Climate-smart initiatives for climate change adaptation and sustainability in prioritized agricultural production systems in Colombia CISCAP[1]

FEASIBILITY STUDY

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[1] The initial tittle of the project was changed from Low-Emission and Climate Resilient Agriculture in Colombia (LECRA) to Climate-smart initiatives for climate change adaptation and sustainability in prioritized agricultural production systems in Colombia (CSICAP). All the references in this document have been changed to CSICAP. If there is any reference to LECRA should be understand as CSICAP.

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ABBREVIATIONS/ ACRONYMS

Abbreviation/ Acronym	Definition
AFOLU	Agriculture, Forestry and Other Land Use
AGROSAVIA	Agricultural Research Corporation of Colombia
AMTEC	Fedearroz Mass Technology Adoption Programme
ASBAMA	Association of Magdalena and La Guajira Banana Growers
ASOHOFRUCOL	Association of Horticulture and Fruit Growers
AUGURA	Association of Banana Growers
CAF	Development Bank of Latin America
CENICAFE	National Coffee Research Center
CENICAÑA	Sugarcane Research Center of Colombian
CGIAR	Consortium of International Agricultural Research Centers
CIMMYT	The International Maize and Wheat Improvement Center
CIPAV	Centre for Research on Sustainable Agricultural Production Systems
CONPES	National Council for Economic and Social Policy
DANE	National Administrative Department of Statistics
DIDTPS	Directorate for Technological Development Innovation and Health Protection - MDR
DNP	National Planning Department
ENSO	El Niño-Southern Oscillation
FEDEGAN	Colombian Federation of Cattle Ranchers
FEDEPANELA	National Federation of Panela Producers
FEDEPAPA	Colombian Federation of Potato Growers
FEDERROZ	National Federation of Rice Growers
FENALCE	National Federation of Cereal and Leguminous Crop Growers
FNC	National Federation of Coffee Growers
GCF	Green Climate Fund
GHG	Green House Gas Emissions
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies
MADR	Ministry of Agriculture and Rural Development
MADS	Ministry of Environment and Sustainable Development
MHCP	Ministry of Finance and Public Credit
NDC	Nationally Determined Contributions
UPRA	Rural Agricultural Planning Unit

EXECUTIVE SUMMARY

Colombia is a country vulnerable to climate change, especially in its agricultural sector. To date, losses associated with climatic phenomena affecting millions of hectares have been recorded, especially with the ENSO phenomena which, between El Niño (1997-1998) and La Niña (2010-11), recorded losses of ~ US$1.5 billion - fifteen times greater than the value of this project. Climate change scenarios for Colombia predict that temperature changes of 1.5ºC will occur by the 2040s. Analyses of the impacts of these changes estimate crop yield losses ranging anywhere from 10-80%. The Colombian government is aware of the risks facing the agricultural sector due to climate change and variability, and its concern is clearly evident in the commitments made by the country in its NDC targets, focusing on strengthening agricultural production Gremios in Colombia as a strategy to involve the private sector and unite efforts to address the problem.

Production Gremios have also expressed their concerns in this regard and recognize that limited funds and the array of difficulties they face - low prices, international competition, high input costs - are leading to the postponement of actions that may result in high costs for the sector. The Ministry of Agriculture and Rural Development took the initiative to implement a pilot project to generate adaptation and mitigation alternatives for rice and maize crops with the approach of strengthening the sector, which generated very good results in terms of products, but especially in terms of the capacity of the Gremio and the reflection of this work in the results at producer level[2]. For this reason, the Ministry of Agriculture and Rural Development brought together different institutions to participate in this initiative, a proposal aimed at achieving significant impact at national level and undoubtedly part of the Colombian government's ongoing commitment to prepare the agricultural sector for what is to come in terms of climate change in the coming decades and, thus, to comply with its international and national climate commitments. The project was structured under the leadership of the MADR and the technical support of Alliance Bioversity-CIAT, with high levels of involvement from gremios (producers associations), in addition to Agrosavia and other national and international institutions. It was a participatory and interactive process, in which progress was made on technical components while being simultaneously discussed with the MADR and DNP.

The resulting project was structured around four project outcomes: i) The targeted productive agricultural value chains have greater climate resilience and adaptability to extreme weather events and climate change; ii) Increased generation and use of climate information in decision-making; iii) Improvement in the well-being of producer families and socio-environmental sustainability of Colombian agriculture; and iv) Improved management of land in agricultural areas contributing to GHG emissions reductions.

The project outcomes are sustained by a series of project results. Specifically, under Component 1, a strengthened and modernized agricultural extension system oriented towards adaptation and mitigation (Component 1.1, with the support of Components 3.1, 3.2 and 3.3) will result in the adoption by farmers and farmer associations of digital agriculture for improved decision making for climate change adaptation and mitigation in the targeted value chains (Result 1.1). The establishment and/or strengthening of agroclimatic services in the selected value chains (Component 1.2, with the support of Components 3.1, 3.2 and 3.3) will result in improved decision making by farmers and farmer associations through the adoption and use of climate services (Result 1.2). Under Component 2, under a strengthened germplasm bank, development of new varieties and massive seed distribution (Component 2.1, with the support of Components 1.1 and 3.1, 3.2 and 3.3), would result in the adoption by farmers and farmer associations of new climate smart practices, technologies, and varieties (Result 2.1). With crop management techniques and other technological options validated (Component 2.2, with the support of Components 1.1, 3.1, 3.2 and 3.3), the project will result in more efficient use of water resources, restoration of soil properties, and improving GHG mitigation practices by farmers and farmer associations (Result 2.2). Under Component 3, Improved business models that provide farmers with reasonable profits and help them adopt climate

[2] An ex-post impact assessment analysis was used to estimate the impact of the pilot project.

mitigation actions (Component 3.1) will result in improved profits and adoption of mitigation practices from new business models in the targeted value chains (Result 3.1). With the development of multi-tool strategies, differentiated and adapted to specific environmental, social, gender and productive contexts (Component 3.2) will result in strengthened institutional capacity through trained producers, technicians, and producers' associations with the information to improve management and adopt climate mitigation practices and technologies (Result 3.2).

It is estimated that the project will benefit more than 194,871 direct rural producers and their families (619,692 people in total) and increase the climate resilience of agricultural systems in 967,997 hectares, distributed in 22 departments (69% of the country's departments) and 219 municipalities (20% of the total number of municipalities). The total emissions that the project expects to reduce over its lifetime are 9,152,034 tCO_2e directly and 34,878,951 tCO_2e indirectly.

The project has some innovative aspects in terms of technology, such as proposing the use of advanced technological tools in the management and processing of information, but also in the area of institutional design, by integrating the producer Gremios in the formulation and implementation of the project as a strategy to guarantee sustainability and the leveraging of resources.

The project risks are not high, but it is necessary to pay special attention to the issue of foreign exchange, and to verify that the measures aimed at reducing or managing operational risks are actually being implemented in a timely manner and are effective.

1. INTRODUCTION

1.1 BACKGROUND

Overview of the Colombian agricultural sector

The Colombian agricultural sector has seen a drastic drop in its share of the national economy in recent decades, from 22% of GDP in the late 1970s to 6.0% in 2015. In recent years, the sector has shown a slight recovery, with reported growth of 2.4% and 2.3% for 2018 and 2019 respectively. For 2019, GDP from agriculture in Colombia was 6.4% of total GDP. For the first quarter, the DANE reported a 6.8% growth for the sector, a fundamental boost the Colombian economy. Specifically, the crops that saw the biggest growth were banana (35%), maize (29.4%), rice (20.9%) and potato (11.2%). Given the expected rise in global food demand, agricultural and agro-industrial exports may be one of the important drivers of growth in Colombia for the coming decades (DNP and GGGI, 2017). According to the DNP and the Global Green Growth Institute (GGGI, 2017) the agricultural sector will have an average growth of 2.5% per year over the next fifteen years. The number of hectares cultivated is expected to increase by 43.8 % compared to 2015 (DNP and GGGI, 2017). In this sense, the challenge for Colombia is enormous, as measures must be taken to achieve this growth based on the conversion of inefficient livestock to agro-industrial crops while controlling the agricultural frontier.

According to the National Agricultural Survey (ENA, 2019), there are 4.6 million hectares under cultivation in Colombia, mostly permanent crops (see Table 1. Areas cultivated in Colombia and the yields of those crops included in the project~~Table 1. Areas cultivated in Colombia and the yields of those crops included in the project~~). The area under pasture occupies 22.9 million hectares (see Table 2: Pasture area in Colombia, livestock inventory and yield indicators~~Table 2: Pasture area in Colombia, livestock inventory and yield indicators~~), not counting what is known as unweeded pastures (8.6 million) and native savannas (5.8 million). Coffee and sugarcane

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crops have high yields that stand out compared to world averages. For the 839,000 hectares under coffee cultivation, average yields of 1.3 ton/ha are reported, while sugarcane reports 299,000 hectares with an average yield of 130 ton/ha.

Table 1. Areas cultivated in Colombia and the yields of those crops included in the project

Crop	Cultivated Area (ha)	Yield (ton/ha)	UPAs[3]
Rice	535,568	5.8	16,896
Maize	418,671	3.3	364,232
Potato	141,465	23	153,177
Panela sugarcane	234,519	5.4	134,410
Coffee	839,661	1.3	588,420
Banana	111,250	28	31,735
Plantain	304,600	9	157,485
Sugarcane	299,407	130	9,813

Source: National Agricultural Survey (ENA), DANE (2019a)

Table 2: Pasture area in Colombia, livestock inventory and yield indicators

Subsector	Area under pasture	Cattle inventory	Number of land plots	Productivity Indicators	
				Milk (liters/cow/day)	Meat (grams/meat/day)
Cattle farming	22,946,697	27,239,767	615,367	6.3	500

Source: DANE (2019a)

According to the National Agricultural Census (2014), the departments with the highest proportion of their territories under agricultural use are Caldas, Córdoba, Arauca and Casanare (more than 70%), while Amazonas, Vaupés, Guaina, Guaviare and Chocó are the departments with the lowest proportion of their territories used for agricultural activities (less than 15%) and their majority is declared as ethnic territory. Caldas, as the department with the highest proportion of its territory under agricultural activity, allocates half of this territory to purely agricultural activities, while Córdoba, Casanare and Arauca allocate only 20%, 7% and 5% respectively. Caldas and Cauca are the departments that leave the least land fallow, to rest from agricultural use, while Cundinamarca and La Guajira leave around 50% of their agricultural land fallow at any one time. In Colombia, large areas of land are owned by few people, (0.4% of the UPAs larger than 500 hectares had 77.3% of the area) and the vast majority of producers are small-scale, concentrated on little land (UPAs smaller than 5 hectares represented 70.4% and occupied only 2.0% of the area); the level of technification of agriculture in Colombia is low: 83.6% of the UPAs do not have agricultural machinery; 66.7% do not use irrigation; 83.5% of the UPAs have not received any

[3] Agricultural Production Units (UPAs) are used in Colombia as a record of the organization of agricultural production, and are therefore close values and a good proxy for the number of producers.

technical assistance; 89.3% have not applied for credit, and 68.4% of the UPAs reported not using chemical fertilizer.

In environmental terms, 33.5% of the UPAs have difficulty accessing water for agricultural activities due to scarcity, mostly in the Caribbean region. However, 82% of the UPAs at the national level report that they conserve natural vegetation, 31% state that they plant trees, and 75.2% of the UPAs report carrying out some activity for soil conservation, with stubble ploughing, minimal tillage and planting without soil removal among the most common practices. According to IDEAM et al (2016), Colombia is responsible for 0.4% of global emissions, with the AFOLU sector contributing 61.2% of emissions. However, it is the only sector that reports carbon absorption corresponding to 46.1% of its emissions. Deforestation, livestock and fertilizer use are the main drivers of emissions in the sector.

Overview of the current situation

The goals of the agricultural sector with the NDC reflect the MADR's concern about climatic phenomena-related events and what is expected to happen in the coming decades. The situation is problematic for all crops and producer Gremios, even for those considered the strongest. Although the coffee and sugar sectors in the country have invested heavily in equipment, instruments and climate research, climatic variations continue to result in huge losses for these sectors, not to mention the other sectors with fewer resources. What complicates the picture even further is that the little that is being done is around climate variability, but in the area of progressive changes over time (e.g., progressive increase in temperature) practically no action is being taken. As observed, climatic variations relevant to agriculture occur at a range of timescales (from days to multiple decades), and it is virtually certain that anthropogenically-driven climate change will alter climatic patterns at all those timescales.

Another major problem is that the few actions that are being carried out in the country in terms of climate action are largely disjointed. Institutions are working in isolation, and the little that is achieved is at an individual level, and therefore any action or lesson learned that could benefit the entire sector may go unnoticed due to the lack of spaces and mechanisms for best practice articulation. Farmers have limited access to practices and technologies suitable for adapting to climate change. Hence, farmers are vulnerable to large crop losses due to both long-term trends in climate and greater climate variability in weather patterns and the urban population faces the prospect of periodic food scarcity and volatile prices. Remedying this dire situation for the whole country requires provision of technologies that counteract the effects of climate change and greater variation in the weather. The country currently lacks appropriate agro-climatic advisory services, and an agricultural research and extension system that can provide producers with time and site-specific information on how to respond to climate variability and climate change.

Colombian agriculture is continually facing challenges and many of these issues are of national interest due to their importance for the country's economic, social and even environmental stability. Every day, agricultural sector Gremios face major challenges, connected to price issues, competitiveness, some with international market problems and others with respect to national markets. Weather-related losses further complicate the picture. The producer Gremios are aware that they must act, but lack of knowledge and limited resources are instead leading to inaction. In large part, these problems result in great pressure being placed on the Colombian government to provide support and relief programs for producers affected by climatic phenomena. In this sense, both the government and the producer Gremios know that a fundamental solution to this problem is required through a structural program aimed at strengthening the agricultural sector in terms of adaptation and mitigation of climate change.

The outlook without this project is not at all encouraging. On the one hand, the government will see how year after year the number of requests from the different Gremios for assistance in terms of crop losses continues to increase. The years in which climate variability phenomena will be disastrous for the sector, as has already happened, which will bankrupt thousands of producers across a variety of crops. The inability to cope with the effects of the progressive changes in climatic variables is due to the fact that we are unable to cover current needs, even those considered most basic, and, in this sense, it is almost impossible to consider appropriate actions for future scenarios. This will necessarily lead to greater social tensions, increased levels of rural poverty, displacement and environmental conflicts.

Description of the problem

Colombia has and will continue to be affected by the negative impact of climate change, including higher temperatures, periods of intense rain and drought, and a higher frequency of ever more extreme events. Climatic variations relevant to agriculture occur at a range of timescales (from days to multiple decades), and it is virtually certain that anthropogenically-driven climate change will alter climatic patterns at all those timescales (Bindoff et al., 2013; Donat et al., 2013; Seneviratne et al., 2018[4]). A clear example of altered climate variability resulting from climate change relates to the El Niño Southern Oscillation (ENSO). ENSO is the most important mode of variability on Earth (Cai et al., 2018[5]), and while 21st century ENSO projections entail highly uncertainty, recent research suggests that the frequency of strong ENSO events is likely to increase as a result of climate change (Cai et al., 2018; Wang et al., 2017[6]; Yun et al., 2021[7]). As is widely known, strong ENSO events can severely impair agricultural productivity in Colombia (Barrios-Perez et al., 2021[8]). Relatively early research (i.e., pre-AR5, e.g., Stevenson, 2012 and references therein) already indicated that climate model simulations suggest changes in the ocean-atmospheric dynamics related to ENSO and its impacts. More recent research (post AR5, feeding into AR6) have contributed substantially to advancing our understanding of ENSO under climate change. Notably, Freund et al. (2020) suggest that future changes to ENSO depend on

[4] Bindoff, N.L., P.A. Stott, K.M. AchutaRao, M.R. Allen, N. Gillett, D. Gutzler, K. Hansingo, G. Hegerl, Y. Hu, S. Jain, I.I. Mokhov, J. Overland, J. Perlwitz, R. Sebbari, and X. Zhang, 2013: Detection and attribution of climate change: From global to regional. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Doschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley, Eds. Cambridge University Press, pp. 867-952, doi:10.1017/CBO9781107415324.022.

Donat, M. G., et al. (2013), Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset, J. Geophys. Res. Atmos., 118, 2098–2118, doi:10.1002/ jgrd.50150

Seneviratne, Sonia I.; Phipps, Steven J.; Pitman, Andrew J.; Hirsch, Annette L.; Davin, Edouard L.; Donat, Markus G. et al. (2018): Land radiative management as contributor to regional-scale climate adaptation and mitigation. In Nature Geosci 529, p. 477. DOI: 10.1038/s41561-017-0057-5

[5] Cai, W., Wang, G., Dewitte, B. et al. Increased variability of eastern Pacific El Niño under greenhouse warming. Nature 564, 201–206 (2018). https://doi.org/10.1038/s41586-018-0776-9

[6] Wang, Chunzai & Deser, Clara & Yu, Jin-Yi & Dinezio, Pedro & Clement, Amy. (2017). El Niño and Southern Oscillation (ENSO): A review. 10.1007/978-94-017-7499-4_4.

[7] Yun, KS., Lee, JY., Timmermann, A. et al. Increasing ENSO–rainfall variability due to changes in future tropical temperature–rainfall relationship. Commun Earth Environ 2, 43 (2021). https://doi.org/10.1038/s43247-021-00108-8

[8] Camilo Barrios-Perez, Kensuke Okada, Gabriel Garcés Varón, Julian Ramirez-Villegas, Maria Camila Rebolledo, Steven D. Prager, How does El Niño Southern Oscillation affect rice-producing environments in central Colombia?, Agricultural and Forest Meteorology. Volume 306, 2021, 108443, ISSN 0168-1923.

both mean state changes and decadal-scale natural variability, whereas Yun et al. (2021) demonstrate an amplification of ENSO-rainfall variability using the CMIP6 ensemble, regardless of the lack of signal in the amplification of the Sea Surface Temperature (SST) anomalies (Figure B1.1.1, also see IPCC, 2021). Various other studies contribute evidence on how ENSO responds to global warming. For instance, Wang et al. (2017) demonstrate that the frequency of extreme El Niño events increases linearly with increased global mean temperature, doubling at 1.5ºC warming. Likewise, Cai et al. (2018) find a likely increase in the number of 'strong' equatorial Pacific El Niño events and associated extreme weather events using CMIP5. Ultimately, while a robust projection of ENSO is not feasible with the current generation of climate model projections, it is clear that ENSO-related climate variations will continue to challenge agricultural production in all regions of Colombia. Strong ENSO events can severely impair agricultural productivity in Colombia (Barrios-Perez et al., 2021). In the following Illustration 1~~Illustration 1~~, each line shows the average of all climate models for the historical period or for the SSPs. Shading is the 5-95% range across CMIP6 models. Taken from IPCC (2021) (Fig. 4.10; Chapter 4, WGI)

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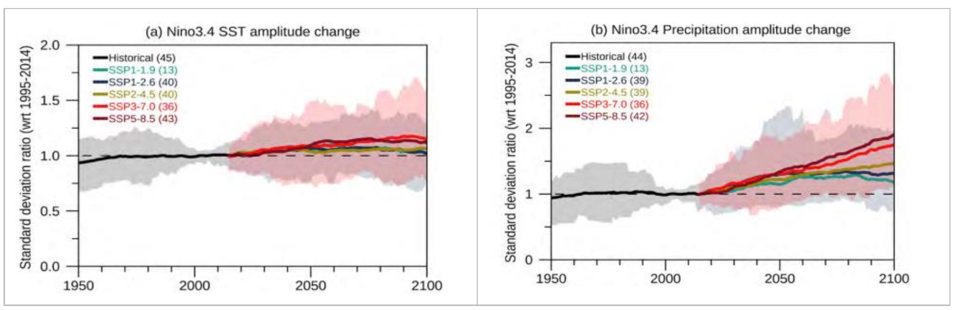


Illustration 1. Changes in amplitude of ENSO variability. Variability of (a) SST and (b) precipitation anomalies averaged over Niño3.4 region for 1950-2014 from CMIP6 historical simulations and for 2015-2100 from four SSPs

According to Colombia's Third National Communication (TNC) under the United Nations Framework Convention on Climate Change (UNFCCC), prepared by Colombia's Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), the agricultural sector will be substantially affected by climate change with yields, land suitability and harvest seasons all impacted by variations temperature and rainfall (IDEAM & UNDP, 2017).

Colombia is highly vulnerable to climate change due to its geographical conditions, which include lowlands with high flood risk, mountainous regions that are home to most of the population and are subject to erosion, landslide risks, periods of water scarcity and above-average temperature increase, all of which will be intensified by climate change. Among the most relevant impacts on the agricultural sector generated by climate change and variability in Colombia are: (i) losses in the livestock sector both in number of animals and productivity; (ii) losses in crop yields; (iii) reduced crop resilience to external shocks associated with changes in climatic variables; (iv) reduced water availability; (v) increased soil erosion; vi) decreased top soil moisture; vii) increased incidence of pests and diseases; viii) increased occurrence of unexpected fires; ix) reduced number of crop cycles; x) increased greenhouse gas emissions, and; xi) reduced food and nutrition security. Because climatic variations occur at a range of timescales and these variations are all affected by long-term climate change, adaptation needs to be framed accordingly. Adaptation strategies can be incremental, systemic, or transformational. Incremental adaptation helps respond to seasonal and interannual variations; systemic adaptation helps prepare for changes in the coming decades; and transformational change involves planning agricultural transitions when systems are no longer viable (Ramirez-Villegas and Khoury, 2013; Rippke et al., 2016[9]).

In general terms, high/low temperatures, rainfall deficit/excess, strong winds, low radiation, high relative humidity, among others, can be a challenge for the production of different crops. Climate variability events have a major impact on the productivity of a range of crops. For example, La Niña events can be a serious constraint for the production of sugarcane, coffee and potatoes, while El Niño events can lead to significant reductions in the production of rice, bananas, maize, potatoes and cattle. The magnitude of the agricultural sector's vulnerability to climatic variation is illustrated by the losses of approximately USD 480 million during the El Niño event in 1997-1998 (ECLAC, 1999) and US$ 1 billion due to La Niña of 2010-11 (IDB and ECLAC, 2012). In the 2010-2011 La Niña, severe rains flooded 3.5 million hectares and affected 3.2 million people, 64.7% of whom lived in rural areas. In the long term, climate change scenarios show generalized temperature increases for the whole country, while rainfall has differentiated annual balances with increases in some regions and decreases in others (see Illustration 2). The temperature in Colombia increased by 0.13° C per decade during the 1971-2000 period according to IDEAM (Ruiz, 2010), and is expected to increase by 3 to 5° C by mid- 21st century (Arnell et al., 2004; IPCC, 2007). Furthermore, rainfall patterns are likely to change.

[3] Fourteen CMIP5 GCMs used in the IPCC Fifth Assessment Report (AR5; IPCC 2013) and employed by IDEAM for the development of the Third National Communication on climate change were used. The resulting layers are at a resolution of 30 arc-seconds (~1Km^2). A set of 12 precipitation layers, 12 monthly maximum and minimum temperature layers, plus one annual layer per variable for each RCP is obtained. In this paper, the maps of mean temperature and total precipitation anomalies for the 2040s for the RCP 4.5 scenario are presented in Illustration 2.

[9] Ramirez-Villegas, J., Khoury, C.K. Reconciling approaches to climate change adaptation for Colombian agriculture. Climatic Change 119, 575–583 (2013). https://doi.org/10.1007/s10584-013-0792-6.

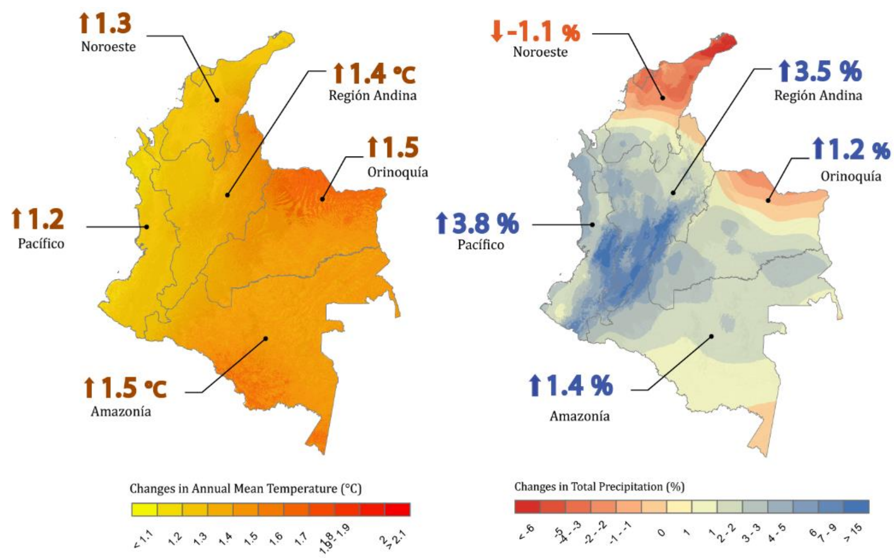


Illustration 2. Anomalies in mean temperature (left) and total precipitation (right) in the 2040s for the RCP 4.5 scenario, taking as reference the models selected by the IDEAM to generate the scenarios for Colombia. [10]

In the case of northern Colombia (dry Caribbean and humid Caribbean), climate variability is a challenge for rice, banana and cattle production, especially prolonged dry periods. In addition, climate change scenarios indicate that there will be higher temperatures and less precipitation. In this sense, these regions have priorities in terms of agroclimatic predictions from Big Data, new drought-tolerant materials, cattle models with greater shade and measures for efficient water use. In the Orinoquia region, the marked periods of dry and rainy seasons represent a challenge. In the case of permanent crops, such as pasture for cattle, fodder production is abundant in the rainy season and a constraint in the dry season. Transient or semi-annual crops find very good water conditions in the sowing periods, but low radiation is the most limiting factor for production, as well as disease-related problems due to high humidity. With rice and maize, it is necessary to work on materials that are tolerant to low radiation, but also tolerant and resistant to diseases, especially when climate change scenarios show increased rainfall in the rainiest months. In the Andean region, crop problems related to climate variability are evident. For example, potato cultivation suffers greatly from both El Niño and La Niña phenomena, as well as from other phenomena. Coffee, for its part, presents many complications under La Niña conditions but, while El Niño conditions can be favorable, the latter climate phenomena tend to result in greater berry borer related problems. Dairy farming suffers from El Niño events and, while shorter rainy periods can favor fodder biomass production, too much can be counterproductive. Climate change scenarios are not so favorable for these crops, as increases in temperature and climate variability

[10] Fourteen CMIP5 GCMs used in the IPCC Fifth Assessment Report (AR5; IPCC 2013) and employed by IDEAM for the development of the Third National Communication on climate change were used. The resulting layers are at a resolution of 30 arc-seconds (~1Km^2). A set of 12 precipitation layers, 12 monthly maximum and minimum temperature layers, plus one annual layer per variable for each RCP is obtained. In this paper, the maps of mean temperature and total precipitation anomalies for the 2040s for the RCP 4.5 scenario are presented in Figure 1.

are expected to result in a displacement of these crops to higher altitude thermal floors, putting pressure on protected areas. Thus, agronomy practices and management with materials more tolerant to climate variability and high temperatures, as well as pest and disease management will be necessary measures for producers in this region. In the inter-Andean valleys, conditions are like the Andean region, but with the aggravating factor of flooding during the rainy season. For sugarcane production, La Niña phenomena are feared by producers because in most cases they result in the loss of large areas of crops due to flooding or reduced productivity due to waterlogging. In these areas, sugarcane, rice and maize crops depend on irrigation water, so dry periods result in crop losses. In these areas, agroclimatic predictions have be shown to perform well, so it is necessary to continue advancing in the improvement of models, especially the integration of crop models and digital agriculture to strengthen recommendations and their dissemination. Materials that tolerate high temperatures, low rainfall and high CO^2 concentrations in the atmosphere are also required for these three crops, as well as tolerance to waterlogging in the case of sugarcane.

The lack of specific knowledge about climatic problems in crops can also be a constraint to adequately identify the solutions required. An example of this was clear during the MADR-CIAT pilot program, since the experiments and analyses carried out determined that the most limiting climatic factor in irrigated rice production in the eastern plains region was radiation during the reproductive phase of the crop, which forced the research areas of Fedearroz and Alliance Bioversity-CIAT to reorient all work plans in their genetic improvement programs for this area. Similar situations arose in other areas of the country; for example, the most limiting climatic factor for rice production in Córdoba is the temperature during the grain filling phase, while in rain-fed rice in the eastern plains it is the distribution of precipitation during the growth phase of the crop. As long as adaptation continues to be considered as a problem of generalizing around some intuitive measures, we will be far from real, competitive and site-specific solutions.

The way in which technological packages are currently generated also represents a major barrier to adaptation and mitigation. Research centers and agricultural technology suppliers must work megadomain structures, and for this reason, experimental centers are located by broad mega-environments, which guarantees that there is at least an initial differentiation in terms of technologies for each of these regions, which each have very marked biophysical differences. The technicians and extensionists work to bring and promote these technologies in each of these megadomains but they are aware of the differences that occur at the level of all the biophysical variables within these mega-environments (precipitation, temperatures, soils, slopes) and the interaction among them, which ultimately affect the performance of the technology. It is unfeasible from a cost point of view to think that the development of the technology would have a greater number of domains, or that the technician/extensionist would not have the tools, capacity or training to be able to adjust these technologies according to all the variables that can affect their performance.

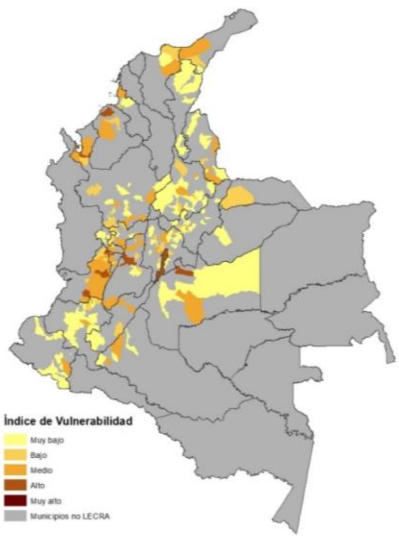
Many of the technologies developed and implemented at the commercial level do not even have all the information necessary to understand how effective they are in responding to particular climatic conditions. Much less are there records and data on the performance of these technologies in terms of water consumption levels, let alone GHG generation. Thus, at this time, of all the crop management technologies adopted by producers at the commercial level, we do not have information on their performance with respect to important indicators that would help to qualify their capacity for adaptation and/or mitigation.

Adaptation and mitigation of climate change is a process that, in addition to having technological options, requires a strengthening of the capacities of key actors involved in the management of climate change in the agricultural sector to generate, communicate and apply information to support decision-making at all scales in an effective and coordinated manner. Any measures taken in this area must take into consideration the great differences in available information and capacity of analysis among the different crops/producer Gremios.

Vulnerability and major risks caused by climate change impacts

Regarding the climate change vulnerability index[11], 4% of the municipalities have a high vulnerability, 38% have a medium vulnerability, 29% have low vulnerability and 29% have very low vulnerability. Regarding the risk, 8% present high risk, 38% medium risk, 17% low risk, and 37% very low risk. Also, it is identified that among the territories where the CSICAP project will be implemented, there are no municipalities with very high vulnerability and very high risk. The following map represents this information in cartographic form.

Vulnerability to climate change by CSICAP Municipalities



Source: Prepared by BIOPARQUE (2021) in the frame of the PPF of the CSICAP project. Based on information from Third National Communication of Colombia to UNFCCC (IDEAM, PNUD, MADS, DNP, CANCILLERÍA, 2017).

[11] The climate vulnerability and risk are qualitatively rated, is based on a quantitative vulnerability index developed by IDEAM and described in IDEAM, PNUD, MADS, DNP, CANCILLERÍA (2017). Based on Chen et al. (2015) the index incorporates 86 Variables, Indicators, and Indices in 6 dimensions, as follows: (i) Food Safety: includes variables related to availability, access and timely consumption of Cassava, Rice, Banana, Cane, Potato, Corn, Beans and Coffee, (ii) Water Resource: use and availability taking as reference the National Water Study (IDEAM, 2014); (iii) Biodiversity and Ecosystem Services: change of land use cover and threatened species; (iv) Health: climatic relationship with human health, either due to differences in temperature or precipitation, as well as the relationship with vectors of associated diseases; (v) Human Habitat: housing and services associated with human settlements, together with territorial management and institutional interaction; (vi) Infrastructure: indicators related to roads, air access, availability of electrical connection, and energy alternatives for adaptive capacity. Available at the link http://documentacion.ideam.gov.co/openbiblio/bvirtual/023731/TCNCC_COLOMBIA_CMNUCC_2017_2.pdf

The indices are very useful because allow for the adequate management of the dimensions analyzed to identify the vulnerability of the territories to climate change.

Additionally, in 2020, the Food and Agriculture Organization (FAO) and UNDP carried out a vulnerability and risk analysis study on climate change in the agricultural sector in Colombia to support the production of the Comprehensive Climate Change Management Plan for the Agricultural Sector (Pigccs-Agriculture).

Changes in the crop suitability zones of the RCP 6.0 scenario for the 2040s can be compared to the historical period 1976-2005, where losses in climatic suitability for maize production are observed of between 13 and 16% when compared to the current suitability zones. For banana crops, they estimate losses of up to 20%, for potato, the estimated losses of suitable areas are calculated to be 29% and for pasture 57%. In the case of maize, the greatest impacts are expected to be in the agricultural sub-region of the dry Caribbean and in the inter-Andean valleys. For potato, the lower altitude areas are identified as the most affected, and in pastures, the entire Andean region. However, it is necessary to consider that these calculations have been generated under the concept of niche analysis and considering changes in climatic suitability of crops and, in this sense, there may be some limitations in terms of varieties (for example, there is a diversity of pastures ranging from sea level to more than 3,000 meters above sea level). It is possible that many of the reported changes in suitability are occurring in areas where the crop under analysis has not historically been cultivated there (e.g., coffee in the eastern plains).

For this reason, the information presented is complemented with a series of studies that have been carried out to analyze the impacts of climate change on different crops and under different methodologies (crop models, scenarios, baselines, spatial resolution, etc.), which are summarized in Table 3~~Table 3~~.

Table 3. Summary of hazards (risks) in the different regions and crops related to the project

Region	Sub-region	Crop: hazard (risk)
Caribbean Region (North)	**Dry and Humid Caribbean**	Rice: High temperatures (low yields) Dry periods (problems for irrigation supply) Maize and Musaceae (banana and plantain): Dry periods (low yields) High temperatures (low yields/increased pests) Cattle: Dry periods (low forage production) High temperatures (animal stress)
Andean Region (central region of country, North to South)	**Inter-Andean Valleys (flat zone)**	Rice: Dry periods (irrigation supply problems) Maize: Dry periods (irrigation supply problems) High temperatures (low yields/increased pest infestation) Sugarcane: Waterlogging (crop loss) Dry periods (irrigation supply problems)
	Foothills/Mid-mountain	Panela sugarcane: High temperatures (increased pest infestation) Excess of water (plant rot) Dry periods (low yields) Coffee: Excessive rainfall (low yields) High temperatures (berry borer infestation) Musaceae (plantain): Dry periods (low yield) High temperatures (low yields/increased pest infestation)
	High Mountain	Potato: Dry periods (low yields) Excessive rainfall (increased disease) Frosts (crop loss) High temperatures (increased pests, displacement of production). Cattle: Dry periods (low forage production). Temperature increases (animal stress)
Orinoquia Region (East)	**Eastern Plains**	Rice: Low radiation (low yields) High humidity (increased disease) Maize: Low radiation (low yields) High humidity (increased disease) Cattle: Waterlogging-rainy season (forage rot). Dry periods (low forage production) High temperatures (animal stress)

Scope

Given the extent and scope of climate change impacts, actions are needed that put climate-smart varieties, agricultural technologies, practices, and information services in the hands of farmers so that they are better prepared to respond to existing and new climate-related stresses. These technologies will help farmers cope with climatic variability and extremes (both which are projected to change under climate change), and continue with their agricultural activities in the shifted temperature and rainfall regimes expected in the coming decades. Likewise, greater knowledge production, management and exchange is needed to strengthen agricultural extension services, improve institutional capacities, and farmers' knowledge and ability to implement climate-smart technologies.

The project will help reduce producer losses due to climatic events and climate change through the development of digital agriculture tools to strengthen rural extension processes to achieve greater coverage and site-specific climate change adaptation and mitigation recommendations. This project will also help close institutional gaps between producer Gremios and the gaps between producers by providing better information for decision making and improving the capacity to interpret and analyze information. The project will develop technologies for adaptation based on improved genetic material that tolerates production-limiting climatic factors and the threats posed by progressive climate change and will begin largescale implementation of these technologies among producers. The project will also evaluate technologies with low carbon and low water footprints and will initiate their widespread implementation. Finally, the project will emphasize institutional capacity building and capacity building of producers, professionals, and key stakeholders as a strategy to ensure the sustainability of the project.

The project is aimed at ensuring that the services generated in digital agriculture (big data and climate services) and new crop varieties are treated as public goods to be managed by the producer Gremios[12] since this will guarantee that the tools are managed by those who know most about each crop, about how to make use of the best information, and that each Gremio's resources will cover the costs of managing these tools in order to offer lower prices to producers. In the case of genetic material, costs are related mainly to seed multiplication and distribution logistics, while with big data and climate services the cost is practically zero since, once the infrastructure is installed and the operation and maintenance costs are covered, the marginal cost of supplying information to a producer tends towards zero.

