) existing legal instruments that do not consider the projected threats from climate change; ii) lack of land use planning implementation and enforcement that has led to deforestation and degradation; and iii) a lack of coordination in planning, implementation and accountability caused by undefined roles and responsibilities of institutions dealing with water management

Barrier 3. Limited coordination and capacity to implement/execute

Implementing/executing entities, government and non-governmental stakeholders in Haiti have limited opportunity and incentive to coordinate efforts to address climate risks. This leads to: i) projects by different organisations often being designed independently, without consideration of how they affect each other or address the broader resilience of the country; and ii) limited coordination among donors or between GoH ministries during project implementation. Local authorities and stakeholders at the forefront of managing climate change impacts are also not equipped and trained to incorporate climate change considerations into decision-making or to design and implement climate-resilient water management. This is evident in the lack of catchment and sub-catchment administration structures and capacity to oversee participatory, equitable and adaptation-focused decision-making on water and land use, which further amplifies households prioritising private gains over catchment-wide benefits.

Barrier 4. Limited access to credit, savings and financial instruments or incentives amongst farmers

There are financial barriers to farmers wanting to implement sustainable land management practices in Haiti. These include a lack of access to capital to invest in start-up costs, maintenance materials and tools, as well as limited "bridging" of household reserves to cope with crises. In this context, "limited bridging of household reserves" refers to the absence of emergency savings or other financial support for farmers so that, if crops fail because of climate change impacts and/or other disasters, they would be able to support their livelihoods immediately after these events until they are able to start generating their own income again. Alternative sources of funding and credit are not available or are difficult to access, which leads to short planning horizons. These planning horizons drive short-term relief activities, such as the production of charcoal at unsustainable rates to meet pressing short-term financial needs. For agroforestry and climate-resilient agricultural practices to be sustainable, incentives for farmers to implement these systems are needed to allow farmers to overcome this short-termism and to allow time for these systems to produce returns.

Barrier 5. Limited incentives for communities to change land management and farming practices or contribute to communal resilience building

Limited understanding of climate change impacts compounds prevailing circumstances, — such as poverty — that emphasise the prevalence of household or individual short-term decision-making over long-term communal resilience and well-being. Households (which have a high discount rate[38]) make decisions in their own interest, without necessarily considering the impact of those decisions on the sub-catchment. Additionally, charcoal production is entrenched in communities as the major source of energy for cooking, having significant economic importance and few available alternatives to households. There is also no experience or incentive among water users to consider sub-catchment scale water management in their household decision-making. Finally, the familiarity of established, unsustainable farming practices is a barrier to better alternatives as households are reluctant to change to new crops or practices without the development of local markets and social safety nets.

Barrier 6. Absence of inclusive and participatory community consultation mechanisms for climate change-induced flood management planning and decision-making

The absence of participatory and inclusive planning, which is a fundamental principle of an integrated flood management approach for climate resilience, means that communities are not currently incentivised to take up adaptation interventions in Haiti. Underlying factors for this include technical and financial capacity constraints at the municipal level. These have historically limited the ability of public officials to effectively engage with appropriate communities and stakeholders during decision-making on land and water resource

[38] A higher discount rate implies greater financial uncertainty and income insecurity.

management. Given the strong influence of social factors such as gender inequality on vulnerability to flood impacts, it is necessary to promote inclusive decision-making processes to ensure buy-in and effectiveness in interventions. Past interventions have been criticised for failing to take gender and other considerations into account by focusing on general agricultural incomes and outputs, access to which is shaped by prevailing systems of privilege.

1.6. Proposed project interventions to overcome existing barriers

The proposed project will contribute to GCF's paradigm shift objective of increased climate-resilient sustainable development through enhancing the resilience of Haiti's Trois-Rivières (TR) watershed to the impacts of climate change-induced flooding. This shift will be achieved by implementing a transformative approach to the way in which the GoH addresses flood impacts from uncoordinated decision-making around flood management at the national and local levels towards adopting an integrated approach to land and water resources management in the watershed. Such a proactive approach will include direct investments into: i) implementing agroforestry systems and rehabilitating 'water towers[39]' through reforestation of degraded landscapes at priority intervention sites; ii) enhancing technical and institutional capacity for productive climate-resilient land management at the national and local levels; and iii) establishing the governance framework for integrated water resources management (IWRM) to support the climate-resilient land management systems and facilitate sustainable use and management of water resources over the long term. The cumulative effect of project interventions will result in the implementation and adoption of a climate-resilient, integrated approach to flood management that can be readily scaled up and replicated nationally and across the Caribbean region. Proposed project outputs and activities are described in detail in Section 9 of this Feasibility Study and Section B.3 of the Funding Proposal.

Context and baseline

2.1. Assessment of baseline physical and geographical characteristics

As a Small Island Developing State (SIDS), Haiti is highly vulnerable to natural hazards. Between 1993 and 2012, the country experienced an earthquake, two droughts, 26 tropical storms and hurricanes and 31 floods[40,41]. Approximately 96% of Haiti's population lives at risk of exposure to natural disasters[42]. This risk will increase under current climate change projections, as natural disasters in Haiti are likely to increase in both frequency and intensity, further contributing to the country's vulnerability to acute shocks and chronic stresses, such as disease outbreaks and weakened water supply systems. In 2014, Haiti was ranked as the most vulnerable country to climate change in the Latin American and Caribbean region by The Development Bank of Latin America, with a vulnerability index of 0.58 and a sensitivity index of 0.22[43]. Haiti's vulnerability is exacerbated by limited institutional and technical capacity to build resilience against extreme climate events. The country ranked 169 out of 188 countries in the 2018 UN Human Development Index (HDI) with a score of 0.503[44]. The country experiences numerous development and adaptation threats, including food and economic

[39] 'Water towers' refers to mountainous areas in Haiti where water for agricultural production and drinking is obtained.
[40] Resilient Productive Landscapes in Haiti (P162908). The World Bank (2018). Available at: http://documents1.worldbank.org/curated/en/268321512771981483/pdf/Project-Information-Document-Integrated-Safeguards-Data-Sheet-Resilient-Productive-Landscapes-in-Haiti-P162908-Sequence-No-00.pdf
[41] International Monetary Fund: Staff Country Reports. *Haiti 2012 Article IV Consultation and Fifth Review Under the Extended Credit Facility*. Available at: https://books.google.co.bw/books?id=F1idLEME-tAC&pg=PT21&lpg=PT21&dq=haiti+1993+-+2012&source=bl&ots=2d9PMMbRri&sig=ACfU3U1rCv9LY-gTIm2I2p36kuySXDUBHA&hl=en&sa=X&ved=2ahUKEwji04zQv6nqAhVOPcAKHc1JAlkQ6AEwAXoECA8QAQ#v=onepage&q=haiti%201993%20-%202012&f=false
[42] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions.
[43] Vulnerability Index to Climate Change in the Latin America and Caribbean Region. The Development Bank of Latin America (2014)
[44] UN Human Development Index (2018) http://hdr.undp.org/en/data

insecurity, political violence, health and education challenges, as well as environmental degradation.

2.1.1. Physical context

Haiti is situated in the Caribbean Archipelago and forms part of Hispaniola Island, together with the Dominican Republic. While the Dominican Republic occupies the east of Hispaniola, Haiti occupies the west, covering an area of 27,750 km^2, with land covering 27,560 km^2, and water 190 km^2[45]. Haiti is located between the Atlantic Ocean and Caribbean Sea and includes five satellite islands (Figure 1)[46], namely: i) La Gonave (670 km^2); ii) La Tortue (180 km^2); iii) Ile-à-Vache (52 km^2); iv) Cayémites (45 km^2); and v) Navassa Island (7 km^2)[47].

The country has a rough and rocky terrain — approximately 80% of the total land area is mountainous — coupled with river valleys and coastal flatlands. More than half of the landscape is steep at a minimum gradient of 40%, while ~21% of the landscape is at 10% or less. The plains, or flatlands, occupy ~20% of the total land area (~5,500 km^2).

Figure 1. Geographical map of Haiti[48].

2.1.2. Geological context

Hispaniola Island borders two large tectonic plates, namely the North American and Caribbean plates. Consequently, two major fault lines run through Haiti — the Enriquillo-Plantain Garden fault in the south, which forms part of the North American and Caribbean plate boundary; and

[45] The World Factbook: Haiti https://www.cia.gov/library/publications/the-world-factbook/geos/ha.html
[46] Geology: Haiti Map and Satellite Image. Available at: https://geology.com/world/haiti-satellite-image.shtml
[47] UNDP (2015) Project Document: Increasing resilience of ecosystems and vulnerable communities to climate change and anthropic threats through a ridge-to-reef approach to biodiversity conservation and watershed management
[48] Geology.com. No date. Haiti Map and satellite image. Available: https://geology.com/world/haiti-satellite-image.shtml.

the Septentrional fault in the north (Figure 2)[49]. This geological occurrence makes Haiti vulnerable to earthquakes and aftershocks, compromising both the livelihoods of Haitians and the natural environment. Earthquakes, and the aftershocks that follow, result in: i) deaths of people in Haiti; ii) the disruption of water systems, which compromise water safety; and iii) the disruption of emergency medical systems[50]. The impacts of earthquakes on Haiti's ecosystems include landslides which result in river blockages, therefore increasing the potential of rapid flooding. Landslides also increase deposits of sediment and debris in rivers and dams[51]. Haiti's most severe earthquake in over 200 years occurred in January 2010, along the Enriquillo-Plantain Garden fault near the capital city of Port-au-Prince (Figure 2). With a magnitude of 7.0, the earthquake resulted in ~200,000 deaths, the displacement of ~1.7 million people[52] and damages estimated at ~US$7.8 billion[53].

Figure 2. Image illustrating the Septentrional and Enriquillo-Plantain Garden Faults which run through Haiti, as well as the epicentre of the earthquake which occurred in 2010[54].

2.1.3. Soil conditions

Soil conditions in Haiti are intrinsically fragile, comprising of newly formed shallow soils that can support forests and grasslands, but that are also susceptible to leaching of water-soluble nutrients and erosion. In 1999, Haiti's annual soil erosion was estimated at 1,316 tonnes $km^{-2}yr^{-1}$[55]. Although largely attributed to the severe deforestation mentioned above, soil erosion is exacerbated by varying biophysical and anthropogenic factors, such as: i) soil types; ii) climatic conditions; iii) topography; iv) extent of deforestation; and v) unsustainable agricultural practices[56].

[49] NPR: The Anatomy of a Caribbean Earthquake (2010). Available at: https://www.npr.org/templates/story/story.php?storyId=122531261
[50] Rapid Environmental Impact Assessment: Haiti Earthquake (2010). Prepared for USAID. Available at: https://www.globalcommunities.org/publications/2010-haiti-eq-impact-assessment.pdf
[51] Rapid Environmental Impact Assessment: Haiti Earthquake (2010). Prepared for USAID. Available at: https://www.globalcommunities.org/publications/2010-haiti-eq-impact-assessment.pdf
[52] FAO and Haiti earthquake 2010. Available at: http://www.fao.org/emergencies/crisis/haiti-earthquake-2010/intro/en/
[53] Rebuilding Haitian Infrastructure and Institutions. World Bank 2019. Available at: https://www.worldbank.org/en/results/2019/05/03/rebuilding-haitian-infrastructure-and-institutions#:~:text=Damages%20and%20losses%20stemming%20from,to%20respond%20to%20the%20crisis.
[54] NPR. 2010. The science behind Haiti's Earthquake. Available at: https://www.npr.org/templates/story/story.php?storyId=122531261.
[55] Raizada, M N and Bargout R N (2013) *Soil nutrient management in Haiti, pre-Columbus to the present day: lessons for future agricultural practices*. Agriculture and Food Security 2:11
[56] Ibid.

The underlying 'parent' rock is predominantly volcanic, and limestone and the subtypes formed are i) udepts; ii) usteps; iii) fluvians; and iv) udults — which vary between being shallow, sandy and nutrient-deficient[57]. Haiti's soils are naturally vulnerable to erosion because of their shallow, sandy and nutrient-deficient characteristics. In addition, these soils are subjected to winds and soil crusting during dry periods and water surplus during wet periods, compromising overall seasonal soil quality. Moreover, more than half of Haiti's landscape has a steep gradient greater than 20%, increasing the risk of low-lying areas in the country to soil erosion during heavy rainfall and flood events.

Soil erosion in Haiti has been exacerbated by excessive deforestation and unsustainable agricultural practices. Approximately 80% of the total population uses fuelwood as a source of energy[58]. However, five kg of fuelwood produces only one kg of charcoal, which is insufficient for household consumption. This leads to extensive deforestation as a result of communities' large-scale tree cutting to acquire sufficient fuelwood for charcoal production[59]. In addition to cutting trees, farmers clear vegetation to cultivate more land to compensate for the low crop yields from the nutrient-deficient soils. This practice resulted in the average size of agricultural plots increasing from 1.8 ha to 2.7 ha between 1997–2003[60].

2.1.4. Ecological context

Haiti's geographic isolation has enabled unique speciation of national fauna and flora, which has resulted in one of the highest levels of biodiversity in the Caribbean region. The tropical climate, combined with the rugged terrain, have contributed to a variety of ecosystems and habitats. However, severe deforestation has adversely affected Haiti's natural ecosystems, creating conditions for erosion and intense flooding. Deforestation has been attributed to, *inter alia*, fuelwood harvesting, increasing population growth and food insecurity. Consequently, indigenous tree cover has been reduced to less than 1% of the total original indigenous tree cover in Haiti[61], compared to the 13% in its neighbouring country, the Dominican Republic[62]. However, traditional agroforestry practices and agroforestry initiatives in Haiti have resulted in an increase in vegetative cover of ~30%. Unlike Haiti's indigenous forests, which were located within the mountain slopes, the current agroforests are primarily located in valleys and accessible agricultural lands (such as those in the north of the country).

2.1.5. Hydrological conditions

Haiti has 160 major rivers and 31 main watersheds, of which 25 watersheds have been, or are being, degraded by deforestation[63]. During rainfall events, the limited vegetation results in higher overland flow speed, decreased water infiltration into soils and, subsequently, increased levels of surface water run-off. Consequently, the rate at which aquifers recharge is also reduced, further compromising the freshwater output of the aquifer-fed rivers in the country[64]. Haiti's poor water quality was illustrated by its 2002 ranking on the Water Poverty Index[65] as having the lowest indices on environmental indicators, including: i) water quality; ii) water stress; iii) water management capacity; and iv) aquatic biodiversity[66]. In addition, Haiti's

[57] Ibid.
[58] Ibid.
[59] Ibid.
[60] Ibid.
[61] Hedges, S. B et al. (2018). *Haiti's biodiversity threatened by nearly complete loss of primary forest*. Proceedings of the National Academy of Sciences in the United States of America. 115 (46) pg. 11850–11855
[62] WWF. Caribbean: Haiti and Dominican Republic. Available at: https://www.worldwildlife.org/ecoregions/nt0127
[63] UNEP in Haiti. 2010 Year in Review
[64] A History of Landscape-level Land Management Efforts in Haiti: Lessons learned from Case Studies Spanning Eight Decades. World Bank (2016)
[65] The Water Poverty Index (WPI) is calculated based on five components, namely: i) resources; ii) access; iii) capacity; iv) use; and v environment. The indices are ranked between 0 – 100, with 0 being the lowest (high water poverty) and 100 being the highest (low water poverty).
[66] Lawrence, P. et al. (2002) *Water Poverty Index: An International Comparison*. Keele Economics Research Paper http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.13.2349&rep=rep1&type=pdf

rivers lack levees and embankments which further exacerbates erosion and consequently increases sedimentation of rivers.

Despite only 15% of the country comprising plains and valleys, these landscapes contain ~85% of Haiti's available groundwater. The remaining 15% of groundwater is found in mountainous areas and comes from springs that originate from multiple aquifer types including karstic, fractured, low permeability, and indigenous aquifers (Figure 3)[67]. Because of deforestation, the ability of aquifers to recharge has decreased to the extent that the water table now seasonally fluctuates by up to 15 meters in many parts of the country. Freshwater is nevertheless still available locally from varied aquifers, including fractured limestones, sandstones, conglomerates, and schist aquifers[68].

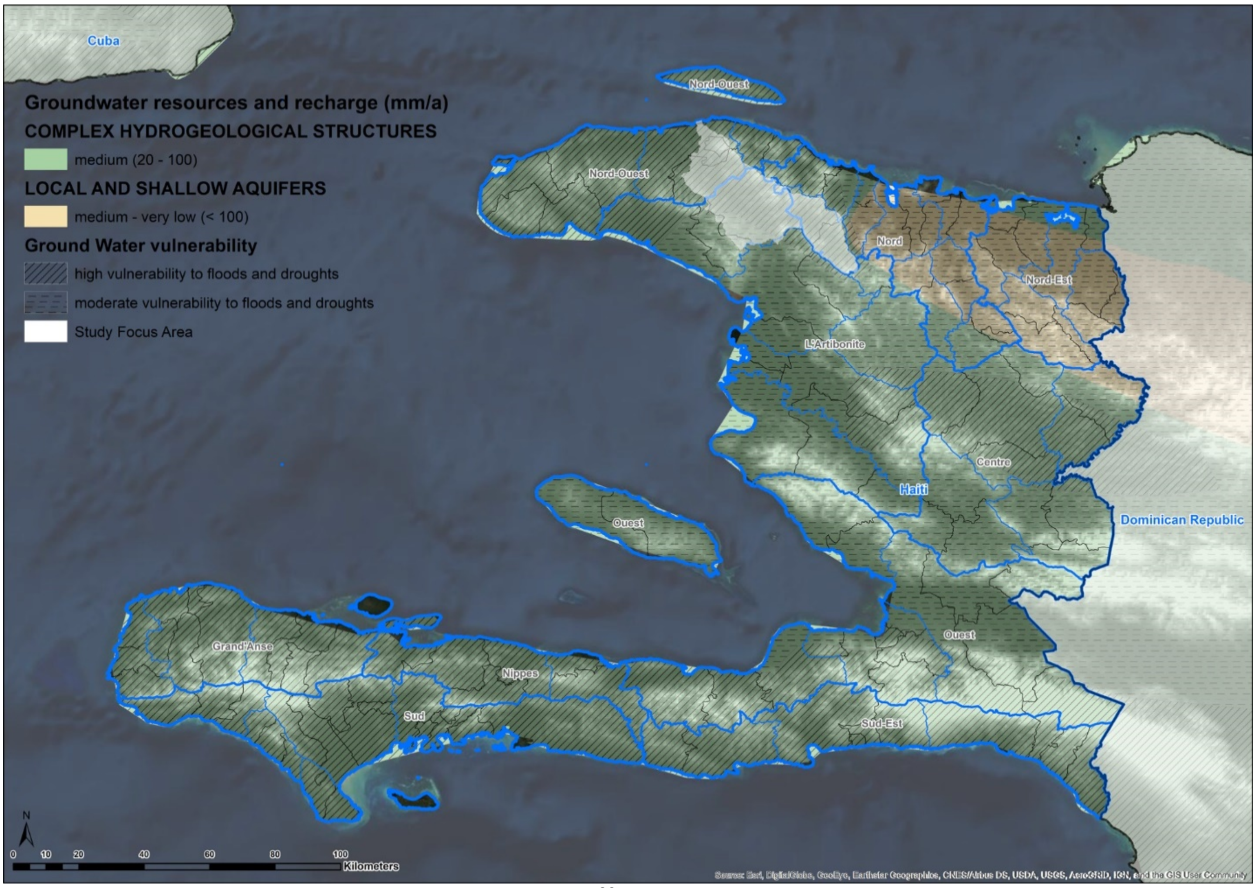
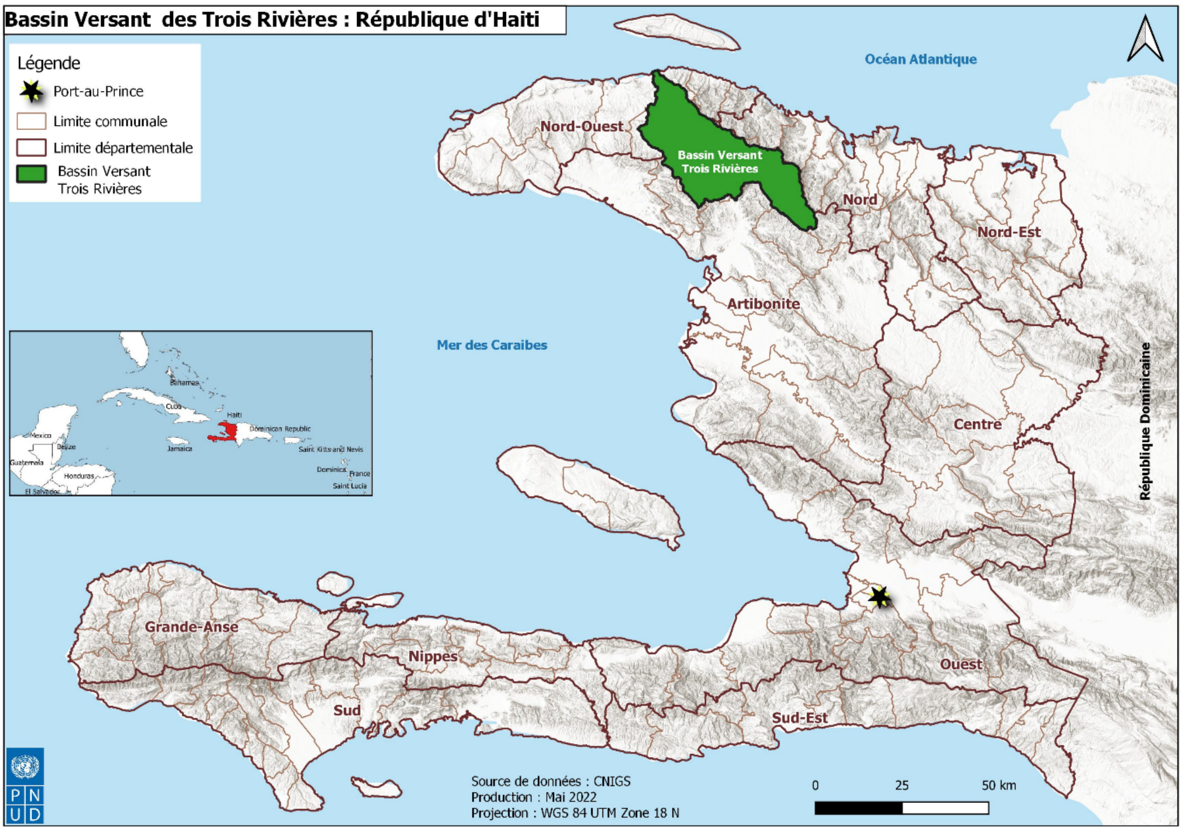


Figure 3. A map of groundwater resources in Haiti[69].

2.1.6. The Trois-Riviéres region

The North and North-West Departments of Haiti encompass the Trois-Riviéres (TR) watershed, which has a catchment area of 897 km^2.

[67] Knowles, R.B., Buckalew, J., Markley, B., and Roebuck, L. 1999. Water Resources Assessment of Haiti. 1-93. Mobile, AL: U.S. Army Corps of Engineers.
[68] The World Bank. 2016. A History of Landscape-Level Land Management Efforts in Haiti: Lessons Learned from Case Studies Spanning Eight Decades. Available at: https://elibrary.worldbank.org/doi/abs/10.1596/25764
[69] Haiti: Watersheds. Source: GoH MARNDR and MoE (2000). Available at: http://umanitoba.ca/faculties/architecture/media/LU_2_Watersheds_Dmytriw.pdf.



TR Watershed in Green

In 2000, the TR watershed had an average flow of 6.5m^3 per second and a runoff coefficient[70] of 18%[71]. The TR watershed is particularly vulnerable to floods, with an erosion and soil potential index[72] of 70 and 26 (out of 100)[73], respectively. The vegetation cover surrounding the TR watershed has been severely over-utilised and degraded. This has been largely attributed to: i) increasing population growth; ii) unsustainable agricultural practices; iii) food insecurity; and iv) limited land-use regulation and enforcement resulting in deforestation. The resultant limited vegetation cover reduces water infiltration and retention, consequently exposing topsoil to further erosion caused by extreme rainfall events and storms.

In addition to the non-climatic drivers of ecosystem degradation in the TR watershed described above, the watershed has been identified as being at particularly high-risk to climate change-induced flooding. It therefore represents a priority region within Haiti for related adaptation responses. The impacts of floods in this watershed are exacerbated by the negative cycle of increasingly intense soil erosion that has been created through current, unsustainable agricultural and land-use practices. During concentrated precipitation events that cause flooding, the limited ground cover resulting from land degradation leads to increased surface runoff and consequently exacerbates soil erosion in the watershed. This erosion is compounded by extensive deforestation in the mountainous parts of the watershed, primarily linked to charcoal production. The impacts of this are, *inter alia*, reduced soil fertility and therefore agricultural productivity. As the TR watershed is a major food producing region in Haiti, this negatively affects food security across the country. Limited alternative options for

[70] Runoff coefficient relates the amount of runoff to the amount of precipitation received.
[71] Haiti: Watersheds. Source: GoH MARNDR and MoE (2000). Available at: http://umanitoba.ca/faculties/architecture/media/LU_2_Watersheds_Dmytriw.pdf
[72] The soil potential index measures the productive potential of the soil in terms of sloping of the landscape, drainage, salinity, and physical characteristics.
[73] Smith, S and Hersey, D (2008). *Analysis of Watershed Vulnerability to Flooding in Haiti*. World Applied Sciences Journal 4 (6): 869–885. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.388.1772&rep=rep1&type=pdf

sustainable livelihoods are available and Haiti's vulnerable production systems are already threatened by climate change impacts (such as flooding). Unless interventions are implemented to overcome this cycle, subsequent flood events under climate change will continue to lead to the destruction of crops, farmland and agricultural infrastructure, as well as the loss of livestock and human lives, exacerbating food and livelihood insecurity in the country.

2.2. Socio-economic baseline

There are several socio-economic factors which influence the vulnerability of Haitian citizens to climate change, particularly to extreme climate events such as hurricanes and heavy rainfall. These include: i) high levels of poverty and food insecurity; ii) rising urbanisation; iii) limited access to secure water and sanitation facilities; iv) gender inequality; and v) the structure and dynamics of the Haitian economy. These factors will be elaborated on in the following sections.

2.2.1. Population dynamics

Haiti has a population of ~11 million people, of which ~51% are women[74]. Despite accounting for more than half the population, Haitian women face numerous systemic barriers to their socio-economic development, including low levels of access to education and public transport and limited disposable incomes[75]. These barriers inhibit women's participation in public life and undermine gender equality. As a result of these challenges, Haiti ranked 150 out of 162 countries on the UNDP Gender Inequality Index in 2018[76].

The country's population is increasing by ~1% per annum and is projected to reach ~14 million by 2050. The long-term population growth projections assume that national fertility rates will decrease from 2.99 births per woman[77] in 2017 to ~2.5 births per woman by 2025–2030[78]. As a result of the above-average fertility rate and the relatively low life expectancy (~63 years[79]), Haiti has a relatively young population demographic with ~32% of the population under the age of 15, median age of only ~23 years, and a low age dependency ratio (Table 1)[80]. Table 1 below provides a summary of relevant baseline, socio-economic and vulnerability indicators for Haiti.

In 2019, the average population density was ~409 people per km^2, with 60% (~6.5 million people[81]) living in urban areas along the 1,535 km coastline[82,83]. Population density is considerably higher in urban areas (see Figure 4 below), where many people reside in informal settlements. The high population density contributes to a high prevalence of diseases, as

[74] World Bank Data. N.d. Population, female (% of total population) - Haiti. Available: https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS?locations=HT
[75] Relief Web. 2010. The Haiti Gender Shadow Report. Available: https://reliefweb.int/report/haiti/haiti-gender-shadow-report
[76] UNDP. 2019. Human Development Report 2019: Haiti. Available: http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/HTI.pdf
[77] United Nations. 2017. World Population Prospects – 2017 Revision. Available: https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html#:~:text=The%20current%20world%20population%20of,Nations%20report%20being%20launched%20today.
[78] Plecher, H. 2020. Haiti: Fertility Rate from 2007 to 2017.
[79] World Bank Data. 2018. Life expectancy at birth(years) - Haiti. Available: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=HT
[80] Index Mundi. 2019. Haiti Demographics Profile 2019. Available: https://www.indexmundi.com/haiti/demographics_profile.html
[81] World Population Review. N.d. Haiti Population (Live). Available: https://worldpopulationreview.com/countries/haiti-population/
[82] Our World in Data. N.d. Population Density, 1961 to 2017. Available: https://ourworldindata.org/grapher/population-density?tab=chart&country=HTI
[83] Our World in Data. N.d. Population Density, 1961 to 2017. Available: https://ourworldindata.org/grapher/population-density?tab=chart&country=HTI.

increased contact between people living in close proximity heightens the rate of disease transmission[84].

Table 1. Baseline population, socio-economic and vulnerability indicators for Haiti.

Indicator		Value	Year
Population	**Total Population**	**~11,123,176**	**2018[85]**
	Population Growth (per 1,000 population)	~1%	2018[86]
	Age dependency ratio — elderly	~8%	2017[87]
	Age dependency ratio — youth and children (under 15 to 15–64 population)	~53%	2017[88]
	Total net enrolment in primary education (men and women)	~88%	2011[89]
	Mean years of schooling (of adults)	~5 years	2018[90]
Five-year indicators	Life expectancy at birth	~64 years	2018[91]
	Average annual rate of population change	1.2%	2019[92]
	Crude death rate (per 1,000 population)	8.5	2019[93]
	Infant mortality rate	4.92%	2017[94]
	Under-five mortality	17,474 deaths per year	2018[95]
Economy	Gross Domestic Product (GDP) *per capita*; PPP	US$1,810	2018[96]
	Gross National Income (GNI) *per capita;* PPP	US$1,820	2018[97]
	Inflation, consumer prices (annual %)	~13%	2018[98]
Vulnerability	Proportion of the population using improved drinking water sources	~58%	2015[99]
	Global Needs Assessment (GNA) Crisis Index	2	2014[100]
	GNA Vulnerability Index	3	2014[101]
	Proportion of the population using improved sanitation facilities	~28%	2015[102]

[84] Relief Web. 2017. Haiti: Cholera Figures (28 September 2017). Available: https://reliefweb.int/report/haiti/haiti-cholera-figures-28-february-2017
[85] World Bank Data. N.d. Population, total. Haiti. Available: https://data.worldbank.org/indicator/SP.POP.TOTL?locations=HT
[86] World Bank Data. N.d. Population growth (annual %) - Haiti. Available: https://data.worldbank.org/indicator/SP.POP.GROW?locations=HT
[87] Our World in Data. N.d. Old-age dependency ratio – 1960-2017. Available: https://ourworldindata.org/grapher/age-dependency-ratio-old
[88] Our World in Data. N.d. Youth dependency ratio, 1960 – 2017. Available: https://ourworldindata.org/grapher/age-dependency-ratio-young-of-working-age-population
[89] UNDP. 2013. MDG Report – Haiti: A New Look.
[90] UNDP. 2019. Human Development Report 2019: Haiti. Available: http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/HTI.pdf
[91] World Bank Data. N.d. Haiti.
[92] United Nations. 2019. World Population Prospects 2019: Haiti.
[93] Ibid
[94] Our World in Data. N.d. Infant Mortality Rate, 1990 to 2017. Available: https://ourworldindata.org/grapher/infant-mortality
[95] World Bank Data. N.d. Number of under-five deaths – Haiti. Available: https://data.worldbank.org/indicator/SH.DTH.0509?locations=HT
[96] World Bank Data. N.d. GDP per capita, PPP (current international US$) - Haiti. Available: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD
[97] World Bank Data. N.d. GNI per capita, PPP (current international $) - Haiti. Available: https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD
[98] World Bank Data. N.d. Inflation, consumer prices (annual %) - Haiti. Available: https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
[99] Our World in Data. N.d. Share of the population with access to improved drinking water, 1990 to 2015. Available: https://ourworldindata.org/water-access#:~:text=Access%20to%20improved%20water%20sources%20is%20increasing%20across%20the%20world,to%20an%20improved%20water%20source.
[100] European Commission. 2014. Global Vulnerability and Crisis Assessment Final Index Rank. Available: http://ec.europa.eu/echo/files/policies/strategy/gna_2013_2014.pdf
[101] Ibid
[102] CIA Factbook. N.d. Haiti. Available: https://www.cia.gov/library/publications/the-world-factbook/geos/ha.html

	Per capita food supply	~2,091 kcal capita^{-1} day^{-1}	2013[103]

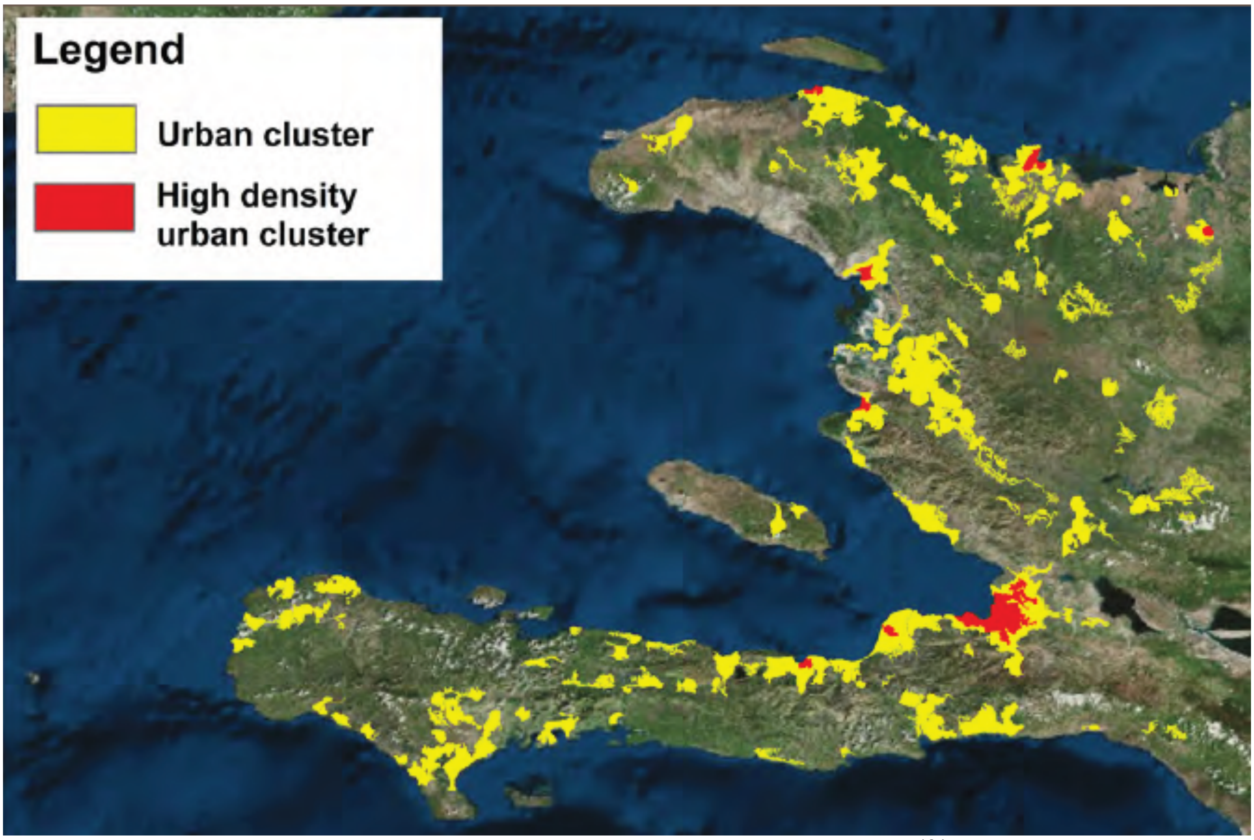


Figure 4. Urban Clusters and High-Density Urban Clusters across Haiti, 2015[104].

2.2.2. Vulnerability of the population

Along with the abovementioned vulnerability to diseases, Haitian communities face an increasing number of development challenges which increase their vulnerability. Classified as a Small Island Developing State (SIDS) and Least Developed Country (LDC), Haiti ranks at a low 169 out of 189 countries on the Human Development Index (HDI) with a score of only 0.503. Haiti's ranking is below the HDI average for low human development group countries (0.507) and considerably below the HDI average for countries in Latin America and the Caribbean (0.759)[105]. Development challenges in Haiti may also be exacerbated by ongoing political discontent, which developed in early 2020 when the President Jovenel Moise began ruling by decree as the terms of many legislators expired[106].

In addition to developmental and political challenges, Haiti is still recovering from the impacts of several extreme climate events and natural disasters as well as ongoing health risks, including: i) the 2016 Category 5 Hurricane Matthew and the resultant flooding and landslides; ii) a magnitude 7 earthquake in 2010, and iii) a cholera outbreak in 2010[107]. Hurricane Matthew

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[103] Our World in Data. N.d. Daily Supply of Calories, 1961 to 2013. Available: https://ourworldindata.org/grapher/food-supply-kcal

[104] Lozano-Gracia, N., and Lozano, M.G. 2015. *Haitian Cities: Actions for Today with an Eye on Tomorrow.* World Bank Group: Washington, D.C.

[105] United Nations Development Programme (UNDP). 2019. Human Development Report: Haiti. Available: http://hdr.undp.org/sites/all/themes/hdr_theme/country-notes/HTI.pdf

[106] Congressional Research Service. 2020. Haiti's Political and Economic Conditions. *Congressional Research Service Report R45034*

[107] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions. *Congressional Research Service Report R45034.* Retrieved from the Congressional Research Service Website: https://www.everycrsreport.com/files/20190701_R45034_fd84e9910b29413f4602daa1fa96183634bb3e9e.pdf.

was the first Category 5 hurricane to make landfall in Haiti since 1963, exacerbating cholera outbreaks introduced in 2010[108] and resulting in increased food insecurity for ~1.4 million people[109]. Approximately 700,000 people's livelihoods were affected by the hurricane, particularly smallholder farmers, small-scale fisherman and herders[110].

The COVID-19 pandemic is projected to significantly undermine economic growth and social wellbeing in Haiti. An 18% year-over-year decrease in remittances — which represented ~36% of GDP in 2019[111] — was recorded in March 2020 compared with March 2019, which will significantly impact the economic wellbeing of Haitian households which depend on them[112]. In addition, limited health care provision — traced back to Structural Adjustment Programmes mandated by the International Monetary Fund (IMF) during the 1980s and 1990s — has exacerbated vulnerability to the pandemic: for example, just 62 ventilators were available across the country prior to the first recorded COVID-19 cases[113].

Haiti is considered one of the world's most vulnerable countries to climate change, multiple natural hazards, acute shocks and chronic stress, with 96% of its population at risk of these events[114]. In the 2018 Climate Risk Index, Haiti was listed as the country most affected by hydro-meteorological disasters during the past two decades[115]. This vulnerability is compounded by urbanisation and a high incidence of poverty amongst the Haitian population. These factors contributed to the Global Needs Assessment Vulnerability Index ranking Haiti amongst the top quartile of vulnerable countries in 2014 (Table 1) based on several vulnerability indicators including the health of children under five and the uprooted people index[116].

Poverty also contributes significantly to the vulnerability of the Haitian population, with ~59% of the population[117] living below the national poverty line of US$2.41 per day[118]. Moreover, ~25% of the total population earns less than US$1.90 per day, which results in severe challenges for these individuals to finance their food expenses[119]. Consequently, one in three Haitians require urgent food assistance[120], and the average Haitian's *per capita* food supply is just ~2,091 kcal capita^{-1} day^{-1} (Table 1) — below the recommended daily average intake of 2,700 kcal capita^{-1} day^{-1} and 2,200 kcal capita^{-1} day^{-1} for men and women, respectively[121]. Food insecurity is most severe in the North-West Department of the country, closely followed by the Artibonite and North Departments, all of which are located in the Trois-Rivieres (TR) region of Haiti. Food insecurity experienced in these departments is demonstrated in Figure 5 below[122].

[108] Further details on this outbreak are presented in Sub-section 2.2.3 of this Feasibility Study.
[109] Germanwatch. 2018. Global Climate Risk Index 2018 – Who Suffers Most from Extreme Weather Events? Weather-related Loss Events in 2016 and 1997 to 2016. Available: http://germanwatch.org/files/publication/20432.pdf
[110] FAO. 2017. Haiti: Hurricane Matthew Situation Report. Available: http://www.fao.org/3/a-bs144e.pdf
[111] Orozco, M. 2020. Migrants and the Impact of the Covid-19 Pandemic on Remittances. *Inter-American Dialogue*.
[112] Cela, T., and Marcelin, L.H. 2020. Haitian Families and Loss of Remittances During the COVID-19 Pandemic.
[113] Bojarski, S. 2020. Coronavirus Exposes Precarious Living Situations in Haiti.
[114] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions.
[115] Germanwatch. 2018. Global Climate Risk Index 2018 – Who Suffers Most from Extreme Weather Events? Weather-related Loss Events in 2016 and 1997 to 2016. Available: http://germanwatch.org/files/publication/20432.pdf
[116] European Commission. 2014. Global Vulnerability and Crisis Assessment Final Index Rank. Available: http://ec.europa.eu/echo/files/policies/strategy/gna_2013_2014.pdf
[117] UNDP. N.d. Haiti: Human Development Indicators. Available: http://hdr.undp.org/en/countries/profiles/HTI
[118] World Bank. 2020. The World Bank in Haiti. Available: https://www.worldbank.org/en/country/haiti/overview
[119] UNDP. N.d. Haiti: Human Development Indicators.
[120] World Food Programme. N.d. Haiti. Available: https://www.wfp.org/countries/haiti
[121] Brazier, Y. 2017. How many calories do you need? Available: https://www.medicalnewstoday.com/articles/263028
[122] Food and Agriculture Organization. 2020. Haiti – Response Overview. Available: http://www.fao.org/3/ca7636en/CA7636EN.pdf

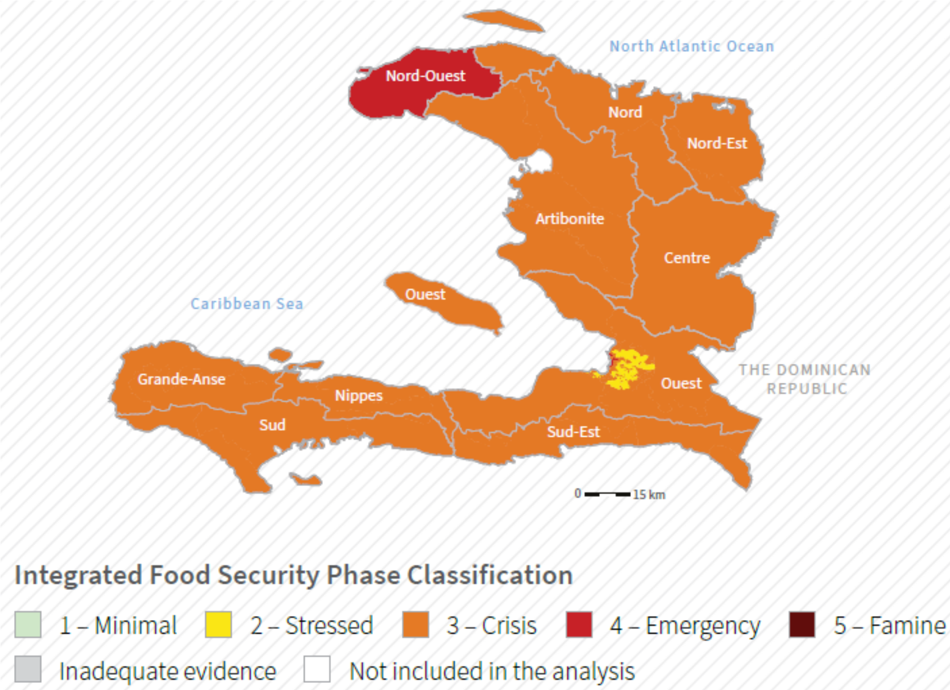

Figure 5. Food Insecurity in Haiti, 2020[123].

High poverty rates increase a population's vulnerability to extreme climate events by constraining their adaptive capacity[124]. Haiti's poverty rates are highest in isolated rural areas, where 52% of the population and 63% of extremely poor households reside[125]. In the Trois Rivieres (TR) region, extreme poverty[126] is highest in the North-West Department, followed by the North Department and lowest in the Artibonite Department, as depicted in Figure 6 below.

Urbanisation is increasing in Haiti as climate change impacts — including increased intensity of floods and droughts — are driving an 'exodus' of farmers into urban areas such as Port-au-Prince and Gonaives in search of alternative livelihood opportunities[127]. Many of these internal economic migrants[128] find employment in the informal sector or in the moto taxi industry[129]. This rising urbanisation contributes to the heightened vulnerability of the Haitian population; with a shortage of affordable housing[130] and high poverty rates, many Haitians migrating to urban areas are forced to resettle in flood-prone areas in densely populated informal settlements[131].

[123] Food and Agriculture Organization. 2020. Haiti – Response Overview.
[124] World Bank. 2010. Disaster Risk Management in Latin America and the Caribbean Region: Country Notes – Haiti. Available: https://www.gfdrr.org/sites/default/files/publication/drm-country-note-2010-haiti.pdf
[125] Taft-Morales, M. 2019. Haiti's Political and Economic Conditions.
[126] The World Bank classifies 'extreme poverty' as any daily income under US$1.90/day.
[127] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative.
[128] An economic migrant refers to an individual who migrates from their place of residence to another location in order to pursue a greater quality of life, generally through finding employment at their destination. This move can happen within a country (internal), for example from a rural to an urban area; or between two different countries. From: International Organization for Migration. 2011. *Glossary on Migration.* 2nd ed. International Organization for Migration: Geneva.
[129] FAO. 2017. *FAO/WFP Crop and Food Security Assessment Mission to Haiti.* FAO, Rome.
[130] USAID. 2016. Haiti: Housing and Settlements (Fact Sheet). Available: https://www.usaid.gov/haiti/shelter-and-housing
[131] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative.

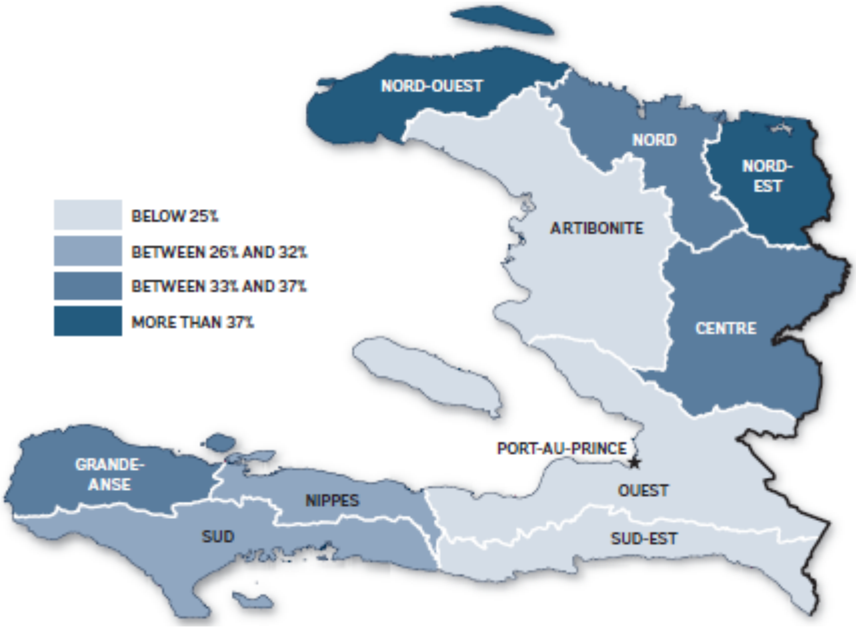

Figure 6. Extreme Poverty Rates in Haiti by Department, 2012[132].

Approximately 65% of Haiti's urban population lived in informal settlements in 2013[133]. This problem was exacerbated by the 2010 earthquake that left ~2 million homeless[134]. In Port-au-Prince, as a result of the higher population density characteristic of informal settlements, residents' risk of being affected by hurricane impacts are two to four times higher than the national average[135]. This increased risk is because dwellings in informal settlements are often poorly constructed and are not reinforced to withstand extreme climate events such as hurricanes and floods. Consequently, the potential for damage is significantly higher compared with formal housing that comply to standard building regulations[136]. Given the prevalence of informal settlements, more than 70% of the urban population is considered at medium- or high-risk from hurricanes[137]. Additionally, the expansion of informal settlements often encroaches on important natural areas — particularly coastal ecosystems, which results in a degradation of valuable ecosystem services such as flood management[138].

2.2.3. Health risks

Inundations from flooding have adverse effects on Haiti's public health and result in: i) the contamination of existing water supplies[139]; and/or ii) the destruction of water supply and sanitation facilities, which reduces water security and results in the increased use of contaminated water[140]. Both impacts enable the spread of waterborne diseases such as

[132] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative. World Bank Group, Washington, D.C.
[133] UNDP. 2013. MDG Report – Haiti: A New Look. Available: https://www.latinamerica.undp.org/content/rblac/en/home/library/mdg/HaitiMDGReport2013/
[134] Amnesty International. 2015. Ten facts about Haiti's housing crisis. Available: https://www.amnesty.org/en/latest/news/2015/01/ten-facts-about-haiti-s-housing-crisis/
[135] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti. *Oxfam Research Reports.* Available: https://oxfamilibrary.openrepository.com/bitstream/handle/10546/314540/rr-climate-change-resilience-haiti-260314-en.pdf;jsessionid=EC22CC2F0C14C211175539E5EB3FF87C?sequence=1
[136] Abunyewah, M., Gajendran, T., and Maund, K. 2017. Profiling Informal Settlements for Disaster Risks. Procedia Engineering, 212.
[137] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative.
[138] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative.
[139] World Health Organization. N.d. Flooding and communicable diseases fact sheet. Available: https://www.who.int/hac/techguidance/ems/flood_cds/en/
[140] Associated Programme on Flood Management. 2015. Health and Sanitation Aspects of Flood Management. *Integrated Flood Management Tools Series.* Available: https://www.floodmanagement.info/publications/tools/Tools_23_Health_and_Sanitation_Aspects_of_Flood_Management.pdf

cholera[141]. This was demonstrated in the 2010 post-earthquake recovery in Haiti, during which poor access to sanitation and safe drinking water contributed to the 2010 cholera outbreak[142]. Haiti's rural populations are particularly vulnerable to these health risks, as just ~19% of its rural households have access to improved sanitation[143,144]. In addition, flooding often has a disproportionately negative impact on the health of women and children compared with men, as the former have a higher level of exposure to contaminated water because of gender roles in the home (including women's expected cooking and cleaning duties). If displacement and relocation occur after a flooding event, women and girls also face a greater risk of gender-based violence — including sexual violence. This outcome may be partially attributed to the breakdown of traditional societal protections in the aftermath of a natural disaster[145].

Flood risk and the associated threat to the health of Haitians who lack access to safe water and sanitation facilities is partially attributable to large-scale deforestation across the TR watershed. In 2014, flood risk[146] in the TR watershed was classified as high in the Artibonite Department, medium-high in the North-West Department and medium in the North Department. Across the North and North-West Departments, extensive deforestation throughout the shared Grand Riviere du Nord Basin has resulted in a decline in total forest cover in this area (including mixed hardwoods and agroforestry) to ~1% by 1998[147]. This large-scale clearing of forests has been driven by increased cultivation of crops including corn, beans and sorghum on steep slopes, as well as a dependence on charcoal and firewood for energy generation. Deforestation enhances flood risk through driving increasing surface water runoff, which in turn leads to reduced groundwater and aquifer recharge, soil erosion, and a greater incidence and intensity of flooding[148].

The COVID-19 pandemic is posing a further health risk to many Haitians. As many countries enter lockdowns because of the pandemic, Haitian migrant workers and diaspora are returning to Haiti, contributing to increases in the local spread of the virus[149].

2.2.4. Gender equality in Haiti

Haiti's long-term economic and democratic development rely on prioritising the protection and empowerment of women. Although Haiti's Constitution established several protections for women (including from workplace discrimination and physical and sexual abuse, as well as guaranteeing the right to political participation), in practice, women routinely face exclusion and harassment in their public and private life. Despite this, Haiti has made some progress regarding gender representation, with the 2012 Constitutional amendment instituting a 30% quota for women in all elected and appointed positions at the national level. The 2015 Electoral Decree extended this quota to local councils and political candidates. Unfortunately, the implementation of these amendments has not been effective, and women seeking political office continue to face considerable obstacles, including patriarchal attitudes towards leadership, a lack of financial support, and threats of violence and intimidation. These barriers partially explain the very low political representation of women in Haiti, with women holding just ~3% of seats in Parliament in 2018[150].

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[141] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[142] Caribbean Development Bank. 2019. CDB supports continued push for improved sanitation in Haiti Available: https://reliefweb.int/report/haiti/cdb-supports-continued-push-improved-sanitation-haiti
[143] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[144] Index Mundi. 2019. Haiti Demographic Profile 2019. Available: https://www.indexmundi.com/haiti/demographics_profile.html
[145] International Federation of Red Cross and Red Crescent Societies. 2015. *Unseen, unheard: Gender-based violence in disasters.* Geneva, Switzerland.
[146] Flood risk was classified on a scale from 1-10, where 1 was maximum risk. Flood risk was 2, 4 and 5 in the Artibonite, North-West and North Departments, respectively.
[147] While agroforestry is not generally considered a form of forest cover; Singh and Cohen (2014) included agroforestry in their evaluation of total forest cover in Haiti.
[148] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[149] Beaubien, J. 2020. COVID-19 Cases Double in Ill-Prepared Haiti. Available: https://www.npr.org/sections/goatsandsoda/2020/05/08/853052522/haitian-doctor-says-this-is-the-worst-epidemic-hes-faced
[150] UNDP. 2019. Human Development Report 2019: Haiti.