It is for this reason that this is a great commitment by the Colombian government and the producer Gremios to face climate change. The government is providing the necessary infrastructure to offer these goods and services while the Gremios are then training and allocating resources to ensure implementation and guarantee the operation and maintenance of this infrastructure set-up into the future. The final beneficiaries will be the thousands of producers who will reduce the risk of losing their crops, who will be better prepared to face climate change scenarios and will contribute to reducing Greenhouse Gas (GHG) emissions, and with co-benefits related to increased

[12] The associations are the institutions that represent the agricultural producers organized by crop, so the boards of directors of these associations are composed of regional representatives of the producers. The associations are private organizations, formed and run by the producers, and therefore represent and define the interests of the producers. All the associations have a representation of more than 80% of the rural producers for each crop. In fact, they manage processes that enable them to take advantage of economies of scale, as in the case of the commercialization of agricultural inputs, in order to achieve more competitive prices for their members.

productivity, cost reduction, improvement in environmental indicators and inclusion of the gender perspective.

It is important to clarify that the project will not carry out the entire breeding cycle, so the materials obtained will be the best available from advanced lines, and in this sense the maximum use of all the genetic potential available is not guaranteed. Likewise, the project will be based on the result of advanced research that represents years of efforts and investments of different institutions and for this reason, exclusive patrimonial rights cannot be established by the project, nor can they be transferred to companies that obtain any commercial gain from such materials. In this sense, the protocol managed by the national government is that the registration, multiplication and delivery of seed to producers is carried out through the producer Gremios, which manage prices which are related to the costs of the mentioned processes (registration, multiplication and delivery of seed) and new research, and not for profit.

The other limitation of the project is that it will not carry out the entire process of developing new low water use and low emission technologies, since it will start by evaluating the technologies that are already being implemented at the commercial level. This is to ensure that the full technology transfer cycle can be completed during the years of project implementation. The process of developing new technologies can take up to five years without including the validation processes required. In this sense, the potential for efficient water use and emissions reduction will be subject to the potential of alternatives that are currently available on the market.

The project has planned a strategy to reach different types of producers and regions according to their conditions and in this sense the strategy for capacity building and information dissemination will be oriented to different types of users. The project will not supply, provide or change the infrastructure related to connectivity for producers or regions, but rather will adjust to current conditions.

Although a very good modeling performance is expected to be achieved, the project will not be able to generate 100% certainty in its predictions. For that reason, training and capacity building will include an understanding of the concept of uncertainty, which was a challenge at the beginning of the MADR-CIAT pilot.

1.2 CLIMATE DRIVERS, PAST CLIMATE AND PAST EXTREME EVENTS

Climate risk profile of the country

Colombia is a country with a great diversity of climates, which change according to latitude, longitude and altitude. In very general terms, Colombia is divided into five broad regions: the Caribbean, Andean, Pacific, Orinoquia and the Amazon. In terms of climatic conditions for agriculture, the country can be subdivided into six main producing regions: dry Caribbean (Caribbean), humid Caribbean (Caribbean), the inter-Andean valleys of the Cauca and Magdalena rivers, mid- and high mountains (Andean) and the eastern plains (Orinoquia).

In terms of rainfall, the northern part of Colombia and the higher parts of the Andean mountains are the driest regions, with rainfall of up to 1,500 mm per year. In the Caribbean region, most agriculture is located in areas between 1,000 and 1,500 mm per year, and in the southern part of this region, rainfall can reach up to 2,000 mm. Rainfall in this region is practically monomodal, with rains beginning in April and continuing through November, with a few dry weeks in between (locally called ‘veranillos’), and a well-defined dry period between December and March. In the high mountainous zone of the Andean region, rainfall distribution is bimodal, with two well-defined dry periods, one more intense between December and March, during which frost phenomena occur, which represent a threat to crops in this zone (especially potatoes). The Orinoquia region has a monomodal climatic behavior similar to that of the Caribbean region, but with the difference that rainfall levels reach up to 2,500 mm per year. Planting dates are normally associated with the onset of rains, so solar radiation levels can be a real problem for crop yields. The inter-Andean valleys are not homogeneous in terms of precipitation; areas such as the upper part of the Cauca River have less precipitation than the upper part of the Magdalena River, which in the latter case can reach 2,000 mm. The lower (northernmost) parts of the inter-Andean valleys are notably rainier with values exceeding 2,500 mm. The behavior in this region can be considered bimodal, with a dry period between December and March and a second between July and September. In the upper regions of the inter-Andean valleys (i.e., the areas located further south), the second period (July to September) is more marked. The bimodal behavior is very similar in the mid-mountain zones in the Andean region, where coffee cultivation is located. The difference lies in the annual precipitation levels, which are generally higher than those of the inter-Andean valleys, with values ranging from 1,800 to 3,000 mm. The rainy season is more intense in the second half of the year (see Illustration 3).

The greatest temperature differences in Colombia are due more to altitudinal values, so the northern part of the country (Caribbean region), the Orinoquia and the inter-Andean valley corresponding to the Magdalena River are the areas with the highest mean annual temperature values which exceed 26ºC. This is followed by the inter-Andean valley of the Cauca River, which experiences temperatures between 22 to 26ºC. The mountainous zone of the Andean region has a gradient in which the temperature drops to 8ºC or even lower in crop zones that are located in strategic ecosystems such as the *páramos* (see **¡Error! No se encuentra el origen de la referencia.**~~**¡Error! No se encuentra el origen de la referencia.**~~). Intra-annual temperature changes occur, but not as marked, with temperatures rising during dry seasons and falling during the rainy season. There are also differences in the thermal gradient between maximum (day) and minimum (night) temperatures, which is very important for several crops. For example, early morning frosts are a threat to the high mountain crops of the Cundinamarca-Boyacá highlands. Similarly, the thermal gradient is very important for sugar concentration in sugarcane production. There are more marked differences in interannual temperature changes associated with ENSO phenomena.

The El Niño phenomenon has a very marked influence in almost the entire Colombian territory, with lower precipitation values and higher temperatures, especially throughout the Andean region (inter-Andean valleys, mid- and high mountains), and the Caribbean region. Of the ten hottest years during the period 1960 to 2011, eight were under the influence of the El Niño phenomenon. The same occurs in these regions with the La Niña phenomenon, but with the opposite effect: excess rainfall and lower temperature values. The six coldest years in the period 1960 to 2011, and the 15 rainiest years, were under the influence of La Niña. These effects vary according to the intensity of the ENSO phenomenon. In terms of hazards, ENSO phenomena currently represent one of the greatest climatic hazards to crops in Colombia.

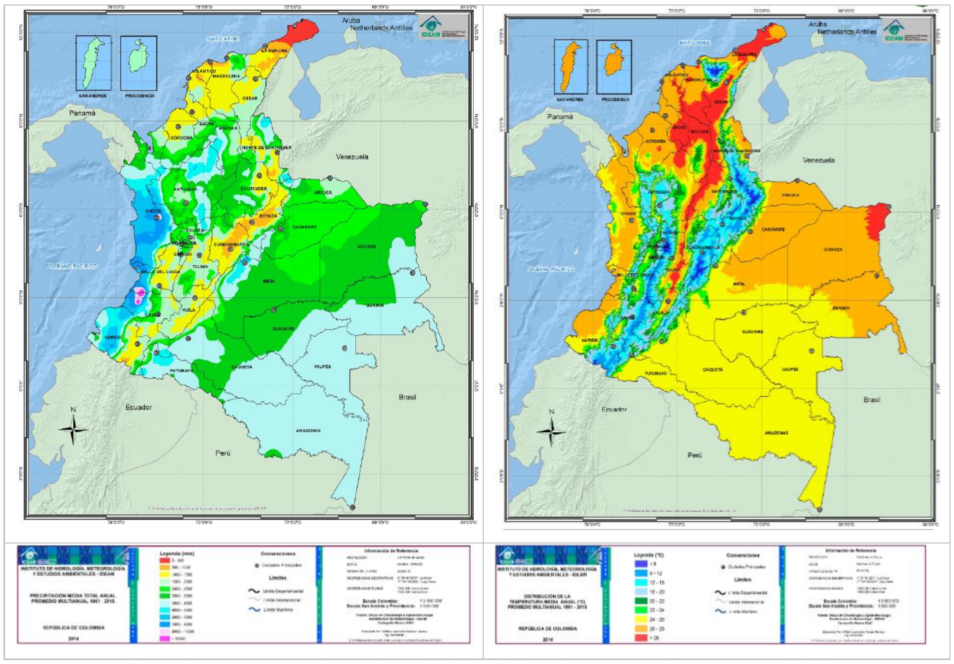


Illustration 3. Mean total annual precipitation (left) and mean annual temperature (right)
Source: [Climate Atlas of Colombia](), IDEAM (2017)

In the case of Colombia, the most recent studies of evidence of climate change are analyses of the period 1970-2010. According to Benavides et al 2011, Benavides and Rocha 2012, Ruiz et al 2012, it has been quantified[13] that average surface temperatures demonstrate a tendency to increase within a range of between 0.5 to 1.3ºC. Both the maximum and minimum temperatures have an increasing tendency, so hotter days and nights are expected. In general terms, in this period precipitation presents an increasing trend. However, it is very important to take into consideration the distributions and intensity, since extreme events represent another significant threat to crops.

As for the agricultural sub-regions, the humid Caribbean zone, especially the banana production area, shows increases in precipitation greater than 15%, while the sub-region of the eastern plains towards the foothills area shows decreases in precipitation (around 5%). In the Caribbean, Orinoco, and northern Andean regions, there were increases in storms or heavy rains. According to the maximum and minimum temperature indicators, days and nights have grown warmer in large areas of the country, especially in the coastal areas of the Caribbean, Andean and the foothill plains regions.

According to the climate change scenarios for the 2040s under the RCP 4.5 scenario (Illustration 2), temperature increases of between 1.2 and 1.5ºC are expected in Colombia. It is important to

[13] This research is based on the analysis of the historical records of daily accumulated precipitation and the daily extremes of minimum and maximum temperature, using the RCLIMDEX program.

note the implications that a temperature increase of this magnitude may represent for agricultural sub-regions of Colombia such as the dry Caribbean, humid Caribbean, eastern Plains and inter-Andean valleys, which currently have already very high temperatures. In terms of precipitation, there is greater variability in the results of the simulation but in general, the results estimate decreases in the northeastern part of the country and increases in the rest of the country. In terms of agricultural sub-regions, the dry Caribbean will be a challenge, in addition to the fact that high temperatures will also increase evapotranspiration.

The IPCC's Sixth Assessment Report (AR6, IPCC[14], 2021) explains that exists high confidence that growth of concentrations of CH4 is largely driven by emissions from fossil fuel exploitation, livestock, and waste, with ENSO driving multi-annual variability of wetland and biomass burning emissions. In the future, it is virtually certain that the ENSO will remain the dominant mode of interannual variability in a warmer world. It was also reported that the frequency and intensity of El Niño events in the period from 1951–2000 was high relative to 1901–1950. Most investigators find that ENSO activity in recent decades was higher than the most recent centuries prior to the instrumental period. Grothe[15] et al. (2019) also found that ENSO variance of the last 50 years was 25% higher than the average of the last 51 millennium. Johnson[16] (2013) found that the frequency of CP El Niño events had increased (although not significantly) over the 1950–2011 period, being accompanied by a significant increase in the frequency of La Niña events with a 4 warm (as opposed to cool) western Pacific warm pool. In summary, there is medium confidence that both ENSO amplitude and the frequency of high-magnitude events since 1950 are higher than over the period from 1850.

According to the Sixth Assessment Report (AR6) of the IPCC (IPCC, 2021), extreme heat (especially in the lowland northern regions) and heavy precipitation events and flooding (across the Pacific and the inter-Andean Valleys) are the most important changes in climatic impact drivers for Colombia. Regarding the latter, unprecedented flooding events have been reported in recent decades in the lower reaches of the Atrato, Cauca, and Magdalena rivers (IPCC, 2021 – Chapter 12; Avila et al., 2019). Extreme precipitation can also drive landslides, with Colombia being considered one of the countries in Latin America with high incidence of fatal landslides. ENSO and climate change are the main causes of these landslides (IPCC, 2021; Sepulveda and Petley, 2015). Greater confidence exists regarding precipitation decreases (IPCC, 2021; https://interactive-atlas.ipcc.ch), and resulting changes in hydrological and agricultural drought. For instance, it is estimated that 62% of the existing streamflow timeseries across the country exhibit a significant decreasing trend (Carmona and Poveda, 2014; IPCC, 2021). Of particular concern are the northern lowlands (Caribbean region, and lower Cauca), where hydrological and agricultural drought affect agricultural production and livelihoods substantially current climates (https://interactive-atlas.ipcc.ch; Perez et al., 2020; Contreras, 2019; Castro, 2019). More evidence is, however, needed in order to assess future projected changes for precipitation-related impact drivers (Illustration 4).

[14] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

[15] Grothe, P.R. et al., 2019: Enhanced El Niño-Southern Oscillation variability in recent decades. Geophysical Research Letters, 1 46(n/a), doi:10.1029/2019gl083906.

[16] Johnson, N.C., 2013: How Many ENSO Flavors Can We Distinguish? *Journal of Climate*, **26(13)**, 4816–4827, 17 doi:10.1175/jcli-d-12-00649.1

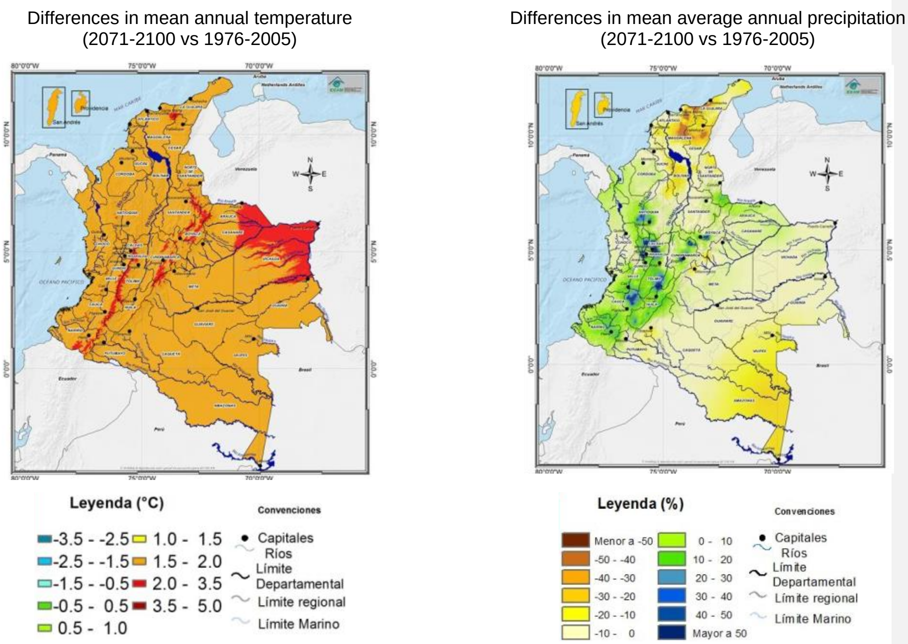


Illustration 4. Changes in temperature and precipitation in Colombia, 2071-2100 vs 1976-2005, RCP 4.5 (IDEAM, PNUD, MADS, DNP, CANCILLERÍA, 2017)

Projected climate change impact

1.2.2.1 Sectoral climate risk profile

The record of crop damage in Colombia due to climatic phenomena is lacking and incomplete (MADR, IDB, IICA and FAO, 2018). At best there is a general record of disaster attention for extreme cases where the intervention of the Colombian government has been required. Therefore, the little existing data on damages in the agricultural sector due to extreme weather events most certainly represents an underreporting of what the real effects of climate on crops has been. According to a report by MADR, IDB, IICA and FAO (2018) on integrated agricultural risk management in Colombia, between 1981 and 2009, 2.4 million hectares were reported to have been affected by extreme weather-related events (floods 51%, droughts 25%, pests 12%, frost 10%, among others). In some cases, the economic value of such damages has been estimated; for example, during the 2007-2008 La Niña phenomenon, losses equivalent to US$ 43.7 million in transitory crops were quantified, while losses in permanent crops were a little over US$ 25.1 million, and in the cattle sector losses amounted to US$ 4.4 billion.

The 2010-2011 La Niña phenomenon, according to the Inter-American Development Bank (IDB) and the UN Economic Commission for Latin America and the Caribbean (ECLAC, 2012), left 221,567 coffee producers affected due to the appearance of pests and diseases. Losses in rice, vegetables and maize were estimated to be US$ 167.5 million, while the losses recorded in the cattle sector were US$ 413 million. According to FEDEGAN (2017), climatic adversities in the period 2009-2016 left a balance of 377 thousand cattle deaths, 5.6 million animals that needed to be relocated and nearly 16 million hectares affected by floods and droughts. This led to economic losses of some 5.5 trillion pesos.

In banana cultivation, according to Augura (2020), average productivity in 2019 was 1,961 boxes per hectare, 41 boxes fewer than in 2018, when it was 2,002 boxes per hectare. The continual ups and downs in Colombia's banana production are mainly due to factors such as low efficiency in water use and climatic conditions in production areas, which means Colombia lags behind in competing with other countries in the region. In one of the main banana-producing areas, Urabá, there are water deficiencies during the first three months of the year, generating water stress in the plants, which subsequently causes lower yields. This situation has led regional producers to seek management alternatives to maintain stable production throughout the year through the application of irrigation to meet the crop's water requirements; however, only 5,315 hectares dedicated to banana production in the region have this technology, representing 14.1% of the total area. The other important producing regions are Magdalena and La Guajira, which experience a contrast in rainfall during the year: excesses in the second half of the year and deficits in the first half. Winds are also a production constraint in this region.

Excessive rainfall poses a risk to the **sugarcane agroindustry**. In 2011, during the winter season, at least 20,000 hectares were flooded as a result of the Cauca River overflowing its banks, with estimated losses of at least US$10 million. That same year, records show that the most widely planted variety - CC 85-92 – became susceptible to a foliar disease (Roya, P. melanocephala), which caused a significant decrease in the area planted to this variety in recent years (Cenicaña, 2020). [17]

1.2.2.2 Climate change risks in the selected territorial unit

Climate Change (CC) is projected to negatively impact the agroecosystems. IPCC (2013)[18] describes the relationships between food security, the food system, and climate change, showing that observed climate change (historical trends) affected the production of food due to the reduction of yields in crops and livestock systems, reductions of food quality, increases of pest and diseases, instability of supply due to increased frequency and severity of extreme events, changes in farmer livelihoods, instability of food prices, disruptions to food storage and transport networks, among others.

Recently the last report of the IPCC's - Sixth Assessment Report (AR6, IPCC, 2021) – reiterates that exists high confidence that growth of concentrations of CH_4 is largely driven by emissions from fossil fuel exploitation, livestock, and waste, with ENSO driving multi-annual variability of wetland and biomass burning emissions. In the future, it is virtually certain that the ENSO will remain the dominant mode of interannual variability in a warmer world. It was also reported that the frequency and intensity of El Niño events in the period from 1951–2000 was high relative to

[17] Communication via email on November 30, 2020 from the director of Cenicaña, Freddy Garces (ffgarces@cenicana.org) as part of the information provided for the preparation of this proposal.

[18] Mbow, C., C. Rosenzweig, L.G. Barioni, T.G. Benton, M. Herrero, M. Krishnapillai, E. Liwenga, P. Pradhan, M.G. Rivera-Ferre,. T. Sapkota, F.N. Tubiello, Y. Xu, 2019: Food Security. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

1901–1950. Most investigators find that ENSO activity in recent decades was higher than the most recent centuries prior to the instrumental period. Grothe et al. (2019) also found that ENSO variance of the last 50 years was 25% higher than the average of the last 51 millennium. Johnson (2013) found that the frequency of CP El Niño events had increased (although not significantly) over the 1950–2011 period, being accompanied by a significant increase in the frequency of La Niña events with a 4 warm (as opposed to cool) western Pacific warm pool. In summary, there is medium confidence that both ENSO amplitude and the frequency of high-magnitude events since 1950 are higher than over the period from 1850.

For the future, it is very likely that rainfall variability related to ENSO will be enhanced significantly by the latter half of the 21st century to changes in the strength and spatial extent of ENSO, despite CMIP6 models are able to reproduce most aspects of the spatial structure and variance of the El Niño- Southern Oscillation (ENSO). Although there is still a large uncertainty about ENSO changes with global warming, most future model projections suggest a future increase in the intensity of the rainfall anomalies associated with ENSO. This results from a projected weakening of the equatorial trade winds and cold tongue, creating a favorable background for eastward and equatorward shifts of atmospheric deep convection (Guilyardi et al, 2016[19]). Instead of the La Niña events with no significant change in their surface expressions, the recent increasing frequency of central Pacific El Niño events is suggested to be related to global warming. There is yet no consensus on the impacts of the recent global warming on such asymmetric changes of El Niño-Southern Oscillation (ENSO) events (Cai et al, 2021[20]). The frequency of the extreme cold/moderate warm events both increases in the central equatorial Pacific over the past decades. We attribute the change of ENSO diversity to the positive cold tongue mode under recent global warming, which gives rise to an intensification, contraction, and westward shift of Walker circulation accompanied by an uplift of the thermocline (Jiang et al, 2021[21]).

In Colombia, for example, warming and precipitation change since 1981 has reduced wheat, rice, and soy productivity, although the impacts were small compared with the technological yield gains over the same period (Lobell et al, 2011), with losses of yield close to 10%. Similar tendencies are displayed in other countries of the Latin America region and the world (Lobell et al, 2011; Lobell and Field 2007). In the same way, assessment of future climate scenarios implications to food production predicts yield reductions, significative suitability losses and negative phenological changes in the main production areas of Colombia. **¡Error! La autoreferencia al marcador no es válida.**~~¡Error! La autoreferencia al marcador no es válida.~~ shows the results of the analyses on the impact of projected CC on crops which have been carried out in Colombia for the different crops and regions related to this project. It is noteworthy that the body of evidence related to climate change impacts on crop production in Colombia is not very substantial. However, it clearly suggests that, even in relatively stringent climate mitigation trajectories such as RCP2.6 and RCP4.5, without adaptation actions climate change will negatively affect all eight agricultural sub-

[19] Guilyardi, E., Wittenberg, A., Balmaseda, M., Cai, W., Collins, M., McPhaden, M. J., Watanabe, M., & Yeh, S. (2016). Fourth CLIVAR Workshop on the Evaluation of ENSO Processes in Climate Models: ENSO in a Changing Climate, Bulletin of the American Meteorological Society, 97(5), 817-820. Retrieved Aug 27, 2021, from https://journals.ametsoc.org/view/journals/bams/97/5/bams-d-15-00287.1.xml

[20] Cai, W., Santoso, A., Collins, M. et al. Changing El Niño–Southern Oscillation in a warming climate. Nat Rev Earth Environ (2021). https://doi.org/10.1038/s43017-021-00199-z

[21] Jiang, N., & Zhu, C. (2018). Asymmetric changes of ENSO diversity modulated by the cold tongue mode under recent global warming. Geophysical Research Letters, 45, 12,506– 12,513. https://doi.org/10.1029/2018GL079494

sectors targeted by CISCAP (see e.g., Ramirez-Villegas et al., 2012; Castro-Llanos et al., 2019; Jägermeyr et al., 2021).

Table 4. Climate change risks and impacts in the targeted agricultural sub-sectors, and adaptation and mitigation interventions and benefits (with information provided is for RCP 4.5 (unless otherwise specified)) [22]

Sector / value chain	Threat / Climate risk	Impacts of climate change	Adaptation interventions and benefits	Mitigation interventions and benefits
Rice	- Low radiation/ low yields; - High humidity/increased diseases - Dry periods/irrigation supply problems - High temperatures/low yields See: Castro-Llanos et al. (2019), Ramirez-Villegas et al. (2012), FAO & MADR (2013), Cortés & Alarcón (2017) Jägermeyr et al. (2021)	For the dry Caribbean region, a 22% reduction in climatic suitability is estimated for 2050 at RCP 8.5 (Castro-Llanos et al.,2019). For the humid Caribbean region, changes in crop phenology are expected by 2050 (Ramirez-Villegas et al., 2012). In the central part of the country, an 80% reduction in climate suitability is expected by 2050 with RCP 8.5 (Castro-Llanos et al., 2019). Impacts are projected to be generally less under more stringent mitigation scenarios such as RCP2.6 or RCP4.5, with less severe yield and/or suitability reductions (Jägermeyr et al., 2021; Ramirez-Villegas et al., 2012). For the eastern plains region, a 25% reduction in yield is estimated for 2030 under RCP 4.5 (FAO and MADR, 2013). In some regions where it is possible to take advantage of better climatic conditions projected for the crop are the middle and upper parts of the Magdalena inter-Andean valley (Cortés & Alarcón, 2017, FAO and MADR, 2013) and the upper part of the Cauca inter-Andean valley (Castro-Llanos et al., 2019).	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models); New varieties tolerant or resistant to drought, water deficit, high temperatures and low radiation (develop, validation, massive multiplication and deliver of seed to farmers).; Water resource planning at the basin level; Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water Benefits: Increase productivity (20%), loss reduction, lower costs (8-13%) and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption, use of genetically improved climate resilient varieties and efficient water use practices.	Interventions: Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development Benefits: Direct emissions reductions 417,323 tCO2e
Maize	- Low radiation/ low yields - High humidity/ increased diseases - Dry periods/ irrigation supply problems - High temperatures/ low yields/increased pests See: FAO and MADR (2013), Goavaerts et al (2019), CIMMYT and CIAT (2019), DNP-BID (2014).	Yield reductions are predicted in the main production areas of Colombia. Estimated yield reductions to 2030 for the humid Caribbean fluctuate between 12 and 28% (FAO and MADR, 2013, Goavaerts et al., 2019, CIMMYT & CIAT, 2019). In the inter-Andean valleys, the yield reduction to 2030 is estimated to be between 6 and 62% (Goavaerts et al., 2019, CIMMYT & CIAT,2019, FAO and MADR, 2013). For the eastern plains region, yield reductions to 2030 are estimated to be between 1 and 20% (Goavaerts et al., 2019, CIMMYT & CIAT,2019, DNP-BID, 2014). At the local level, in Cereté (Córdoba) a decrease in yield of between 13% to 28% is expected, in Espinal (Tolima) between 6% to 8%, and in Uribe (Meta) from 1% to 3%.	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models); New varieties tolerant or resistant to drought, water deficit, high temperatures and disease resistance (develop, validation, massive multiplication and deliver of seed to farmers); Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development. Benefits: Increase productivity (10-27%), loss reduction, and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption, use of genetically improved maize varieties and efficient water use practices.	Interventions: Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development. Benefits: Direct emissions reductions 86,495 tCO2e.
Cattle	- Waterlogging-rainy season/ Forage rot	For cattle farming, the economic impacts of climate change in Colombia show that the departments	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recommendations)	Interventions: Landscape restoration and

[22] Appendix 2 presents in more detail the table *Climate change risks and impacts in the targeted agricultural sub-sectors, and adaptation and mitigation interventions and benefits.*

Código de campo cambiado

Código de campo cambiado

	- Dry periods/ low forage production - High temperatures/ animal stress (DNP-IDB, 2014; DNP-BID, 2015), CIAT and CORMACARENA (2018)	experiencing the greatest reductions in cattle production are Nariño (18.5% reduction in production when compared to the 1970-2010 baseline scenario), Casanare (6.0%), Córdoba (5.4%), Caquetá (4.6%), Guaviare (3.6%) and Cundinamarca (3.5%) (DNP-IDB, 2014, DNP-BID, 2015).	for ranchers; New forages varieties tolerant or resistant to drought, water deficit and excess (develop, validation, massive multiplication and deliver of seed to farmers); Quantifying the water footprint; Evaluation of efficient water use practices; Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water. Benefits: Increase in 12% in productivity for beef cattle and double the yields for dairy farming resulting increased profitability from adoption of technologies for agroclimatic risk management and digital agriculture adoption and efficient water use practices.	technology transfer and scaling (implementation of sustainable livestock models: silvo-pastoral systems, pasture rotation, pasture improvement, living fences); Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development; Quantifying the carbon footprint. Benefits: Direct emissions reductions 7,727,180 tCO2e
Panela sugarcane	- High temperatures/ increased pest infestation - Excess of water/plant rot - Dry periods/low yields Since there are no specific studies on this crop, the risk comes from the expert's opinion from the gremio, Agrosavia, Cenicaña and CIAT.	This is a crop of great social importance in Colombia, as it is the basis for the livelihoods of some 160,000 families of smallholder farmers. However, little has been studied and there is practically no research related to climate. However, it is expected to have similar behavior as sugarcane, and may experience gradual loss of climate suitability and decrease in yields by 2050 (Ramirez-Villegas et al., 2012).	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recommendations) for panela sugar cane producers. New varieties tolerant or resistant to drought, water deficit and high temperatures (develop, validation, massive multiplication and deliver of seed to farmers); Quantifying the water footprint, water resource planning at the basin level, evaluation of efficient water use practices; Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water. Benefits: Increase productivity (65%), loss reduction, lower costs (30%) and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption and efficient water use practices.	Interventions: Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development; Quantifying the carbon footprint. Benefits: Direct emissions reductions 708,425 tCO2e.
Potato	Dry periods/low yields Excessive rainfall/increased diseases Frosts/crop loss High temperatures/increased pests, displacement of production DNP-BID (2014), FAO and MADR (2013)	The areas for this crop are concentrated in the high zones of the mountains of the Andean region, and the estimated yield reduction to 2030 is estimated at between 10% and 40% (DNP-BID, 2014, FAO and MADR, 2013). DNP-BID (2014) estimates that Nariño and Cundinamarca will have the greatest reductions in yields. The drop in yields compared to those simulated in the baseline scenario are related to the higher expected occurrence of irregular precipitation periods (rainfall concentrated in short periods and long periods without rain) and increases in air temperature that affect various physiological processes of the crop. In Cundinamarca, a decrease in yields ranging from 5% to 35% when compared with those estimated for the 2000-2010 period is expected. In addition, in the case of Boyacá, there would be a downward trend ranging from 7% to 12% for yields between the period 2041 and 2070.	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recommendations) for potato producers; New varieties tolerant or resistant to drought, water deficit and high temperatures (massive multiplication and deliver of seed to farmers); Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development (conservation tillage models) Benefits: Increase productivity and loss reduction (16-20%), lower costs (10%) and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption and efficient water use practices.	Interventions: Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development (conservation tillage models). Benefits: Direct emissions reductions 116,500 tCO2e

Coffee	Excessive rainfall/low yields High temperatures/berry borer infestation Ramirez-Villegas et al. (2012), (CIAT-USAID-FNC, 2017).	Coffee is distributed in the mid-mountain zone across the entire mountain geography of the Andean region. Here, changes in the phenology of the crop are expected by 2050 (Ramirez-Villegas et al., 2012), a gradual loss of climatic suitability and decrease in yields by 2050, above 1500 masl (Ramirez-Villegas et al., 2012), and an intensification of problems related to pests and diseases (below 1500 masl) by 2050 (Ramirez-Villegas et al., 2012). In a specific study in Colombia's 'coffee-growing region' as it is known, it was reported that by 2030, 22% of the current suitable coffee-producing area is expected to have been lost (CIAT-USAID-FNC, 2017).	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models); New varieties tolerant or resistant to pest resistance (massive multiplication and deliver of seed to farmers); Water resource planning at the basin level; Evaluation of efficient water use practices. Benefits: Increase productivity (10-15%), loss reduction, lower costs (3-7%) and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.	
Sugarcane	Waterlogging/crop loss Dry periods/irrigation supply problems FAO and MADR (2013). Ramirez-Villegas et al., (2012).	Higher temperatures, higher dioxide concentration, and higher yields 12.5% (FAO and MADR, 2013). Gradual loss of climate suitability and decrease in yields by 2050 (Ramirez-Villegas et al., 2012).	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models); New sugarcane varieties tolerant or resistant to drought, water deficit and excess (develop, validation, massive multiplication and deliver of seed to farmers); Benefits: Increase productivity by 20%, loss reduction, and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption and use of genetically improved varieties.	
Musaceae	Dry periods/low yield High temperatures/ low yields and increased pest infestation	Banana crop is concentrated in two regions of the country, one near the humid Caribbean zone and the other near the dry Caribbean. Changes in crop phenology are expected by 2050, changes in pest and disease incidence (below 500 masl) by 2050 and gradual loss of climatic suitability and decrease in yields by 2050, below 500 masl (Ramirez-Villegas et al., 2012). Plantain crop is found throughout much of the national geography and in different thermal floors. By 2030, problems are expected with high temperatures and therefore loss of climatic suitability in the lower parts, especially in the dry humid Caribbean and the Orinoquia (CIAT, 2014).	Interventions: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recommendations) for banana and plantain producers; New varieties tolerant or resistant to drought, water deficit and high temperatures (validation, massive multiplication and deliver of seed to farmers); Quantifying the water footprint; Water resource planning at the basin level; Evaluation of efficient water use practices; Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water. Benefits: Increase productivity (16-22%), loss reduction, lower costs (15%) and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption, and efficient water use practices.	Interventions: Massive implementation of agronomic management technologies and transformation processes that promote low-carbon development.; Quantifying the carbon footprint. Benefits: Direct emissions reductions 96,111 tCO2e.

Source: Own elaboration. [1] IDEAM, 2015

2. ANALYSIS OF BASELINE SCENARIO/INVESTMENT

2.1 BIOPHYSICAL

Project Location/Area

Colombia is divided into five (5) major regions. The Caribbean region in the north of the country, with a drier agricultural sub-region towards the northeastern side, and another with more rainfall towards the southwestern area. The Andean region crosses the entire country from south to north, starting in the extreme south and bordering the Caribbean region to the north. This region includes the three mountain ranges, from the upper end of the western cordillera to the upper end of the eastern cordillera. In the middle of the three mountain ranges flow the two main rivers of this region (Cauca and Magdalena). The agricultural sub-regions here are differentiated by 'thermal floors' or altitudes, where the most intensive and mechanized agriculture is located in the lower part, called inter-Andean valleys (flat zone), the middle mountain that begins in the hills that border the inter-Andean valleys, reaching the limits of the high mountain, which, the latter, begins around 1800 meters above sea level. The third region is the Orinoquia, which includes the agricultural sub-region known as the eastern plains, located on the eastern side of Colombia, with flat and very favorable areas for agricultural mechanization. Finally, the Amazon and Pacific regions, the former in the south of the country and the latter on the western side of the country, will not be included in the project. These two regions contain the largest area of Colombia's natural ecosystems, many of which are protected as national natural parks. Agriculture there is marginal and therefore was not prioritized in the implementation of this project.

The project will implement actions in 22 departments (69% of the country's departments) and 219 municipalities (20% of the total number of municipalities) shown in the map in Illustration 5~~Illustration 5~~. The rice crop actions will be carried out in 32 municipalities, which are located in three regions: Caribbean (dry and humid Caribbean), Orinoquia (eastern plains) and Andean (inter-Andean valleys). Maize cultivation will have actions in 37 municipalities, with the same geographical location as rice for technified maize, but also includes mid-mountain areas in the Andean region. Sugarcane will have actions in 47 municipalities in the Andean region, but very concentrated in a specific area in the upper part of the inter-Andean valley of the Cauca River. In the case of coffee, actions will be carried out in 26 municipalities distributed from south to north, while in the case of sugarcane they will be concentrated in 11 municipalities in the central zone. In the case of Musaceae, actions will focus on 12 municipalities, most of them in the Caribbean region (dry and humid Caribbean), and a few municipalities (in the case of plantain) in the Andean region (mid-mountain). Potato crops will be grown in 30 municipalities in the Andean region (high mountains). Cattle is dispersed throughout all regions, but actions will be concentrated in 24 municipalities of high importance for the cattle sector, representing each of the cattle-producing ecoregions (humid Caribbean, dry Caribbean, eastern plains, inter-Andean valleys, mid- and high mountain).

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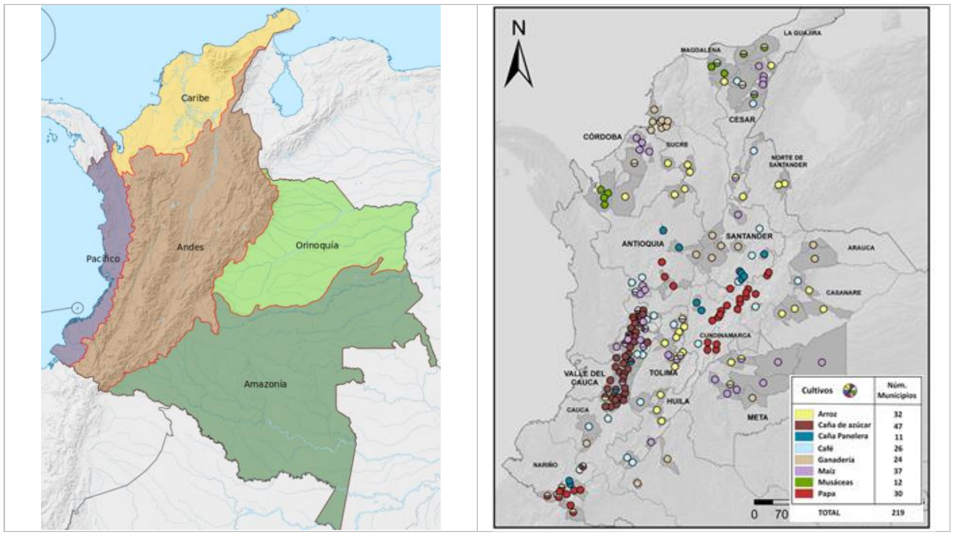


Illustration 5. Regions of Colombia (left) and sites of direct project intervention by crop (right)
Source: Left hand map [Geographical Regions](), righthand map authors' own

The following table (Table 5) shows the departments where the project will carry out actions and the number of municipalities involved:

Table 5. List of departments and number of municipalities reached by the project

Department	Municipalities	Percentage	Cumulative
Valle del Cauca	32	14.6%	14.6%
Antioquia	19	8.7%	23.3%
Cauca	14	6.4%	29.7%
Santander	14	6.4%	36.1%
Cundinamarca	13	5.9%	42.0%
Tolima	13	5.9%	47.9%
Boyacá	12	5.5%	53.4%
Cesar	12	5.5%	58.9%
Nariño	12	5.5%	64.4%
Meta	11	5.0%	69.4%
Sucre	11	5.0%	74.4%
Caldas	7	3.2%	77.6%
Córdoba	7	3.2%	80.8%
Magdalena	7	3.2%	84.0%
Huila	6	2.7%	86.8%
Norte de Santander	6	2.7%	89.5%
Guajira	5	2.3%	91.8%
Risaralda	5	2.3%	94.1%

Department	Municipalities	Percentage	Cumulative
Casanare	4	1.8%	95.9%
Quindio	4	1.8%	97.7%
Arauca	2	0.9%	98.6%
Caquetá	2	0.9%	99.5%
Quindío	1	0.5%	100.0%
Total	**219**	**100%**	

In these municipalities, agricultural activities occupy 12.8 million hectares (69% of the total land) where 24.8% are underutilized and 21.9% are overutilized. The latter is very important when defining adaptation and mitigation measures. Most of the underutilized lands correspond to flat areas with good soils that are under extensive cattle ranching, and therefore it is considered that the land could have a more intensive use. On the other hand, the overutilized lands are located in hillside areas with steep slopes, where agricultural activities must be very limited or under special management conditions to avoid soil degradation. An important aspect to point out is that the project will not implement actions near deforestation hotspots or in wetland areas, even though there are strategic wetland areas nearby in the regions to be worked on. Illustration 6 presents a map of land use conflicts in the municipalities where the project will implement actions.