Consultations with appropriate project stakeholders during the development of the proposed project revealed that women are disproportionately impacted by flooding because: i) women tend to perform most of the emotional work[151] in the aftermath of flooding events, which impacts their mental health; ii) women and girls face a higher threat of gender-based violence, particularly if displacement occurs[152]; iii) women and girls are more likely to experience food insecurity if household access to food is limited[153]; and iv) women are more likely to adopt negative coping mechanisms in the aftermath of a flooding event such as resorting to sex work[154], which can increase their exposure to HIV/AIDS[155]. Women with HIV/AIDS are also at risk of increased levels of gender-violence[156]. In addition, people with HIV/AIDS experience declining health and weakened immune systems, which undermines their productivity and ability to earn income, resulting in food and nutritional insecurity and increasing vulnerability to HIV-related illnesses such as tuberculosis[157]. These consultations with project stakeholders (including local communities and women's and youth groups) prior to the proposed project's development also revealed that women tended to experience relatively higher casualties during flooding events compared with men and are more likely to be affected by waterborne diseases which accompany flooding (Sub-section 2.2.3 above) because of gender roles and expectations of women in the household.

The proposed project will create gender-responsive benefits by promoting the active involvement of women throughout the project life cycle. Women will be fully involved in decision-making during the design stage of flood-proofed infrastructure and soil conservation adaptation measures. During the project's implementation stage, concerted efforts will be made to ensure the equal participation of women. Finally, equal participation of women will be pursued and achieved after implementation has concluded through ongoing management and water governance, particularly in the proposed Water Governance Committees. Further detailed information on gender mainstreaming is provided in the Gender Action Plan (Annex 8).

2.2.5. Major economic sectors in Haiti

Haiti is a free market economy[158] with low labour costs. Services is the largest economic sector (~58% of GDP), followed by agriculture (~22% of GDP) and industry (~20% of GDP). The Haitian population generally work in either the service industry (~50% of the workforce) or the agricultural sector (~38% of the workforce)[159]. The labour market has a relatively high rate of unemployment compared with the average for Latin America and the Caribbean (~14%[160] and

[151] The concept of "emotional work" developed by Hochschild (1979:561) refers to the "act of trying to change in degree or quality an emotion or feeling", and in this context relates to emotions associated with the aftermath of a natural disaster including, *inter alia*, stress, anxiety and fear. Emotional work is generally performed on oneself but may be performed on others through assisting them to manage their emotions and/or feelings. From: Hochschild, A.R. 1979. Emotion Work, Feeling Rules and Social Structure. *The American Journal of Sociology,* 85(3), 551-575.

[152] International Federation of Red Cross and Red Crescent Societies. 2015. *Unseen, unheard: Gender-based violence in disasters.* Geneva, Switzerland.

[153] Drolet, J., Dominelli, L., Alston, M., Ersin, R., Mathbor, G., and Wu, H. 2015. Women rebuilding lives post-disaster: innovative community practices for building resilience and promoting sustainable development. *Gender and Development*, 23(3): 433–448.

[154] Llorente-Marron, M., Diaz-Fernandez, M., Mendez-Rodriguez, P., and Arias, R.G. 2020. Social Vulnerability, Gender and Disasters. The Case of Haiti. *Sustainability*, 12.

[155] Relief Web. 2010. The Haiti Gender Shadow Report. Available: https://reliefweb.int/sites/reliefweb.int/files/resources/37A5134A38ACF0608525781F0079CEC1-Full_Report.pdf

[156] International Federation of Red Cross and Red Crescent Societies. 2015. Unseen, unheard: Gender-based violence in disasters. Geneva, Switzerland.

[157] UNAIDS, 2008. HIV, *Food Security and Nutrition.*

[158] An economy can be described as free market when the production and distribution of goods and services responds to variation in consumer demand and producer supply. Alternatively, a command economy describes a situation where the production and distribution of goods and services is controlled by the government.
From: Depersio, G. 2020. What are some examples of free market economies? Available: https://www.investopedia.com/ask/answers/040915/what-are-some-examples-free-market-economies.asp

[159] Index Mundi. 2019. Haiti Economy Profile 2019. Available: https://www.indexmundi.com/haiti/economy_profile.html

[160] World Bank Data. N.d. Unemployment, total (% of total labour force) (modelled ILO estimate) - Haiti. Available: https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=HT

8%[161], respectively, in 2018). Haiti is also the poorest country in the Americas and the only LDC in the Western Hemisphere, with an annual GDP *per capita* of ~US$1,810 in 2018 (refer to Table 1 above for further economic indicators)[162].

In Haiti's agricultural sector, much of the workforce are smallholder farmers[163], with ~90% of Haiti's rural employed workforce engaging in a household-owned activity[164]. Nationally, ~78% of all Haitian households engage in agricultural activities[165]. National agricultural output consists largely of cereals: maize is the predominant crop, followed by sorghum and rice[166]. In the TR watershed — which includes the North Department, the North West Department and the Artibonite Department — the most common crops cultivated include corn and tubers in the North and North West Departments[167], and rice and corn in the Artibonite Department[168]. Approximately ~80% of national rice production is cultivated in the Artibonite Department[169].

Smallholder farmers have reported their yields being affected by several baseline challenges. First, a dependence on rain-fed agriculture has resulted in agricultural yields being undermined by increasing rainfall variability, and four of the five growing seasons between 2013-2017 were characterised by "erratic weather". This challenge is compounded by deteriorating irrigation infrastructure, which increases farmers reliance on rain-fed agriculture and thus their exposure to climate change impacts including rainfall variability. Second, low access to agricultural inputs — particularly certified seed — is an obstacle to improved agricultural yields. Several seed distribution programs have been undertaken in Haiti but were often unsuccessful because of factors including logistical challenges — particularly seeds being distributed too late in the growing season — as well as inappropriate seed being distributed that was not adapted to local climatic conditions[170]. Finally, high levels of flooding have been recorded in the Artibonite valley, caused in part by the deliberate overflowing of the Peligre hydropower dam to generate electricity. Flooding has resulted in crop losses and an inability to harvest in recent years, undermining Haiti's agricultural productivity[171].

The agricultural sector is highly vulnerable to frequent extreme climate events and natural disasters[172]. For example, the gale-force wind speeds and torrential rains associated with the 2017 Hurricane Irma significantly undermined yields of pulses, maize and rice by ~10%, ~5% and ~6% respectively compared with pre-hurricane forecasts. In the TR watershed, 30-40% of the total crop area in the North and North West Departments were affected by strong winds, while ~36% and ~15% of the Artibonite Department crop areas dedicated to rice and pulses respectively were impacted[173].

There are several infrastructural, social and financial barriers to economic growth in Haiti. First, poor maintenance of electricity infrastructure has resulted in a ~58% loss in generation

[161] International Labour Organization. 2018. Unemployment in Latin America and the Caribbean Down slightly in 2018. Available: https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_655210/lang--en/index.htm#:~:text=LIMA%20(ILO%20News)%20%E2%80%93%20The,Labour%20Overview%202018%20regional%20report.
[162] World Bank Data. N.d. GDP per capita, PPP (current international US$) - Haiti.
[163] Index Mundi. 2019. Haiti Economy Profile 2019.
[164] This includes agricultural and non-agricultural based activities. From: Coello, B., Oseni, G., Savrimootoo, T. and Weiss, E. 2014. Rural development in Haiti: Challenges and opportunities. *Report No. 95540.* World Bank Group: Washington, D.C.
[165] "Agricultural activities" include any farm-based activity undertaken either on an owned farm for subsistence or income-generating purposes, or as agricultural wage labour. From: Coello *et al.* 2014. Rural development in Haiti: Challenges and opportunities.
[166] GCF. 2019. *Increasing Resilience of Vulnerable Farmers in Southern Haiti: Concept Note*.
[167] ICA, Haiti. 2017. Livelihood zones, 2014. Available: https://geonode.wfp.org/layers/geonode%3Ahti_pop_livelihoodzones_fewsnet2014_geonode_20170417
[168] ICA, Haiti. 2017. Livelihood zones, 2014. Available: https://geonode.wfp.org/layers/geonode%3Ahti_pop_livelihoodzones_fewsnet2014_geonode_20170417
[169] Furche, C. 2013. The Rice Value Chain in Haiti: Policy Proposal. *Oxfam America Research Backgrounder Series.* Available: http://www.oxfamamerica.org/publications/haiti-rice-value-chain-policy
[170] FAO. 2017. *FAO/WFP Crop and Food Security Assessment Mission to Haiti.* FAO, Rome.
[171] Singh, B. and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti.
[172] Index Mundi. 2019. Haiti Economy Profile 2019.
[173] FAO. 2017. *FAO/WFP Crop and Food Security Assessment Mission to Haiti.* FAO, Rome.

capacity; contributing to an unstable electricity supply characterised by frequent supply cuts[174]. Second, low levels of education pose a significant social barrier which contributes to a shortage of skilled labour. The average Haitian accesses just ~5 years of schooling[175]. Third, an over-dependence on remittances is a considerable financial barrier to economic development. Although Haiti has tariff-free access to the United States, remittances remain the primary source of foreign exchange and accounted for ~36% of total GDP[176] and two times the combined value of Haitian exports and foreign direct investment in 2019[177]. With many countries entering lockdown because of the COVID-19 pandemic, overseas workers are being affected and a projected 317,136 Haitian diaspora may lose their jobs, significantly impacting remittance levels as detailed in Sub-section 2.2.2 above[178].

2.3. Natural resources and agriculture

Agriculture is the major economic sector in Haiti, contributing to ~20% of its GDP and providing employment for more than 70% of the rural population[179]**.** Despite this, agricultural production is low — the country imports 51%[180] of its food — because of the sector's decline over recent decades as a result of neglected rural infrastructure, limited agricultural research and extension, poorly defined land tenure, limited access to credit, and under-investment in human capital[181]. Haiti's vulnerable production systems are threatened by climate change impacts (such as flooding) which are expected to exacerbate food insecurity in the country, particularly in catchment areas such as the Trois Rivières (TR) watershed located in the northern region of Haiti (Figure 7).

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[174] Singh, R.J., and Barton-Dock, M. 2015. Haiti: Toward a New Narrative.
[175] UNDP. 2019. Human Development Report: Haiti.
[176] Orozco. 2020. Migrants and the Impact of the Covid-19 Pandemic on Remittances.
[177] Index Mundi. 2019. Haiti Economy Profile 2019.
[178] Bojarski, S. 2020. Decline in Remittances from Pandemic Could Be Hard Felt in Haiti. Available: https://haitiantimes.com/2020/04/28/decline-in-remittances-from-pandemic-could-be-hard-felt-in-haiti/ [Accessed 08/07/2020]
[179] Haiti: Towards A New Narrative Systematic Country Diagnostic. 2015. World bank. http://documents.worldbank.org/curated/en/319651467986293030/pdf/97341-SCD-P150705-IDA-SecM2015-0130-IFC-SecM2015-0071-MIGA-SecM2015-0046-Box391466B-OUO-9.pdf
[180] Export.gov. 2019. https://www.export.gov/apex/article2?id=Haiti-Agricultural-Sector
[181] Haiti: Towards A New Narrative Systematic Country Diagnostic. 2015. World bank. http://documents.worldbank.org/curated/en/319651467986293030/pdf/97341-SCD-P150705-IDA-SecM2015-0130-IFC-SecM2015-0071-MIGA-SecM2015-0046-Box391466B-OUO-9.pdf

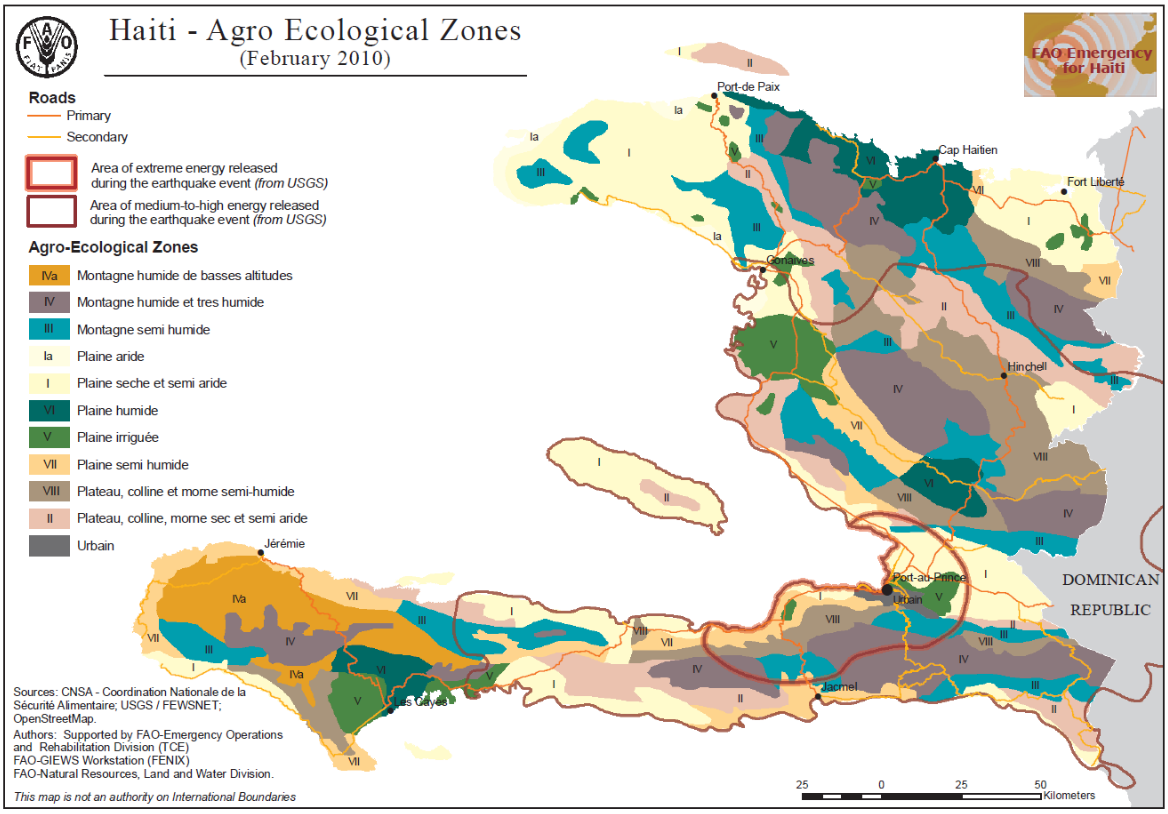

Figure 7. Agro-ecological zones of Haiti, showing the variation within the TR catchment[182].

Land use varies considerably between the communities within the different departments in the TR catchment (Figure 7). Table 2 indicates the land use for each of the three departments within the catchment. The data only represents general land use across the three departments that encompass the catchment, as sub-catchment land use data is not available. Land in this mountainous region is vulnerable to degradation because of widespread deforestation for charcoal production and a focus on annual crop production which leaves the soil bare during most of the year. These land-use factors reduce vegetative cover and increase surface runoff which in turn results in soil degradation, erosion and downstream flooding. High poverty levels and environmental stressors keep the local population in a cycle of degradation and reconstruction through the lack of available resources for constructing resilient infrastructure. This cycle is expected to worsen under climate change and lead to accelerated ecological degradation and deforestation in catchment areas.

[182] FAO. 2010. http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/216006/

Table 2. Land use within each of the three departments covering the Trois Rivières (TR) catchment, indicated by percentages related to the total area of arable land[183,184,185]. The variability in land use is also demonstrated in Fig. 5, illustrating how the agro-ecological zones within the TR catchment vary from dry and semi-arid areas to humid mountain forests.

	Artibonite	**Nord (North)**	**Nord-Ouest** (North West)
Cereals	61.5	17.2	24.5
Beans	16.9	16.8	28
Vegetables	11	30.6	28
Fruits & Nuts	2.3	19.1	11.4
Oil & Protein Crops	1.2	1.4	3.4
Cacao, Coffee & Spices	0.6	5.1	0.5
Sugarcane	4.3	6.1	0.9
Other	2.2	3.7	3.4

While deforestation has always been prevalent in the TR catchment, it has intensified after 1986, when the Haitian national government reduced the number of forestry and agricultural officials within the sub-catchments. This coincided with a global market decrease in coffee prices (Figure 8), which resulted in coffee farmers resorting to tree harvesting to supplement their incomes. At present, ~1% of Haiti's land cover is indigenous natural forest. In comparison, agroforestry cover — predominantly a mix between fruit, coffee and cocoa trees, annual crops, and forage for livestock — makes up ~30% of land cover. These areas are however located mainly in valleys and near built-up areas, not on the erosion-prone degraded slopes within the TR catchment, which means the region's agroforestry does not yet provide adequate flood attenuation benefits within the TR catchment. Continuous deforestation and surface tillage on sloped land also prevents self-sustained natural regeneration of tree stands, contributing to flood severity because of increased surface runoff. Over time, floods are further worsened as a result of cumulative sediment load downstream[186].

Figure 8. Historical coffee prices on the world markets. A visible drop in prices started in 1986 and lasted until 1992[187].

[183] MARNDR (2011). R'ecencement Generale de l'Agriculture (RGA) 2008/2009. Resultats Provisoires Department de l'Artibonite. Port-au-Prince, Haiti. 209 pp.
[184] MARNDR (2012a). R'ecencement Generale de l'Agriculture (RGA) 2008/2009. Resultats Provisoires Department du Nord. Port-au-Prince, Haiti. 213 pp.
[185] MARNDR (2012b). R'ecencement Generale de l'Agriculture (RGA) 2008/2009. Resultats Provisoires Department du Nord Ouest. Port-au-Prince, Haiti. 212 pp.
[186] Bruschi VM, Bonachea J, Remondo J, Gómez-Arozamena J, Rivas V, Méndez G, Naredo JM, & A. Cendrero A. 2012. Analysis of geomorphic systems' response to natural and human drivers in northern Spain: Implications for global geomorphic change. Geomorphology, 196, pp. 267–279. DOI: 10.1016/j.geomorph.2012.03.017
[187] Source: https://www.macrotrends.net/2535/coffee-prices-historical-chart-data

2.3.1. Charcoal production

The main driver of deforestation across Haiti is charcoal production — also a major economic activity within the TR watershed. Charcoal demand is high in Haiti and unlikely to decrease in the near future because of the slow uptake of efficient cookstoves and alternative cooking fuels such as liquid petroleum gas (LPG). Farmers also resort to charcoal production to supplement their income as a response to low yields, crop failure or unexpected expenses, particularly in extremely wet or dry years. As a result, most of the native forests have been harvested over time with minimal efforts of reforestation[188].

The general practice of charcoal production in the country is inherently unsustainable. Tree stands are harvested in parcels which creates bare plots within arboreous areas. This alters the micro-climate and hydrology, leading to a decrease in the number of tree species and enhanced tree mortality along forest edges. As a result, ecological fragmentation pushes the remaining forested patches beyond their tipping points[189,190], causing their sustained decline and eventual permanent dieback. The consequent increase in flood frequency, erosion and sediment loads, as well as the reduction in base-flow during the dry season, were raised during stakeholder consultations (see Annex 7). During these consultations, most of the interviewees noted the contrast between the current hydrological situation compared to pre-1986 when deforestation was less prevalent.

2.4. Climate profile

Haiti is characterised by a year-round hot and humid tropical climate and is subject to variability driven by the El Niño Southern Oscillation (ENSO). It is divided into tropical rainforest and tropical monsoon climates with small areas of arid steppe and temperate climates (Figure 9). The rainy season is long, particularly in the northern and southern regions of the island, with two pronounced peaks in rainfall occurring between March and November. Haiti is located in the middle of a hurricane belt, with the most severe storms routinely occurring from June to October and typically causing widespread flooding[191].

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[188] World Bank. 2017. Charcoal in Haiti. A National Assessment of Charcoal Production and Consumption Trends. World Bank, Washington. Available at: http://documents.worldbank.org/curated/en/697221548446232632/pdf/134058-CharcoalHaitiWeb.pdf

[189] Brinck K, Fischer R, Groeneveld J, Lehmann S, Dantas De Paula M, Putz S, Sexton JO, Song D & Huth A. 2017. High resolution analysis of tropical forest fragmentation and its impact on the global carbon cycle. Nature Communications, DOI: 10.1038/ncomms1485

[190] A tipping point is defined, for the purposes of the Global Biodiversity Outlook, as a situation in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and the services to people it underpins, at a regional or global scale. Tipping points also have at least one of the following characteristics: i) The change becomes self-perpetuating through so-called positive feedbacks, for example deforestation reduces regional rainfall, which increases fire-risk, which causes forest dieback and further drying; ii) There is a threshold beyond which an abrupt shift of ecological states occurs, although the threshold point can rarely be predicted with precision; and iii) The changes are long-lasting and hard to reverse. There is a significant time lag between the pressures driving the change and the appearance of impacts, creating great difficulties in ecological management. Reference: Biodiverse Information System for Europe. 2019. https://biodiversity.europa.eu/topics/tipping-points#:~:text=A%20tipping%20point%20is%20defined,a%20regional%20or%20global%20scale.

[191] World Bank. 2011. Climate risk and adaptation country profile: Haiti. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_HTI.pdf

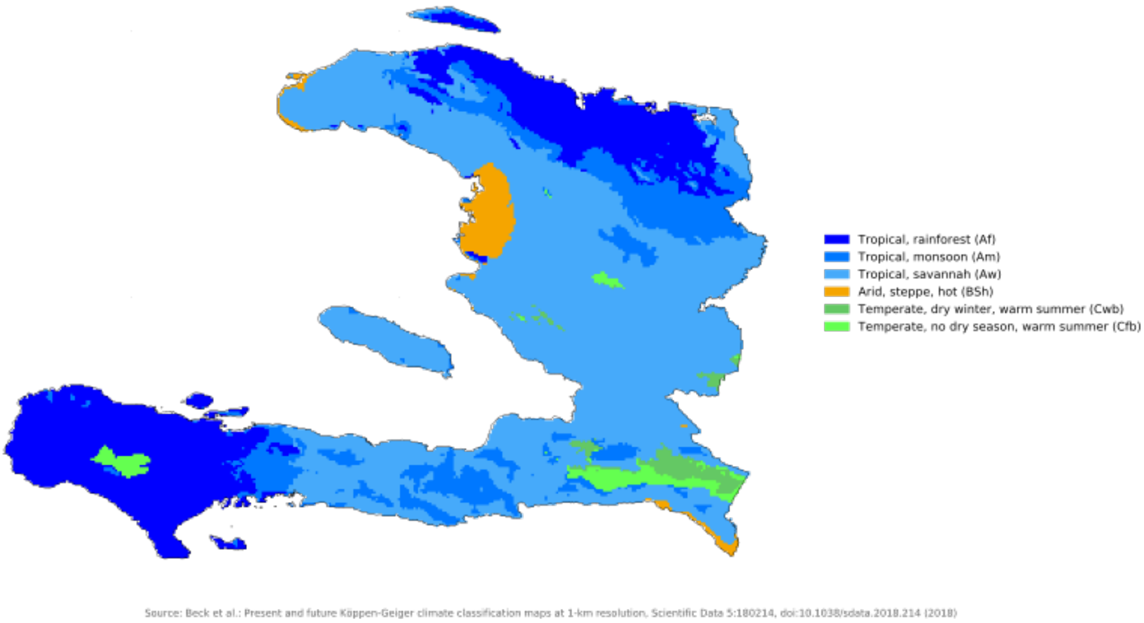


Figure 9. Köppen-Geiger climate classification map for Haiti (1980–2016)[192].

2.4.1. Temperature

The average annual temperature in Haiti is 24.4°C (Figure 10), with monthly temperatures typically ranging between 19–28°C in winter and 23–33°C during summer (Figure 11). The size of the country allows for latitudinal variation in mean monthly temperatures. Still, temperatures are consistently high in the lowland areas, ranging between 15–25°C in winter and 25–35°C during the summer months. Across the island, cooler temperatures occur during the northern hemisphere winter (December to February), and warmer temperatures occur in summer (July to August). Temperatures peak in July to August and the mean annual range in temperatures between the coolest and warmest months of the year is between 3°C and 4°C. Occasional surges of cooler air from North America — occurring from October through early April during the passage of cold fronts — contribute to minimum temperatures that can fall below 20°C, particularly for northern portions of the island[193].

[192] Beck HE, Zimmermann NE, McVicar TR, Vergopolan N, Berg A & Wood EF. 2018. Present and future Köppen-Geiger climate classification maps at 1 km resolution. Scientific Data 5:180214. doi:10.1038/sdata/2018/214.
[193] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf

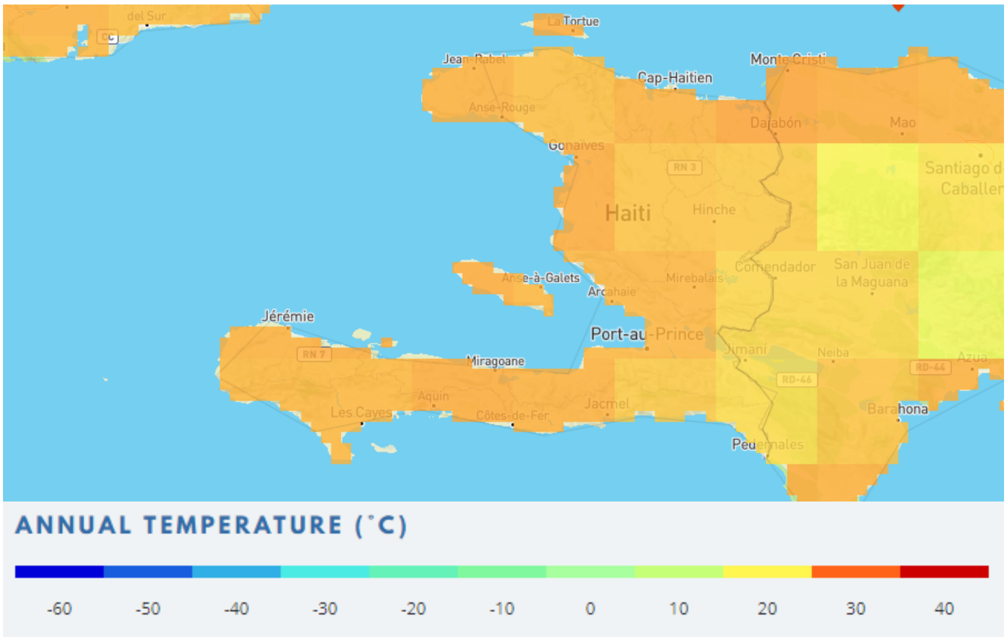


Figure 10. Average annual temperature of Haiti (1901–2016)[194].

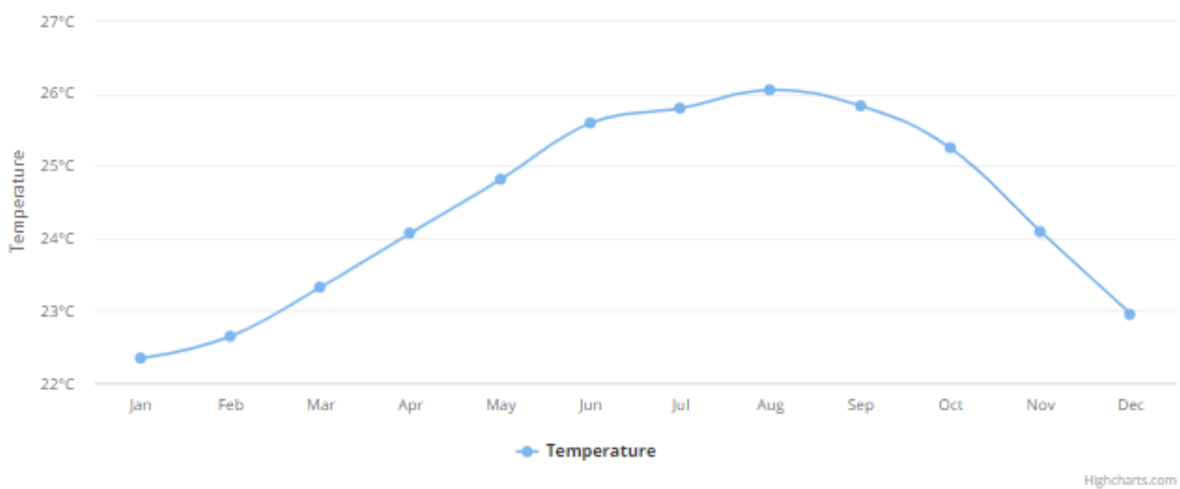


Figure 11. Average monthly temperature of Haiti (1901–2016)[195].

2.4.2. Rainfall

The average annual rainfall in Haiti ranges between 1,400–2,000 mm, with uneven distribution across the country (Figure 12), while the average monthly rainfall ranges from 40–210 mm (Figure 13). Heavier rainfall occurs in the southern peninsula and on the northern plains and mountains, whilst rainfall decreases from east to west across the northern peninsula. The eastern central region receives a moderate amount of precipitation, while the western coast from the northern peninsula to Port-au-Prince, is dry[196].

Rainfall levels differ according to the island's varied topography, with the central regions receiving more rainfall than the northern and western regions. Northern and windward slopes in the mountainous regions receive up to three times more precipitation than the leeward side.

[194] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf.
[195] Ibid.
[196] USAID. 2015. Climate Change Information Fact Sheet: HAITI. Available at: https://www.climatelinks.org/sites/default/files/asset/document/Haiti%20Climate%20Info%20Fact%20Sheet_FINAL.pdf

Annual precipitation in mountainous areas averages 1,200 mm, while the annual precipitation in the plains is as low as 550 mm. The Plaine du Gonaïves and the eastern part of the Plaine du Cul-de-Sac are the driest regions in the country, where, combined with the effects of high temperatures, evaporation rates are high. The North-West, Artibonite, North-East, and Central Departments frequently experience repeated droughts caused by erratic rainfall patterns coupled with limited water management infrastructure[197].

Figure 12. Average annual precipitation of Haiti (1901–2016)[198].

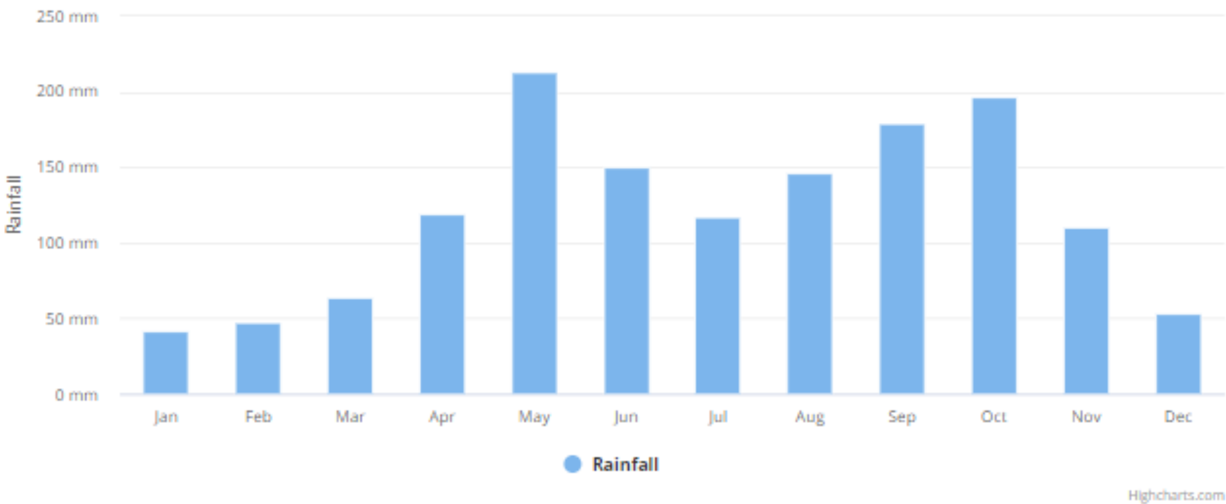


Figure 13. Average monthly rainfall of Haiti (1901–2016)[199].

[197] World Bank Group. 2019. Climate Knowledge Portal: Haiti Country Context. Available at: https://climateknowledgeportal.worldbank.org/country/haiti/climate-data-historical
[198] Ibid.
[199] Ibid.

2.4.3. Baseline flood conditions

Floods are the leading contributor to climate change vulnerability in Haiti[200], resulting from intense rainfall events, tropical storms and hurricanes. The country's most populous cities are located both along the valleys leading to the coast, as well as along or near the coastline. This means that when it rains, steep hills upstream direct rainwater towards urban areas, exacerbating flooding. Widespread deforestation in the upper reaches of these valleys, coupled with limited drainage infrastructure, creates an environment conducive to flooding. This flood risk is compounded by the steep topography of the island, with approximately two-thirds of all land in Haiti being sloped at more than 20% — further contributing to erosion and landslide risk[201]. The capital city of Haiti, Port-au-Prince, is particularly vulnerable, with a large portion of its inhabitants residing on floodplains in poorly constructed housing[202]. While the government administers a flood early-warning system, it does not yet provide adequate, accurate and real-time data, restricting the ability of communities to respond to flood events promptly. Disaster risk reduction and management systems are further limited by the fact that there are few accessible and adequate shelters located on high ground and equipped with the food and medicine necessary to serve vulnerable communities[203].

The low-lying plains of the Ouest and Artibonite Departments and the narrow coastal zones of the Sud, Sud-Est, Grande Anse, and Nippes Departments are particularly vulnerable to flooding. Additionally, on the Cul-de-Sac Plain of the Ouest Department, the Rivière Blanche and Rivière Grise basins are subject to severe flooding. Heavily populated coastal towns, such as Jacmel, Les Cayes, and Gonaïves, are also at high risk of flooding as they lie in the direct path of tropical storms (Figure 14). Low-income communities located near rivers and coastal floodplains are particularly vulnerable to the impacts of hurricanes, experiencing fatalities during the storm season as a result of both flooding and gale-force winds. For example, in 2004, more than 2,800 people died in Gonaïves following Hurricane Jeanne. In addition to the inland flood impacts of intense rainfall, hurricanes result in storm surges which flood coastal plains with saltwater. This saltwater increases the salinity of soils and groundwater reserves, with considerable economic losses resulting from the negative impacts on agriculture. Other priority sectors, such as public health, are also negatively affected by torrential rains through inundations, as they facilitate the spread of diseases such as cholera. These impacts are often compounded by deliberate overflowing of the Peligre hydropower dam to maintain the power supply in metropolitan Port-au-Prince, exacerbating flooding in the Artibonite Valley. The Canot irrigation dam was built to divert irrigation water to larger and wider areas and to ease flooding via two channels on either side of the Artibonite River. Instead of alleviating floods, however, these diversion spillways facilitate inundations because of the overflow events caused by the upstream release of water behind the Peligre and Dominican Republic hydropower dams[204].

Haiti's vulnerability to flooding (described above) is attributable to a variety of climate- and non-climate-related drivers. Climate-related drivers include: i) the changes in variability of rainfall and extreme weather events; ii) intense seasonal rainfall; and iii) storm surges in coastal zones. Non-climatic drivers include: i) degraded and eroded watersheds; and ii) sedimented river channels. Many of these drivers, both climatic and non-climatic, are interlinked and combine to increase the impacts of flooding. For example, as a result of the reduced infiltration linked to deforestation and catchment degradation, heavy rainfall during

[200] USAID. 2015. Climate Change Information Fact Sheet: HAITI. Available at: https://www.climatelinks.org/sites/default/files/asset/document/Haiti%20Climate%20Info%20Fact%20Sheet_FINAL.pdf
[201] USAID. 2017. Climate risk profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf
[202] World Bank. 2011. Climate risk and adaptation country profile: Haiti. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_HTI.pdf
[203] Oxfam. 2014. Climate change resilience: The case of Haiti. Available at: https://www-cdn.oxfam.org/s3fs-public/file_attachments/rr-climate-change-resilience-haiti-260314-en_2.pdf
[204] Ibid.

tropical storms and hurricanes (sometimes as much as 40 mm/hour) causes rapid runoff and extensive erosion. This erosion reduces the depth of fertile soils, while the resulting sedimentation reduces storage capacities of water bodies. The degradation of forests also reduces water retention capacity of soils in the catchment, exacerbating surface runoff. As a result of the combination of these effects, the impacts of future floods become increasingly more intense, leading to loss of lives and livelihoods in larger numbers. Additionally, by destroying fertile soils and damaging property and livelihoods in communities within flood-prone areas, flooding causes low-income communities located near these areas to experience considerable economic losses[205].

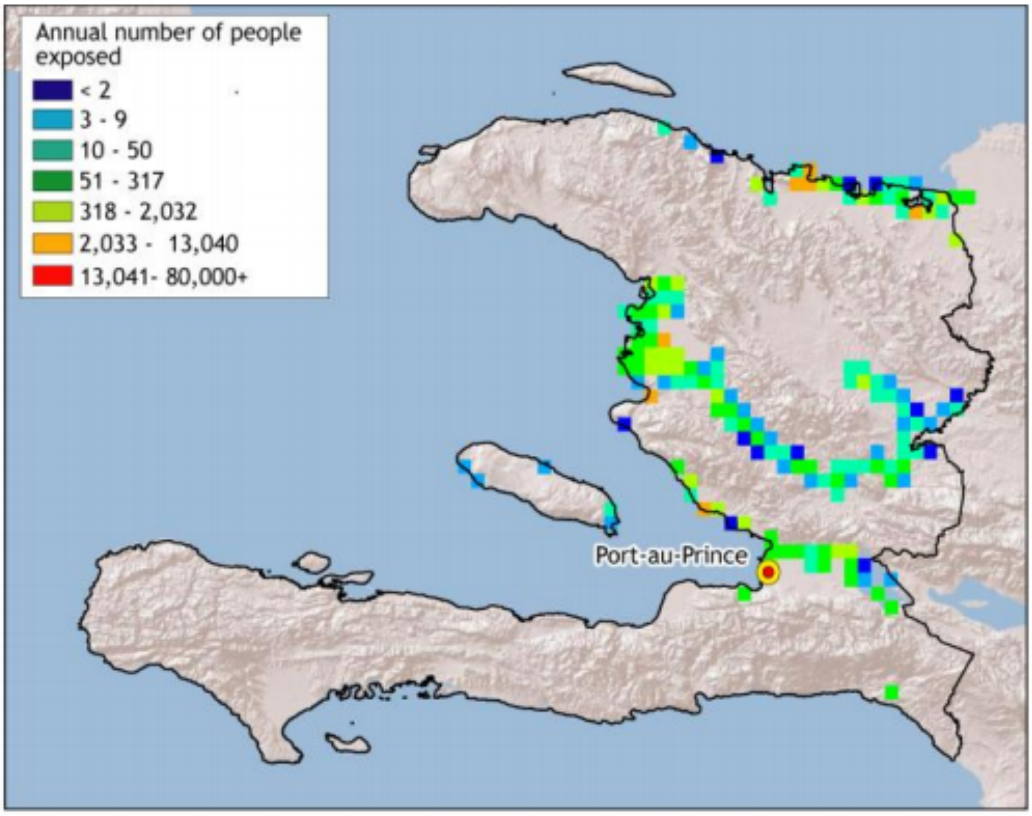


Figure 14. Physical exposure to flooding in Haiti[206].

Hydrological data are sparse for the Trois Rivieres watershed, and it is therefore not possible to provide an accurate baseline of flood conditions specific to the project target area. Only for one river, the Artibonite, is flow rate data available. Specifically, these are: i) 1:25 year flood — 1,111 m^3 per second; ii) 1:10 year flood — 1,046 m^3 per second; iii) 1:05 year flood — 981 m^3 per second (major flood); iv) 1:1.5 year flood — 785 m^3 per second (bank-full flood); and v) mean discharge — 296 m^3 per second. The primary hydrologic discharge record comes from historical rain gauges operating in the watershed. However, there are no known water-surface elevation profiles or surface water extent measurements. A flood hazard map has been produced by the Government of Haiti's natural hazards agency, but it is only available for the river downstream of Gros Morne (Figure 15). With an unknown quality and accuracy, it is unclear how well this flood hazard map represents historical flooding. Indeed, it is clear in some areas that the flood hazard extent is erroneous because it extends up steep, non-channelled hillslopes. Encouragingly, however, there is a correspondence between the flood hazard map and the largest historical flood modelled under the technical analyses[207]

[205] Ibid.
[206] World Bank. 2011. Climate risk and adaptation country profile: Haiti. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_HTI.pdf
[207] Please refer to Section 3.4: Flooding trends.

commissioned to support the delivery of this Feasibility Study (Figure 15)[208]. From the gauge data that is available and specific to the proposed project's target area, a maximum daily flow observation from the Gros Morne gauge of 585 m^3 per second was recorded in November 1927. Based on a hydraulic analysis, it was estimated that the Gros Morne River flow represents ~50% of the total flow for the Trois Rivieres watershed[209]. This information was used to inform the modelling performed to determine future flood potential of the project target area, as described in Section 3.4: Flooding trends.

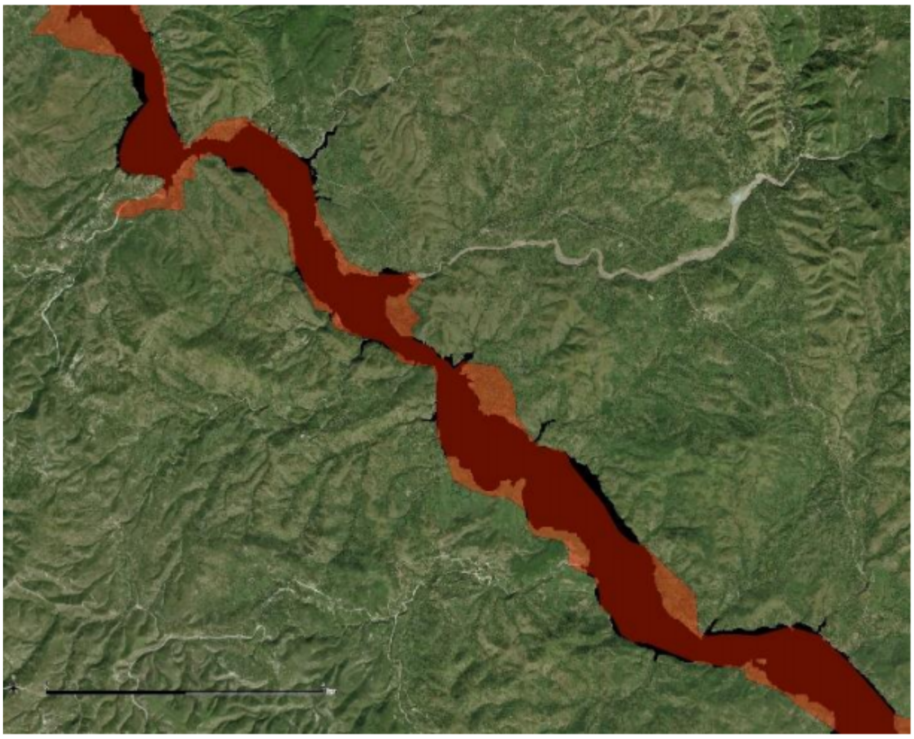


Figure 15. Close-up view of the middle Trois-Rivieres River, ~15 km downstream of Gros Morne. The shaded areas show correspondence between the: i) Haiti natural hazard agency flooding map (red); and ii) extent of the largest historical flood modelled under the hydrodynamic report commissioned to support the delivery of this Feasibility Study (black)[210]. The dark red area shows correspondence, whilst the pale red area shows the non-corresponding flooding map, and the black area shows the non-corresponding data from the model.

2.4.4. Sea Level Rise

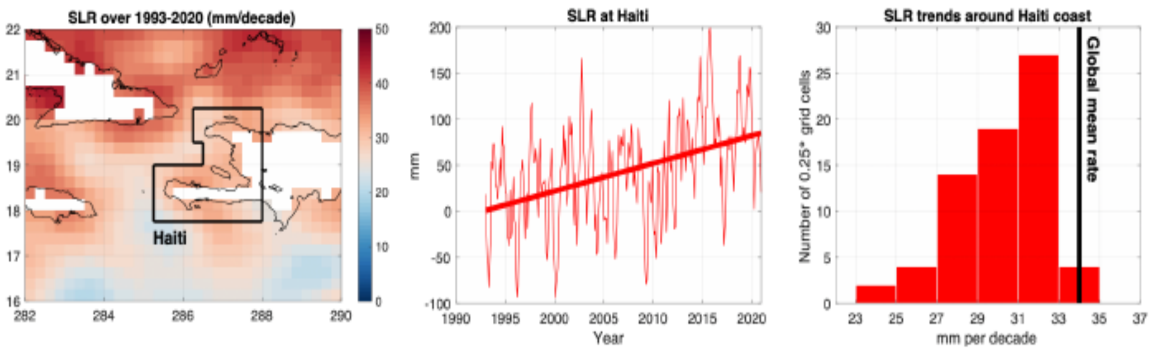
Past rates of sea level rise (SLR) were calculated using satellite altimetry and historical tide gauge records. Satellite altimetry covers the recent past (since 1993), and provides a very robust and reliable measurement of rates of SLR—both globally and regionally. Historical tide gauge records in the Caribbean region, on the other hand, are spotty and should be used with extreme caution. While they are difficult to compare directly with altimeter measurements (or climate model projections), they can provide a valuable longer-term perspective.

The altimeter data analyzed was the EU Copernicus Marine Environment Monitoring Service (CMEMS) L4 sea surface height product, reprocessed 1993–2020. This product is available globally at monthly temporal resolution and 0.25° spatial resolution and is a blend of

[208] Minear, J.T. and Water Science International LLC. No date. Summary Report of Hydrodynamic Model Results: Assessment of Past and Future Flood Potential, Trois-Rivieres Watershed, Haiti.
[209] Water Science International LLC. No date. Hydrology Summary Report to the United Nations Development Programme: Assessment of future flood potential for the Trois-Rivières watershed.
[210] Minear, J.T. and Water Science International LLC. No date. Summary Report of Hydrodynamic Model Results: Assessment of Past and Future Flood Potential, Trois-Rivieres Watershed, Haiti.

measurements from the TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and Jason-3 satellite altimetry missions.

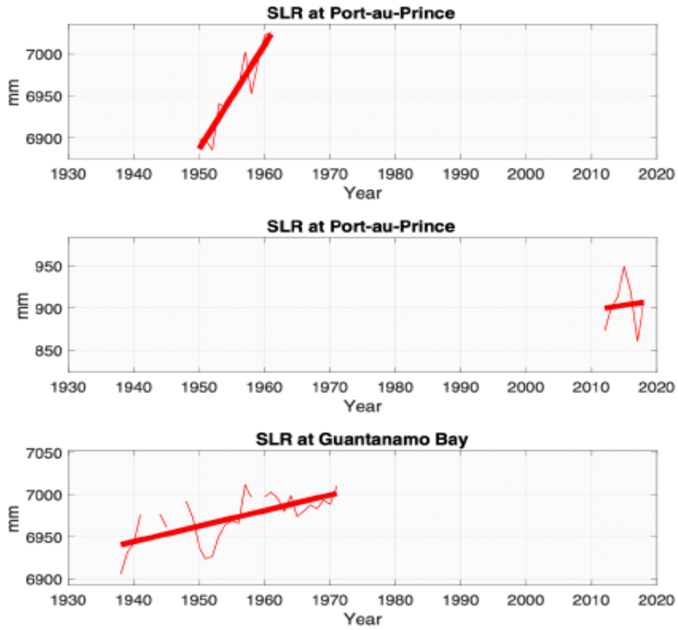
Based on the altimeter measurements over 1993–2020, the average rate of SLR at Haiti has been 30.13 ± 6.5 mm per decade, which is 11% less than (but within error of) the global mean rate of SLR (~34 mm per decade). The figure below shows a map of the SLR trends in the vicinity of Haiti, a time series of sea level change averaged around Haiti, and a histogram of all of the SLR trends at the individual grid cells within the Haiti region.



Two historical tide gauge records were obtained from Haiti (Port-au-Prince), and one from Guantanamo Bay, Cuba (approximately 330 km northwest of Port-au-Prince) for comparison. The three records were available at different temporal resolutions (from daily to annual); for consistency, all records were converted to annual prior to analysis. The three records are as follows.

- Permanent Service for Mean Sea Level, Station 583 (Port-au-Prince, Haiti), 1950–1961.
- University of Hawaii Sea Level Center, Station 799 (Port-au-Prince, Haiti), 2012–2018.
- NOAA Center for Operational Oceanographic Products and Services (CO-OPS), Station 930-051. Guantanamo Bay, Cuba), 1938–1971.

The figure below shows the time series for each of the three historical tide gauge records analyzed. The three records cannot be plotted onto a single graph because they are all relative to different fixed datums, but the relative rates of SLR can be compared directly, and the y-axis limits are equivalent in each plot (a total span of 160 mm).



For the first Port-au-Prince record (1950–1961), the rate of SLR was 123 ± 33 mm per decade. This is considerably higher than the rate of SLR observed by the altimeter record since 1993. For the second Port-au-Prince record (2012–2018), the rate of SLR was insignificant (12 ± 156 mm per decade), which is unsurprising since it is computed over a very short period of only seven years. For the Guantanamo Bay record (1938–1971), the rate of SLR was 18 ± 8 mm per decade over the full period, which is 61% of the rate of SLR observed by the altimeter record since 1993. However, during the period over which the Guantanamo Bay record and the first Port-au-Prince record overlap (1950–1961), the rate of SLR at Guantanamo Bay was much higher—78 mm per decade, which suggests that the trend observed in the first Port-au-Prince record was strongly influenced by natural, regional climate variability and not solely anthropogenic climate change.

Overall, these results from the historical tide gauge records indicate that SLR at Haiti has been ongoing for several decades, and significant decadal variations are superimposed upon the long-term anthropogenic trend.

Climate change in Haiti

Analysis of historical climate data in Haiti shows that the country has undergone changes in both temperature and rainfall. Across the country, the maximum, minimum and mean temperatures have all increased from 1901–2013. Minimum and maximum temperatures increased by ~0.12°C and ~0.10°C per decade, respectively. This has been accompanied by a corresponding decrease in daily temperature ranges[211]. In addition, there have been changes in the average amount of annual rainfall in Haiti, with observations from 1960–2010 showing a decrease in total monthly rainfall of ~5 mm per decade[212]. Using data from between 1905–2005 collected from 78 rain gauges in Haiti, it has been shown that there is large variability in annual rainfall (509 mm to 2,434 mm). Across stations and months, the mean monthly rainfall was found to be ~115 mm for the same period[213]. Despite the decrease in average annual rainfall, there is a trend towards more concentrated precipitation events[214]. This means that rainfall events occur less often but with greater intensity, consequently leading to a greater risk of flooding. Coupled with an increase in the intensity of Atlantic hurricanes since 1980[215], these conditions have led to an increase in the frequency and severity of climate change-induced flooding in Haiti.

A methodology has recently been developed to provide tailored climate change projections that are applicable to Small Island Developing States (SIDS) such as Haiti, which account for changes in rainfall and surface water balance[216,217] based on the latest generation of global climate models (GCMs). For this Feasibility Study, a hybrid statistical downscaling approach was used that leveraged high resolution (5 km), satellite-based rainfall observations[218] with the latest suite of Intergovernmental Panel on Climate Change (IPCC)-class GCMs as part of the Coupled Model Intercomparison Project phase 5 (CMIP5)[219].

Downscaled climate projections[220] indicate that, by the end of the 21st century, Haiti will experience a: i) warmer climate where, between 2081–2100, the average annual temperature is expected to increase by between 1.7°C (RCP4.5) and 3.7°C (RCP8.5); ii) drier climate where, between 2081–2100, total annual rainfall is expected to decrease by between 9% (RCP4.5) and 20% (RCP8.5); and iii) a future where tropical storm/hurricane genesis, frequency and tracks are similar to the very recent past (last two decades) but intensities (rainfall rates and wind speeds) are increased. These projections are described in detail below.

211 IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf

212 World Bank. 2011. Climate risk and adaptation country profile: Haiti. Available at: https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_HTI.pdf

213 Moron, V., Frelat, R., Jean-Jeune, P.K., and Gaucherel, C. 2015. Interannual and intra-annual variability of rainfall in Haiti (1905–2005). *Clim Dyn* 45:915-932.

214 BRGM (France) & CIAT. Atlas des menaces naturelles en Haiti. Available at : http://ciat.gouv.ht/sites/default/files/articles/files/ATLAS%20HAITI%20FRENCH%2005032017_LR.pdf

215 US Climate Change Science Programme. 2008. Weather and Climate Extremes in a Changing Climate. Synthesis Assessment. Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Eds. Thomas R. Karl, Gerald A. Meehl, Christopher D. Miller, Susan J. Hassol, Anne M. Waple, and William L. Murray. 180 pp.

216 Karnauskas, K.B., Donnelly, J.P., and Anchukaitis, K. J. 2016. Future Freshwater Stress for Island Populations. *Nature Climate Change*, 6.

217 Karnauskas, K. B., Schleussner, C.F., Donnelly, J.P., and Anchukaitis, K. J. 2018. Freshwater Stress on Small Island Developing States: Population Projections and Aridity Changes at 1.5°C and 2°C. *Regional Environmental Change*.

218 Funk, C., *et al*., 2015. The climate hazards infrared precipitation with stations — a new environmental record for monitoring extremes. *Nature Scientific Data*, 2, 150066.

219 Taylor, K. E., Stouffer, R.J. and Meehl, G.A. 2012. An Overview of CMIP5 and the Experiment Design. *Bulletin of the American Meteorological Society*, 93.

220 IDB. 2015. Haiti: historical and future climatic changes.

3.1. Temperature trends

The annual mean daytime temperatures for the Caribbean region show an increase of 0.19ºC per decade over the period 1961–2010[221]. This is less than the increase in mean night-time temperatures of 0.28ºC per decade over the same period, with the resultant change being a decrease in the mean annual daily temperature range. Under the RCP4.5 scenario, maximum increases in temperature of 1,02°C and 1,87°C are expected for 2025 and 2055, respectively, and maximum increases of 1,18°C for 2025 and 2,57°C are expected for 2055 under the RCP8.5 scenario[222]. Furthermore, the gridded data[223] for Haiti (Figure 16) likewise show a warming trend for the country. When calculated for the period 1901–2013, minimum temperatures showed a slightly higher rate of increase (~0.12 ºC per decade) than maximum temperatures (~0.10 ºC per decade), which is consistent with the decrease in daily temperature range. Overall, mean temperatures increased at a rate of 0.09 ºC per decade in Haiti over the 112-year period[224]. Since 1960, a similar trend is observable in mean temperatures which have increased by 0.45°C, with warming occurring most rapidly in the warmest months (June to November). The frequency of hot days and nights increased by 63 and 48 days per year, respectively, between 1960–2003, whilst the frequency of cold days and nights has decreased steadily since 1960[225,226].

Figure 16 shows a linear trend which characterises the time series. The dominance of rising temperatures in the historical data is true for the entire Caribbean region where the linear trend accounts for approximately half of the variability seen (

6). Figure 16 also shows decadal variability (groups of years which are warmer or colder) and considerable interannual variability (swings between one year and another). Figure 17 shows that the linear trend accounts for 55–60% of the temperature time series for Haiti during July to October.

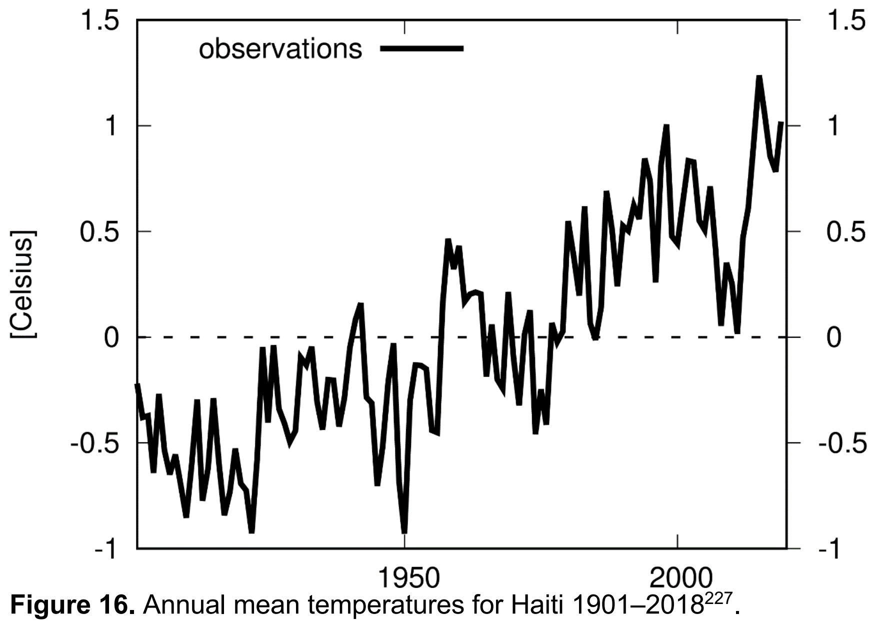


Figure 16. Annual mean temperatures for Haiti 1901–2018[227].

[221] Campbell, J. D., M. A. Taylor, T. S. Stephenson, R. A. Watson, and F. S. Whyte, 2011: Future climate of the Caribbean from a regional climate model. *Int. J. Climatol*., 31, 1866–1878
[222] Haiti. First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC).
[223] CRU TS 3.10: fully interpolated dataset with high resolution (0.5°). Monthly gridded fields based on monthly observational data, which are calculated from daily or sub-daily data by national meteorological services and other external agents.
[224] University of East Anglia Climatic Research Unit. Jones, P.D., Harris, I. 2013. Retrieved from KNMI Climate Explorer. Available at: http://climexp.knmi.nl/plot_ atlas_form.py
[225] USAID. 2015. Climate Change Information Fact Sheet: HAITI.
[226] World Bank Group. 2019. Climate Knowledge Portal: Haiti Country Context.
[227] Ibid.

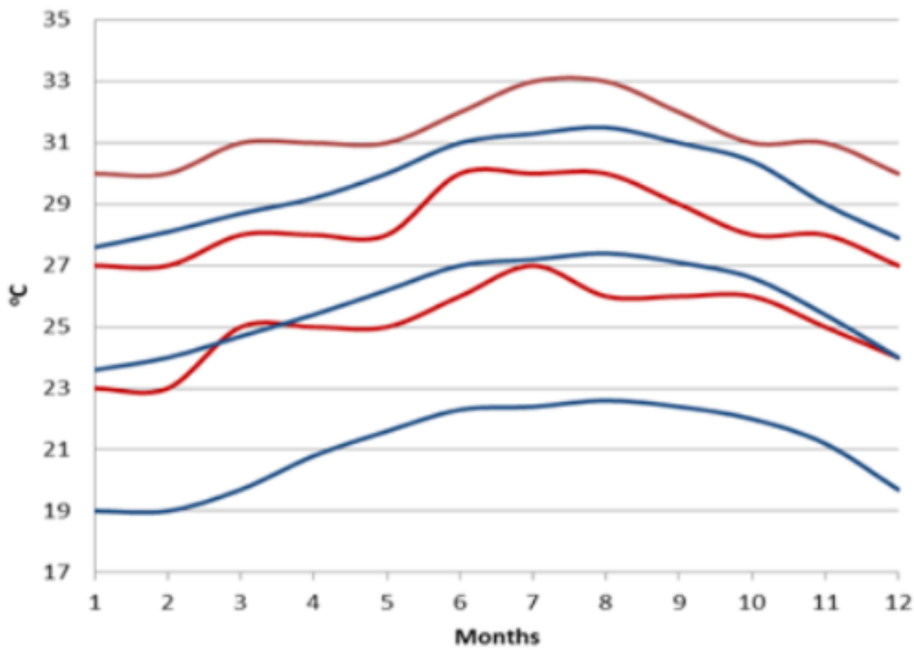


Figure 17. Temperature profile of Haiti. Red lines represent maximum (top), mean (middle) and minimum (bottom) temperatures for Port-au-Prince. Blue lines follow the same pattern but are for Cap Haitien[228].

Across the country, using IPCC general circulation model (GCM) CMIP5 gridded datasets[229], mean annual temperatures are projected to increase, irrespective of RCP scenario through the end of the century. The mean country temperature increase from the GCMs will be 0.66–0.78°C for the 2020s, 0.80–1.11°C for the 2030s, 0.92–1.86°C for the 2050s, and 0.87–3.32°C for 2081–2100. Increases for maximum temperatures and minimum temperatures are projected to be approximately the same.

Data from regional climate model (RCM) gridded datasets[230] suggest greater temperature increases for downscaled regions in Haiti than those determined from the CMIP5 GCM ensemble. This is expected since the GCM ensembles average across the entire country. Minimum temperatures, however, show slightly higher increases than for mean and maximum temperatures. There is some spatial variation (across the country and even within grid sections) with coastal regions generally showing slightly smaller increases in temperature variables than interior regions to their east. Temperature change is generally uniform across all three-month seasons, while August to October has slightly higher values for minimum, maximum and mean temperature increases than other three-month seasons[231].

Results from separate downscaled projections specific to the Trois Rivieres (TR) region[232] also indicate a warming trend. Consistent with previous non-downscaled CMIP5 projections[233], the results generated for the project area indicate that future changes in the baseline climate at Trois Rivières will be severe and robust, particularly for the end of the century. The daily maximum temperature for the TR region is projected to increase by 1.5°C and 3.3°C at mid-

[228] Weather station data obtained from http://www.weatherbase.com/
[229] CMIP5 (IPCC AR5 Atlas subset) This is the dataset used in the IPCC WG1 AR5 Annex I "Atlas". Only a single realisation from each of over 20 models is used. All models are weighed equally, where model realisations differing only in model parameter settings are treated as different models. Retrieved from KNMI Climate Explorer. Available at: http://climexp.knmi.nl/plot_ atlas_form.py
[230] PRECIS Perturbed Physics experiments performed for the Caribbean. Available from the Caribbean Community Climate Change Centre.
[231] Ibid.
[232] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.
[233] Maloney, E., *et al.* 2014. North American climate in CMIP5 experiments: Part III: Assessment of Twenty–First Century projections. *Journal of Climate*, 27, 2230–2270.

and end-century, respectively (Figure 18). Warming of the surface air temperature in Haiti — and more generally across the island of Hispaniola — is in line with the expected enhanced warming toward the interior of landmasses. This is because warming tends to be moderated by proximity to the ocean[234].

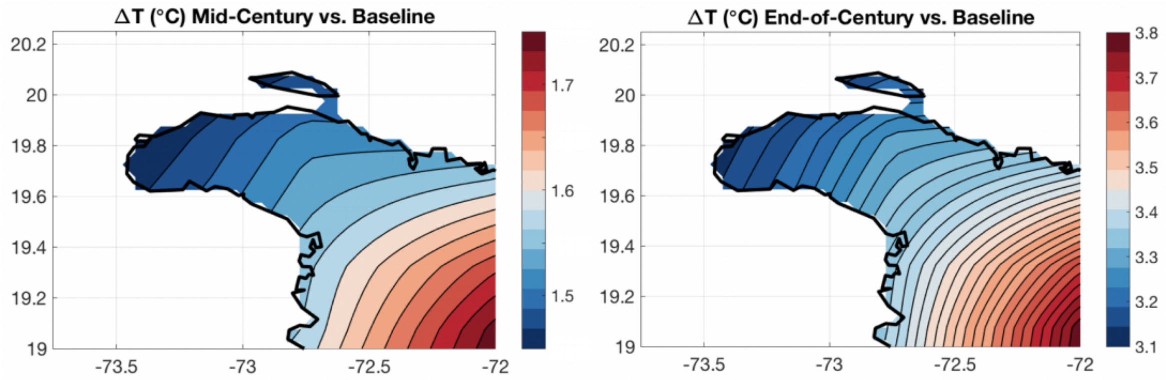


Figure 18. Multi-model mean changes in annual mean surface air temperature in °C for the mid-century (2041–2060) and end–century (2081–2100) periods relative to the baseline (1991–2010). Blue shading does not indicate cooling, it indicates less warming. The contour interval is 0.02°C[235].

Changes in hydrological extremes are best viewed through a hydrological model translation of downscaled GCM outputs, but some insight into such changes can be achieved by looking directly at the downscaled data. To provide a temporal illustration of the downscaled projections, Figure 19 shows the daily time series of downscaled maximum daily temperature. This is for the Gros Morne area of the TR region for two downscaled GCMs. From the CMCC climate model, it is projected that this region of Haiti will be subject to considerable warming of maximum daily temperatures, with summertime temperatures reaching 40°C by 2100[236].

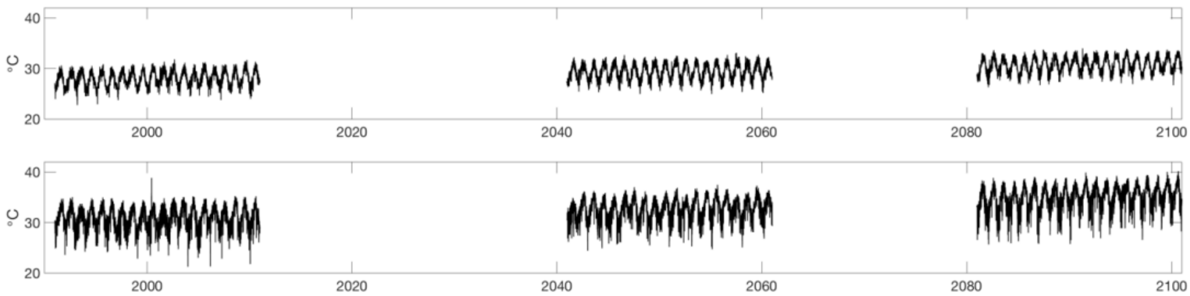


Figure 19. Daily time series of downscaled maximum daily temperature (°C) at the Gros Morne area of the Trois Rivières region of Haiti (72.675°W, 19.675°N) for two GCMs (NCAR CCSM4 and CMCC CM)[237].

To illustrate the changes in the distribution of maximum daily temperature extremes for the same location simulated by the GCMs, Figure 20 shows the evolution of the frequency distribution in each model from the baseline period to mid- and end-century. The GCMs all show that the mean will shift towards a warmer climate, and the extreme warm events will become more extreme (or equivalently, what is currently considered extreme will become the new baseline climate)[238].

[234] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.
[235] Ibid.
[236] Ibid.
[237] Ibid.
[238] Ibid.

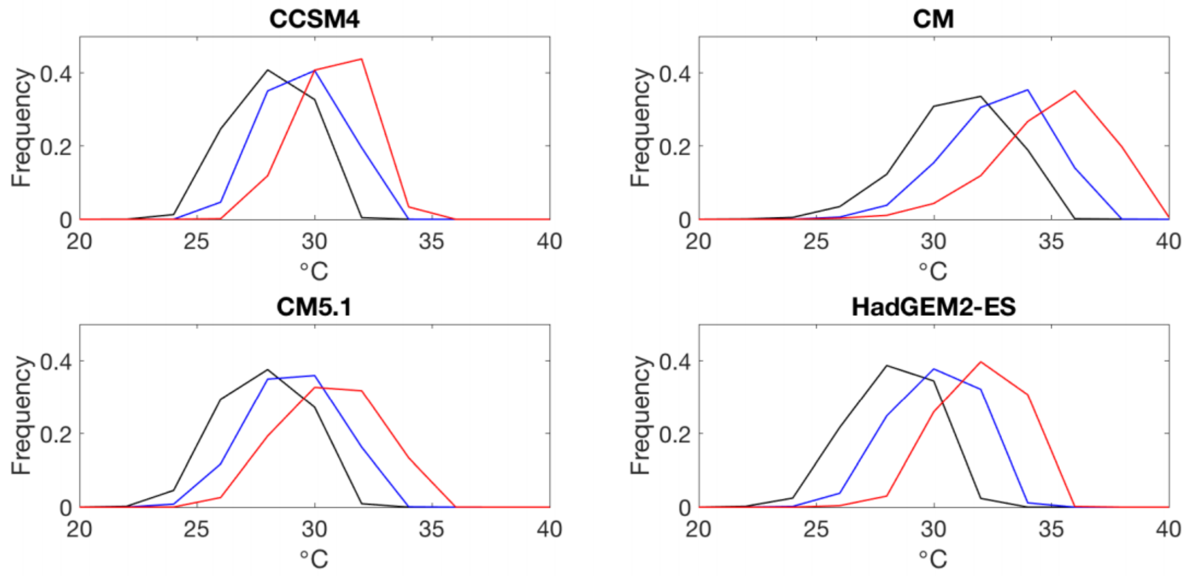


Figure 20. Frequency distributions (histograms) of maximum daily temperature (°C) for the baseline period (black), mid-century (blue) and end-century (red) periods. Each model is shown in a separate panel of the plot as labelled at the top of each panel[239].

Additionally, reliable satellite observations of sea surface temperature (SST) (Reynolds et al. 2002), show that the ocean surrounding Haiti has been warming significantly over the analysis period (Figure 2). The observed trend in SST averaged over 75°W–72°W, 17°N–21°N was 0.17°C per decade, for a total warming of 0.70°C over the period 1982–2021. Although not a complete explanation, this warming trend of the adjacent ocean surface is physically consistent with an increase in rainfall—both the mean and increase in extremes.

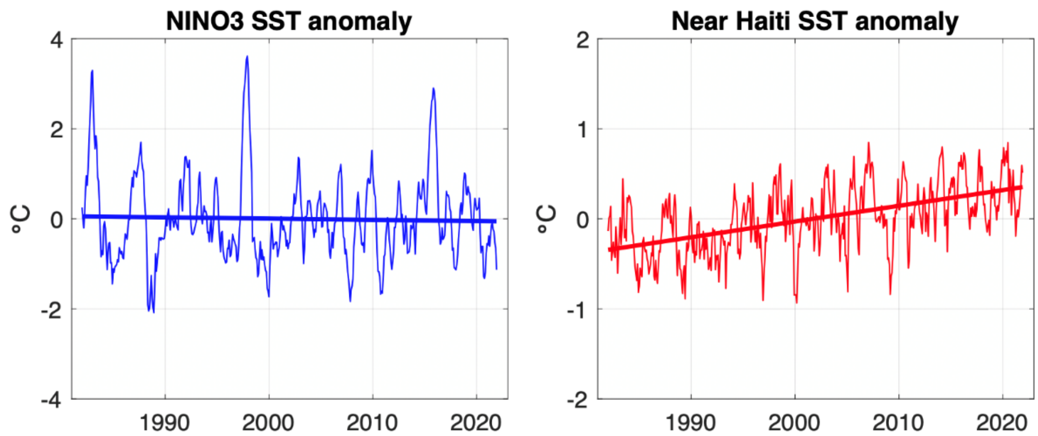


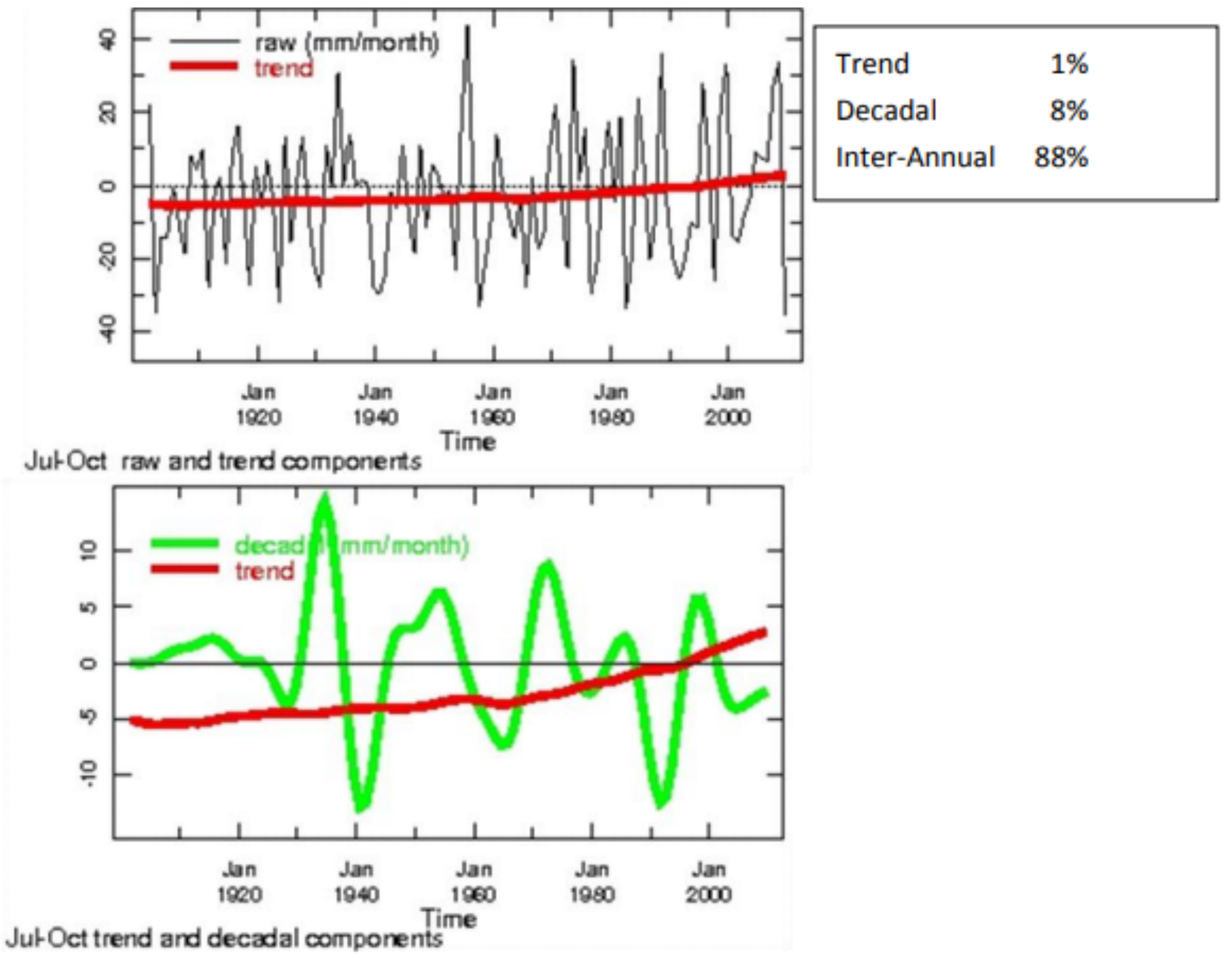
Figure 21 Left: Observed sea surface temperature (SST) (°C) in the NINO3 region of the eastern equatorial Pacific Ocean (150°W–90°W, 5°S–5°N) from satellite observations. Right: As in left, but in the vicinity of Haiti (75°W–72°W, 17°N–21°N). The trend in NINO3 (thick blue line) is approximately zero and statistically insignificant, while the SST trend near Haiti (thick red line) is positive (0.17°C per decade) and significant at the 90% confidence level based on a two-tailed Student's t-test

3.2. Rainfall trends

[239] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.

Interannual (year to year) variability is a major feature of Haiti's historical rainfall record. Figure 21 shows the annual rainfall anomalies from the beginning of the twentieth century as derived from CRU gridded data. The rainfall record does not show a linear trend like the temperature time series, but instead shows considerable interannual and decadal variability. This prevalence of the interannual timescale in the rainfall time series is typical of Caribbean rainfall (Figure 22)[240].

The short-term variability is partially because of the El Niño/La Niña phenomenon which drives interannual climate variability in the Caribbean. El Niño events tend to occur every three to five years, though increases in the frequency, severity and duration of events have been observed since the 1970s. Because an El Niño event exerts a considerable influence on the Caribbean climate, it is not unusual to find its timescale of variability (i.e. three- to five-year cycles) in regional rainfall and temperature records. During an El Niño event, the Caribbean tends to be drier and hotter, particularly during the late wet season from August through November. There is also a tendency for reduced hurricane activity during El Niño events as records indicate that meteorological droughts occurring over the Caribbean in 1997–1998 and 2010 coincided with El Niño events. However, during the early rainfall season (May to July) in the year after an El Niño, the Caribbean region tends to be wetter than usual. The El Niño also has an impact on the Caribbean dry period as it tends to induce opposite signals over the north and south Caribbean. This means that, in general, a La Niña event produces the opposite conditions in both the late wet season (i.e. wetter conditions) and the dry season (i.e. a wetter south Caribbean)[241].



[240] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf
[241] Ibid.

Figure 22. (a) Average July to October rainfall anomalies over the Caribbean from the late 1800s with trend line imposed. (b) Trend and decadal components of the average July to October rainfall anomalies over the Caribbean from the late 1800s[242].

The Trois Rivières region of Haiti (marked on Figure below) receives approximately 1 meter of rainfall per year (averaged over 1981–2021)[243]. During this time annual rainfall in the Trois Rivières region of Haiti has increased by 152 mm (or 15%) since 1981—a trend that is statistically significant at the 90% confidence level (p = 0.08) based on a two-tailed Student's t-test.

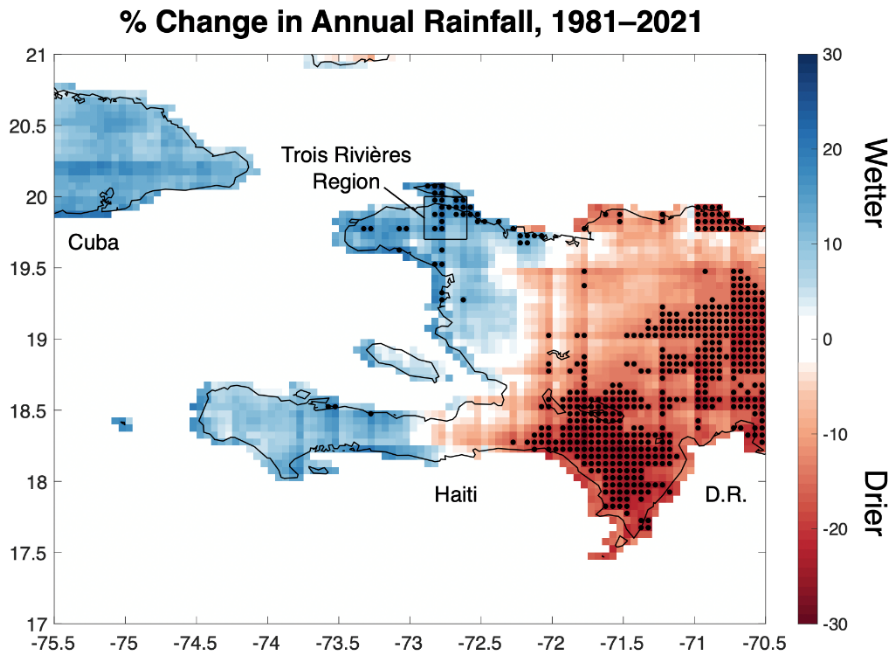


Figure X. Map of observed linear trends in annual rainfall from 1981–2021. The units are percent change over the 41-year period. Black dots indicate locations where the trend is statistically significant at the 90% confidence level based on a two-tailed Student's t-test.

In addition to the change in annual rainfall, the statistics of daily extremes in the Trois Rivières region of Haiti have changed over the analysis period (Table below). Comparing the earlier and later 20-year periods, the frequency of moderate rainfall days (10 mm or more) increased by 12%, the 75th percentile daily rainfall event increased by 30%, and the 90th percentile daily rainfall event increased by 9%. Comparing the first and last decades of the period of analysis yields similar results but more amplified given the greater separation between the two time periods compared. In that comparison, the moderate rainfall days increased by 15%, and the 75th and 90th percentile daily rainfall events increased by 52% and 10%, respectively. These results indicate that the daily rainfall extremes are becoming more extreme, in addition to an overall increase in annual rainfall.

Time period comparison	**Freq. 10 mm/day**	**75th percentile**	**90th percentile**

[242] University of East Anglia Climatic Research Unit. Jones, P.D., Harris, I. 2013. Retrieved from KNMI Climate Explorer. Available at: http://climexp.knmi.nl/plot_ atlas_form.py.

[243] Observed precipitation at daily and annual resolution from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) version 2 data set (Funk *et al.* 2015) is used here. CHIRPS v2 is a 41-year long, quasi–global rainfall data set beginning in 1981, which blends 0.05° spatial resolution satellite observations with in situ station data (where available) to create daily gridded rainfall time series at a ~5 km resolution.

1981–2000 vs. 2002–2021	12.4%	29.7%	8.8%
1981–1990 vs. 2012–2021	14.5%	51.7%	9.6%

Table 1. Comparison of relevant statistics on daily rainfall record from the Trois Rivières region of Haiti based on the CHIRPS v2 data set.

Previous studies have shown that the most important driver of rainfall in Haiti is the low-level zonal component of wind that flows over the Caribbean Sea. A wetter anomaly in Haiti is because westerly wind patterns decrease the low-level wind, while a drier than normal anomaly in Haiti is a result of easterly patterns increasing the low-level wind. The low-level wind is strongly influenced by sea surface temperature (SST) gradients between the Pacific and Atlantic which are in turn modulated by El Niño/La Niña events. Figure 23 also shows some decadal variance, with wet anomalies in the 1900s, 1930s, early 1940s, 1960s, and mid to late 2000s. Dry anomalies are evident in the 1910s, 1920s, and almost every year between 1967 and 2002 (except 1978–1979, 1981, 1994, 1996 and 1999). The last three decades were especially dry with multi-year droughts between 1975–1977 and 1985–1993. In summary, variations of annual rainfall in Haiti combine irregular, multi-decadal variability with insignificant variations, usually lasting for periods of approximately three or seven to nine years[244].

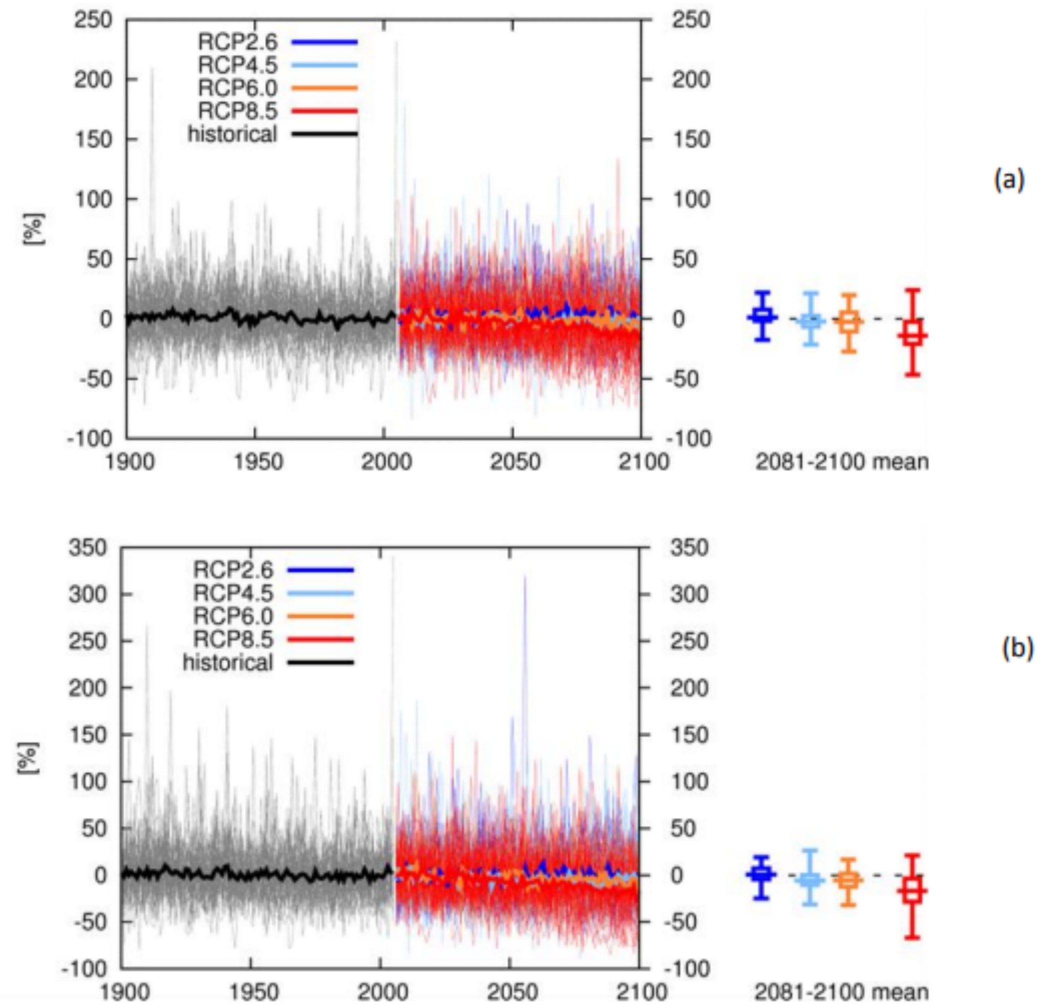


Figure 23. (a) Relative annual precipitation change (%) and (b) relative August to November precipitation change (%) for Haiti with respect to 1986–2005 AR5 CMIP5 subset. On the left, for each scenario one line per model is shown plus the multi-model mean and, on the right, percentiles of the

[244] Moron, V., Frelat, R., Jean-Jeune, P.K., and Gaucherel, C. 2015. Interannual and intra-annual variability of rainfall in Haiti (1905–2005). *Clim Dyn* 45:915-932.

whole dataset. The box extends from 25% to 75%, the whiskers from 5% to 95% and the horizontal line denotes the median (50%)[245].

Country-level GCMs, scenario averages suggest that a drying trend will begin for Haiti from as early as the mid-2020s, with 3–4% less average rainfall. The 2030s will be up to 6% drier, the 2050s up to 17% drier, and by the end of the century, the country may be up to 20% drier under the most severe scenario (RCP8.5). The GCMs suggest that change in summer rainfall is the primary driver of the drying trend. By the mid-2030s, summer rainfall is expected to have decreased by 3–5%, while by the end of the century the mean decrease will be 3–20%. Dry season rainfall, however, generally shows small increases or no change. Mean increases are consistently between 4–6% across all examined time periods[246] and RCM projections reflect the onset of a drying trend from the mid-2020s which will continue to the end of the century[247]. These drying trends are supported by Haiti's First National Communication to the United Nations Convention on Climate Change (UNFCCC), which reports that, under the RCP8.5 scenario, the period 2030–2040 is expected to be up to 6% drier in Haiti, the period 2050–2060 up to 17% drier, and the end-of-century time period expected to be 20% drier. Under the RCP4.5 and 6.0 scenarios, Haiti is expected to be between 9 and 12% drier, respectively, for the end-of-century time period.[248]

Results from separate projections specific to the TR region[249] using GCM models also indicate a drying trend. Downscaled multi-model mean results predict a 5% and 22% overall reduction in annual precipitation by mid- and end-century, respectively (Figure 24). It should, however, be noted that this does not directly imply any information about potential changes in floods. These events are instead typically associated with extreme but shorter-term (more concentrated) rainfall anomalies that may operate independently from a trending baseline, such as that revealed by these projections.

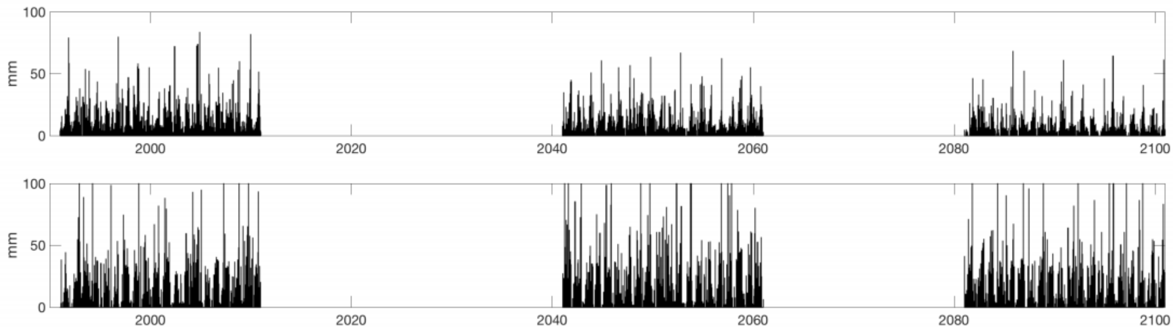


Figure 24. Multi-model mean changes in annual mean precipitation (%) for the mid-century (2041–2060) and end-century (2081–2100) periods relative to the baseline (1991–2010)[250].

To contextualise the observed stream gauge data from Gros Morne, used to validate the hydrological model simulations performed in support of generating downscaled projections for the TR region, bulk changes in precipitation are of interest for the periods 1924–1940 and 1962–1966. Estimated changes in annual mean precipitation (%) were drawn from the

[245] University of East Anglia Climatic Research Unit. Jones, P.D., Harris, I. 2013. Retrieved from KNMI Climate Explorer. Available at: http://climexp.knmi.nl/plot_ atlas_form.py.
[246] CMIP5 (IPCC AR5 Atlas subset) This is the dataset used in the IPCC WG1 AR5 Annex I "Atlas". Only a single realisation from each of over 20 models is used. All models are weighed equally, where model realisations differing only in model parameter settings are treated as different models. Retrieved from KNMI Climate Explorer. Available at: http://climexp.knmi.nl/plot_ atlas_form.py
[247] PRECIS Perturbed Physics experiments performed for the Caribbean. Available from the Caribbean Community Climate Change Centre.
[248] Haiti. First National Communication to the United Nations Framework Convention on Climate Change (UNFCCC).
[249] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.
[250] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.

historical simulations from four GCMs, and the multi-model ensemble mean results are shown in Figure 25. The Trois Rivières region was estimated to be ~2% and ~8% wetter in 1924–1940 and 1962–1966 respectively, compared to the baseline period (1991–2010)[251].

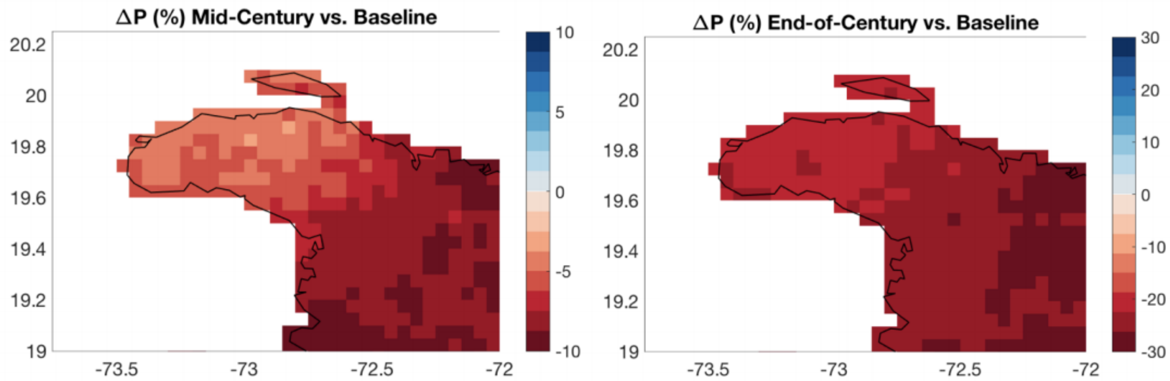


Figure 25. Bulk changes in precipitation (annual mean, %) in 1924–1940 and 1962–1966 compared to the baseline period (1991–2010) estimated from four GCMs. The maps shown are representations of the multi-model ensemble mean. Each of the GCMs conducted a different number of ensemble runs for the historical experiment: 6 x NCAR CCSM4, 1 x CMCC CM, 10 x CNRM CM5.1 and 4 x MOHC HadGEM2–ES. The individual models were averaged into single-model ensemble means before calculating the multi-model ensemble mean fields[252].

As mentioned previously, some insight into changes in hydrological extremes can be learned directly from the downscaled data. To provide a temporal illustration of the downscaled projections, Figure 26 shows daily time series of downscaled precipitation for the Gros Morne area of the Trois Rivières region for two downscaled GCMs. It should be noted that this figure is used to show rainfall levels used to inform surface hydrological modelling (please refer to Section 3.4: Flooding trends). To exhibit changes in the distribution of downscaled rainfall extremes for the Gros Morne area, Figure 27 shows the baseline frequency distribution of rainfall alongside the fractional changes in frequency of rainfall for every amount from 0–40 mm. At mid-century, the baseline drying is shown by the increase in near-zero precipitation and decrease in routine (~10 mm) rainfall amounts, but there is also an increase in extreme precipitation events (>30 mm). At the end of the century, the baseline drying appears to characterise even the amplitude of extremes, albeit with considerable inter-model spread in the projected changes in daily rainfall amounts exceeding 20 mm[253]. It should be made explicit that one of the models used in the multi-model analysis (CNRM CM5.1) is not an outlier at mid-century. Instead it predicts a modest reduction (~10%) in rainfall over the TR region, similar to the multi-model mean. At the end-of-century period, however, CNRM CM5.1 predicts a slight (~10%) increase in rainfall and is the only individual model that predicts an increase in that region for that time period. The CNRM CM5.1 model, therefore, is an outlier in its rainfall projection over the TR region at the end of the century. This is because global climate models vary considerably in terms of biases in climatological and regional precipitation and the CNRM CM5.1 model is one of two with a substantial positive rainfall bias (too much rain in the mean state) in the Caribbean region.

[251] Ibid.
[252] Ibid.
[253] Ibid.

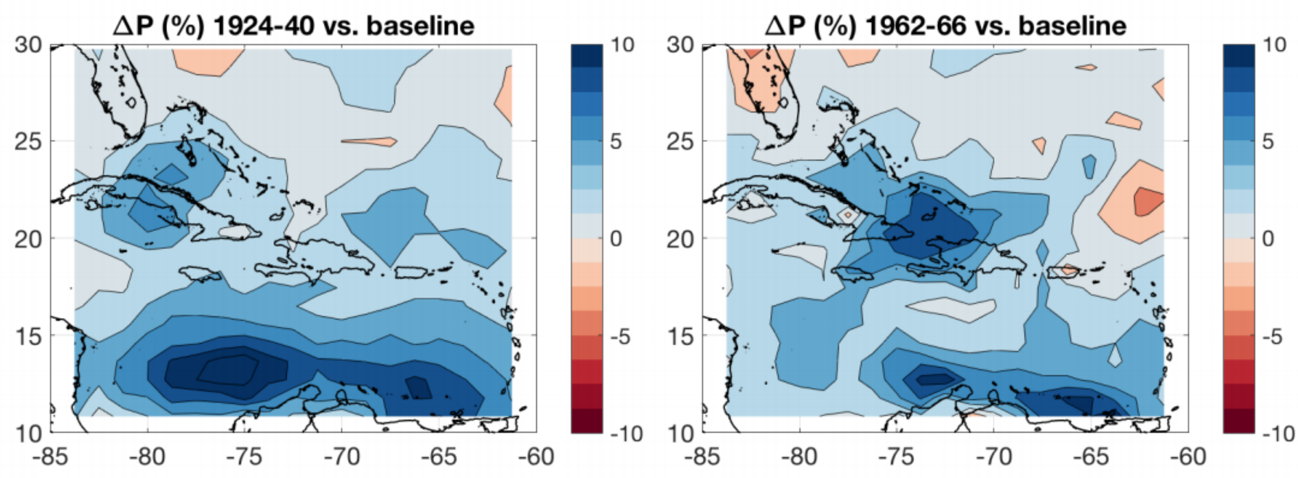


Figure 26. Daily time series of downscaled precipitation (mm) at the Gros Morne area of the Trois Rivières region of Haiti (72.675°W, 19.675°N) for two GCMs (NCAR CCSM4 and CMCC CM)[254].

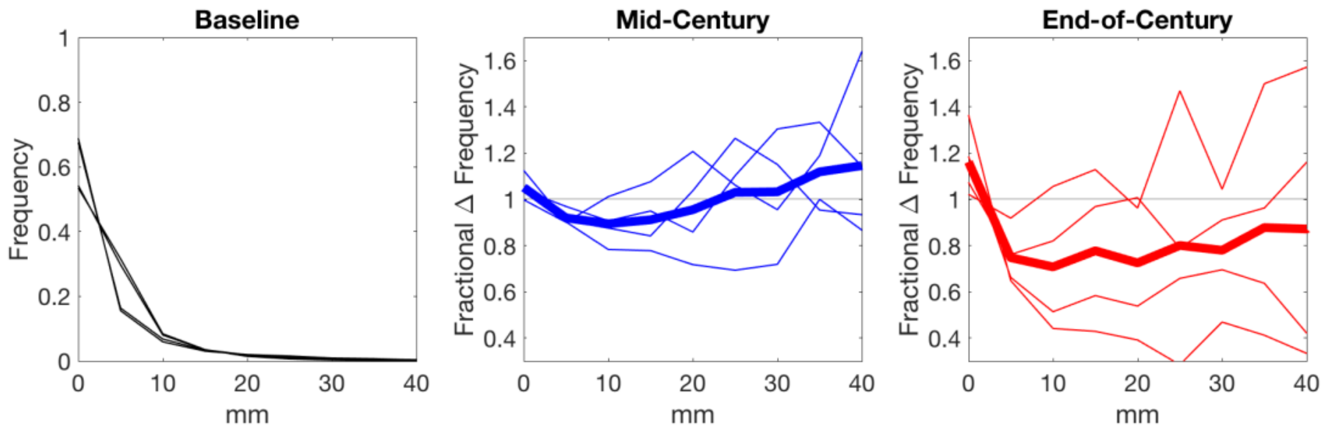


Figure 27. Frequency distributions (histograms) of daily rainfall (mm) for the baseline period (black) and fractional changes at mid-century (blue) and end-century (red). Each model is shown in thin lines, while the multi-model mean fractional changes in frequency are shown in thick lines[255].

3.3. Tropical storm and hurricane trends

Most measures of Atlantic hurricane activity show a considerable increase since the early 1980s i.e. when high-quality satellite data became available[256,257,258,259]. These include measures of intensity, frequency and duration as well as the number of Category 4 and 5 storms. While the historical record of Atlantic hurricanes dates to the mid-1800s, and indicates other decades of high activity, there is uncertainty regarding frequency and intensity in the record prior to the satellite era (early 1970s). Therefore, the ability to assess longer-term trends in hurricane activity is limited by the quality of available data[260].

[254] Ibid.
[255] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.
[256] Bell, G. D., Blake, E. S., Landsea, C. W., Kimberlain, T. B. Goldenberg, S. B. Schemm, J. and Pasch, R. J. 2012. [Tropical cyclones] Atlantic basin [in "State of the Climate in 2011"]. *Bulletin of the American Meteorological Society*, 93, S99-S105, State of the Climate.
[257] Bender, M. A., Knutson, T. R., Tuleya, R. E., Sirutis, J. J., Vecchi, G. A., Garner, S. T. and Held, I. M. 2010. Modeled impact of anthropogenic warming on the frequency of intense Atlantic hurricanes. *Science*, 327.
[258] Emanuel, K. 2007. Environmental factors affecting tropical cyclone power dissipation. *Journal of Climate*, 20.
[259] Landsea, C. W., and Franklin, J. L. 2013. Atlantic hurricane database uncertainty and presentation of a new database format. *Monthly Weather Review*, 141.
[260] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf

The recent increases in hurricane activity are partially linked to higher SST in the tropical Atlantic. The Power Dissipation Index (PDI) is an aggregate measure of hurricane activity, combining frequency, intensity, and duration of hurricanes into a single index. Both Atlantic SST and Atlantic hurricane PDI have risen sharply since the 1970s and there is also evidence that PDI levels in recent years are higher than in the previous active Atlantic hurricane period in the 1950s and 60s. There is minimal consensus that the increases in hurricane activity is attributable primarily to climate change, particularly since other modulators of SST such as the Atlantic multidecadal oscillation (AMO) are in a positive (enhancement) phase[261].

Notwithstanding long-term trends, the ENSO phenomenon plays a major role in modulating hurricane activity in the North Atlantic from year to year. El Niño contributes to fewer Atlantic hurricanes than La Niña. El Niño produces upper level westerly and lower level easterly wind anomalies across the tropical Atlantic which in tandem result in higher vertical wind shear. El Niño and La Niña also influence where Atlantic hurricanes form. During El Niño events fewer but more major hurricanes develop in the deep Tropics from African easterly oceanic waves. La Niña events, however, cause more hurricanes to form in the deep Tropics with these systems having a greater likelihood of becoming major hurricanes, and of eventually threatening the Caribbean[262].

Figure 27 shows the historical paths associated with hurricanes in the tropical Atlantic between 1959 and 2001 for El Niño events (top panel) and La Niña events (bottom panel). The typical path of hurricanes that impact Haiti is from the southeast to northwest, with the majority approaching from the south of the island[263]. Because of its small size, however, this does not make the rest of Haiti — including the TR region — less susceptible to storms and hurricanes. Indeed, the TR region is particularly vulnerable to the resulting impacts of hurricanes because of land degradation from deforestation for charcoal production and crop farming on the surrounding steep slopes. These practices have caused large-scale changes in the natural landscape of the TR region, as a lack of tree cover results in decreased infiltration and increased surface runoff, leading to flooding, erosion and soil degradation within the catchment area.

[261] Ibid.
[262] Ibid.
[263] Ibid.

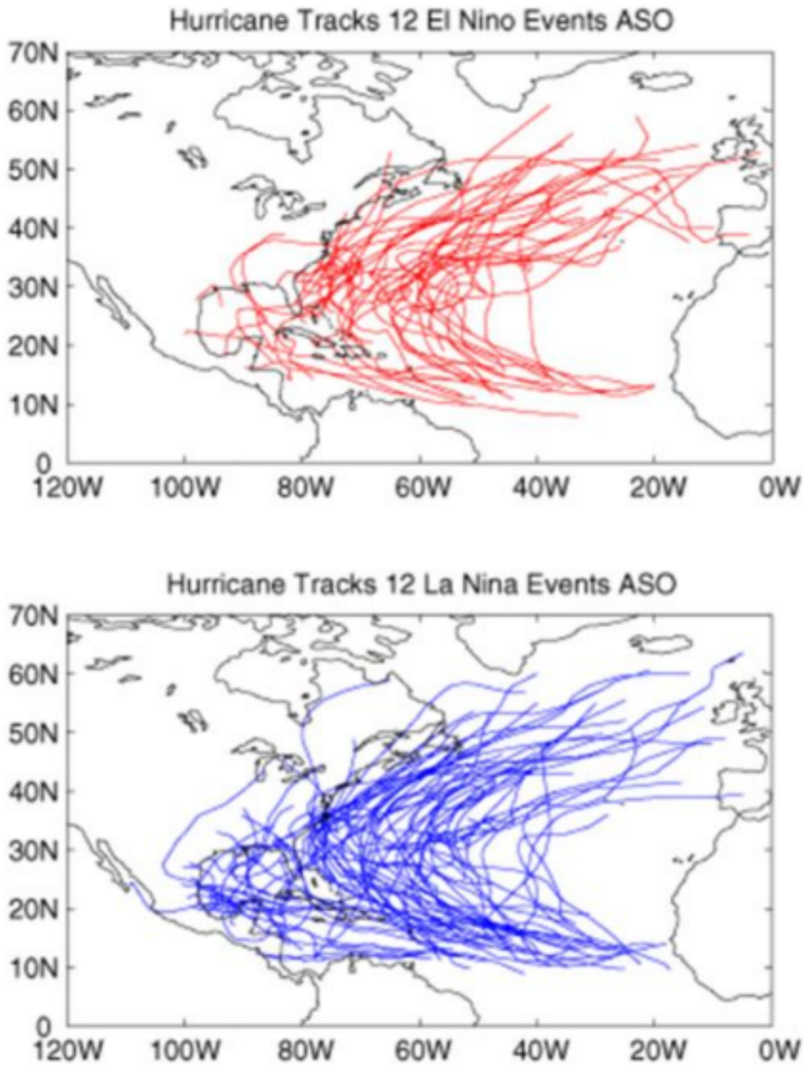


Figure 27. All hurricanes impacting the Caribbean basin between 1950 and 2014 (a). Hurricanes (b) and tropical depressions and storms (c) whose centre of circulation passed within 200 km of Haiti[264].

Projections of hurricanes and storms vary under climate change. For example, estimates show that there will be: i) increased hurricane intensity of 5–10% and a related precipitation increase of 2% by 2050[265]; ii) similar tropical storm/hurricane genesis, frequency and tracks to the very recent past (last two decades) but increased intensities (rainfall rates and wind speeds)[266]; and iii) a relatively modest (~3%) but robust (agreement among five out six downscaled GCMs) increase in the frequency of tropical storm tracks averaged over the 21st century (2006–2100) compared to a baseline period of 1950–2005[267]. Despite this, there is widespread consensus within the available literature that rainfall variability is expected to increase, resulting in more intense rainfall in the wet season. Sea-level rise and an increased frequency of storm surges is also expected, with coastal plains becoming increasingly prone to the influx of saltwater and soil salinisation, resulting in farmers becoming unable to cultivate them. These factors will exacerbate the current challenges of flooding and erosion in areas that lie in the direct path of tropical storms and hurricanes. In the absence of adaptation efforts, these dynamics will in turn have severe impacts on water resources, land, agriculture, and forest ecosystems. In

[264] IDB. 2015. Haiti: historical and future climatic changes. Available at: https://publications.iadb.org/publications/english/document/Haiti-Historical-and-Future-Climate-Changes.pdf
[265] USAID. 2017. Climate Risk Profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf
[266] World Bank. 2017. Charcoal in Haiti. A National Assessment of Charcoal Production and Consumption Trends. World Bank, Washington. Available at: http://documents.worldbank.org/curated/en/697221548446232632/pdf/134058-CharcoalHaitiWeb.pdf
[267] Karnauskas, K.B. 2018. Report on Climate Change Projections for the Trois Rivières Region of Haiti. UNDP.

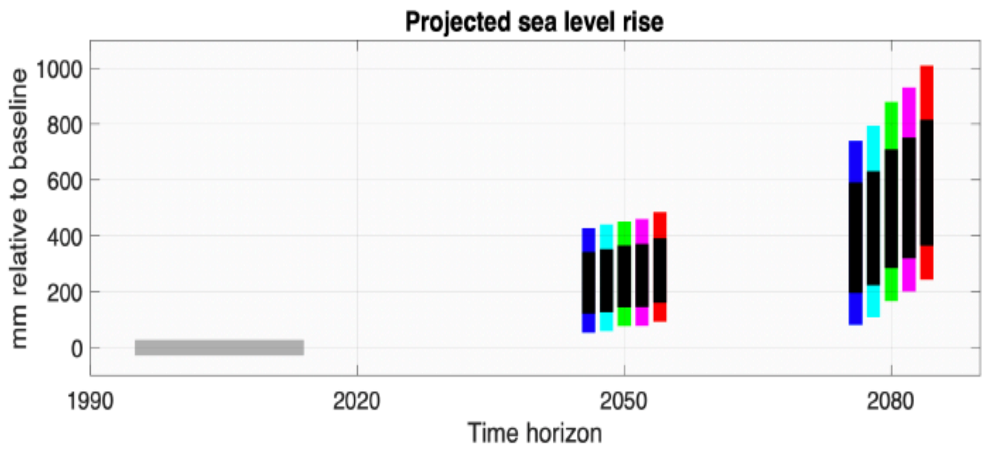
addition, the annual population growth of ~1% in Haiti will compound pressure on agricultural systems and natural resources[268].

3.4. Projected Sea Level Rise in Haiti

Future rates of SLR at Haiti were calculated from global climate model (GCM) projections associated with the 6th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). SLR at the time horizons of 2050 and 2080 were calculated. All projections are relative to a 1995–2014 baseline (consistent with IPCC AR6). Both the scenario uncertainty and the scientific uncertainty were included in the analysis.

To account for spread across GCMs, consistent with recommended practice of the NASA Sea Level Change Team, likely ranges are assessed based upon the combination of uncertainty in the temperature change associated with an emissions scenarios and uncertainty in the relationships between temperature and drivers of projected sea-level change, such as thermal expansion, ocean dynamics, and glacier and ice sheet mass loss. In general, 17th–83rd percentile results are interpreted as likely ranges, reflecting the use of the term likely to refer to a probability of at least 66%.

The aggregated projections are shown in the figure below; the baseline is indicated by the gray bar at zero covering the period 1995–2014. The five different coloured bars centered on each time horizon (2050 and 2080) represent the five different scenarios (SSPs) described above. The full color range for each bar indicates the 5th–95th percentile spread across GCMs, while the inner black bars indicate the likely range encompassing the 17th–83rd percentiles. At 2050, the median projections of SLR at Haiti ranges from 224 mm under SSP1-1.9 to 269 mm under SSP5-8.5, with a full likely range (from the 17th percentile of SSP1-1.9 to the 83rd percentile of SSP5-8.5) of 121–392 mm. At 2080, the median projections of SLR at Haiti ranges from 376 mm under SSP1-1.9 to 566 mm under SSP5-8.5, with a full likely range (from the 17th percentile of SSP1-1.9 to the 83rd percentile of SSP5-8.5) of 196–816 mm.