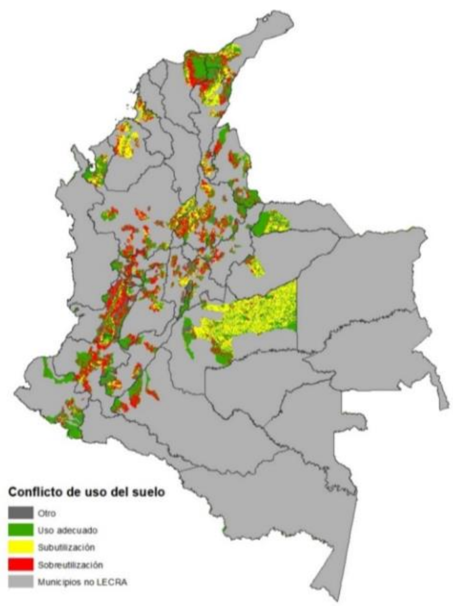


Illustration 6. Land use conflicts
Source: Based on IGAC (2012).

With respect to water resource management, according to the water shortage vulnerability index (WVI)[23] calculated for the project municipalities (see Table 6~~Table 6~~), in an average year, almost half of the municipalities are categorized as highly vulnerable. In dry years, 44% of the municipalities have very high vulnerability, followed by high and medium vulnerability.

Con formato: Fuente: 11 pto

Table 6. Distribution of project municipalities according to their vulnerability to water shortages

WVI	Average year	Dry year
Very low	1.0%	0.0%
Low	19.6%	4.2%
Medium	14.1%	18.6%
High	48.2%	33.1%
Very High	17.0%	44.1%

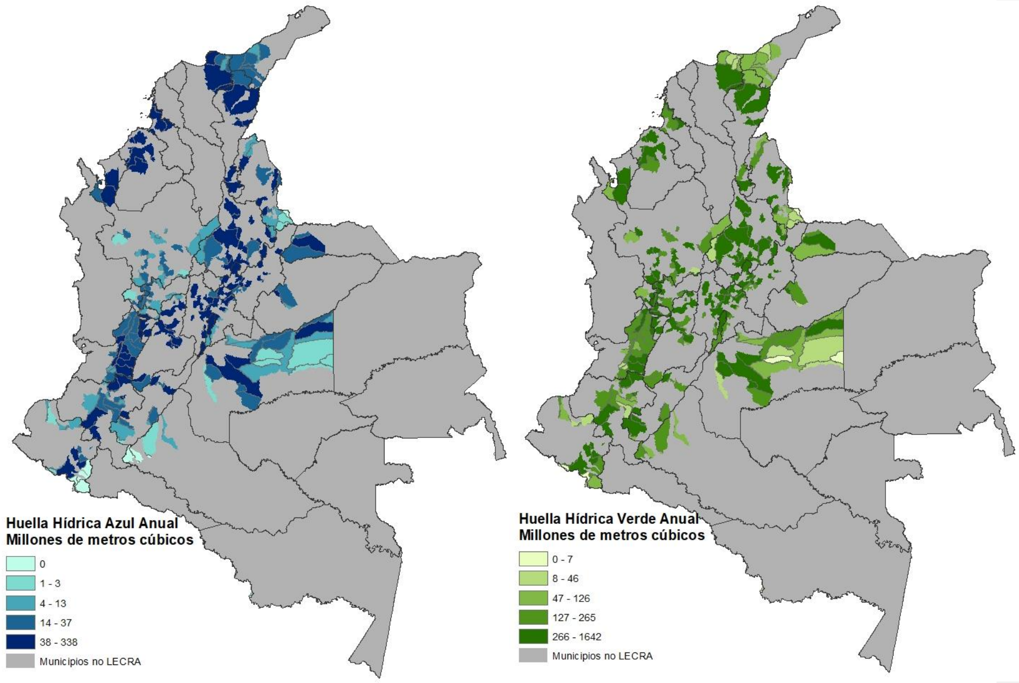
Source: Based on (IDEAM, 2019).

With regard to water use in the municipalities included in the project, according to (IDEAM, 2019), the green water footprint[24], which is an approximation of the footprint of the agricultural sector and natural ecosystems due to the expansion of the agricultural frontier (CTA; GSI-LAC; COSUDE; IDEAM, 2015), is 39,430.44 million m^3 per year in comparison with the total green water footprint of the country which is 51,681.67 million m^3 per year. Illustration 7 shows the green water footprint of Colombia and the project municipalities. For its part, the blue water footprint , present in the agricultural sector as irrigation (CTA; GSI-LAC; COSUDE; IDEAM, 2015), is 5,857.72 million m^3 per year for the project's municipalities, in contrast to the country's total footprint corresponding to 8,329 million m^3 per year. Illustration 7~~Illustration 7~~ shows the blue water footprint for Colombia and for the project's municipalities.

Con formato: Fuente: 11 pto

Regarding information related to risk management and climate change, the areas vulnerable to disasters such as floods, landslides and torrential flows were identified, which, if they were to materialize, could have a significant impact on the project's municipalities. It was identified that in the project's project municipalities: 3,628,169 hectares present high and very high susceptibility to land movements (SGC, 2015), 3,517,996 hectares present high and very high risk of torrential flows (IDEAM, 2010), and a total of 604,136 hectares are within areas of periodical flooding (IGAC-IDEAM, 2012; 2016).

[23] Measures the degree of fragility in a water system's ability to maintain a water supply for water-using sectors and risk of water shortages, both in average hydrological conditions and in extreme, dry year conditions.
[24] The green water footprint is the water stored in the soil, and is quantified by estimating the water evapotranspired by vegetation associated with an anthropic process (crops) that does not originate from irrigation water (rainfed agriculture).



Map A. Blue water footprint **Map B. green water footprint**

Illustration 7. Water footprints for the project's intervention municipalities
Map A blue water footprint and Map B green water footprint.
Source: Based on (IDEAM, 2019).

Geology, topography and soils

Caribbean Region:

The region represents 11.6% of the entire Colombian continental territory. Several important biomes in this region will be outside the direct scope of the project, such as the desertic area of La Guajira, La Mojana area (except for some specific points for rice cultivation in the Mojana of Sucre), Montes de Maria, the entire southern part of Bolivar and Magdalena, the Sierra Nevada de Santa Marta, which stands out for being one of the major water sources for the departments of Magdalena, Cesar and La Guajira, and almost the entire department of Cesar, except for the northern part. Although agricultural activity is dispersed throughout much of the country, the agricultural areas where the project will develop activities are concentrated in northern Antioquia, northern Córdoba, northern Sucre, and in the lowlands in the vicinity of the Sierra Nevada mountain range. These are areas of foothills, plains, alluvial valleys and, in some cases, hillsides. In most cases these are low altitude lands (less than 130 masl) and therefore warm (28ºC).

It is difficult to make a short classification of soils in the region given their great diversity but, in general terms and thinking about the agricultural areas where the project will be located, these are alluvial soils with very good conditions for agricultural and cattle activities, especially for their fertility and good physical conditions, with the only exception being the risk of flooding or waterlogging that can occur with the saturation of the drainage channels that evacuate excess water during the rainy season.

Andean Region

This region comprises 25% of Colombian territory. In the high mountain zone, there are soils with very good conditions for agricultural production. They are deep soils with very good physical conditions, a high content of organic matter and therefore carbon, but this is due more to low mineralization rates. They are areas with very variable slopes, from areas with high slopes, predominantly undulations, but there are also flat areas, even mechanized areas.

A little lower in altitude, in the mid-mountain zone, there are also very good soils for agricultural production, generally deep and with high organic matter content, and with loamy textures. Mineralization rates are higher there. The slopes are steep and therefore mechanization is very restricted. Care of the soils is therefore fundamental as they are very prone to erosion. The type and slope of the soils are conducive to avoiding flooding and waterlogging problems, and the dry seasons are not as drastic as in other regions.

In the case of the inter-Andean valleys (flat area), the soils are of sedimentary origin in very flat areas, providing very good conditions for agriculture since the physical and chemical conditions of these soils are very good with high fertility. In fact, they are the most expensive agricultural soils in the country and have the highest rental value. The vast majority of these soils are located in the upper (southernmost) parts of the Cauca and Magdalena rivers. In the case of the Cauca River, it has major problems with flooding and waterlogging. This is a region that has transformed the ecosystem to a large extent and has adapted the agricultural lands to the riverbanks and even channeled some of the rivers by means of embankments or “jarillones”, causing the risk of flooding to increase considerably.

Orinoquia Region

This region represents 22% of the country’s total area, starting in the upper part of the eastern mountain range (2.6% of this territory) with a steep drop (steep slopes) that quickly reaches what is known as the eastern plains. However, this is not a homogeneous zone; on the contrary, it is composed of very different ecosystems with strikingly different connotations for agricultural production. Firstly, there is a transition zone of the foothills called the piedmont, where most of the population and intensive farming is concentrated (compared to the other systems in this region). It is a flat area with low slopes and is divided by a series of rivers and streams that flow down from the upper part of the mountain range. It is the area with the best road connections, as the main road crosses from south to north following the entire piedmont region. This is an area that has been heavily intervened by man, but still has great potential for growth in productivity and agricultural development (not in the expansion of the agricultural frontier).

Continuing towards the east (central-northern zone) is the ecosystem known as the floodable savannah (21.2% of this territory), which, as its name indicates, is flooded most of the year, related to the rainy season. This territory is limited to the east by the Meta river which, together with a large water network that flows into this river (Meta) and a natural containment barrier on its eastern side, contributes to the flooding of the territory. It is precisely in the natural containment barrier of the Meta River where a new landscape called the altillanura plana (11.9% of this territory) begins. It is a region of natural savannahs that is gradually being transformed by agriculture, and it is precisely where the greatest agricultural development of the country is expected in the coming years. So far, this development has mainly taken place in the department of Meta (precisely in the project's area of intervention) since it is the part that has the best road connection. The rest of this territory continues to the east and corresponds to the department of Vichada, which will not be the object of project intervention because it is a territory dominated by native savannahs.

There are also other landscapes that make up this region but which are not the object of direct project intervention (the dissected Altillanura, the Orinoco-Amazonas transition zone, the Andean-Orinoco-Amazonas convergence zone). It is worth mentioning that one of the largest deforestation hotspots in the country is located in the south of the Orinoquia region, precisely in the Orinoco-Amazonas transition zone landscape. This makes the region a major contributor to GHG emissions. In total, the region contributes about 17% of total emissions, but contributes 25% of emissions in the AFOLU sector. Aside from deforestation, livestock and rice production are the two largest contributors to emissions in the AFOLU sector.

The project will work in three of the four departments that make up the region, concentrating on the piedmont and altillanura plana regions. Both regions are characterized by a flat relief, especially the latter, with the former having slightly undulating areas. Soil characteristics in these regions are good in terms of physical conditions but fertility is low. The soils are classified as oxisols, soils considered heavy or clayey and with high aluminum content, especially in the flat highlands. These soils dry out and become waterlogged easily, which is why the very dry and rainy seasons have such a significant impact on agricultural production. These soils are easily eroded by runoff.

Hydrology and hydrography

Hydrology has a great influence on the location of farms, either because the river valleys are rich in minerals or because their proximity provides the water for irrigation systems on farms that require large quantities of water (rice, sugarcane, and bananas).

Caribbean Region:

This region receives the termination of the western and central mountain range and a branch of the eastern mountain range, and therefore also receives the two main rivers of the Andean region (Cauca and Magdalena), which gradually begin to disperse through depressions left by the hills, forming one of Colombia's most important wetland complexes. This region receives most of the excess water from the entire Andean region, acting as a flood buffer zone before reaching the plains that connect with the coastal zone. This wetland zone is a complex water network that maintains high water levels for approximately six months of the year. In the humid Caribbean part is the Momposina Depression where a wetland sub-region called La Mojana is formed, which regulates the flooding of the Cauca and San Jorge riverbeds, and where a project financed by the Green Climate Fund is currently being implemented.

There is another series of rivers no less important, and especially key for the supply of irrigation water for crops in the areas where the project will be active (the Sinu River, the Atrato River and the rivers that flow down from the Santa Marta snow-capped mountains).

Further north in the region, in the departments of Bolívar, Magdalena and Atlántico, there are other important bodies of water, including marshes and other smaller rivers. The Ciénaga Grande de Santa Marta, with an area of 450 km^2, is located in the northwestern part of the Magdalena Department in the region known as the Outer Delta of the Magdalena River. The sources that supply these marshlands are the rivers of the western slope of the Sierra Nevada de Santa Marta, the Magdalena River and the Caribbean Sea. It is estimated that the Colombian Caribbean has 82% of the country's marsh ecosystems.

Andean Region

The Andean region is delimited by three mountain ranges and between them flow the two main rivers of this region (Cauca and Magdalena), these two rivers form the two main inter-Andean valleys that cross the country from south to north. In these mountain ranges, especially in the highlands, there are a number of rivers and streams that flow through the mountains in search of the Cauca and the Magdalena. Thus, the mountains of Colombia are made up of a number of basins on each side of the mountain ranges. In the high zones of the Andean mountain region, there are typically important ecosystems for the hydric regulation of the basins (e.g. páramos or high Andean forest), in the mid-mountain altitudes, and generally associated with the banks of the rivers and streams are forests that also fulfill an important regulating role. In the middle of the lowlands and in some parts of the highlands there is agricultural production. Most of this agriculture is dry farming, with the exception of some small irrigation systems that are located in the higher elevations due to the dry periods that occur there. Although the entire Andean region has a very good supply of rainfall, water scarcity is felt during the dry season, especially in the inter-Andean valleys in the flat areas, due to the high demand for water by other activities not associated with agriculture (domestic, commercial, and industrial), since this is the most densely populated area of Colombia. This has led to increased pressure on natural resources, resulting in the poor condition of the watersheds. The behavior of the rivers and streams is increasingly torrential and the regulatory power of the watersheds has decreased substantially. For this reason, any change in climate in this region will have important implications. The physical conditions of the soils lend themselves to good water storage and regulation capacity, but this has been lost due to poor management of this resource by agriculture.

The lower, flatter areas of this region, known as the inter-Andean valleys, receive the rivers that flow through the mountains and are therefore prone to flooding and waterlogging. This is especially true in the upper zone of the Cauca River (where sugarcane production is located). The flat areas of the inter-Andean valleys are the areas that benefit most from irrigation systems, but many of them do not have reservoirs and this, added to the poor condition of the watersheds and the high demand for water by other sectors, means that the water supply to these districts in the dry season decreases drastically. This makes the planning of planting and the distribution of water among users a major problem.

Orinoquia Region

This is a region rich in water resources and hydrography. The Altillanura region is crossed by rivers and streams. Irrigation systems have not been sufficiently developed largely because there is a very good water supply for semi-annual crops, which are planted at the beginning of the rains and harvested in the dry period. Most rice and maize are planted under rainfed conditions. The few irrigation systems that exist in the area are located in the foothills and are gravity irrigation systems. The dry season is more pronounced in the Altillanura plana, where perennial crops and pastures suffer the most. Despite this, the flat conditions make gravity irrigation systems virtually unviable, and pumping water results in much higher production costs.

The piedmont zone receives the rivers that flow down from the mountain range. In rainy periods these river flows become torrential and, when they reach the flat zone, they overflow, leading to floods. In this zone there are also the upper parts of the region's large rivers that flow into the Meta River. These rivers flow through the flat areas of the plains at a low speed, but their flow is very variable depending on the rainy season. Hydric regulation in the supply areas is very low.

Ecology

Colombia has great natural wealth, which is evident even in areas that have long been farmed or altered by humans for many years. The municipalities included in the project, for example, hold great natural wealth. There are 4,645,200 hectares of forest, 1,327,296 hectares of wetlands (IAvHumboldt, 2015), 1,154,526 hectares of paramos (IAvHumboldt, 2012) and 221,814 hectares of tropical dry forest (IAvHumboldt, 2014) immersed in the landscapes that make up these municipalities. There are specific restrictions in the case of páramo ecosystems, the details of which are extensively addressed in Annex 6. Illustration 8~~Illustration 8~~ presents the ecosystems that are part of the project's municipalities. It is important to highlight that the project will directly involve only those properties located exclusively in areas included in the official agricultural frontier established by Resolution 261 of 2018, excluding from intervention any area destined for conservation as established by all national regulations. Agricultural properties that come from a transformation of natural ecosystems in the last 10 years will not be considered for this project. Likewise, there will be strict compliance with the use restrictions established in the regulations. The beneficiary properties must have all the environmental permits required by law that apply to each context (e.g., water use permits, dumping, etc.).

Con formato: Fuente: 11 pto

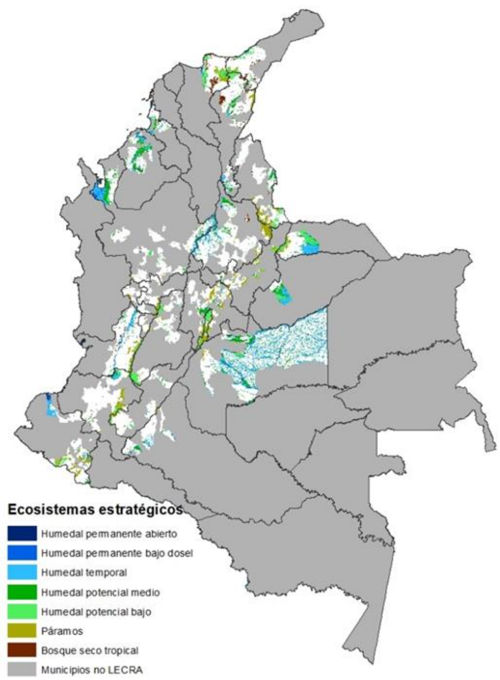


Illustration 8. Strategic ecosystems of paramos, wetlands and tropical dry forest
Source: Based on (IAvHumboldt, 2014) (IAvHumboldt, 2012) (IAvHumboldt, 2015).

It is important to keep in mind that agricultural properties are part of landscapes, which are composed of water networks, forest fragments, biological corridors, wetlands and a series of biomes. Among the most intractable tensions are with potato production and cattle ranching in páramo ecosystems, the use of surface and subway water and the transformation of the landscape by sugarcane production, the quality and quantity of water from rivers, streams and wetlands, and the use of this resource in rice production, livestock production and the protection of river and stream banks, livestock and coffee production and the need for biological corridors to connect different ecosystems, the exploitation of some binder species for the production of panela, and conflicts over water use in some banana-growing regions.

In this sense, although the project will not generate any direct intervention in strategic natural ecosystems, it must ensure the protection of the landscapes in which it is immersed, and it is even expected to generate information and implement practices that reduce some of these tensions.

Although they will not be subject to intervention, some key biomes that are immersed in agricultural ecosystems in each region are mentioned below.

In the Caribbean region, we can find a large part of the remnants of the dry forest, which is one of the most threatened ecosystems in Colombia. This region is also known for its richness in wetlands. Some emblematic species to mention: the white-headed marmoset (*Saguinus oedipus*), Ceiba (*Ceiba pentandra*), and White cedar (*Gyrocarpus americanus*).

In the Andean region, the páramo is a key ecosystem in the region and will be frequently referenced in this project, particularly because part of the potato and livestock production is located in this ecosystem. Although the project will be careful not to make direct interventions within the páramo, it is necessary to be cautious of any indirect effects. In fact, several project actions are aimed at reducing the environmental effects of conventional farming of crops such as potatoes, such as reducing the use of pesticides, fertilizers and soil removal.

Another important ecosystem in this region is the high Andean forest and the biological corridors that connect the remnants of these forests with each other and with other ecosystems such as the páramo and Andean forest located in the mid-mountain zone. In the latter, the biological corridors and the banks of rivers and streams play a decisive role in the ecosystem health of the watersheds, as it is one of the most heavily forested areas. In the lower part, in the flat zone of the inter-Andean valleys, the dry forest becomes more important, given that the remaining enclaves of this biome are minimal, as are the wetlands and the creek and river banks, which are almost non-existent due to the interventions that have been made in the past to expand the agricultural and livestock industries. As previously mentioned, these are some of the most expensive agricultural lands in the country and, for this reason, the pressure on natural ecosystems was and continues to be high. Some emblematic species of the Andean region are: the spectacled bear (*Tremarctos ornatus*), the frailejones (*Espeletia spp*), Yarumo (*Cecropia peltata*), and oak (*Quercus humboldtii*).

In the Orinoquia region (eastern plains), the critical elements of the ecosystems are the gallery forests, morichales or swamps, wetlands, and dry forest. Some emblematic species include: the crested heron (*Philherodius pileatus*), chiguiro or cabybara (*Hydrochoerus hydrochaeris*), moriche palm (*Mauritia flexuosa*), caracaro (*Enterolobium cyclocarpum*), and scarlet ibis (*Eudocimus ruber*).

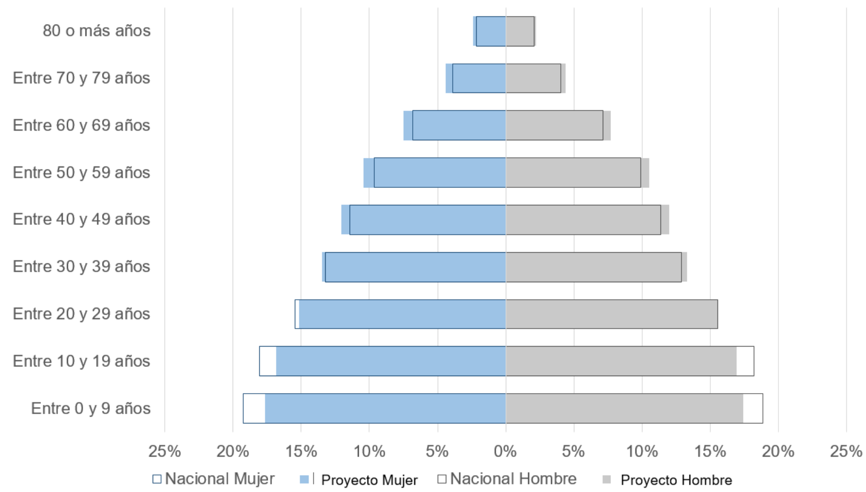
2.2 SOCIO-ECONOMIC

Population and demographics

According to DANE figures (2020a), the territories where the project will be implemented have a rural population of 2.99 million people, of which 51.8% (1.55 million) are men and 48.2% (1.44 million) are women. For the distribution of this population by age group, Graph 1 shows a progressive behavior both in the population pyramid of the rural inhabitants of the project's municipalities, as well as that of the nation as a whole.[25] This is related to a greater participation of children under 10 years of age and a relatively homogeneous reduction for each of the age groups.

[25] The population of the project's municipalities are represented in the graph by filled bars, while the national rural information is shown in the bars without filling and only outlined.

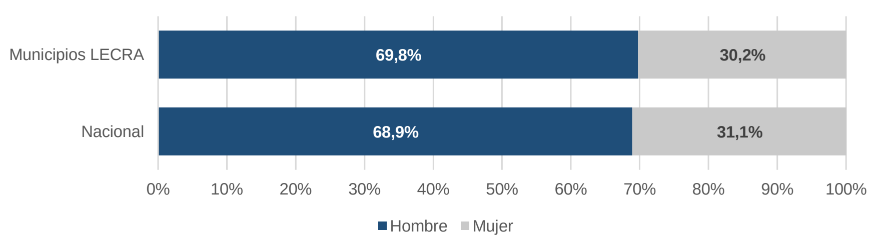
Graph 1. Population pyramid for rural areas: the project's municipalities and rural areas nationally (2020)



Source: Based on DANE (2020a).

In terms of male and female participation in decision-making within households, of the 941,500 households in the project municipalities, seven out of 10 are headed by men, which is higher than the situation in rural areas on a national level (68.9%) (Graph 2). Of those households that are headed by females, only 26.0% of the women live with a spouse, while 33.9% of female heads of household are single, 24.9% are widowed, and 24.1% are separated (common-law or married). These figures reflect a high number of households headed only by women, which increases the household's risk of falling into poverty, given that women typically earn less income than men to support their dependents. In contrast, 72.0% of male-headed households live with their spouse, 40.4% of male heads of household are in common-law partnership, and 30.6% are married.

Graph 2. Percentage of male- and female-headed households in the project's municipalities and rural areas nationally (2018)



Source: Based on DANE (2020b).

The DANE (2020c), identifies that, of the 10.38 million rural people living in the project's departments[26], 3.47 million are in a condition of multidimensional poverty[27], corresponding to 33.5%, slightly lower than the national figure (34.5%). In order to capture territorial differences, the map in Illustration 9~~Illustration 9~~ presents the adjusted multidimensional poverty index (MPI) calculated by the DANE based on data from the National Population and Housing Census 2018.

Con formato: Fuente: 11 pto

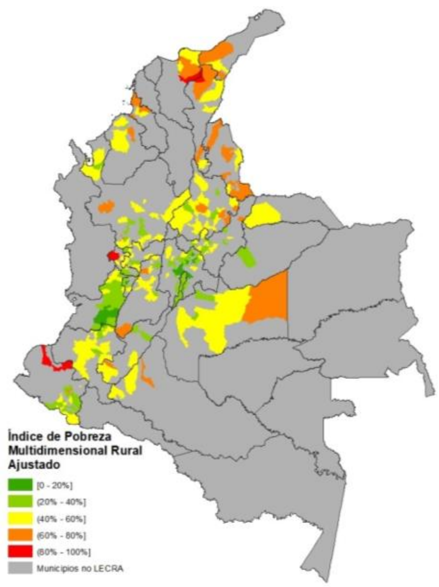


Illustration 9. Adjusted Rural Multidimensional Poverty Index in project municipalities (2018)
Source: Based on DANE (2020b).

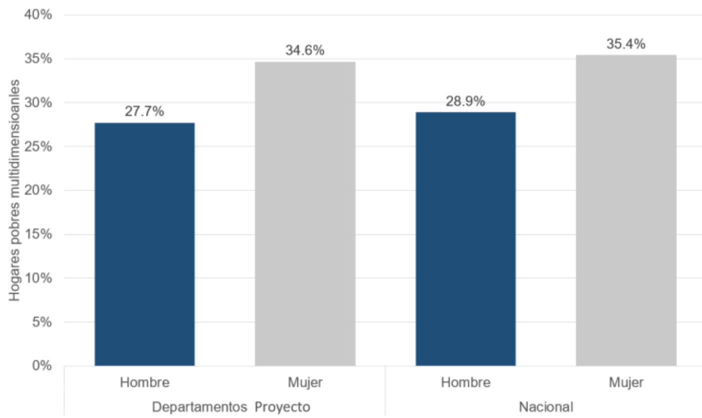
It is observed that 47.3% of the municipalities prioritized by the project have multidimensional poverty incidence rates between 40% and 60% with overall average at 43.4%. Most of the country's municipalities with the highest levels of rural poverty (above 60%) are not part of the project, and the average adjusted rural MPI for the remaining municipalities is estimated at 54.0%.

Comparing poverty incidence according to the gender of the household head, Graph 3 shows that 34.6% of rural households headed by women are considered multidimensionally poor, compared to 27.7% of households headed by men. The main deprivations affecting female-headed households correspond to informal work (91.9%), low educational attainment (75.5%), limited

[26] A department is considered that which has at least one municipality to be involved in the project.
[27] Based on the Social Conpes 150 of 2012, the Multidimensional Poverty Index (MPI) was defined to recognize the absence of desired social conditions in households and for individuals, through the identification of simultaneous deficiencies in the dimensions of educational conditions of the household, conditions of children and youth, work, health and home services and housing conditions.

access to an improved water source (38.5%) and falling behind in school (32.9%). However, when compared to male-headed households, there is a large difference in long-term unemployment (6.6% for male-headed households and 21.8% for female-headed households), reflecting the restrictions on women's entry into the labor market.

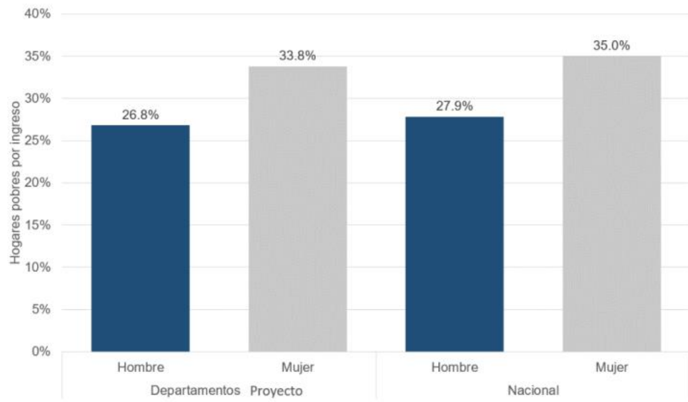
Graph 3. Percentage of rural households living in multidimensional poverty by sex of household head in the project's departments and rural areas nationally (2019)



Source. DANE (2020c).

Similarly, the following Graph 4 provides information on the condition of monetary poverty, presenting the percentage of people who do not have sufficient per capita income to cover the basic basket of goods and services. It is identified that, in the departments involved in the project, 34.6% of the rural population face monetary poverty, which is lower than the national rural poverty rate of 36.1%. Additionally, from DANE (2019b), it is estimated that of the 2.1 million rural households headed by men, 26.8% are income poor, significantly less than the 33.8% of households headed by women deemed income poor (673,800 households). This situation is explained by the lower income-generating capacity of female-headed households (with an average monthly income of COP$959,800, in contrast to the COP$1.1 million of male-headed households).

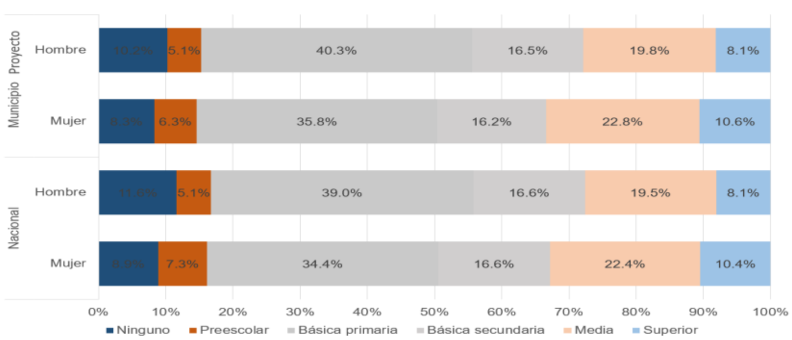
Graph 4. Percentage of rural households living in monetary poverty by sex of household head in project's departments and rural areas nationally (2018)



Source: Based on DANE (2019b).

With respect to the educational conditions of the rural population, the following Graph 5 shows calculations based on DANE (2020b), which shows that of the 2.0 million people over 15 years of age living in the municipalities included in the project, 12.1% do not know how to read or write. This figure is higher than the national rural illiteracy rate (11.9%), and is similar between men and women (12.2% and 12.0%, respectively). When analyzing educational levels by gender, women have higher levels of education than men: 22.8% have secondary education and 10.6% have higher education, while 19.8% of men have vocational secondary education and 8.1% have higher education. However, more than 50% of the population does not have basic secondary education, showing serious limitations in the accumulation of human capital in rural areas of the country.

Graph 5. Educational level attainment by rural men and women over 15 years of age in project's municipalities and rural areas nationally (2018)



Source: Based on DANE (2020b).

Regarding the labor market, the population in the labor force totals 7.7 million for the project's departments, of which 57.1% are employed and 18.6% are employed in household occupations. When analyzing activity according to sex, there are large differences between men and women: while 74.2% of men are considered employed, this figure for women does not exceed 37.5%. In addition, 38.0% of the female population is employed in household occupations, while the participation of men in such occupations is barely 1.5%. In the departments involved in the project, 69.3% of those employed are men and 30.7% are women. This shows the preponderance of men in the development of productive activities in rural areas, both in these departments and at the national level. Additionally, there are large differences between the incomes earned by men and women in the agricultural sector. Specifically, in the agriculture, livestock and hunting sub-sector, men's average income corresponds to 74.5% of the current legal monthly minimum wage (smmlv), while women's average income is 33.5% of 1 smmlv. In analyzing these data according to occupational position, it can be seen that employers earn the highest labor income (131% of 1 smmlv for men and 106% for women), followed by employees (129% for men and 98.2% for women), day laborers (99% for men and 64% for women), and, finally, self-employed workers, who earn the lowest income in the sector (57% of 1 smmlv for men and 34% for women).

The unemployment rates show that while men have an unemployment rate of 3.2% in the project departments, the rate for women is 9.9% (similar to the national rate). Therefore, the labor market in rural areas is not able to absorb the supply of female workers. This situation is related to the structure of the rural economy, where agricultural and livestock activities predominate and in which male paid labor prevails. Nevertheless, rural women participate in productive work as unpaid family workers and in care economy activities closely related to agricultural production, such as the production, transformation and provision of food for household consumption and for day laborers, and animal care.

Institutional structures

The MADR, in accordance with the provisions of Decree 1985 of 2013, has among its functions to formulate, direct, coordinate and evaluate rural policies on agricultural, fisheries and forestry development, within the areas of its competence. The Ministry is responsible for formulating actions to promote national inter-institutional coordination leading to the implementation of plans, programs and projects for rural and agricultural development, as well as formulating, coordinating, adopting and following up on agricultural development policy as it relates to agricultural production chains. Accordingly, it is responsible for developing the following objectives:

- "To promote a territorial approach to rural development, and to strengthen the productivity and competitiveness of agricultural products through comprehensive actions that improve the living conditions of rural inhabitants, enable the sustainable use of natural resources, generate employment and achieve sustained and balanced growth in the regions.
- To promote the articulation of institutional actions in the rural context in a focused and systematic manner, under principles of competitiveness, equity, sustainability, multisectoriality and decentralization, for the socioeconomic development of the country."

The **Directorate of Innovation, Technological Development and Health Protection** (DIDTPS), within the framework of Article 20 of the aforementioned Decree, will have among its actions the following responsibilities:

1. *Design and evaluate policies, plans, programs and projects for agricultural development in terms of prevention, surveillance and control of sanitary, biological and chemical risks for animal and plant species.*
2. *To propose norms, instruments and procedures for research, technological development, innovation and technical assistance in agriculture, fisheries, aquaculture and forestry to improve the competitiveness of the sector.*
3. *To design and implement strategies and instruments focused on climate risk management through actions for the identification, prevention, and adoption of mitigation and adaptation measures in production systems in coordination with the Directorates of Production Chains and of Financing and Agricultural Risks. (...) 16. To contribute, within the framework of its competencies, to the design and implementation of rural development programs with a territorial approach.*

The MADR has prioritized the phenomena of climate variability and change as one of the most serious threats facing the agribusiness sector, but with a very limited response to this problem due to the great complications that the sector presents in terms of prices, competitiveness, conflict, social tensions, among others. The needs and demands of the sector are enormous and far exceed the limited resources available to it. The MADR's determination to address climate threats is clear, and this has been documented in the commitments assimilated in the NDCs, and recently during the formulation of the Comprehensive Plan for Climate Change Management in the Agricultural Sector (PIGCCAgro). The strategy selected by the MADR is to prepare producers to face climate challenges by strengthening the institutional framework that brings them together, and the provision and strengthening of public goods and services that enable them to have adaptation and mitigation options at hand at the lowest possible cost. One of the goals of the NDCs is to strengthen 10 producer Gremios by 2030, and the establishment of Agroclimatic Technical Work Groups (MTA) in 27 departments, reaching one million users.

In this project, the **Ministry of Agriculture and Rural Development (MADR)** will be responsible for executing the resources and technical implementation of the project through the **Directorate of Innovation, Technological Development and Health Protection (DIDTPS)** before the Ministry of Finance and CAF, for which it will have a project execution unit made up of a work team that will be under the leadership of the Director of the DIDTPS. The MADR selected the Alliance Bioversity-CIAT as the project's procured party, carrying out the entire direct contracting process under the regulatory framework permitted by Colombian law. For this reason, a working team was formed between the MADR, the Development Bank of Latin America (CAF) and Alliance Bioversity-CIAT to formulate this project, in which the MADR acts as the leader of the initiative, CAF as the accredited agency before the GCF and Alliance Bioversity-CIAT as the technical leader of the project formulation.