These results indicate that Haiti should anticipate a significant acceleration of SLR over the coming 25–50 years, where 816 mm total (or a rate as high as 170 mm per decade) at 2080 is considered to be within the likely range.

3.5. Flooding Trends

[268] USAID. 2017. Climate Risk Profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf

Technical analyses — commissioned specifically to contribute to the completion of this Feasibility Study — were performed to estimate the impacts of climate change on flood inundation in western Haiti, with a focus on the Trois-Rivières watershed. The summary of the analyses presented here focusses on the effects of current and future climate change on total water discharge (hereafter referred to as flood flows). Future projections indicate a decrease in mid-century (2041–2060) daily maximum flood flow, followed by a significant increase in daily maximum flood flow in the late-century (2081–2100) compared to historical (1991–2010) flood flow simulations. The future projections of 100-year flow events and 20-year flow events[269] mimic the projected changes for daily maximum flow, also exhibiting a mid-century decrease and late century increase. Figure 28 shows the distribution of the maximum daily flood flows for the historical, mid-, and late-century periods. The median values for these periods exhibit modest changes, while the most extreme events (the highest and lowest daily flow rate values as indicated by the box plot whiskers) become greater towards the end-century. A logarithmic scale is used on the vertical axis — meaning that small differences towards the top of the plot correspond to much larger differences than those in the middle and bottom of the plot. Figures 29 and 30 depict the 100-year and 20-year flows, respectively. These flows were estimated by fitting the simulated data to a Log Pearson type-III distribution, which is a probability distribution specifically suited to the skewed nature of flood frequency data. Both the 100-year and 20-year flows show similar future changes to the maximum daily flows, namely the median values are relatively stable, and the extremes increase in the future[270].

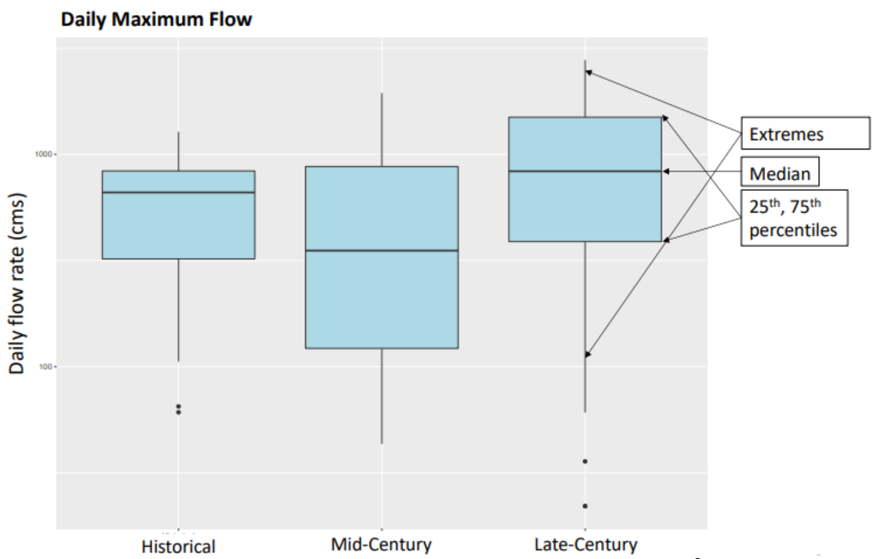


Figure 28. Distribution of daily maximum streamflow (m^3 per second) from the 10 top-performing Variable Infiltration Capacity (VIC) simulations for the historical (1991–2010), mid-century (2041–2060), and late-century (2081–2100) periods under climate simulations from four climate models (CCSM4, CMCC, CNRM and HadGEM4). Box plots show the outliers as black dots, the interquartile range is contained within the box and the median is shown as a thick horizontal line[271].

[269] This terminology pertains to the theoretical return period for an event, which is the inverse of the average frequency of occurrence. For example, a 100-year event has a 1% chance of occurring while a 20-year event has a 5% chance of occurring
[270] Water Science International LLC. No date. Hydrology Summary Report to the United Nations Development Programme: Assessment of future flood potential for the Trois-Rivières watershed.
[271] Ibid.

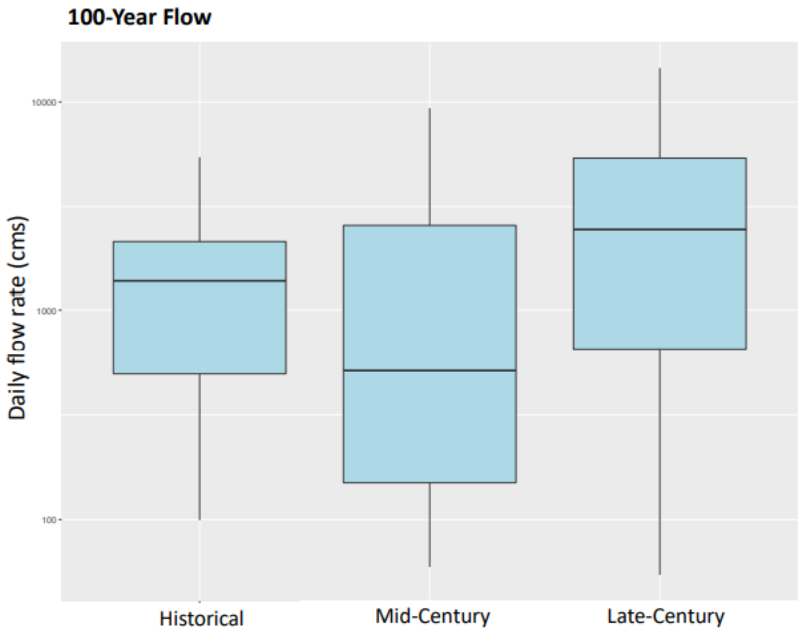


Figure 29. Distribution of 100-year streamflow (m^3 per second) from the 10 top-performing VIC simulations for the historical (1991–2010), mid-century (2041–2060), and late-century (2081–2100) under climate simulations from four climate models (CCSM4, CMCC, CNRM and HadGEM4). Outliers are black dots; the interquartile range is contained within the box and the median is shown as a thick horizontal line[272].

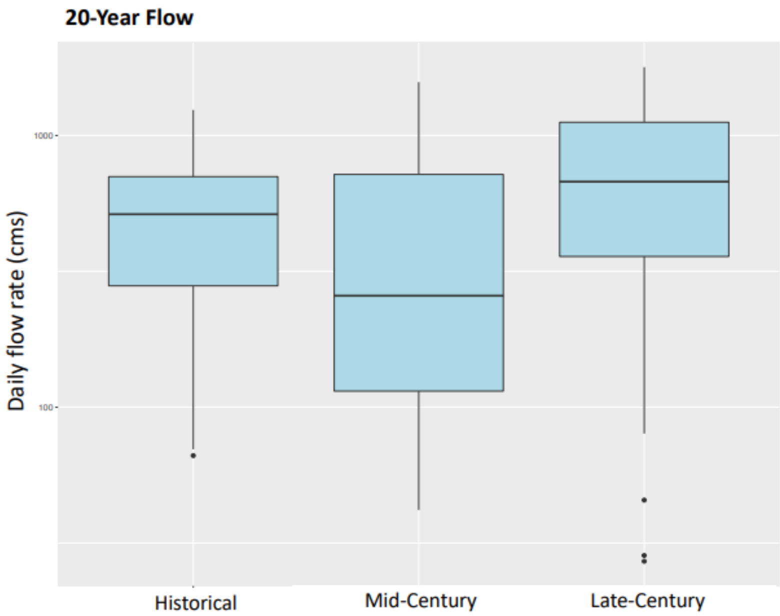


Figure 30. Distribution of 20-year streamflow (m^3 per second) from the 10 top-performing VIC simulations for the historical (1991–2010), mid-century (2041–2060), and late-century (2081–2100) under climate simulations from four climate models (CCSM4, CMCC, CNRM and HadGEM4). Outliers are black dots; the interquartile range is contained within the box and the median is shown as a thick horizontal line[273].

An important caveat to note with the results of the 100-year floods is that the four climate models used present differing behaviours. Specifically, the CNRM model used (light green box plots in Figure 31) exhibits anomalously high flows in the historical period. This causes the behaviour seen in Figure 29, where the historical period has the largest flow and is inconsistent

272 Ibid.
273 Ibid.

with the 20-year and maximum daily flows (Figures 30 and 28, respectively). However, if the CNRM model is excluded, the 100-year flows follow more closely with the expectation of increasing extreme flows into the future (Figure 32)[274].

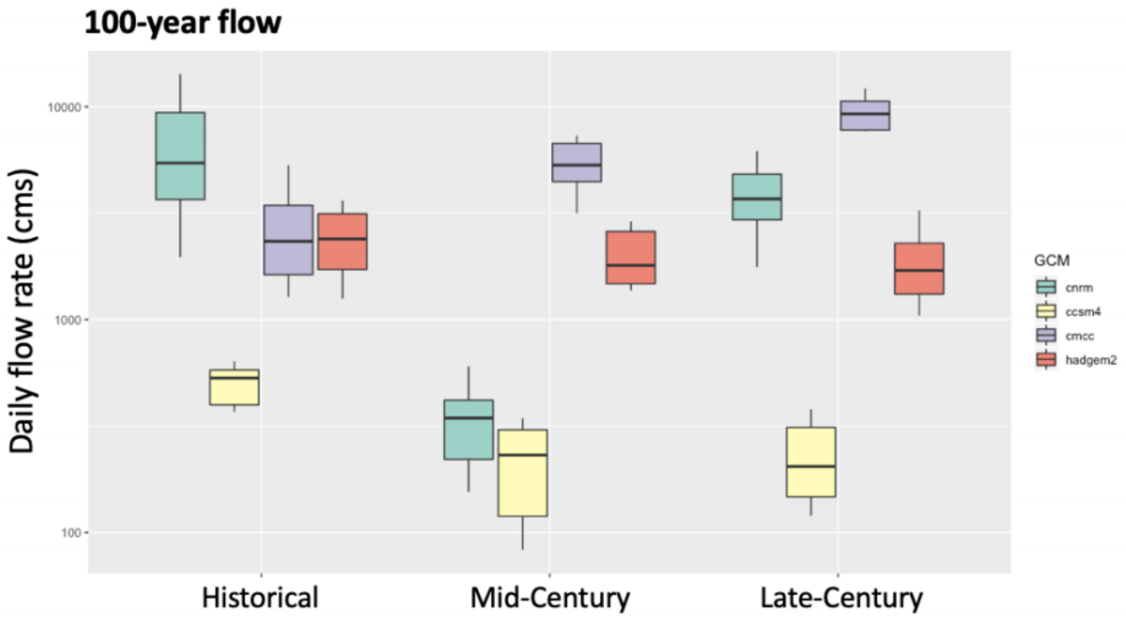


Figure 31. Distribution of 100-year streamflow (m^3 per second) from the 10 top-performing VIC simulations for the historical (1991–2010), mid-century (2041–2060) and late-century (2081–2100) under climate simulations from each of the four climate models (CCSM4, CMCC, CNRM, HadGEM4) shown in different colours. Specifically, the CNRM model is shown by green box plots, the CCSM4 by yellow, the CMCC by blue and the HadGEM4 by red box plots. The interquartile ranges are contained within the box and the median is shown as a thick horizontal line.

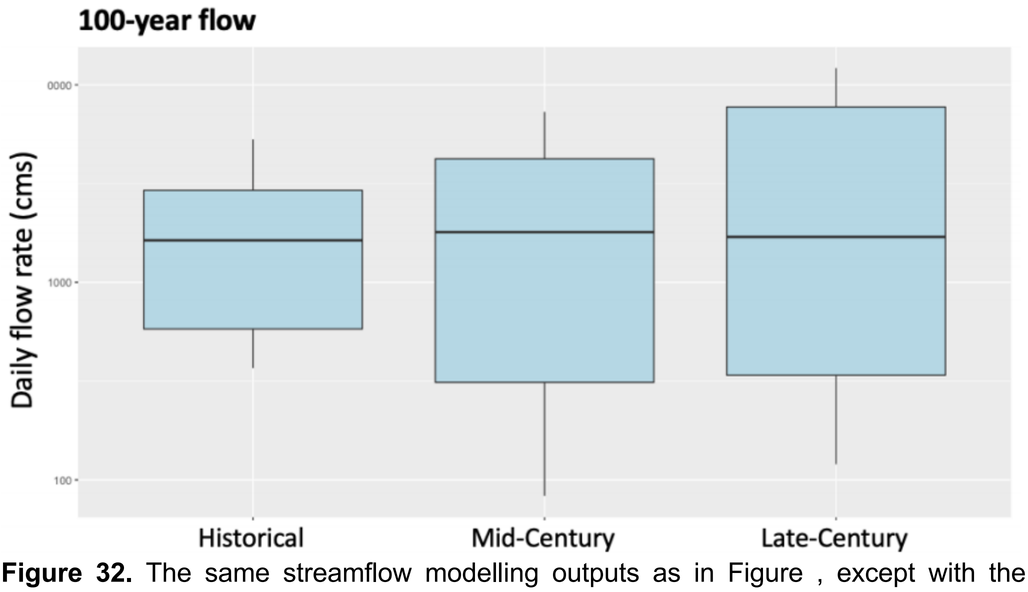


Figure 32. The same streamflow modelling outputs as in Figure , except with the CNRM model removed. The results now show a steady increase in extreme 100-year stream flows (m^3 per second).

River discharge, depth and flood extent projections indicate similar decreasing trends through the mid-century, before increasing in the late century. The exception to this is the forecasted

[274] Ibid.

maximum for 20-year flows, where projections indicate an increase from the historical baseline into the mid- and late-century (Table 3)[275].

Table 3. Summary of hydrodynamic results for the Trois Rivieres watershed for 12 different flow scenarios[276]. Hist100, mid100 and late100 is the historical, mid-century and late-century 100-year ensemble maximum flow, respectively. Hist20, mid20 and late20 historical, mid-century and late-century 20-year ensemble maximum flow, respectively.

LISFLOOD model run results		hist100	mid100	late100	hist20	mid20	late20
max	Mean Depth (m)	6.61	3.84	5.55	2.12	2.23	2.37
	Max depth (m)	35.33	22.40	30.85	18.54	19.01	19.47
	Extent (km^2)	44.47	37.13	41.96	22.82	24.44	26.25
med	Mean Depth (m)	2.32	2.04	2.42	1.96	1.88	1.94
	Max depth (m)	19.22	18.17	19.68	17.28	16.37	17.07
	Extent (km^2)	25.95	21.83	28.47	17.13	14.59	16.84

Projections for the maximum extent of flooding in the TR watershed for the 100-year flow event are as follows: i) a decrease by 17% from hist100 to mid100; and ii) an increase by 12% from mid100 to late100. For the 20-year flow event, the maximum extent of flooding is projected to: i) increase by 7% from hist20 to mid20; and ii) increase by 7% from mid20 to late20[277]. These results are summarised in Table 4 below.

Table 4. River discharge values used for the hydrodynamic runs, as determined from the results of the Hydrologic Report[278] (summed at the outlet (m^3 per second))[279].

LISFLOOD model run	hist100	mid100	late100	hist20	mid20	late20
max	14,407	7,375	12,313	1,600	1,958	2,341
med	2,117	1,386	2,508	979	691	900

It should be noted that incorporating the effects of sediment transport and fluvial geomorphic changes on hydrological conditions in the TR watershed was outside the scope of the commissioned modelling and analyses described above — despite these likely being major factors in contributing to an increased risk of flooding. On the ground, considerable changes in the watershed's sediment supply have recently occurred, confirmed by a review of aerial photography from the last two decades[280]. The images show increases in sediment supply as evidenced by growth in the tributary delta. This is because flood flows cause bed and bank movement, which subsequently may lead to more flood-related damage. In the flood flow

[275] Minear, J.T. and Water Science International LLC. No date. Summary Report of Hydrodynamic Model Results: Assessment of Past and Future Flood Potential, Trois-Rivieres Watershed, Haiti.
[276] Ibid.
[277] Ibid.
[278] Water Science International LLC. No date. Hydrology Summary Report to the United Nations Development Programme: Assessment of future flood potential for the Trois-Rivières watershed.
[279] Minear, J.T. and Water Science International LLC. No date. Summary Report of Hydrodynamic Model Results: Assessment of Past and Future Flood Potential, Trois-Rivieres Watershed, Haiti.
[280] The authors of the Hydrodynamic Report (which was prepared in support of the proposed project) undertook an analysis of aerial photography. This analysis included comparing historical NASA imagery to recent imagery for the last 20 years available on Google Earth to determine changes to the watershed area. The findings from the analysis indicate that anywhere along the main river, and particularly at the tributary confluences, nearly every year during the analysed time period indicates a major shift in the river bars and the deltas at the tributary confluences. This indicates that changes in sediment supply are likely to have occurred at least over the past 20 years.

model results above, however, the bed and banks of the river are assumed to be immobile. Moreover, with the overall steepness of the gradient of the landscape in the Trois Rivieres watershed, even small flows are enough to mobilise large volumes of sediment. The above results are therefore likely to be conservative, as a small volume of sediment added from tributaries to the mainstream river would be enough to reduce local channel capacities and subsequently increase flood risk[281].

3.6. Climate Change Impacts

Major impacts on agricultural production and livelihoods are caused by flooding in most of Haiti's 30 major watersheds as a result of intense seasonal rainfall, storm surges in the coastal zones, deforested and eroded landscapes, and sediment-laden river channels. Soil erosion and flooding caused by extreme rainfall events have reduced soil fertility and crop yields as flooding washes away fertile soil, depositing it on riverbeds. Given the near-complete absence of embankments and levees, this cycle then intensifies the next round of flooding. These combined impacts lead to the destruction of crops, farmland, and agricultural infrastructure, as well as the loss of livestock and human lives, with future climate change expected to exacerbate these problems. The agricultural sector is particularly vulnerable to the impacts of flooding as it accounts for ~22% of the country's GDP, with 40% of Haitians dependent on the sector (crops, livestock, and fisheries) for their income and livelihoods. Impacts from flooding after storms and hurricanes have already been experienced by much of Haiti's population. For example, in 2004, over 2,800 people lost their lives in Gonaïves as a result of Hurricane Jeanne. Additionally, hillside erosion led to crop destruction as gravel flooded the farmers' fields, making cultivation difficult afterwards. In 2008, the South, Nippes, and South-East Departments were impacted by four hurricanes in rapid succession — affecting more than 800,000 people[282].

Much of the agricultural sector in the country consists of subsistence farming, which is particularly vulnerable to climate change given the lack of irrigation and extensive reliance on rainfed agriculture. Future climate change will likely impact both small-scale subsistence farming and larger, commercial agricultural operations that contribute considerably to Haiti's overall GDP. For example, climate change will negatively impact the economic viability of export agriculture, decreasing Haiti's competitive advantage in the global trade of crops such as coffee and cacao, as well as the amount of productive land available for growing them[283]. If average annual rainfall declines, temperatures continue to rise and storms intensify as predicted, the yields of subsistence farmers will likely decrease, adversely affecting nutrition and the resilience of agricultural livelihoods[284,285].

Climate change has already impacted subsistence farmers' livelihoods as the rainy season now begins up to three months later than it did in the past. Rains arrive in May and as late as June rather than in March, thereby extending the dry season. This disrupts agricultural planning considerably and hinders the planting of rainfed, staple crops such as corn and beans. As a result, there are decreases in yields and already low farm profitability, which in turn negatively affect food security. For example, the October 2010 to March 2011 second

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[281] Ibid.
[282] Oxfam. 2014. Climate change resilience: The case of Haiti. Available at: https://www-cdn.oxfam.org/s3fs-public/file_attachments/rr-climate-change-resilience-haiti-260314-en_2.pdf
[283] Centro Internacional de Agricultura Tropical. 2013. Prediction of the impact of climate change on coffee and mango growing areas in Haiti. Available at: http://dapa.ciat.cgiar.org/wp-content/uploads/2014/03/CC_impact_coffee-mango_Haiti_CRS-CIAT_final.pdf
[284] World Bank. 2011. Vulnerability, Risk Reduction, and Adaptation to Climate Change: Haiti. Available at: http://sdwebx.worldbank.org/climateportalb/doc/GFDRRCountryProfiles/wb_gfdrr_climate_change_country_profile_for_HTI.pdf
[285] USAID. 2017. Climate Risk Profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf

bean crop sustained considerable yield losses because of flooding. Following this, the sowing of the first bean crop of 2011 was impeded because of delayed rains[286].

Climate change will also — through increasing temperatures and intensity of storms — shift disease burdens, impact health infrastructure, and exacerbate existing health challenges in Haiti. The country's healthcare system already requires considerable support from international donors and will continue to be highly stressed during extreme weather events and health crises. Haiti has the lowest rates of access to clean drinking water and improved sanitation in the Western Hemisphere, both of which are compromised during flood events[287]. Flooding also increases the risk of outbreaks of vector- and water-borne diseases such as dengue fever, malaria, Zika, and cholera — with effects compounded by flooding-related damages to road infrastructure which makes it difficult to access healthcare services, especially for rural communities.[288] Moreover, as climate and weather impact agriculture as described above, vulnerable communities will also suffer from increased malnutrition and resultant compromised immune systems — leading to reduced recovery rates, increased burdens on the country's healthcare system and an increased loss of lives[289].

[286] Oxfam. 2014. Climate change resilience: The case of Haiti. Available at: https://www-cdn.oxfam.org/s3fs-public/file_attachments/rr-climate-change-resilience-haiti-260314-en_2.pdf
[287] Jourdain, J.F. 2011. Climate Change and the Water Sector in Haiti: A Two-extreme Perspective on Vulnerability from Drought to Floods. Available at: https://unfccc.int/files/adaptation/workshops_meetings/nairobi_work_programme/application/pdf/haiti.pdf
[288] USAID. 2017. Climate Risk Profile: Haiti. Available at: https://www.climatelinks.org/sites/default/files/asset/document/2017_Cadmus_Climate-Risk-Profile_Haiti.pdf.
[289] Ibid.

Options analysis: grey versus green infrastructure as cost-effective flood management solutions in the Trois-Rivières (TR) watershed

An options analysis was undertaken for the proposed GCF project to determine the most appropriate and cost-effective flood control measures for the Trois-Rivières (TR) watershed. Specifically, two options for enhancing climate-resilient flood management were assessed, namely: i) promoting an integrated approach to flood management in the watershed underpinned by implementing Ecosystem-based Adaptation (EbA) interventions using green infrastructure[290] solutions (e.g. agroforestry systems and reforestation of embankments); and ii) constructing hard engineering solutions, which involve using grey infrastructure (manmade systems such as storm surge barriers, dykes, levees and reservoirs) as a flood defence strategy.

Flooding within the TR watershed is primarily caused by floodwater surges during the occurrence of intense, concentrated rainfall events and storms. Direct damages from these events include increased erosion of riverbanks, sedimentation of rivers and the flooding of coastal plains with saltwater. This saltwater increases the salinity of soils and groundwater reserves, considerably impacting agricultural productivity. Indirect damages result from, *inter alia*, the spread of water- and vector-borne diseases. Grey and green infrastructure act through different mechanisms to reduce flood risks and the extent of the associated damages. Installing engineering solutions in a riverbed to manipulate streamflow — including through the construction of dams, dykes and raised riverbanks — increases the storage capacity and/or reduces peak discharge of a river, therefore reducing flood-related damages. Conversely, implementing green infrastructure solutions changes the hydrological behaviour of a watershed by reducing the rainfall runoff coefficient, resulting in increased infiltration and decreased surface runoff. This, consequently, leads to: i) a reduction in peak runoff and increased water retention in the watershed; ii) lower sediment loading; iii) reduced erosion; and iv) a more sustained baseflow during the dry season. Both green and grey infrastructure are effective at reducing flooding-related impacts, however, they require decidedly different implementation and exit strategies, as well as have different implications for watershed management[291].

4.1. Options for grey infrastructure

During in-country missions[292] undertaken for the development of the proposed project, options for installing grey infrastructure as a flood defence strategy in Haiti's TR watershed were explored. Historical occurrences of floods, future risk of flooding and the socio-economic impacts of implementing grey interventions in project target sites were used to determine the suitability of these interventions as an efficient and effective flood management solution in the TR watershed. Following this initial assessment, two distinct categories of potential interventions were defined, namely: i) infrastructural improvements to prevent flooding in specific locations — such as the raising of river banks, as well as re-dimensioning and restoring of bridges and canals; and ii) interventions to reduce the peak discharge during flood events — such as flood control dams.

[290] *"Green infrastructure refers to the interconnected set of natural and man-made ecological systems, green spaces, and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing a wide range of services and strategic functions in the same way as traditional hard infrastructure."* State of Green Infrastructure in the Gauteng City-Region (GCRO 2013). Available at: http://www.gcro.ac.za/media/redactor_files/Green%20Infrastructure%20Citylab%20information.pdf.

[291] World Bank. 2019. Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/31430/9781569739556.pdf?sequence=4&isAllowed=y

[292] Further details on stakeholder engagements are presented in Annex 7.

Potential sites for these grey engineering solutions were identified throughout the TR watershed[293]. This identification included locations where the structural integrity of natural riverbanks required strengthening. Specifically, in the commune of Champagne, a section of a reinforced concrete riverbank was identified as needing to be raised. In the commune of Pilate, a bridge was determined to require raising, and waterways and discharge openings were seen to need restoration and/or re-dimensioning. Near Port-de-Paix, riverbanks close to built-up areas were identified as requiring reinforcement to protect the buildings on top of and alongside the banks. Additionally, one of Port-de-Paix's main canals was identified as requiring structural upgrades to increase its capacity to facilitate discharge of floodwater surges. For interventions to reduce the peak discharge during flood events, numerous locations for flood control dams were identified. Table 5 provides an overview of the proposed areas for the implementation of grey infrastructure within the TR watershed, as well as reasons for implementation of the specific interventions identified.

Table 5. Overview of potential grey infrastructure interventions for reducing flood risk within the TR watershed.

Department in Haiti	Community	Communal section	Proposed intervention	Reason for intervention
Artibonite	Gros-Morne	Ravine La Rate	Development of torrential correction dams and deposit areas	Reduce peak discharge and protect the road between Gros-Morne and Pilate
Artibonite	Gros-Morne	Ravine Le Houe	Development of torrential correction dams and deposit areas	Reduce peak discharge and protect the road between Gros-Morne and Pilate
North	Pilate	Ravine Cyclette	Extension of the urban canal and modification of the bridge	Protect low-lying urban areas from floods
North	Pilate	Ravine Cyclette	Optimisation of the canal outlet to Trois Rivières	Protect low-lying urban areas from floods
North	Plaisance	Champagne	Increase right side river embankment to protect the urban centre (market)	Protect the urban area on the right bank against floods
North	Plaisance	Champagne	Protection of the left side bank downstream against erosion	Prevent erosion of the bank on the left bank to avoid calving of the riverbank towards the main road
North-West	Port-de-Paix	Rivière de Port-de-Paix	Development of torrential correction dams	Protect the urban area on the right bank against floods
North-West	Port-de-Paix	Rivière de Port-de-Paix	Modification of the urban canal and upstream extension of the canal	Protect the urban area on the right bank against floods
North-West	Port-de-Paix	Rivière de Port-de-Paix	Protection of riverbanks against erosion within the urban area	Prevent destruction of buildings on left and right side of the river because of riverbank erosion
North-West	Bassin-Bleu	Ravine Gédéon	Development of torrential correction dams and deposit areas	Reduce peak discharge to protect urban areas
North-West	Bassin-Bleu	Ravine Gédéon	Creation of a discharge channel on the right of the alluvial cone	Protect urban areas against floods

[293] Further details on the selection of priority intervention sites are presented in Section 10 of this Feasibility Study.

North-West	Bassin-Bleu	Ravine Canave	Development of torrential correction dams and deposit areas	Reduce peak discharge to protect urban areas
North-West	Bassin-Bleu	Ravine Canave	Creation of a discharge channel on the left of the alluvial cone	Protect urban areas against floods

Despite the installation of grey interventions being an effective flood protection solution, there are several critical disadvantages that reduce the viability of such options being selected as the preferred adaptation strategy to be implemented under the proposed project. First, because grey interventions (e.g. dams and bank reinforcement structures) have limited adaptive potential, there is a risk of locking the GoH into investing in infrastructure that does not account for future changes in flood conditions. Second, these interventions are often expensive to install, operate and maintain. This, coupled with national and local governments' historically limited financial resources and capacity to repair damaged infrastructure, means grey infrastructure interventions would not be a financially sustainable adaptation strategy for implementation in the TR watershed. Third, the most appropriate method of construction should use locally sourced building materials to improve cost- and time-efficiency, avoiding the need to import materials to Haiti which is a geographically isolated SIDS. However, this would require harvesting of timber, and other limited resources, from the country's already degraded landscape. Because of the extent and scale of grey interventions that would be required for effective flood control in Haiti's TR watershed, this will have a considerable negative impact on surrounding local ecosystems, likely resulting in further watershed degradation and exacerbating flooding impacts on downstream areas. Sourcing the required materials outside of the TR watershed would result in similar problems being caused in other watersheds. This is consequently not a viable option proposed under the project. Fourth, implementing grey interventions in Haiti's TR watershed (which is near the northern coast of the country) would expose the infrastructure, not only to gradual wear and tear caused by coastal weather, but also to the direct impacts of hurricanes and tropical storms. The impacts of these storms on infrastructure in Haiti have already caused severe damages and economic losses. For example, in August and September 2008 the country was struck by four different tropical storms and hurricanes, causing ~US$8 billion in property and infrastructural damages. More recently, Hurricane Matthew, which was a Category 4 storm that struck Haiti during October 2016, caused an estimated ~US$2 billion[294] in infrastructural damages.

Based on the above analysis, implementing grey infrastructure to reduce the impacts of climate change-induced flooding in Haiti's TR watershed is not a viable option. Because of this, implementing EbA interventions — particularly agroforestry systems and reforestation activities — was assessed during the development of the proposed project as an alternative solution for flood management in the watershed. Further details on this solution are presented in the section below.

4.2. Options for green infrastructure

During the development of the proposed project, EbA interventions (green infrastructure) were assessed an alternative adaptation strategy to grey infrastructure for adapting to the impacts of climate change-induced flooding in the TR watershed. Specifically, potential interventions explored were: i) implementing agroforestry systems at priority sites; and ii) rehabilitating water towers[295] through reforestation activities. These interventions were all validated as viable adaptation options through extensive stakeholder consultations[296]. During these discussions

[294] The University of Fondwa. 2018. The History of Natural Disasters in Haiti. Available at: https://ufondwa.org/history-natural-disasters-haiti/
[295] "Water towers" refers to mountainous areas in Haiti where water for agricultural production and drinking is obtained.
[296] Further details on these engagements are presented in Annex 7: Stakeholder engagement plan.

and site visits, stakeholders determined that 17,740 ha of land was available for agroforestry and 7,700 ha for reforestation[297], with those two EbA interventions being selected because of their proven flood-reduction benefits and potential to deliver a wide variety of socio-economic and environmental co-benefits.

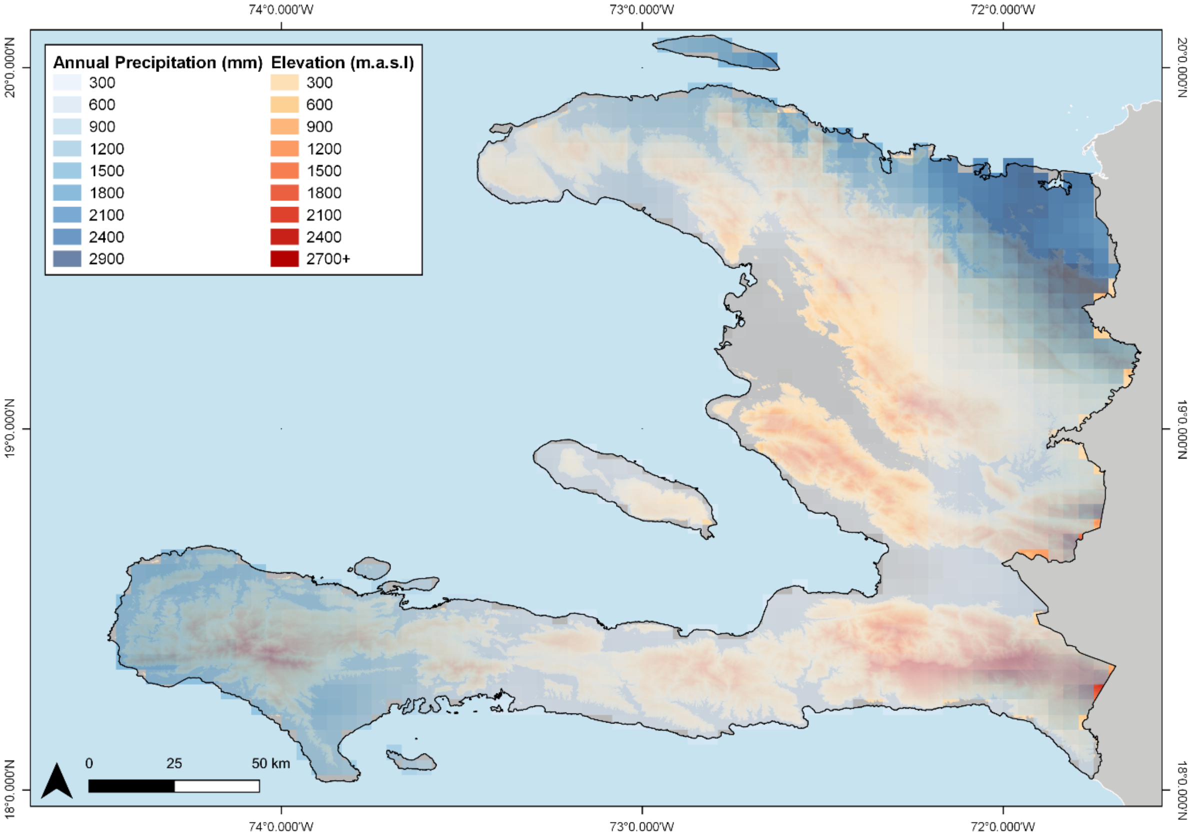

Figure 32. The water towers of Haiti, showing areas of high rainfall and elevation where water for agriculture originates.

During project development, the expected flood-reduction benefits from these interventions were analysed supported by a Financial and Economic Assessment (FEA) (Annex 3) to determine their cost-effectiveness. Based on these assessments, it is expected that implementing 17,740 ha of agroforestry systems and reforesting 7,700 ha of degraded land will result in a 40% reduction in peak runoff[298], with restoration interventions, in particular,

[297] Further details on priority intervention sites are presented in Section 10 of this Feasibility Study.

[298] The reduction in peak runoff is calculated Based on changes in the runoff coefficient (RC) in areas target for restoration, reforestation and/or agroforestry activities before and after intervention. The available RC data does not have a sufficiently high resolution to identify the maximum RC values within the catchment. The analysis therefore used literature estimates (Beck *et al*) that resulted in an average RC value of **0.4** for all parts of the catchment based on the weighted average for the each of each commune. The baseline RCs for each commune are: Port-de-Paix 0.3; Chansolme 0.35; Bassin-Bleu 0.49; Gros-Morne 0.33; Plaisance 0.48; Pilate 0.42; Marmelade 0.43

The RCs after restoration intervention are then expected to reduce to around **0.15**, a representative value for forested areas within the catchment. The reduction in RC for the targeted intervention areas to 0.15 therefore reduces the *average RC* for the watershed to 0.24 — i.e. a reduction of 40% from the baseline estimate of 0.4.

Several underlying assumptions have been applied to maximise the validity of the estimates, considering existing uncertainties. These include that:

- the RC of 0.15 for forested areas within similar landscapes in Haiti is accurate and representative for successful reforestation efforts;
- the total number of hectares of intervention is known, i.e 17,740 ha of agro-forestry and 7,700 ha of ecosystem rehabilitation
- By assuming high runoff areas (steep slopes and heavily degraded) to currently have an RC of 0.4, we deliberately underestimate the actual RC for these areas. Assuming then that this RC decreases to the known value for forested areas is a safe assumption.

expected to reduce floodplain extents in the target areas by 20% and 26% under the 20-year and 100-year flood scenarios, respectively (Figures 33 – 37). By the end of this century, these EbA interventions are expected to result in a more than 50% reduction in the number of households across the TR watershed affected by 100-year flood events (declining from 1,342 households at risk of flooding under the baseline scenario to 638 households with project interventions). Similarly, a 35% reduction in the number of households at risk to 20-year flood events in the TR watershed is expected as a result of EbA interventions — declining from 463 under the baseline scenario to 300 houses at the end of the century.[299] In addition to their flood-reduction benefits, EbA interventions have the potential to deliver considerable co-benefits that extend beyond flood-risk reduction, such as reduced sedimentation of water supply infrastructure, an increase in the lifespan of dams and additional income from agroforestry for smallholders. Moreover, in the heavily degraded TR watershed, soil erosion is a considerable challenge, as the loss of fertile topsoil negatively affects agricultural production. Additionally, sediment-laden runoff causes downstream waterways to clog up, further increasing flood risk. Implementing green infrastructure solutions directly addresses these challenges by reducing soil erosion and, consequently, sedimentation of primary freshwater resources.

This reduction is considered a conservative estimate, as the calculations consider average baseline RCs for the whole watershed, whereas the project will in fact prioritise the most heavily degraded sloping areas for reforestation — i.e. those areas that have the highest baseline runoff coefficients.

[299] Further evidence for the benefits of agroforestry and reforestation interventions to be implemented under the proposed project are presented in Annex 3: Financial and Economic Assessment.

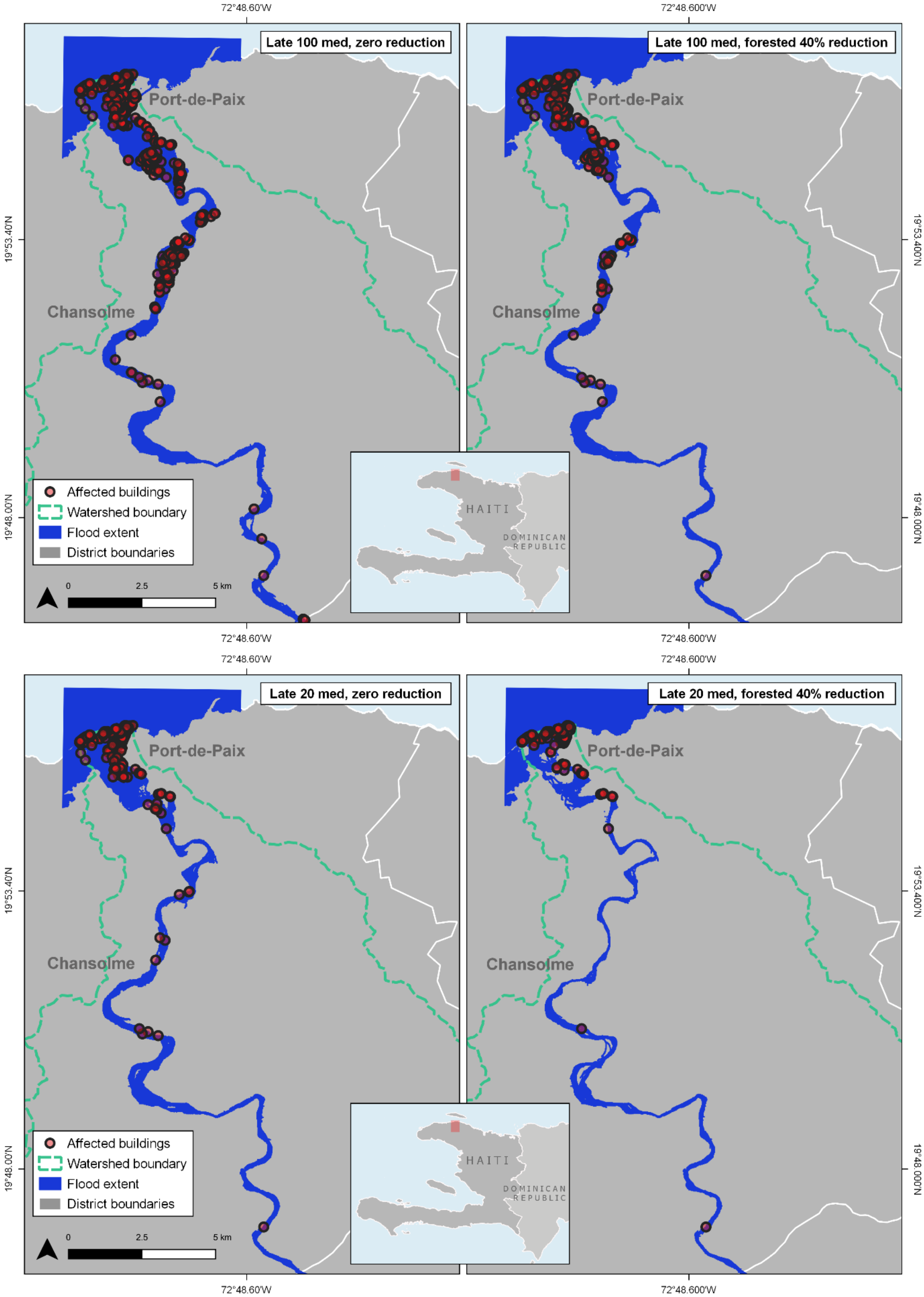

Figure 33. Flood extent around the Port-de-Paix and Chansolme regions under different scenarios. *Top left*: 20-year with no intervention; *Top right:* 20-year with a 40% reduction in surface runoff; *Bottom left*: 100-year with no intervention; *Bottom right:* 100-year with a 40% reduction in surface runoff.

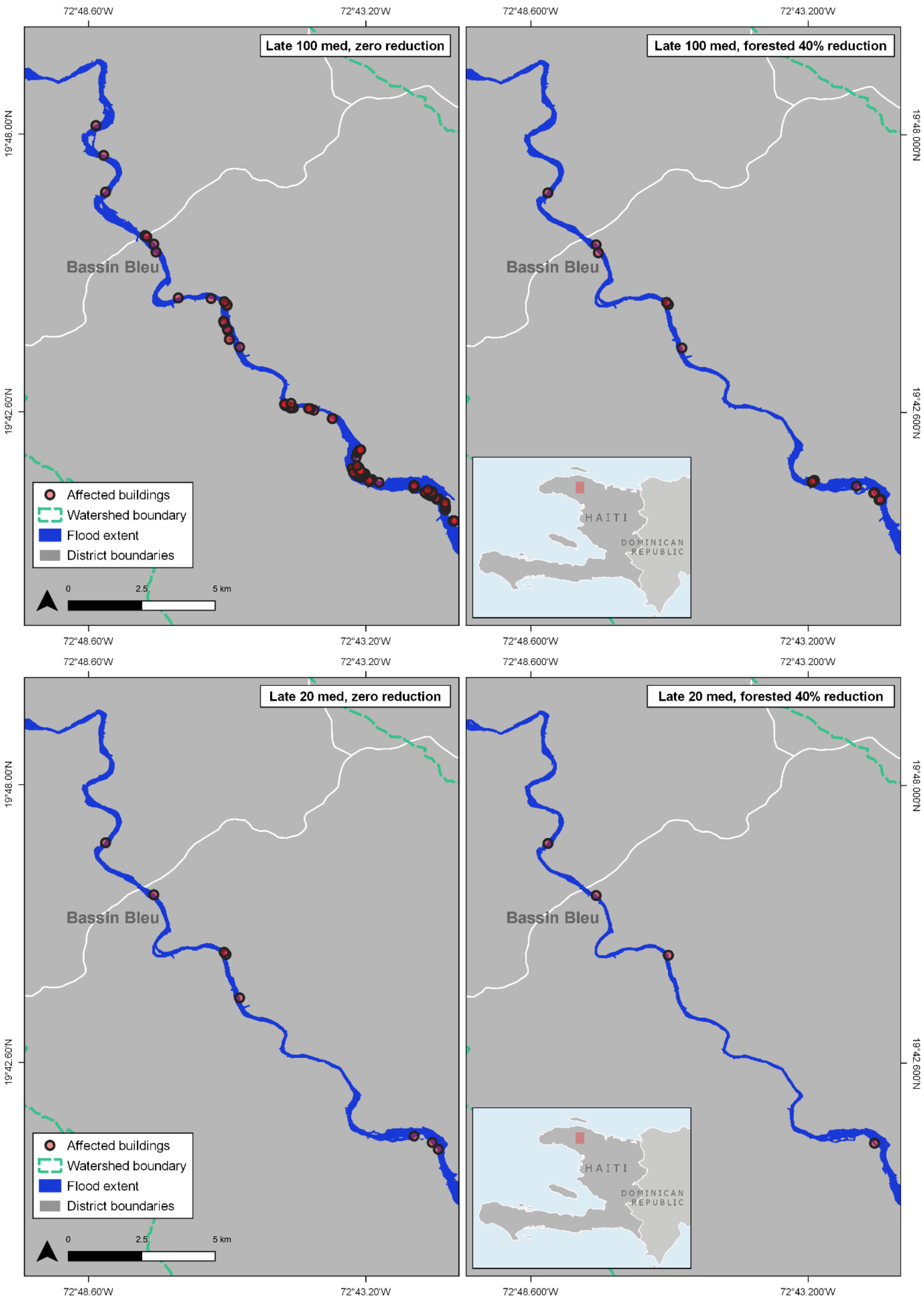

Figure 34. Flood extent around the Basin Bleu region under different scenarios. *Top left*: 20-year with no intervention; *Top right:* 20-year with a 40% reduction in surface runoff; *Bottom left*: 100-year with no intervention; *Bottom right:* 100-year with a 40% reduction in surface runoff.

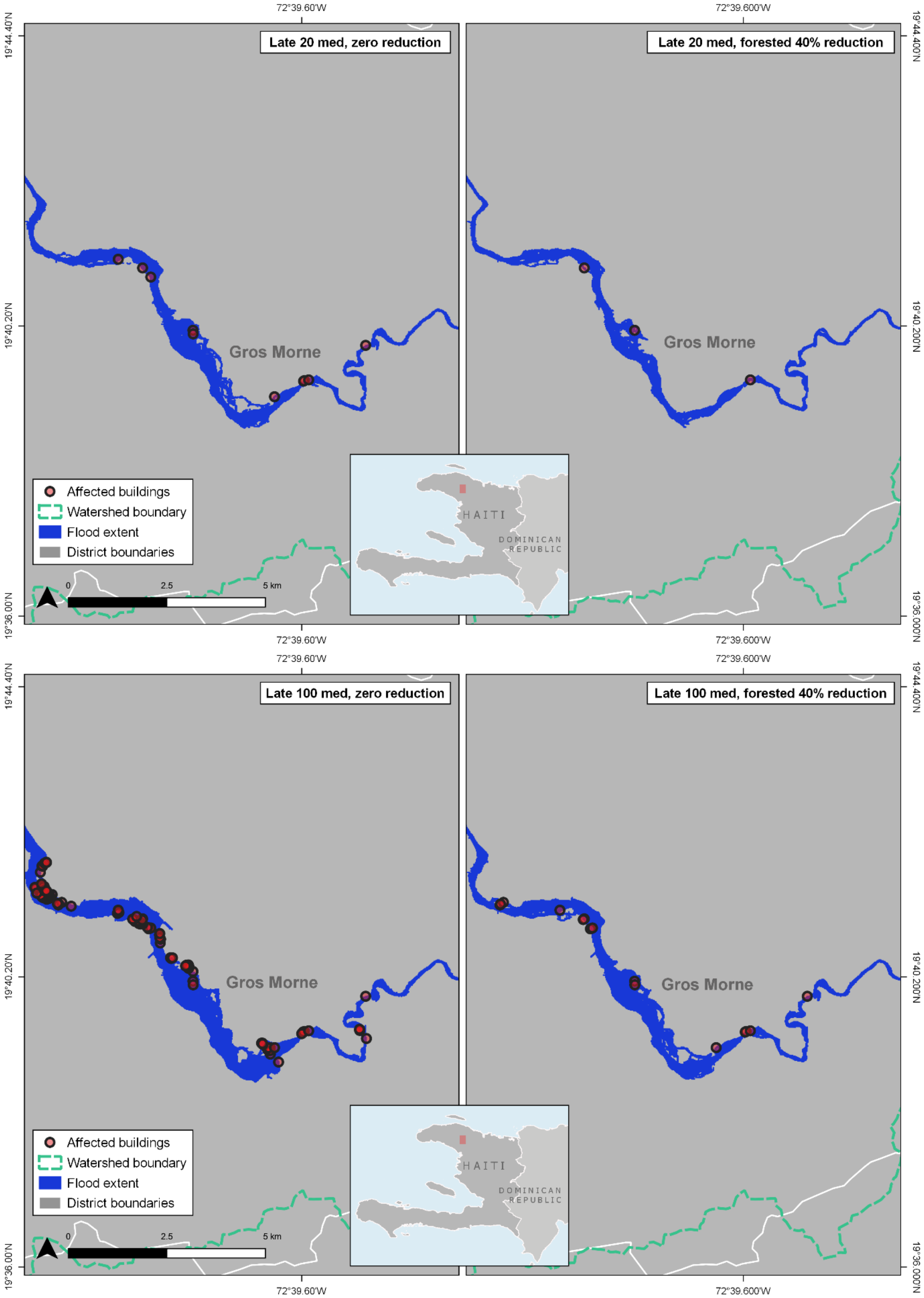

Figure 35. Flood extent around the Gros Morne region under different scenarios. *Top left*: 20-year with no intervention; *Top right:* 20-year with a 40% reduction in surface runoff; *Bottom left*: 100-year with no intervention; *Bottom right:* 100-year with a 40% reduction in surface runoff.

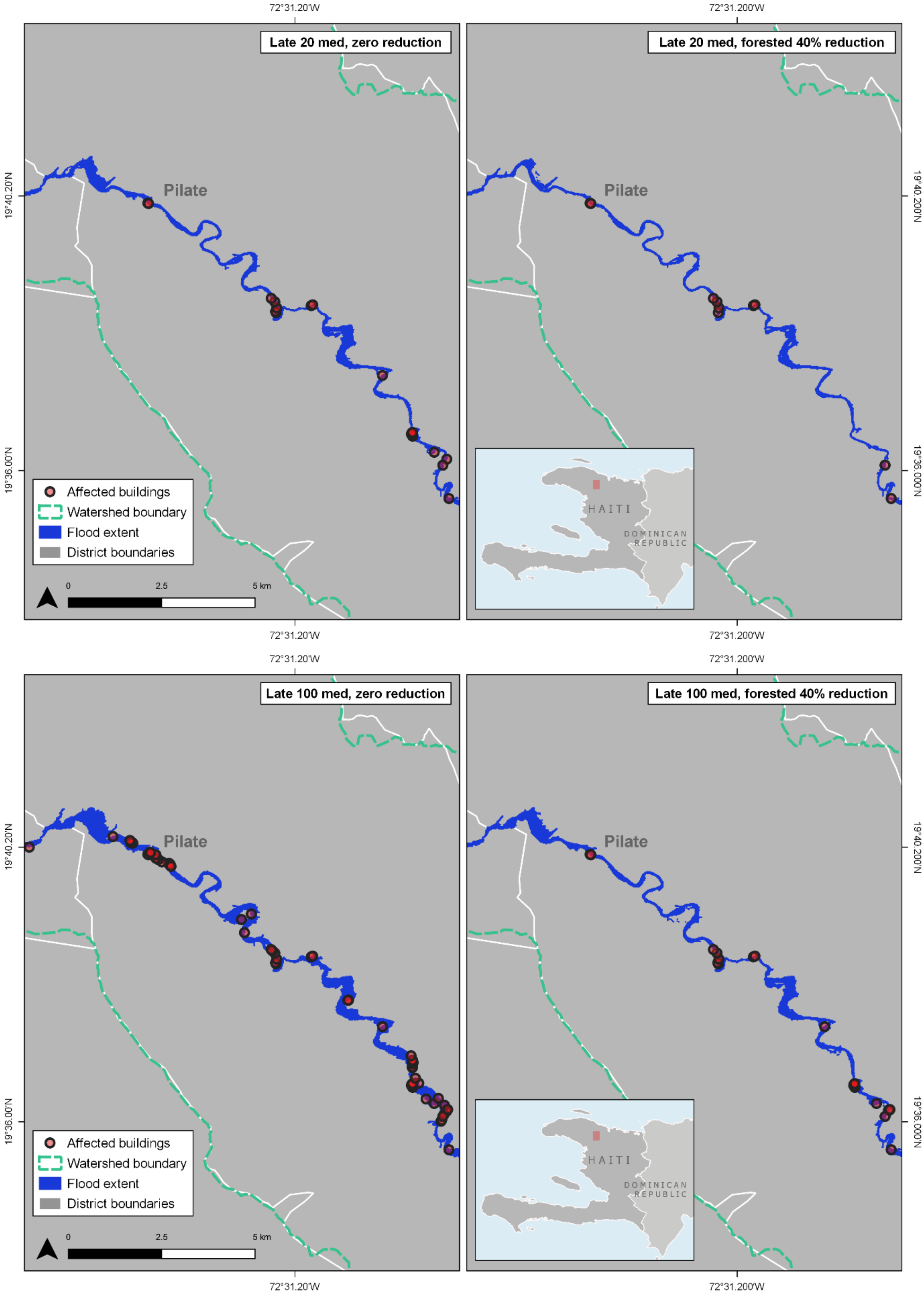

Figure 36. Flood extent around the Pilate region under different scenarios. *Top left*: 20-year with no intervention; *Top right:* 20-year with a 40% reduction in surface runoff; *Bottom left*: 100-year with no intervention; *Bottom right:* 100-year with a 40% reduction in surface runoff.

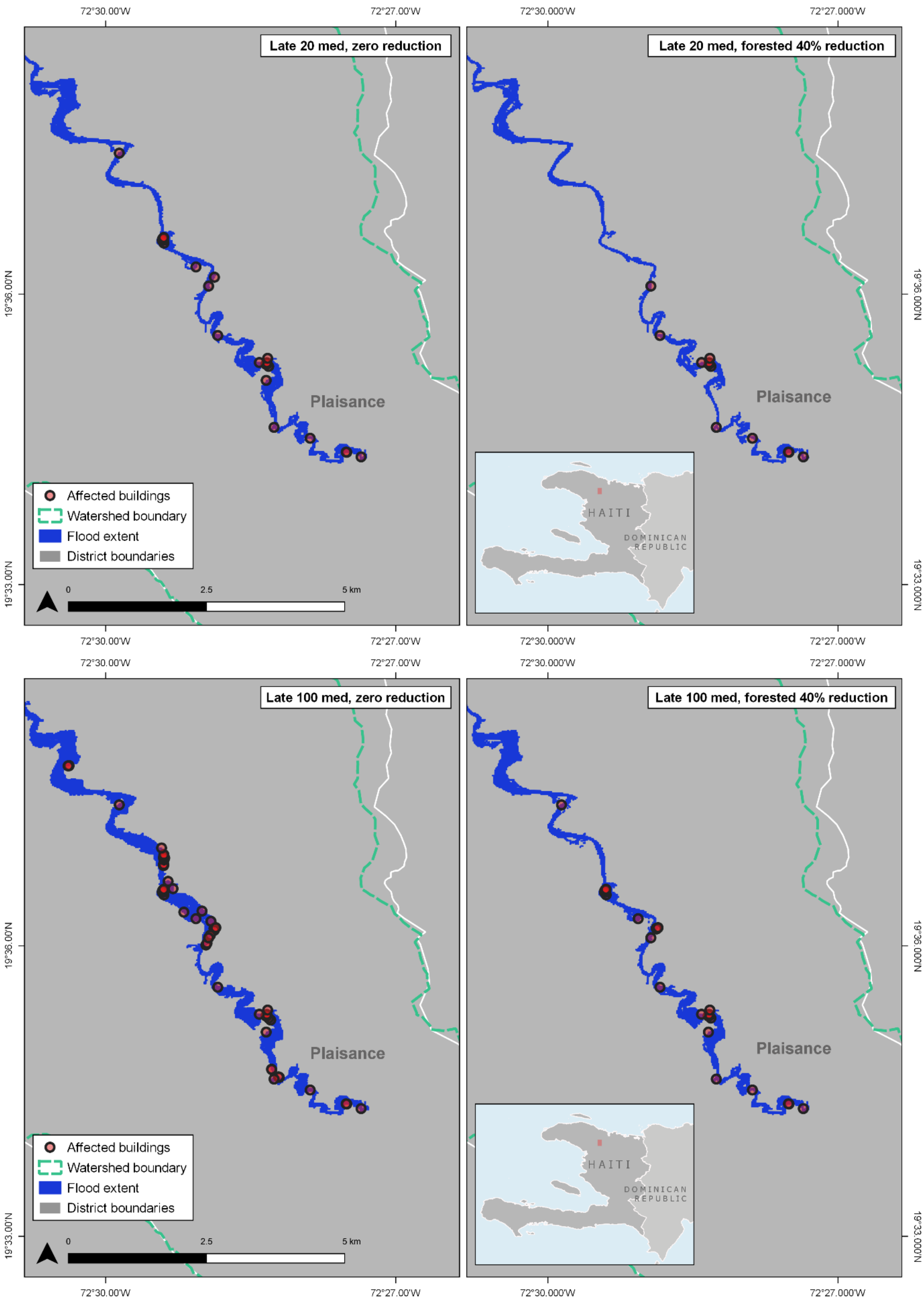

Figure 37. Flood extent around the Plaisance region under different scenarios. *Top left*: 20-year with no intervention; *Top right:* 20-year with a 40% reduction in surface runoff; *Bottom left*: 100-year with no intervention; *Bottom right:* 100-year with a 40% reduction in surface runoff.

A major advantage of using EbA interventions as an effective adaptation strategy is that their flood mitigation potential increases relative to the extent of the intervention. Consequently, as the impacts of climate change-induced flooding become increasingly severe in the future, the effectiveness of these interventions as an adaptation solution to flood impacts will also increase. This, however, does reveal a caveat in that the flood attenuation effect is less pronounced during the initial years of implementation as the introduced vegetation establishes itself within soils. The establishment of vegetation, along with its flood attenuation benefits, are further compromised if soils are of low quality. Despite this, implementing agroforestry and reforestation activities in the TR watershed is expected to confer long-term flood-reduction benefits as well as numerous socio-economic and environmental co-benefits. Reforestation activities enhance the provisioning of ecosystem goods and services, including improved quality and quantity of freshwater supply, as well as improved infiltration and productivity of soils. For example, healthy watersheds extend the lifespan of reservoirs, reduce wear on hydropower equipment and reduce operational and maintenance (O&M) costs of water treatment plants[300]. Such advantages have been proven elsewhere, with benefits being considerably higher than costs. Examples include Portland, Oregon (USA) where officials estimate that their US$9 million investment in green infrastructure has yielded savings of US$224 million across 20 years in stormwater costs related to repairs and maintenance[301]. The relevant, peer-reviewed literature confirms that similar benefits may be achieved under the proposed GCF project as the installation of green infrastructure has been shown to be an effective flood-risk reduction strategy in numerous instances[302,303,304]. In addition, the case for green infrastructure is strengthened by its superior ability over grey interventions to enhance the resiliency of drainage and flood networks under future climate change[305]. Therefore, as green interventions confer continued, long-term benefits despite changing climatic conditions, and present a less expensive option, they are an appropriate option for the proposed GCF project. Reforestation also re-establishes natural flood mitigating effects that are limited in degraded ecosystems, such as increased surface roughness which reduces overland flow. This complements the implementation of agroforestry (discussed below), which also increases vegetative cover to reduce the risk of flooding.

Despite a considerable reduction in tree cover across the TR watershed, there is an extensive area under agroforestry in the target area which provides an already established form of green infrastructure that can be scaled up for the proposed project. Using the incentive of financial benefits to farmers as leverage for the expansion of agroforestry systems has the potential to further increase tree cover within the watershed. From consultations with farmers and other stakeholders during project development, it was apparent that most interviewees were already aware of the importance of trees to ensure watershed health. Although deforestation and timber harvesting for charcoal production is widespread within the watershed, it is likely that the financial benefits to farmers of a shift to agroforestry will reduce watershed degradation by providing alternative livelihood options. This is because agroforestry involves the cultivation of mixed systems with, *inter alia*, fruit trees, coffee, cocoa, cereal crops, and livestock. Not only

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300 World Bank. 2019. Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/31430/9781569739556.pdf?sequence=4&isAllowed=y

301 USEPA (United States Environmental Protection Agency). 2010. Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure. Available at: https:// nepis.epa.gov/Exe/ ZyPDF.cgi/P100FTEM.PDF?Dockey=P100FTEM. PDF

302 Kong, F. *et al*. 2017. Modeling stormwater management at the city district level in response to changes in land use and low impact development. *Environ. Modell. Software*, 95.

303 Haghighatafshar, S. *et al*. 2018. Efficiency of blue-green stormwater retrofits for flood mitigation – conclusions drawn from a case study in Malmö, Sweden. *J. Environ. Manage*., 207.

304 Versini, P.A., *et al*. 2018. A distributed modelling approach to assess the use of Blue and Green Infrastructures to fulfil stormwater management requirements. *Landscape Urban Plann*., 173.

305 World Bank. 2019. Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/31430/9781569739556.pdf?sequence=4&isAllowed=y

does this provide diversification of livelihoods but also acts to buffer farmers against climate-related food insecurity by reducing the dependence on harvesting a single crop type[306].

During field surveys in the project target area, farmers and representatives from farmer associations noted that the long-term economic potential of growing fruit trees, for example, could outweigh the short-term financial gains of harvesting timber for charcoal production — validating a willingness to shift to agroforestry and away from unsustainable agricultural practices. To facilitate a shift towards this sustainable solution, financial needs in the short term will be met through complementary alternative livelihood options with commodities that may be harvested more frequently — for example, beekeeping and mushroom cultivation. The implementation of agroforestry systems will be combined with a policy framework for climate-resilient integrated water resources management and sub-watershed land use plans to formalise sustainable approaches to land and water resources management under future climate change conditions. Furthermore, these interventions will be supplemented by activities focused on enhancing small-scale farmers' access to finance for agricultural inputs and the provision of food vouchers to address chronic food insecurity that arises following the impacts of flooding and extreme climate events such as hurricanes. Together, these interventions will reduce the likelihood of trees being felled for charcoal production by providing viable alternative livelihood options to beneficiaries. Evidence for this is presented in the FEA (Annex 3), which found that agroforestry systems under the project would produce an incremental net return of US$ 150 per ha per year. Economic benefits are also likely to extend to the commercial agricultural sector and therefore the Haitian government through the expansion of domestic sales and export markets because of improved agricultural output.

4.3. Preferred approach

Based on the above analyses, implementing grey interventions to reduce the impacts of climate change-induced flooding in Haiti's TR watershed is unsustainable in the local context and therefore not a viable adaptation strategy for the proposed project. Previous projects and initiatives in Haiti have identified numerous challenges in the mobilisation of public funds for the operation and maintenance of grey infrastructure. Failure to maintain and repair structures severely compromises the effectiveness of grey interventions to reduce flood risk. In addition, the local harvesting of building materials for the construction of grey infrastructure would reduce the efficacy of this intervention because of the associated environmental degradation that would likely result from such harvesting. Since the identified grey interventions would be designed as an interlinked system — in which downstream and upstream interventions work in conjunction — failure of upstream grey infrastructure will impact the effectiveness of downstream infrastructure and likely exacerbate flood impacts. Consequently, insufficient maintenance and/or the inability to carry out repairs are likely to lead to a scenario where flood-related impacts are worse than the current baseline. In addition to being expensive, grey infrastructure has limited adaptive potential and produces few adaptation co-benefits.

In addition to the practical implementation challenges, there is higher financial risk associated with installing grey infrastructure compared to implementing EbA interventions in Haiti. This is largely because of the country's exposure to extreme climate events (e.g. hurricanes) and natural hazards (e.g. earthquakes), which have already resulted in costly damages to infrastructure in the country. Because of these factors, there are limited incentives for implementing, operating and maintaining grey infrastructure as an adaptation strategy to

[306] The GCF. 2017. Strengthening the resilience of smallholder agriculture to climate change induced water insecurity in the Central Highlands and South-Central Coast regions of Vietnam. Available at: https://www.greenclimate.fund/sites/default/files/document/18780-strengthening-resilience-smallholder-agriculture-climate-change-induced-water-insecurity.pdf

climate change-induced flooding in Haiti[307]. Furthermore, following an assessment of potential adaptation benefits that would be expected from implementing grey and green infrastructure, respectively, it was found that the costs of grey infrastructure outweigh the benefits within the Haitian context. This is supported by similar projects and initiatives which, despite not being implemented in Haiti, provide a strong indication that green infrastructure is a more cost-effective option than grey infrastructure. Indeed, this not only applies to installation and implementation of related interventions, but also to operation and maintenance of infrastructure beyond any initial capital outlay[308]. For example, the City of Philadelphia (USA) found that the net present value (NPV) of green interventions for flood management ranged from ~US$ 1.9–4.5 billion, while the grey infrastructure NPV totalled only US$ 60–140 million over a 40 year period[309]. Using a system of wetlands, North Carolina (USA) controlled stormwater runoff for US$ 0.47 per thousand gallons where conventional, grey controls would have US$ 3.24[310]. Overall, therefore, it has been found that the benefits of green interventions outweigh those of grey and present a more cost-effective option. By using and enhancing natural systems, green infrastructural solutions and associated co-benefits can be provided at a lower cost and for a longer period, while delivering a more considerable impact in addressing flood risks[311].

An approach to flood management in Haiti's TR watershed that is underpinned by green infrastructure is considered the more sustainable and cost-effective option for the proposed project. Following the full analysis presented above, a comprehensive suite of recommended interventions has been designed to enable Haiti to reduce flood-related impacts in the TR watershed. These interventions include: i) implementing green infrastructure (agroforestry and reforestation activities) to strengthen flood resilience, supported by capacity-building programmes for land-use management; ii) establishing and promoting climate-resilient agricultural and land-use practices to enhance food security in the watershed; and iii) improving national and local governance frameworks for the implementation of integrated water resources management at national, catchment and sub-catchment levels to contribute to creating an enabling environment for climate-resilient flood management in Haiti.

Seven target communes in the TR watershed (Port-de-Paix, Chansolme, Bassin Bleu, Plaisance, Pilate, Marmelade, Gros Morne) with a combined total population of ~715,000[312] have been identified and selected to receive agroforestry and reforestation activities under the proposed project. Projected flood reduction benefits from the implementation of these activities will result from, *inter alia*, increased surface roughness, reduced overland flow and improved groundwater infiltration. This will enhance flood attenuation across the TR watershed in upstream and downstream communities as previously degraded ecosystems will be restored through increasing vegetative cover. As stated previously, this is evidenced by a projected 50% reduction in the number of households affected by 100-year flood events and a 35% reduction in the number of households at risk to 20-year flood events in the TR watershed. Moreover, considerable co-benefits will be seen by households within the target area as green infrastructure interventions also enhance ecosystem goods and services provisioning. By providing non-timber forest products: i) livelihoods will be diversified

[307] The GCF. 2017. Strengthening the resilience of smallholder agriculture to climate change induced water insecurity in the Central Highlands and South-Central Coast regions of Vietnam. Available at: https://www.greenclimate.fund/sites/default/files/document/18780-strengthening-resilience-smallholder-agriculture-climate-change-induced-water-insecurity.pdf

[308] Alberta Water. No date. Green v Grey Infrastructure. Available at: https://albertawater.com/green-vs-grey-infrastructure

[309] Stratus Consulting. 2009. A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds. Stratus Consulting: Boulder, Colorado.

[310] PlanNYC. 2011. NYC Green Infrastructure Plan: A Sustainability Strategy for Clean Waterways. Available at: www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf.

[311] World Bank. 2019. Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute. Available at: https://openknowledge.worldbank.org/bitstream/handle/10986/31430/9781569739556.pdf?sequence=4&isAllowed=y

[312] UN OCHA. 2015. Haiti administrative level population estimates. Available: https://data.world/ocha-haiti/1139e980-6631-44c3-91f5-0ff665396f60

alongside enhanced market access and therefore reduced pressure will be placed on forests for charcoal production; ii) water quality and quantity will be improved; and iii) agricultural productivity will improve with the increased fertility of soils. The combination of these benefits and co-benefits, as well as the reduced cost of implementation of green interventions compared to grey infrastructure and avoided O&M costs, highlight green solutions as the preferred approach. This is further supported by the FEA (Annex 3), which found that implementing agroforestry and reforestation interventions under the project will produce an NPV of US$11.3–56.9 million and an Internal Rate of Return of 14.5–25.7%[313]. The modelling that was conducted for the hydrological studies considered a theoretical portion of the mainstem river in the targeted watershed. Specifically, the models assessed the potential benefit of restoring degraded land across the sampled area.

Given that the target watershed is 897 km^2, the target area of 254km^2 (77km^2 of reforestation and 177km^2 of agroforestry) is ~28% of the total area. If one considers that targeted area of intervention will reduce floods by 26% for a 100-year flood, a simple linear extrapolation suggests that this would reduce overall flooding by 7.3% across the whole watershed. However, this assumes that interventions are randomly distributed across the watershed – which is not the case for the project. Areas targeted for intervention have been specifically selected to target areas with the highest potential for flood reduction benefits (steep slopes and areas closer to the riverbed that would increase runoff and chances of landslides), suggesting that estimates from such linear scaling would be too conservative.

Legal, institutional and strategic framework

5.1. Legal framework

5.1.1 Constitution of Haiti (1987)[314]

The 1987 Constitution of Haiti addresses Haiti's roles and responsibilities towards the country's natural resources through its Articles 253-258. Article 253 addresses conservation, stating that "since the environment is the natural framework of the life of the people, any practices that disturb the ecological balances are strictly forbidden". Regarding agricultural policy, Articles 245–252 address its economic importance, while Article 257 recognises agriculture as integral to the wellbeing of Haiti's population, as well as its socio-economic progress. The above-mentioned articles, particularly Articles 253–258, are indicative of the alignment of the proposed project impacts to the constitution. The proposed project focuses on enhancing climate-resilience in the Trois-Riviéres (TR) region of Haiti, which will contribute to fulfilling the responsibilities outlined in the constitution.

5.1.2 Presidential Decree on Environmental Management (2006)[315]

Haiti's Presidential Decree on Environmental Management was established in 2006 to outline the roles and responsibilities of various stakeholders in Haiti's environmental management. Through this decree, authority over forest management and water resources was transferred from the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR[316]) to the Ministry of Environment (MoE), further outlining MoE's environmental management responsibility. The objectives of the proposed project, together with proposed interventions to improve the resilience of ecosystems, align with and contribute to the objectives outlined in the decree.

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313 Further details on the Financial and Economic Assessment, which includes a sensitivity analysis, are presented in Annex 3.
314 1987 Constitution of Haiti. Available at: https://wipolex.wipo.int/en/text/217597
315 The Monitor (2006) Presidential Decree on Environmental Management (2006).
316 This is the French acronym for the Ministry of Agriculture, Natural Resources and Rural Development which has been used throughout this Feasibility Study.

The decree's objectives are listed as follows:

- Prevent and anticipate actions that may negatively affect the quality of the environment and ensure harmony between the environment and development.
- Enable close and permanent monitoring of pollution and degradation and mitigate their adverse effects on the environment and human health.
- Promote the protection and expansion of forest and agro-forest cover, particularly on sloping terrains.
- Strengthen the National System of Protected Areas (NSPA) and the conservation of Haiti's biological diversity.
- Develop policies for the development and restoration of damaged ecosystems, as well as for the improvement of the living environment[317].
- Encourage sustainable use of natural resources and renewable energy technologies.
- Develop a national culture of environmental protection and restoration through education and awareness raising.

5.1.3 National Policy to Combat Climate Change (2019)[318]

The main objective of Haiti's National Policy to Combat Climate Change (PNCC) is to contribute to the well-being of the population through an economic development process that is: i) inclusive; ii) climate-resilient; and iii) focused on using renewable energy sources available in the country.

Specific objectives of this policy are to:

- considerably reduce climate change-related damages to the country's strategic sectors;
- reduce or avoid at least 5% of GHG emissions in the energy and AFOLU (Agriculture, Forestry and other land use) sectors;
- build the capacity of public and private sectors' stakeholders for climate change mitigation;
- integrate climate change considerations into national, regional and local development planning and budgeting;
- create an enabling environment for wealth creation and economic activities' diversification to increase Haiti's GDP compared to a business as usual scenario;
- enable financial mobilisation to adapt to climate change; and
- encourage more coordination between institutions.

The proposed project focuses on increasing the climate resilience of the most vulnerable communities (including farmers) in the TR region of Haiti, which contributes to achieving the PNCC's abovementioned objectives on addressing climate change impacts.

5.1.4 Haiti's Initial (First) and Second National Communications on Climate Change to UNFCCC (2001 and 2013)[319,320]

Haiti's Initial and Second National Communications (INC and SNC) to the UNFCCC highlights priority areas to address the impacts of climate change in Haiti. These priority areas include: i) implementing climate-resilient solutions to reduce the vulnerability of communities, as well as major economic sectors (such as agriculture), to climate change-induced flooding; ii) promoting the adoption of integrated land and water resources management; and iii) strengthening cohesion between existing and planned integrated resource management

[317] which includes both natural and built environment
[318] Ministry of Environment. National Policy to Combat Climate Change. Available at: https://www.mde.gouv.ht/phocadownload/PNCC-HAITI-2019%20Final.pdf
[319] Ministry of Environment. Initial (First) National Communications (2001). Available at: http://www.un-gsp.org/sites/default/files/documents/haiti_inc_french.pdf
[320] UNEP. Enabling Activities for the Preparation of the Second National Communication under the UNFCCC. Available at: http://www.un-gsp.org/sites/ddocefault/files/uments/haiti_prodoc_29.09.2005.pdf

initiatives to ensure best practices are applied to the development of climate change projects and programmes. The proposed project promotes the adoption of integrated land and water resources management combined with the implementation of ecosystem restoration interventions to reduce the impacts of climate change-induced flooding, which contributes to the INC and SNC's adaptation action areas.

5.1.5 Nationally Determined Contribution (2015)[321]

Despite being one of the lowest emitters of greenhouse gases (GHG) globally, Haiti has committed to reducing their GHG emissions by 31%[322] by 2030, compared to a business as usual scenario. To complement the mitigation activities in Haiti, four key adaptation priorities were identified in the country's NDC, namely: i) promoting integrated water resources and watershed management; ii) integrated coastal zone management and infrastructure rehabilitation; iii) preserving and strengthening food security; and iv) information dissemination, education and awareness raising. The proposed project's aim to enhance climate-resilient land and water resources management, as well as implementing ecosystem-based adaptation (EbA) solutions to reduce the impacts of flooding[323], contributes to the NDC's adaptation priorities.

5.1.6 National Environmental Action Plan (1999)[324]

Haiti's National Environmental Action Plan (NEAP) was established to guide the country's environmental management for the period 2000–2015. The NEAP's priorities include: i) reducing poverty; ii) regulating natural resources exploitation; iii) reducing desertification; and iv) providing a framework to improve prevention and responses to climate risks that lead to disasters. Through its agroforestry, reforestation and IWRM interventions, the proposed project is aligned with the priorities of the NEAP.

5.1.7 National Action Plan for Integrated Management of Watersheds and Coastal Areas (2001)[325]

The National Action Plan for Integrated Management of Watersheds and Coastal Areas (IMWACA) in Haiti was established in 2001 to develop and implement initiatives to restore degraded watersheds and coastal areas. Representatives from MoE and MARNDR were engaged as stakeholders to develop the following four strategic focus areas of this plan:

- the restoration of coastal ecosystems and associated watersheds;
- the creation of a new institutional and legal framework to address the integrated management of watersheds and coastal areas;
- the reduction of communities' vulnerability to natural disasters; and
- the establishment of transboundary cooperation on the integrated management of watersheds and coastal areas with the Dominican Republic.

The implementation of the proposed project will promote the rehabilitation and restoration of Haiti's TR region, therefore contributing to the strategic areas put forward in the IMWACA National Action Plan.

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[321] Ministry of Environment. *Contribution Prévue Déterminée au Niveau National* (2015) Available at: http://www.un-gsp.org/sites/default/files/documents/cpdn_republique_dhaiti.pdf

[322] 5% being unconditional and an additional 26% being conditional — if Haiti is provided with sufficient financial and technical support for the required mitigation measures.

[323] Flood reduction benefits that are expected to be conferred by project interventions are quantified and presented in Section Section 4.3 of this Feasibility Study, as well as Annex 3: Financial and Economic Analysis. The projected impacts of climate change-induced flooding in Haiti's TR watershed are presented in Section 3 of this Feasibility Study.

[324] GEF (2013) Project Identification Form: Ecosystem Approach to Haiti's Cote Sud.

[325] GEF (2013) Project Identification Form: Ecosystem Approach to Haiti's Cote Sud.

5.1.8 National Adaptation Programme of Action (2006; 2017)[326,327]

Haiti's National Adaptation Programme of Action (NAPA) was developed in 2006 (and revised in 2017) to determine the country's most climate-vulnerable and inform the prioritisation of adaptation solutions in the country. Based on the 2006 NAPA, the following adaptation priorities were identified, the: i) watershed management and soil; ii) coastal zones management; iii) promotion and preservation of natural resources; iv) improvement of food security; v) protection and conservation of water resources; vi) construction and rehabilitation of infrastructure; vii) improvement of waste management; and viii) increasing awareness of climate change through education.

The revised National Adaptation Programme of Action (NAPA), developed in 2017, identified four priority areas for addressing the impacts of climate change — namely, soils, agriculture, coastal zones and water resources. Focus was placed on these areas because they were identified as the most vulnerable to the impacts of climate change such as flooding, hurricanes and tropical storms. Addressing these negative impacts will contribute considerably to climate-resilient sustainable development in Haiti. The proposed project will align with the 2006 and 2017 NAPA by implementing climate-resilient interventions in Haiti's TR region, including by using an integrated approach to land and water resources management.

5.1.9 Strategic Development Plan of Haiti (2012)[328,329]

The Strategic Development Plan of Haiti (SDPH) provides a long-term development and economic reconstruction plan for the country after the 2010 destructive earthquake. The plan comprises four project areas, namely: i) territorial; ii) economic; iii) social; and iv) institutional refoundation. The proposed project aligns specifically to the territorial refoundation[330] project area. The relevant programmes under territorial refoundation include:

- The environmental programme. This programme prioritises: i) mainstreaming climate change considerations into planning and awareness-raising initiatives at the national and local level; ii) establishing a network of protected areas; iii) restoring degraded ecosystems; and iv) ensuring sustainable management and use of forests.
- The watershed programme. This programme prioritises: i) protecting watersheds by using reforestation plans based on agro-ecological zoning; ii) constructing flood regulation structures; and iii) reducing the environment as well as Haitian communities' vulnerability to storms.

5.1.10 Action Plan for Water Resources Management in Haiti (1999)

The Action Plan for Water Resources Management (APWRM) in Haiti highlights the need for: i) reforms and legal frameworks in the water sector; ii) capacity building among policymakers and water users; and iii) recognition of the economic importance of water resources as well as the need for integrated management of these resources. A 2018 review of the 1999 Action Plan noted gaps in the country's capacity for implementing IWRM because of: i) limited knowledge on IWRM; ii) the unavailability of management instruments for IWRM; and iii) limited finance for the efficient implementation of IWRM interventions. The proposed project contributes to the long-term objectives of the APWRM and specifically addresses the gaps

[326] GEF (2013) Project Identification Form: Ecosystem Approach to Haiti's Cote Sud.
[327] UNDP (2015) Project Document: Increasing resilience of ecosystems and vulnerable communities to climate change and anthropic threats through a ridge-to-reef approach to biodiversity conservation and watershed management.
[328] UNDP (2015) Project Document: Increasing resilience of ecosystems and vulnerable communities to climate change and anthropic threats through a ridge-to-reef approach to biodiversity conservation and watershed management.
[329] The Ministry of Planning and External Cooperation. Government Priorities: Strategic Development Plan for Haiti. Available at: http://www.mpce.gouv.ht/index.php/planification/grands-chantiers
[330] Territorial refoundation, with relevance to the project, refers to improving regional and town planning, local development, environmental protection, rehabilitating watersheds and increasing drinking water supply and sanitation capacities.

identified in the 2018 APWRM review through the implementation of IWRM activities under Output 3.

5.2. Institutional Framework

5.2.1. The Ministry of Environment

The mandate of Haiti's MoE is to develop and establish appropriate measures for the country's environmental protection and management. This includes strengthening the management and conservation of forests and parks, as well as the necessary legal frameworks for these activities. The MoE is also responsible for developing the necessary policy and planning documents that guide the development and implementation of climate change programmes, including the PNCC and NAPA (see Section 5.1 of the Feasibility Study). Moreover, the MoE serves as the national focal point for climate change-related matters and obligations under the UNFCCC. Although the MoE plays an important role in environmental protection and management as well as addressing climate change impacts in Haiti, their management and technical expertise to do so efficiently and effectively is limited[331]. For example, the MoE is centralised, with limited human and financial capacity to fulfil tasks in departments and communes[332].

5.2.2. The Ministry of Agriculture, Natural Resources and Rural Development

The Ministry of Agriculture, Natural Resources and Rural Development (MARNDR) develops policies related to agriculture, animal husbandry, natural resources and rural development. Their mandate further includes: i) improving production systems; ii) training of farmers through extension services; iii) enabling agricultural market access; and iv) enabling job creation[333]. Within MARNDR, there are numerous specialised departments such as the National Meteorological and Hydrological Service, National Service for Water Resources and National Care for Meteorology departments, which collectively assume a technical advisory role.

5.2.3. The Ministry of Public Works, Transport and Communication

The Ministry of Public Works, Transport and Communication (MTPTC) is the Haitian government's legislative policy and regulatory agency for: i) public works; ii) transport; iii) communications; iv) drinking waters; and v) energy. The MTPTC is primarily responsible for: i) management of public physical infrastructure, including urban and rural amenities, as well as drinking water supply systems; ii) establishing town planning regulations and technical building standards; and iii) regulating provisions of services provided by private and public entities[334]. Although the MTPTC's role is essential to the water sector — particularly ensuring access to safe drinking water and sanitation services, the ministry has limited financial capacity to fulfil its mandate. These include implementing regulatory frameworks, facilitating the decentralisation of water supply management, coordinating donor assistance and regulating water service providers. This limitation is further highlighted in its sub-departments, particularly the National Directorate for Water Supply and Sanitation (DINEPA), which strongly

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[331] Stoa, R (2017). *Water Governance in Haiti: An Assessment of Laws and Institutional Capacity*. Florida International University College of Law. Faculty Publications.

[332] Bush, M (2018). *Climate Change Adaptation in Small Island Developing States*. Wiley Blackwell. Toronto, Canada. Available at: https://books.google.co.za/books?id=d0hFDwAAQBAJ&pg=PA148&lpg=PA148&dq=environmental+territorial+collectivities+in+haiti&source=bl&ots=0Lc5DoQhUO&sig=ACfU3U0tltdgjdMdztOLO8d-pJlEJTluQQ&hl=en&sa=X&ved=2ahUKEwj3sNevs-rpAhVwVBUIHVMwDLIQ6AEwC3oECAwQAQ#v=onepage&q=environmental%20territorial%20collectivities%20in%20haiti&f=false

[333] Devex. Ministry of Agriculture, Natural Resources and Rural Development: Mission. Available at: https://www.devex.com/organizations/ministry-of-agriculture-natural-resources-and-rural-development-marndr-haiti-123634

[334] Ministry of Public Works, Transport and Communications: Responsibilities of the Ministry. Available at: http://www.mtptc.gouv.ht/accueil/le-ministere/page_attributions.html

relies on financial assistance from NGOs and international development agencies to fulfil their respective mandates[335].

5.2.4. The Inter-Ministerial Committee for Regional Planning

The Inter-Ministerial Committee for Regional Planning (CIAT) was established following the Prime Minister's decree in 2009. Its mission is to develop policies related to: i) land use planning; ii) protection and management of watersheds; iii) water management; iv) sanitation; and v) town planning. CIAT's responsibilities further include: i) coordinating and harmonising government actions; ii) ensuring the revisions of legal, regulatory and institutional frameworks of regional planning; iii) guaranteeing provision of the necessary human, technical and financial resources; and iv) managing activities which contribute to the overall mission[336]. Although CIAT is mandated to ensure the alignment of institutions and actions to address environmental degradation, it experiences human capacity limitations, resultantly making it centralised[337].

5.2.5. The National Centre for Geospatial Information

The National Centre for Geospatial Information (CNIGS) was established in 2005 and is a semi-autonomous entity under Haiti's Ministry of Planning and External Cooperation (MPCE) — which forms a part of the Prime Minister's Cabinet[338]. It is responsible for Haiti's geographical information systems technology and services, further serving as a repository for the geospatial data of the country. Although not formally mandated to collect hydrological and meteorological data, CNIGS manages 24 automatic meteorological stations that were provided by the European Union (EU) and is considered a reliable and effective technical partner in data management by national and international agencies.

5.2.6. Civil Society Organisations focused on addressing climate change

Civil Society Organisations (CSOs) in Haiti play a vital role in raising awareness on *inter alia*: i) environmental degradation; ii) challenges and impacts of climate change; iii) food insecurity; and iv) the role of climate finance in increasing the climate resilience of the country's population and major economic sectors, including agriculture. In Haiti, CSOs are particularly important partners in the design and implementation of development projects and programmes. Below is a list of CSOs which, in addition to being most noteworthy in Haiti, were involved in the stakeholder consultation and project design processes for the proposed GCF project.

The Research and Technological Exchange Group (GRET)

GRET is an international development NGO governed by French law, which primarily focuses on the following areas: i) agriculture; ii) water and sanitation; and iii) natural resources and energy. Their experience includes operating as an implementing partner on a project entitled 'Improving food and nutritional quality and access to social protection in the Trois-Riviéres watershed' which focuses on improving livelihood resilience, particularly to climate change. Through this project, GRET has collaborated with various public institutions and local

[335] Stoa, R (2017). *Water Governance in Haiti: An Assessment of Laws and Institutional Capacity*. Floriday International University College of Law. Faculty Publications.
[336] The Inter-Ministerial Committee for Regional Planning: CIAT Presentation Note. Available at: http://ciat.gouv.ht/pages/note-de-pr%C3%A9sentation-du-ciat
[337] Stoa, R (2017). *Water Governance in Haiti: An Assessment of Laws and Institutional Capacity*. Floriday International University College of Law. Faculty Publications.
[338] UN Spider Knowledge Portal. National Centre for Geospatial Information. Available at: http://www.un-spider.org/sites/default/files/CNIGS.pdf

authorities, particularly in the Artibonite and North-West Departments[339]. As a partner institution of the proposed project, GRET's work experience and presence in the TR region will be particularly valuable to the delivery of project interventions[340,341].

Heifer International

Heifer International is an American development NGO which has been operating in Haiti since 1999. Their work focuses on: i) economic development; ii) environmental sustainability; iii) food security and nutrition; iv) risk mitigation and resilience; and v) women's empowerment and social capital. Heifer has partnered with several national- and local-level Haitian institutions, including MARNDR and MPCE. Through these partnerships, Heifer works to improve food security and strengthen water resource governance in the North-West and North-East Departments by promoting integrated water resource management (IWRM). Given their technical expertise and extensive work experience in Haiti, Heifer is well-placed to contribute to the implementation of the proposed project interventions. These include adopting and implementing an integrated approach to water resources management in Haiti as an effective response to climate change-induced flooding in the TR watershed[342].

Protos (Join for Water)

Protos is a Belgian development NGO that focuses primarily on improving water access, use and management, particularly by using an integrated approach to water resources management. In the North-West Department of Haiti, Protos' work includes: i) rehabilitating and expanding drinking water infrastructure; ii) training in water use and management; and iii) training and increasing awareness on effective hygiene practices. Protos furthermore aims to improve food security for the inhabitants of the TR region[343], together with GRET and Heifer International. Moreover, our project interventions strongly align with Protos' mission in the TR region of the country[344].

The Haitian Civil Society Platform on Climate Change

The Civil Society Platform on Climate Change (PSC-CC) of Haiti was established to mainstream climate change considerations into relevant public policies in Haiti. In line with its mandate, PSC-CC's objectives include: i) strengthening coordination among stakeholders involved in the mainstreaming process; and ii) promoting the participation of women in decision making and mainstreaming gender-responsive adaptation measures into policy[345]. PSC-CC's objectives and efforts to mainstream climate change considerations into the relevant legal frameworks are well-placed in assisting the proposed project interventions to strengthen governance and capacity for climate-resilient IWRM.

Welt Hunger Hilfe Haiti (Agro Action Allemande)

Welt Hunger Hilfe is a German aid organisation with a global focus on the achievement of Sustainable Development Goal 2: Zero Hunger. Their work in Haiti includes preserving watersheds in the North Department through soil conservation[346]. In addition, Welt Hunger Hilfe aims to improve the climate resilience of rural communities in the Caribbean Biological

[339] GRET Professionals for Fair Development. Haiti: Activities https://www.gret.org/projet/projet-damelioration-de-la-securite-alimentaire-et-nutritionnelle-et-dacces-a-la-protection-sociale-dans-le-bassin-versant-de-trois-rivieres/
[340] GRET Professionals for Fair Development. Haiti https://www.gret.org/countries/latin-america-caribbean/haiti-en/?lang=en
[341] GRET Professionals for Fair Development. About Us. https://www.gret.org/discover-gret/about-us/?lang=en
[342] Heifer International: Haiti https://www.heifer.org/about-us/where-we-work/haiti.html
[343] Join For Water. What We Do: Haiti https://www.joinforwater.ngo/en/what-we-do/haiti
[344] Join For Water. What We Do https://www.joinforwater.ngo/en/what-we-do
[345] The Civil Society Platform for Climate Change http://www.psccchaiti.org/spip.php?article1
[346] Welt Hunger Hilfe. Project Sheet: Haiti https://www.welthungerhilfe.org/our-work/countries-projects/project-sheet/haiti/

Corridor by implementing EbA[347]. Welt Hunger Hilfe's technical expertise specialises in *inter alia*: i) increasing agricultural production with integrated watershed resources management; ii) providing humanitarian assistance and disaster preparedness; iii) improving water and sanitation and health services and systems[348]. This expertise is indicative of the alignment of the proposed project and Welt Hunger Hilfe, particularly in improving the climate resilience of communities through integrated watershed resources management.

Société Audubon Haiti

The Société Audubon Haiti (SAH) is a local non-profit foundation established to contribute to the protection and restoration of Haiti's natural ecosystems. They contribute to conservation by collaborating with relevant partner institutions on scientific research to inform these institutions' awareness-raising campaigns and conservation strategies, including: i) developing Important Bird Areas (IBA) and Key Biodiversity Areas (KBA); ii) assisting the GoH with determining potential protected areas; and iii) supporting legislation aimed at conserving Haiti's natural environment[349,350]. SAH is well-placed to support the interventions of the proposed project, particularly in rehabilitating and restoring the ecosystems in the TR region.

Friends of the Earth International

Friends of the Earth International (FOEI) is a global environmental network of 73 national member groups and ~5,000 local activist groups. Located in this network is Haiti Survie, an environmental organisation that works closely with farmer organisations to address climate change impacts and land degradation by implementing EbA and sustainable agriculture solutions in the country. Their mission includes:

- halting and reversing environmental degradation and depletion of natural resources;
- nurturing ecological and cultural diversity and enabling sustainable livelihoods;
- empowering local communities, with a focus on the most vulnerable groups (including Indigenous Peoples and women), by encouraging public participation in decision making; and
- collectively ensuring environmental and social justice, human dignity, and respect for human rights[351,352].

The objectives of the proposed project align with the mission of FOEI to address the impacts of climate change and degradation on vulnerable communities.

Helvetas

Helvetas is a Swiss development organisation — with an operational branch in Haiti — committed to improving the livelihoods of disadvantaged and vulnerable communities. The organisation's work focuses primarily on disaster risk management, sustainable and inclusive economies, water supply, and gender and social equity[353]. In Haiti, Helvetas' work includes: i) supporting access to clean and safe drinking water and sanitation facilities; ii) advocating against deforestation; and iii) promoting sustainable forestry and agricultural practices. Helvetas' experience, particularly in promoting sustainable forestry and agriculture practices, will be beneficial in supporting the agroforestry interventions of the proposed project.

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[347] Welt Hunger Hilfe. Project Sheet: Haiti https://www.welthungerhilfe.org/our-work/countries-projects/project-sheet/haiti-ecosystem-based-adaptation-and-forest-reconstruction/
[348] Welt Hunger Hilfe. Haiti: Strategies and Goals https://www.welthungerhilfe.org/our-work/projects-programmes/haiti-strategies-goals/
[349] Société Audubon Haiti. http://audubonhaiti.org/program/
[350] Société Audubon Haiti http://audubonhaiti.org/aboutus/mission/
[351] Friends of the Earth International. Mission and Vision https://www.foei.org/about-foei/mission-and-vision
[352] Friends of Earth International. Member Groups: Haiti. https://www.foei.org/member-groups/latin-america-and-the-caribbean/haiti
[353] Helvetas. Haiti https://www.helvetas.org/en/switzerland/what-we-do/where-we-work/partner-countries/haiti

Oxfam International

Oxfam International was formed by a group of independent NGOs to address the challenges of poverty and injustice in vulnerable communities globally. The organisation integrates disaster risk management and climate change into their development and humanitarian programmes to influence international, national and local actors to support inter-agency coordination mechanisms. Oxfam International began working in Haiti in 1978 and their priorities include:

- strengthening equality in accordance with the law by working with empowered women, youth and smallholder farmers; and
- increasing the resilience of marginalised and vulnerable communities[354].

The proposed project aligns with the priorities outlined by Oxfam International, particularly improving the resilience of vulnerable communities to climate change impacts.

Past and ongoing projects

6.1. Projects and initiatives with a focus on climate change

Several complementary active and planned investments are targeted at enhancing climate resilience and reducing flooding in Haiti. Most of these initiatives involve, *inter alia*: i) the strengthening of institutional capacities, policies and regulations, ii) food security, iii) social protection and disaster risk management. Disaster risk management includes flood control, as well as implementing on-the-ground adaptation activities such as reforestation, improved irrigation and climate-smart agriculture. A review of these different projects in Haiti suggested a lack of general integration as well as limited government coordination to guide their development and implementation.

The proposed project has been designed with a vision of integration across activities in the TR catchment– combining a flood governance framework with the implementation of integrated water resources management (IWRM) and climate-resilient land management techniques at national, catchment and sub-catchment levels. In addition, local produce markets will be strengthened, which will improve the food security of local communities and reduce the engagement in unsustainable land management practices.

6.1.1. Regional initiatives and projects with a focus on adaptation and resilience

CARICOM Regional Framework and Implementation Plan for Achieving Development Resilience to Climate Change (2009–ongoing; Caribbean Community Climate Change Centre (CCCCC), United Kingdom Department for International Development DFID, and Climate Development Knowledge Network (CDKN)

The CARICOM framework is a regional initiative focussed on strengthening climate resilience across the Caribbean Community of countries (CARICOM), and its implementation plan is based on the regional framework developed by the Caribbean Community Climate Change Centre (CCCCC). The overarching objective of the initiative is to establish and execute a multi-sectoral implementation strategy for achieving climate resilience in the Caribbean region. To achieve this objective, the initiative comprises five main strategic objectives, namely: i) mainstreaming climate change adaptation strategies into the sustainable development agendas of CARICOM states; ii) promoting the implementation of specific adaptation measures to address key vulnerabilities in the region; iii) promoting institutional change and

[354] Oxfam International. Haiti. https://www.oxfam.org/en/what-we-do/countries/haiti

research to reduce greenhouse gas (GHG) emissions through fossil fuel reduction and conservation, and switching to renewable and cleaner energy sources; iv) encouraging action to reduce the vulnerability of natural and human systems in CARICOM countries to the impacts of a changing climate; and v) promoting institutional change and research to derive social, economic, and environmental benefits through the sustainable management of forests in CARICOM countries. The outcomes of the proposed GCF project align with the broader objectives of the CARICOM regional framework, i.e. reducing vulnerability, increasing adaptive capacity and putting in place improved governance structures with regards to disaster management.

CSIDS-SOILCARE Phase 1: Caribbean Small Island Developing States (SIDS) multi-country soil management initiative for Integrated Landscape Restoration and climate-resilient food systems (2019–ongoing; The Global Environment Facility (GEF), Food and Agriculture Organisation (FAO); US$23.5 million grant)

The overarching objective of the CSIDS-SOILCARE initiative is to achieve climate-resilient Land Degradation Neutrality (LDN)[355] across the Caribbean nations of Haiti, Antigua and Barbuda, Belize, Grenada, Guyana, Jamaica, St. Lucia and Dominica. This objective will be fulfilled in each country by: i) expanding the knowledge on national and regional soils and creating an enabling environment to support sustainable soil management, climate-smart agriculture and LDN implementation; ii) preventing the spread of land degradation through the rehabilitation of degraded areas and promotion of integrated landscape management and restoration; iii) building resilience to land degradation, natural disasters and climate change impacts through climate-smart agriculture and enhanced drought-risk management; iv) enhancing food systems and alternative livelihoods through the promotion of innovation in agriculture and livestock production systems; v) mobilising the private sector in support of LDN; and vi) improving monitoring and evaluation (M&E), knowledge management and communications around rehabilitation activities. The proposed project will complement the objectives of the CSIDS-SOILCARE initiative by implementing activities that contribute directly to soil erosion prevention through reforestation, in addition to enhancing local agricultural productivity through the implementation of agroforestry systems.

6.1.2. National initiatives and projects with a focus on adaptation and resilience

Pilot on Ecosystem-based Disaster Risk Reduction (Eco-DRR) in Haiti (2013–2016; United Nations Environment Programme (UNEP) & the European Union (EU); US$300,000 grant)

The Eco-DRR project was implemented within the Côte Sud (South Coast) Initiative (CSI), a larger programme of UNEP focused on building coastal resilience. The Eco-DRR project was aimed at reducing disaster risks in the Municipality of Port Salut in Haiti through a landscape or Ridge-to-Reef (R2R)[356] approach. The project comprised the following main components:

[355] Land Degradation Neutrality (LDN) has been defined by the Parties to the United Nations Convention to Combat Desertification as: "A state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems."

[356] 'Ridge to Reef' (R2R) aims to protect, demonstrate sustainable approaches, and provide better economic understanding of the links between terrestrial, freshwater and marine ecosystems. Well-managed coastal and estuarine ecosystems support livelihoods, income from fisheries, agriculture, tourism, and buffer coasts from the impacts of climate change. Wetland and marine environments (including coral reefs) are less vulnerable to damage and deliver greater ecosystem services when rivers are kept healthy. Coasts and river deltas support the economies of many of the largest cities in the world, and also many isolated countries such as Haiti. Solutions to water pollution are found in coordinating the use and management of land and water at the landscape scale from source to sea. By linking action and implementation in river basins and coasts, the aim is to support ecosystem services and improve livelihoods. The R2R approach is a holistic ecosystem based or landscape-scale approach to land-use management and biodiversity conservation that focusses on the terrestrial, aquatic, estuarine and coastal ecosystems, and the linkages between these ecosystems.
https://www.thegef.org/sites/default/files/project_documents/FINAL_R2R_5517_PRODOC_30Apr2015_PMC__223_325.pdf

i) to undertake field interventions to reduce disaster risk across the entire Haitian landscape from the hillsides to coastal areas; ii) to develop local and national capacity for implementing Eco-DRR resulting in improved coastal zone management; and iii) to support national advocacy on Eco-DRR. Best practices were derived from the components focussed on: i) the production of seedlings, ii) the use of seedlings and mango tree grafts to establish fruit orchards; iii) vetiver propagating and planting activities; iv) soil management techniques to reduce erosion and stabilise hillsides; v) and activities aimed at supporting cooperatives and improving value chains. The Eco-DRR project identified the need to work closely with more permanent technical municipal government staff and strengthen their capacity and ownership of the project. In addition to this, community-based organisations (CBOs) were vital to the project and required significant capacity development considering their limited leadership and decision-making skills. The proposed GCF project will build on the outcomes of the Eco-DRR project by contributing to disaster risk mitigation at the landscape level in Haiti. Specifically, the proposed project will integrate best practices learned from the establishment of seedling nurseries to support land rehabilitation efforts.

Strengthening Climate Change Resilience and Disaster Risk Reduction in Agriculture to Improve Food Security in Haiti post-Earthquake (2012–2016; The Global Environment Facility (GEF), Food and Agriculture Organisation (FAO); US$2.7 million grant)

The aim of this disaster risk reduction (DRR) project was to address the vulnerability of farmers in Haiti's livelihoods by strengthening the resilience of their agricultural systems against the threats of climate change, particularly in post-disaster contexts. Outputs from this project included a Feasibility Study (FS) and a cost-benefit analysis (CBA) of best agricultural and environmental practices for farmers, as well as training sessions to promote and disseminate the Farmer Field School[357] approach. The project was completed in 2016 and the 2017 terminal evaluation report concluded that: i) the vulnerability of rural beneficiaries was reduced; ii) the efficacy of Farmer Field Schools was reported to the government; iii) communal agricultural offices have insufficient financial means and human resources to continue the project among vulnerable rural populations; iv) a lack of agriculturally orientated micro-credit institutions in target communities limited growth and farmers' potential income, particularly women; and v) the project's experiences can be replicated in other departments with similar agricultural potential and climate risks. The proposed GCF project will complement these activities by assisting smallholder farmers in disaster-prone areas to improve their agricultural outputs by using sustainable, climate-resilient methods, thereby strengthening the rural livelihoods of their dependent communities dependent.

Ecosystem Approach to Haiti Côte Sud (2014–ongoing; The Global Environment Facility (GEF), Ministry of Environment, Ministry of Agriculture and Natural Resources; US$49 million grant)

The objective of this ecosystem project is to increase resilience to climate change impacts and natural disasters in the Southwestern Peninsula of Haiti. This will be achieved through the

[357] The farmer field school (FFS) approach was developed by FAO and partners nearly 25 years ago in Southeast Asia as an alternative to the prevailing top-down extension method of the Green Revolution, which failed to work in situations where more complex and counter-intuitive problems existed, such as pesticide-induced pest outbreaks.

In a typical FFS a group of 20-25 farmers meets once a week in a local field setting and under the guidance of a trained facilitator. In groups of five they observe and compare two plots over the course of an entire cropping season. One plot follows local conventional methods while the other is used to experiment with what could be considered "best practices". They experiment with and observe key elements of the agro-ecosystem by measuring plant development, taking samples of insects, weeds and diseased plants, and constructing simple cage experiments or comparing characteristics of different soils. At the end of the weekly meeting they present their findings in a plenary session, followed by discussion and planning for the coming weeks.

Alternative practices are not automatically assumed to be superior to conventional practices. It is up to the farmers to decide what works best through his or her testing and observations. What the FFS does is provide a risk-free setting in which to discuss, dissect, modify and experiment with new agricultural management ideas.

development of a protected areas network that supports ecosystem services, sustainable production in agro-ecological value chains and access to sustainable energy sources for rural areas disconnected from the main national electric grid. Specific interventions under the project include: i) integrating ecosystem-based adaptation (EbA) into DRR measures, value chains and protected areas development; ii) promoting low-carbon development pathways for Grand Sud's economic growth; and iii) reinforcing existing natural resource-based value chains and creating new income-generating activities in the Grand Sud region. The proposed project aligns with these objectives by using EbA approaches to enhance productivity and local resilience in Haiti, as well as strengthening local financial mechanisms for agriculture to support vulnerable farmers' livelihoods.

Increasing Resilience of Ecosystems and Vulnerable Communities to Climate Change and Anthropogenic Threats Through a Ridge to Reef Approach to Biodiversity Conservation and Watershed Management (2013–ongoing; The Global Environment Facility (GEF), Ministry of Environment; US$51.8 million grant)

This R2R project's objective is to increase the climate resilience of Haiti's coastal communities, while concurrently conserving threatened coastal and marine biodiversity. By establishing protected areas in the marine and coastal zones of target watersheds, the project uses an R2R approach to better secure biodiversity and ecosystem functionality and enhance relevant ecosystem services such as carbon sequestration. The project is currently underway and focusses on three protected watershed areas, namely: i) the Three Bays in the northeast; ii) Cayemites-Barradères on the northern coast of the Southwestern Peninsula; and iii) Marigot-Massif la Selle-Anse a Pitre at the eastern limit of the South-eastern Department. The proposed GCF project will complement these objectives by implementing IWRM in the north of Haiti. Project interventions will also include reforestation activities to increase vegetation density which will enhance carbon sequestration, as well as reduce flood-related impacts by decreasing overland water flow and inundation.

Strengthening Adaptive Capacities to Address Climate Change Threats on Sustainable Development Strategies for Coastal Communities in Haiti (2008–2018; The Global Environment Facility (GEF), Least Developed Countries Fund, Ministry of Environment; US$13.3 million grant)

The objective of this adaptation project was to strengthen the adaptive capacity of populations and productive sectors in Haiti's coastal areas to address the increasing threats of climate change to these sectors. This objective was achieved through: i) focussing on institutional and individual capacity development through better water resources management and sustainable agricultural practices; ii) establishing a sustainable financial framework for Climate Risks Management (CRM) in coastal areas; and iii) piloting on-the-ground coastal adaptation measures followed by codifying and disseminating best practice knowledge. The complete project's terminal evaluation report highlighted the need for continued technical and financial support for adaptation strategies and technologies across Haiti, aligning with broader goals of the proposed GCF project.

Increasing Resilience of Vulnerable Farmers in Southern Haiti (2019–ongoing; Green Climate Fund (GCF), FAO, the Ministry of Environment (MdE) and the Ministry of Agriculture, National Resources and Rural Development (MARNDR); US$22 million grant)

This project will increase the climate change resilience of ecosystems and vulnerable farmers in Haiti to improve the country's food, nutrition and water security. The project's R2R approach includes the following components: i) Component 1 focusses on land restoration through watershed management on the 'ridge', soil conservation and agroforestry in the 'lowlands', and mangrove protection and conservation at the 'reef' level; ii) The second component aims to enhance the adaptive capacity of vulnerable farmers and increase the resilience of value chains of selected products at the ridge, lowlands and reef levels; and iii) Component 3 addresses the enabling environment and delivery capacity that jointly determine the feasibility, sustainability and scalability of the activities pursued in Components 1 and 2. The proposed project will complement these objectives by implementing activities that further contribute to preventing soil erosion through reforestation interventions, as well enhancing agricultural productivity through the introduction of agroforestry systems.

Strengthening Hydro-Meteorological Services Project (2015–2020; MARNDR, Ministry of Finance and the World Bank, US$5 million grant)

This project aimed to strengthen capacity in Haiti to collect hydro-meteorological and climate data, in addition to providing access to hydro-meteorological and climate information to end-users in the civil protection and agricultural sectors. The first phase of the project focussed on developing a baseline of the existing data collection networks and highlighting critical gaps required for an optimal network. During the same phase, the project provided technical assistance to Haiti's public hydro-meteorological services to strengthen data delivery linkages with end-users while building the technical capacity of MARNDR and line ministries. The second phase focussed on improving the data network's coverage and enhancing accessibility and customisation of hydro-met information that is critical for decision-making in key sectors (particularly civil protection and agriculture). The proposed GCF project will build on these achievements by introducing up-to-date, locally relevant and sustainable land management interventions to the project target area, as well as improving the capacity of government and non-governmental institutions to enhance and maintain ecosystem functioning towards mitigating flood risk.

Municipal Development and Urban Resilience Project (2017–2023; World Bank, Ministry of Interior and Local Authorities (MICT); US$55.4 million grant)

This project aims to both reduce urban flooding and enhance climate resilience in Cap-Haitian city; and strengthen the capacity of six municipalities in the Cap-Haitian metropolitan area for climate-responsive management of urban areas. Achieving these objectives includes improving planning, financial management and basic service delivery under future climate change conditions. The project will furthermore contribute to sustainable and resilient urban development in these Cap-Haitian metropolitan areas through a combination of: i) investments in flood-risk reduction; ii) building the capacity of municipalities for improved accountability and management of urban systems; and iii) improved access to basic infrastructure such as small urban equipment, water and sanitation facilities and transport networks. The proposed project aligns with the aims of mitigating the impacts and severity of flooding on vulnerable communities, albeit it through different methodologies such as ecosystem restoration.