The project will have thirteen (13) strategic partners for project implementation. To implement the project, Alliance Bioversity-CIAT will work in coordination with the following trade organizations: Fedearroz (rice), Fenalce (maize), Fedegan (livestock), Fedepanela (sugarcane), Fedepapa (potato), Federación Nacional de Cafeteros - Cenicafe (coffee), Asocaña - Cenicaña (sugarcane), Augura, Asbama and Aohofrucol (musaceae). In addition, the Colombian Agricultural Research Corporation (Agrosavia) and institutions such as The International Maize and Wheat Improvement Center (CIMMYT) and the Centre for Research on Sustainable Agricultural Production Systems (CIPAV) of Colombia will be strategic partners in the implementation. These strategic partners will have a role in the implementation of project activities and therefore will be assigned a budget that will be subject to results and deliverables. The importance of these partners lies in the fact that they are the institutions that will be responsible for the continuity and sustainability of the project's actions once it is completed.

These are national institutions that have a presence in the different producing regions of each crop, with high levels of recognition and outreach to producers and advanced technical knowledge of the production systems prioritized in the project. These are entities with financial capacity that will assume some of the costs of project implementation through counterpart entities.

One such case is Agrosavia (Colombian Agricultural Research Corporation), a decentralized public entity of mixed non-profit participation of a scientific and technical nature whose purpose is to work for the generation of scientific knowledge and agricultural technological development through scientific research, the adaptation of technologies, technology transfer and advisory services in order to improve the competitiveness of production, to increase equity in the distribution of technological benefits, sustainability in the use of natural resources, the strengthening of Colombia's scientific and technological capacity, and to contribute to improving the quality of life of the population. Agrosavia has 23 offices nationwide, strategically distributed in the agricultural sub-regions (all of the project's sub-regions).

Agrosavia played a major role in supporting the MADR in the formulation of Law 1876 of 2017, through which the National Agricultural Innovation System was created. This Law formulates three subsystems:

1. National Subsystem of Agricultural Research and Technological Development.
2. National Subsystem of Agricultural Extension.
3. National Subsystem of Education and Training for Agricultural Innovation.

The three subsystems are fundamental in tackling climate change in the agricultural sector, and in fact must incorporate this issue into their components. In this sense, the development of new technologies, the expansion of coverage and the modernization of the extension system, and capacity building with the three components of the project are perfectly aligned with the MADR's strategy in the SNIA Law.

The **agricultural Gremios** are non-profit legal entities under private law, created with the purpose of supporting or defending the common interests of their members and contributing to the development of the national rural sector. These Gremios represent the producers and are recognized by the MADR. Some crops have parafiscal funds, administered by the Gremios (Fedegan, Fedearroz, Fenalce, Fedepapa and Fedepanela), which are public funds derived from the sale of crops for the purpose of benefiting the sector that generates them through investment programs, in accordance with the rules that regulate them.

The **Ministry of Finance and Public Credit (MHCP)** and the **National Planning Department (DNP)** will be part of a monitoring committee for this project and will therefore have direct control over the project's progress and reports. Other national institutions (Ministry of Environment and Sustainable Development (MADS), IDEAM, and UPRA) will also be invited to participate in the project monitoring.

Regarding the capacity of Alliance Bioversity-CIAT as an procured party, it is important to mention that it is an agricultural research institution that seeks to make agriculture more eco-efficient, make better use of resources to be more competitive and achieve sustainable productivity, leaving a minimal ecological footprint. Its mission is to "reduce hunger and poverty and improve human health in the tropics through research aimed at increasing the eco-efficiency of agriculture". Supported by the Colombian government and the Rockefeller, Ford, and Kellogg foundations, CIAT was formally established in 1967 and began its research in 1969. The results of the impact analysis of the institution reside in more than 250 journal articles and other papers published since the 1970s. The production of such material has grown exponentially, at an annual rate of approximately 10%, starting with 9 publications in the Center's first decade and reaching a total of nearly 170 in the last decade. In recent years, many of these publications (almost 40%) have examined the impact of the crops for which the Alliance of Bioversity International and CIAT is responsible within the CGIAR. Nearly a third of the studies have reported on new tools and methods for impact assessment. The remainder have focused on the impact of research on climate change, soil fertility, crop biofortification, participatory research, and other topics. For more information on our work over the past few years, please access the following link: http://annualreport2015.ciat.cgiar.org/

La Alianza Bioversity CIAT es miembro del Consorcio CGIAR, que es (CGIAR) una asociación global que une a organizaciones dedicadas a la investigación para un futuro alimentario. Su investigación está dedicada a reducir la pobreza rural, aumentar la seguridad alimentaria, mejorar la salud humana y la nutrición, y garantizar una gestión más sostenible de los recursos naturales, la cual es conducida por los 15 centros que son miembros del Consorcio CGIAR en estrecha colaboración con cientos de organizaciones asociadas, incluidos institutos de investigación nacionales y regionales, organizaciones de la sociedad civil, el mundo académico y el sector privado.

The Alliance of Bioversity International and CIAT is a member of the CGIAR Consortium, which is a global partnership that unites organizations dedicated to research for a food future. Its research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable natural resource management, which is conducted by the 15 centers that are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector.

En Colombia, la Alianza Bioversity CIAT tiene fuertes relaciones con programas nacionales de investigación en diferentes cultivos con organizaciones como FEDEARROZ, FENALCE, FEDEGAN, CENICAÑA, ASBAMA, AGROSAVIA, CIPAV, y trabajos conjuntos con centros de investigación internacionales del CGIAR como CIMMYT. Desde el año 2012, el CIAT y el MADR establecerion un marco de trabajo para fortalecer la capacidad de adaptación del sector agropecuario a través de un trabajo piloto que se viene fortaleciendo con diferentes convenios de cooperación.

In Colombia, the Alliance of Bioversity International and CIAT has strong relationships with national research programs for different crops with organizations such as FEDEARROZ, FENALCE, FEDEGAN, CENICAÑA, ASBAMA, AGROSAVIA, CIPAV, and joint work with international CGIAR research centers such as CIMMYT. Since 2012, CIAT and MADR have established a framework to strengthen the adaptive capacity of the agricultural sector through pilot project that has been strengthened through various cooperation agreements.

Regarding the institutional capacity of the partners, it is important first of all to mention that there are marked differences among them, which were considered when formulating the project. The first group is made up of the Gremios with the greatest capacity for environmental and social management (with averages equal to or greater than 80%): Asbama, Asocaña, Fedearroz and the National Federation of Coffee Growers. The second group has a medium capacity (with averages between 50% and 65%) and is made up of Fedepapa and Fenalce. Fedegan and Fedepanela did not answer most of the questions in the SADCI format, but it should be mentioned that a qualitative evaluation was made of these Gremios and it was possible to identify the efforts being made by each of these two entities, where Fedegan is located in the high capacity group and Fedepanela in the medium capacity group.

With respect to the component about rules, regulations and guidelines for quality management and PQR, the Gremios with the highest scores are Fedearroz, Fedegan and the National Federation of Coffee Growers, while Fedepapa has a medium score and Asbama, Fenalce, Asocaña and Fedepanela have a low score. Asbama, Fedearroz, Asocaña and the Federación Nacional de Cafeteros were the highest rated Gremios in terms of environmental standards, regulations and guidelines, while Fedepapa and Fenalce had an average rating. Fedepanela did not submit any information.

With respect to inter-institutional relations, in general, the Gremios have a high capacity and relations with other entities and organizations, which reflects their mission to represent and advocate for the interests of their members, mainly to the national government, as well as the need to seek strategic allies to join efforts to improve the conditions of their members and the competitiveness and profitability of their production. In terms of inter-institutional relations associated with environmental issues, Fenalce had an average rating and Fedegan a low rating. Fedepanela did not submit any information.

In terms of internal linkages, the National Federation of Coffee Growers, Fedearroz, Fedepapa, Asocaña, Asbama and Fedepanela presented a high score, while Fenalce and Fedegan presented a medium score. Likewise, in relation to internal capacity to manage environmental issues, Fedearroz, Asbama, Fenalce, Asocaña, the National Federation of Coffee Growers and Fedepapa presented a high score, while Fedegan presented a low score and Fedepanela did not present any information. In terms of financial capacity, only Asbama, Asocaña and the National Federation of Coffee Growers reported allocating specific resources to environmental management issues. The rest of the Gremios do not allocate specific resources to these issues. Regarding the capacity for monitoring, follow-up and evaluation of environmental and social issues, Fedearroz, Fedepanela and Asocaña had the highest score, followed by Fedepapa and the National Federation of Coffee Growers. Fenalce and Fedegan had a medium rating and Asbama a low rating.

The heterogeneity of capacities both within and among the Gremios shows that it is necessary to work on strengthening them so that these issues do not compromise the results and sustainability of the project.

Stakeholder Views

The project contracted an independent firm to carry out consultations with different key stakeholders (Gremio officials, extensionists, affiliated producers, including ethnic groups, and institutional stakeholders at the regional and national levels) in the areas where direct intervention will take place, and areas of indirect influence, in order to investigate perceptions and recommendations for project implementation. In this sense, the most relevant points of view highlighted by these key stakeholder groups are presented below[28].

It is important to increase the coverage of the agricultural extension service, as well as the capacity of technicians, in terms of new knowledge and technologies, and to provide them with resources and tools to improve the approach and ongoing work with producers. New technologies are also required to cope with climatic phenomena, especially new genetic material and technologies that use less water.

[28] Para mayor detalle ir al Anexo 7

A new culture in use of new technological tools and the use of climate information services is required, and a necessary first step will be the understanding of this information and its use. In this sense, it is necessary to make progress in the modernization of the agricultural sector through the use of technologies. However, these must be technologies that are easy for producers to access, intuitive, didactic, reliable, and relevant in time and place. Similarly, they recommend the use of participatory methodologies (the experience of demonstration farms is important for neighbors to make the decision to adopt changes).

Gremio officials and extensionists recognize that most producers are older men and that young and female producers are more open to the implementation of new practices, which is why they consider it important to involve them in the project. The extensionists and producers also suggest involving the producers' sons and daughters in some activities, for which alliances with educational institutions can be created. In addition, they suggest undertaking long-term projects (more than two years) to build trust with the communities, which will allow for ongoing work with extensionists. To this end, the extensionists point out that it is necessary to investigate and take into account the cultural aspects of the regions in which the activities are carried out.

Producers are pleased with the advances in knowledge about environmental management thanks to local environmental awareness campaigns that have been carried out by a number of projects. However, it is important that the measures do not negatively affect the productivity and quality of the products, and hopefully the result of the new technologies will be differentiated products with established market niches and differentiated prices.

The cost of the new technologies should not be so high as to increase/prevent the chances of mass adoption, and the project should consider support for implementation, especially in the case of small producers or those with low incomes.

On the other hand, the Gremios recognize that some of them have more developed capacities and greater resources than others, and therefore they suggest the promotion of alliances among them, as well as with regional, national and international research centers and universities. To these entities, the extensionists add the NGOs, because of their experience in community and productive work with vulnerable populations.

2.3 POLICY AND LEGISLATION

The Colombian government has been committed for several years to the fight against climate change. To highlight some public policy initiatives in this area, it started with the formulation of the National Strategy for Reducing Emissions from Deforestation and Forest Degradation - ENREDD+ (in 2009). Two years later, two new initiatives were formulated, the approval of a CONPES document that sought to consolidate an institutional strategy for the articulation of policies and actions on climate change in Colombia (CONPES 37000 of 2011) and the Colombian Strategy for Low Carbon Development - ECDBC. A year later, in 2012, came the Financial Strategy to reduce the State's Fiscal Vulnerability in the event of a Natural Disaster and the National Climate Change Adaptation Plan PNACC.

Subsequently, in 2015, Colombia undertook one of the greatest challenges in terms of mitigation and adaptation to climate change, which was to develop its Intended Nationally Determined Contribution - NDC. This included commitments directly related to the agricultural sector, such as the strengthening of 10 production Gremios and 15 departments with Agricultural Technical Committees, in addition to other adaptation and mitigation measures. Subsequently, in 2016, a decree established the organization and operation of SISCLIMA in order to "*coordinate, articulate,* *formulate, monitor and evaluate policies, standards, strategies, plans, programs, projects, actions and measures on climate change adaptation and greenhouse gas mitigation, whose intersectoral and transversal nature implies the necessary participation and co-responsibility of national, departmental, municipal or district public entities, as well as private entities and non-profit entities"* (Decree 1298 of February 24, 2016).

In 2018, guidelines for climate change management were established through Law 1931 of July 27, 2018, which aims to *"establish guidelines for climate change management in the decisions of public and private persons, the concurrence of the Nation, Departments, Municipalities, Districts, Metropolitan Areas and Environmental Authorities mainly in the measures they take to adaptat to climate change, as well as in mitigation of greenhouse gases, with the objective of reducing the vulnerability of the population and ecosystems of the country against the effects of climate change and promote the transition to a competitive, sustainable economy and low carbon development".*

In the same year (2018), CONPES 3934, Green Growth Policy was formulated, which seeks to lead the country to a transition towards a more sustainable, competitive and inclusive economic model, through the efficient use of natural resources in economic sectors, including the agricultural sector. This policy seeks to boost the country's productivity and economic competitiveness by 2030, while ensuring the sustainable use of natural capital and social inclusion, in a climate compatible manner. The policy includes four lines of action to improve the performance of the agricultural sector; 1) Strengthening capacities for agricultural production management and sustainable agricultural production, 2) Management and technology transfer for sustainable agricultural production, 3) Development of a strategy for financing sustainable agricultural projects, and 4) Strengthening the market to stimulate companies and products that leverage green growth.

In terms of agricultural innovation and extension, Law 1876 of 2017, created the National Agricultural Innovation System (SNIA), defined new functions, competencies and joint working mechanisms for national and regional entities and agencies, and created the public agricultural extension service to improve the productivity, competitiveness and sustainability of the Colombian agricultural sector. The law is based on the recognition of the productive and social organization of the country as a participatory planning process that allows the harmonization of agricultural uses and rural land tenure, favoring an adequate balance between agricultural production, efficient land use, and social, environmental and economic sustainability. It also involves, within agricultural extension, actions aimed at generating comprehensive competencies in agricultural producers for the sustainable management of natural resources and the adoption of practices for mitigating and adapting to climate change.

In the area of financing and agricultural risks, Law 16 of 1990 created the National Agricultural Credit System and the National Agricultural Credit Commission - CNCA as administrator for system, as well as the Fund for the Financing of the Agricultural Sector - Finagro. In line with the above, Law 69 of 1993 established agricultural insurance and created the National Agricultural Risk Fund, administered by Finagro, as mechanisms to encourage and protect the production and marketing of foodstuffs against natural and biological risks affecting agricultural activities. Within this framework, the CNCA defines the conditions for accessing the Agricultural Insurance Incentive. In the same sense, Law 101 of 1993 on Agricultural Development opened the possibility of creating development funds through parafiscal contributions for agricultural and fishing.

2.4 BASELINE INVESTMENT

At the initiative of the MADR and in response to the impacts that are frequently affecting crops due to the phenomena of climate variability and change, a pilot project was carried out to work on alternatives **to reduce crop losses due to climatic factors**. The MADR signed a Technical and Scientific Cooperation Agreement with the International Center for Tropical Agriculture - CIAT - at the end of 2012. The project set out to improve the competitiveness of the agricultural sector by strengthening the investment of resources in research, technological development and innovation. This alliance made it possible to join efforts, resources, and institutional capacities to strengthen the agricultural sector's capacity to adapt to climate variability and change and to improve the efficiency of resource use in production systems in some regions. A major result of this agreement was the joint work between the national government, academia, research centers, NGOs and farmers' Gremios in the production chains.

The pilot project was designed with four components: (a) agroclimatic risk management, (b) site-specific agriculture, (c) testing new technologies for adaptation, and, (d) evaluating sustainable production systems. The rice, maize and bean crops were worked on with Fedearroz and Fenalce.

In this first stage, progress was made in **the development of climate forecast models and their validation for some of the prioritized zones**, the first Site-Specific Agriculture analyses were also carried out. **Advanced lines with tolerance to drought and waterlogging were evaluated and the water footprint was measured for different production** systems, including rice. The Gremios (Fedearroz and Fenalce) have found great potential in the information and tools generated during the two years of work. Similarly, **a process of capacity building was initiated for the Gremios' technical staff**, and in some specific areas information was delivered directly to producers. The pilot project also included other topics such as; **measuring the carbon footprint** of palm trees, intensive silvopastoral systems and fruit trees; **measuring soil loss and the water footprint of potatoes, as well as evaluating cassava materials.**

Table 7 below presents a list of the most relevant projects to be considered for project implementation.

Table 7. List of past and current projects

Project Name	Funding Source	Total Investment	Project Site	Key Results	Challenges
MAPA Project	Adaptation Fund (Colombia)	US$16.7 millon	54 municipalities in 18 departments	- Creation of database for agroclimatic analysis. - Regional biophysical context analysis - Agroclimatic characterization of 18 subregions carried out. - Analysis of the suceptibility of 18 departments - 54 technology validation scenarios	The use of post-project outputs and outcomes
Aclimate Colombia Phase I and II	MADR	US$13,7 millon	40 municipaliies in 17 departaments	- 24 new drought-tolerant bean resilient genetic materials - 2 new resilient rice varieties - 10 new maize genetic materials Creation of National and Regional MTAs	Reach working agreements between the public and private sectors and research centers.

Project Name	Funding Source	Total Investment	Project Site	Key Results	Challenges
				- Big Data analysis for rice and maize in six (6) locations - 2,000 producers receiving agro-climatic forecasts and technical support.	Generate confidence in climate predictions among trade Gremios. Appropriation by producers of the concept of uncertainty.
ProNDC Project	GIZ	EU$9 millon	Related to agriculture: Cereté (Córdoba) San Onofre (Sucre)	Implementation of 2 adaptation measures and 2 mitigation measures for maize and livestock	Joint working among different national, regional and local institutions.
The Sustainable Colombian Livestock Project (SLP)	Global Environment Facility and the UK Gov	24.0	87 municipalities in 12 departaments	40,600 ha sustainable livestock	Integration of public institutions into the project
The Caquetá Connected Landscapes Project (Caquetá CLP); and	USAID	8.4	4 municipalities from the Departament of Caqueta	2,040 ha in SSP	La seguridad en las áreas de trabajo
The Orinoquia Sustainable Bovine Production (Orinoquia SBP).	Ecopetrol, Equion Energía Limited, Santiago Oil Company, and Emerald Energy	4.4	Departament of Meta	6,900 ha in sustainable livestock	Establish alliances with different institutions

3. MARKET ANALYSIS

3.1 INTRODUCTION

The crops prioritized in the project (rice, corn, potato, panela, livestock, coffee, Musaceae, sugar cane) contribute more than half of the agricultural GDP in Colombia. Therefore, making these crops more resilient to climatic phenomena is a priority strategy within the NDC. These crops are widely heterogeneous in relation to their international, national, and local markets, value chain composition and financial and extension services, among others. Each of these crops is of strategic importance for the country. Below is an overview of Colombia's participation in these products' global production and market, their relevance for domestic consumption and the national economy. This summary also provides information on each product's value chain composition, the key actors that can benefit from the project. It also addresses this project's participating gremios, their functions, their services to the producer and their role in the project.

3.2 INTERNATIONAL MARKETS

In 2020, of the products considered in the project, those with the largest share in the global market production were corn, rice, and milk, each with a global production exceeding 600 million tons per year. The products that move the least volume globally are coffee and panela, with 10 and 8 million tons per year. Sugarcane and Musaceae are in the middle range, with volumes between 160 and 180 million tons per year. Potato is in the top range, with about 370 million tons and meat is in the lower range, with about 70 (see Table 8). A different picture emerges if we look at Colombia's participation in global production[29]. Colombia's participation is highest in panela and coffee production (16.0% and 8.1%), while rice, potatoes, corn, livestock (both meat and milk) are below 1.5%. Musaceae stands at around 4%. The relative importance in exports also varies, since Colombia's participation in global exports is close to 10% in coffee, banana (Musaceae). Although sugar exports are important for Colombia, its share in the world market is relatively low. Products such as meat, plantain and panela have very low export volumes.

Table 8. Colombia's participation in the global production of the products considered in the project

Crop	Global production (million tons per year)	Colombia's participation in the world market
Rice	751	0.4%
Corn	1.116	0.1%
Potato	370	0.8%
Panela	8	16.0%
Livestock-Meat	68	1.2%
Livestock-Milk	638	1.2%
Coffee	10	8.1%
Musaceae	162	3.9%
Sugar cane	176	1.3%

Source: USDA World Agricultural Production 2021 for rice and corn and FAOSTAT for potatoes, Musaceae, livestock, coffee, sugar cane.

[29] World Production refers to the total quantity produced without differentiating between exports and domestic consumption

The Asian continent is the largest rice producer; China, India, Indonesia, Bangladesh, and Vietnam produce 544 million tons of rice and concentrate three-quarters of world production[30]. Brazil is the country with the highest rice production in the American continent, with an approximate production of 11 million tons, ranking tenth in world production. The United States, with a production of 10.3 million, ranks eleventh among global rice producers. Colombia is ranked in position 25 of rice production, with a production of 2.9 million tons, and is the fourth main producer in the American continent, after Brazil, the United States and Peru.

Regarding the volume of rice traded internationally, it is estimated that in 2020, approximately 46 million tons of white rice were exported. This means that 9% of total production is destined for international markets, which indicates that a large proportion of the rice produced is used for internal consumption in most countries. Although the product's price is important, the focus is particularly on import tariff policies revolving around the food sovereignty debate.

The situation with corn is very different from rice. Corn has been more open to international competition, and therefore, the price is decisive in the producer's decision to sow. Production incentives policies in each country affect offer price. International prices for this product were notably high in mid-2008 and between mid-2010 and mid-2013. Recently, the international price has followed a growing trend since August 2020, and it reached its maximum level in May 2021 with 304.2 USD/t. This was in response to strong world demand, especially from China, as this country increased its corn imports from an average of 7 tons to 26 million tons. Likewise, the global economic recovery has allowed an increased use of grain to manufacture its derivatives, leading to a significant reduction in inventories, leaving buyers subject to the new season's production. Recently in 2021, the price has been highly volatile, mainly in response to climatic conditions that are determining the crop yields for the current season. This situation has created incentives to increase the area planted in the main producing countries, the United States (1.3%) and Brazil (5.1%). Additionally, expectations regarding high prices are maintained, supported by solid world demand. A 10.1% increase in production is expected compared to the 2020/21 campaign, driven by the increase in planted areas and better yields. The main corn producers globally are the United States, China, Brazil, and Argentina.

China is the largest potato producer worldwide, with more than 91 million tons harvested in 2019 and a market share of 25%. India is in second place with a total production of 50 million tons, seeing a 1 million ton drop in its total harvest, mainly caused by the strong hailstorms that occurred nationwide at the end of 2019. The 10 main potato-producing countries (China, India, Russia, Ukraine, USA, Germany, Bangladesh, France, the Netherlands, and Poland) contribute 66% of production.

The countries with the highest potato imports in the international potato market are Belgium, the Netherlands, United States, Germany, France, and Spain. The first two countries mostly buy fresh potatoes, which they use to produce processed potatoes, taking advantage of their industry to offer their products to the world, which is why they are also the two countries with the highest exports. Colombia is ranked 43rd in imports worldwide. The main exporting countries are the Netherlands, Belgium, and Germany, while Colombia is ranked 51st globally. The three most exported sub-categories are: fresh potatoes, representing 42% of total, processed potatoes (41%) and seed potato (7%).

Regarding the production of panela, India and Colombia concentrate practically all global production; more so India, with more than 8/10 of production. This is because they are the two main panela consuming countries. The international market for this product is just opening up; in Colombia for example, the first report on exports was presented in 2012 for an amount of US $1.2 million and was solely destined to the US. In 2020, panela exports amounted to $17.6 million, corresponding to a little more than 12,300 tons. In the beginning, only groups of Colombians, Venezuelans, or Mexicans abroad demanded panela but, today, it has become an increasingly relevant food, not only in non-Latino homes, but also in different segments of international gastronomy, who prefer it for its flavor and aroma, and who are especially interested in organic production.

[30] Dry paddy rice

The beef market is already strongly consolidated internationally. However, Colombia is just starting to join this market, especially the Asian market, where beef consumption has increased. For now, the main export destinations are Russia (26%), followed by Lebanon (20%), Jordan (12%) and Hong Kong (11%). The main destinations for live cattle are Iraq (43%), Egypt (29%), Jordan (15%) and Lebanon (13%). This export market generated USD $123,328 of meat exports, while live cattle generated USD $143,849. However, Colombia also imports beef and offal, with 6,682 tons imported during 2020, mainly from the United States (57%), Argentina (20%) and Paraguay (13%) (DANE 2020).

Although Colombia has strong milk production, imports have grown, especially from the United States and the European Union. FEDEGAN (2021) reports that a total of 73 thousand tons of milk and dairy products were imported in 2020, the highest level in history, which represents just over 820 million liters of equivalent liquid milk. Exports only totaled 4 thousand tons. Likewise, it is estimated that in a few years, powdered milk from the United States and the European Union will be able to enter with zero tariffs, which may put national milk producers at greater risk due to the impact of raw materials such as powdered milk and whey (FEDEGAN 2021).

Coffee in Colombia continues to be a flagship product, with an annual production of 14 million bags, and it is the main source of soft-washed coffee for the market. In volume, Colombia is the third-largest coffee producer in the world, behind Brazil and Vietnam. The demand for coffee in the world has been growing at a steady 2% annual rate, with an 8%-11% increase in the consumption of specialty coffee, which includes both high-quality cup coffee and environmentally friendly coffee that are socially just and have a specific geographic origin. The latter is very relevant for Colombia since 95% of Colombian producers have less than 5 hectares planted with coffee, which classifies them as family economies. Colombia exports 12.7 million 60-kilogram bags annually. The international price of coffee is mainly regulated by supply and demand on the New York Stock Exchange and by each producer country's dollar exchange rate, which also determines the costs of production of supplies and freight. Given the above, production costs are decisive in each country's competitiveness in this market (FEDECAFE 2020b).

Bananas are another important export product for Colombia. In 2020, exports totaled US 916.2 million, with 109 million boxes, increasing 6.5% in value and 9.34% in volume compared to 2019 exports. In the first semester of 2020, the price of this Colombian fruit was US $ 8.62 per box on average, and for the second semester, US $ 7.68 per box, with an annual average of US $ 8.15 per 20 kg box, lower than in 2019 when it was $ 8.54 per box. In particular, the price per box in the Caribbean Region ranges between US 7 (first half of the year) and US 6 (second half of the year). The European Union member countries were the destination of 63% of banana exports, for a total of 69 million boxes. It is important to clarify that due to BREXIT, the total number of boxes exported in 2020 to the United Kingdom is equivalent to 14% of the exports and is not considered part of the E.U. exports. Exports to the United States amount to 13% and the remaining 8% to other destinations.

It is important to note that the European Union, the main destination of Colombian bananas, has "Biodiversity", "From farm to table" and the "European Green Pact" policies that require the banana agribusiness to reduce the use of agrochemicals by 50% by 2030, while integrating the concept of agroecological agriculture. This, with the objective of ensuring healthier food, more biodiverse soils, and efficient use of water resources, reducing greenhouse gas emissions by at least 55 %, integrating clean energy and technological innovation, in order to classify the banana industry as a resilient and competitive agribusiness on a global scale.

Plantain export volumes are still very low and therefore the importance of plantain for Colombia lies more in domestic consumption. The main destination countries for Colombian plantain exports are (in descending order): United States, United Kingdom, Belgium, and Spain, which together accounted for nearly 90% of plantain exports in 2019 and Colombia received 63 million dollars from plantain exports. As of February 2020, plantain exports have grown by 149.3%, increasing from 15,733 tons to 39,320 tons in the 2019/20 period. The main destination country for exports during 2020 was the United States, with a 50% contribution to the market and 19,482 tons shipped, with a 253% quantity increase, compared to the same period in

2019 (Minagricultura 2020). Plantain exports grew by 20% between 2019 and 2020, with 141,028 tons shipped. To grow in this market, Colombia must especially compete with exports from Ecuador, Venezuela, and Costa Rica, and with the entry of competitors from the African continent.

In the international context, in a group of 110 producers and 115 global exporters, Colombia remains among the 15 largest sugar producers and exporters in the world (based on the 2014-2018 average) (ASOCAÑA 2020). However, its participation is not significant, given the dominance of big players such as Brazil, India, and Thailand. In 2019, there was a significant increase in sugar imports, mainly originating in Andean Community countries, and ethanol imports originating in the United States, which affected production decisions and was reflected in a drop of harvested area (-3,7%), reduced milling (-6.8%), and sugar production, including sugar used for ethanol (-5%). Sugar imports grew 136% compared to 2018, amounting to 250 thousand tons imported from 17 countries. However, 91% of these imports originated in Peru (40%), Bolivia (35%) and Ecuador (16%), countries that do not pay tariffs. The volume of sugar imports in 2019 was the third highest in history; as of March 2020, there was a 53% increase compared to the same quarter of 2019. According to ASOCAÑA reports (2020), during 2019, 2.2 million tons of sugar were produced, approximately 1.5 million were sold in domestic trade, 700 thousand tons were exported, and 250 thousand tons were imported, meaning that national consumption is approximately 1,769,933 tons of sugar. As for bioethanol, another product derived from sugar cane, 443,570 million liters were produced, which added to imports of 269,492 million liters, which implies that national consumption amounts to 718,576 million liters. The recovery of the international sugar price during the second half of 2020 placed the prices of white sugar for that year at an average level of USD 376 per ton, 13% above the levels of 2019 (Asocaña, 2021).

3.3 National and local markets

A large part of the production (> 90%) of most of these products is destined for domestic consumption, except for bananas (Musaceae) and coffee, which are mostly (> 90%) destined for export, and in the case of sugar cane, a little more than 30% of production is exported. The participation of almost all products in the national market is very high (>80%), except for corn with the lowest participation (one fifth), and coffee, which is around half. Another important aspect is its contribution to the national economy. Livestock (meat and milk) and coffee generate the highest contributions to agricultural GDP, each exceeding 10% (counting meat and milk separately), while the participation of other crops is below 3% (see Table 9).

Table 9. National importance of prioritized crops according to their contribution to agricultural GDP and their participation in the national market

Crop	Participation in Colombian agricultural GDP	Production destined for domestic consumption	Participation in the domestic market
Rice	3.8%	100%	89.9%
Corn	3.0%	100%	19.0%
Potato	2.4%	100%	98.5%
Panela	0.8%	99.0%	100%
Livestock-Meat	11.1%	94.5%	99.2%
Livestock-Milk	10.7%	99.9%	99.1%
Coffee	10.1%	7.4%	55.6%
Musaceae	7.1%	71.2%	100%
Sugar cane	2.8%	66.2%	84.3%

Source: Information provided by the gremios (producers associations).

There are several noteworthy points: Colombia produces the best coffee in the world and has a large share in world exports; however, it must import lower quality coffee to meet national demand. Sugarcane has the highest productivity indicators in the world; however, its share in the world market remains low. Globally, panela is a little-known and little-consumed product, but Colombia is one of the few countries (along with India) where this product is culturally and socially important. Although the share of Colombia's world production is very low in certain products (rice, livestock, potatoes, rice), Colombian consumers are highly dependent on them and producers are highly dependent on the income derived from these products, which makes them strategic for the country.

The milling industry is the main buyer of green paddy rice in Colombia, and the intra-annual price fluctuation is very strong, given the marked harvest periods, which influence the producer's decision regarding sowing dates. This makes agroclimatic predictions very important, since early sowing to get a good price can expose the crop to a low environmental supply. Rice imports vary from year to year, but it can be argued that there is a growing trend. Dry paddy rice imports have remained high since 2012 when they amounted to more than 160 thousand tons[31], while in 2020 326,308 tons were imported. The main countries of origin of rice imports in Colombia are in descending order, the United States (83.28%), Ecuador (16.52%), Italy (0.11%) and Thailand (0.1%).

Colombia has five rice-growing areas that share agroecological, socioeconomic and cultural similarities: Central zone (Tolima, Huila, Cundinamarca, Caldas, Boyacá, Cauca and Valle del Cauca), the Plains or Llanos zone (Meta, Casanare, Arauca, Vichada and Guaviare and the plains foothills of Cundinamarca), Bajo Cauca (Antioquia, Bolívar, Córdoba, Sucre and rice municipalities of Córdoba and Chocó), North Coast (Cesar, Magdalena, Atlántico and La Guajira) and Santanderes (Santander and Norte de Santander). The central zone contributes 34% of national production[32], with an average productivity of 7.2 t/ha, and comprises 32% of total producers. The plains zone contributes 45.8% of national production, but has a lower productivity (5.3 t/ha) and larger farms, since it only comprises 14% of total producers. Lower Cauca contributes 8.8% of national production, has a low productivity (3.9 t/ha) and concentrates a large number of producers (36%), indicating there is a large presence of small producers with a very low technological level in this area. The North Coast contributes 4.4% of the national production, with an average productivity of 5.4 t/ha and concentrates 7% of the producers. Finally, the Santanderes region contributes 7% of production, with average yields of 5.8 t/ha and comprises 12% of all producers.

Regarding the national corn market, producers maintain positive expectations vis-à-vis its price, because the international market's behavior has led national prices to increase, generating a higher income for Colombian producers. In this sense, the area planted for 2021-A[33] increased by 15.03% compared to the same semester of 2020. However, it is important to consider that increases in soybean prices have driven producers' decisions to move from planting corn to planting soybean. The area planted with modified yellow corn has remained stable during the last three years. Regarding production, during the first half of 2020, approximately 300 thousand tons of modified yellow corn were obtained, while 450 thousand tons were obtained during the second half of the same year. There is evidence of a 350-370 thousand ton decrease in the production of modified yellow corn in the first semester of 2021. Regarding yields, it remained stable at 5.6 T/ha between the first half of 2019 and the second half of 2020, while in the first half of 2021, this yield tended to decrease to 5.4 T/ha.

For the year 2020, total corn production was 936,079 tons for yellow corn and 444,162 tons for white corn. Each region in the country has particular use and marketing conditions. In the department of Córdoba, total production amounted to 223,850 tons: 115,940 tons of yellow corn and 107,910 tons of white corn. The product is mainly marketed in the town of Cereté, where there are big buyers (pre-cooked flours and animal

[31] It is important to note that rice imports correspond to white rice, but white rice and dry paddy rice were considered equivalent in order to compare imports with national production figures
[32] Refers to green paddy
[33] The letter refers to the semester of the year; A is the first semester and B the second semester

feed) and storage infrastructure, which is insufficient to meet the demand for this service. Buyers from Antioquia come to the department and use the corn for the production of arepas, mazamorra and other preparations. In the department of Meta, total production amounts to 355,410 tons, of which 311,778 tons are yellow corn and 43,512 tons are white corn. There is a significant percentage of yellow corn production used for self-consumption, for animal protein production. Production is marketed through buyers from Cundinamarca, Boyacá, Santander, and Casanare. The total production of the department of Tolima was 164,100 tons, of which 125,050 tons were yellow corn and 39,050 tons was white corn. Production is marketed through companies that finance production, threshing machines in the department, some poultry companies and buyers from Cundinamarca, Huila, and Antioquia. The Valle del Cauca department has excellent grain quality. Total production was 134,873 tons, of which 50,774 tons were yellow corn and 84,099 tons was white corn. Production marketing is carried out through companies that finance producers' harvest and buyers from Cali, Antioquia, Nariño, and the coffee producing region. In the department of Cesar, total production amounted to 67,609 tons, of which 36,972 tons were yellow corn 30,637 tons was white corn. The production of the northern area of the department is destined for Barranquilla and Santa Marta and the production of the southern area of the department is marketed in Medellín and Bucaramanga's central wholesaler.

Of the total potato produced in the country, approximately 8% is destined for the industry, 10% corresponds to self-consumption, 64% goes to wholesale plants and the remainder is seed potato. Most of the potato grown by medium and large producers from the departments of Cundinamarca and Boyacá is sent to the Corabastos-Bogotá wholesale market, making it one of the most important markets. The wholesale level is considered key for potato marketing since it is where potato sale conditions are determined. Likewise, wholesalers have the capacity to operate every day and grant credit to their suppliers, and they also have the sales force to reach public markets, institutions, markets, and convenience stores. Finally, local wholesalers and merchants transport potato to terminal markets in cities where it is then distributed to supermarkets, institutions, public markets, and convenience stores, where it is purchased by consumers.

There are particular aspects regarding production in specific locations localities. Cundinamarca is the main supplier of potatoes for industrial processing and from this department, potatoes are also shipped to a large part of the Colombian territory, while Boyacá, Nariño and Antioquia allocate most of the production to fresh consumption.

According to FEDEPAPA (2018), Cundinamarca is the main potato producer. During the 2018 campaign, for example, it reached one million annual tons, of which 72% was destined for the fresh market, 10% for self-consumption, 9% for seeds and 9% for the industry. Boyacá, as the second potato producer with 671 thousand tons, during this same period, allocated 73% for the fresh market, 12% for self-consumption, 8% for seeds and 7% for the industry. Nariño is the third largest potato producing department. During the same period, it managed to produce 574,000 tons of potatoes, allocating 71% for the fresh market, 12% for self-consumption, 9% for industry and 8% for seed production. (Velez & Villareal 2021).

Per capita potato consumption has followed a decreasing trend. While in 2000 it was 74.4 kg/person/year, in 2018 it dropped to 58.9 kg/person/year. This fact is associated with two main factors: i) potato production in Colombia does not grow at the same rate as the population and ii) potato consumption is influenced by changes in the population's eating habits and by the consolidation of substitutes such as rice, pasta, and plantain (Minagricultura, 2019).