Strengthening Disaster Risk Management (DRM) and Climate Resilience Project (2019–2025; World Bank, The Global Environment Facility (GEF), The MICT; US$35 million grant)

This GEF-funded project aims to improve early warning and emergency evacuation capacity in Haitian municipalities selected based on their high risk to climate impacts. In particular, the project aims to increase the provision of and accessibility to safe havens for use by civil society during extreme climate events, such as floods and hurricanes. The project will achieve its aims by: i) strengthening disaster preparedness and emergency response; ii) promoting building regulations and resilient construction practices at the local level; iii) constructing and/or rehabilitating selected emergency shelters as well as improving road infrastructure and communication activities for achieving social mobilisation; iv) financing the implementation of emergency works, rehabilitation and associated impact assessments in the event of an extreme event; and iv) enhancing project management and implementation support for climate-resilient DRM activities. The outcomes of the proposed project align with the DRM project — although while both projects focus on strengthening disaster response activities, proposed GCF project focusses on these interventions in the agricultural sector at the landscape level.

Sustainable Land Management of the Upper Watersheds of Southwestern Haiti (2008–2017; The Global Environment Facility (GEF), IADB (Inter-American Development Bank), Ministry of Environment (MDE); US$21.5 million grant)

This project's objective was to address and contain the rapid environmental degradation in the upper watershed of Southern Haiti through integrating Sustainable Land and Forest Management (SLFM) practices at the watershed level. The required interventions of the project included: i) strengthening local watershed management committees for SLFM; ii) implementing SLFM technologies, for example, a forest restoration and carbon sequestration monitoring system; and iii) strengthening local regulatory frameworks related to land tenure. The proposed GCF project will build on the outcomes of the SLFM project by further strengthening watershed management approaches in Haiti, as well as integrating lessons learned with regards to building local institutional capacity.

Strengthening Capacity to Mainstream Environmental Sustainability and Climate Change Adaptation (2014–2022; European Union; US$5.7 million grant)

The overall objective of this project is to strengthen the Government of Haiti's (GoH) capacity to mainstream environmental sustainability and climate change adaptation into development policies, strategies, programmes and projects. The project activities include strengthening institutional capacity for environmental management and mainstreaming of climate change in the planning and implementation of reconstruction, development and energy-related activities. Tangible adaptation outcomes under the project will include field-tested practices and techniques for enhancing the population’s resilience to climate change risks which have been evaluated with regards to their dissemination and upscaling potential. The proposed GCF project similarly supports reducing vulnerability to climate change by increasing capacity and improving adaptation measures and governance structures.

Natural Disaster Mitigation Program II (2016–2021; IDB (Inter-American Development Bank); US$42 Million grant)

The objective of this IDB-funded project is to improve watershed management — particularly in rural areas in Haiti — to mitigate the risk of natural disasters associated with climate change. Specific aims of the project are to i) increase capacities for adaptation to climate change and disaster risk management in the agriculture sector; ii) improve water and sediment conservation in selected gullies of priority watersheds; iii) reduce the risk of rural economic losses caused by floods in targeted watersheds; and iv) restore[358] the educational capacity of the Faculty of Agronomy and Veterinary Medicine. The proposed GCF project will build on the outputs of this project, specifically by improving watershed management, increasing rural livelihoods’ resilience to climate change and reducing the threats posed by flooding.

[358] The faculty was heavily damaged in the Haiti 2010 Earthquake disaster

LDC/SIDS Portfolio Project: Capacity Building for Sustainable Land Management (2007–2011; GEF, MoE, Ministry of Agriculture (MoA), UNDP; ~US$2.5 million grant)[359]

This SLM project's objective was to introduce interventions to enhance and maintain ecosystem functioning through capacity building in, as well as the mainstreaming of, SLM in Haiti. Project interventions contributed to reversing land degradation trends through the creation of an enabling environment for SLM, by developing capacities within appropriate government and civil society institutions and other stakeholder groups. Reversing of land degradation trends was also achieved through mainstreaming SLM considerations into the Haitian government's planning processes. The proposed GCF project will build on both the mainstreaming and capacity-building interventions by introducing updated and locally-relevant SLM interventions to the project target area, as well as improving the government and non-governmental institutions' capacity to enhance and maintain ecosystem functioning towards mitigating flood risk.

6.2. Projects and initiatives without a focus on climate change adaptation

Integrated risk and disaster management in Haiti (2018–2027; Copenhagen Consensus Centre (CCC), Government of Canada; ~US$16.5 million grant)[360]

This disaster management project, funded by the Canadian Government and implemented by the CCC, targets communities vulnerable to flooding across Haiti by building their resilience through enhanced forecasting of, and preparation for, the negative impacts of flood events. Under this project, a model of Integrated Risk and Disaster Management (IRDM) is currently being implemented in Haiti. The IRDM model has two main components, namely: i) developing an Early Warning System (EWS) for flood risk, based on flood risk mapping in 65 municipalities identified as being at risk; and ii) facilitating the provision of temporary multifunction shelters for people and livestock. Under the second component, 117 shelters will be constructed, which can provide temporary protection during and immediately after natural disasters for the equivalent number of people evacuated during Hurricane Matthew (~175,500 people). Moreover, these shelters aim to be multifunctional through their design to accommodate both people and animals, with an average capacity of 1,150 people and 450 animals per shelter. Coupled with the flood EWS, the project aims to reduce losses in human and economic capital (including livestock) to maintain the livelihoods of local communities. The objectives of the proposed project are strongly aligned with those of this disaster management project, particularly regarding the project design's aim to protect agricultural livelihoods and reduce the impacts of flooding on these livelihoods.

Haiti's Technological Innovation for Agriculture and Agroforestry Program (PITAG) (2018–2023; Inter-American Development Bank (IDB), Global Agricultural and Food Security Program (GAFSP) and International Fund for Agricultural Development (IFAD); ~US$78 million grant)[361]

The primary aim of PITAG is to restore agricultural productivity in the areas of Haiti most affected by 2016's Hurricane Matthew, namely the South and Grande Anse Departments. This programme will enhance smallholder farmers' revenues and the food security of local communities that depend on agricultural livelihoods. To achieve this, PITAG aims to improve the use of natural resources through the creation and transfer of sustainable agricultural and

[359] The GEF. No date. LDC/SIDS Portfolio Project: Capacity Building for Sustainable Land Management. Available at: https://www.thegef.org/project/ldcsids-portfolio-project-capacity-building-sustainable-land-management-0
[360] Copenhagen Consensus Centre. 2017. Integrated risk and disaster management in Haiti. Available at: https://www.copenhagenconsensus.com/sites/default/files/haiti_priorise_natural_disasters_-_english.pdf
[361] GAFSP. No date Technological Innovation for Agroforestry and Agriculture Program (PITAG). Available at: https://www.gafspfund.org/projects/technological-innovation-agroforestry-and-agriculture-program-pitag#:~:text=Technological%20Innovation%20for%20Agroforestry%20and%20Agriculture%20Program%20(PITAG),South%2C%20and%20Grande%20Anse%20departments.

agroforestry technologies from implementing partners to smallholders. The proposed GCF project will complement and build on the PITAG programme by restoring degraded land in the TR catchment and promoting the adoption of an integrated water resources management (IWRM) strategy to improve watershed management. Through these interventions, the proposed project will contribute to improving soil quality in the TR catchment which, in turn, will increase agricultural productivity and promote on-farm biodiversity.

Haiti Reforestation Project (2017–2022; USAID; US$2.5 million grant)[362]

USAID's current Haiti Reforestation Project aims to reduce the threat of deforestation and increase tree cover in targeted areas in the northern region of Haiti. This project is in line with USAID and the Government of Haiti's (GoH) mutual goals to restore ecosystems in targeted forest areas to enhance their ability to provide ecosystem goods and services to Haitian communities. Ecosystem restoration is particularly being used to support and improve food and water security in Haiti's vulnerable communities. USAID expects this six-year project to reduce the threat of deforestation by increasing tree cover and directly supporting the GoH's efforts to manage healthy watersheds. This support will be provided by developing a participatory process that will empower local communities to develop sub-watershed management plans, as well as helping the GoH address economic risks and challenges. The proposed GCF project will complement this USAID project in providing benefits that support increased ecosystem resilience and soil conservation measures, which will reduce the impacts of extreme weather events.

Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region (2012–2019; IFAD, GoH; ~US$16.5 million grant)[363]

This project was implemented to support local organisations working on irrigation schemes and watershed management in the Nippes and Goavienne regions in the southwest of Haiti. Specifically, interventions under the project focused on enhancing sustainable livelihoods and incomes of the country's most climate-vulnerable groups (such as rural communities and low-income households) in these regions through: i) strengthening sustainable agricultural production through efficient water management and the consolidation of both collective and individual irrigated agriculture; ii) improving the value of irrigated agriculture production, and increasing farmers' access to markets and financial services; and iii) enhancing the planning, organisational and management capacities of grassroots organisations to increase their access to markets and financial services. The proposed project aligns with these interventions, as it will assist farmers in the TR region of Haiti through improving market access of farmers, which will in turn systematically increase the resilience of agricultural livelihoods[364].

Sustainable Land Management (SLM) of the Upper Watersheds of South Western Haiti (2009–2017; The Global Environment Facility (GEF), IDB and Ministry of Environment (MoE); ~US$21 million grant)[365]

The objectives of this SLM project were to address the rapid environmental degradation in the upper watersheds of southern Haiti, as well as enhance the GoH's understanding of the

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[362] National Cooperative Business Association: CLUSA International. No date. Haiti: USAID Reforestation Project. Available at: https://ncbaclusa.coop/project/haiti-usaid-reforestation-project/

[363] IFAD. No date. Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region. Available at: https://www.ifad.org/en/web/operations/project/id/1100001532

[364] Improved market access has been shown to be beneficial in increasing resilience to climate change for smallholder farmers. The GCF. 2017 Strengthening the resilience of smallholder agriculture to climate change induced water insecurity in the Central Highlands and South-Central Coast regions of Vietnam. Available at: https://www.greenclimate.fund/sites/default/files/document/18780-strengthening-resilience-smallholder-agriculture-climate-change-induced-water-insecurity.pdf

[365] The GEF. No date. SFM Sustainable Land Management of the Upper Watersheds of South Western Haiti. Available at: https://www.thegef.org/project/sfm-sustainable-land-management-upper-watersheds-south-western-haiti

impacts of land-use change on carbon sequestration and emissions avoided. These objectives were achieved by: i) implementing sustainable land and forest management practices at the watershed level, including reforestation activities; and ii) establishing a carbon stock and sequestration monitoring system to analyse the impacts of land-use change and vegetation or forest cover on carbon sequestration potential and GHG emissions avoidance/reductions. The proposed GCF project will draw on lessons from this GEF-funded project to inform the implementation of an integrated approach to land and water resources management to address the impacts of climate change-induced flooding in the TR region of Haiti. Such an approach will involve: i) establishing and promoting an IWRM strategy in the region; and ii) implementing restoration and agroforestry activities to increase vegetation density. Restoring degraded land will not only enhance the carbon sequestration capacity of the soil, but it will also be particularly beneficial for reducing flood impacts in the TR region by attenuating flow from heavy rainfall and storm events, thereby reducing inundation. Although this GEF project was focused on carbon sequestration and the proposed GCF project's focus will be on reducing flood impacts, the GEF project may be used to inform the GCF project and lead to interconnected benefits.

Cholera Emergency Response Project (2010–2014; The World Bank; US$15 million grant)[366]

The objective of Haiti's Cholera Emergency Response Project was to improve health and hygiene practices across the country in order to reduce the spread of cholera and strengthen the institutional capacity to respond to outbreaks. The project financed two components, namely: i) support to the government's response to cholera at decentralised levels; and ii) emergency response capacity building. Specific interventions included: i) rehabilitation of hospital wards for infectious and diarrhoeal diseases; ii) installation of incinerators for proper waste management; and iii) support for epidemiological surveillance. The proposed GCF project complements this initiative as best practices and lessons learned may be drawn from the Cholera Emergency Response Project to inform differences in approaches to addressing health issues in urban and rural areas.

Food Crops Intensification Project — Phase II (1998–2010; IFAD, GoH: ~US$20 million grant)[367]

To extend the achievements of the first phase mentioned below, the overall aim of the Food Crops Intensification Project was to intensify agricultural production in two different areas of Haiti, namely the Mirebelais and Lascahobas communes of the Centre Department. Building on phase one of the project, the second phase's objectives were to: i) strengthen the capacity of grassroots organisations to improve their agricultural practices; ii) provide financial support to community initiatives; and iii) improve rural communities' access to decentralised and sustainable financial services. As part of its efforts to strengthen grassroots organisations, the project included intensive literacy and training programmes. The proposed GCF project will complement these activities by assisting smallholder farmers to improve outputs of their agricultural systems through a sustainable, climate-resilient approach, therefore strengthening agricultural livelihoods and the rural communities dependent on them. This will be because the capacity-building interventions and financial mechanisms implemented under the IFAD project may be used to extend the proposed GCF project's benefits beyond completion to continue supporting agricultural livelihoods in the future.

[366] The World Bank. No date. Cholera Emergency Response Project. Available at: https://projects.worldbank.org/en/projects-operations/project-detail/P120110
[367] IFAD. No date. Food Crops Intensification Project – Phase II. Available at: https://www.ifad.org/en/web/operations/project/id/1100001070

Helping communities in Haiti prepare for natural disasters (2003–2006; OXFAM, The Red Cross; US$200,000 grant)[368]

This project, implemented by Oxfam and Red Cross, targeted communities vulnerable to flooding and other natural disasters in the Borgne commune and the city of Cap Haitien, in Haiti's Nord Department. In conjunction with GoH and civil protection committees, the overall aim was to help vulnerable communities better prepare for natural disasters. This project's objectives included reducing immediate risks to populations by building and improving infrastructure to help mitigate flood impacts, as well as raising awareness of the risks associated with natural disasters and ways to reduce their impact among affected populations. Specific interventions to achieve these objectives included: i) building flood defences in target areas; ii) improving disaster preparedness and coordination in response to floods; and iii) strengthening civil protection committees' ability to respond to flood events. Although it will be through different interventions such as ecosystem restoration, the proposed GCF project aligns with the Oxfam project because it will similarly reduce the impacts and severity of flooding on vulnerable communities.

Food Crops Intensification Project — Phase I (1981–1997; IFAD, GoH: ~US$17 million grant)[369]

This agriculture project, led by IFAD with support from the GoH, was implemented in the Port-de-Paix commune — the capital of the Nord-Ouest Department of Haiti. The overall aim of the project was to intensify agricultural production of staple food crops for smallholder farmers with low outputs. Specific objectives for this first phase included: i) establishing an erosion control programme; ii) helping farmers reduce post-harvest losses; and iii) improving infrastructure, market conditions and support services for farmers. Additionally, the project supported credit schemes to finance inputs for poor farmers through the Bureau of Agricultural Credit (BAC). The proposed project will complement these objectives by implementing activities that also contribute to soil erosion prevention through reforestation interventions, as well the enhancement of agricultural productivity through the introduction of agroforestry systems.

Best practices and lessons learned

7.1. Implementing Ecosystem-based Adaptation (EbA) interventions in the Trois-Rivières (TR) watershed

The TR watershed has been severely affected by climate change-induced flooding in recent years. An increase in concentrated, heavy rainfall — combined with the increasing frequency and intensity of hurricanes and tropical storms — are resulting in rapid erosion of fertile soils throughout the watershed. This, in turn, leads to the sedimentation of rivers, which negatively affects the health of the TR watershed's local population by increasing the spread of water- and vector-borne diseases (such as cholera). These impacts are exacerbated by the watershed's steep topography and highly deforested landscape, which intensifies flow rates because of reduced ground cover, further increasing erosion and river sedimentation. Given the near-complete absence of embankments and levees, this cycle intensifies during the next series of flood events, resulting in the destruction of crops, farmland and agricultural infrastructure, as well as a loss of livestock and human lives[370]. Current, unsustainable agricultural practices such as charcoal production contribute to these negative effects by *inter*

[368] OXFAM. No date. Helping communities in Haiti to prepare for natural disasters Available at: https://www.oxfam.org.uk/donate/donate%20to%20a%20project/the%20projects/~/media/Files/OGB/Get%20involved/Philanthropy%20and%20partnerships/Donate%20to%20project/Haiti/New%204839_haiti_web.ashx
[369] IFAD. No date. Food Crops Intensification Project. Available at: https://www.ifad.org/en/web/operations/project/id/1100000088
[370] OXFAM, Welt Hunger Life, NATHAT, and Cap-Haitien.

alia reducing soil fertility and therefore agricultural productivity. As the TR watershed is a major food-producing region in Haiti, these impacts on soil quality have severe consequences for food security across the entire country. In the absence of urgent adaptation measures in the TR watershed, flood events will continue to lead to increased food and livelihood insecurity, as agricultural production is compromised further under an increased intensity and frequency of flood events as a result of climate change.

Results from the Options Analysis (Section 4) undertaken for the proposed project suggest that implementing agroforestry systems and rehabilitating degraded forests in the watershed are the most cost-effective and efficient complementary options for addressing the impacts of climate change-induced flooding in the watershed. To ensure that these interventions confer maximum adaptation benefits, they have been designed according to regional and international best practices, in addition to lessons from past and ongoing initiatives in Haiti. These best practices and lessons will also be applied to the implementation of the adaptation interventions, as described below.

7.1.1. Functional diversity as best practice in climate-resilient agroforestry systems

The technical implementation of agroforestry and reforestation is strongly dependent on baseline conditions which vary according to soil type, hydrology and micro-climates. These factors play an important role in the performance of tree varieties in a particular region[371]. Therefore, species selection on agroforestry and reforestation initiatives requires close collaboration with farmers and local extension agencies.

The limited knowledge of the performance of many tree species under uncertain future climate scenarios demands the optimisation of genetic and species diversity from similar sources and conditions to those in the existing site. When used in agroecosystems, this approach increases these systems' resilience to climatic and environmental change. In these systems, connectivity refers to the extent to which species and resources interact across patches, habitats or social domains. Connectivity is, therefore, a core element of the resilience of agroecosystems to climate-induced environmental change — and should be integrated into planning and management at the landscape level[372]. Species diversity and connectivity will be considered in the planning of relevant project activities.

In the use of agroforestry, diversified food systems perform better than monocultures under changing climatic and environmental conditions, therefore reducing the risk of crop failure and the associated livelihoods threats. Diversification can occur in many forms (for example genetic variety, species or structural) and over different scales — including within crop, field or landscape level. Potential diversification measures may include: i) diversification at the crop scale (for example using a mixture of crop varieties that have different plant heights); ii) diversification at the field scale (for example within areas between and around fields planted with trap crops or plants that provide natural protective barriers); and iii) diversification at the landscape scale — which may be achieved by integrating multiple production systems (such as mixing agroforestry management with cropping, animal husbandry, and fallow periods to create multi-use parcels of agricultural land).[373] Agroforestry activities under the project will implement a mix of these diversification interventions, among others.

7.1.2. Best practices for establishing tree crops for agroforestry systems

Selecting species for agroforestry and restoration

[371] S. T. Chew (1989). Agroforestry Projects for Small Farmers: A Project Manager's Reference. A.I.D. Evaluation Special Study No. 59. USAID, 81 pp.
[372] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
[373] GCF. 2019. Increasing resilience of vulnerable farmers in Southern Haiti. https://www.greenclimate.fund/sites/default/files/document/21520-increasing-resilience-vulnerable-farmers-southern-haiti.pdf

Indigenous species of trees, shrubs and grasses are preferable for use in restoration initiatives because they are adapted to local ecological conditions and therefore readily contribute to ecosystem functioning and resilience. Exotic species on the other hand, need to be thoroughly researched before use in reforestation to avoid environmental disturbances such as invasion and loss of biodiversity. While indigenous species are preferred, using them correctly in forest restoration[374] is challenging, because of a lack of available research on specific species' uses — particularly those with little timber value. Another important influence on species selection is farmer preference, particularly in agroforestry projects. Experiences from past projects[375] indicated that farmers favoured production tree species (such as fast-growing species used for charcoal production) over fruit species — often because of strong commercial demand for timber and wood for charcoal production. The criteria for selecting species for restoration activities under the project are listed below.[376]

- *Social preference:* Restoration involving tree planting is most likely to be successful if species are selected according to local preferences. Well-known and researched (for example from a management and marketing perspective) species are usually preferred. In addition, consideration of cultural aspects and the identification of cultural keystone species can lead to a better appreciation of and respect for traditional systems in general[377].

- *Soil protection and improvement:* In landscapes with specific environmental risks — such as soil erosion, salinisation and pollution — it is important to select species that are well adapted to such limiting conditions. These species should have the ability to improve environmental conditions such as soil architecture, fertility and infiltration capacity.

- *Hydrological balance:* In landscapes with major water constraints, species should be selected that are adapted to local conditions and are capable of retaining runoff and facilitating water infiltration into the soil. When selected species and planting densities are not well adapted to environmental conditions, revegetation may have negative impacts on the hydrological regime — reducing both river flows and groundwater levels.

- *Biodiversity conservation:* Landscapes with endangered species may require specific selection criteria for *in situ* or *ex situ* conservation. An inventory of endangered flora and an assessment of their populations and reproductive strategies is required for the identification of species requiring restoration interventions.

- *Economic production:* Restoration actions can produce short- and long-term economic benefits, which encourages the support of local communities and defraying costs. The economic value of species and the availability of markets should be assessed and discussed in detail among stakeholders of the proposed project.

Planning

Planted forests managed for the production of timber or non-timber forest products (NTFPs) can be used by communities to raise their standard of living, as well as contribute to local sustainable development[378]. However, if poorly designed and managed, planted forests can have adverse impacts on people, the environment and biodiversity. Adequate planning is

[374] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
[375] Murray, G.F. & Bannister, M.E. (2004). Peasants, agroforesters, and anthropologists: A 20-year venture in income-generating trees and hedgerows in Haiti. Agroforestry Systems. 61-62. 383-397. 10.1023/B:AGFO.0000029012.28818.0c.
[376] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
[377] Garibaldi, A. & Turner, N. 2004. Cultural keystone species: implications for ecological conservation and restoration. Ecology and Society, 9(3).
[378] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/

therefore required for any planting interventions to suit and consider local conditions and factors.

To define activities which are most relevant in the short-, medium- and long-term, detailed knowledge of the watershed geography and hydrology is necessary — including flood zones, path networks and human infrastructure. Depending on available resources, this research can be conducted by using field surveys and remote sensing. See Section 10 for the geographic modelling of priority target areas relevant to the project.

Best practices for planting agroforestry and reforestation sites

Historically, reforestation projects in Haiti have achieved limited long-term success — primarily because of: i) inadequate soil moisture during the dry season; ii) inadequate monitoring of seedlings; and iii) a lack of incentives for farmers on rented/tenure land to invest in long-term efforts, such as agroforestry or tree cultivation[379]. In general, sites with private tenure arrangements, higher soil moisture content and cooler north or northeast facing slopes have had higher rates of success[380].

The optimal time for tree planting is generally when the soil has sufficient water levels to satisfy the needs of seedlings for the first few months of growth — although this depends on local climatic conditions. Insufficient rainy periods coupled with a risk of drought stress soon after planting, requires increasing water harvesting and soil water storage potential (for example by using soil preparation techniques). The planting period should be planned so that seedlings are ready for planting at the most appropriate time — with adequate root development to enable them to survive initial periods of droughts or floods. The planting site should be prepared before the first rains of the season by digging holes (60 cm × 60 cm × 40 cm deep) on clay soils, or on compacted, calcareous or lateritic soils — by using heavy-duty tractors with deep tines to dig furrows. In light or friable soils, planting holes can be dug at the time of planting[381]. These planting guidelines will be applied accordingly in the preparation of project sites.

Achieving optimum tree density is an important part of the planting planning process. Optimum density varies with slope and tree type, which requires an adjustment of planting densities to the carrying capacity of the site (in terms of soil conditions and water availability) and the species used. Planting density is commonly determined by equating the number of seedlings or cuttings per hectare with the average annual rainfall in millimetres (mm). For example, if the average annual rainfall is 250 mm, the planting density should be 250 seedlings or cuttings per hectare[382]. Among the land management techniques applicable in seasonally dry conditions, conserving soil moisture and reducing weeding requirements — through soil conditioning and mulching — are likely to be more cost-effective than irrigation and weeding or the application of herbicides[383]. Additional practices such as terracing and alley cropping — with contour hedgerows — promote slope stabilisation and further reduce erosion, in addition to improving soil moisture retention within catchment areas. In combination with supplemental on-farm water storage infrastructure, these measures contribute to seedling survival in drier periods. Mixing species and planting seedlings on plots with mature trees also increases the

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379 B. Singh, and M. J. Cohen, 2014: Climate Change Resilience, the Case of Haiti. Oxfam Research Reports, 36 pp.
380 S.D. Sprenkle-Hyppolite, A.M. Latimer, T.P. Young, and K.J. Rice (2016). Landscape Factors and Restoration Practices Associated with Initial Reforestation Success in Haiti. Ecological Rest. December 1, 2016 vol. 34 no. 4 306-316, DOI: 10.3368/er.34.4.306.
381 FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
382 FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
383 Ibid.

rates of seedling survival[384]. Local project site conditions will be considered before implementing any of these land management interventions or planting approaches.

Managing and protecting planted trees

The major factors that negatively affect the establishment and growth of seedlings are flooding, drought, fire and the intrusion of livestock. It is vital that seedlings and cuttings need are protected from these aspects in the first 2–3 years after establishment. This can be done by planting above localised flood plains and pathways, establishing a network of firebreaks and implementing integrated grazing management in cases where fencing is cost-prohibitive[385]. In addition to these measures, weeds will need to be controlled during the initial tree establishment phase as they compete with tree seedlings for soil and water resources. In drier areas, low inherent soil moisture requires the complete removal of weeds, manually or mechanically. The baseline conditions of the specific project planting sites will influence to what extent these factors are used in implementation and management.

Depending on the type of agroforestry system, the maintenance of tree crops includes pruning and thinning. Pruning refers to the cutting of side-branches — level with the trunk — to improve the shape of the trunk and the quality of the wood[386]. This practice is generally used for the production of fodder or wood fuel, as well as to reduce crop shading. Thinning, on the other hand, is the removal of a proportion of the trees in a growing forest to encourage the increased growth of the retained trees by providing them with more space for crown and root development[387]. Thinning can also result in the removal of undesirable or diseased trees. The timing and intensity of thinning and pruning activities should be carefully planned under the project — and only carried out after determining the respective costs and benefits[388].

Cost considerations for Agroforestry and Reforestation

Past projects have shown a high level of variation in the cost of agroforestry interventions. Much of this variation can be attributed to the types of inputs required for the specific approach adopted. The higher end of cost estimates include all input costs, including the cost of labour and other community inputs. Other initiatives directly involve farmers in agroforestry activities, including community participation in the provision of labour for maintenance, plot establishment and harvesting as well as providing local inputs such as seedlings and compost, depending on availability. This approach not only reduces the cost of agroforestry and reforestation interventions considerably, but also develops local interest in the activities to promote ownership of agroforestry and forest plots. The table below lists the relative costs of restoration and reforestation from previous projects, as well as noting the approach considered in calculating the costs. Based on these values and considering the best practices for community involvement in Haiti, a value of ~USD600 per hectare was estimated for both agroforestry and reforestation activities[389].

Project	Activity	Cost Per Hectare	Notes

[384] S.D. Sprenkle-Hyppolite, A.M. Latimer, T.P. Young, and K.J. Rice (2016). Landscape Factors and Restoration Practices Associated with Initial Reforestation Success in Haiti. Ecological Rest. December 1, 2016 vol. 34 no. 4 306-316, DOI: 10.3368/er.34.4.306.
[385] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
[386] FAO. 2000b. Management of natural forests of dry tropical zones. FAO Conservation Guide. Rome (available at: www.fao.org/docrep/005/ w4442e/w4442e0b.htm).
[387] Ibid.
[388] Chidumayo, E.N. & Gumbo, D.J., eds. 2010. The dry forests and woodlands of Africa: managing for products and services. London, Earthscan (available at: www.cifor.org/publications/pdf_files/Books/BGumbo1001.pdf).
[389] This estimate was aligned to that of the Heifer International project which adopted a community-based approach, adjusted for inflation

USAID / Projets de Reboisement dans le Nord et le Nord-Est d'Haïti	Agroforestry	USD 4,000	This package takes into account all the expenses related to the implementation of the agroforestry plots such as planting, purchase of seedlings, transportation, products and labor for planting and maintenance)
Ariste, R. Agroforesterie en Haiti. Couts et avantage. Copenhague consensus	Agroforestry	USD 2,050	This package covered almost all of the costs of establishing the agroforestry plots.
Heifer International project	Agroforestry	USD 435	This package takes into account a participation of the community in the implementation of the plots. Not all the amount is covered by the project, the farmers support in the labor to install the plots and the maintenance
USAID / Projets de Reboisement dans le Nord et le Nord-Est d'Haïti	Reforestation	USD 1,000	This package takes into account all expenses related to reforestation activities (e.g., planting, seedling purchase, transportation and maintenance).

7.1.3. Establishing seedling nurseries

The availability of good quality seedlings is necessary to create a sustainable agroforestry and reforestation production cycle — therefore, the project will require dedicated seedling nurseries. The methods and techniques used in tree and shrub nurseries will determine seedling quality and field performance. The production of seedlings should consider the availability and proximity of suitable water, while the nurseries should be located as close as possible to the planting sites. Nursery size and capacity should be planned according to the requirements of the revegetation sites.

Seed sourcing should be undertaken ahead of the intended project seeding or planting period. Timely seed sourcing allows sufficient time for identifying and producing optimal nursery stock to meet restoration objectives. Propagation material should be matched to the current environmental conditions of the target project sites — with consideration of future changes. Where local tree populations are genetically impoverished or too degraded or fragmented to constitute good sources of seed for restoration, seeds from other sources growing in similar conditions to the target site should be acquired and used[390].

Provenance trials of the genetic material present at targeted sites can provide valuable information on the suitability of the respective material for project-specific activities. For example, provenance trials can provide information on resistance to droughts, adaptation to different soil types, resistance to disease and fire, as well commercially important traits — such as fruit or stone size, pulp mass, and biofuel potential[391].

Partnerships between the project, the Ministry of Environment (MDE) and the Ministry of Agriculture (MARNDR) will enable a system of decentralised nurseries to be set up in strategic sites within the project area — encouraging community members' involvement in nursery development and maintenance. Farmer-Based Organisations (FBOs) and NGOs should participate in the creation and functioning of these facilities as a means of leveraging local best practice knowledge and ensure community ownership beyond the funding period of the project. The sustainability of the project also requires communication and coordination among restoration practitioners, nursery managers and seed suppliers. In the planning phase of the

[390] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/
[391] FAO. 2020. Action Against Desertification http://www.fao.org/documents/card/en/c/ca6932en/

project, restoration practitioners should inform nursery managers of the seeds and cuttings they require and help them identify suppliers.

7.1.4. Stakeholder participation in agroforestry activities

Leveraging farmer incentives for adopting and carrying out agroforestry

As farmers are the primary beneficiaries of and participants in agroforestry activities in the project, favourable social, economic and environmental conditions that influence their preferences — particularly regarding different sets of species and their agroecological functions — should be ensured. Based on best practices[392], prescriptive technical planning on the placement of infrastructure and investments are unsuitable for implementing farmer-managed agroforestry systems. A participatory approach is required to ensure that farmers' preferences for species and tree functions are known and respected. Participation in Integrated Water Resource Management (IWRM) will be most ensured when the direct, visible benefits of the programme are consistent with the people or community's interests[393].

Lessons learned from previous projects in Haiti[394] indicate that farmers' uptake of agroforestry interventions occur only under certain conditions, namely: i) being able to acquire tree seedlings free of charge; ii) having the freedom to inter-plant trees and food crops without reducing crop yield; and iii) ensuring that trees could provide them with income. Farmers with smaller farms are reluctant to sacrifice annual crop space for planting trees[395]. In such cases, sensitisation on the monetary benefits of agroforestry is advised, along with FBO-based outreach activities to support farmers in the transition to agroforestry[396]. As indicated by past projects, the ability to harvest trees within three years after planting — for example, to use for charcoal production — was also appealing to most farmers and increased their willingness to adopt agroforestry practices. Under the fulfilment of these conditions, farmers were able to manage the implementation of agroforestry systems themselves.

During stakeholder consultations, landowners who exhibit the most interest in rehabilitating their land should be identified as beneficiaries and grouped according to the proximity of neighbouring land parcels to facilitate efficient stakeholder coordination across a large area. These landowner groups will be able to coordinate tree planting among themselves, along with assistance from MARNDR regarding long-term management of seedlings as laid out in a co-signed agreement. This written agreement will specify the responsibilities between the respective stakeholder groups

Relevant traditional knowledge and local initiatives

Historically, agroforestry has been used in the mountainous regions of Haiti in the form of "Creole gardens" or *jaden lakou* in Haitian Creole. These multipurpose gardens — primarily based on coffee, banana, breadfruit and cocoa — have historically provided farmers with income, food security, and fuelwood[397]. Another traditional Haitian cropping system is known as *bann manjé* or "band of food", where perennial food crops such as plantains, sugar cane, cassava, pigeon peas and pineapple are planted in combination with annual crops such as

[392] GEF. 2009. STAP Scientific and Technical screening of the PIF: SFM Sustainable Land Management of the Upper Watersheds of South Western Haiti. Available: https://www.thegef.org/sites/default/files/project_documents/STAP%2520screen%25203132%2520IADB%2520SLM%2520SW%2520Haiti_0.pdf

[393] Tefera, B., and L. Stroosnijder (2007), Integrated watershed management: A planning methodology for construction of new dams in Ethiopia, Lakes & Reservoirs: Res. Manage., 12, 247– 259.

[394] Murray, G.F. & Bannister, M.E. (2004). Peasants, agroforesters, and anthropologists: A 20-year venture in income-generating trees and hedgerows in Haiti. Agroforestry Systems. 61-62. 383-397. 10.1023/B:AGFO.0000029012.28818.0c.

[395] Murray, G.F. & Bannister, M.E. (2004). Peasants, agroforesters, and anthropologists: A 20-year venture in income-generating trees and hedgerows in Haiti. Agroforestry Systems. 61-62. 383-397. 10.1023/B:AGFO.0000029012.28818.0c.

[396] B. Singh, and M. J. Cohen, 2014: Climate Change Resilience, the Case of Haiti. Oxfam Research Reports, 36 pp.

[397] UNDP. 2018. Sustainable management of wooded production landscapes for biodiversity conservation.

sweet potato, yams, and other annual crops in a system of contour hedgerows and alleyways[398]. Both the *jaden lakou* and *bann manjé* approaches are examples of polyculture cropping systems which have multiple economic and environmental benefits for Haitian farmers. For example, the perennial plants help to reduce erosion through their well-established root systems while simultaneously providing leafy material as a soil amendment in the alleyways between the hedgerows. Economic benefits that are likely to be realised from the implementation of these systems include savings garnered from locally generated staple foods and livestock fodder, as well as excess produce being sold at the market.

The establishment of agroforestry systems in Haiti will also have several key environmental benefits. For example, as part of project activities, replacement sources of wood for charcoal and/or fuel can be established by using supplemental woodlots to reduce informal harvesting pressure on newly established agroforestry systems and protected areas — therefore assisting in the management of tree-based revegetation efforts. An example of this is the local practice of planting *jarden chabon* or 'charcoal gardens'[399]. Using this approach, farmers prepare a field to be planted with annual crops while also intercropping with wood tree seedlings until shade competition starts affecting the field crops. Following this process, the trees are clear cut and converted to charcoal before beginning the cycle again.

Several organisations that have worked in implementing agroforestry systems in Haiti are able to offer collaborative assistance and information on best practices in the project region. These organisations and mechanisms are listed below.

- The Food and Agriculture Organisation of the United Nations' (FAO) Forest and Landscape Restoration Mechanism (FLRM) can support Haiti in coordinating the development and implementation of agroforestry projects and programmes[400].
- The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (REDD) and REDD+, which includes agroforestry activities, can be mobilised to help increase forest cover. This would require the MoE to create a framework to work on REDD and REDD+ funds[401].
- The Fédération des Coopératives Cacaoyères du Nord (FECCANO), in Haiti's Nord Department, is an association of farmers whose members produce fair trade cocoa for the international market. This is initiative can boost agroforestry systems that include cocoa production in Haiti.
- The Foundation Seguin launched an initiative in the Sud-Est Department that combines a bamboo out-grower intervention with local bamboo furniture manufacturing businesses, creating a proven business model for farmers to maintain bamboo hedgerows as a production crop, while also delivering the associated hydrological benefits of bamboo contour hedgerows[402].
- The Audubon Society of Haiti has produced guidelines for the implementation of revegetation activities in the country, which have been referenced by the Ministry of Environment (MDE) in similar projects[403].

[398] Murray, G.F. & Bannister, M.E. (2004). Peasants, agroforesters, and anthropologists: A 20-year venture in income-generating trees and hedgerows in Haiti. Agroforestry Systems. 61-62. 383-397. 10.1023/B:AGFO.0000029012.28818.0c.
[399] Smucker G. and Timyan J. 1995. Impact of tree planting in Haiti: 1982-1995. Haiti Productive Land Use Systems Project, Southeast Consortium for International Development and Auburn University, Petionville, Haiti
[400] FAO. 2019. The Road to Restoration: A Guide to Identifying Priorities and Indicators for Monitoring Forest and Landscape Restoration. http://www.fao.org/3/ca6927en/CA6927EN.pdf
[401] UN-REDD Programme. 2019. https://www.un-redd.org/
[402] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.
[403] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti. http://wedocs.unep.org/bitstream/handle/20.500.11822/14211/Haiti_Eco_DRR_case_study_2016.pdf?sequence=1&isAllowed=y

7.1.5. Monitoring the outputs of agroforestry and reforestation activities

Monitoring activities should use ecological, biological and socioeconomic measures and indicators over a sufficient period to assess the reproductive success of the species used. These monitoring activities should include user-friendly tracking tools on the number of seedlings produced and distributed, survival and growth indicators, and if possible, productivity indicators. Data collection for specific project indicators should be specified in implementing stakeholder contracts. This serves the dual purpose of: i) motivating stakeholders to maximise the benefits and sustainability of their activities; and ii) facilitating the monitoring of project results by the Project Management Unit (PMU)[404].

As part of such ongoing monitoring activities, record-keeping is required for good genetic management in individual restoration projects — as well as at nurseries and seed banks. Adoption of a certification scheme, such as the OECD Forest Seed and Plant Scheme, would ensure not only systematic record-keeping but also traceability of germplasm distribution. Records of the genetic base and source of materials used in restoration projects will help to evaluate the qualities germplasm and inform decisions about where to make future collections of planting material in restored vegetation sites. These monitoring activities and related technical assistance should be supported by the measuring and geo-referencing of selected land parcels. Feedback from the monitoring by the MDE and MARNDR partners is particularly important for nurseries and seed suppliers[405] as a means of increasing the survival rates of planted seedlings. Restoration practitioners, if not linked to the nursery where their planting material is produced, should provide feedback to nursery managers about problems experienced with their planting material in the field.

Possible causes of low seedling survival rates include unfavourable planting season, inadequate planting skills, as well as human and animal disturbance[406]. Training seminars and field visits for relevant staff of the partner ministries, nursery managers, NGOs and farmers can assist in addressing any arising challenges.

7.2. Strengthening technical and institutional capacity for integrated land and water resources management at the community/farmer, municipal level and national levels

Limitations to technical and institutional capacity for land and water resource management exist at the community/farmer, municipal and national levels in Haiti. At the community/farmer level, stakeholders' technical and financial capacity to engage in climate change adaptation interventions are limited, in addition to a constrained functional knowledge of the agroecological landscape (see Section 8 on barriers below). Farmers at the community level also have limited technical capacity to derive profit and/or income security from livelihood actives that utilise natural resources, such as agroforestry. At the municipal level, officials and line-workers lack the technical skills necessary to incorporate climate change considerations into their operations, as well as to design climate-resilient water and land management policies. Relevant municipal operations include, *inter alia*, agricultural extension services that involve: i) providing information on appropriate agricultural practices and techniques; ii) assisting with agricultural decision-making on seeds and varieties; and iii) supplying appropriate climate change information for the growing season[407]. Limited technical capacity

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[404] GEF. 2018. Final Evaluation of the Sustainable Land Management of the Upper Watersheds of South Western Haiti Program. https://www.thegef.org/sites/default/files/project_documents/3132_2018_TER_IDB_Haiti.pdf

[405] Bozzano, M., Jalonen, R., Thomas, E., Boshier, D., Gallo, L., Cavers, S., Bordács, S., Smith, P. & Loo, J. 2014. Genetic considerations in ecosystem restoration using native tree species. Rome, FAO and Biodiversity International (available at www.fao.org/3/a-i3938e.pdf).

[406] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti. http://wedocs.unep.org/bitstream/handle/20.500.11822/14211/Haiti_Eco_DRR_case_study_2016.pdf?sequence=1&isAllowed=y

[407] Goertz, H. 2016. Integrating Gender and Nutrition within Agricultural Extension Services: Haiti Landscape Analysis. *Working Paper*. USAID and US Government Feed the Future Project.

at this level also leads to the inability to adequately consider the needs of all stakeholders in decision-making on both water and land management (see Section 8 on barriers below). At the national level, a limited capacity to effectively collaborate between ministries and departments persists (detailed in Section 8 barriers below). Poor coordination has resulted in the duplication of activities between different departments and ministries, as well as policies, projects and programmes designed without consideration to other affected sectors, potentially undermining the objectives of other ministries. This has further resulted in an inability to implement multi-sectoral activities effectively.

The proposed project design has drawn on best practices from previous projects to effectively address capacity gaps at the respective levels. The main best practices are detailed below.

At the community level, the following three important best practices learned have informed the proposed project design:

- Stakeholders will receive targeted training focused on, *inter alia*, climate change impacts, climate-resilient agricultural practices, and functional knowledge of the relationship between land use and hydrology in the TR watershed (Activity 1.1).
- Technical assistance will be provided to users who are implementing agroforestry and/or reforestation activities (Activity 1.2).
- Technical training and financial assistance will be provided to farmers implementing climate-resilient agroforestry practices (Activity 2.2).

At the municipal level, the following key best practice has informed the proposed project design:

- The technical capacity of public officials to effectively design and implement sustainable land-use and water management policies and practices will be enhanced (Activity 2.1).

At the national level, the following main best practice has informed the proposed project design:

- The lack of capacity to effectively coordinate between appropriate departments and ministries on multi-sectoral projects and programmes will be addressed through the creation of communal development councils and multi-sectoral management structures (Activity 2.1).

7.2.1. Community/farmer level

Given the technical and financial constraints at the community/farmer level (see Section 8 on barriers below) farmers and their communities have minimal capacity to implement the adaptation interventions necessary to enhance their resilience to climate change. The proposed project will draw on in-country knowledge and best practices from previously undertaken projects and programmes to address these capacity gaps at the community/farmer level.

Conventional top-down approaches have proven inadequate in transferring necessary technologies to assist farmers in responding to rapid and large-scale changes to address complex situations, such as drought and resulting water insecurity, that may occur throughout the growing season[408]. Past projects have indicated that participatory, people-centred learning approaches are more effective in strengthening the capacity of farmers and rural communities by using direct analysis of local production systems, constraints and possible

[408] GEF. 2009. STAP Scientific and Technical screening of the PIF: SFM Sustainable Land Management of the Upper Watersheds of South Western Haiti. Available: https://www.thegef.org/sites/default/files/project_documents/STAP%2520screen%25203132%2520IADB%2520SLM%2520SW%2520Haiti_0.pdf

interventions[409,410]. By adding their knowledge to existing theoretical information, farmers eventually identify, evaluate and adopt the most suitable practices and technologies to their farming system. Technical training on sustainable agricultural practices designed with these considerations, has proven effective in assisting smallholder farmers in improving their production[411].

Rigorous engagement with beneficiaries has furthermore proven essential to strengthening community ownership of project interventions. Because many beneficiary rural communities are in isolated areas, engagement will ensure that the project design reflects the unique circumstances of their context. Improved local farmer and community ownership also: i) increases support for project interventions; and ii) ensures the sustainability of the project, as beneficiaries have a stake in interventions and therefore an incentive to maintain activities beyond the project lifespan. Location-specific curricula can be developed as part of farmer-based problem analysis — as supported by FAO's 'Compendium on Good Agricultural and Environmental Practices for Adaptation to Climate Change'[412]. Such curricula can include a range of technical topics including soil, crop and water management, seed multiplication and varietal testing, integrated pest and disease management, agropastoralism, aquaculture, agroforestry, nutrition, agricultural value chains, as well as links to markets. Ideally, the duration of these training courses extends over an entire production cycle from pre-season planning to post-harvest processing, to ensure that all aspects of the production process are addressed. As agroforestry systems are semi-perennial, these courses should focus on at least the first harvest season. Community engagement during the development of the proposed project revealed that technical capacity building is also required for these beneficiaries to implement climate-resilient agricultural practices effectively, as well as to use new farming equipment and maintenance facilities.

The proposed project design draws on these lessons by incorporating capacity building at a farmer/community level by providing training to farmers and women's associations. This training will increase recipients' adaptive capacity to climate change by covering topics such as expected climate change impacts and the effects on livelihoods, agroforestry as a climate-resilient livelihood alternative, as well as benefits of community-based reforestation to enhance climate change resilience (Activity 1.1 and 1.2). These training programmes will respond to the specific technical capacity constraints highlighted by project beneficiaries during consultations for the proposed project (see Annex 7).

7.2.2. Municipal level

Local offices — including municipal and agricultural extension offices — play an important role in land and water management at a watershed level, as well as in maintaining communication between farmers and the national government. This role is supported by an emphasis on decentralised government[413] at a national level[414]. These institutions, however, are unable to fulfil these functions and effectively mainstream climate change considerations into their

[409] Green Climate Fund (GCF). 2019. Concept Note: Increasing resilience of vulnerable farmers in Southern Haiti. Available: https://www.greenclimate.fund/sites/default/files/document/21520-increasing-resilience-vulnerable-farmers-southern-haiti.pdf [Accessed 22/06/2020]

[410] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.

[411] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.

[412] Sala, S., F. Rossi, and S. David. "Supporting agricultural extension towards Climate-Smart Agriculture. An Overview of existing tools. Compendium. Climate-Smart Agriculture & Extension. Rome. GACSA." (2016).

[413] Decentralised government refers to the 'transfer of authority and responsibility for public functions from the central [national] government to intermediate and local governments or quasi-independent government organizations and/or the private sector'. This often applies to certain public sector functions, such as, *inter alia,* the provision of healthcare, electricity, water. From: The World Bank Group. N.d. Decentralization: What, Why and Where. Available: http://www1.worldbank.org/publicsector/decentralization/what.htm

[414] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.

decision-making processes because of financial and technical capacity constraints (Section 8 barriers below)[415]. Historically, a lack of technical capacity — particularly regarding theoretical and practical knowledge on climate change adaptation — to incorporate climate change considerations into the operations of agricultural extension services has been a considerable barrier to improving the climate resilience of the smallholder agricultural sector[416]. These operations include, *inter alia*, assisting farmers with agricultural decision-making — for example on seeds and crop varieties — and providing information on appropriate agricultural techniques and practices[417].

Technical capacity shortages have previously been addressed through numerous interventions. First, knowledge-sharing mechanisms in agricultural extension and environmental outreach organisations were developed to prevent duplication and attract investment climate-resilient agricultural practices from both donor institutions and the private sector [418]. The proposed project will incorporate this lesson through Activity 3.3 — which will inform lessons learned and best practices through consistent monitoring and evaluation, which will then be disseminated to the relevant stakeholders by using appropriate institutions established by project interventions. Furthermore, the provision of targeted training to farmers and women's associations, in addition to the implementation of targeted awareness campaigns, will function as important knowledge-sharing mechanisms (Activity 1.1).

Second, technical training and workshops have previously been provided to municipal actors in specific communes and departments across Haiti to raise awareness on the importance of mainstreaming climate considerations into decision making and enhance their capacity to do so[419]. A vital element of these training programmes is the training of facilitators in season-long field-based programmes that complement practice with theory. Training facilitators generally include NGO and extension workers, staff from farmer organisations and occasionally local farmers[420]. These lessons will be included in the proposed project by implementing awareness campaigns throughout Haiti (Activity 1.1), providing field-based training to appropriate stakeholders (Activity 1.2), as well as technical training to municipal officials on the implementation of sustainable land management (SLM) (Activity 2.1) and IWRM (Activity 3.2).

Third, past projects have both developed existing multi-stakeholder platforms at the local and regional level[421] and established new platforms[422] to improve capacity for decision-making and collaboration on multi-sectoral projects. The optimisation of these platforms included a focus on stakeholder representation — including municipal officials and representatives from civil society, Non-Governmental Organisations (NGOs) and Community-based Organisations[423]. The proposed project will draw on this lesson by establishing: i) communal development councils to address priority areas identified in the capacity needs assessment (Activity 2.1); ii) Catchment IWRM Committees and Sub-Catchment Water Resource User Associations

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[415] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.
[416] GCF. 2019. Increasing resilience of vulnerable farmers in Southern Haiti. https://www.greenclimate.fund/sites/default/files/document/21520-increasing-resilience-vulnerable-farmers-southern-haiti.pdf
[417] Goertz. 2016. Integrating Gender and Nutrition within Agricultural Extension Services: Haiti Landscape Analysis.
[418] Green Climate Fund (GCF). 2019. Concept Note: Increasing resilience of vulnerable farmers in Southern Haiti.
[419] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.
[420] Sala, S., F. Rossi, and S. David. "Supporting agricultural extension towards Climate-Smart Agriculture. An Overview of existing tools. Compendium. Climate-Smart Agriculture & Extension. Rome. GACSA." (2016).
[421] UNDP. Date. Increasing resilience of ecosystems and vulnerable communities to CC and anthropic threats through a ridge to reef approach to BD conservation and watershed management. Project Document. Available: https://www.thegef.org/sites/default/files/project_documents/ID5380__SUBMISSION_4648_Haiti_LDCF_ProDoc_19Dec2014.pdf
[422] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.
[423] UNDP. 2013. Increasing resilience of ecosystems and vulnerable communities to CC and anthropic threats through a ridge to reef approach to BD conservation and watershed management. Project Document. Available: https://www.thegef.org/sites/default/files/project_documents/ID5380__SUBMISSION_4648_Haiti_LDCF_ProDoc_19Dec2014.pdf

(established in Activity 3.1) in each of Haiti's 31 catchments; and iii) a Catchment Water Resources Management Committee to manage IWRM in the TR watershed (established in Activity 3.2). These institutions will provide a platform for all appropriate stakeholders to participate in decision-making at the municipal level.

Close monitoring of project implementation — as well as sanctions[424] in the event of failure by service providers[425] — has been demonstrated as an essential requirement for the success of capacity-building interventions in previous projects[426,427]. The "Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti" (2013–2016) project found that output-based training was also successful in ensuring effective capacity-building interventions designed to improve the practices of municipal actors. For example, outputs included the development of a locally managed early warning system, as well as the strengthening of the Vetiver Cooperative and Fishers' association[428]. The proposed project design will draw on this lesson by incorporating both monitoring and evaluation systems in Activity 3, which will include assessments on the success of capacity-building interventions. The lessons learned developed during monitoring and evaluation (Activity 3.3) will be used to iteratively adjust the implementation strategy throughout the project lifespan to ensure the effectiveness of interventions.

7.2.3. National level

Previous projects have indicated a lack of technical capacity and research at the national level in Haiti, particularly regarding awareness on the importance of climate-resilient practices in relevant land and water management policies and an inability to effectively mainstream these considerations into decision-making[429,430,431]. Specific technical capacity gaps have previously been addressed by the provision of training sessions to numerous public sector representatives on Ecosystem-based Disaster Risk Reduction (Eco-DRR). Eco-DRR is a successful climate change adaptation method that the Government of Haiti has subsequently promoted in several global events — including the 2014 World Parks Congress[432]. In addition, training has also been directed at improving the capacity of the MANRDR, MDE and Bureaux Agricole Communal[433] of the MARNDR to mainstream climate change adaptation into their policies, projects and programmes[434]. The proposed project Activity 3.2 has incorporated these lessons by providing training and workshops for appropriate government representatives to enhance their capacity to implement the Water Act, related water management policies and SLM in the TR watershed.

[424] 'Sanctions' here refers to 'a penalty, or some coercive measure, intended to ensure compliance'. Examples of sanctions used by the government range from fines to imprisonment. From: Lumen. N.d. The Symbolic Nature of Culture. Available: https://courses.lumenlearning.com/boundless-sociology/chapter/the-symbolic-nature-of-culture/

[425] 'Service providers' at the municipal level describes any organisation contracted to provide a service necessary to undertaking project activities, such as construction of grey infrastructure or provision of training workshops.

[426] International Fund for Agricultural Development (IFAD). 2018. Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region: Supervision Report. Available: https://www.ifad.org/documents/38711644/40046455/Supervision%20mission,%20February%20-%20March%202018/a41bd84b-2999-4978-9d25-1cf8b31d627e [Accessed 22/06/2020]

[427] GCF. 2019. Concept Note: Increasing resilience of vulnerable farmers in Southern Haiti. Available: https://www.greenclimate.fund/sites/default/files/document/21520-increasing-resilience-vulnerable-farmers-southern-haiti.pdf [Accessed 22/06/2020]

[428] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.

[429] UNEP. 2016. Coastal Partners: Applying ecosystem-based disaster risk reduction (Eco-DRR) through a reef-to-ridge approach in Port Salut, Haiti.

[430] Lejonc and Palazy. 2018. Final Evaluation of the Sustainable Land Management of the Upper Watersheds of South Western Haiti Program.

[431] Stoa, R. 2017. Water Governance in Haiti: An Assessment of Laws and Institutional Capacities. Tulane Environmental Law Journal, 243.

[432] UNEP. 2016. Coastal Partners: Applying ecosystem-based disaster risk reduction (Eco-DRR) through a reef-to-ridge approach in Port Salut, Haiti.

[433] A municipal agricultural office, or agricultural extension office.