Panela is produced in 29 Colombian departments and 565 municipalities. The panela market is characterized by a high degree of intermediation between the producer and the final consumer, which creates a dispersed and inefficient marketing system. In this sense, as the distance between the local producer and regional, national, and international markets increases, a rent-seeking process takes place, and its main beneficiaries are the large wholesalers that supply the main purchasing centers nationwide. Per capita panela consumption in Colombia is the highest in the world (19.5 kilos), and although there is no exact data, it can be inferred that it increased during 2020 due to higher prices motivated by stronger demand, thereby creating higher profits for producers compared to the two previous years. Another aspect that supported price increases was that the government included panela in the solidarity food baskets delivered during the pandemic. Specifically, according to DANE's SIPSA (Integrated Price System) the panela price in January was, on average, approximately US $1.0, while in November 2019, it was US $0.69, showing an increase of more than 45% over two months. This price uncertainty is one of the main problems faced by the agro-industrial panela chain in Colombia. The departments with the greatest influence in this subsector (Boyacá, Cundinamarca, Cauca, Antioquia, Santander, Nariño, Valle del Cauca, Tolima, Caldas, Norte de Santander, Risaralda, and Huila) concentrate 83% of the cultivated area. At the departmental level, the highest producer prices are found in Caquetá, Valle del Cauca, and Risaralda, while the lowest prices are found in Cundinamarca, Nariño, Boyacá, and Santander, where the higher supply usually leads to lower prices. Intermediaries operate in the panela markets of the main producing municipalities. They buy panela directly from the producers on a specific day of the week and their fundamental function is to collect panela and transport it to supply centers in urban areas or distribute it in retail markets. Wholesale marketers generally operate in supply centers in cities and receive the panela from the collectors and sell it to retail distributors, grocers, and supermarkets. Retail distributors are generally agents that operate in non-panela-producing cities and municipalities and are in charge of buying panela from producers or in wholesale markets and selling it directly to consumers through stores, supermarkets, department stores or retail marketplaces.

In 2020, Colombia's cattle herd included a total of 28.8 million heads of cattle; 20.7% were calves younger than one, 54.2% were females (mainly over three years old), and 25.2% were males (mostly between one and two years old) (ICA 2020). Most of the departmental livestock inventory was concentrated in Antioquia, Casanare, Córdoba, Meta, Caquetá, and Santander. Regarding productive orientation, this cattle herd is distributed as follows: 39% for dual purpose, 35% for cattle raising, 20% for cattle fattening and 6% for specialized dairy (FEDEGAN, 2018). Regarding livestock farms, according to ICA figures (2019), there were 623,000 farms with cattle in 2019. Of the total livestock farms, 81.8% have less than 50 cattle, 9.2% have between 50 and 100 cattle, 8.1% between 101 and 500 cattle, and only 1% have more than 500 cattle (ICA, 2019).

Regarding local markets, according to ICA (2020), there were 12.6 million cattle in the departments of Córdoba, Sucre, Guajira, Santander, the highlands of Cundinamarca and Boyacá, Nariño, and the Plains (Llanos) region in 2019. The departments of Meta, Casanare and Córdoba comprise a large percentage of these (17%), followed by Santander, Cundinamarca, and Boyacá with 13%, 12% and 10%, respectively. Finally, Sucre owns 9% of bovine distribution, followed by Nariño with 3% and La Guajira with 2%. In the department of Córdoba, 56% of cattle is used for breeding, while 22% are used for dual purpose and 22% for fattening. Livestock in Cordoba produce 395 million liters of milk per year, and about 400 thousand cattle are sacrificed. In Sucre, 65% of cattle are use for dual purpose, 35% for breeding and 10% for fattening. In this department, 174.5 million liters of milk were produced and about 120 thousand cattle were slaughtered during 2013 (FEDEGAN 2014c). In the department of Meta, 50% of cattle are used for breeding, 24% for fattening and 22% for dual purpose. However, although it is an important livestock area, it has a low stocking rate and the production per kilo of meat is 4.3% above the national average (FEDEGAN 2014a). Casanare owns 2.1 million cattle, and the orientation is mainly towards breeding (73%), followed by fattening (16%) and dual purpose (10%) (FEDEGAN 2014a). On the other hand, Santander produces 268 million liters of milk per year, and in 2013 the slaughter supply amounted to 279 thousand bovines. The livestock orientation in this department is mainly dual purpose and breeding with 36% of the herd, respectively, followed by fattening with 25% (FEDEGAN 2014b). As for Nariño, according to the livestock census carried out by the sustainable livestock working group, there are about 378,987 heads of cattle in 2017, and the department's livestock orientation is purely dairy (85%), dual purpose (12%), and raising and fattening (3%). During 2017, the share of departmental milk production amounted to 5.7% of national production, which is equivalent to 327.6 million liters (Ganadería sostenible 2017).

According to FEDECAFE (2020), there were 844 thousand hectares planted with coffee in 2020 and the departments of Huila, Tolima and Antioquia had the largest planted area. At the national level, coffee production in 2019 was estimated at 14.8 million 60 kilo bags, 9% higher than at the end of 2018. According to AGRONET (2019), in 2019 Antioquia contributed 19% of national production, followed by Huila (17%), in third place Tolima (12%) and in fourth place, the department of Cauca (7%). The above indicates that coffee production in Colombia is currently dispersed throughout the territory and is not concentrated in a specific region. The average yield was determined at 1.07 t/ha, and the departments with the highest yields were Antioquia, Huila, and Nariño with 1.56 t/ha, 1.42 t/ha and 1.48 t/ha respectively. The production volume achieved in 2020 was unprecedented. This is attributed to the status of the coffee-growing sector in Colombia, which currently has the best indicators in history: 83% of coffee plantations have rust-resistant varieties, are on average 6.6 years old, have an average density of 5,243 trees/ha. and a productivity of 21.4 bags/ha. Of the coffee area in Colombia, 83% is produced under the young technically advanced production system[34], which consists of sun-grown crops that are under nine years old, or totally or partially shade-grown crops that are under 12 years old, with densities equal to or greater than 2500 trees per hectare. Sixteen percent of the planted areas correspond to old and technically advanced coffee, or sun-grown crops that are at least nine years old. The remaining 1% corresponds to traditional plantations, with a density of less than 2,500 trees per hectare (FEDECAFE 2021).

Based on the National Federation of Coffee Growers' purchase guarantee scheme operating in more than 500 points across Colombia, about 95% of the international price is directly transferred to the producer, which means distribution in rural areas, favoring employment and infrastructure development.

National domestic consumption during 2017 amounted to 1.5 million 60 kg bags of green coffee. The average household consumed 805.8 grams of green coffee equivalent per month, with important differences between urban and rural areas (FEDECAFE 2020a).

The number of hectares planted with bananas in Colombia increased by 227 hectares between 2019 (51,227 hectares) and 2020. Average productivity in 2020 was 2,134 boxes per hectare, which is 173 boxes more than in 2019 (1,961 boxes). Bananas for export in Colombia are grown in the departments of Antioquia (Urabá), Magdalena, La Guajira and Cesar. The Urabá banana zone, in the department of Antioquia, is located from South to North, in the municipalities of Chigorodó, Carepa, Apartadó and Turbo. Urabá is home to approximately 70% of the country's banana export activity. The Magdalena banana zone is located in the municipalities of Santa Marta, Ciénaga, Zona Bananera, Aracataca, El Reten and Fundación. In the case of the production in La Guajira, the banana zone is concentrated in the municipalities of Riohacha and Dibulla, while in Cesar it is concentrated in the municipality of Agustín Codazzi. AUGURA comprises 100% of unionized Urabá producers, which is equivalent to 35 thousand hectares and 3,100 hectares in Magdalena. Regarding sociodemographic aspects, AUGURA members in the Magdalena region represent 540 producers, of which 500 correspond to small farms (0.5 to 5 hectares), while in Urabá there are 313 farms, 261 of which are medium-sized and large farms (> 50ha) and 52 farms are micro and small producers (5 to 50 ha). ASBAMA includes 75% of the producers in Magdalena and 100% of the producers in Cesar and La Guajira, which in total are equivalent to more than 9 thousand hectares.

Regarding plantain, the price for the country's producers has remained stable, generating profit margins that range from 10% to 15%, depending on the technical advances. The difference between the amount paid to producers and the amount paid by consumers has increased between 1.5 and 2 in the past five years. This is largely due to intermediation. Regarding supply-side dynamics, 406 thousand tons were sold in the country's main wholesalers in 2020 and the consumer price was on average US $ 0.48 per kilogram in Corabastos Bogotá. In the Urabá region, the product is mainly destined for export. Producers routinely tape and bag the product and they carry out product classification and packaging processes. In other areas of the department, plantains are marketed to large stores, with the required quality standards. In Caldas, there is high intermediation and plantain organizations are not very strong, so producers engage in individual marketing. Regarding the productive component, very good quality fruits are obtained, but the producers are reluctant to participate in export processes, since they consider that the price offered is not

[34] This classification is used by the National Federation of Coffee Growers to define the different types of coffee production systems according to the degree of technical progress, where young and technically advanced is the highest level of technical progress

competitive. In Meta, plantain is marketed through intermediation and the potential client is the Bogota wholesale market. The department of Quindío has high plantain production, but low consumption. Intermediaries play a key role in marketing. In Valle del Cauca, the Dominican Harton plantain dominates production, which mainly takes place in the northern part of the department. Marketing is mainly carried out through intermediaries and production is destined for non-specialized markets located in the southern part of the department. On the other hand, plantain is also destined to the industry; the product is sent to the coffee region where the plantain chip processors are located. Lastly, plantain is also sold for the production of plantain flour, although the volume used for this is smaller. A small part of the production is destined for export through trading companies in Pereira and Armenia. In Córdoba, there is a strong influence of intermediation; the producers do not tape nor bag the product because they consider that these processes raise costs. They are not very inclined to carry out export processes, since they consider that cutting the fruit some weeks earlier causes it to weigh less become less profitable. Intermediaries transport plantains from La Guajira mainly to Santa Marta and Riohacha. In some cases, the producer transports the product directly to the destinations mentioned above, but the marketing risks increase.

In the national sugar production market, in terms of internal transactions, during 2019, 898,243 tons of white sugar were sold, representing 59.1%, followed by 378,783 of refined sugar with a 25% share in the domestic market. In total, 1.5 million tons of sugarcane derivatives were sold during this period, and apparent consumption, which is the sum of the tons produced at the national level, plus imports, amounted to 1.7 million tons (ASOCAÑA 2020). Much of the production process, including primary crop production and processing, is practically concentrated in a "sugar cluster", located in the Geographical Valley of the Cauca River, which runs from the north of the Cauca department, through the center of the department of Valle and reaches the southern part of the Risaralda department. In this region, the location of different actors have positive effects on economic and social activities in more than 51 municipalities in 6 departments, some of which are affected by unemployment, violence, and economic deterioration. These problems have been partially mitigated by the development of the production chain.

3.4 VALUE CHAIN AND KEY PROJECT ACTORS

The value chains of the project's agricultural products are also heterogeneous and are generally grouped into four main nodes: supply, agricultural production, transformation, and marketing. For example, in the case of rice, the supply node comprises the suppliers of products and services that are necessary for rice cultivation. These include suppliers of technical assistance, technology, agro-businesses, seed suppliers, irrigation districts, suppliers of labor, machinery rental services, and suppliers of financing services. The market for certified rice seeds in Colombia is mostly represented by four producing companies: FEDEARROZ, Semillano, Semillas Huila, Pajonales. Based on their own germplasm, these companies carry out research in cultivar development. They generate cultivars periodically and offer them to farmers through certified seeds that are used every year to sow between 40 and 65 percent of the cultivated area in Colombia. The remaining proportion of this area is exploited by planting paddy or sack seed, which generates a decrease in yields and increases sanitary risks in production. The supply node plays an important role in technology transfer, which must be taken into account by the project. Agricultural production, the node that concentrates the project's direct beneficiaries, comprises all rice-producing farmers. According to the IV National Rice Census carried out by FEDEARROZ-FNA, this activity involves 16,403 producers. The transformation node is made up of the economic entities that dry, process, and transform green paddy rice into brown rice, white rice, and their by-products. This activity is clearly developed and represented by the rice mills. There were 123 rice mills in 2019. The marketing node is mainly made up of companies dedicated to the final marketing of the white rice produced by the mills. Likewise, rice importing companies in Colombia are beginning to gain more relevance, especially Adm Rice Inc., which covers a large part of this market (83.04%), followed by Cialzdora Ledesma and Ledesma Agrogruled SA (16.52%), Wismettac Asian Foodsinc (0.12%) JFC INTL INC (0.12%) F Divella SPA (0.11%) and Golden Grain Enterprise Co LTD (0.1%).

About corn, eighty-one percent of the demand is met through imported corn, coming mainly from the United States as a result of the Free Trade Agreement negotiation, while the remaining 19% of the demand is supplied through national production. Sixty-eight percent of the total corn consumed in the country is used to manufacture balanced feed. The companies in this node include Solla S. A., Alimentos Finca SAS, ITALCOL Group, Contegral SA. Part of the corn also reaches drying and storage companies, whose main buyers are Almaviva (Tolima, Meta, and Santander), Fenalce, Almagrario (Tolima), COOMEAGRO, Coagrpuerto (meta) and COALCESAR (Santander).

Sixty-four percent of the national production is formally marketed through regional wholesale intermediaries, threshing machines and the pre-cooked flour industry and some balanced feed companies, while the remaining 36% is carried out through non-formal markets, self-consumption of small producers and short marketing circuits. Thirty-two percent of the total corn (national and imported) is intended for human consumption. It is used for pre-cooked flours, milling, starches, grit production, corn threshers and green consumption (fresh corn). National corn production is mainly sold to national flour industries, whose main buyers are Harinera del Valle, La Soberana, Alimentos Polar, Ingredion, Levapan, Solarte, Kellogg’s, Pepsico Alimentos and Molinos del Atlántico (Garcia 2021). These production companies are mainly located in the departments of Valle del Cauca, Cundinamarca, Santander, and Antioquia. Marketing is carried out mainly in retail, convenience stores and supermarkets, department stores and chain stores.

Most of the production and distribution of corn seeds in Colombia is in the hands of transnational companies (Pioneer, Monsanto, Syngenta, Advanta), Fenalce and Semivalle. These companies research, develop, multiply and market corn seeds in their conventional version and also in their technology-improved version. In the case of the producer association, international entities such as CIMMYT are supporting the implementation of cooperation programs to conduct research, produce and market conventional and technology-improved corn seeds at accessible prices for all types of producers in the country. Some variety seeds are produced by small companies with limited coverage and are generally "selected" seeds, according to the ICA categorization. ICA is an entity attached to the Ministry of Agriculture and has the responsibility to legislate on sanitary, phytosanitary, production and inputs control issues.

Potato cultivation faces great challenges, and one of them is the high degree of marketing intermediation. In this regard, Fedepapa carried out market surveys and identified marketing margins for different wholesale agents (4% to 6%), grocers (35%), the "washer-selector" (19%) and supermarkets (26%). Imports are another threat facing domestic production. Before Colombia had trade agreements with other countries, it imported about 2,500 tons of pre-cooked potatoes; McCain and McDonald’s imported the highest volumes. With the entry into force of FTA, around 50,000 t/year are now imported.

In Colombia, there are about 50 firms dedicated to potato processing. The largest ones are concentrated in Bogotá and in the departments of Valle del Cauca, Cauca, Nariño, Putumayo, Huila, Cundinamarca, Tolima, and Meta. Their characteristics in terms of productive capacity, technological development and bargaining power vary considerably. An exercise to characterize this industry carried out by Fedepapa found that around 10 large and medium-sized firms control more than 95% of the processed product market, particularly in the line of potato chips and pre-fried frozen French fries. The largest industries have large-scale production systems and state-of-the-art technologies. This is a critical and relevant actor for the project, which may be interested in participating to the extent that it can benefit from the proposed technologies. The remaining 5% of the firms are small home-based industries (micro-enterprises), mostly dedicated to assorted fried foods (known as "fried cocktail" or “coctel de fritos” in Spanish) that focus on meeting demand from stores, small supermarkets, and informal markets.

In Colombia, potato production is mostly carried out on the basis of the use of informal seeds obtained by farmers on their own farms (from previous harvests), from farms in the same region or bought in marketing centers, estimating that only 5% of the total planted area uses certified seeds. It is not usual for potato producers to renew seeds. It is estimated that 75% of farmers use seeds from the same origin in periods that can vary between two and five productive cycles. This affects crop productivity since the seed gradually degenerates if it fails to go through a cleaning process as certified seeds do. The reason for the low use and production of certified seeds in Colombia seems to be associated with two factors. In the first place, farmers perceive this input to be too expensive. Second, the lack of a permanent supply of certified seeds, mainly because the seed price depends on the price of commercial potatoes. When the prices of consumer potatoes are high, farmers sell all their production and try to find certified seeds for the next cycle, and this has an impact on the increase of seed prices. In contrast, when consumer potato prices are low, farmers do not have sufficient resources to purchase certified seeds and therefore use informal seeds that are available at low prices.

In the panela sugarcane chain, there are 276 peasant organizations and the vast majority correspond to groups of small-scale producers, which gives an idea of how atomized production is. According to FEDEPANELA's classification, 88.8% of producers represent small-scale production, 10.5% correspond to medium-scale, and 0.7% to large-scale. The departments with the highest number of panela sugarcane growers are, in descending order, Cundinamarca, Antioquia, Cauca and Nariño. These four departments comprise about 50% of the country's panela sugarcane producers. The departments where medium-scale producers participate with more than 15% of production are Santander, Boyacá and Risaralda, and the departments with the participation of large producers that contribute more than 2%, are Boyacá, Santander, and Valle.

Regarding seeds, CENICAÑA developed an offer that was adjusted by AGROSAVIA, for Colombia's panela sector. With this technology, selected seeds for panela sugarcane are obtained. These seeds are necessary for greater productivity and competitiveness in these productive systems. Each germinated plant has a unit cost of $560; 13,000 germinated plants are required for sowing 1 ha. These plants weigh approximately 900 Kilograms and cost $7,280,000

Industrial consumers are other agents who use panela as an input for manufacturing processed products. Some companies in Colombia use panela to make products such as chocolates, aromatic beverages, refreshing drinks, flours for custard, pharmaceutical products, and cosmetics, among others. Finally, exporters must be considered as part of marketing. Producers (usually business producers), directly contact buyers abroad or export agents who buy panela from producers and sell to importers abroad. Exporters are responsible for carrying out sanitary and customs procedures to place the panela in ports of departure (land, sea, or air). The efficiency of the marketing channels is generally measured by the added value that is given to the product during marketing, in terms of its selection, standardization, presentation, quality certification and timely delivery, among other attributes perceived by the buyer and the consumer, with low marketing margins between the producer's sale price and the consumer's purchase price.

Regarding meat production, primary production is concentrated in producers and animal slaughter farms, some of which include complete cycles (breeding, raising, and fattening the animal). Live cattle marketing is quite common. This process occurs through commission agents or collectors, who can place the cattle in livestock auctions or fairs to be marketed (Bravo 2021). The next node in the meat production chain is the transformation that includes all cattle slaughter and dressing processes before being distributed (fresh or refrigerated), either to national, local, regional, and international markets, in accordance with INVIMA certifications and authorizations for such destinations. Mainly fresh or chilled meat, or meat derivatives are marketed, where retail distributors (such as traditional outlets and supermarkets) and wholesale distributors (such as specialized butchers and wholesalers) participate.

The main actors in the transformation node are Athenea Foods - Minerva Foods in Ciénaga de Oro, with a capacity of 850 heads a day, Frigorífico Guadalupe in Bogotá with 2000 cattle a day, Frigorifico Vijagual in Bucaramanga, with a capacity to process 1632 animals a day, and finally, Frigosinú SA in Montería with slaughter capacity of 1200 cattle per work shift. Lastly, final consumers are also part of the meat production chain. These include all actors whose main activity is the consumption of meat and meat by-products. These are divided according to the Colombian meat market: national market (either local, regional, or nation-wide) and international market (with their respective main destinations). In Colombia, there are about 40 auctions, 206 slaughterhouses (PBA) and 16 meat processing plants with INVIMA export authorization.

Meat production is distributed through formal and informal channels, from its production in breeding, fattening, full cycle, or dual-purpose farms until it reaches the final consumers. Collectors can also deliver livestock lots to placement agents, who take them to fairs or auctions (lean or pre-fat cattle), or take them directly to informal slaughterhouses (PBA) for slaughter, and then sell the carcasses to butcher shops and marketplaces, in some cases after having negotiated with merchants or distributors in these locations.

The milk chain is practically divided equally into formal and informal trade. Formal trade comprises collection centers of cooperatives or associations (groups) and collection centers of processing companies. In Colombia, there are about 400 dairy companies that buy and transform milk using the formal channel. In terms of volume management, the most relevant are Colanta, Alpina, Nestlé de Colombia, Alquería, Parmalat, MEALS de Colombia S.A.S (Grupo Nutresa) and Gloria de Colombia. This product reaches consumers through department stores, supermarkets, and mini-markets, hard discount stores, etc. There is also a very important segment of institutional purchases, which includes public purchases for assistance programs, armed or medical forces, HORECA, etc. Last but not least, convenience stores and bakeries. Informal sales are more difficult to track and record, but are known to be handled especially through raw milk vendors (called "cruderos/jugreros" in Spanish) and informal cheesemakers.

The coffee value chain in Colombia is mainly based on 540 thousand producers distributed across 860 thousand hectares in the Andes mountains and the Sierra Nevada de Santa Marta. They preferentially sell dry parchment coffee to cooperatives and private buyers, who must thresh the coffee and create green coffee, or eventually roasted coffee, for export. Abroad, large coffee roasters and instant coffee producers prepare roast and ground coffee for popular brands that sell in supermarkets, or at a very small scale, for the specialty coffee market, which supplies coffee for specialty shops and baristas. These processes involve a large amount of rural labor, technical assistants, equipment companies for farms and mills, sellers of agricultural inputs (pesticides and fertilizers), transporters who take coffee from the farm to the threshers and to the loading ports, as well as specialty and sustainable coffee certifiers. More recently, the agrotourism node has become part of the chain. The chain components that are in direct connection with the final consumer, those who sell roasted coffee as retailers on large surfaces, retailers, micro-roasters, and baristas in coffee shops, may have a special interest in offering a product that is not only sustainable, but environmentally friendly.

The National Federation of Coffee Growers has an improved seed production system managed by the National Coffee Research Center (CENICAFE), where the Genetic Improvement Program delivers the lines that make up the new varieties to the Experimentation Program, which plants the seed lots in the experimental fields in various parts of the country. The lots are harvested in a controlled manner, and the seed is selected per the Colombian Agricultural Institute's (ICA) certification procedures, generating about 70 tons per year, which are distributed in 1 kg bags among the Departmental Coffee Grower Committees, who sell the seed to interested producers as part of a non-profit operation. In this way, some 300 million new plants enter to renovate coffee production, thereby strengthening resilience through young plantations. The market for improved coffee seeds is practically non-existent in the world. Due to long replanting periods (considering it is a semi-perennial crop), the plantations can last for a 20-year period, with adequate renovations based on stumping. However, although informal seeds sale occurs in very low volumes, they can be costly for coffee growers, due to the uncertain genetic identity of the planted material, its susceptibility to diseases, and the difficulty of making short-term changes to varieties, as this crop takes 18 to 24 months to produce its first harvest.

AUGURA brings together the main national marketers, such as C.I. Unibán and C.I. Banacol. It also brings them together indirectly, through their own farms, the trading companies C.I. Banafrut, C.I. Tropical and C.I. FullFruits. In the Magdalena region there are 7 small producer cooperatives such as Emprebancoop, Coomulbanano, Coobamag, Coobafrio, Asobanarcoop, Banafrucoop and Coodeban. It should be noted that the producer association (gremio) includes actors and companies with a cross-sectoral integration, such as aerial spraying companies for the control of black sigatoka, river transport, cardboard, plastic and stamps companies and factories, as well as supplies warehouses and deposits, among others. There are also institutions such as the Regional Autonomous Corporations, which work closely with producers to ensure compliance with each region's environmental regulations and will benefit indirectly from the project's results. Each of the producers associated with AUGURA, either individual farms or banana groups, as well as the cooperatives and marketers previously described, will benefit, and will become an integral part of the project, since the resources they contribute to AUGURA will be used to fund the gremio´s contribution to the project.

In the same sense, ASBAMA in Magdalena brings together important national trading companies that have a large participation in markets, such as the United States market. The three large marketers that are directly linked to the Association are C.I. Tecbaco, C.I. Banasan and C.I La Samaria; while C.I Uniban is indirectly related to the Association. These companies support producers' technical activities, such as those related to irrigation, fumigation, and transportation systems. In particular, the C.I. Tecbaco also offers services related to manufacturing and distributing cardboard for fruit packaging. Foundations such as Fundeban and Fundación Banasan, belonging to C.I Tecbaco and C.I Banasan, respectively, operate as part of corporate social responsibility. These foundations promote social development in the communities located in their areas of influence, by developing and strengthening skills and empowering people to work in favor of their communities. Moreover, these initiatives promote a culture of environmental preservation and comprehensive knowledge among community members.

Banana seeds currently come from in vitro cultures due to the nature of the Musaceae. In Colombia, 100% of export bananas belong to the Cavendish variety, which has different clones such as Valery, Williams, Gran Enano, among others. These are mostly distributed by the Rahan Meristem company. With the current Fusarium R4T problem, the most devastating fungus for Musaceae, there is an open discussion for the banana producer association to begin expanding its genetic base and planting different varieties to diversify the crop. Hence, one of the important points to address in this project is to develop Foc R4T and black sigatoka resistant banana varieties, establishing a multiplication platform that allows producers to access these varieties. In the case of seeds, they cost between US $ 0.55 and 0.83, depending on their physiological status. However, if a company develops a variety with partial or total resistance to Foc R4T and black sigatoka, the cost in the market will be very high, because these alternatives are not currently available in the world.

The plantain's agri-food chain in Colombia comprises producers, marketers, processing industries, seed producers, supply producers, exporters, universities, research centers and regional and national institutions that accompany the process, such as ICA, SENA, UNAD, CIAT, Asohofrucol, secretaries of agriculture and regional autonomous corporations, among others. Regarding plantain producers, the different organizations and associations at the national level are relevant actors. These include the National Colombian Federation of Plantain Producers, Fedeplacol, which brings together the main plantain producer associations in the country and generates synergies between plantain producers and technological advances in the sector. In terms of agribusiness, there are four main companies that account for 93% of the plantain agribusiness market in Colombia. The actors that participate in the plantain chain in Colombia could participate in project activities; for example, producer organizations could participate in the components related to efficient water use and emissions reduction. However, they lack the financial resources to co-finance the project.

In Antioquia, the plantain chain is very important and comprises 40 actors. The support entities node accounts for 50% of participants, including producer associations (gremios) such as Augura, Asohofrucol, entities such as SENA, ICA, research entities such as CORPOICA, CIB and Cenibanano; other entities such as Corpourabá, Ministry of Agriculture, Secretariat of Agriculture and Rural Development of Antioquia, Coopiagrán, Association of Agricultural Engineers of Urabá (Inagru), mayors of the municipalities of the subregion of Urabá and Southwest Antioquia that have prioritized this issue and the universities in the academic sector: Universidad Nacional de Colombia (Medellín Campus), UCO, UPB, Fundación Universitaria de Estudios Superiores de Urabá -FESU and the Politecnico Colombiano Jaime Isaza Cadavid. Likewise, the primary sector has a notable presence with 14 associations of plantain producers from Urabá, such as Fedeplan, Fedeplaur, producers from the Southwest such as the Cooperativa San Juan, Comsab, Asosanjorge, Agrecam, Asopraan and Asopreck, among others.

The sugar cluster is a complex productive structure that brings together 14 sugar mills, 2,750 cane suppliers, more than 40 food and beverage companies, 6 distilleries, 11 energy co-generators, 2 paper producers, 3 sucro-chemical companies, 21 sugarcane-bagasse transport companies, a research center and more than 50 large specialized suppliers, as well as hundreds of small and medium-sized companies that provide goods and services, many of which have been exclusively established to meet the chain's specific needs. The industry has five solid allies; ASOCAÑA, which represents the Colombian sugar sector, PROCAÑA, which includes cane growers, AZUCARI cane producers from the north of Valle del Cauca and the Risaralda Valley, TECNICAÑA, the Colombian society of sugar cane technicians, and CENICAÑA, the Colombian sugar cane research center. Those represented by ASOCAÑA, AZUCARI and PROCAÑA would benefit directly from technologies developed. In the case of TECNICAÑA, it will allow them to transfer information, technologies and knowledge generated by the project in different national and international events such as seminars, workshops, courses, and their biennial meeting. On the other hand, different universities in the region (seven in total) and others at the national level (Universidad Nacional de Colombia, Universidad del Tolima, Universidad de Antioquia, etc.), have signed agreements with CENICAÑA, which will allow them to participate in research, innovation, and technological development processes, while training human capital to address climate change and reduce greenhouse gas emissions. In the future, this human capital will contribute to the Colombian agricultural and agro-industrial sectors.

The sugarcane seed requires special attention to ensure that users have a sufficient quantity of quality seeds of the recommended cane varieties. Cenicaña has been working on this process for more than 40 years and hence, different multiplication systems are available. Through the variety multiplication service, and based on different varieties of sugar cane, between 2004 and 2021, CENICAÑA produced about 9,181,171 plants with the individual bud extraction system, for an annual average of 510,000 plants. The plant production system using individual buds ensures varieties that are largely free from systemic diseases (viruses and bacteria). Similarly, more than one hundred varieties for panela production have been delivered to the sugar cane subsector (Agrosavia, Universidades de Caldas and Amazonas), to be included in their regional tests. Two of these varieties have already been registered (CC 93-7711, CC 93-7510) and variety CC 01-1940 is pending authorization for registration. There is an in vitro culture system (temporary immersion) that allows pathogen-free plants to be produced especially for foundation seedlings. This seed, produced by plants, in in vitro cultivation or in packages, has been delivered to the 13 mills and suppliers that are part of the Colombian sugar industry in order to produce healthy basic, semi-commercial and commercial seedbeds. There is no private market for sugarcane seed in Colombia; therefore, through their gremios (producers associations), producers are in charge of conducting research, developing new materials, and sharing and distributing them. The costs are recovered through promotion fees to finance research and seed production.

3.5 GREMIOS' FUNCTIONS AND SERVICE PROVISION

The agricultural producer´s associations (gremios) are non-profit legal entities under private law, created with the objective of satisfying or defending the common interests of their associates and contributing to the development of the national rural sector. These producers' associations (gremios) represent producers and are recognized by the MADR. Some of these crops benefit from parafiscal funds, administered by the gremios (Fedegan, Fedearroz, Fenalce, Fedepapa and Fedepanela). These funds are public and are collected from crops sales, with the purpose of making investments that will benefit the same sector that generates them, per applicable regulations.

The National Federation of Rice Growers, created in 1947, is a national association comprising rice producers. A regional committee of rice growers is elected every two years by all the farmers in the area through a member assembly. This committee represents each region in the gremio called FEDEARROZ and aims to defend and represent rice farmers at the national level. FEDEARROZ focuses on producers, promoting their technological progress, seeking their economic efficiency and increased competitiveness. FEDEARROZ's currently has 6,696 active members and its research considers the political, economic, social and technical context affecting production.

For over 10 years, FEDEARROZ's technical team has allocated resources and efforts to study the interaction of rice cultivation with the climate, and to design strategies and alternatives to face challenges posed by climate change and variability. Similarly, in recent years, work has focused more on reducing rice cultivation's contribution to climate change and its environmental impact. With its own resources, it has made efforts to train professionals in areas such as physiology, meteorology and soil and water management, in the implementation of a network of meteorological stations throughout rice planted areas, in the generation of rice varieties that are more efficient in water use, in the innovation of alternatives for crop management under adverse climatic conditions, and in transferring these technologies to farmers. Likewise, FEDEARROZ continues to promote the implementation of better agronomic practices that reduce the environmental impact of rice cultivation, improve irrigation water management, reduce the application of agrochemicals, increase the use of biological controls and biofertilizers and take advantage of harvest residues, among others.

Large investments are required to ensure that climate change adaptation and mitigation actions have a significant impact. For this reason, for almost a decade, FEDEARROZ has participated in various inter-institutional agreements and projects that have contributed to these objectives. The agreements established with international institutions and funds (FONTAGRO, IICA, JICA, CIAT, FAO, USAID, UKSA) and with national institutions (Regional Corporations, MADR, Universidad de Tolima, Córdoba) have enabled conducting research in these areas and have significantly contributed to reducing the Colombian rice sector's vulnerability, helping it to become more resilient, sustainable, and environmentally friendly. However, the impact is still insufficient to prevent climate change from affecting the sustainability of rice cultivation in Colombia and, therefore, greater investments exceeding the capacity of the rice´s producer associaare necessary.

The National Federation of Rice Growers FEDEARROZ provides agricultural extension services through different programs. The AMTEC [35] technology mass adoption program, which began implementation in 2012, is FEDEARROZ's main strategy to achieve the rice sector's competitiveness and sustainability goals. By 2020, this program had an impact on an area of 394,421 ha. This was achieved through the participation of 45 comprehensive technical advisers participating in the program, who provide direct technical assistance to more than 700 rice farmers in the country, with a total of 21,031 ha. Additionally, the National Rice Fund has 26 professionals in technology transfer, who are in charge of outreach activities for different actors in the rice production chain. On the other hand, at the national level, there are approximately 175 private technical assistants who carry out extension activities and receive constant training and support from FEDEARROZ-National Rice Fund. Regarding technology transfer events, during 2019 and 2020, FEDEARROZ carried out more than 600 in-person events with the participation of nearly 15,000 people trained in various topics. Moreover, there are inter-institutional projects that allow increasing the coverage of technical assistance and extension programs. This is the case of the agreement between the United Nations Development Program, FEDEARROZ and the Ministry of the Environment, which aims to provide an extension service and technical advice for treating harvest residues to reduce the use of persistent organic pollutants. This initiative is supported by 13 professionals and has a direct impact on an area of 4,259 ha. Likewise, the Co-financing-technical assistance Agreement, between the Tolima Association of Agricultural Engineers ASIATOL and the National Federation of Rice Growers FEDEARROZ, seeks to have a direct impact on 24,000 ha through direct advice in the context of the AMTEC program. This will initially include 18 private technical assistants in the department of Tolima. Finally, it is important to mention that

[35] This program supports producers' adoption of new technological developments, while considering the land's particular production characteristics

the irrigation districts also serve as entities that provide agricultural extension services, mainly to small farmers.

Regarding financing, most of the agricultural credit is financed through public resources, through a second-tier party (FINAGRO[36]), which provides agricultural credit services under different modalities and lines of credit, through different financial entities. However, the union's performance is very important for the amounts of the different lines or the creation of special lines.

In the case of rice, for example, FINAGRO has four general credit lines. This financial offer depends on the farmer's size and type (small, medium, large, and associative schemes). According to the type of financial product accessed and the type of farmer, the interest rate varies from annual effective DTF [37] -1% for small farmers, to annual effective DTF + 5% for large producers. Regarding the terms, the financing periods fluctuate between 3 and 8 years and some include a grace period of up to one year. According to the statistics provided by FINAGRO in 2020, more than US $ 730 million were granted to the rice sector represented in 9,248 credit operations with an average value of US $ 79 thousand. Regarding the promotion of resilient and low-carbon technologies, the special line of credit "All sustainable machinery and infrastructure" grants an additional subsidy for credits related to infrastructure and equipment for water resource management (irrigation and drainage) or the adoption of alternative energy sources (wind, solar, biomass or the use of biofuels) in its production processes.

FEDEARROZ will adopt different roles to participate in the project's research and development activities, depending on the activity and the institution's capacities in each work area. Therefore, FEDEARROZ will assume responsibilities in different stages, including the conceptualization and methodological proposals, design and experimental setups, information collection, information analysis. FEDEARROZ will act as a bridge between the different actors in the chain and the project researchers and developers, generating spaces for dissemination, discussion, and transfer, which will enable specifying the requirements of the different types of beneficiaries, and ensure that the project's products meet their needs. Additionally, FEDEARROZ will provide technical support with its experience and expertise in the different areas of agricultural, commercial, and experimental production, rice cultivation and with its knowledge of the local and social dynamics of each rice-growing area. Once the project is completed, FEDEARROZ will continue promoting, expanding, and transferring project results, and will ensure the sustainability of the project's initiatives. Additionally, FEDEARROZ will monitor and evaluate the impact of the project and the adoption of the technologies involved.

FENALCE was created in 1960 and represents the country's cereal, legume, and soybean growers, including corn but not rice cultivators. FENALCE represents federated committees before the National Government and other public or private entities. It is supposed to promote scientific and economic research, technology transfer for the cultivation, processing, marketing, and industrialization for its crops. For this, it may create research centers or work in association with public or private research entities. The producer association (gremio) also has the power to implement information and statistical systems on production, consumption, price, marketing, and markets. FENALCE also provides technical support and accompaniment to its associates in aspects related to seeds, tillage systems, efficient use of inputs, good practices for eco-efficient crop management, harvesting and post-harvest. It currently has more than 28,000 affiliated producers.

Regarding technical assistance, FENALCE, with the support of the National Cereal Fund, has a network of 520 technical assistants and has strengthened this system by relying on the methodologies developed by CIMMYT and other actors implemented in Mexico through the MASAGRO Program, based on the following

[36] FINAGRO is a national mixed-economy company linked to the MADR and supervised by the Colombian Superintendency of Finance that promotes the development of the Colombian rural sector with financing and rural development instruments that stimulate investment. Acts as a second-tier entity, i.e., it grants funds to financial institutions on concessional terms so that they in turn may grant loans for productive projects. Partners across de country with national and local banks (https://www.finagro.com.co/nuestros-aliados).