[434] Lejonc and Palazy. 2018. Final Evaluation of the Sustainable Land Management of the Upper Watersheds of South Western Haiti Program.

Past projects have also indicated a limited capacity for collaboration between different public sector stakeholders — particularly the MoE and MANRDR — on multi-sectoral projects caused by a lack of mechanisms and/or channels for collaboration[435,436]. Previous interventions to address this capacity gap include: i) the creation of a joint Communication for Development structure between the MoE, FAO and MANRDR that accelerated the decision-making process by functioning as a platform for appropriate stakeholders to participate in the project[437]; and ii) the establishment of an interagency working group between the MoE, the MARNDR and associated donors to promote intergovernmental collaboration on the implementation of various project activities[438]. The proposed project design draws on these lessons by establishing communal development councils and multi-sectoral management structures (Activity 2.1), as well as Catchment IWRM Committees (Activity 3.1). These institutions will improve inter-governmental communication and enhance the effective implementation of project interventions.

7.2.4. Strengthening agricultural value chains in Haiti

A considerable challenge to adopting diversified agricultural practices in Haiti is defining the appropriate balance of crops that contribute to both financial and ecological measures of sustainability. Robust value chains and improved access to markets are necessary to ensure farmer livelihood stability which, in turn, contributes to rural community resilience against the major climate impacts in the area. The project will generate financial incentives for farmers to adopt crop diversification strategies through strengthening the capacity of sellers on local markets to secure increased availability of local products and promote trade with partner producers under the project.

The project will incentivise the adoption of crop diversification strategies by providing subsidies through the creation of a food voucher (E-voucher) system. In addition, the project will build climate-resilient agricultural value chains through improved market access mechanisms (such as enhancing the transportation of agricultural produce, for example, by developing agricultural tracks, and by improving water supply systems), which will provide vulnerable farmers with greater opportunities in terms of access to input and selling produce. This will involve working with farmers to identify and develop appropriate markets for this more diversified range of agricultural products with the support of the local extension offices, line ministries and FBOs.

The purpose of the E-voucher system is to provide farmers with clear incentives to undertake and invest in climate-resilient activities. The targeted subsidies will facilitate farmers' access to climate resilient inputs — such as resilient varieties of seeds — and provide a means to invest in diversification strategies and cross-cutting options (i.e. reduction in input costs).This will stimulate farmers and other actors from the private sector — such as seed producers and sellers — to fulfil a critical role in strengthening value chains in Haiti.

If the E-voucher system is applied in combination with farmer training programmes and the support of local seed production, it can contribute to the provision of the much-needed investment for smallholder farmers. Furthermore, if investment in this system is made with the intent of increasing food production, promoting income generation, promoting nutritional security and as a buffer to price volatility, the impact on the livelihood of smallholder farmers

[435] FAO. 2017. Final evaluation of the project "Strengthening Climate Change Resilience and Disaster Risk Reduction in Agriculture to Improve Food Security in Haiti after the Earthquake". Available: https://www.thegef.org/sites/default/files/project_documents/GEFID%25204447_2017_TER_FAO_Haiti%2520LDF.pdf [Accessed 23/06/2020]

[436] GCF. 2019. Concept Note: Increasing resilience of vulnerable farmers in Southern Haiti.

[437] FAO. 2017. Final evaluation of the project "Strengthening Climate Change Resilience and Disaster Risk Reduction in Agriculture to Improve Food Security in Haiti after the Earthquake".

[438] GCF. 2019. Concept Note: Increasing resilience of vulnerable farmers in Southern Haiti.

will be much more visible and tangible. Under the project, a network of village agents will be established to monitor, review and update the E-voucher system where required, based on detailed assessments of its effectiveness within the context of Haiti. This will ensure that the system is adapted to the country context and that it continues to respond to the needs of the target communes in the TR watershed beyond the project lifetime.

7.3. Enhancing Integrated Water Resource Management

The diversity of stakeholders involved in the water management in Haiti require the implementation of Integrated Water Resource Management (IWRM) to ensure that a balance between economic efficiency, social equity and environmental sustainability in water use will be achieved. IWRM has become the international best practice approach to water management because it accommodates the interconnectedness of water and the complexities around negotiating water use and allocation between diverse stakeholders. IWRM should be implemented at different levels, including at the farmer/community, municipal and national levels, and is particularly important in situations where existing water resources have been fully allocated, to the extent that for one user to increase their resource share, another users' share must decrease accordingly[439].

Water in Haiti serves numerous functions, including irrigation use in agriculture, as a source of energy at the Peligre dam and hydroelectric power station and for potable water and sanitation[440]. The Peligre dam influences water availability for irrigation in the Artibonite Valley through regulating ~6,480 km^2 of the Artibonite River watershed[441], providing water for irrigation to ~29,000 ha of agricultural land in the Artibonite region and thus contributing to ~75% of national rice production (130,000 tons of rice). The dam also reduces the flood peaks of 10-year return flooding events by 500 m^3/s[442]. At present, there are ~50 Non-Governmental Organisations (NGOs) involved in water management in Haiti, as well as nine public institutions responsible for different aspects of water management. These include the:

- Ministry of Environment (MDE);
- Ministry of Agriculture, Natural Resources and Rural Development (MARNDR);
- Ministry of Public Works, Transportation and Communication (MTPTC);
- National Division for Potable Water and Sanitation (DINEPA);
- Ministry of Population and Public Health (MSPP);
- Ministry of Planning and External Cooperation (MPCE);
- Ministry of Commerce (MCI);
- Ministry of National Education and Professional Training (MENFP); and
- Ministry of Interior and Communal Districts (MICT)[443].

The presence of multiple public sector stakeholders involved in water management in Haiti poses a considerable challenge to ensuring water security for the country. This is because these stakeholders can have overlapping areas of responsibility leading to duplication of activities — for example, the MARNDR, the MSSP and the MENFP are all mandated with some aspect of water quality regulation[444]. The absence of an IWRM strategy has resulted in difficulties in regulating aspects of water use where multiple public sector stakeholders have jurisdiction. For example, the unregulated expansion of both agriculture and human

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[439] Global Water Partnership (GWP). 2009. Lessons Learnt from Integrated Water Resources Management in Practice. Policy Brief 9. Available: https://www.gwp.org/globalassets/global/toolbox/publications/policy-briefs/09-lessons-from-iwrm-in-practice-2009.pdf [Accessed 22/06/2020]

[440] Widmer, J., Sergile, F., Cheremond, Y., and Glenn Morris Jr., J. 2018. A Vision for Water in Haiti, 2018. VisiEAU, 2018. Available: https://epi.ufl.edu/media/epiufledu/haiti/Haiti-Water-Summit_English.pdf [Accessed 22/06/2020]

[441] Gregory L. Morris Engineering. 2008. Sedimentation Study of Peligre Reservoir, Haiti. Available: http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=EZSHARE-1646601995-13

[442] IDB. 2016. TC Document: Improvement of Sediment Management in the Peligre Reservoir. Available: https://ewsdata.rightsindevelopment.org/files/documents/06/IADB-HA-T1206.pdf

[443] Widmer et al. 2018. A Vision for Water in Haiti, 2018.

[444] Widmer et al. 2018. A Vision for Water in Haiti, 2018.

settlements into natural areas has led to widespread deforestation, which results in, *inter alia,* the deterioration of water quality and greater flood and drought risks. The poor regulation of water resources contributes to the expansion of human settlements into watershed areas – residential or industrial developments have previously expanded into watersheds because of weak enforcement of regulations, potentially undermining the supply of important ecosystem services, including freshwater provision. For example, the construction of several large-scale industrial and residential developments was initiated in the Trou-du-Nord Watershed (North West Department) in 2017, despite a lack of data on available water supplies to service this development[445]. Haiti's average annual rainfall levels are projected to decline by ~6–20% by 2030 in a business-as-usual scenario, which will further exacerbate water scarcity in the country, requiring effective and efficient management and conservation of necessary water resources.

7.3.1. Principles of Integrated Water Resource Management

The Global Water Partnership (GWP) outlined five key lessons for IWRM, which include: i) adapt IWRM to the local context; ii) align IWRM with national development strategies and institutional frameworks; iii) incorporate the requirements of all water users and stakeholders in the design and implementation of IWRM; iv) ensure appropriate institutions and infrastructure are flexible and can respond to a dynamic context; and v) apply IWRM at multiple spatial scales. These lessons are further discussed below.

IWRM should be applied as a pragmatic and institutional approach that is adapted to local contextual factors, rather than as a 'blueprint' check-box activity[446]

Important contextual challenges to water security in Haiti include: i) large-scale deforestation and resulting soil erosion and heightened flood risk; ii) the impact of unregulated urbanisation and the expansion of human settlements on water quality; and iii) inadequate coordination between ministerial line departments, which further inhibits the effective management of water resources required to meet current and future water resources[447]. These considerations have previously been included in initiatives such as the "Sustainable Land Management of the Upper Watersheds of South Western Haiti" programme (2008–2017), which demonstrated the importance of considering the root causes of contextual challenges when designing interventions. Under this programme, gullies were developed to reduce erosion in the upper watersheds of southern Haiti. The program did not, however, include interventions to address the upstream expansion of free-range herding and agriculture, which were deemed to be the main cause of erosion[448]. The proposed project design has incorporated these lessons through the: i) participatory development of community land-use plans and restoration strategies (Activity 1.1), which will both regulate deforestation and restore important water towers; and ii) addition of an IWRM strategy to the National Water Act (Activity 3.1). These activities will address the "root causes" of erosion and poor water management in the TR watershed.

IWRM should be integrated with a country's national development strategy and institutional framework[449]

Currently, sustainable water resource management in Haiti is not adequately integrated into the country's national development strategy nor the institutional frameworks governing the

[445] Stoa, R. 2017. Water Governance in Haiti: An Assessment of Laws and Institutional Capacities.
[446] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[447] Widmer et al. 2018. A Vision for Water in Haiti, 2018.
[448] Lejonc, G. and Palazy, L. 2018. Final Evaluation of the Sustainable Land Management of the Upper Watersheds of South Western Haiti Program. Available: https://www.thegef.org/sites/default/files/project_documents/3132_2018_TER_IDB_Haiti_0.pdf [Accessed 22/06/2020]
[449] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.

provision of water-related services by the aforementioned ministries. The multiple stakeholders involved in water governance in Haiti — particularly the six ministries responsible for different aspects of water governance — are partially responsible for this poor integration, because of difficulties in coordinating budgets and activities between government ministries[450]. For example, although there are four border conventions between Haiti and the Dominican Republic to promote trans-boundary natural resource management, neither country has implemented these agreements because of limited financial resources and poor integration with national budgets[451]. Agricultural users account for ~82% of total water withdrawals, and this sector has previously exploited water resources at an unsustainable rate as a result of inadequate information access on water availability. Moreover, poor regulation of land and water resources has resulted in widespread agricultural expansion and deforestation — driving greater soil erosion, declining water quality, higher risk of flooding and habitat destruction[452].

These challenges were encountered in previous projects, such as the "Increasing resilience of ecosystems and vulnerable communities to climate change and anthropic threats through a ridge to reef approach to biodiversity conservation and watershed management" project (2013–ongoing), which found that climate change impacts — specifically sea level rise and increased flood risk — had been poorly incorporated into existing environmental policies and decision-making strategies. To address this challenge, project activities included collaboration with the MoE to mainstream climate considerations — including ecosystem-based adaptation — into national plans and policies, including the National Action Plan for Integrated Management of Watersheds and Coastal Areas. The proposed project will draw on this lesson through Activity 3.1, which will use GCF resources to evaluate existing policies and identify areas that have not incorporated IWRM, in addition to strengthening national government capacity for implementing the Water Act and specific proposed IWRM components.

The importance of establishing strong lines of communication between different institutional levels to promote effective collaboration on cross-cutting activities was demonstrated in the "Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region" project (2012–2019), which indicated the need for the MARNDR to engage in a dialogue with the Ministry of Social Affairs to develop a regulatory framework that would support the establishment of water management committees[453]. The proposed project has drawn on these lessons through the establishment of Catchment IWRM Committees (Activity 3.1) that will, *inter alia*, serve as a platform for collaboration on decision-making between ministries and other civil society stakeholders.

The "Small Irrigation and Market Access Development in the Nippes and Goavienne Region" project (2012–2019) further noted the necessity for an Integrated Irrigated Areas Management Plan to be developed to support project interventions[454]. The proposed project will address this through Activity 1.1, which will develop community-produced land-use management plans for 33 communal sections within the seven target communes across the TR watershed. These plans will outline the sub-catchment management priorities and develop an action plan for community catchment restoration in degraded areas.

[450] Widmer et al. 2018. A Vision for Water in Haiti, 2018.
[451] Widmer et al. 2018. A Vision for Water in Haiti, 2018.
[452] Stoa. 2017. Water Governance in Haiti: An Assessment of Laws and Institutional Capacities.
[453] International Fund for Agricultural Development (IFAD). 2018. Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region: Supervision Report. Available: https://www.ifad.org/documents/38711644/40046455/Supervision%20mission,%20February%20-%20March%202018/a41bd84b-2999-4978-9d25-1cf8b31d627e [Accessed 22/06/2020]
[454] IFAD. 2018. Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region: Supervision Report.

IWRM strategies should be collaboratively designed to reflect the diverse needs of all stakeholders who use and affect water resources[455]

Meaningful engagement with stakeholders in the development and implementation of IWRM practices will improve decision-making quality, develop trust between stakeholders and increase the likelihood of successful project interventions by garnering community buy-in and support[456]. Local water users expressed a strong interest in 'playing a hands-on role' in water management resources within their sub-catchments during stakeholder consultations undertaken in the development of the proposed project.

Moreover, authentic engagement with all stakeholders will ensure that the optimal use and management of water resources is achieved. For example, the management of the Peligre dam and hydropower station is an important stakeholder in water management in the project region because of its flood regulation and water provision services. The management of the Peligre hydropower station impacts stakeholders downstream, as the deliberate overflowing of the dam to maintain generation levels results in flooding in the Artibonite valley below and creates adverse impacts for farmers[457]. The engagement of the Peligre hydropower station management in IWRM Committees (Activity 3.1) will therefore help to ensure that their activities do not adversely affect downstream stakeholders.

The importance of engagement with all stakeholders during all stages of project development has been noted in previous projects, including the "Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region" project (2012–2019), which found that establishing an interface between water users and established watershed management committees and local water users was essential to ensure their effective operation[458]. This interface should include mechanisms for negotiation and conflict resolution, particularly regarding the allocation of water resources[459]. The proposed project will draw on this lesson by including Activity 3.2, which will increase the capacity of Sub-Catchment Water Resource Users Associations by implementing training on IWRM. These institutions are expected to serve as an interface between water users and proposed Catchment IWRM committees (established in Activity 3.2).

IWRM strategies will evolve as contextual factors shift. Adaptable institutions and infrastructure should be designed to support this dynamic management approach[460]

The requirements of different stakeholders will evolve, particularly as a result of climate change impacts — including projected increases in average temperatures and reduced average annual rainfall levels[461] — as well as population growth and land-use change. The incorporation of IWRM into water management at all levels of government will provide the flexibility and responsiveness necessary to adapt institutions and policies to a changing context[462]. This consideration has been observed in previous projects, such as the "Sustainable Land Management of the Upper Watersheds of South Western Haiti" programme (concluded in 2018) which demonstrated implementation flexibility as an important characteristic of project management. This characteristic enabled the project management

[455] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[456] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[457] Singh, B., and Cohen, M.J. 2014. Climate Change Resilience: The Case of Haiti. *Oxfam Research Reports.*
[458] IFAD. 2018. Small Irrigation and Market Access Development Project in the Nippes and Goavienne Region: Supervision Report.
[459] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[460] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[461] UNDP. 2014. Project Document. Available: https://www.thegef.org/sites/default/files/project_documents/ID5380__SUBMISSION_4648_Haiti_LDCF_ProDoc_19Dec2014.pdf [Accessed 22/06/2020]
[462] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.

team to "adapt to field conditions and correct the inefficiency of some activities"[463]. The incorporation of a full-time Monitoring and Evaluation Expert into the proposed project management team (Activity 3.3) will enable iterative adjustments to the implementation strategy, ensuring the flexibility required to adapt to changing social and environmental factors that may arise over the project lifespan.

IWRM should be applied at multiple spatial scales, including at catchment and sub-catchment levels[464]

Within the TR watershed, the challenges and resulting interventions in upstream sub-catchments compared with downstream sub-catchments often vary substantially. For example, upstream sub-catchment priorities include the reduction of runoff and enhancement of water retention, while downstream sub-catchment priorities include the reduction of flood impacts generated upstream[465]. To compensate for this variation, the management structure between national, catchment and sub-catchment level will be uncomplicated, and water users will be able to implement sub-catchment activities with guidance from the TR Catchment Water Resources Management Committee. At the catchment level, the proposed TR Catchment IWRM Committee will be responsible for designing and implementing a Catchment IWRM Plan, which will align with the national policy framework (Activity 3.2). At the sub-catchment level, Sub-Catchment Water Resources User Associations in the TR region will receive training on the implementation of collaboratively produced IWRM plans (developed in Activity 3.2). The participation of the Sub-Catchment Water Resources User Associations will ensure that decisions at the catchment level consider all potential impacts on downstream sub-catchments within the TR watershed.

Barriers to the preferred solution

Several barriers to the preferred adaptation solution have been identified for Haiti. These are summarised below and explained in detail in Section 8 of this Feasibility Study. The barriers fall broadly in the themes of technical and institutional barriers (Barriers 1, 2 and 3), financial barriers (Barrier 3), and social/psychological barriers (Barriers 5, 6 and 7).

8.1. Technical/Institutional barriers

<u>Barrier 1. Limited technologies, resources and knowledge for climate-resilient flood management</u>

Communities in Haiti, particularly farmers, are not informed about current and projected climate change impacts, particularly flooding, on agricultural production, other land-use practices and water resources. This insufficient information — as well as limited data gathering and decentralised analysis — leads to inadequate responses to flood threats, constraining the ability of affected communities to react or adapt.

As a result of this limited knowledge management and information sharing (and compounded by the lack of incentives to build community resilience, as discussed in Barrier 2), communities may not consider climate change in their activities and practices, or the effect their actions will have on amplifying the impacts of climate change. Furthermore, there is limited technical knowledge amongst communities on how to adapt to these changes and increase resilience, particularly using nature-based solutions. For example, although communities are aware of a relationship between droughts and deforestation, there is limited awareness of the need for collective action on catchment-wide rehabilitation. Also missing is a functional understanding

[463] Lejonc and Palazy. 2018. Final Evaluation of the Sustainable Land Management of the Upper Watersheds of South Western Haiti Program.
[464] GWP. 2009. Lessons Learnt from Integrated Water Resources Management in Practice.
[465] Stoa. 2017. Water Governance in Haiti: An Assessment of Laws and Institutional Capacities.

of the impact of reforestation on the general climate-resiliency of the agro-ecological landscape with regards to water availability, soil erosion, agronomic viability and overall economic sustainability. Similarly, the limited understanding of climate change impacts on agricultural practices and methods on how to make farming systems more climate change resilient increases the vulnerability of farmers in the long run.

There is also limited practical and technical experience for commercialising natural regeneration to establish and manage financially sustainable local, small-scale tree propagation operations that serve local reforestation and agroforestry needs. Although propagation materials, such as seeds and cuttings, are available in the country or can be sourced locally, the limited capacity (which is further hindered by financial barriers, as discussed above) impedes the availability of locally available saplings for reforestation efforts. Generally, workers prefer to migrate to cities or engage in alternative rural occupations, as these options are perceived to offer more financial stability than tree propagation operations and agroforestry.

<u>Barrier 2. Absence of integrated, climate-sensitive water and land management policy and governance frameworks</u>

Currently, there are no integrated, climate-sensitive water or sustainable land management policies and governance frameworks in Haiti. The country lacks overarching water management legislation[466], a formal cadaster[467], or standard practice for land tenure arrangements. This has reduced long-term security (and therefore potentially limited liability or responsibility) for tenant farmers on leased agricultural land. In the agriculture and environmental protection sectors, there is a lack of effective and relevant strategies to promote sustainable landscape management. These strategies could include implementing agroforestry and other forms of production that demonstrate short- and medium-term benefits (such as health and income security) to households. Despite many relevant water and land-use projects having been carried out over the past decades (see also Barrier 3), there is also a lack of integration of applicable lessons learned into an overarching framework of public policies and the practices of institutions, NGOs, local organisations and local authorities. The absence of a regulatory framework and enforcement of sanctions and property rights also reinforces an open-access approach regarding the use of community assets, which is compounded by social barriers (see Barriers 5 and 6).

In terms of governance, there are no administrative structures at the catchment and sub-catchment levels, as the National-Departmental-Municipal-Communal structure follows political rather than geographical boundaries. Although the Ministry of Environment does intend to create catchment-level administrative structures to be supported at the secondary administrative layer through sub-catchment water user associations, there are currently no local water resources user associations or other community committees that have the skill and capacity for integrated water resources management. This lack of vertical coordination and oversight is evident in line ministries providing minimal support to local communities. Although some ministries are present in rural communities, they are not very active, which leads to farmer associations not having the resources and capacity to implement changes in conservation or productive practices for better managing water resources.

This constrained policy and governance framework — as well as the limited integration of lessons-learned — has resulted in three major concerns, namely: i) existing legal instruments that do not consider the projected threats of climate change; ii) lack of land use planning implementation and enforcement that has led to increased deforestation (especially in riparian

[466] Although the establishment of a Water Act has been identified as one of the Ministry of Environment's priorities in its 2019-2022 Triennial Plan.
[467] Or 'cadastre', an official register of the ownership, extent, and value of real property in a given area, used as a basis of taxation.

forests), indiscriminate degradation of protective soil cover and decreased slope protection; and iii) a lack of defined roles and responsibilities of institutions dealing with water management, which has led to uncoordinated efforts by donors and stakeholders and subsequent problems in planning, implementation and accountability. An enabling framework that addresses climate change risks is necessary to ensure the sustainability of interventions for increasing communities' resilience to climate change in the short-, medium- and long-term.

Barrier 3. Limited coordination and capacity to implement/execute

The roles and mandates of different agencies and government departments are often unclear, creating a lack of accountability and cohesion, which in turn impedes timely responses to crises and climate change threats. Partially attributable to the absence of an overarching integrated institutional framework, implementing/executing entities, government and non-governmental stakeholders have limited opportunity and incentive to coordinate efforts to address climate risk. This leads to: i) projects by different organisations often being designed independently, without consideration of how they affect each other or address the broader resilience of the country; and ii) limited coordination among donors or between GoH ministries during project implementation. For example, projects for collecting hydro-meteorological data have been undertaken by several different international NGOs and agencies, without proper coordination or oversight by the responsible government institutions.

Local authorities and stakeholders at the forefront of managing climate change impacts are also not adequately equipped and trained to incorporate climate change considerations into decision making or to design and implement climate change-resilient water management. As described above in Barrier 1, this is evident in the lack of catchment and sub-catchment administration structures and capacity to oversee participatory, equitable and adaptation-focused decision-making on water and land use, which further amplifies households' prioritisation of private gains over catchment-wide benefits.

8.2. Financial barriers

Barrier 4. Limited access to credit, savings and financial instruments or incentives amongst farmers

There are financial barriers to farmers' implementation of sustainable land management practices in Haiti. These barriers include a lack of access to capital to invest in start-up costs, or maintenance materials and tools, as well as limited "bridging" of household reserves to cope with the impacts of climate change and natural hazards. In this context, "limited bridging of household reserves" refers to the absence of emergency savings or other financial support for farmers so that, if crops fail because of climate change impacts and/or other disasters, they would be able to support their livelihoods immediately after these events until they are able to start generating their own income again.

Alternative sources of funding and credit are not available or are difficult to access, which leads to short planning horizons. These planning horizons drive short-term relief activities, such as the production of charcoal at unsustainable rates to meet pressing short-term financial needs. For agroforestry and climate-resilient agricultural practices to be sustainable, incentives for farmers to implement these systems are needed to allow farmers to overcome this short-termism and to allow time for these systems to produce returns.

8.3. Social/psychological barriers

Barrier 5. Limited incentives for communities to change land management and farming practices or contribute to communal resilience building

Limited awareness of climate change impacts and how these will affect people in terms of their health and livelihoods compound prevailing circumstances, such as poverty, that emphasise household/individualist short-term decision-making over long term communal resilience. Households (which have a high discount rate) make decisions in their own short-term interest, without necessarily considering the impact of those decisions on the sub-catchment. For example, households having a limited understanding of the drought-mitigating impacts of reforestation may be more likely to engage in cutting down trees for short-term economic gain or bridging funds in when unexpected events — such as floods — arise. Similarly, households question why they should invest in reforesting areas that could previously be harvested without financial repercussions, or support practices that 'only' benefit the community at large, especially when those limited resources could be spent on household needs. Furthermore, charcoal production is well entrenched in communities as it is the major source of energy for cooking and has significant economic importance, while the availability of alternative fuels is poor. There is also no experience or incentive among water users to consider sub-catchment scale water management in their household decision-making. Finally, the familiarity of established, unsustainable farming practices is a barrier to better alternatives as households are reluctant to change to new crops or practices without the development of local markets and social safety nets, even if their livelihoods would be more resilient as a result.

For project investments to be sustainable, strategies must be considered that enable communities to internalise the short-, medium- and long-term implications of current and proposed practices to contextualise these practices relative to projected climate impacts. For example, community consultation has identified that health risks are a key concern of households. This could be leveraged through encouraging buy-in for interventions that would improve household- and community-level resilience to climate change-induced health risks.

<u>Barrier 6. Absence of inclusive and participatory community consultation mechanisms for climate change-induced flood management planning and decision-making</u>

The absence of participatory and inclusive planning, which is a fundamental principle of an integrated flood management approach for climate resilience, means that communities are not currently incentivised to take up adaptation interventions in Haiti. Underlying factors include technical and financial capacity constraints at the municipal level, which have historically limited the ability of public officials to effectively engage with appropriate communities and stakeholders during decision-making on land and water resource management. For example, Haiti's national budget does not allocate financial resources for disaster risk management at a local level, significantly undermining the ability of, *inter alia,* disaster management committees to fulfil their mandates[468]. Moreover, public participation is not emphasised among Haitian public institutions at both local and national level. Public officials often lack experience in meaningfully engaging with citizens in decision-making processes on, *inter alia*, natural resource management[469].

Given the high influence of social factors (such as gender inequality) on vulnerability to flood impacts, it is necessary to promote inclusive decision-making processes to ensure buy-in and effectiveness of interventions. Considerations should be made for specific groups, such as women and people living with disabilities. These groups often face additional barriers to receiving timely warning information because of their relatively unequal access to telecommunications technology as well as the significant amount of time they spend in or near the home. Additionally, as men migrate to cities for work, this may place additional burdens on women's labour to implement agroforestry or other climate-resilient practices. Past

[468] UNEP. 2016. Applying Ecosystem-based Disaster Risk Reduction (Eco-DRR) through a ridge-to-reef approach in Port Salut, Haiti.
[469] Calogero, A., Flores, P., Biscan, B., and Jarrot, S. 2017. *A Participatory Approach to Urban Planning in Slum Neighbourhoods of the Metropolitan Area of Port-au-Prince.* Summary Report. Urban Crises Learning Partnership.

interventions have been criticised for failing to take gender and other considerations into account, focusing more on general agricultural incomes and outputs — access to which is shaped by prevailing systems of privilege and access. Taking these intersectional influences into account, the success of climate change-driven flood management measures depends considerably on the equitable involvement of all stakeholders in the decision-making process, especially by disadvantaged and underrepresented groups.

Project interventions to overcome barriers

The proposed project will overcome the abovementioned barriers to build the climate resilience of Haiti's TR watershed. Barrier 1 will be addressed by investing directly in implementing an integrated approach to climate-resilient flood management in Haiti. This approach will involve: i) strengthening governance for and national- and local-level decision-makers' and communities' capacity to implement Integrated Land Management (ILM) and Integrated Water Resources Management (IWRM) in Haiti, using a participatory approach; ii) restoring 7,700 ha of degraded forest and implementing 17,740 ha of agroforestry systems in the watershed to reduce the impacts of climate change-induced flooding on ecosystems and communities; and iii) implementing a social protection system, coupled with enhanced technical capacity and access to finance of national and local representatives to facilitate the adoption of climate-resilient sustainable land-use practices and livelihoods.

Under the climate-resilient Integrated Land and Water Resources Management (ILWRM) approach proposed under the project, community groups (including farmer and women's associations) will be encouraged to participate in the development of community land-use plans for each of the 33 communal sections within the seven target communes in the TR watershed. The development and implementation of these community land-use plans will be supported by the establishment of the necessary national governance framework for climate-resilient IWRM. This will involve strengthening national capacities for the implementation of the Water Act and developing an inclusive and equitable water management governance framework for the TR catchment, namely the Catchment Water Resources Management Committee (CWRMC). Furthermore, lessons generated through the implementation of all project interventions will be shared through the relevant committees and associations — at the catchment and sub-catchment levels — to inform adaptative management of these interventions under future climate change conditions. Combined, these key activities will overcome Barriers 2 and 3, with the participatory decision-making around land and water resources management contributing to addressing Barrier 6.

Barrier 4 will be addressed through a combination of long- and short-term interventions to address the immediate impacts of a flood event in Haiti, as well as facilitate access to finance to support the uptake of climate change adaptation solutions in response to the projected increasing impacts of climate change in Haiti. Specifically, the technical capacity and access to finance of national and local representatives involved in agriculture in the TR watershed will be enhanced to facilitate their adoption of climate-resilient sustainable land-use practices and provide an alternative livelihood option to unsustainable charcoal production in the watershed. This will be supported by providing immediate financial relief to vulnerable households in the TR watershed to enable these households to sustain themselves immediately after a flooding event.

Barrier 5 will be addressed by creating incentives in the TR watershed for the adoption of sustainable land and water resources management techniques that are resilient to climate change-induced flooding. This will be achieved under each element of the ILWRM approach proposed under the project by: i) demonstrating the wide variety of adaptation benefits and alternative livelihood options associated with the proposed EbA solutions such as reforestation and agroforestry (Output 1); ii) optimising the agricultural value chain and increasing the knowledge of vulnerable communities of the benefits of implementing climate-resilient agricultural techniques (Output 2); and iii) creating an enabling policy environment and strengthening governance in Haiti at the national and local levels for integrated, climate-resilient land and water resources management (Output 3).

Output 1. Ecosystem-based flood management solutions implemented in 25,440 hectares of the Trois-Rivières watershed

At present, climate change-induced flooding is exacerbated by degraded landscapes and forests because of large-scale tree clearing for agricultural and charcoal production. During heavy rainfall events and flooding, the limited surface cover combined with the near-complete absence of embankments along the river intensifies soil erosion and river sedimentation. Implementing agroforestry systems and rehabilitating degraded forests in the TR watershed will address these problems by significantly reducing peak runoff and flooding extent in the area. These flood-reduction benefits will be realised through increasing vegetative cover in the watershed, which will attenuate flow by considerably reducing surface runoff and increasing the infiltration capacity of the soil. Reductions in water flow will reduce the risk of damage to public infrastructure and private property (e.g. homes and agricultural equipment), which will likely result in a decline in the observed annual damages and economic losses caused by flooding in Haiti. Furthermore, the implementation of these EbA interventions will have numerous environmental and social benefits for vulnerable households living in the target communes in the TR watershed. Rehabilitating degraded forests and establishing agroforestry systems will improve natural filtration of overland flows, removing water pollutants and, consequently, contribute towards avoiding sedimentation of key freshwater sources in the TR watershed. This will lead to improved water quality of these sources which, in turn, will contribute to reducing the spread of water- and vector-borne diseases (e.g. cholera), therefore safeguarding the health of communities living near to the priority intervention sites. The EbA interventions will also increase the ecosystem goods and services they provide (e.g. an improved quality and quantity of water supply, increased prevalence of agricultural pollinators and enhanced soil fertility[470]), which will contribute positively to improving these communities' livelihoods.

Further livelihood benefits will be realised through the implementation of agroforestry systems in the target communes, including: i) agrisilvicultural systems — which are a combination of crops and trees, such as alley cropping; ii) silvopastoral systems — which combine forestry and grazing of domesticated animals; and iii) agrosilvopastoral systems that combine trees, crops and animals[471]. At present, most of the vulnerable communities living in the TR watershed depend on agriculture to sustain their livelihoods, with an observed increase in unsustainable charcoal production in years where the impacts of climate change have had particularly severe effects on agricultural yields and other livelihood options. Under this project output, vulnerable communities will be encouraged to adopt alternative livelihood options (such as beekeeping and mushroom cultivation). It is feasible for these livelihood options to be implemented alongside or independently of agroforestry services to catalyse a shift away from unsustainable charcoal production towards land use practices that will continue to provide long-term benefits under future climate change conditions.

The implementation of agroforestry systems and reforestation of degraded mountainous slopes to manage flooding in Haiti's TR watershed will be supported under this project output by strengthening the technical and institutional capacity of community groups, including farmer and women's associations, for climate-resilient land-use planning. Specifically, this will include developing community land-use plans for use across 118 communities within 33 communal

[470] Thompson, I.D. *et al*. 2011. "Forest Biodiversity and the Delivery of Ecosystem Goods and Services: Translating Science into Policy", *BioScience*, 61 (12).
[471] FAO. 2015. Forestry: Agroforestry definition. Available at: http://www.fao.org/forestry/agroforestry/80338/en/

sections within the 7 target communes in the TR watershed. The development of these plans will facilitate the identification of climate change impacts, particularly flooding, on the TR watershed and design of appropriate actions for addressing these impacts. Such actions include the implementation of EbA interventions as flood reduction measures and the promotion of sustainable, climate-resilient land-use practices and techniques (e.g. agroforestry) to reduce the risk of increased land degradation under future climate change conditions. These plans will then be used to inform training on climate-resilient land-use management that will be delivered by the Responsible Parties to communities and farmer and women's associations in all seven communes. The training will focus on the practical application of climate-resilient land-use management and agricultural techniques and improving communities' understanding of the linkages between land-use and hydrology of the TR watershed, particularly the implications of unsustainable land-use practices on the frequency and intensity of flooding in the watershed.

To support this training, awareness-raising campaigns will be designed and implemented in each of the seven target communes in the watershed. These campaigns will focus on: i) increasing the knowledge of people living in the TR watershed on sustainable land-use practices and promoting the uptake of these practices; ii) encouraging community members to participate in the development of community land-use plans; and iii) raising awareness among people living in the target communes on the impacts of climate change-induced flooding and effective adaptation and landscape management solutions for addressing these impacts. These capacity-building initiatives combined with the implementation of EbA interventions will contribute towards a shift in the TR watershed towards the adoption of sustainable land-use management techniques and practices that are resilient to climate change-induced flooding.

Activity 1.1 Strengthen the capacity of community groups, including farmer and women's associations, for climate-resilient land-use planning in seven target communes in the Trois-Rivières watershed

Under this activity, community members and farmer and women's associations in 33 communal sections within the 7 target communes in the TR watershed (Port-de-Paix, Chansolme, Bassin Bleu, Plaisance, Pilate, Marmelade, Gros Morne) will be trained on climate-resilient land-use management. This training will be delivered by the Responsible Parties that will be selected. The target communes will be grouped by proximity to one another and each RP will be responsible for providing training to these groups. UNDP will determine the appropriate entities responsible for the provision of training in each group of communes. Farmers in the target areas will also be targeted to receive training on the development of sustainable agroforestry business models that will contribute to both improving livelihood security and enhancing the use of sustainable land-use practices in the TR watershed. The focuses of the trainings will be on:

- the expected impacts of climate change, particularly flooding, in Haiti and the associated consequences of these impacts on the population's livelihoods;
- linkages between land-use and hydrology of the TR watershed, particularly the implications of unsustainable land-use practices on the frequency and intensity of flooding in the watershed;
- promoting sustainable, climate-resilient agricultural practices such as slope stabilisation, riparian protection, and contour line farming, as well as the importance of protecting forest areas, as viable options for improving hydrological function of the watershed and reducing flood impacts;
- the role of the community in sustainable charcoal production and reforestation, as a strategy for increasing climate resilience in the watershed; and
- practical aspects of agroforestry as a climate-resilient livelihood alternative.

The groups of people targeted for training will also be encouraged to participate in the development of community land-use plans for 33 communal sections within the TR watershed, which will inform this training. The development of these plans will focus on identifying the impacts of climate change, particularly flooding, on the TR watershed and designing appropriate actions for addressing these impacts. Such actions include the implementation of EbA solutions to reduce flood risk in the watershed as well as the promotion of sustainable, climate-resilient land-use practices and techniques (e.g. agroforestry) to reduce the risk of increased land degradation under future climate change conditions. A central component to the effectiveness of these plans is creating buy-in from beneficiary groups for the sustainable implementation of climate-resilient land-use practices such as agroforestry and securing commitment from beneficiary communities to maintain the adaptation interventions that will be implemented under Activity 1.2 during and after the project period.

Activity 1.2. Implement ecosystem-based flood management solutions in the Trois-Rivières watershed

This project activity will focus on reducing the impacts of climate change-induced flooding in the TR catchment and Port-de-Paix. This will be achieved by implementing 17,740 ha of agroforestry systems and rehabilitating 7,700 ha of forests in priority areas in the watershed. Implementing these EbA interventions will result in a 40% reduction in peak runoff, with rehabilitation interventions, in particular, expected to reduce floodplain extents in the target areas by 20% and 26% under the 20-year and 100-year flood scenarios, respectively. By the end of this century, the EbA interventions are projected to result in a more than 50% reduction in the number of households affected by 100-year flood events (declining from 1,342 households at risk of flooding under the baseline scenario to 638 households with project interventions). Similarly, agroforestry and reforestation interventions under this project activity are expected to result in a 35% reduction in the number of households at risk to 20-year flood events in the TR watershed. This is representative of a decline from 463 under the baseline scenario to 300 houses at the end of the century under a 20-year flooding scenario.

The implementation of agroforestry systems has a particularly high adaptation impact potential because of the provision of ecosystem goods and services (e.g. improved quality and quantity of water, more productive and stable soils, and crop pollination) combined with the creation of alternative livelihood options to unsustainable land uses (e.g. unregulated charcoal production). Under Activity 1.2, the establishment of agroforestry systems will include establishing nurseries, planting seedlings (e.g. for fruit production and reforestation) and providing ongoing technical assistance to end users (Tables 1 and 2). All agroforestry activities will also involve extensive engagements[472] with farmer and women's associations to encourage a progressive and gender-responsive transition towards sustainable agroforestry businesses that are sustainable over the long term. The rehabilitation of water towers through reforestation will also be undertaken in a participatory way and include: i) community engagement; ii) the provision of ongoing technical assistance for reforestation activities; iii) the development of long-term sustainable management plans for reforested areas at the sub-catchment level; and iv) encouraging the involvement of public institutions in the development and implementation of sustainable land management and reforestation strategies.

[472] These engagements will not be undertaken using a cash-for-work approach, but rather encourage targeted groups to participate in the establishment of agroforestry systems and enhance the uptake of these systems as viable alternatives to unsustainable land uses (e.g. unsustainable charcoal production).

Table 6. Permanent species suited for cultivation within the TR catchment.

Permanent species for the implementation of agroforestry systems in the TR catchment													
	Scientific name	Type of plant	Food	Shadow	Fodder	Fuel	Medicinal	Income	Timber	Hedge	Erosion control	Soil improver	Native (N), Currently Grown (G), or Newly Introduced (I) in Haiti
Fruit production													
Avocado (Avocatier)	*Persea americana*	Tree	X					X					G
Cocoa (Cacaoyer)	*Theobroma cacao*	Tree	X		X	X	X	X				X	G
Custard-apple (Cachiman)	*Annona reticulata*	Tree											G
Coffee Caféier	*Coffea arabica*	Shrub	X					X					G
Kassod tree (Cassia)	*Senna siamea*	Tree			X	X	X		X	X	X	X	G
Jamaica cherry (Cerise)	*Muntingia calabura*	Tree	X				X					X	N
Grapefruit (Chadequier)	*Citrus maxima*	Shrub	X					X					G
Lemon (Citronier)	*Citrus limon*	Shrub	X					X					G
Coconut tree (Cocotier)		Tree	X										G
Soursop (Corossol)	*Annona muricata*	Tree	X				X	X	X				N
Breadfruit (Lamveritable (arbre à pain))	*Artocarpus altilis*	Tree	X	X	X	X	X					X	G
Leucaena (Lisina)	*Leucaena leucocephala*	Shrub			X	X			X		X	X	G

Mango (Manguier)	*Mangifera indica*	Tree	X					X					G
Orange (Orange doux/sure)	*Citrus sinensis*	Shrub	X					X					G
Forest													
American mahogany (Acajou)	*Swietenia mahagoni*	Tree		X		X	X	X	X				N
Ironwood (Bayawonn)	*Prosopis juliflora*	Shrub	X		X	X	X		X		X	X	G
Moringa tree (Benzolive)	*Moringa oleifera*	Tree	X		X	X	X		X		X	X	G
Cedar (Cèdre)	*Cedrella odorata*	Tree				X	X	X	X				N
Oak (Chene)	*Quercus petraea*	Tree		X				X	X				G
Bitterwood (Frene)	*Simaruba glauca*	Tree					X	X					N
Guaiac (Gaiac)	*Guaiacum officinalle*	Tree		X			X	X	X				N
West Indian Laurel (Laurier)	*Ocotea leucoxylon*	Tree						X	X				G
Hispaniolan pine (Pin)	*Pinus occidentalis*	Tree		X		X		X	X				G
Ice-cream bean (Poix doux ou Sucrin)	*Inga edulis*	Shrub	X	X	X	X						X	G
Saman or Rain tree (Saman)	*Albizia saman*	Tree	X	X	X	X	X		X			X	G

Table 7. Examples of agroforestry systems deployed in, and suited for, the TR catchment.

Examples of agroforestry systems with permanent species presented above		
Before permanent species reach full tree/shrub size, the spaces between them can be filled with perennial food crops (e.g. plantains, sugar cane, cassava, pigeon peas and pineapple), in combination with annual crops (e.g. sweet potato, yams, and other annuals).		
Example 1		
Stage (year)	Species	Ecosystem goods and services[473]
1	Ice-cream bean	• Ice-cream bean seeds germinate at a rapid rate. • As they contain nitrogen-fixing properties, ice-cream beans are planted in improved fallows. • Ice-cream bean litter is high in nitrogen, lignins and polyphenols, which resultantly improves soil quality. Although the litter decomposes slowly, it provides for long-term accumulation of organic nitrogen and serves as effective weed control.
2	West Indian Laurels and/or *Saman* trees	• West Indian Laurels and *Saman* trees provide fodder for livestock and shade for coffee and cacao plantations.
3	Cacao and Coffee	• Cacao and coffee beans are sold to generate an income.
Example 2		
1	Moringa tree	• Moringa trees grow at a rapid rate. • Given their nutritional content and drought-resistance, moringa trees are an appropriate food source for ensuring food security. • Moringa trees are suited to environments which experience strong winds and droughts and resultantly provide soil erosion control. • The seed cake, which is a by-product of oil extraction, can be used as soil conditioner or fertiliser.

[473] Available at: http://www.worldagroforestry.org

		• Moringa leaves are a good source of protein, Vitamins A, B and C and minerals such as calcium and iron. In addition, the leaves make a useful mulch.
2	Soursop	• Soursop is native to Haiti and is a source of food for humans. • While small and early-bearing, soursop trees are planted as intercrops between larger fruit trees (such as mango, avocado and santol) and later uprooted when the fruit tree requires more space.
3	Mango or avocado	• Mangoes and avocados are sold to generate income.
Example 3		
1	Bitterwood	• Bitterwood is native in Haiti. • The press cake produced from the milling operation is used as an organic fertiliser, particularly in coffee plantations and sugarcane, cotton and maize fields. • In addition to their rapid and linear growth, bitterwood trees are adaptable to shallow soils, making them a suitable species for agroforestry.

2	*Saman* and /or American mahogany	• *Saman* trees provide shade as well as a cool microclimate for plants that grow beneath their canopies. • The seed pods contain a sweet-flavoured pulp which is often consumed by children. The pulp can also be used in making fruit beverages. • *Saman* tree pods have a crude protein content of 12–18% (dry matter) with 41% digestibility for goats. The pods are also suitable fodder for cattle and horses. • The trees are suitable for sustainable non-destructive wood harvesting methods, such as pollarding. • *Saman* wood produces 5,200–5,600 kcal/kg of biomass fuel when burned and regrows rapidly after lopping or pollarding, making it a valuable source of high-quality firewood and charcoal. • The *Saman* tree is highly prized for carvings, furniture and panelling because of the light and dark pattern the sapwood and the heartwood create.
3	Cacao and Coffee	• Cacao and coffee beans are sold to generate an income.
Example 4		
1	Leucaena	• Leucaena leaves have a high nutritive value (high palatability, digestibility, intake and crude protein content) and is suitable fodder. • As it is in bloom almost throughout the year, Leucaena provides constant forage to honeybees. • It is a suitable firewood species. • Leucaena has a forceful taproot system which helps break-up compacted subsoil layers, improving the penetration of moisture into the soil and subsequently decreasing surface runoff.

		• Leucaena is used as a shade tree on cocoa, coffee and tea plantations. It often serves as a shelterbelt, providing shade and wind protection for a variety of crops, particularly during early growth. • The tree has high nitrogen-fixing potential (100–300 kg N/ha a year) related to its abundant root nodulation. • Leucaena was one of the first species to be used to produce green manure in alley-cropping systems. The leaves, even with moderate yields, contain enough nitrogen to sustain a maize crop.
2	Cedar	• Cedar flowers are a source of nectar for honey production. • Cedar trees are suitable for firewood. • Cedar wood is lightweight and comparatively soft. It is suitable timber for furniture, decorative veneer, musical instruments, wooden novelties and doors. • As the trees have many low branches and a spreading crown, they provide shade and serve as windbreakers in courtyard gardens and cocoa and coffee plantations. • Cedar trees can be planted as ornamentals along roads and in parks. They are planted for this purpose in, for example, peninsular Malaysia, Papua New Guinea and Singapore. • Cedar trees are highly susceptible to *Hypsipyla* infestations and as a result, it is recommended that the trees are planted in mixed plantations, for example with *Leucaena leucocephala*.
3	Cacao and Coffee	• Cacao and coffee beans are sold to generate an income.

Output 2 Climate-resilient agricultural practices, optimised value chains and social safety nets established to promote SLM and reduce degradation in the Trois-Rivières watershed

Output 2 will be fully co-financed by Heifer. The key objectives of the Heifer support are to: i) strengthen food security governance; ii) encourage sustainable development in the agricultural sector; iii) safeguard natural resources in the TR watershed; and iv) promote access to a sustainable social safety net that encourages local agricultural development. While most of the Heifer-funded interventions can be implemented in the absence of the proposed GCF project, its impact will be minimised without the key adaptation interventions that are to be implemented under Output 1 of the proposed project. Therefore, the co-finance has been made available conditional on the approval of the GCF project. Likewise, the proposed project is dependent on the co-financed interventions to complete the integrated approach to climate-resilient flood management in Haiti (Output1) and maximise the paradigm shift potential of the project. This will be achieved by facilitating a transformative shift in Haiti's agricultural sector from unsustainable practices (e.g. the cultivation of annual crop types and clearing of forests for charcoal production) towards sustainable options that are resilient to the impacts of climate change-induced flooding.

To facilitate this shift, a suite of complementary interventions will be implemented under Output 2 of the project to promote the adoption and implementation of sustainable land-use practices in Haiti. This will be achieved by: i) strengthening the technical and institutional capacity of people involved in agriculture at the commune, inter-commune and department levels for implementing productive climate-resilient agricultural practices (such as agroforestry systems with alley cropping and contour bunds, as well as local *Bann Manjé*[474] systems); ii) enhancing smallholder farmers' access to financial resources to facilitate the uptake and implementation of climate-resilient agricultural practices over the long term; and iii) establishing a social protection system that will provide immediate post-disaster support to vulnerable households affected by climate change impacts, particularly flooding. As a result of these interventions, the project will enable vulnerable farmers and households living in the watershed to return to normalcy in the immediate aftermath of a flood event. This will reduce the adverse social and economic impacts associated with these events and promote livelihood security amongst these people. Together, interventions under Output 2 will stabilise access to markets for farmers and producers, incentivising the uptake of climate-resilient, sustainable land-use practices and alternative livelihoods such as agroforestry. By diversifying agricultural produce and agroforestry system varieties to prevent seasonal production peaks and providing technical support to farmers to adapt supply to demand, overproduction periods will be reduced. This, in turn, will contribute to regulating price volatility of agroforestry and agricultural produce, attracting further investment into sustainable products and making the adoption of alternative livelihood options more feasible for the vulnerable people living in the TR watershed.

Activity 2.1. Strengthen institutional capacity at the commune, inter-commune and department levels in Haiti's Trois-Rivières watershed for productive and sustainable land-use management

Under this activity, a capacity needs assessment will be conducted for the agricultural sector to identify the technical and institutional requirements for transitioning the sector from unsustainable land-use practices towards a sustainable landscape management (SLM) approach to land and water resources management that is climate resilient. Capacity will be assessed in six of the seven target communes in the TR watershed. From the capacity needs assessments, opportunities will be identified, and plans made to enhance the management of natural resources and promote the uptake of climate-resilient agricultural practices to increase productivity. To facilitate the uptake of these new

[474] *Bann Manjé* translates to "a band of food", hedgerows that comprise perennial crops (e.g. plantains and cassava), in combination with annual crops (e.g. sweet potato and yam). The hedgerows provide structural integrity to stabilise soils to prevent erosion, whilst the crops provide a source of food security and income generation.

sustainable practices, governance mechanisms and frameworks for SLM will be developed in the TR watershed through the establishment of communal development councils. These councils will represent all agricultural sector stakeholders, including smallholder farmers, in the six communes. Additionally, multi-sectoral governance structures will be established to oversee and manage the implementation of interventions designed to address priority areas identified in Sub-activity 2.1.1 Support for the governance structures established under Sub-activity 2.1.2 will be provided through strengthening the capacity of relevant government entities, including the Ministry of Agriculture, Natural Resources and Rural Development (MARNDR), National Coordination of Food Security (NCFS) and Ministry of Social Affairs and Labour (MSAL), to implement SLM at the department level. This will enable the adoption of SLM practices to be guided in a manner that is compatible with the effective functioning of the entire watershed and that contributes to enhancing flood management across the TR watershed.

Activity 2.2. Enhance the technical capacity and access to finance of national and local representatives involved in agriculture in the Trois-Rivières watershed for adopting climate-resilient sustainable land-use practices

This project activity will increase the technical capacity of farmers to implement climate-resilient agricultural techniques and land-use practices, using the findings from the capacity needs assessments being conducted under Activity 2.1. Specifically, this will be achieved through implementing targeted adaptation interventions in Haiti's TR watershed to optimise the agricultural value chain and promote the use of climate-resilient agricultural techniques across the sector. Such interventions will include enhancing the transportation of agricultural produce (e.g. by developing agricultural tracks), as well as improving water supply systems (e.g. irrigation and water pumps) to address decreasing water security caused by the impacts of climate change-induced flooding. Infrastructural upgrades will also be undertaken in the form of increasing the storage capacity and quality of post-harvest facilities, as well as establishing local processing facilities for agricultural produce to optimise agricultural production in the watershed. These interventions will be supported by the provision of climate-resilient agricultural inputs (e.g. climate-resilient seed varieties) to vulnerable households that depend on subsistence agriculture for their livelihoods. This will be supplemented by delivering technical skills training on climate-resilient agricultural techniques and SLM to farmers. Specifically, this will involve: i) enhancing their ability to effectively manage and organise irrigation and other associations; ii) facilitating participatory access to agricultural inputs, farming equipment, maintenance facilities; and iii) upskilling of maintenance staff.

Strengthening these key elements of the agricultural value chain in Haiti's TR watershed will not only enhance the climate resilience of agricultural production in the country, but also contribute to increased food security in the watershed by improving market access for farmers and those people who depend on agriculture for their livelihoods. This increased market access will be supported by the establishment of an agricultural finance mechanism under the Agricultural Village Savings and Credit Associations (VSCA). Social feasibility assessments, including risk assessments and community engagement, are part of the VSCA creation process. Following these assessments, the operational regulations of the VSCA (e.g. interest rates) are defined by the members themselves. VSCAs are groups of 20 to 30 people who save in the form of shares according to their economic means. One share is equivalent to 10 Haitian gourdes and it is possible to buy a maximum of 5 shares per week. After three months have passed, the saver can make loans at an interest rate fixed by the whole group, up to three times the value of his savings. This system works in one-year cycles. At the end of each cycle, the savings and the profits resulting from the interest are redistributed among the members according to the total amount saved by each member. VSCAs constitute a social fund from penalties paid by members for non-compliance with operating principles (e.g. late or absent from meetings) to support members' social problems (e.g. bereavement and/or community work). The VSCAs therefore provide their members with small, flexible financial services of savings, microcredit and micro-insurance, requiring limited administrative work, or the provision of guarantees. Within the framework of the proposed project, VSCAs are levers for households benefiting from the social safety net to develop small economic activities with the credits or the amount of "remunerated" savings obtained at the end of the year, in order to increase their income in a sustainable way. Under Activity 2.2, the VSCAs will facilitate the adoption and implementation of sustainable, climate-resilient agricultural practices, which will contribute to livelihood and food security under future climate change conditions.

Activity 2.3. Implement a social protection system to support vulnerable households at risk to food insecurity because of climate change

This project activity will support households affected by chronic food insecurity to recover their nutritional and financial autonomy immediately after being impacted by climate change-induced flooding. Subsistence farmers living near to floodplains along the TR watershed are particularly vulnerable to these events, which often result in the near-complete destruction of their agricultural yields grown to support their livelihoods. When this happens, most of these farmers take up unsustainable charcoal production as a last resort to support their livelihoods, which in turn results in increased degradation of the landscape, exacerbating soil erosion and sedimentation of the TR watershed and its tributaries. While Activity 2.2 provides a long-term solution to addressing these negative impacts, this activity will provide the required immediate relief to vulnerable people affected by these events, concomitantly reducing further pressure on the environment by providing an alternative option to resorting to unsustainable charcoal production. Specifically, Activity 2.3 will facilitate the development of a social safety net whereby food vouchers will be provided to vulnerable households affected by food insecurity. To determine eligible households for these vouchers, vulnerable households will be identified through a site survey and/or assessment, with their details captured in a database for future reference. Recipients of these vouchers will be able to redeem the vouchers for local produce at selected primary and secondary markets. These vouchers will also serve as a form of currency (or e-voucher), which will provide recipients with purchasing power to exchange the vouchers for specific goods. A total of 934 farmers (households) will be selected to participate in the operation of the food voucher system. Participating farmers will receive training on *inter alia* hygiene, modalities of exchange and personal security.