[37] Historically, Colombia has used the fixed-term deposit rate (DTF) as a reference.

components: i) BIG DATA. This information and neural analysis are used to determine and prioritize the soil, climate and management variables that intervene in the definition of crop productivity, ii) FENALCHECK, a list of the main 10 practices that explain more than 85% of crop productivity and are the basis for producers' technology transfer, iii) e-Agrology: System for managing programs and projects carried out by FENALCE, which include three components: Research, Extension and Impact Platform, and iv) Innovation Networks, which determine the actors involved in the corn chain, their roles and the impact they have in terms of production, logistical support, mechanization, harvesting, transformation and added value, research, and institutional or private rural extension services. The above allows coordinating all aspects that intervene in the systemic production, marketing, and transformation of corn for the formulation of policies, programs, projects, and other technical and union initiatives in favor of cereal producers. It is common for large producers to individually hire technical assistants to guide planting and crop management. FENALCE, for its part, has a minimum network of technical assistants strategically located to cover each region with at least one technical assistant.

Regarding financing, in 2020, FINAGRO reported credit placements for US $ 41 million, in 3,008 operations, for an average operation value of US $13 thousand, mainly through Special Credit Lines such as strategic sectors, promotion of domestic corn supply, contract farming, full throttle. Other frequent financing sources for producers in certain regions come from regional agricultural supplies companies.

In its capacity as a producer association, FENALCE has led the definition of activities within each project component, considering the technological and social needs of corn producers. In the project, FENALCE coordinates the technical and budgetary execution of activities in each project component, coordinates with each partner - actor in the proposal (CIAT, CIMMYT, AGROSAVIA) the implementation of project activities to make sure they are executed per established protocols, manages work meetings to define support required by each institution for normal project development, coordinates with cooperating partners actions that help improve project operation and results, and contributes to the preparation of the project's partial and final technical and financial progress reports. After the project, FENALCE will ensure that the products and infrastructure generated continue to serve the producers. It will also ensure project continuity, maintain national and international inter-institutional relations for research projects on best practices in agriculture, promotion, transformation, and marketing, strengthen the innovation networks created and work in favor of the producers, and disseminate the results while recognizing partners and cooperators' work and funding.

FENALCE uses information that IDEAM generates and distributes for free. The capacities developed by the gremio were acquired in the context of a MADR - CIAT agreement that allowed them to develop a climate information system over the course of five years. FENALCE - FNL finance a US $33 thousand per year climate prediction project. Some 30 agronomists located in the producing regions are responsible for making recommendations and disseminating them. On average, each engineer costs the Cereal Development Fund about US $ 20,000 per year. A social communicator carries out dissemination activities, including proofreading, editing, and publishing content on social and physical networks with an approximate cost of US $ 42 thousand, including materials and human resources. There are high costs related to human resources, servers, and information analysis programs. In general, human resources corresponding to a systems engineer and a programmer, an analyst, the cloud information service, and computer equipment, among others, represents about US $70 thousand per year. Regarding seed multiplication, delivery, and monitoring, FENALCE incurs in annual costs of around US $420 thousand.

Since corn is planted across all the country's regions and climates, developing technologies, genetic resources, and productive infrastructure for the particular conditions of each region is expensive and the union (gremio) does not have the necessary resources, tools, and other capacities. Fenalce considers that a single entity cannot carry out a proposal of this scope in Colombia. Therefore, for the proposal to be successful and sustainable, it is necessary for national and international entities with specific strengths in each component to come together and receive support from cooperators interested in a socially viable and climate-smart agriculture.

Fedepapa, created in 1974, has the responsibility of representing potato producers in Colombia, generating sectoral policy guidelines before the national government and national and international organizations. Fedepapa is in charge of developing programs, projects, products, and services aimed at the potato production's system's technological improvement and environmental, social, and economic sustainability. It currently has more than 20,000 affiliated producers. When reviewing the rural coverage of professionals directly assigned to the potato subsector, without including those assigned to commercial houses, data shows that on average, they must provide direct assistance to 3,000 farmers per year, but in reality, this goal does not exceed 800 farmers per person per year. If technical assistance is included in the objectives of the global and national guidelines for 2020 aimed at lowering poverty rates by 20%, increasing performance by 20% and reducing environmental impacts by 20%, these needs would be double the figure mentioned above and would amount to 6,000 users per professional. This would be physically impossible to cover. As the administrator of the National Potato Development Fund, PEDEPAPA has developed technical assistance projects (2015-2016) and rural extension projects (2017-2020) in the nine potato-producing departments. These projects have evidenced the need for technical support through trained and specialized personnel providing guidance on how to transfer crop technology and how to exploit the potential markets of potato-producing regions. On average, 5,000 potato producers have been directly and indirectly served per year, which represents a national coverage of 5%.

In 2020, FINAGRO granted potato loans amounting to US $ 98 million through 21,183 operations, for an average operating value of US $ 4,639.

Created in 1976, FEDEPANELA is a national producer association committed to conducting research and ensuring the technological, economic, social, and environmental development of the panela subsector. This gremio guides public policies and manages public and private resources to contribute to the improvement of the quality of life of panela producers. FEDEPANELA has a strategic plan titled "Towards union and sectoral sustainability and modernization," which is based on six fundamental pillars: Chain Sustainability, Knowledge Management, Institutional Sustainability, Building Social Capital, Marketing and Communications, and Environmental Management. Currently, around 18 thousand producers are affiliated.

As the administrator of the Panela Development Fund, FEDEPANELA allocates more than 50% of parafiscal resources to the Technical Assistance and Rural Extension Program, covering the 15 panela producing departments through 70 technicians and 20 supporting personnel, besides people from other areas of the producer association. Through this program, panela producers have been provided with comprehensive technical support in cane cultivation, panela production process, productive infrastructure, strengthening organizational, agribusiness and commercial aspects and compliance with environmental and health regulations, among others.

The Special Lines of Credit - LEC offers an interest rate subsidy to small, medium, and large producers who require financing to develop their productive processes in the Colombian agricultural and rural sector. In 2020, FINAGRO allocated resources of US $64 million for loans for panela sugarcane in 18,962 operations, for an average value of US $ 3,410 per loan. The credit lines offered include Full-fledged and Sustainable Infrastructure, Economic Reactivation, Strategic Sectors, Contract Agriculture, Purchase of Land for Agricultural Use, Rural Women and Rural Youth, and Black Afro-Colombian Raizales and Palenqueras Communities. There are no special lines for resilient and low-carbon technologies for this crop. The producer's association affiliates have little knowledge of private-sector loans such as Crédito Verde-Bancolombia; Bancóldex - Sustainable Development; Green Line - Davivienda and Environmental Credit Line (Seco). In panela growing departments and municipalities, it is common for governors and mayors to allocate resources to promote agricultural initiatives and technologies for the cultivation and processing of this product. It is important that during the initial phase, the project is shared with these actors to coordinate actions.

The project's functions are mainly focused on coordination, implementation, evaluation and technology transfer, through the following activities: supporting the quantification of the water footprint in the panela sugarcane production system, supporting an evaluation on the efficient use of water in the cultivation of panela sugarcane and in the transformation process that allow increasing producers' capacity for climate change adaptation; evaluating the mitigation potential of the panela sector by evaluating the carbon footprint in traditional and sustainable production systems; carrying out a hydrological assessment to determine water availability in basins according to management practices and climate forecasts and identifying water harvesting points; strengthening institutional capacities and end-users (knowledge management); transferring technology and scaling practices regarding efficient water consumption and emissions mitigation to increase climate change adaptation and mitigation at the regional level; sharing the results of this work and its implementation as part of the Producer's Association technical assistance programs.

Related to the project's technology innovation, development and transfer, there are few existing services that can be used as a reference. Regarding climate information, for example, IDEAM offers the monthly climate prediction service (with a 3-month horizon) and meteorological forecast at different scales (1 day and 3 days). The service offered by IDEAM is totally free; from the spatial point of view, its scale is general, and free. Providers of this type of service at a national and international level offer meteorological forecast services at 12, 24, 48, 72 and 168 hours, for up to seven weather elements, with costs ranging between US $2.5 and $3.5 per 100 hectares. Generally, the cost of the climate projection on a monthly scale with a one-month horizon (1km x 1km) is included in the forecast costs. Regarding the analysis of images taken using unmanned aerial vehicles, the average cost of taking the pictures, generating a mosaic and an analysis of spectral indices is about US $1,400 per 100 hectares. For an area under 100 hectares, the cost may be higher, and each flight may have associated logistic costs of up to US $450.

Crated in 1963, FEDEGÁN is the Colombian livestock union that brings together regional and local cattle organizations, as well as other types of entities linked to the national cattle activity. As a provider of services to cattle ranchers, FEDEGÁN, is an integrated organization that coordinates different resources under the sole orientation and objective of achieving the welfare of cattle ranchers by modernizing their activity and achieving productivity and competitiveness levels that allow strengthening livestock farming in the national market and positioning it in international markets. Some of the services include Almagán (www.almagan.co), a website that sells agricultural inputs and intends to influence livestock costs in the future by helping the rural sector overcome connectivity barriers and promoting a cultural change that favors this type of technology. The Mechanization program was created in 2007 to facilitate the purchase of machinery and equipment at the lowest price in the market, including equipment to improve the quality of milk and meat. The National Bovine Feeding Program began in 2010 as the "Program for the Mitigation of the Impact of the El Niño Phenomenon". The second phase the "Winter Emergency Plan" was carried out in 2011 with support from the MADR, providing funds to subsidize the transportation and rental costs of the more than 40 warehouses throughout the country. Fedegan has 120 regional unions affiliated with more than 120 thousand farmers. However, the gremio serves all cattle ranchers in the country by managing the National Livestock Fund. Fedegan-FNG has 170 technicians, besides personnel who work in other areas (e.g., administrative staff).

Colombian livestock farming is currently financed by means of agricultural loans granted by banks, Colombian agricultural financing resources and organizations working in livestock competitiveness issues, such as FEDEGAN. According to FINAGRO figures, about 122 thousand livestock operations were financed in 2020, of which 78% corresponded to livestock farmers dedicated to meat production and 21% were livestock producers dedicated to dairy production. The amount granted in credit was US $1,200 million, for an average operating value of US $9,754. The interest rate for producers, including subsidies, will be up to DTF + 2% annual cash for small producers; up to DTF + 4% effective per year for mediums; and up to DTF + 5% annual effective for large producers (context ganadero n.d.). So far, there is a livestock sustainability line that finances investments to improve the efficiency of animal production systems, such as silvopastoral systems, which aim to increase livestock production efficiency and improve soils. This line of credit has a maximum term of up to 7 years, with a grace period of up to 2 years. The interest rate, with subsidy, for small producers is up to DTF plus 2% annual effective; for medium-sized companies up to DTF plus 4% annual effective; and for large companies up to DTF plus 5% annual effective (contextoganadero n.d.).

The National Federation of Coffee Growers of Colombia (FNC) has grouped coffee producers since 1927. It finances and dictates the research interests of the National Coffee Research Center (CENICAFE), which leads this project in aspects regarding this crop. Through the FNC Extension Service, Cenicafé coordinates knowledge transfer to coffee growers, and coordinates with the FNC's Commercial Management Area to connect with the rest of the chain, which includes the final consumer. This activity ensures that once the project is finished, the results can be maintained using the existing union infrastructure and parafiscal resources that are part of the National Coffee Fund.

Since 2010, the National Federation of Coffee Growers has carried out a series of activities aimed at adapting Colombian coffee growing to climate change. The most significant achievement is having increased from 25% to 82% the percentage of area planted with Coffee Rust-resistant varieties. This implies better preparedness for extreme rain conditions and avoiding fungicides. Additionally, a network of 126 automatic weather stations was installed to monitor weather conditions in all coffee-growing areas. Besides the historical time series records used for long-term analysis, information from the network allows issuing short-term alerts in the monthly Agrometeorological Bulletin (71 issues have been printed to date).

Among other measures, the genome sequencing of the Caturra and Híbrido de Timor varieties was completed. This is a fundamental tool for the release of new coffee varieties, such as Cenicafe1, with greater genetic diversity that helps it cope better with climatic variability. Other measures include preparing improved materials for future varieties. Furthermore, as part of the "More Agronomy, More Productivity" strategy, the adequation of the coffee plant microclimate has been adapted through agroforestry systems that provide adequate shade according to the environmental endowment.

Similarly, the union (gremio) considers that no weather forecast service is particularly adjusted to the mountainous conditions prevailing in Colombian coffee growing areas, where permanent cloudy conditions make it difficult to collect real-time data from satellite information for short and medium-term predictions. Therefore, services available in the market lack necessary and specific information to develop models for these conditions. Herein lies part of the importance of the project for the agroclimatic predictions component.

For 60 years, the National Federation of Coffee Growers has offered a Rural Extension Service, as part of its public goods offer for coffee growing activities. With the objective of transferring to coffee growers the knowledge generated and validated by the National Coffee Research Center (CENICAFE), the Extension Service has divided the entire coffee country into 1005 districts, each with an extension agent assigned to work in group activities and in individual visits to the farm with the area’s coffee growers. Since 2016, the Extension Service has worked on the strategy "More Agronomy, More Productivity, More Quality" which is based on eight basic farm management concepts that significantly impact crop productivity. All these are based on scientific experimentation carried out by CENICAFÉ. This strategy has enabled stabilizing coffee production at 14 million bags per year, for six years.

Through the Ministry of Agriculture and its Agricultural Sector Financing Fund (FINAGRO), the Colombian government offers several lines of credit in order to renew aged coffee plantations susceptible to coffee rust, one of the most damaging diseases due to the effect of climate change. These credits have a grace period of 24 months (until the crop enters the productive phase) and the payment term is 84 months, with interest rates up to DTF (average interest on 90- day Fixed Term Deposits) + 7% effective annual rate. For the year 2020, FINAGRO reported credit placements in coffee for US $ 327 million in 104,143 operations, for an amount per operation of US $ 3,410. For coffee growing, Banco Agrario offers preferential interest rates for projects that support environmental improvement, in particular Agroforestry Systems, which can be assigned to shade-grown coffee crops. These are called Green Credit lines. Unfortunately, credits generally involve a lot of documentation and coffee growers often lack land tenure titles, and studies and approvals are not made in time for disbursements to take place when required.

AUGURA was created in 1963 to represent, promote and strengthen the Colombian banana agribusiness. It brings together banana producers and marketers from the Urabá region and the Magdalena department.

It works on four fundamental components: representation to defend the interests of the banana agribusiness before official bodies and national and international entities; scientific and technological innovation to offer new strategies and processes that favor the productivity and competitiveness of the banana sector; banana sustainability to strengthen the social, cultural, economic and environmental impact of the banana agroindustry through union management tools; and information to generate, analyze and offer tools and information products with added value that facilitate decision-making, supporting and strengthening knowledge among its affiliates.

The banana sector has independent farms or producers, banana groups (several associated farms) or trading companies that may own their own farms. For the first case, individual producers must individually contract technical advisory services, while in the other cases, each group or marketer has its own equipment and personnel to carry out the extension on the farms. This situation has led to multiple differences between agronomic recommendations for decision-making regarding the crop since there are differences in fertilization, pest and disease control plans, harvest parameters and cultivation practices, among others.

For the year 2020, FINAGRO reported credit placements for banana worth US $ 60 million in more than three thousand operations for an average operation value of US $20 thousand. For the specific case of the banana sector, there are no special lines for resilient and low-carbon technologies. The currently bankable activities for cultivation are agricultural production (planting, upkeeping, land purchases, acquisition of inputs, certifications, infrastructure construction, purchase of machinery), transformation and commercialization (machinery and equipment, operating costs, transformation and transportation), support services (projected operating and operating costs, machinery and support service equipment) and other activities (payment of financial liabilities, non-financial liabilities, consolidation of liabilities, technical assistance, and agricultural and rural working capital).

Since 2020, the AUGURA gremio and its CENIBANANO research center have addressed with the MADR team and the CIAT Bioversity Alliance, the needs of the banana cultivation sector in their quest to reduce emissions and improve the use of water resources. In this context, the proposal has been prepared with each of the gremio's actors (producers, technicians, researchers, etc.), to assess opportunities for improvement in each field of action. Once implementation begins, the gremio has the infrastructure (Experimental Field and associate farms, laboratory, offices, equipment, etc.), as well as personnel (researchers, assistants, technical assistants) to develop each of the proposed activities. The project will ensure adequate resource execution, correct implementation of field practices and models and effective training and information delivery to banana producers. Once the project is completed, AUGURA will establish a work plan to ensure continuity of the technologies, models, and developments. This will help ensure that 100% of the associated banana growers can implement them.

Considering strong climate variations, agroclimatic predictions in the banana sector imply having a wide range of equipment (stations) distributed in production areas, as well as a platform that allows transforming climatic data and models into agroclimatic information that considers issues such as production, pests, diseases, among others. It should be noted that to date there is no simulation model for banana cultivation that considers atmospheric-soil-plant data, which is one of the purposes of this project. Climate data services currently cost approximately US $ 100,000 per year, per area of interest, which implies a significant amount of money considering that processing, storing, and interpreting this information to apply it to this crop is of utmost importance for decision-making.

The banana union (gremio) sees the need to implement projects that impact climate change through emissions reductions and efficient water use. Therefore, the Ministry of Agriculture and Rural Development and the Ciat-Bioversity Alliance formulated this project, which includes a short, medium, and long-term scope and requires significant amounts of cash that the banana union cannot assume 100%, at least in the initial stage, where it is necessary to hire personnel, purchase equipment and inputs, among others. In the last two years, AUGURA has invested US $3.3 million in biosecurity actions to prevent the spread of Fusarium Raza 4 Tropical, the most devastating disease for crops, which was reported in the department of La Guajira in August 2019. On the other hand, all research in the areas of physiology, plant health, soils and precision agriculture, biotechnology and agroclimatology is carried out through the Banana Research Center, where US $ 0.97 million are invested each year. The union also invests US $ 2.2 million a year in dredging the León River, which enables navigation and allows transporting fruit to the ships in Urabá, removing more than 1.3 million cubic meters of sediment each year. In turn, US $ 0.55 million are invested in clearing the main rivers and streams in the Urabá region in order to improve the drainage of the properties and prevent flooding in the communities surrounding the banana activity. In road maintenance, around US $ 1.1 million are invested for internal roads that transport the fruit between producing regions. Regarding production costs, it is necessary to highlight that aerial control of black sigatoka in cultivation alone costs 75 million dollars per year. However, the union is committed to providing the funds offered for this project and assuming maintenance costs after project completion, to ensure its continuity.

ASBAMA was created in 1996 as a producer association that groups together banana and plantain producers from the Magdalena and La Guajira Departments, representing them before national and international public and private entities and promoting the sector's economic, social, and environmental development, by identifying, structuring, proposing, and managing projects and initiatives, as well as accompanying and supporting them in their implementation. In this sense, the Association constantly encourages the improvement of the industry and promotes research initiatives regarding cultivation and its production chain. Through social, financial, and environmental management, ASBAMA promotes the sustainability of the sector, and strives for continuous improvements in terms of productivity and competitiveness. Other relevant issues for this union are labor practices, crops' phytosanitary status, water resources care, climate change, technology transfer, and the security of the banana sector in the Caribbean Region. In terms of articulation, it is important to note that the union is developing strategies with some municipal mayors, with the National Police and with the ICA, the agricultural sector authority. A strategy is implemented with ICA to address Fusarium TR4, in the context of a phytosanitary emergency declared in the country in 2019. Specific activities carried out to monitor TR4 include biosafety, phytosanitary surveillance, disclosure of risk and analysis and diagnosis. By 2021, 160 producers associated with the union and 220 small non-members are benefiting through different initiatives.

ASOHOFRUCOL was founded in 1995 as producer association and agribusiness organization representing the interests of Colombian producers of fruits, vegetables, roots and tubers, aromatic or medicinal plants and spices. Since 1996, ASOHOFRUCOL manages the National Fund for Fruit and Vegetable Development – FNFH. Per a contract signed with the Ministry of Agriculture and Rural Development, it is in charge of collecting the Parafiscal Fee for Fruit and Vegetable Development, and at the same time, it is responsible for investing these resources in plans, programs, and projects for the benefit of the subsector. ASOHOFRUCOL brings together more than 43,000 producers linked to the production and marketing of fruit and vegetables, including plantain producers. The Association is organically made up of 18 Departmental Committees and is directed by a national Board of Directors, elected within the 18 committees gathered in a National Assembly and is in charge of ensuring that the Association fulfills its purposes for the subsector. At the same time, the Association is established as a National Agricultural Technical Assistance Service Provider - EPSAGRO. The most relevant functions of the gremio during and after the project are aimed at monitoring, sustaining, and replicating technologies through professionals and personnel participating in the National Plan for the Promotion of Horticulture, who carry out their activities in the prioritized departments: Antioquia, Caldas, Meta, Quindío, Valle del Cauca, Córdoba, and La Guajira.

In terms of financing, FINAGRO reported a loan placement for 2020 worth US $ 70 million in approximately 25 thousand operations, for an average amount per operation of US $ 2,800. Colombia needs Low Emission Agriculture and Climate Change Resilient technologies focused on plantain production. Unfortunately, economic resources available to the different actors in the sector are scarce and are limited to the crop's productive dimensions, with very little left for research projects.

The subsidized interest rate ranges from the IBR [38] or benchmark bank indicator + 0.9% for small producers and associative schemes, to IBR + 1.9% for medium producers and IBR + 3.9% for large producers. The maximum terms to grant the subsidy will be up to 7 years with a grace period of up to 2 years. Although this special line of credit has been in force since June 1, 2021, one of the main reasons why it is not used massively by plantain sector actors is that it is yet not widely known.

Cenicaña was created in 1977 as a private non-profit scientific and technological corporation, and is part of the organizational structure of Asocaña, a non-profit organization (gremio), founded on February 12, 1959, and comprising sugar mills and growers, whose mission is to represent the agro-industrial cane sector and promote its evolution and sustainable development. The following sugar mills are part of Asocaña: Cabaña, Carmelita, Del Occidente, Manuelita, María Luisa, Mayagüez, Pichichí, Risaralda, Sancarlos, Ríopaila-Castilla, Incauca and Providencia. A significant number of sugarcane growers in the region are also part of Asocaña.

In sugar cane cultivation, the extension service is provided through Cenicaña's Technical Cooperation and Technology Transfer Service (SCTT), which has eight professionals who are responsible for technology transfer, two communications professionals and two assistants. It has the support of 38 suppliers' technical assistants who are direct employees of the 13 sugar mills. This facilitates sharing research results and new technologies with mills technicians and workers and to about 2,700 cane growers in 52 municipalities of the Cauca, Valle del Cauca, Risaralda, and Caldas departments.

The following are used as extension strategies: general and targeted Technology Transfer Groups (GTT), the Learning and Technical Assistance Program (PAT) and the Integra program, which provide an opportunity to transfer technology and support sugar mills and growers while emphasizing social, agro-environmental, and economic sustainability. A new strategy called the "Circle of Innovative Farmers" was recently established and "Experimenta" will soon be launched. The latter consists of discussions between farmers, users of a certain technology, to analyze its advantages, difficulties and additional adjustments required for widespread adoption. There are also printed publications to support the transfer of technologies, such as books, booklets, technical series, instructional brochures, and methodological guides for facilitator training. A website has been set up and social media is used to disseminate information to technology users. Around 1,200 people are trained each year on farms, sugar mills and in the Cenicaña Training Center and around 50 visits are received per year (between 800 and 1000 people). Visitors are mainly farmers, students, and international missions.

In 2020, FINAGRO approved a total of 1600 credit operations for sugarcane for a value of US $ 747 million, resulting in an average value of each operation of US $ 467 thousand.

According to the annual projected budget, three general components will continue to be financed upon project completion. These three components are part of the research and development core: Intelligent Agriculture of the agronomy program, analytical services, information technology-telecommunications and agrometeorology; Genetic Improvement of the variety program and Knowledge Management of the training and technology transfer service, respectively. These two programs and four services cost USD $ 3.96 million annually and represent 43.1% of the annual budget.

Crosscutting intelligent services such as telecommunications and networks for field data collection are required. For this reason, for over 28 years, the sugarcane sector, through CENICAÑA, has established different networks and telecommunication infrastructure. This has required a significant investment and has allowed collecting highly valuable data and information that no other public or private institution can provide to respond to the needs of the project. For example, only one of the five networks, such as the meteorological network, has required an accumulated investment of about USD $10 million. It is a network made up of 37 meteorological stations, operated and administered by CENICAÑA. Each RMA station has

[38] Authorities designed the Benchmark Banking Indicator (IBR) to respond to the need for a short-term reference rate to promote equity market development.

a specialized program, meteorological instruments, and telecommunications systems suitable for collecting meteorological and climatological data, which generate precise information on the areas of influence and maintain a daily and hourly record of the behavior of different atmospheric variables in certain places. On the other hand, commercial, climate and soil information that has been compiled for over 43 years in a temporal and spatial manner, has an incalculable value for CENICAÑA. No other private institutions or for-profit entities have access to this information. This information will enable developing models to forecast, project and reduce the risks of climate variability and change for the sugarcane sector. In Colombia, CENICAÑA is the only institution that conducts research aimed at developing local disease-resistant varieties that adapt to different mega-environments and agro-ecological zones. This requires 10 to 13 years to develop, an annual investment of USD1.94 million. This investment in local research can only be achieved through joint efforts of different actors, who are committed to investing in long-term research and development at the hands of the Colombian sugarcane sector.

There is another important aspect to consider. Law 1876 of 2017 creates the National Agricultural Innovation System - SNIA, and contemplates the formulation of the Departmental Agricultural Extension Plan (PDEA) to strengthen agricultural extension systems. Antioquia's Departmental Agricultural Extension Plan 2020-2023 considers benefiting at least 5,600 producers with the agricultural extension service in the department (1,400 permanent). This figure includes plantain producers (Departmental Agricultural Extension Plan 2020 -2023 from Antioquia). In Caldas, the goal considered in the Departmental Agricultural Extension Plan 2020-2023 is the provision of the Agricultural Extension service to 20% of small producers of the plantain production chain in the four-year period (15,000 producers in total in the Department) (Departmental Agricultural Extension Plan 2020-2023 of Caldas). The Departmental Agricultural Extension Plan seeks to benefit 18,181 producers in the 29 municipalities of the department, in 11 prioritized chains and 27 production lines, including bovine meat, milk producers, pisciculture (fish), small species (pigs, chicken, among others), beekeeping (honey), cocoa, coffee, cereals, forestry (pine, rubber, eucalyptus), beans, fruit and vegetables (plantain, guava, pineapple, papaya, watermelon, citrus fruit, yucca, passion fruit, among others). Plantain is the most important line of the horticultural chain (Departmental Plan of Agricultural Extension 2020-2023 of the Meta). In Quindío, the goal of the Departmental Agricultural Extension Plan 2020-2023 is focused on increasing by 10% the producers that exceed the national average through a good agricultural extension program (Departmental Agricultural Extension Plan 2020-2023 of Quindío). In Valle del Cauca, the goal of the technology transfer support service will be to cover 100 producers with the service. Córdoba has a Departmental Agricultural Extension Plan that will allow municipalities to coordinate strategies for the provision of agricultural extension service in their areas of influence in order to organize production in the territory.

4. GAPS AND NEEDS

4.1 GAPS, NEEDS AND BARRIERS

Currently, the Colombian agricultural sector is facing major challenges due to climate change and variability, which directly affect field productivity and farmers' livelihoods. Much of the productive activity in the country does not have monitoring systems, computer models or digital tools to capture or analyze valuable information to support decision making, making production systems even more vulnerable to climate. The effects of climate variations on crop productivity could be mitigated through the design and adoption of high-precision digital tools for monitoring the different stages of crops, and a better and more advanced agroclimatic monitoring system.

In conversations held with the different Gremios that are part of this proposal, it was possible to identify a limited capacity in the recording and management of information, both climatic (e.g. historical weather records, seasonal climate forecasts) and crop (e.g. physiology, soil moisture, nutrient balance, pests and diseases), to support climate-smart decision making. In general, farmers receive limited information to facilitate decision-making in the face of climate change, the usual way is through rural extensionists, which only reaches 17% of farmers, according to the last national census.

In terms of climate, the weather service's climate predictions are aimed at a national coverage, so they have shortcomings at the regional level (e.g. departmental, municipal, local), which can be considered critical for decision making at this scale. Improving climate predictions at the regional level and improving their understanding, is a priority among trade Gremios. In addition, agroclimatic simulation models (tools that help to represent the processes that occur within production systems to understand how they will behave under specific climatic conditions) are often not adequately calibrated to the conditions of each area and, therefore, do not represent the physiological processes of plants well, making it impossible to use them in decision-making for planning and adaptation systems.

In terms of digital agriculture to capture crop information, although some Gremios such as Fenalce and Fedearroz have developed digital platforms for capturing and reporting producer data (e.g. AMTEC[39] in rice), there are still limitations in terms of efficient management and analysis of the information. In fact, institutions such as Fedepanela, Fedepapa, Augura, Asohofrucol and Asbama do not yet have a workflow that allows them to at least efficiently collect agronomic data. Most of the institutions have little infrastructure for the implementation of information management systems and crop monitoring is still manual, and they rely mainly on classical extensionism for agricultural advice. As a result, there is still a large gap in technology to bring tools of the digital era, such as drones, sensors and satellite image analysis to the Gremios. These tools would allow farmers (and the technicians who advise them) to better prepare for extreme weather events and the climate variability experienced year after year, thus optimizing their yields through adequate and timely risk management in the field.

Finally, across most production systems (with a few exceptions such as sugarcane and coffee) it is evident that the technical assistance system has a reduced coverage, leaving a large percentage of the farming population without this valuable information. This is partly due to the fact that digital communication tools (e.g. text messaging, multimedia messages, chatbots) have not been sufficiently exploited to increase the number of users accessing these information

[39] http://www.fedearroz.com.co/new/amtec.php

services, and also because many of the technicians and professionals who are part of the Gremios do not understand agroclimatic information or do not have the skills to implement information analysis methods. Developing abilities in analytical skills and agroclimatic information processing is therefore of vital importance for the Gremios and production systems.

One of the barriers to having an adequate system of recommendations for adaptation and mitigation to climate change (already mentioned), is the deficient coverage of the technical assistance system for most crops, which is inefficient to the extent that it is provided on a farm by farm basis, without good data recording, monitoring and follow-up. Thus, the visits to a farm by a technical assistant, in most cases are no more than once per year. Likewise, there are great limitations in data capture, management and analysis, and limited capacity for information analysis, despite the developments in Big Data. Technicians do not have the necessary knowledge to handle Big Data tools and therefore all data recording and analysis is done individually and with some basic calculations in Excel. This is why technicians are just limited to handling technological packages by megadomains, since they do not have site-specific information or the capacity to handle tools that process all (little or a lot) of the information available to them. There is a need to implement and/or modernize systems for information capture, analysis and dissemination that are more efficient and have greater coverage and the capacity to provide site-specific recommendations and improve the capacity of technicians to use these tools. It is also necessary to develop an adequate climate service at producer level, based on the development of agroclimatic models.

In terms of crop management recommendations regarding climate, there are currently gaps in meteorological monitoring. The climate predictions that are generated are poorly contextualized and are not local in scale. Agroclimatic models have not been properly developed, where there is a lack of baseline information, calibration or evaluation. The climate-production system relationship, variables and critical moments within the crop cycle are not well known. The application and use of agroclimatic information projections are limited by the lack of capacity in agricultural advisory services and inefficient dissemination mechanisms. They do not include new regions within the existing platform (maize, coffee, potato), there is a lack of characterization of climate hazards (potato, livestock), a lack of resources to calibrate crop models with agroclimatic projections, and the lack of knowledge to calibrate such models (rice, maize, sugarcane). In addition to the need to achieve the development of all these models, there is the need to train technicians and producers in the mastery and understanding of the recommendations that come out of these tools, and the connection of agroclimatic predictions with Big Data platforms in order to contextualize each recommendation at a site-specific level.

An important step that is expected to be taken with this project is to improve the information available at the site-specific level, and to accompany that information with recommendations that are supported by predictions with high performance that make it possible to generate a good degree of confidence in producers. The proper selection of a variety in relation to the environmental supply can make a difference of up to 40% in yield. However, this must be complemented with the development and implementation of technologies to face different circumstances that may arise due to the predicted climatic conditions. In this sense, it is necessary to develop technological options to maintain high yields under different types of stress factors, for example, abiotic factors, such as low solar radiation, high nightime temperatures, high CO_2 concentrations and reduced rainfall (drought), as well as biotic factors that can be exacerbated when certain climatic circumstances occur, as is the case with phytosanitary problems.

Water is becoming an increasingly limiting factor in agricultural production, both due to excess and deficit, as rainy seasons are increasingly greater in total volume and more intense,while on the other hand, dry seasons are more marked with higher temperatures, both during the day and at night. This requires a range of technological options that contribute to generate alternatives for producers, ranging from; new genetic material available, more efficient irrigation systems, and crop management techniques that reduce water consumption to rainwater harvesting systems.

In general terms, the process of technology development and transfer is slow, and it could be argued, that it is nonexistent for adaptation and mitigation of climate change for most crops, even though the economic, social and environmental problems that are being generated by climate change in the agricultural sector are recognized in different areas. Therefore, it is necessary to invest in the development and transfer of technologies for adaptation and mitigation. There is a clear commitment in the agricultural sector to aim at the objectives proposed in the NDC for adaptation and mitigation of climate change in the sector, and at the same time a high degree of awareness of the importance of joining efforts between the different institutions of the private sector (Gremios), public sector (MADR), research centers (The Alliance of Bioversity International and CIAT, Agrosavia, and crop research centers) to design a strategy that allows prioritizing and coordinating efficient actions aimed at concrete results in the coming years. A major barrier has always been to bring all these institutions together towards a common goal.

The reduction of crop emissions also represents a challenge, especially when in many cases, the producer does not see a direct benefit in the adoption of this type of technology. In this case, the development of these technologies must be tied to factors of high interest for producers, such as increased yields, cost reduction, efficient use of inputs, etc. A major constraint to achieve this is the limited information available that allows producers to compare technologies. In most cases, these comparisons are made through intuitive analyses, and in the best cases it is done with modeling that takes as a reference factors from other regions or technologies with data that may not be close to the conditions of our regions. In the case of the MADR-CIAT pilot, we were able to make some direct measurements in GHG measurement (intensive silvopastoral systems, maize) and carbon sequestration (fruit trees and cocoa), aswell as in water use (rice and maize), which showed that the reference values being used were far from the values measured for our national conditions. This work also made it possible to compare the yield and cost differences of various technologies that had already been adopted at a commercial level. This allows producers to make comparisons about different variables of interest for their technologies, versus others that are already being implemented commercially by other farmers. Comparing technologies that are already being implemented at a commercial level, represents an advantage over the development of new technologies, since adoption rates are much higher, given the intrinsic uncertainty of the adoption process of new technologies that are just entering the market. It is necessary to consider this type of strategy, especially in mitigation-related issues.

One of the most important mitigation issues in Colombian agriculture is the use of nitrogen. In many crops and areas in Colombia the use of fertilizers has been low, and in the best cases, some nitrogen fertilizer is used. On the other hand, crops and areas that are more technified use very high levels of fertilizers, causing inefficient use. In this sense, information about the efficient use of nitrogen fertilizers in Colombia is fundamental for mitigation. This is because, on the one hand, the most technified crops and most technified areas must make progress on issues related to low input use (quality issues) and lower costs (profitability and competitiveness), and that the information generated is also useful to guide the less technified areas, that are immersed in a race to increase productivity. To meet these challenges, better information and analysis of different technologies at the service of producers is required. Currently, the logic that is managed at the agricultural and technical producer level are the magadomains, and therefore strictly apply to the technological packages defined for each mega-environment. The use of Big Data platforms fed with good information on the implications of the different technologies, is fundamental for adaptation and mitigation at the local level. It is necessary to generate adequate information at the level of each technology, to inform and guide producers on the advantages and disadvantages of adopting these technologies, and especially the adjustments or implications at the specific site level.

Another major challenge of the project will be to align mitigation actions with plans and programs that are being promoted or discussed at national level. In this sense, the participation of Gremios, the MADR and DNP is important and relevant in order to prioritize and guide actions towards national commitments. For example, in the Colombian livestock sector, a commitment to sustainable livestock farming is gaining more and more strength. Likewise, it is necessary to implement some business models to capture the benefits within the chain, e.g. differentiated meat or dairy products (e.g. meat or milk with a low carbon footprint).

The development of new materials will play a fundamental role in adaptation, but it may also play a key role in mitigation. The development of new materials must take into account a multiplicity of variables to be able to aim at high values of technological adoption. Producers review figures related to productivity, costs, management tasks, and quality parameters, among others, but it is also necessary to ensure that these new materials are stable in the face of different climatic adversities, or designed for particular climate conditions (e.g. ENSO). In addition to the above, it is necessary to take into account other considerations that will contribute to the adoption and mitigation of climate change, for example, more efficient use of water, tolerant environments with lower levels of nitrogen that generate fewer emissions. One example is forage species, which fix nitrogen from the environment, allowing the animal diet to improve and reduce emissions from cattle.