The security of the voucher system is linked to the establishment of 150 new Agricultural Village Savings and Credit Associations (VSCAs) in the TR watershed. VSCAs will provide additional financial support to the voucher system, which will secure its effectiveness as a food relief mechanism, as well as considerably increase the potential for scaling up and replication throughout the region. To ensure that this system remains operational beyond the lifetime of the project, a network of village agents will be established, with their primary responsibilities being the monitoring of existing VSCAs and creation of new ones. Moreover, to optimise selected farming markets contributing to the implementation of the food voucher system, market performance will be monitored regularly, and the relevant adjustments made to the system where required. This process will be community-driven, led by the selected network of village agents. The exit strategy for the food voucher system links to the establishment of agroforestry systems for these same households as well as support in enabling community appropriate financial mechanisms include women-led ROSCAs (informal rotating savings and credit associations). So food vouchers would allow them to ensure there is interest and scope to implement agroforestry and this investment will then provide subsistence and cash to forego the vouchers.

Output 3 Strengthened governance and capacity for climate-resilient integrated water resources management (IWRM)

Output 3 of the project will contribute to GCF Outcome A5.0 — Strengthened institutional and regulatory systems for climate-responsive planning and development — and support the interventions under Output 2 focused on climate-resilient sustainable land management. This will be achieved by establishing the governance framework required to facilitate the adoption of a climate-resilient integrated water resources management (IWRM) approach in Haiti's TR watershed. Specifically, interventions under Output 3 will: i) strengthen national capacities for the implementation of the Water Act; ii) promote the adoption of an integrated, climate-resilient water management governance framework at the catchment and sub-catchment levels in the watershed; and iii) monitor the impact of IWRM plans and EbA interventions (Output 1) on flooding and water resources management in the TR watershed.

At present, the government is organised along departmental and communal lines. As a result, there is an overlap between existing water governance structures, particularly at the catchment and sub-catchment levels. This leads to challenges in coordination and planning, as well the effective and efficient implementation of an integrated approach to water resources management in the TR watershed. While the GoH has made good progress in drafting the Water Act to address these challenges, there is a need for technical assistance for the 'last mile' of its drafting. Under Output 3 the capacity of the GoH will be strengthened to develop and implement the Water Act, which is an essential legal foundation for enabling participatory, integrated water resources management in Haiti's TR watershed. This will involve: i) drafting provisions to Haiti's Water Act for the adoption of an integrated approach to water resources management; ii) establishing Catchment IWRM Committees (*Committes de GIRE des Bassins Versants;* CGBVs) within 31 catchments in Haiti; and iii) establishing Sub-Catchment Water Resource Users Associations (*Associations d'Usagers des Ressources en Eau du Sous-bassin versant;* AssURES) within the sub-catchments of the 31 catchments. These committees will work with different stakeholders in the 31 catchments and sub-catchments to manage the efficient use of land and water resources. Furthermore, the committees will be responsible for fostering community empowerment and ownership over these critical resources under future climate change conditions. Together, these activities will ensure that the Water Act is developed and implemented to respond not only to national level priorities, but also to the adaptation needs of vulnerable communities living in the TR watershed.

To support the implementation of the Water Act and the transition towards an integrated management structure for land and water resources in the TR watershed, a Catchment Water Resources Management Committee (CWRMC) will be established. This committee will work with representatives from productive sectors (e.g. agriculture), land users at sub-catchment level and Sub-Catchment Water Resources User Associations (SCWRUAs) to develop, implement and manage an inclusive, integrated water management governance framework in the watershed. This will involve these committees working together to develop climate-resilient IWRM plans, which define roles and responsibilities for end users that promote sustainable water resources management and an equitable distribution of the available resources at the catchment and sub-catchment levels. The CWRMC, together with the relevant land users, SCWRUAs, CGBVs and AssURES will ensure that the management of water resources in the catchment considers climate change impacts, particularly the expected impacts at landscape level as well as on upstream and downstream flow dynamics.

Ensuring that all adaptation interventions are monitored throughout the implementation phase is critical for facilitating adaptive management and assessing the effectiveness of these interventions in reducing climate change-induced flooding in the TR watershed. The implementation of EbA interventions under Output 1 , combined with the improved governance and capacity of relevant decision-makers and actors involved in land and water resources management (Output 2 and 3), is expected to reduce the impact of climate change-induced flooding on the TR watershed and communities living nearby, while concomitantly catalysing a shift from segregated land and water resources management towards the use of an integrated governance framework that is resilient to the impacts of such flooding. Moreover, these interventions will generate considerable health benefits for the vulnerable communities living in the TR watershed, reducing the spread of water- and vector-borne diseases as contamination of freshwater sources (e.g. rivers) and food is reduced.

To ensure that these adaptation benefits continue to be realised by all beneficiary groups throughout the project period, continuous health monitoring and impact evaluations will be undertaken under Output 3 This Monitoring and Evaluation (M&E) will commence at the end of Year 1 and will continue throughout the implementation phase until project closure. UNDP will commission an expert to undertake the health monitoring and impact evaluations of the EbA flood management solutions. The World Health Organisation (WHO) will provide technical support to this expert, as they are currently monitoring cases of water- and vector-borne diseases in Haiti and therefore have a pre-defined methodology that would allow comparison studies to be undertaken across watersheds. The contracted expert will be responsible for: i) undertaking a baseline assessment of the prevalence of water- and vector-borne diseases within the TR watershed; ii) analysing the impact of climate change-induced flooding on the spread of these diseases; and iii) assessing and reporting on the health benefits of the adaptation interventions implemented under the project, particularly the reduced spread of water- and vector-borne diseases as a result of implementing EbA interventions under Output 1. Finally, lessons generated through the implementation of all project interventions will be shared through the relevant committees and associations at the catchment and sub-catchment levels to inform adaptative management of these interventions under future climate change conditions.

Project activities that will be implemented under Output 3. are summarised below. Further details on these activities, including on the associated sub-activities and deliverables, are presented in Section E.6 of this Funding Proposal and Section 9 of Annex 2: Feasibility Study.

Activity 3.1Strengthen national capacities for the implementation of the Water Act

Under this activity, the capacity of the GoH will be strengthened to develop and implement the Water Act, which is an essential legal foundation for enabling participatory, integrated water resources management in Haiti's TR watershed. At present, the government is organised along departmental and communal lines. As a result, there is an overlap between existing water governance structures, particularly at the catchment and sub-catchment levels. This leads to challenges in coordination and planning, as well the effective and efficient implementation of an integrated approach to water resources management in the TR watershed. While the GoH has made good progress in drafting the Water Act to address these challenges, there is a need for technical assistance for the 'last mile' of its drafting. Under Activity 3.1 provisions will be drafted to the Water Act to ensure that it promotes an integrated approach to water resources management, including considerations for the coordinated development of water, land and related resources. This will contribute towards: i) maximising economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems under future climate change conditions; and ii) facilitating efficient, integrated adaptation responses to the impacts of climate change in Haiti. Provisions to the Water Act will also recommend the establishment of Catchment IWRM Committees (*Committes de GIRE des Bassins Versants, CGBVs*) within each of the 31 catchments in the country, and the establishment of Sub-Catchment Water Resource Users Associations (*Associations d'Usagers des Ressources en Eau du Sous-bassin versant*, or AssURES).

Activity 3.2. Develop an integrated, climate-resilient water management governance framework targeting the catchment and sub-catchment levels in the Trois-Rivières watershed

Given that the TR watershed is one of the most vulnerable watersheds in Haiti to climate change-induced flooding, the implementation of an integrated water resources management strategy is a priority action for increasing the climate resilience of its population. Under this activity, an inclusive and equitable water management governance framework will be developed for the TR catchment, namely the Catchment Water Resources Management Committee (CWRMC). This committee will work with representatives from productive sectors (e.g. agriculture), land users at sub-catchment level and Sub-Catchment Water Resources User Associations (SCWRUAs) to achieve two main goals. First, these groups will work together to develop climate-resilient IWRM plans for end users at the sub-catchment and catchment levels that promote sustainable water resources management and an equitable distribution of the available resources among all users. The IWRM plans will define roles and responsibilities of institutions and civil society stakeholders for water resources management (complementary to the decentralised management of water resources to be established in the Water Act under Activity 3.1). It will also promote a landscape management approach that will be linked to the implementation of community land-use plans (Activity 1.1), considering gender dynamics. Second, the CWRMC, together with the relevant land users and SCWRUAs, will ensure that the management of water resources in the catchment considers climate change impacts, particularly the expected impacts at landscape level as well as on upstream and downstream flow dynamics. Training on the climate-resilient IWRM plans will also be delivered focusing on the application of these plans in decision-making. The combined result of these actions will be the establishment and operation of an integrated governance framework that will contribute to preserving climate-resilient, sustainable land and water resources management beyond the lifetime of the project. During the implementation of Activity 2.2 considered efforts will be made to securing equitable representation, participation and leadership of women.

Activity 3.3. Implement regular monitoring and evaluation of water resources at the catchment and sub-catchment levels to support the implementation of integrated water resources management (IWRM) plans

From project inception (Year 1), continuous health monitoring and impact evaluations will be undertaken and will continue throughout the implementation phase. The implementation of EbA solutions under Output 1of the project are expected to significantly reduce the extent of climate change-induced flooding in the TR watershed and reduce erosion caused by extreme rainfall events. Such reductions in flood extent are also likely to reduce the spread of water- and vector-borne diseases, as contamination of freshwater sources (e.g. rivers) and food is reduced. By monitoring the evolution, frequency and location of flood-related illnesses from the start of the project, the impact of the project can be assessed once a sufficient time series of observations is completed. UNDP will commission an expert to undertake the health monitoring and impact evaluations of the EbA flood management solutions. The World Health Organisation (WHO) will provide technical support to this expert, as they are currently monitoring cases of water- and vector-borne diseases in Haiti and therefore have a pre-defined methodology that would allow comparison studies to be undertaken across watersheds. The contracted expert will undertake a baseline assessment of the prevalence of water- and vector-borne diseases within the TR watershed and analyse the impact of climate change-induced flooding on the spread of these diseases. Following this assessment, the expert will report on her/his findings and provide the required health impact data to assess the health benefits of the EbA interventions implemented under the project. Simultaneously, this expert, assisted by representatives from SCWRUAs, will monitor dry season baseflow at four locations along the main stem of the Trois-Rivières (TR) river. This will be done to provide a stable indicator of the increased infiltration capacity of the soil because of forest rehabilitation and restoration activities to be implemented under Activity 1.2 of the project. The monitoring will facilitate an evidence-based assessment of these EbA solutions as effective measures for reducing the impacts of climate change-induced flooding in the TR watershed and for improving the health of the watershed's population. Finally, lessons generated through the implementation of all project interventions will be shared through the relevant committees and associations at the catchment and sub-catchment levels to inform adaptative management of these interventions under future climate change conditions.

Site selection

While most of Haiti is at risk to the impacts of climate change, the country's Trois-Rivières (TR) watershed (which extends across the Artibonite, North and North-West Departments) has been identified as particularly high-risk[475]. Two of these areas were identified as most vulnerable to climate hazards — including *inter alia* cyclones, floods, droughts and earthquakes — in the climate hazard

[475] according to four different studies and assessments (including Oxfam's).

vulnerability assessment for the Republic of Haiti's NAPA (2006)[476];[477] performed by Mathieu et al.[478] (Table 8). Specifically, the four most vulnerable departments that are, in descending order of vulnerability: i) the North-West department; ii) the South department; iii) the West department; and iv) the North department. These priority areas were further confirmed in the updated version of the NAPA published in 2017[479]. The Artibonite and South-East departments were also added to the list of highly vulnerable departments. The North-East and the Centre are the least affected.

Table 8. Climate risk vulnerability assessment as per the study done by Mathieu et al. (OXFAM study) — a lower number represents a higher risk.

Department Hazard	Cyclone	Flooding	Drought	Earthquake/Tsunamis	Total
North-West	5	4	1	2	12
South	1	3	3	6	13
West	4	1	6	5	16
North	7	5	4	1	17
Grand-Anse	2	7	9	3	21
South-East	3	6	5	8	22
Artibonite	9	2	8	4	23
North-East	6	9	2	7	24
Centre	8	8	7	9	32

The prioritization of these departments is further highlighted when taking into account the country's socio-economic and environmental contexts. Although the Three Rivers watershed is not the largest watershed in the country, its population — located in six cities and three departments — is highly vulnerable to the impacts of climate change. TR watershed is prone to frequent flooding in the municipalities it crosses, with adverse effects particularly on poor communities who do not have sufficient resources to adequately respond. The rural areas of Trois-Rivières — such as Marmelade, Plaisance, Pilate, Gros-Morne, Bassin Bleu, Chansolme, and Port-de-Paix — are home to 80% of Haiti's population of extremely poor people. These areas have an extreme poverty rate of 40%, which is almost twice the national average of 23.9%, and much higher than any other area (for comparison, Port-au-Prince has an extreme poverty rate of 4.9%). In addition to the high rate of poverty, which inhibit communities from adapting and responding to climate impacts, the impacts of extreme climate events are being compounded by ecosystem degradation caused by unsustainable agricultural practices such as the increasing area under crop cultivation, and particularly the practice of leaving soil bare and exposed to extreme weather for most of the year. During intense rainfall and storm events that cause flooding, the limited ground cover leads to increased surface runoff and consequently exacerbates soil erosion in the watershed. This erosion is compounded by extensive deforestation in the mountainous parts of the watershed, primarily linked to charcoal production. The demand for charcoal in Haiti is high because of its use as a primary source of fuel to meet household energy demands. This demand is unlikely to decrease in the foreseeable future, with many farmers in the TR watershed resorting to charcoal production as an alternative livelihood in response to low yields, crop failure or unexpected expenses (particularly in extremely wet or dry years). As a result, most of the native forests have been harvested, with minimal effort towards reforestation activities[480].

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476 Haiti - National Adaptation Programme of Action (2006)

477 The NAPA defines a set of priority activities to promote adaptation in the Least Developed Countries (LDCs) that will enable them to become resilient against future with climate change threats. A participatory and decentralised approach was used in the preparation of the Haiti's NAPA so that the document would adequately reflect the expectations of all communities, particularly the most vulnerable in the country. This approach was implemented in 2006 by a NAPA formulation team supported by another multi-sectoral team whose mission was to work together to ensure the success of the work. In addition, at the country level, departmental teams were formed and involved in the process. These teams made it possible to clearly identify vulnerability in their respective areas and, at the end of the work, to come up with priority options that were highly relevant to the findings, as well as highly appropriate activities.

478 Mathieu, P., Constant, JA., Noël, J., Piard, B. Cartes et étude de risques, de la vulnérabilité et des capacités de réponse en Haïti

479 Haiti - National Adaptation Programme of Action (2017)

480 World Bank. 2017. Charcoal in Haiti. A National Assessment of Charcoal Production and Consumption Trends. World Bank, Washington. Available at: http://documents.worldbank.org/curated/en/697221548446232632/pdf/134058-CharcoalHaitiWeb.pdf.

These practices have radically changed the TR watershed's natural landscape, where the large-scale removal of tree cover has decreased infiltration capacity of the soil and contributed to increased surface runoff during heavy rainfall events. This, in turn, has considerably increased flood frequency and intensity in the TR watershed, with floods washing away fertile soils and causing sedimentation of riverbeds and blocking drainage infrastructure. Given the near-complete absence of embankments and levees in the watershed, this cycle then intensifies the next round of flooding, leading to the destruction of crops, farmland and agricultural infrastructure, as well as the loss of livestock and human lives[481]. Vulnerable communities that depend on agriculture for their livelihoods will be particularly affected by the increased flooding, exacerbating the adverse economic, environmental and social conditions already being experienced in the area.

The overall target area for restoration and reforestation is 254.4 km^2, comprising 77 km^2 for reforestation and 177.4 km^2 for agroforestry. These targets are based on the outputs of a multicriteria analysis which considered elevation, housing density, proximity to water sources and farm area within the seven target communes. The total target area for agroforestry assumed a participation ratio of 75% in priority areas, and only 35% in non-priority areas. Non-priority areas for agroforestry included all farm areas in the seven communes that were not classified by the multicriteria analysis as priority areas. Further details on the inputs into the multicriteria analysis and the adjustments made to reach the final targets are presented below.

10.1. Selecting the priority watershed

The selection of the Trois-Rivières (TR) watershed was based on the prioritization of the Haiti NAPA (National Adaptation Programme of Action) (2006 and updated 2017). The NAPA prioritizes adaptation actions and activities for the entire country based on a methodology including a stocktaking exercise of existing reports and studies, field data (when available) and stakeholder consultations. The information was compiled and then a series of simulations was run to arrive at a multi-criteria prioritization. The final list of priority activities for adaptation from the NAPA are:

Option 1: Watershed management and soil conservation

Option 2: Coastal zone management

Option 3: Valorization and conservation of natural resources

Option 4: Preserving and strengthening food security

Option 5: Water Protection and Conservation

Option 6: Construction and rehabilitation of infrastructure

Option 7: Waste management

Option 8: Information, Education and Awareness

This indicates watershed management and soil conservation as the top activity to be prioritized in the country. The 2017 PANA update confirms this prioritization and reinforces agriculture and climate resilient livelihoods, and watershed management as top 3 priorities. In terms of regions, the NAPA carries out a similar exercise considering risk of cyclones, flooding, drought and earthquakes and tidal waves. In this exercise, the South, West, Northwest and Artibonite regions are prioritized for interventions. This project site, the TR watershed, is located in the Northwest and Artibonite regions. The other top priority regions are the South (where FAO is developing its own GCF proposal) and Ouest (where the capital Port-au-Prince is located, where most of the international donations are delivered, rendering the value add of the GCF intervention to be much smaller, and where the prioritized activity of watershed management would have limited scope of being

[481] OXFAM, Welt Hunger Life, NATHAT, and Cap-Haitien.

implemented due to dense urbanization). Three additional criteria support the choice to select the TR watershed as the project site:

1. Poverty context: Although the TR is not the largest watershed in the country, its population — located in six cities and three departments — is highly vulnerable to the impacts of climate change. TR watershed is prone to frequent flooding in the municipalities, with adverse effects particularly on poor communities who do not have sufficient resources to adequately respond. The rural areas of Trois-Rivières — such as Marmelade, Plaisance, Pilate, Gros-Morne, Bassin Bleu, Chansolme, and Port-de-Paix — are home to 80% of Haiti's population of extremely poor people. These areas have an extreme poverty rate of 40%, which is almost twice the national average of 23.9%, and much higher than any other area (for comparison, Port-au-Prince has an extreme poverty rate of 4.9%), which inhibit communities from adapting and responding to climate impacts.

2. Existing support to adaptation: Currently foreign aid accounts for more than half of Haiti's national budget and the country received USD13 billion in international aid between 2010 and 2021[482]. However, the funding is allocated very heterogeneously across topics and regions. There are few adaptation projects generally and even fewer in the TR watershed, which historically has been overlooked in terms of funding for development and climate change projects[483]. Therefore, the additionality of GCF funds is much higher in this region compared to others.

3. Land degradation: The impacts of extreme climate events in the TR watershed are being compounded by ecosystem degradation caused by unsustainable agricultural practices such as the increasing area under crop cultivation, and particularly the practice of leaving soil bare and exposed to extreme weather for most of the year. During intense rainfall and storm events that cause flooding, the limited ground cover leads to increased surface runoff and consequently exacerbates soil erosion in the watershed. This erosion is compounded by extensive deforestation in the mountainous parts of the watershed, primarily linked to charcoal production. The demand for charcoal in Haiti is high because of its use as a primary source of fuel to meet household energy demands. This demand is unlikely to decrease in the foreseeable future, with many farmers in the TR watershed resorting to charcoal production as an alternative livelihood in response to low yields, crop failure or unexpected expenses (particularly in extremely wet or dry years). As a result, most of the native forests have been harvested, with minimal effort towards reforestation activities[484]. These practices have radically changed the TR watershed's natural landscape, where the large-scale removal of tree cover has decreased infiltration capacity of the soil and contributed to increased surface runoff during heavy rainfall events. This, in turn, has considerably increased flood frequency and intensity in the TR watershed, with floods washing away fertile soils and causing sedimentation of riverbeds and blocking drainage infrastructure. Given the near-complete absence of embankments and levees in the watershed, this cycle then intensifies the next round of flooding, leading to the destruction of crops, farmland and agricultural infrastructure, as well as the loss of livestock and human lives[485]. Vulnerable communities that depend on agriculture for their livelihoods will be particularly affected by the increased flooding, exacerbating the adverse economic, environmental and social conditions already being experienced in the area.

10.2. Priority intervention sites

[482] https://www.nytimes.com/2021/07/08/world/haiti-foreign-aid.html
[483] Haiti - Update of the National Adaptation Programme of Action (2017)
[484] World Bank. 2017. Charcoal in Haiti. A National Assessment of Charcoal Production and Consumption Trends. World Bank, Washington. Available at: http://documents.worldbank.org/curated/en/697221548446232632/pdf/134058-CharcoalHaitiWeb.pdf.
[485] OXFAM, Welt Hunger Life, NATHAT, and Cap-Haitien.

The priority areas for the implementation of agroforestry and reforestation interventions in the TR watershed were defined using a multicriteria model that considered three variables. These were the slope of the terrain, distance from river channels and a maximum natural vegetation cover of 50%. Data from the ALOS DSM model — a global digital surface model with a 30-metre spatial resolution pixel, generated from the Panchromatic Remote-Sensing Instrument for Stereo Mapping (PRISM) on the ALOS satellite — was used to run the multicriteria model[486]. Specifically, it was used to determine the slope of the terrain starting from the relevant riverbeds within the project area. The results from the analysis undertaken show that ~60% of the priority areas are recommended for reforestation and ~40% of the priority areas are recommended for agroforestry. The map below (Figure 38) contextualises the location of the priority intervention sites, which are presented in Figures 41a, b, c, and d below.

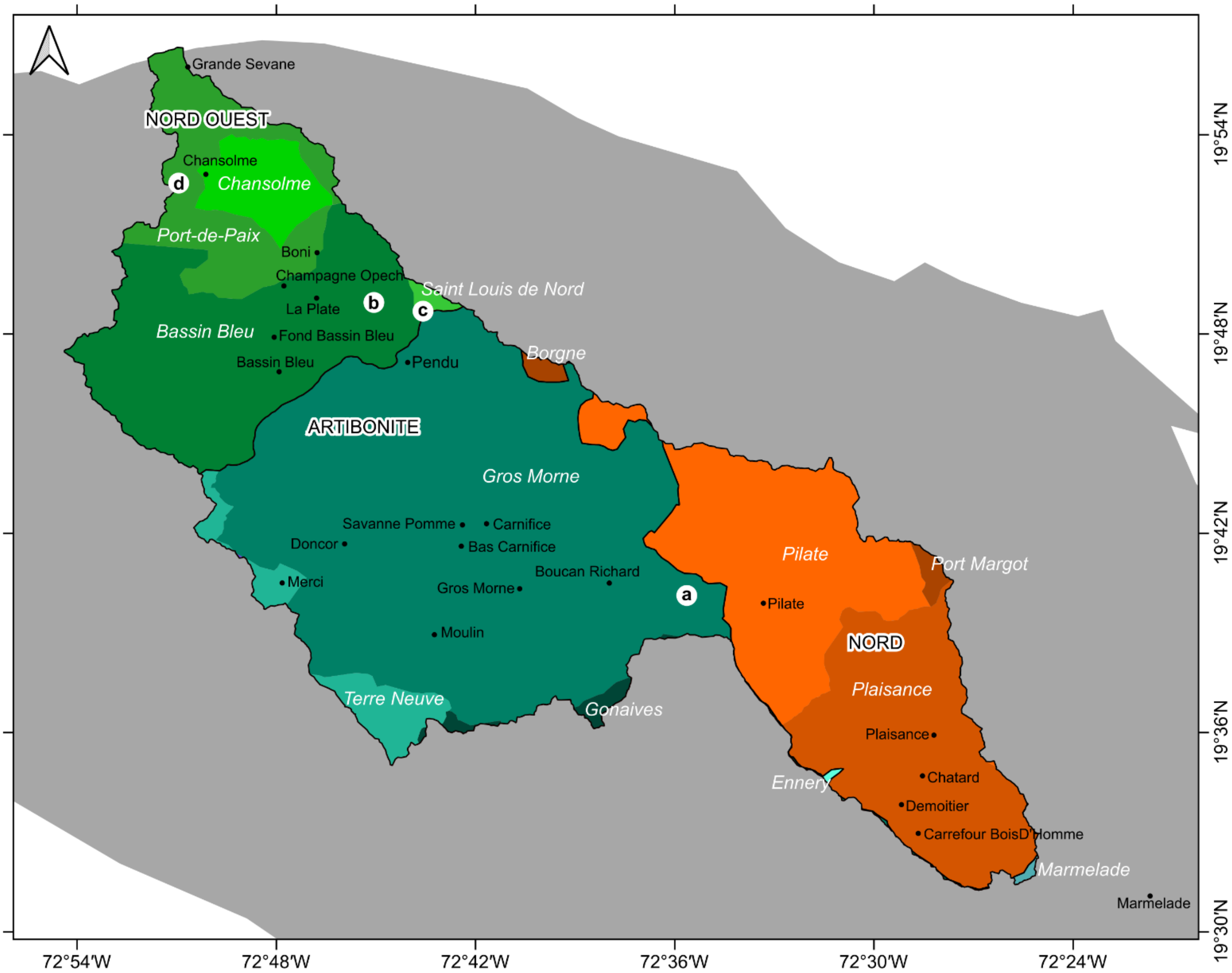

Figure 38. Map showing the northern part of Haiti where the priority intervention sites are located[487].

Within the project area, only land with a slope above 36% was considered for prioritisation and areas close to rivers received greater values (higher priority) than areas further away from rivers. This is because areas close to rivers are subject to greater erosion than areas further away from riverbanks. The resultant prioritisation value from these two variables was indexed to be between 0 and 1. These

[486] ALOS Global Digital Surface Model "ALOS World 3D — 30m (AW3D30)". No date. Available at: https://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm
[487] Nations online. No date. Political map of Haiti. Available: https://www.nationsonline.org/oneworld/map/haiti_map.htm

indexed variables were then added to create a priority index (Figure 39). Polygons with priority index values above the 90th percentile were defined as high priority areas, and polygons with values between the 30th and 90th percentile as medium priority areas. Low priority areas were therefore defined as polygons with values below the 30th percentile. Areas with natural vegetation cover over 50%, according to Global Forest Watch data, were not considered. All analyses used the Google Earth Engine[488] platform to provide 3D satellite imagery of potential project target areas — upon which modelling outputs could be overlaid.

$$\text{Normalized slope: } DN = \frac{\text{Slope} - \text{Minimum slope}}{\text{Maximum slope} - \text{Minimum slope}}$$

$$\text{Indexed water bodies distance: DistW} = \left(\frac{\text{Distance} - \text{Mínimum Distance}}{\text{maximum Distance} - \text{Mínimum Distance}}\right)^{-1}$$

$$\text{Being the Priority Index: Index\_priority=DN+DistW}$$

Figure 39. The equations used to determine the priority index.

The survey and geographical identification of every house in the project area also contributed to determining the impact of floods with a 100- and 20-year statistical return period (floods which are expected to occur once every 100 and 20 years, respectively). This was done by correlating the shapefiles of the hydrological scenarios of surface runoff and flooding, based on three climate models, with the survey of houses completed by the modelling team.

The outputs from the model confirmed that the most appropriate means of reducing surface runoff, and consequently attenuating the impacts of flooding, is by focussing the agroforestry and reforestation efforts in higher altitudes and in areas with steep slopes. This is shown in Figure 40, which highlights the priority areas with a terrain elevation model of the project area. Consequently, the terrain elevation models indicate that 15.6 km² of land should be classified as of high priority, 75.46 km² should be classified as of medium priority and 86.46 km² should be classified as of low priority for implementation of agroforestry and reforestation interventions in the TR watershed. These values were used as inputs into the multicriteria analysis in determining the project area (see Section 10.2 below).

488 Google. No date. Earth Engine. Available at: https://earthengine.google.com/

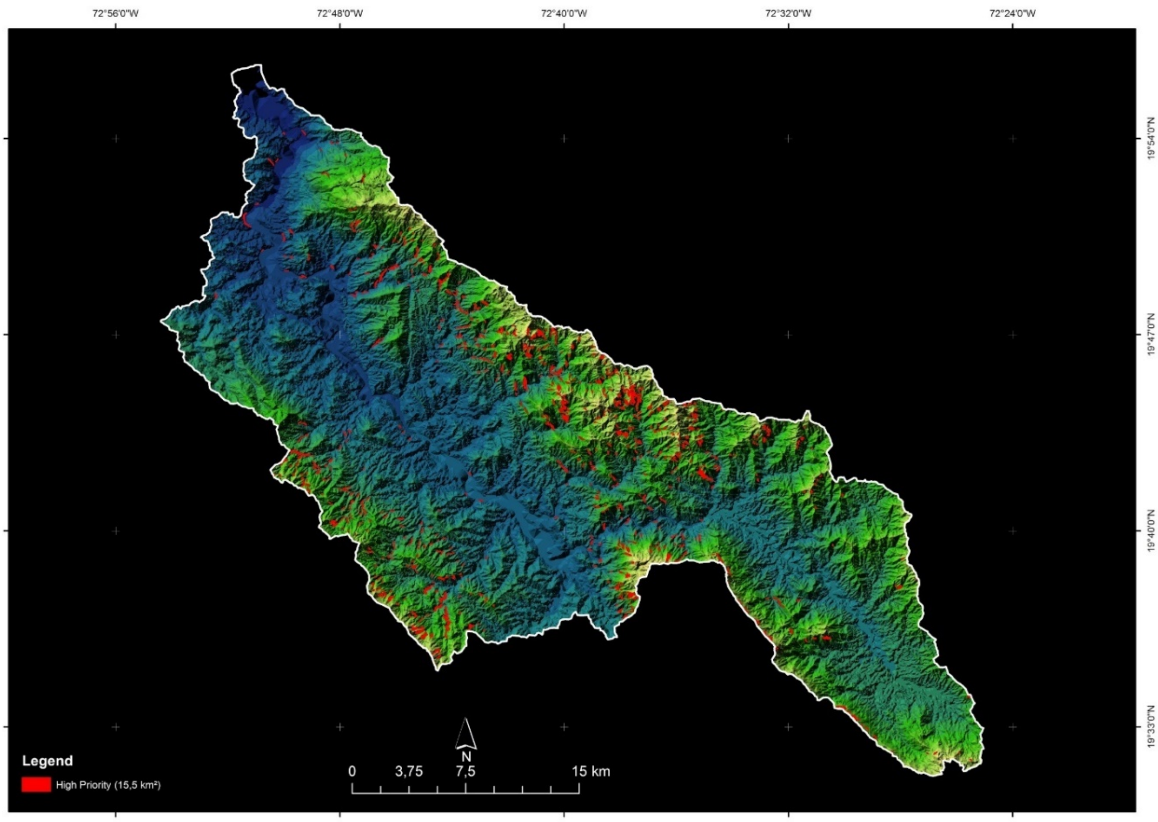

Figure 40. Terrain elevation model of the TR watershed showing high priority areas for agroforestry and reforestation interventions in red. The blue areas show lower elevations, whilst green areas indicate higher elevations.

10.3. Land use types among priority areas

Once the polygons identified as priority areas were established, the multicriteria model was then built to classify the optimal land use of each polygon into two intervention options, agroforestry or reforestation. The key variables used to classify polygons were density of houses/buildings and proximity to rivers and/or water sources. Because the implementation of agroforestry as part of the proposed project is most appropriate with a low cost to benefit ratio, it is best suited for areas with a high density of houses and near water sources.

To calculate density of buildings, the model required an optical survey to geographically identify every structure in the project area using WorldView-3 satellite images with a 30 cm spatial resolution[489]. The survey identified 72,962 houses/buildings, each with coordinates unique to their location. On the basis of this data, a building point layer was created and used in both models as well as in the assessment of flood impacts with and without project interventions, as described below. Building locations were then used to calculate the density of the coordinate points using a kernel function with a 700 m radius. As a result, the density of buildings was used as an input to provide the model with the number of buildings in a 700 m radius, for each pixel in the satellite images. Based on this, the model tends to give higher priority to agroforestry interventions in places with a higher concentration of buildings/houses.

The hydrographical information was the same used to model the priority classes' areas and was delivered by the project personnel to the modelling team. In this model, the criteria used was the density of houses and the distance from rivers. Areas closer to rivers and with a greater density of houses received greater prioritisation values than the areas further away from them, and with a low density of buildings. Both variables were indexed to be between 0 and 1. These indexed variables

[489] Digital Globe. No date. WorldView-3 Satellite Imagery. Available at: http://worldview3.digitalglobe.com/

were then added to create a heat map on top of which the original polygons — along with the priority classes — were plotted.

Afterwards, the mean value of the sum of all pixels within each of the polygons was calculated. This average mean value was used as the reference value to select either agroforestry or reforestation as the most suitable intervention strategy. The selection between agroforestry and reforestation was set to happen at 50% of the reference value. Pixel values were averaged for all 5,552 priority polygons and the totality of the polygons was classified into 100 parts. When using the 50th percentile to choose the type of intervention (reforestation or agroforestry) in the 5,552 priority polygons for environmental recovery that were generated by the prioritization model, areas that had an average pixel value below that of the 2,776th polygon were prioritised for agroforestry, and those with a value above that were prioritised for reforestation. This classification ensured that the priority areas in closer proximity to houses and built-up areas — which are often the most likely areas within the TR region chosen to be converted to agroforestry — were classified as proposed agroforestry plots under the project. Conversely, more remote areas were classified as reforestation intervention areas for the proposed GCF project. Figures 37a, b, c and d below demonstrate the results of this classification method for several areas within the TR catchment. The results show that ~60% of the priority areas are recommended for reforestation and ~40% of the priority areas are recommended for agroforestry. Table 9 shows the statistics for each priority class for both the reforestation and agroforestry interventions within the project area.

Table 9 Number of polygons and corresponding priority areas for the reforestation and agroforestry intervention options before participation rates are accounted for.

Intervention option	Number of polygons	Priority Area (km²)	Area (%)
Reforestation	3,339	105.87	59.77
Agroforestry	2,332	71.25	40.23

Results from the multi-criteria analysis indicates that a total of 177.12 km^2 (rounded to 177.2 km^2 to include the entire recommended priority area) should be set aside for implementing both agroforestry and reforestation interventions. This priority area assumes a 100% uptake rate of interventions. However, it is anticipated that only 75% of farmers will adopt agroforestry practices in the priority areas (see below).

Within the total area, the extent of priority areas for reforestation and agroforestry, as well as the extent of non-priority areas for agroforestry alone, were then determined. Priority areas for reforestation were classed as agricultural land where agroforestry will be introduced, and communal land where reforestation will occur. Since not all agricultural land where agroforestry will be introduced is classed as a priority area for reforestation, the actual area reforested (through the introduction of both agroforestry and reforestation) under the project will be larger than the prioritised areas. This will extend beneficiary farmers within the TR catchment beyond target communities whose land falls within priority zones.

Table 9 shows the total number of farmers, as well as the number of the ~75% of farmers that are member of a farmers' association. Based on the average farm sizes in each commune (0.985 ha per farm), this results in a total area of approximately 392 km^2 that is being farmed by association members. 75% of a total of 51,565 farms in the TR catchment is equivalent to ~38,673 farms owned by farmers who belong to a farmers' association. With an average farm unit size of 0.00985 km^2, this indicates that the total area of agricultural land available for intervention within the catchment is ~381 km^2. The resulting reforestation area sizes, disaggregated by community, is shown in Table 10. Of the 392.81 km^2 deemed to be suitable for agroforestry-related activities, 100.2 km^2 is classed as priority land. The remaining 292 km^2 (total area of farms owned by associated farmers minus the total area of priority land) is classed as non-priority.

Table 101. Overview of the number of farms and the 75% of associated farms, and the area that they represent.

Community	Number of farms within the TR catchment	Number of potential participants (75% of associated farmers)	Agricultural area (association members, km^2)
Port-de-Paix	5,028	3,771	45.48
Chansolme	4,085	3,064	26.15
Bassin-Bleu	4,739	3,554	29.41
Gros-Morne	16,739	12,554	131.00
Plaisance	11,808	8,856	86.01
Pilate	8,311	6,233	69.21
Marmelade	855	641	5.55
Total		**38,673**	**392.81**

Participation of farmers that own and/or farm within priority areas will be considerably higher than that of farmers in non-priority areas, for two reasons. First, these areas will be included as priority areas for the introduction of agroforestry in communal land use plans. Second, since these areas are at high risk of degradation (because of, *inter alia*, limited existing land cover and steep gradients of slopes), the benefits that a farmer can achieve from the introduction of agroforestry are high, making a strong case for the transition to agroforestry. The expected rate of farmers' participation in these areas is therefore assumed to be 75%, whereas for non-priority areas participation is estimated at 35%. This will result in a transition to agroforestry systems in approximately 75.2 km^2 out of the total 100.2 km^2 that will be reforested by farmers. Similarly, 102.2 km^2 of non-priority communal land will be set aside for agroforestry. This will bring the total area of land under the proposed project where agroforestry will be implemented to 177.4 km^2 and to 77 km^2 for reforestation (no discount on participation rate) (Table 11). Therefore, when estimated participation rates are considered, a total of 254.4 km^2 out of the potential 469.2 km^2 will be targeted for reforestation and agroforestry interventions. The total area of 177.4 km^2 set aside for agroforestry corresponds to ~18,000 beneficiary farmers (with individual farms measuring an average of 0.985 ha in the catchment). Overall, the existing forested area within the TR catchment, i.e. 308 km^2, is set to increase by over 80%. Resultantly, the target catchment's forested area will increase from a baseline of 34% to 62% upon successful project completion — an increase well above the minimum of 20–30%, required to have a meaningful impact on the hydrology and resilience to flooding of the catchment.

Table 2. Total impact area, with the areas for each priority class per activity specified.

					Priority class			
		Total Area	Participation (%)	Impact area (km^2)	High	Medium	Low	No priority
Reforestation		77.0	100 %	77.0	36.3	30.3	10.4	0.0
	Priority	100.2	75%	75.2	33.4	36.8	5.0	0.0

Agroforestry	**Non-priority (assoc. farm area, minus priority area)**	292	35%	102.2	0.0	0.0	0.0	28.6
Total impact area				**254.4**				

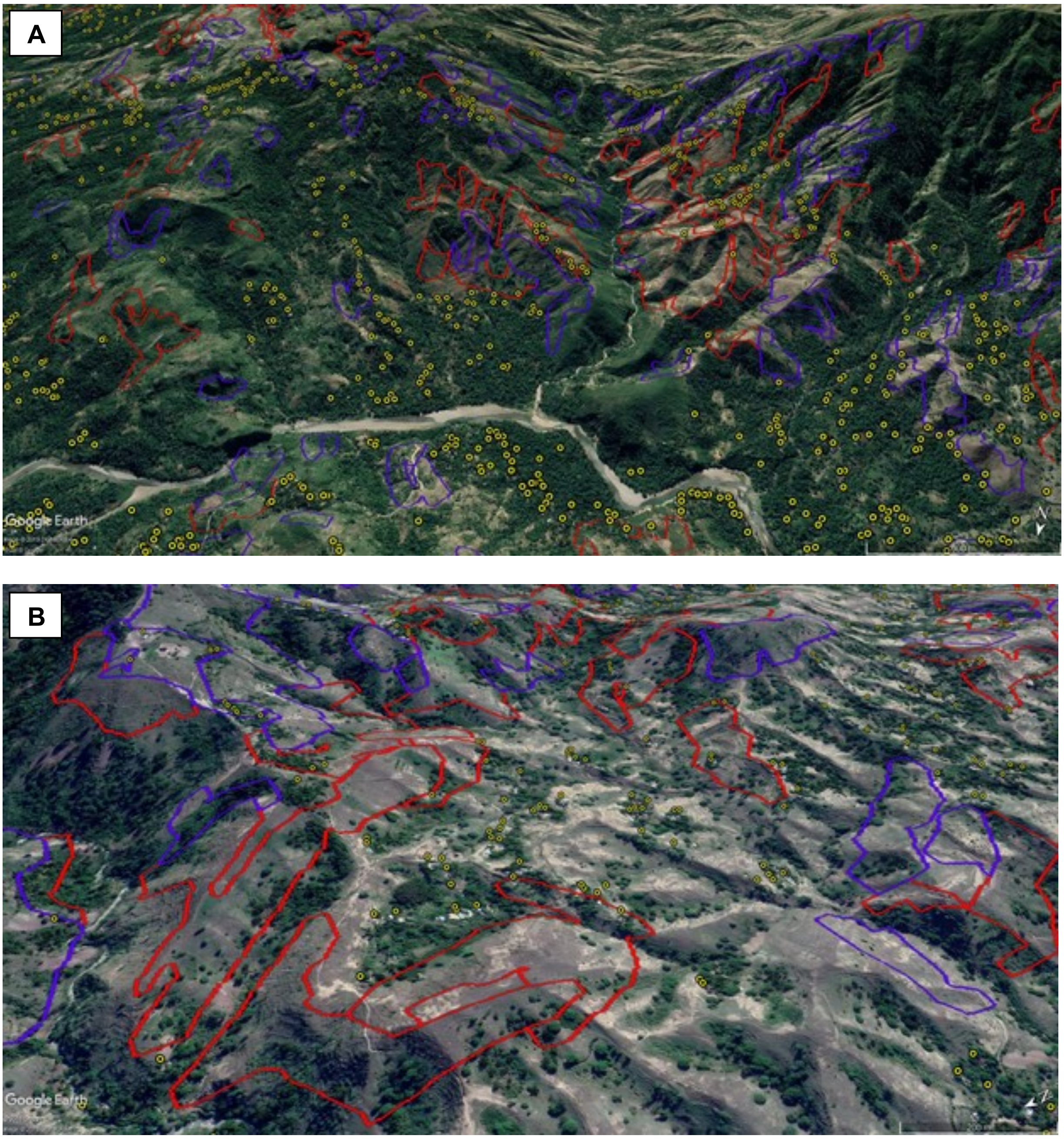

Figure 41a and b. Priority areas for reforestation (blue polygons) and priority areas for agroforestry (red polygons) interventions for various areas within the TR catchment, demonstrating the results from the classification method. a) Department Artibonite, Gros Morne Commune, Boucan Richard Section; and b) Bassin Bleu Commune, Nord Ouest Department, La Plate Section.

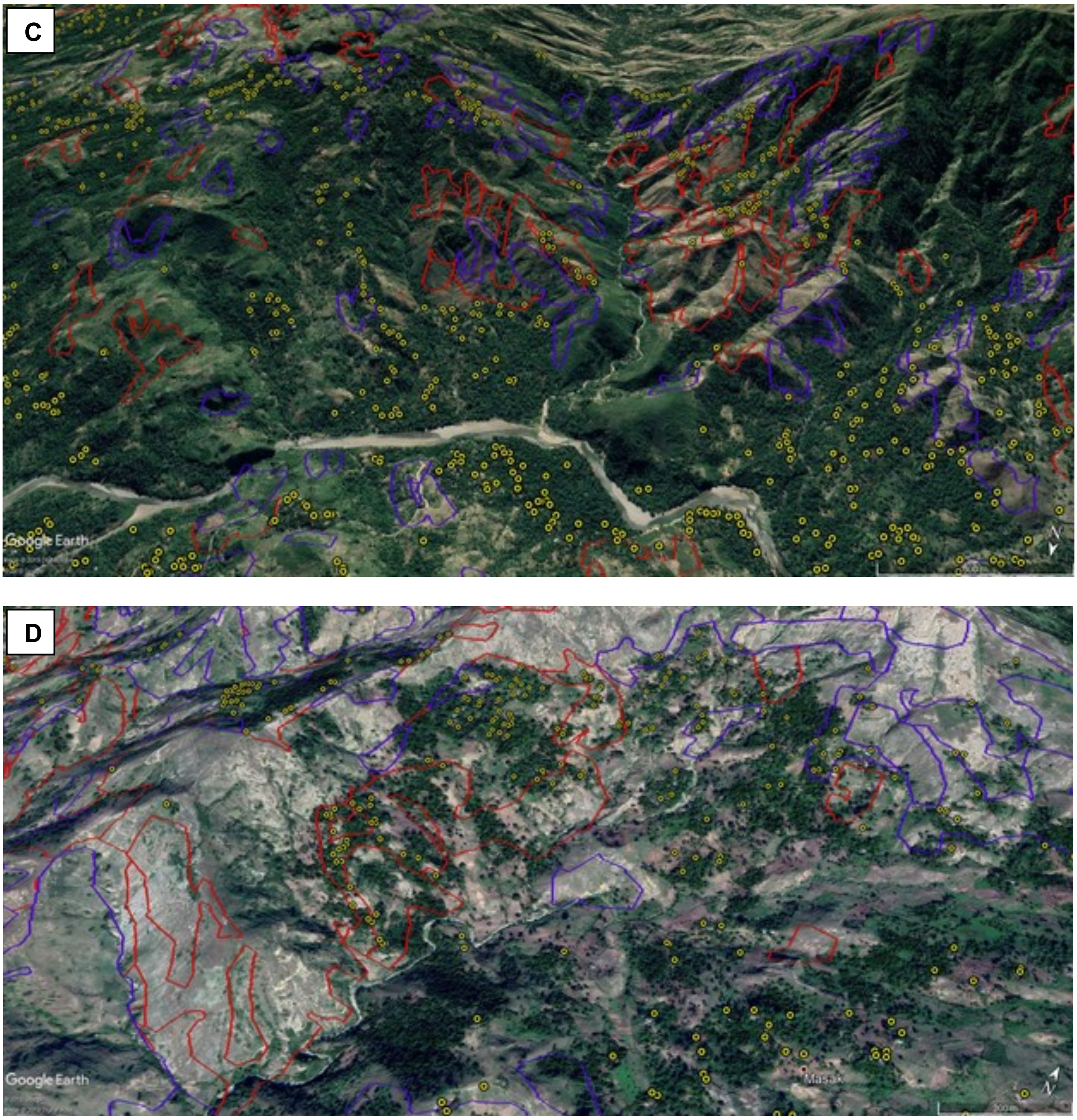

Figure 41c and d. Priority areas for reforestation (blue polygons) and priority areas for agroforestry (red polygons) interventions for various areas within the TR catchment, demonstrating the results from the classification method. c) near Masak, in the Saint Louis du Nord Commune, Lafagne/Chamoise Section; and d) near Nan Jean Louis in Port de Paix Commune, La Corne Section.

Calculation of Direct and Indirect Beneficiaries

The identification of direct beneficiaries takes into account populations that receive both direct support as a result of project interventions while also receiving adaptation benefits in the form of flood protection, increased capacities for adaptation, food and water security.

Indirect benefits is identified as the population that receives indirect support from the project and is benefited indirectly by the project through increased household income and improved land management as well as the project's various co benefits.

Through its implementation the project will provide direct benefits to 292,600 people and 441, 272 people, thus accounting for the population residing along the TR watershed.

Output	**GCF Result Area**	**Adaptation Benefits Description per Output**	**Direct Beneficiaries**	**Indirect Beneficiaries**	**Methodology and Assumptions**
1. Ecosystem-based flood management solutions implemented in 25,440 hectares of the Trois-Rivières watershed	ARA 1 & 4	Flood protection from EBA/ Reduction in losses and damages from floodings	**Number:** At least 292,600 • People identified living 30 meters from the river or its tributary edge. • The total number also includes the following: ○ 54,252 male and female farmers within the 33 communal sections (13,921 women and 40,331 men) ○ 99 leaders of grassroots community organizations (CBOs) ○ 99 CASECs and 363 ASECs as these are elected officials gender desegregation will be calculated during project implementation	**Number**: At least 441,272 people (2019 population estimates)	**Targeted Support:** Population residing/economically dependent on/or with land within the priority target areas identified through the multi criteria modelling or in communal areas directly adjacent to these that is willing to participate (*REF: Figure 3a and 3b within the FP for priority areas*) and will receive support resulting in the implementation and maintenance of sustainable agroforestry models and the rehabilitation of forests (water towers) guided by community land use plans. • Members of farmers associations within the 33 targeted communal sections selected will be initially targeted • Women members of farmers associations within the 33 targeted communal sections selected will be initially targeted • Community leaders within the 33 targeted communal sectors as identified by their communities (through social screening processes) will be initially targeted **Adaptation Benefit:** Population living 30 meters near the river edge or the river's tributaries will receive

					flood protection from EBA interventions. **Indirect Beneficiaries:** People that reside in target areas (33 sub communal sections within the project's 7 communes) that will benefit from the improved land planning. Information calculated based on results of 2003 National Census with projected population growth rates to 2019 (See Annex 3) minus the number of direct beneficiaries [441,272 direct beneficiaries]
Adaptation beneficiaries under ARA 1 & 4			**Direct Beneficiaries** 292,600 (Male: 140,448, Female: 152,152)	**Indirect Beneficiaries** 441,272 (Male: 211,811 Female: 229,461	See above.
2. Climate-resilient agricultural practices, optimised value chains and social safety nets established to promote SLM and reduce degradation in the Trois-Rivières watershed	ARA 2	Enhanced productive capacity and improved (climate smart) water management resulting in increased food security and increased land productivity	**Number**: 57,9884 • 5,400 people through a farmer field school approach (180 groups of 30 farmers) along the 33 communal sections • • Adaptation interventions and training on the implementation of climate-resilient agricultural techniques and sustainable land management will be provided to farmer's associations within each of the 33 communal sections and will be open to all members (total 54,252 farmers within the 33 communal sections (13,921 women and 40,331 men)) • 3,736 (1,943 women and 1,793 men) members of household receiving food coupons (934 times 4)	**Number**: 217,008 • Members of the households of the associated farmers that will benefit from increased household incomes	**Targeted Support:** Producers within the 7 communes in the Trois-Rivières watershed (Port-de-Paix, Chansolme, Bassin Bleu, Plaisance, Pilate, Marmelade, Gros Morne) that will receive technical capacity building, training and support for sustainable land management and agriculture techniques, and adaptation interventions and in the establishment/enhancement of VSCAs as a means to mobilize their own savings. In the case of those most vulnerable, food coupons will be provided. - **Adaptation Benefit:** all members (total 54,252 farmers within the 33 communal sections) that adopt climate-resilient sustainable land-use practices and as a result increase their incomes and food security This also accounts to the members of 934 the households receiving -food coupons (totalling 3,736 people when taking into account 934 * 4 under the assumption that there are 5 members in each household. The head of household is not added to this number to avoid double counting under the assumption that they are included within the 54,252 farmer population that is being benefited as a result

					of the adaptation interventions) **Indirect Beneficiaries:** Members of the households of the associated farmers that will benefit from increased household incomes and farmers within the farmers associations within the 7 communes who will benefit through indirect training provided by their representatives minus their representatives not accounting members of household receiving food coupons (3,736[1])
3. Strengthened governance and capacity for climate-resilient integrated water resources management (IWRM)	ARA 2	Improved health and water security from better monitoring and adaptative management of water resources	Number: 340 (30% women) (102 women and 238 men) Local Representatives receiving targeted training support and also receiving adaptation benefits in their role as water users. While the project will training a total of 540 officials, only 340 are assumed to be residents within the TR watershed.	**Number:** 733,532 The total number takes into account the total population of the TR watershed that are also water users (733,872 minus the number of direct beneficiaries 340 that receive both targeted support and adaptation benefits.	**Targeted Support:** 100 technical staffs at the level of the 3 departmental directorates and the 7 communal agricultural offices of the Ministry of Agriculture of Natural Resources and Rural Development (MARNDR); 100 technical staffs at the level of the National Coordination of Food Security (CNSA); 100 technical staffs at the Ministry of Social Affairs and Labor (MAST); 100 technical staffs in the 3 departmental directorates of the Ministry Of the Environment (MDE); 140 representatives of associations of the 7 target communes, that will receive capacity building in IWRM and land management & sustainable management. Of the above, 340 are residents of the TR are and 200 are national staff. **Adaptation Benefit:** Increased governance capacity for sustainable water management in the face of climate change resulting in the governance structure that will facilitate the implementation and enaction of the Water Act or similar policy measures required. **Indirect Beneficiaries:** the number of water users whose governance fall underneath the watershed associations and the key sector (National Census adjusted for population

					growth, using 2019 population estimates) of the population of 7 communes, these will benefit from the policies that will result from the increase capacities created within local and sectoral leaders for climate change.~~–~~
Adaptation beneficiaries under ARA 2			**Direct Beneficiaries** 58,328 (male:42,362/ female: 15,966)	**Indirect Beneficiaries** 679,280 (male: 311,764/ female:367,516)	**Direct Beneficiaries:** sum of 2 outputs as there is no overlap. 57,988 is farmers & members of households receiving food coupons and 340 which are technical staff of ministries and associations, but not farmers. **Indirect Beneficiaries:** It is 733,872 people which also account for the total number of water users minus 58,328 of the direct beneficiaries to avoid double counting. These direct beneficiaries are also water users. This number also includes the 217,008 members of households that will increase their income/food security as these are also ~~-~~water users.
Total Project direct and indirect beneficiaries			**Direct Beneficiaries** 292,600 (Male: 140,448, Female: 152,152)~~X~~	**Indirect Beneficiaries** at least 441,272 (male: 211,811 /female: 229,461)	**Direct Beneficiaries:** 292,600 (ARA 1&4). The 58,328 (ARA 2) are already included in 292,600. **Indirect Beneficiaries:** It is 733,872 water users (ARA 2) minus 292,600 of the direct beneficiaries which are also water users (ARA 1 & 4).