Another major challenge for the sector in adapting to climate change is the use of good quality seeds. For example, in the case of potato cultivation, only 4% of the area planted uses certified seed. Access to good quality seed is indispensable in any production system, as it contributes significantly not only to obtaining high yields, but also to quality production and, therefore, profitability. Seed quality, and the genetic potential it carries, largely determines yield potential, resistance to pests and diseases, adaptability to the climate of each agro-region, and resilience to the impacts of climate change. Seeds are recognized as the most important basic input for all crops. CIMMYT experiences show that improved hybrids adapted to particular areas can achieve yield increases-between 37% in irrigated, and 105% in rainfed, relative to regional controls. In this sense, the multiplication of good quality seed will be a decisive factor for adaptation, especially in crops such as sugarcane, potatoes, musaceae (banana and plantain) and coffee. In the cases of maize and rice, the Gremios have seed multiplication systems that respond very well to the needs of producers. In other cases (e.g. coffee) there are materials that perform well for specific problems, but their propagation and multiplication are complicated and slow. In these cases the development of new multiplication techniques, make it possible to reach producers with material that is fundamental to face the challenges of climate change.

One major challenge to achieve adoption at scale of the climate-smart practices and technologies is the access to financial instruments to fund the innovations development and implementation, as well as business models that enable farmers to get returns from implementing such innovations. Climate risks are one of the major risks for agriculture financing and credible and recent data is one of the main reasons to explain the lack of tailored financial products for agricultural sector. Therefore, it is crucial to use the data and information generated through this project for de-risking agriculture and hence, informing financial institutions to develop science-informed tailored products for agricultural stakeholders. Moreover, the development of novel and inclusive models will enable farmers to increase their profitability and opportunities to reach new markets that value climate-resilient and low-carbon production.

It is also necessary to ensure the empowerment of the sector's stakeholders in charge of working directly on this task. In this regard, the technical teams and extension systems of the Gremios are fundamental. That is why, it is important that all technological developments and technology evaluations are carried out by the Gremios' professionals, accompanied by a capacity building strategy that ensures that all these processes can be maintained and sustained over time. It is also important that the scope and implications for the sustainability of these technological developments be analyzed jointly with the Gremios in order to have a very good understanding of the technical, logistical and financial commitments that each of the Gremios must acquire for their sustainability. It is also necessary to strengthen other key actors in the agricultural sector in terms of resilience and climate change mitigation. Producers, professionals, institutions and other actors in the production chains need to increase their capacities, knowledge and attitudes, towards the new technologies or processes required to achieve a shift towards climate-resilient and low-carbon practices and technologies.

In general, the ability of technicians and the extension services in the agricultural sector in Big Data tools is low. Research developed by the Alliance of Bioversity International and CIAT has revealed limitations in their academic training, such as: (i) extensionists unfamiliarity with technological tools, (ii) low ability to interpret results, formats, and visualizations generated through ICTs: (i) limited familiarity of extensionists with technological tools, (ii) limited ability to interpret results, formats, and visualizations generated through ICTs. In addition, the CGIAR and other organizations have found that extensionists have: (iii) a lack of clarity in their mandate, (iii) a lack of facilitator role, (iv) a lack of entrepreneurial spirit, (v) limited vision of productivity, and (v) few technical skills about topics such as climate change. These professionals have very limited access to training or updating programs about climate change adaptation and mitigation technologies (including, the use of information, artificial intelligence, climate services, efficient use of resources, and the use of varieties tolerant to extreme climate factors, among others).

Most farmers are unaware of the causes or ways to mitigate climate change in agricultural and livestock activities. They do not understand the economic and environmental benefits or contributions derived from the adoption of modern technologies, or at least the benefits they expect, the adoption of which is usually accompanied by additional costs, increased time or added complexity in their production process.

All of the above can be summarized in six major challenges:

i. Modern agricultural extension services require greater capacity for information analysis and management.
ii. Extensive use and appropriate application of agro-climatic information.
iii. Limited knowledge of genetic resources and their tolerance to climatic variability.
iv. Limited knowledge of water footprint and water-efficient technologies.
v. Limited knowledge of carbon footprint at the crop and technology levels.
vi. Vulnerable business models, lack of tailored financial instruments and limited technical capacities and strategic knowledge transfer.

5. ANALYSIS OF SOLUTIONS/APPROACHES

5.1 DESIGN PROCESS AND PRINCIPALS

The MADR, as project leader, selected the priority crops to work on within the framework of the project, according to the progress and goals considered in the NDC. Once the crops were selected, an approach was made to the Gremios through the Alliance of Bioversity International and CIAT to present the objectives of the proposal (other basic information contained in the concept note), and a review of the results achieved in the MAD-CIAT pilot. Likewise, the scheme and form of work is presented, where the Gremios together with the Alliance of Bioversity International and CIAT and the participation of Agrosavia carry out the following activities: i) identification of the most important threats faced by each crop in terms of climatic phenomena and mitigation, ii) an account of the progress (if any) in this area, iii) prioritization of the work sites according to the information available and the knowledge of the technicians in each area on the different risks that exist and mitigation options, iv) followed by a discussion on the different technological options to address the problem. From there, the structuring of the project begins, defining the scope, products, activities, sub-activities and budget.

To develop this entire process, work teams are formed, and the topics are defined, into which groups of professionals from the Alliance of Bioversity International and CIAT are organized. The Gremios and Agrosavia (in the case of maize with the participation of CIMMYT), and in the case of livestock with the participation of the CIPAV Foundation[40]. In this respect, we sought to form a working team of professionals with the highest levels of knowledge of each topic/problem[41]. The project was structured under the premise of strengthening the capacities of the Gremios, which will be directly responsible for continuing with the operation of the solutions proposed during and after the project. In this regard, each of the proposed solutions considers the technical, operational and financial implications to continue its operation, and the solutions were limited to the capacity of the Gremio to maintain such operation[42].

A list was made of the needs of each Gremio in terms of; equipment, infrastructure, technical capacity in terms of number, training and location of professionals, the support required from the Alliance of Bioversity International and CIAT, and the contributions that could be provided by Agrosavia[43]. The resources requested and the timing are formulated under the personalized and permanent guidance of experts in each of the topics to accompany the professionals from the Gremio in their training, application and implementation of each of the identified solutions. For this reason, different degrees of accompaniment are observed, depending on the strength of each of the Gremios in the different topics. The process is formulated in a transitional manner and, little by little, the Gremios are taking control over each of the different topics until reaching 100% in the last year of the project, where the participation of the Alliance of Bioversity International and CIAT becomes tangential and a support for any doubt or situation that may arise.

[40] Both (CIMMYT and CIPAV) have been invited by the association and MADR to be part of this process as they are considered key actors for the development of the process.
[41] 147 professionals from 16 institutions
[42] This point is very important since the technical teams must support and defend these proposed activities before the boards of directors, which are the ones that grant the authorization to assume this commitment on behalf of the association.
[43] Agrosavia has an important role to play as it seeks to strengthen it in different areas so that it can bring, apply, replicate or adjust these solutions to other crops that are not considered in this project, especially those that do not have associations that represent them.

A range of cutting-edge technological alternatives were identified, but with different implications and considerations, taking into account not only the capacity of the Gremios but also the conditions of the producers in each of the work zones. The importance of this work lies in the need to verify that the proposed solutions are in line with the needs and conditions of the producers. For example, it is not possible to propose a solution based exclusively on the use of the Internet if the producers/area to be worked on do not have this resource. As a result, another type of alternative was chosen, which the technicians in the regions recommended based on the mechanisms and tools that work best in each locality.

For the different components, an estimate was made of the information storage and processing capacity required, taking into consideration the current capacity and the future maintenance capacity that can be assumed by the Gremios. This coordination is important to generate economies of scale, optimization and coordination of the required resources.

During the formulation process, there were three opportunities to review the progress of the formulation for each crop, in which the different teams presented their progress to the MADR, DNP and CAF, and received comments, observations, feedback and requests for specific adjustments to the proposal. The teams initially moved forward independently, then meetings were held with all the teams by crop, to ensure coordination and coherence of the actions proposed for each crop, and later meetings were held by work Result to ensure coordination and coherence between the different work teams and proposals for the different crops.

More executive meetings were also held between institutional leaders to review the scope, products and their relationship to the budget and expectations within the framework of the agricultural sector in the area of climate change.

Given the project's execution time, we opted for solutions that guarantee its massive implementation with producers no later than year 4 of the project. In this regard, in the case of genetic improvement, the work will be based on advanced lines, and the phenotyping platform technique will be incorporated. In the case of efficient water use and emissions reduction, the scaling up of technologies that are already on the market and are being applied commercially will be used. This scaling-up strategy is conceived and designed based on the technical and extension capacity of each of the Gremios in the different regions. In those regions, the project will strengthen certain areas and specific topics to achieve greater coverage. It will also support the distribution and delivery of genetic materials and some inputs required for the implementation of some of the technologies.

5.2 POTENTIAL SOLUTIONS/APPROACHES/OPTIONS ANALYSIS

The formulation of the proposal is in the hands of highly trained and experienced professionals in the field with the greatest knowledge of the crops, problems and technological options. The Gremios have accumulated years of permanent interaction with their producers, represent their interests and know their needs and capabilities very well. The Alliance of Bioversity International and CIAT has highly qualified international scientists who are at the forefront of technology. Agrosavia is the national research institution, so it brings together a large number of professionals who know the technologies very well as well as the national geography, and especially the adaptation of technologies to different local contexts. Thus, the proposed solutions are the result of a deep knowledge of the country and of the users, years of experience, and a high level of expertise.

In the case of the use of digital tools, we analyzed the option of purchasing high resolution images (temporal and spatial), which can contribute to greater precision than free access images. Likewise, the use of drones and non-remote sensing could be substituted by the calibration and validation of these high-resolution images. This alternative was discarded since the costs of purchasing these images are high, especially if one considers the fact that these purchases would have to be maintained in the future, something that the Gremios would not be able to sustain. For this reason, this option is considered unfeasible.

Complementary data to feed the Big Data platform can also be obtained from experimentation. In fact all the information coming from of this study will have experimental plots (and for the capture of information) and the records will be uploaded to the platform. The option considered to improve data capture instead proposes to take data in the field, in producers' farms, under the commercial conditions that may arise. This technique makes it more expensive to isolate the effects of the different variables, which is relatively easy to do with data from experimental work. However, the costs of generating data for all crops, in different regions and for different variables is prohibitively expensive. For this reason, the use of experimental plots to capture complementary information from Big Data platforms was discarded[44].

Other mechanisms to generate agronomic analysis of agroclimatic prediction are through the dedication of time of thematic and crop experts to jointly analyze the possible impact of climate predictions on crops. Similarly, the recording of climatic events and crop behavior can be used to create a kind of repository of data on crop response to different climatic events. However, both were discarded. The first reason being, was the complexity of the databases that need to be analyzed and the time that these groups of professionals need to invest in order to generate all the analyses, and the possible risk of missing a variable that could have a significant impact on the results. Additionally, the cost of this alternative would be very high due to the level of training and time that professionals would have to invest in these issues. The second reason, is that it would be too costly, due to the type of registration required, not to mention the cost of subsequent analysis. An important point to consider, is that the Big data platform will provide this analysis for the historical information available and can continue to be fed with information from producers and/or technicians.

In terms of Big data analysis, one possibility considered was to perform the analysis through conventional statistical methods, which is easier in terms of complexity, less demanding in terms of analysis capacity, and therefore in terms of information processing capacity. Also, there is a greater number of professionals who can master these techniques, and the capacity building process would be easier to implement. Despite all these advantages, this option was discarded for quality reasons, since the professionals involved in the team working on this topic considered that traditional statistical methods do not adequately capture the processes and relationships between physiological variables and the environment when there is a multiplicity of interacting factors, whereas techniques based on machine learning and artificial intelligence do. In the end machine learning and artificial intelligence are more flexible in terms of assumptions and have proven to be very useful in agricultural analysis. However, it is very important to involve experts in different disciplines at the beginning and in some key moments of the information processing and analysis to avoid spurious relationships.

In terms of information dissemination, outsourcing the process of sending recommendations to producers is less cumbersome, and unifying the tools in a single dissemination system would definitely generate economies of scale. These options are discarded, on the one hand because of the costs involved in the permanent contracting of this service, and secondly, because the unification of the service in a single system is unfeasible given the different conditions of the producers of the different crops and regions. The major cost of this service is represented in the development of the recommendations, which in fact is already a job that will be in the charge of

[44] It is important to be clear that the Project will have experimental plots for other purposes and the information generated there will be used to feed the Big Data platforms, but plots will not be installed experimentally exclusively to take data required by these platforms.

the Gremios' professionals. Thus, the dissemination of messages with a system that contemplates multiple tools for dissemination is costly through outsourcing the service. While the Gremios will make the most of the mechanisms already established, which is of greater impact for the dissemination of the recommendations, since they will also be responsible for sustaining this service.

As for genetic materials, one possibility is to acquire products available on the market for delivery to the grower. In this sense, the supply of these materials is almost nil for these crops, and the few options available have a very limited advantage in the face of mild to moderate climatic phenomena. Therefore, the development of these materials is required. Another option evaluated was to carry out the whole breeding cycle in order to start from particular climatic problems and thus develop genetic material with the greatest possible potential to face such problems. In terms of impact this will surely be a great result. However, the time of the whole breeding cycle is beyond the time for the execution of this project, even for cases in which the cycle is shorter (e.g. rice and maize). For this reason, it was decided to work with advanced lines, and to implement the phenotyping platform to accelerate the breeding process and tools, such as rapid generational advancement and accelerated introgression of desirable traits.

Seed multiplication is another process that can be outsourced. However, this brings with it several drawbacks. On the one hand, there is the private sector's profit motive, so the value of these products will depend on the demand for them and their production would be in the hands of a single supplier (monopoly). There would also be the risk of losing all the previous investment made to deliver the producers varieties that are not economically exploiting the patrimonial rights. Certainly, the institutions involved in the development of new materials, even though they do not exploit them economically[45], are not willing to give them up. Seed multiplication directly by the producer is another option, considering that seed distribution costs practically disappear. However, the challenges and risks involved are greater. On the one hand, there would be a limitation in the techniques to be implemented, since it would be necessary to consider techniques that require a lower level of complexity and investment. Even so, the protocols used continue to be a challenge for producers, and even more so, the logistics and supply of inputs and materials, since they are not the same as those used in conventional production. For these reasons, risks increase, such as low seed yields, contamination of materials, and non-uniformity of materials. Although seed distribution costs would be considerably lower, individualized seed production costs increase considerably. It is important to keep in mind that the proposed strategy is to generate pre-basic seed centrally, keeping the scale production decentralized, but concentrated in one point in each area to reduce the risks mentioned above. Therefore the training strategy will be focused on groups of local nurserymen.

The performance of the matarials generated by new propagation techniques also represents benefits in crop indicators. For example, in the case of propagation of individual buds in sugarcane, the value of seed transportation is reduced by 90%, the seedling stand is 50% higher, losses due to pest and disease attacks are reduced, production can increase by up to 50%, and the vegetative period is shorter by up to 4 months.

In the case of low water consumption and low emissions technologies, given that in most cases there is no direct measurement information but only approximations, a qualitative evaluation was made with expert criteria on the mitigation potential and the potential to reduce water consumption of different technological options that are already being implemented at the commercial level. The following Table 10shows the results for mitigation as an example.

[45] Generally, the value of the seed sold by the associations is a function of the costs of the multiplication of the material and all the logistics and costs of quality assurance and respective certifications.

Table 10. General list of measures analyzed and discussed and used as a basis for specific pro-crop discussions with germplasm managers

Category	Practice	Mitigation potential	Cobenefits
Agroforestry/ silvopatterns	Intercrop planting	High	Carbon sequestration Biodiversity Moisture retention Soil health Restoration Increased quality and yield
	Live fences	High	
	Fruit crops	Medium	
	Planting density	Medium	
Fertilization	Organic Fertilizers	Low to medium	Biodiversity Soil health Nutrient optimization Yield increase
	Bioferments	Medium	
	Efficient fertilizer use	Low to medium	
	Slow release fertilizers	Medium	
	Nitrification inhibitors	Medium	
Irrigation	Microtubes	Medium	Increased performance
	Micro-spraying	Medium	
	Irrigation + solar energy	Medium to High	
	Fertigation	Medium	
Coverage	Use of leguminous crops	Medium	Restoration Nutrient supply Erosion reduction
Pruning	Integrated pruning management	Medium	Soil carbon stock Less dependence on pesticides
Materials	Increased yields	Medium	Intensification Less pressure on forest
	Tolerance to pests and diseases	Low	
New areas	Zero burning	High	Biodiversity
	Establishment in degraded areas	High	Restoration

Of the existing reports with mitigation potential, most focus on management practices such as planting nitrogen-efficient crop varieties, minimum tillage, integrated soil fertility management, incorporation of agroforestry arrangements, use of renewable energies and wastewater treatment. Among the practices with the greatest mitigation potential in soil management are agroforestry, balanced nitrogen (N) management and crop rotation (N_2O) (Snyder et al., 2009; Adviento-Borbe et al., 2007).

Novel and inclusive business models to incorporate climate-smart practices and technologies and make the case for establishing value propositions between farmers and buyers will be done by successfully proven and tested methodologies jointly developed by scientists at CIAT and key stakeholders. Moreover, the project will generate science-based information to inform financial institutions about the strategies that agricultural sectors are implementing to de-risks the agricultural activities and therefore, incentivize them to develop tailored financial solutions to benefit farmers, as well as competitiveness of both agriculture and financial sectors.

The participatory process starts from the formulation, recognizing the different approaches, e.g. The Alliance of Bioversity International and CIAT and Fedegán speak of Knowledge Management processes, CIMMYT speaks of the "HUB" extension model, Agrosavia has studied and implemented linkage plans, outlining learning styles, the other Gremios refer to technology transfer plans, and let us not forget the trajectory and importance of the Extension Service of the coffee growers. It was agreed not to debate the advantages and disadvantages of the different approaches, and that the important thing is to focus on the goal of generating changes in the beneficiaries, applying all the experience, lessons learned, and methods and means, in such a way that in the end all the approaches are enriched with the different actors involved.

5.3 SELECTION OF PREFERRED SOLUTION/APPROACH

The first challenge is the limited coverage capacity of extension services and the analysis capacity of the Gremios and information management. It is here that the solution proposed by the project is the implementation of a **Big Data system (Result 1.1)** for each of the crops, which considers the entire process; of organizing existing databases, capturing missing information through different methods, ranging from surveys, collecting information from technicians, tools for reporting from producers, instrumentation with sensors in the field, and analysis with remote sensing, among others. All these systems will have capture, reporting and storage devices and mechanisms connected to centralized databases to make this process more efficient. Script/algorithms will be developed to analyze large databases and the different processes will be automated to achieve greater efficiency and lower costs for the Gremio. All the necessary systems infrastructure will be acquired to set up a platform that will automate the entire data capture, storage and analysis reporting process, and will have interfaces and systems for disseminating information and recommendations to technicians and producers through different mechanisms, according to the conditions of the beneficiary producers and work areas. The result is the delivery of recommendations to producers with site-specific information at the farm, or even lot level. This entire process will be carried out with an emphasis on strengthening the Gremios' (gremios) capacities. In this regard, all the infrastructure and equipment required, as well as personnel and training needs, were planned with the Gremio. The Gremio will be involved from the beginning with the implementation of the technological option and will be responsible for its operation during and after the project.

The results of the analysis of the Big data platforms will lead to site-specific recommendations focused on climate change adaptation and mitigation. In this sense, the technician or producer will receive precise information on the adjustments that need to be made on each farm or lot, about the recommended technology package for that megadomain, based on the behavior of different varieties, crop management and/or technologies, in the face of climate phenomena, which is extracted from mining of hundreds of thousands of data. As the project begins to generate emissions information through the sensors installed in the field for sensing or even through information generated by other components of the project, site-specific adjustments with lower emission levels can be identified[46].

A second challenge is the limited use and adequate application of agroclimatic information. In this regard, it is proposed to create and/or strengthen the entire system of **climate services (Result 1.2)** in the Gremios. This involves improving the climatological network, improving the performance of climate models and new generation forecasting systems, calibrating crop models and integrating them with climate forecasts, developing new early warning services such as the occurrence of pest and disease infestations, and sub-seasonal services such as weather forecasting services. The big leap at this point is to be able to move from probabilistic information at the level of Colombia's major regions[47] to deterministic predictions associated with crop damage thresholds at the level of localities (municipalities or even villages). This service will be integrated to the Big Data platform, so crop management recommendations will be site-specific.

Limited knowledge of genetic resources and their tolerance to climate variability. The development of **genetic materials (Result 2.1)** tolerant or resistant to certain environmental

[46] Given the uncertainty of this mitigation mechanism, it is not considered in the calculations of the project's direct mitigation potential.
[47] Groupings of 200 municipalities or more

conditions is undoubtedly one of the key elements in adaptation. However, the time taken for the whole breeding cycle extends far beyond the period of this and most projects. In the MADR-CIAT pilot, just as for this project, it has been decided to resort to the use of advanced lines and other mechanisms to reduce the breeding cycle, such as the phenotyping platform and the application of certain techniques. The other important aspect is to be able to reach producers with material available in a timely manner for planting. Here we will carry out mass multiplication of genetic material with good performance (in terms of stability), under different environmental conditions, and material with specific conditions that are tolerant or resistant to certain climatic phenomena. This material will be delivered according to the threats identified in each of the areas, and for some materials the recommendations of the agro-climatic forecasts will be taken into account.

To accelerate the process in the breeding cycle, state-of-the-art phenotyping and sequencing techniques will be used to identify the adaptation potential of new materials to environments with water deficit or excess, and low nitrogen availability. New varieties produced through conventional breeding or assisted by genomic selection models, adapted to climate change conditions, will provide technological options for climate change adaptation and mitigation.

In the case of forage for cattle, species with the potential to increase animal productivity and reduce emissions of methane and nitrous oxide, greenhouse gases associated with animal feed, will be released through the Forage Network. Some examples are *Cenchrus ciliaris* and *Cannavalia brasiliensis*; 15 accessions of *Centrosema molle* and *C. macrocarpum*, 25 accessions of *Clitoria ternatea*, 5 accessions of *Arachis pintoi*, and approximately 130 accessions of *Megathyrsus máximum* are in the pipeline. All of the above with high potential for adaptation and desirable nutritional characteristics.

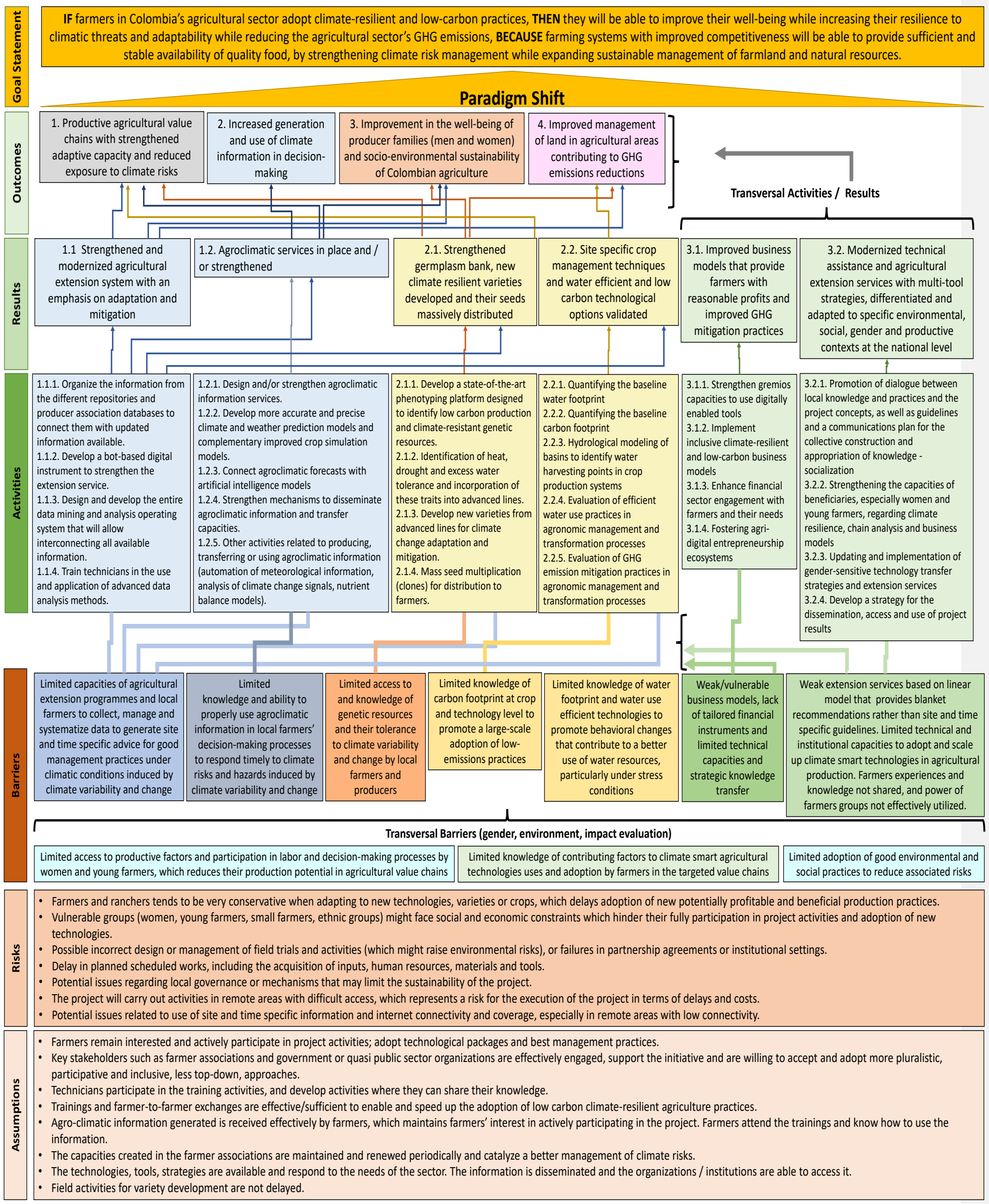
Another major challenge is the limited knowledge that exists on **the water and carbon footprints (Result 2.2)** of different crop management techniques and technologies. At this point, it is specifically proposed to generate information on water consumption and GHG generation for conventional systems in the first two years, and also to measure the same variables for the crop management technologies or practices, that have been identified by the working groups and prioritized by experts in the field. All these techniques or management practices are available and implemented at a commercial level. In this sense, the lots are located to make the respective measurements, the equipment is purchased and installed, all the measurement records are kept, and finally a comparison is made, not only of the reduction values in water consumption and/or emissions, but also in changes in key variables for the producer such as yield, costs or product quality. Subsequently, the entire scaling-up process is carried out, for which project resources will be used to implement technologies at the farm level. Although this is a massive scaling up of the technology, the farms where the implementations are being carried out will still be considered as training centers for producers and technicians in each area. It is expected that for each producer or direct beneficiary of the project, another producer will adopt the technology indirectly (during the project implementation period and two more during the life of the project).

Another challenge will be the vulnerable business models, lack of tailored financial instruments and limited technical capacities and strategic knowledge transfer. In fact, this is a variable with great differences between the different Gremios or even between topics. For this reason, an analysis of current and potential innovations of business models will be assessed in the light of climate-smart market opportunities, a study on financial barriers and opportunities for increasing the access to tailored financial products and an analysis of the capacities and needs of each of gremios will be carried out. After 4 years, all these analysis will inform the strategies so that gremios will have identified **novel and inclusive business models**, financial institutions will have access to **information to develop tailored financial products** to support scaling of climate-smart technologies and gremios will have close to 100% empowerment in each of the technologies proposed in the framework of the project. It is considered that all the development and evaluation of technologies should be done hand in hand with the gremios, and that the entire transfer process should be led by themselves. At this point, it is proposed to work on: 1. Novel and inclusive climate-smart business models for agricultural private sector **(Result 3.1)**, 2. Modernized technical assistance and agricultural extension services **(Result 3.2)**, which are addressed to support (i) implementation of approaches for technology transfer and extension services and (ii) institutional strengthening towards resilience.

The project also considers the implementation of the **monitoring and evaluation (M&E) and monitoring, reporting and verification (MRV)** frameworks that will allow for project follow-up and ongoing corrective actions to be taken and to know the results and impacts of the project during and at the end of its implementation. The project also contemplates the implementation of the environmental and social management **framework and the gender action plan** to ensure that the project does not widen gender gaps and does not generate a negative social and environmental impact. On the contrary, the actions considered therein aim to close these gaps and reduce environmental impacts.

A summary of the project's theory of change can be seen in following Figure (Illustration 10).

Illustration 10. General outline of the project's theory of change



6. DETAILED PROJECT DESCRIPTION

6.1 SCOPE OF PREFERRED SOLUTION

The **digital agriculture** component (Big data and Climate services) aims to organize, improve and optimize the management of the information currently available to the Gremios, and proposes the implementation or strengthening of platforms for the capture, analysis and dissemination of data for climate-smart decision making. Big data platforms will make it possible to enrich the agronomic data recorded by each organization and, based on this, to use data mining and artificial intelligence methods as part of a process of searching for information to support decision making. These platforms will be implemented and/or adjusted in the locations defined by the Gremios, and the data analysis will include primary information (captured at the time of the project) and secondary information (historical or from secondary sources). For potatoes, sugarcane, musaceae and livestock. Development would start from scratch, since the aforementioned crops do not have a similar system, while for sugarcane, rice and maize, there is already significant progress at this time, and therefore efforts will focus more on strengthening the current platforms. The platforms will be co-developed between the Alliance of Bioversity International and CIAT and each Gremio but will be operated and managed by the Gremio. The use of commercial information from growers will be encouraged to identify best practices to increase yields and reduce the negative effects of climate change on the crop, as well as the use of analytical methods adapted to each context of the information, maintaining the principles of efficiency and simplicity.

Through the implementation and strengthening of climate services, which involve the co-production, translation, transfer and use of agroclimatic information, smallholder farmers will have the opportunity to intensify production, adopt improved technologies and practices, invest in climatically favorable seasons and protect scarce assets in unfavorable seasons. Improved climate-related information will also help public, private and civil society actors in the food system, whose decisions impact food and rural livelihood security, to manage the impacts of climate risks. To strengthen communication and dissemination of climate-smart information through digital means, it is proposed to develop and implement an instant messaging system with relevant information on planting dates, varieties and other agronomic practices that will contribute to better decision making.

Finally, training sessions are planned for personnel from the Gremios and other actors in the sector on topics related to climate change, digital agriculture and information analysis using data mining. Each Gremio has identified a certain number of researchers and personnel who will be involved in these training sessions, which are directly linked to component 3 on capacity building and institutional innovation.

In component 2, related to **genetic improvement, crop management techniques and other technological options**, Result 2.1. on genetic improvement proposes the development of new varieties and hybrids that respond to the needs and limiting factors. The strategy consists of three phases: development and optimization of phenotyping for each limiting characteristic, evaluation of germplasm to identify tolerance or resistance to biotic and abiotic factors, and finally implementation of the characteristics that provide tolerance to the different factors in advanced breeding lines or varieties. A great challenge in this result will be to reach thousands of producers in a short time with germplasm ready to be released. The intended strategy is to be able to use all the development that is currently available on breeding, thus ensuring different types of deliverables from breeding lines in selection phases to lines for evaluation of agronomic tests. Seeds will then be mass multiplied and delivered to thousands of producers. In this sense, the project considers different mass propagation systems, producing thousands of seeds in a very short period of time, according to the conditions of each crop, and especially ensuring quality (pathogen-free seed).

Result 2.2, related to water and carbon footprints, seeks to quantify the carbon footprint and baseline water footprints for different crops, but also for different alternative technologies that can contribute to reduce water consumption, GHG emissions and increase carbon sequestration. It also includes watershed hydrological modeling processes to determine water harvesting points in productive systems. This component also considers the scaling up of technologies on a massive scale. A first route is through the landscape approach. In this case oriented to the reconversion of livestock farms to more sustainable systems under a landscape scale intervention approach; and in the second case, oriented to the restoration of riverside ecosystems associated with sugarcane landscapes. A second intervention approach is direct interventions on farms without responding to a particular landscape structure. The latter is a massive implementation of agronomic management technologies and transformation processes that allow a more efficient use of water and promote low carbon development in crops. These practices are related to the management of fertilizers and bioproducts (potato, maize, rice, sugarcane, banana and plantain), optimization of irrigation systems (rice, sugarcane, potato and banana), conservation agriculture (potato and maize), use of crop residues (coffee, maize, banana, sugarcane, sugarcane, banana, banana, sugarcane and plantain), maize, banana, sugarcane), low-emission planting materials (rice and sugarcane), optimization of processing systems (sugarcane, maize and sugarcane), water harvesting (rice, sugarcane, banana and plantain), pasture management, animal welfare, and good livestock husbandry practices.

Component 3 on *innovative and inclusive business models through modernized innovation systems and a more engaged financial sector* has a cross-cutting function and seeks to ensure that certain issues of great importance to the project are appropriately integrated into the two previous components. The first point to be addressed are the **business models and the engagement with financial institutions** both local and national.

Business models integrate the value chain analyses including relevant stakeholders in a given sector and across scales that are interrelated along the supply chain. Hence, this activity proposes the definition of sectoral scaling strategies with a climate change adaptation and mitigation approach. This includes the description of the current state of each production line, and the identification of the main actors involved at the territorial level and their functions, recognition, and portrait of the socioeconomic system in which they interact and their performance, and economic analysis and added value along the chains. The expanded panorama sought in this first point leads not only to the construction of a baseline for the chain, but also to the identification of bottlenecks and opportunities for leverage in terms of the enabling environment for scaling up changes that favor the implementation of measures to reduce, mitigate and adapt to climate change. These are in turn the main inputs for the design of a shared vision, definition of objectives, action strategies and coordination with all the stakeholders involved.

Then, pilot cases will be identified, for example, farmers groups and buyer companies to assess commercial relations to design strategies and propose scaling activities that lead to design tailored climate resilient and low-carbon business models through the LINK methodology. After this assessment, enhancement plans will be developed to guide farmers and buyers towards the implementation of actions aligned to the project, while success factors for achieving scale are identified with other relevant stakeholders.

Business models are the building blocks of the value chain. Improvements and changes made to the business models of the pilot cases have implications for the actors involved. Moreover, the business models go hand in hand with the chain's upstream and downstream business linkages.

Thus, as a chain solution to promote change, upgrading the business models is an option to move from shared vision and strategy to value chain development, i.e., structural change to favor the development of low-emission and climate-smart value chains.. All of the above is done in a participatory manner with the actors involved, for which a set of workshops, meetings with the parties involved and the construction of dialogue tables for the discussion of the agreements are carried out.

And the second key aspect in this component is assembling the data and knowledge generated in components 1 and 2 for supporting the transformation into **modernized technical assistance and agricultural extension services** through an integrated capacity building strategy. The component will focus on four types of profiles, with specific language and message needs. These profiles are: i) Agricultural producers, men and women, with different scales of production; ii) Professionals and technicians in the agricultural sector, in Gremio activities, research and technology transfer, in the public and private sectors; iii) Agricultural sector entities in the country, Gremios, national entities, secretariats of agriculture, water districts, NGOs, among others; and iv) Field workers, especially in banana production.

For the Monitoring and Evaluation System, the project includes the creation of a data storage platform where all information related to ongoing activities will be stored. This platform will have the technical and encryption/security support of the CGIAR data management program. To set up the system, there will be a focal point, a person in charge of each Result and Gremio who will help in the task of uploading progress. The platform will be designed based on the components and results and has different modules. This platform is designed to securely store and centralize the information that will help the M&E process, as well as keep it for future requirements. Once the platform is up and running and constantly updated, the M&E team will be in charge of collecting and reporting the information coming from the platform, in addition to the data that will be collected in the field by the different teams. In addition to the information on the platform, other sources of primary information will be used during the project for M&E, such as focus groups and monitoring pilots. These will be done in the second and fourth year of the project. This information will be delivered in the form of semi-annual, annual and final reports. The platform will be designed to have a dashboard of key indicators that the different stakeholders can access to consult the progress of the objectives and achievements.

With regards to evaluation, it is proposed to be carried out at three levels: (a) micro or household level (producers and their household), where the basic question is: What is the result of the program intervention in the established outcome; (b) at meso or organizational level with a focus on Gremios where the Gremio strengthening on the issue of climate change will be evaluated; and, (c) at macro level, which Includes the analysis that the project may have on changes in government policies, at different national, departmental or local levels, on the issue of climate change.

Given that the project activities contemplate to a large extent the change in the performance of the prioritized production systems, the MRV system establishes a monitoring mechanism that will include: i) Generation of emission factors: Prior to the massive implementation of mitigation technologies, pilot plots will be implemented according to productive typology, prioritized region, crop and prioritized mitigation practice, in order to evaluate the performance of the mitigation potential of the practices in comparison with conventional production systems, ii) Survey and counting protocol: the survey and counting will be carried out every year once the process of massive implementation of technologies begins. The surveys will allow identifying the productive typology of each intervened producer and the activity data of each farm in order to generate the inventory of emissions per intervention, iii) Protocol for the evaluation of the performance of the technologies: the protocol includes technical visits to each producer to collect information related to inputs used, yield, areas, among other parameters.

In the case of the environmental, social and gender plan, a series of actions will be implemented that arose from the analysis of the current situation of the crops and Gremios with respect to these three issues. In this sense, the actions are aimed at ensuring that the gaps in this area are not widened and that no negative impact is generated in terms of these three issues. On the contrary, the actions are designed to seek to close these gaps.

6.2 Project Objective and Target Sites

The **overall objective** of the project is to reduce the vulnerability of agricultural production to climate hazards in order to minimize their impact on the sector's competitiveness and ensure sufficient and stable availability of quality food by strengthening climate risk management, while reducing greenhouse gas emissions from agricultural production. The project seeks to change the current agricultural production paradigm of intensive use of inputs, with little adaptation of technologies to reduce the vulnerability of crops to droughts, floods and other climatic stressors. For this paradigm shift, the Project establishes three (3) purposes: (i) implement digital agriculture systems and climate services to modernize agricultural extension services and provide adaptation and mitigation recommendations that support the reduction of agro-climatic risks and crop loss, while stimulating a low-emissions sector; (ii) develop, validate and scale up technologies (genetic improvement, crop management and other technologies) to increase resilience and low-carbon agricultural development; and (iii) develop innovative and inclusive business models through capacity strengthening for modernized innovation systems and a more engaged financial sector. .

The selected sites were chosen by common agreement between the Gremios, scientists from the Alliance of Bioversity International and CIAT, Agrosavia, MADR and DNP, according to the information available on the greatest climatic risks for the crops to be worked on, or according to the mitigation potential and the synergies and complementarities with other projects. In addition, some considerations on security aspects and installed capacity of managers and other organizations with presence in the regions were also taken into account in the background. Illustration 11~~Illustration 11~~ shows the general panorama of the project's work sites differentiated by crops.

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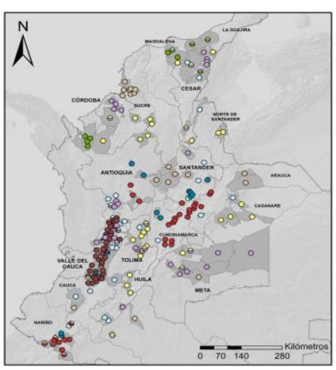
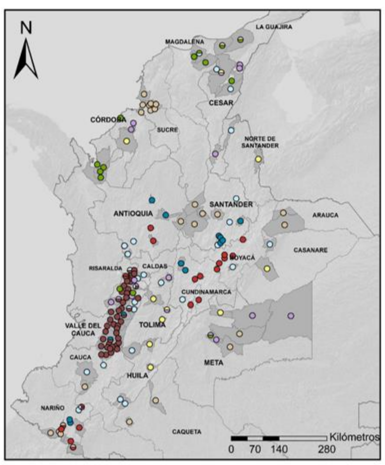


Crops	Number municipalities
Rice	32
Sugar cane	47
Panela cane	11
Coffee	26
Livestock	24
Corn	37
Musaceas	12
Potato	30
TOTAL	219

Illustration 11. Municipalities in which the project will have direct intervention

It is estimated that the project will benefit more than 194,871 direct rural producers and their families (619,692 people in total) and more than 104,000 indirect producers and is expected to increase the climate resilience of agricultural systems in a total of 967,997 hectares, distributed in 22 departments (69% of the country's departments) and 219 municipalities (20% of the total number of municipalities).

The overall objective of Component 1 - *Digital agriculture and climate services for the modernization of the countryside with emphasis on adaptation and mitigation*, is to modernize the agricultural extension system through the implementation and use of digital agriculture systems and climate services in order to provide recommendations for adaptation and mitigation measures, with direct technical support to more than 126 thousand producers, but reaching more than 250 thousand producers through the climate services platforms and the Agroclimatic Technical Work Groups (MTA). We want producers and technicians participating in this component's activities to have the best digital technology and information in their hands to reduce losses, increase their productivity, adaptive capacity, and improve efficiency in resource use, as well as the ability to use this technology and information effectively in their contextualized, accurate and site-specific decision making. This component will have interventions in 179 municipalities (See Illustration 12).



Crops	
Rice	10
Sugar cane	50
Panela cane	13
Coffee	28
Livestock	27
Corn	17
Musaceas	15
Potato	19
TOTAL	179

Illustration 12. Areas (municipalities) of intervention of component 1 (Results 1 and 2)

Component 2 of the project seeks the massive implementation of technologies and crop management options to improve the resilience of production systems and low-carbon agricultural development, considering genetic improvement alternatives, efficient use of water and soil resources, and other adaptation and mitigation options. This component is composed of two results, **Result 2.1** that seeks to strengthen the germplasm bank, the development of new varieties and mass multiplication of seeds adapted to extreme precipitation and temperature conditions and/or that lead to lower greenhouse gas emissions, and **Result 2.2** that focuses on the development and scaling up of crop management techniques and other climate-resilient and low-carbon technological options.

In the case of component 2, interventions will be carried out on more than 130,000 hectares with 17,657 direct beneficiary producers and their families (56,148 people in total). Likewise, interventions will be carried out in a total of 146 municipalities in the country for product 2.1, and in 123 municipalities for product 2.2 (see Illustration 13).

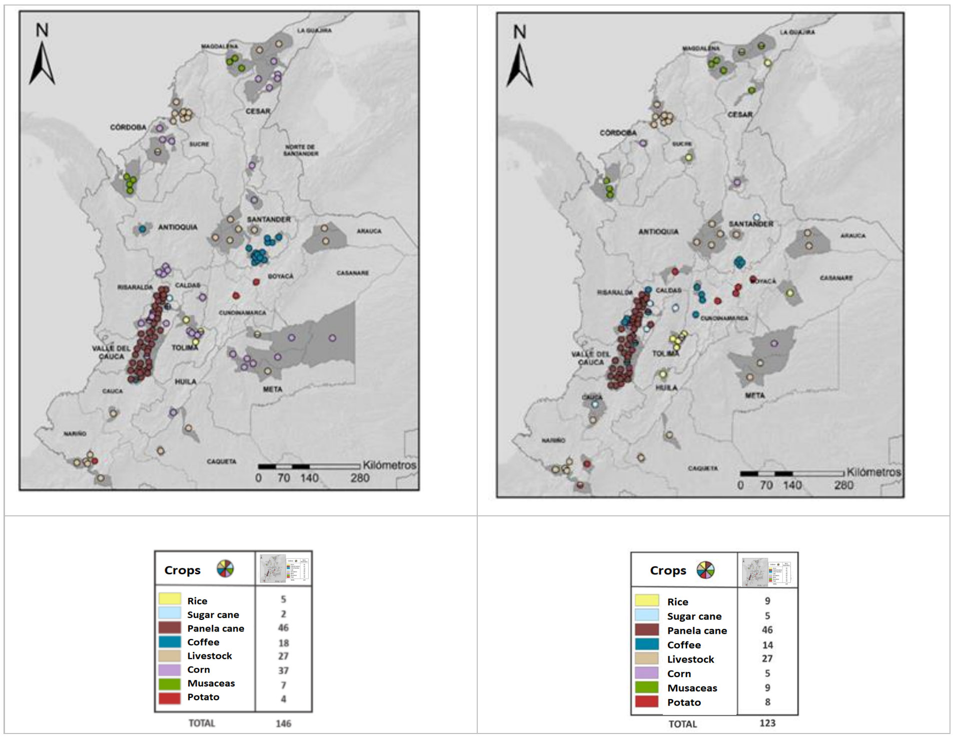


Illustration 13. Areas (municipalities) of intervention of component 2 product 2.1 (left) and product 2.2 (right)

The actions developed in **component 3** will be crosscutting to the entire project; therefore, the areas where this component's actions will be carried out correspond to all 219 (municipalities) that will be intervened in the project. Regarding beneficiaries (see Table 11), it must be taken into account that this component contemplates a greater coverage of beneficiaries for capacity building, so there are no hectares implemented in technologies or indirect beneficiaries. The beneficiaries of this component are related only to trained people.

The objective of this component is to strengthen the capacities of agricultural sector entities (considering Departmental and Municipal Agriculture Secretariats), technicians and training reinforcement for producers in the implementation of resilient and low-carbon technologies under environmental, social and gender considerations, in order to ensure adequate technological appropriation.

Table 11. Beneficiaries of component 3

Crop	Producers (people)	GremioProducer associations/ gremios Professionals	Professionals from other organizations	Organizations in the sector
Rice	3,491 (11,101)	30	300	20
Coffee[48]		0	0	0
Panela Cane	12,000 (38,160)	30	50	0
Sugarcane	800 (2,544)	80	40	4
Livestock	16,350 (51,994)	47	150	3
Maize	6,000 (19,080)	30	110	8
Musaceae	684 (2,175)	130	50	10
Potato	14,500 (46,110)	30	50	4
Total	53,825 (171,164)	377	750	49

This project has also incorporated monitoring and evaluation (M&E) processes for adaptation processes and monitoring, reporting and verification (MRV) for mitigation processes.

[48] In the case of coffee cultivation, it is a association with a very strong extension system and very well known in Colombia for many years providing a service with a great coverage and quality, so they will assume all the extension to scale-up the technological adoption on their own.

6.3 PROJECT RESULTS- DESIGN AND PRINCIPALS

Component 1. Digital agriculture and climate services for rural modernization with an emphasis on adaptation and mitigation.

Result 1.1 - *Strengthened and modernized agricultural extension system with an emphasis on adaptation and mitigation.* The project seeks to modernize and expand the coverage of agricultural extension in Colombia. The expected result is the development and strengthening of Big Data platforms and the appropriation of these technologies by the Gremios for the dissemination of climate-smart recommendations. It is proposed to build a system that allows the Gremios to integrate the agronomic information databases they have available (e.g., varieties, planting dates, yields, applied fertilization practices, irrigation, harvest dates, etc.) along with historical climate information, so that it can be analyzed and provide agro-climatic information for better decision making.

The scope of this activity will be different for each production system and Gremio. For potato, livestock, banana and plantain crops, this system will be developed in its entirety. In the case of sugarcane, there is currently a platform with a basic information capture module. Therefore, the scope will be focused on improving and expanding information capture, setting up the information processing and analysis system and developing the product generation system. In the case of rice and maize, it will be oriented to improve the Big Data platforms that were worked on in the MADR-CIAT pilot project. In this case, the information will be expanded, the information processing algorithms will be updated and improved, with special emphasis on the generation of platform results and site-specific decision making. In the case of sugarcane cultivation, a Big Data system is already in operation, therefore, this system will be complemented with the necessary instrumentation to cover the collection of information on some variables, including water availability for the crop.

In all cases, these systems will be managed by the Gremios and AGROSAVIA, seeking their appropriation and empowerment in such a way that they will be an input for the Unified National System of Rural and Agricultural Information, without generating an additional and permanent cost in the long term at the national government level (an aspect that will be clearly defined in the different implementation agreements).

To achieve these results, the following activities are considered:

Activity 1.1.1. Organize the information from the different repositories and producer association databases (public and free-access systems) to connect them with updated information available from existing free-access platforms through remote sensing or other sources.

SA1. Development of a strategy for data collection associated with environmental, social, technological, productive and economic indicators.

A first step is to analyze the main variables that affect each of the crops (rice, maize, potato, sugarcane, livestock, banana and plantain). This work is carried out by scientists from different disciplines of each crop from the Alliance of Bioversity International and CIAT, the Gremios and Agrosavia. These variables must be differentiated according to the different stages of the crop cycle. This will be a key task, since it will be used to define the variables to which the search and data collection work will be carried out. Subsequently, we will proceed with the search for information in the different historical databases and research carried out by the Gremios and other existing private or public databases that are freely accessible.

The purpose of this work is to identify the sites and access routes to the different variables required according to the repositories in which the information is found and, in the case of information that is found in isolation, a guide form will be prepared to capture the information and to structure, consolidate and centralize an easy-to-consult database that includes all this information. This work requires high-capacity servers given the volume of data to be handled and will be provided with web hosting services, server maintenance and some licenses. These databases will handle two types of information, free access or without access restrictions and restricted information (since it is individual producer information). For this reason, each Gremio will manage its own platform, and the system will have a security system to guarantee data privacy. Likewise, each Gremio will be responsible for the operation of each platform during and after the project.

Regarding the variables for which information is not available, a shock plan will be implemented for the massive collection of this information in the field for the variables where this is possible (e.g. physicochemical analysis of soils). For this purpose, a procoloto for data collection and a mobile application will be developed for the technicians in charge of this task, which will be in line with the information storage platforms managed by each Gremio. Some Gremios already have some platforms that will be strengthened with new information modules (sugarcane SIPA system, Maize E-agrology-SIRIAv.2.0 system). Variables that require the implementation of a permanent monitoring system over time will be addressed in sub-activity 4 (Instrumentation for data collection) of activity 1.1.3.

It is necessary to take into account at this point the heterogeneity that exists in each of the crops and Gremios with which we are going to work, ranging from crops concentrated in a few regions (e.g. sugarcane) to others that are scattered throughout the national geography (pastures/livestock). In the case of livestock, there is a database of animals by age group, but there is no good database of pasture information. Some crops that are scattered in several geographic regions have frequent censuses (e.g. rice), while it is not known for sure how many hectares are planted other crops that are more concentrated in specific regions (e.g. potato). This will be a major challenge that the project will have to address.

For the use of open access information from remote sensing platforms, the design of the methodology for downloading and processing images covering the areas of interest of all crops will be carried out. Following the open source line, programming in Python, C++ and/or GIS tools such as Google Earth Engine and QGis will be used.

SA2. Development of a protocol for the integration of databases with existing crop information.

Once the databases are received, their respective processing will be done, which will include joining databases, transforming variables and selecting information of interest, for which a protocol and the necessary scripts will be developed to integrate all the information, including climatic information, soil, crop management, and some socioeconomic and environmental variables. Each crop will have a protocol and the necessary scripts (programmed in R, Python, Penthao, among others) to integrate the information coming from different databases and/or information sources.

SA3. Processing and cleaning of database information.

With the data professionals (systems engineers and data engineers), a reproducible workflow will be designed to perform an adequate quality control for the information collected by the field technicians, including validation of secondary climate and soil information. This workflow will be a script, which can be programmed in R, Python, Penthao, among others.

SA4. Consolidation of the processed information in a database management system.

Finally, a consolidated and clean matrix will be generated. This can be one of the most time-consuming tasks and may take considerable time given the volume of information to be handled in the project. It is important to get to this point in a timely manner because it will be the basis for all the analyses to be performed.

SA5. Data analysis using methods based on machine learning and computational optimization.

Once the databases are organized and cleaned, the analysis work will begin in order to find patterns that explain the main yield variations in the different crops and to determine the most efficient agroclimatic practices that are associated with better yields under different climatic conditions or with low emissions. For this purpose, an exploratory data analysis involving machine learning and statistical techniques will be conducted, then a data-driven model by region will be developed, in which several models such as neural networks, random forest, CART, will be tested, and in which the variables of climate, soil and agronomic management will be used as inputs, output yield and/or profitability. In the case of livestock, the effect on variables such as production (meat and milk) and calving will be considered in the analysis.

To achieve this sub-activity, it is necessary to have a high computational capacity, since it will allow the historical storage of the crop data, as well as the capacity to run different predictive and explanatory models. All this analysis is considered when defining the capacity of the servers.

SA6. Socialization of results for validation of field recommendations.

A series of socialization activities with producers and professionals of the sector are considered, in order to share the findings in the Big Data analysis, with the purpose of receiving feedback from the platform users, especially to understand the specific characteristics of the regions or types of producers, as well as the specific circumstances which may help to understand or adjust the analyses made. The plan is to have a yearly workshop in each of the locations involved. Another important element of this exercise it to be able to understand the type of information, the timely moment, and result presentation format in order to generate the information in the proper way and moment for decision-makers, considering the different audiences[49]. This sub-activity is linked to the objectives of Result 3.2 (capacity strengthening), mainly oriented to the empowerment of beneficiaries. Therefore, the generated workshops and field days will count with professionals of Result 3.2 to guarantee the use of adequate methods and materials for each specific audience and purpose.

SA7. Development of algorithms for data analysis.

The necessary algorithms will be developed to automate data analysis processes included in sub-activity 5, as well as all previous data collection and cleaning processes. As lesson learned from the MADR-CIAT pilot, the automation of these processes allows the Gremios to have a greater ownership of these tools, since the staff demand of time decreases considerably, allowing them to maintain and even increase the coverage. In this sub-activity, there are important items to have in mind; i.e., have a process quality control protocol that allows to verify that procedures and information is correct, in a short period of time, and that therefore, the results and recommendations are valid, before going to the public. Secondly, the Gremio's capacity

[49] I consider that producers can be under different circumstances which impede their access or understanding of the data, as well as the difference between crops and regions, and the capacity of Gremios to accompany the producers.

strengthening is essential in the entire data collection, cleaning, and analysis processes, as well as in the capacity of management of the entire system's programming, maintain and repair in order to guarantee operation sustainability, as well as future expansions or changes. In this case, there will be an expert team on computer programming, who will be in charge of developing all information technology tools required.

SA8. Design or adjustment of platforms for data collection, storage and dissemination.

Once all the technological development for the analysis of Big Data is available, follows the structuring of the architecture and commissioning of the Web system to support the entire platform, including data collection, storage and analysis, giving special emphasis in this sub-activity, to interphases with technicians and producers, both for the collection and delivery of results and recommendations. Results of sub-activity 6 will be taken into consideration in order to know the exits for platform users, and will additionally have a validation phase for the use of the tool. This validation phase consists of releasing preliminary versions to be manipulated by a group of people, resulting in adjustments that will later be implemented to improve the same platform. Finally, there are different trips proposed to socialize the tool with stakeholders.

Activity 1.1.2. Develop a bot-based digital instrument to strengthen the extension service.

This activity is mainly directed to the rice, potato and maize sectors. The plan is to develop communication tools to facilitate the interaction between humans-machines, to provide automatic response to frequent questions between farmers and technicians. This will facilitate the dissemination of recommendations resulting from data analysis. It will also integrate recommendations emerging from results of product 1.2 on agroclimatic forecasts. Part of the tasks required to develop this tool, will be to test several pattern recognition models in texts exchanged by producers and technicians, as well as collecting data directly from potential users, a data baseline which is important for decision-making. This will be developed through workshops, interviews, questionnaires and focal groups, creating an automatic assistant with whom to exchange agroclimatic information with producers, using chats or text messages about sowing dates, varieties selected, forecasted rainfall, etc. To ensure the development of an effective and useful tool for the producers, a series of validation workshops assisted by the developers and technicians will be made, collecting users' experience data. The plan is to assess technologies such as: IBM Watson to categorize voice messages, images, texts through API p, and the modules Speech to Text, Text to Speech, Watson Assistant Natural Language Understanding and Tone Analyzer, which are used to infer automatic answers in crops in Central America, using IVR (iterative voice response) or Chatbots. In our case, we not only propose to use the exchange of questions in the chat to infer answers, but to develop more robust analyses through the use of artificial intelligence that may complement and facilitate the field work of technicians, and monitor the impact of technologies.

SA1. Development of mass dissemination systems based on a bot (automatic response interaction system) to strengthen the extension services of the producer associations.

The first task is to identify the most frequent information needs of producers, mentioned to technicians. This will be done through consolidation of the information baseline exchanged via chats with producers and technicians. This is done with the purpose of identifying producers' needs which are frequently asked. For that reason, authorization will be requested to download this information in a database. Information will also be collected via interviews, questionnaires and possibly focal groups, which will demand travel and logistic expenses.

Next is the Bot development phase, which responds to farmers' frequently asked questions. In this case, conversations (chats) will be analyzed to identify the most frequently asked questions by the producers. As part of the tasks, several pattern recognition models will be tested, contributing to the creation of an automatic assistant which may exchange information with users, answering questions such as: When to plant? Which varieties shall be planted? Which is the agroclimatic forecast? To establish this service, a GPU processor is required, as well as certain web services and licenses for the commissioning of the service. It is worth mentioning that the GPU may be shared between Gremios, developing a common service. A period of time is required to train on artificial intelligence models (chatbots) for the dissemination of a specific site data.

SA2. Engaging with potential users to collect a baseline of the information more frequently required for decision making through workshops, interviews, questionnaires and possibly focus groups.

Once the tool is obtained tests will be made by sending messages to evaluate the tool's usability level, with technical support to evaluate the degree of understanding, use and application of the recommendations, and work on improving the system, language and even the content. Work will also be done with key stakeholders on workshops, interviews, questionnaires and focal groups which allows the largest amount of feedback possible, before starting its operation.

The previous input will be used to make all the requirement system adjustments, both in the language used, as well as the optimal releasing times, presentation form, and data content.

SA3. Creating an automatic wizard to exchange agroclimatic information with producers, through chats or text messages on planting dates, choice of varieties and rain forecasts, among others.

Likewise, Big Data platforms shall manage different interfaces which facilitate consultation by different users. To expand the number of users trained with digital technologies, it is planned that several routines which are only in Code R or Python are developed under graphic interfaces, such as shiny. The group of data scientists and developers will work together on this sub-activity. A validation with module users is considered to be made once it is designed in a beta stage. Training for different crop technicians is also included.

We also consider the deployment of graphic interface module in a Docker container, which allows to maintain the functionality in different operating systems. The developers shall ensure that the system can be executed in any operating system, preparing a Docker image that encapsulates all system requirements. This will allow users to run the program without compatibility problems and making sure all software requirements are available.

Each Gremio will have their own platform with visualization dashboards according to the type of user, enabling specific consultations. These interfaces will also have usability assessment.

Recommendations resulting from the Big Data platforms will also connect with the DrAgro system managed by Agrosavia, in order to achieve greater coverage of the recommendations.

Activity 1.1.3. Design and develop the entire operating system of data analysis and mining which will allow the interconnection of all available information. It will also develop

systems which allow the automation of analysis and modelling processes to have more robust recommendations and agile and efficient processes.

This activity will include a series of sub-activities which range from collection of information in the field, to the interpretation of biotic and abiotic phenomena in the productive systems, through the use of metrics derived from remote and local sensors. This will give the Gremios tools to follow-up the production systems, increasing their response capacity viz a viz adverse weather condition. Three (3) types of information will be used: i) multi-spectrum images collected from the plant's zenith, using drones and satellites, ii) humidity, temperature, and pH sensors, directly located on the plant, soil and animal, and; iii) digital images taken with cameras.

In rice, potato, sugar cane, cattle pasture, maize and musaceae, multi-spectrum cameras will be used (collecting wave length ranges of specific waves through the electromagnetic spectrum), available via satellite and/or drone, to characterize the plant under the conditions in which it is cultivated. This will allow the rapid identification of areas sowed with a specific system and detect which areas are under a determined development condition, or even identify regions which may be susceptible to risks due to extreme environmental conditions. For productive systems such as livestock farming, rice and sugar cane, local sensors will be used to constantly monitor growth conditions and productivity of plants and animals. Finally, with the digital photographs taken on the field, counting the presence of pests in crops will identify the population of insects present under different weather conditions.

Professionals will receive training on new methodologies, such as computer optimization and remote sensors (satellite images), which will strengthen even more the monitoring and optimal decision making of producers in the farms or lots. On the other hand, it is proposed to develop graph interfaces based on tools such as R Shiny, Java or C++ for users who do not program on R, or other more advanced languages, in order to increase the number of technicians capable of using data analysis tools.

SA1. Identification of variables to improve analyses and recommendations at a specific site.

In sub-activity 1 of activity 1.1.1, the variables to be followed-up in each of the crops, were defined. For each of these variables, a measurement protocol and data registration will be made. Within the prioritized regions, the lots for the installation of equipment and the corresponding logs will be defined.

SA2. Instruments for the collection of data using remote sensors (drones) and non-remote sensors (performance sensors, soil humidity sensors, electroconductivity sensors, leaf humidity sensors, etc.).

Remote sensoring work made in sub-activity 1 of activity 1.1.1., will define variables to be validated in the field. This will use data coming from working lots of all project components in order to evaluate the performance of certain variables (i.e., type of crop, performance, phenology). For more specific variables (i.e., nutritional deficiency, water deficit), we will identify certain lots in which an entire protocol will be installed, as well as data registration for performance validation of the satellite data. Such variables at a specific site will be registered.

Some variables (i.e., presence of pests and diseases, presence of arvenses, waterlogging) will be analyzed through data collected by multi-spectrum cameras in drones. These cameras will allow collecting information in at least five (5) portions of the spectrum, or bands (blue, red, green, infrared, red edge). The importance of having different bands is that the plant has a different interaction through the spectrum, depending on its vitality. For example, a plant with a certain high severity level due to a disease, will reflect less energy in the infrared portion. That means that at the end, it will be possible to have a spectrum profile characterization for the different problems related to climate and their potential effect on the plant's performance. For validation of this information, we will work in at least 10 lots (greater than 2 has.) per every zone of each of the crops. It is important to mention that flights will be executed in different crop cycle stages, since the susceptibility and risk vary throughout the crop's cycle.

The field technicians will be in charge of applying protocols for the collection and registration of data in the different sites. Field data will be initially used to validate remote sensor information performance (both by satellite and drones), and then the machine learning models will be trained to have better remote data. Apart from the server, it will be necessary to have a specialized software to properly use the images taken by the cameras, licenses in NVIDIA, and GPU, PIX4D, PCI Geomatics.

Emissions produced by bovines shall also be monitored with non-remote sensors. This will be done by installing devices to measure the emissions level according to the animal's different diets. This will allow the evaluation of the most adequate diet to minimize methane emissions from the herd of cattle. Likewise, sensors will be installed to measure the physiological performance of the animals in relation to the different weather variables and stress, which allow the identification and correlation of emission levels with these factors. At the same time, information will be registered regarding the production, reproduction and quality of forage, as well as their costs, in order to complement the analysis made.

Similar to activity 1, a series of socialization activities with producers and professionals of the sector are considered. The goal is to share technology and data obtained through remote and local sensors. The plan is to have yearly workshops in each of the involved locations, as well as dissemination material under support of the Result 5 team, to guarantee the language and content are appropriate for the different types of audiences.

SA3. Development of a data management routine that allows integration of information taken by Big Data platform instrumentation.

It is necessary to have the entire development of systems that allows that all information taken or reported by the technicians or producers in the field, data from the sensors and even data downloaded from other sources, have an automated quality control process and direct integration with the databases, having controls made by Gremio professionals. This will substantially reduce operating costs, but will guarantee the quality of the process and its results.

Activity 1.1.4. Train technicians in the use and application of advanced data analysis methods.

Each of the previous activities have included socialization with technicians and producers in order to analyze results, usability tests and receive feedback to improve the tools. This activity is focused on strengthening the training, dissemination and socialization processes for the use and implementation of the developed tools. It is important to have a very good characterization of the different users in order to be able to establish a plan according to everyone's needs[50].

[50] Task to be developed by Result 3.2 team.

SA1. Design and implementation of a training, dissemination and socialization program on the use, requirements and advantages of the Big Data platform oriented to Gremio technicians, other professionals, producers and relevant stakeholders.

An intensive training plan is considered from Gremio professionals in order to guarantee the proper domain and empowerment of the developed tools. Training sessions will include new digital tools, such as machine learning, computer optimization, remote sensors (satellite images), drones and field sensors. This will be taught through workshops and courses with emphasis on the development of data mining skills, evolutive IT, remote and field sensors. An elite group of Gremio professionals will be formed, who will attend their practice at the venue of Alliance Bioversity-CIAT to implement procedures and routines, as well application of methods with the Gremio's own data, receiving support and follow-up by researchers of the Alliance Bioversity-CIAT.

Massive events, tours and workshops for different types of tools' users will be organized in order to promote their use[51]. All these activities will have support dissemination material (booklets, brochures, presentations, etc.), which will be developed with advice from professionals in Result 3.2. Text messaging services will be available, as well as the Project and Gremio's web pages, SSL Wildcard Certificate and cloud instances, services such as WhatsApp, among others, to support dissemination of the tools use.

SA2. Developing, validating and implementing a module based on graphical interfaces to facilitate data analysis and consultation, aimed at producer association technicians

Training modules will be developed, validated and implemented to improve the handling of graphical interfaces and at the same time generate feedback to improve the platforms.

SA3. Training of trainers on Information Literacy for producers with an ethnic and gender focus and develop and implement dissemination means

With the support of the social and gender team, training of trainers will be carried out in order to strengthen and achieve an appropriate language in the trainings that allows a greater inclusion of different groups of attendees.

Result 1.2. Agroclimatic services in place and/or strengthened

Generally, farmers experience extreme weather conditions and climate variability events, with significant losses in their productive systems. With timely and systematic agroclimatic information, farmers will be able to be better prepared to face these events. However, farmers usually have limited access to crop planning information. If they have access, they can hardly understand it, or when they understand it, they do not know how to use it, since the information cannot be processed or put into context, and finally, it is not considered for decision making in the field. Farmers plan their crops according to prior years' events, increasing their vulnerability. For that reason, activities herein are based on the design and/or strengthening of climate services focused on the user, which allow an effective production, translation, transfer and use of agroclimatic data.

Some crops (i.e., potatoes, sugar cane, cattle, bananas and plantain) do not have an agroclimatic forecast tool. Therefore, Activity 1.2.1 will mainly focus on the process to have platforms which allow these crop sectors to have climate services for their users. This activity will also be

[51] Including Climate Participative Integrated Services for Agriculture (PICSA) to reach producers with limited access to information tools.

accompanied by the strengthening of instruments for the collection and registration of weather information, as required. Currently there is a platform operating this service from rice and maize crops (AClimateColombia; Sotelo et al., 2020) which was designed, installed and commissioned within the pilot agreement MADR-CIAT, and independently operate platforms for sugar cane and coffee crops. For these crops, we will focus on strengthening climate services existing in Activity 1.2.2. Information systems will be strengthened with last generation models and the improvement of weather forecasts and crop models, as well as new alert information systems related to pests, diseases, abiotic factors and the planning of water management in irrigation systems.

All this information and the strengthening of the sectors will also strengthen the operation of Agroclimatic Technical Groups (MTA for its acronym in Spanish) of the country, supporting the management and operation of at least fifteen (15) MTA's.

Activity 1.2.1. Design and/or strengthen agroclimatic information services.

Climate information services will be designed, implemented and/or strengthened to support producers' decision-making and avoid losses in their productive systems. The result of this activity is to broaden the current agroclimatic forecasting system, to other productive systems in order to have timely and reliable information about the main climate threats and recommendations for crop management, in order to avoid agricultural losses.

SA1. Development and Implementation of Improvements in the Existing "AClimateColombia" and "Will it rain, or not?" Platforms

A first step is the collection of climate and agricultural information in order to calibrate and validate climate and crop models. Methodologies to generate seasonal weather forecasts will be implemented, evaluating their adjustment based on historical information available in sites prioritized by the Gremios.

Initially, evaluation of current weather forecast models' performance will be made (from 1 to6 months), in different areas of the country, which complement evaluations already made[52], emphasizing the periods or moments of interest for the physiological development of the crop and the climate variables of interest. The adjustment of data provided by different models (GFS, ECMWF, CHIRTS) will be evaluated with respect to observed data and the country's atmospheric characteristics (ITCZ, SST, etc.). A revision (state of the art) of downscaling will be applied to already implemented alternatives (Machine learning, neural networks, diffuse logic, SOM, etc.), selecting and evaluating the most promising downscaling techniques, as well as dynamic downscaling models. Based on this analysis, the downscaling methodology (configuration) will be selected, adjusted to the required decision-making needs. Alternate new downscaling methods will also be evaluated, with spatial grid coverage. All improvements will be operationally implemented in the project's platform. Meteorological factors will also be explored (i.e., tropical activity in the Atlantic Ocean) in the seasonal and sub-seasonal climate behavior, and include its effect on the seasonal and sub-seasonal predictions.

All forecasts will be strengthened by including next generation models such as the NextGen model developed by the International Research Institute for Climate and Society – IRI. The improvement of weather forecasts will allow the achievement of better agroclimatic modelling results, which integrates weather data (historical and forecasted) with physiological variables of the systems. Additionally, an international consultant will be contracted to reinforce training on weather forecast

[52] https://www.sciencedirect.com/science/article/pii/S2405880718300177

of all personnel participating in the project. Weather forecast improvements will be automated in all processes.

Information generated in the different project plots will be used to make additional validation and calibration processes, and experimental crop plots will be assembled with equipment for the measurement of climate variables, with special equipment to record specific growth and accumulation of biomass by organ, and throughout the crop's cycle, phenology and definition of growth stages and development in the different sites. These includes, among others, growth parameters, as well as gas exchange in photosynthesis, respiration, transpiration and definition of thermal thresholds as input for the development of the crop model. Based on the primary data of each crop cycle, the predictive models of the climate and crop are validated and adjusted, and the performance of the integration of both models (climate and crop), denominated agroclimatic models.

Once agroclimatic models demonstrate a good performance, the integration and alignment of the Aclimate[53] platform is made, and in the case of rice crops, it is included in the "Is it going to rain, or not?" [54] platform. The required capacity of servers will be considered taking into consideration all the activities of component 1 (both product 1.1 and 1.2), since although there is some information individually managed given the protection condition of already existing data and databases, the processing program for all climate data will be processes through the optimization of the use of all servers under the responsibility of project-participating Gremios.

SA2. Development or strengthening of a climate data collection network (meteorological stations network) in prioritized sites.

The meteorological network of Colombia mainly consists of the stations of IDEAM[55], stations of CARs[56], Agrosavia, the Gremios and some of the private sector. There are certain regions of the country that do not have adequate coverage and therefore, it is required to install meteorological stations that, at a short term, allow having data to evaluate the performance of the weather forecasting models, but that at long term serve as source of additional information that enhances information feeding the models. All this is accompanied by the respective equipment installation and calibration protocols. These stations will be connected on line to register the data on the Gremio servers, which interconnect with the Big Data analysis and climate modelling. Automation processes for data quality control (outliers detection algorithm) will also be used.

Gremios will be responsible for the management and maintenance of these stations during and after the project is completed. Each Gremio knows the costs and responsibilities of maintenance and operation of the equipment and therefore, the number of stations is in agreement with each Gremio's capacity.

SA3. Identifying and mapping areas that are vulnerable to experience water and biological stress, based on their water supply.

Climate information will be analyzed to identify areas with water stress problems

[53] This platform was created in the MADR-CIAT pilot in 2014 and currently continues working for rice and maize crops. https://pronosticos.aclimatecolombia.org/

[54] This platform was developed by Fedearroz after the MADR-CIAT pilot, as result of capacity building during the pilot http://clima.fedearroz.com.co/

[55] State national entity in charge of this data management.

[56] Decentralized entities in charge of environmental matters.

SA4. Creating, structuring and implementing the Cenicaña AgroClimate Service for the Cauca River Valley, including the automation of the productivity prediction system for sugarcane and the analysis of climatic variables.

The information generated in SA1 will be used to predict the productivity of sugarcane and the risks identified according to the climate prediction, and this information will be available to sugarcane producers.

SA5. Adjusting and validating climate prediction models in coffee and its relationship with diseases, and making recommendations.

For the adjustment and validation of the climate prediction models in coffee, the SA 1 procedure will also be followed, and the results of the validation will be used to review the recommendations associated with diseases.

Activity 1.2.2. Develop more accurate and precise climate and weather prediction models and complementary improved crop simulation models by using new-generation climate models, improving the performance of climate prediction models, modeling crop physiological processes, including alerts for pests, diseases and other abiotic factors (for example, frosts), and irrigation planning and optimization.

The aim of this activity is to evaluate the currently available weather forecasting abilities in the regions where the priority productive systems are located, and incorporate next generation models to improve their performance. In some of these systems, we will evaluate other forecasting with greater spatial and temporal coverage (i.e., sub-seasonal weather forecasts) which offer exits for the meteorological variables required by agroclimatic models.

Note ll Agroclimatic models currently available have calibrated and incorporated cultivars and varieties, making difficult their use in decision-making. Therefore, these activities aim at designing and implementing calibration protocols (through field experiments) for some of the productive systems. Likewise, information available for current decision-making can be broadened, including not only the sowing dates and varieties, but also the irrigation and fertilization regimes. For some crops (i.e., rice, coffee, sugar cane and musaceae), an advance towards new alert information services will occur. These alerts include pests, diseases, abiotic factors and planning of water management in irrigation systems. In this case, it is necessary to advance in the calibration and validation of pest and disease behavior modelling. Efforts to optimize calibration methods of crop models may be used as input in operational processes for variety improvement.

SA1. Evaluation of weather forecast at different timeframes (i.e., seasonal, sub-seasonal) exploring the influence of meteorological factors (i.e., Tropical activity in the Atlantic Ocean), in the seasonal climate behavior and include such effect in the seasonal forecast.

The objective of the activity is to analyze, evaluate, adapt and translate the sub-seasonal and temporal forecasts to generate new agroclimatic products which respond to crop needs in relation to decision-making at all relevant temporal phases (time, seasonal, sub-seasonal). Additionally, methods will be developed to determine new climatic indicators at seasonal scale (i.e., rainfall distribution, initiation and ending of rainy seasons), which also serves to support field decision making.

Analyze and evaluate the performance of sub-seasonal forecast for different regions in order to generate products to make decisions between week 1 and 3. A forecast model based on AI will be developed and evaluated. Sub-seasonal forecast models developed by IDEAM/IRI will be evaluated. Locations using this type of thematic output will be evaluated in terms of their forecasting. Once validated and having adequate performance results, the platforms AclimateColombia and "Will it rain, or not?' will be implemented. All this process will be accompanied by the capacity building of Gremios.

Analysis, evaluation and adaptation of new products and meteorological seasonal and/or sub-seasonal indicators will be made to assess methodologies for the forecast of relevant variables in the production of some crops, such as the initiation and ending of rainy seasons and temporal rainfall distribution.

Another Product to be evaluated in the case of rice and sugar cane crops will be time numeric prediction models to generate products that include decision making within a timeframe of 1-10 days. In these cases, we will evaluate time forecasts with producers in the field, and in a technical manner, using the observed data. This may include GFS and ECMWF forecasts. The validated results with good performance in rice crops will be implemented in the "Will it rain?" platform, while in the case of sugar cane crops, it will be implemented in the Gremio's platform (in this case, Cenicaña[57])

SA2. Development and implementation of new calibration methods for simulation models (i.e., generic variety groups), as well as data collection protocols during experimental evaluations (i.e., crop improvement and harvest monitoring groups).

This sub-activity focuses on the improvement of crop modelling and therefore, will focus on work for the development and implementation of new calibration methods (i.e., generic variety groups) and data collection protocols during experimental evaluations (i.e., crop improvement and harvest monitoring groups), in such a way that the variety, or group of varieties, are already available in the system when released to the market[58].

The first step consists of reviewing the agronomic data collected in the Big Data work and complete with repository information of experimental plots results. New crop models' calibration methodologies/criteria based on regional sensitivity analysis will be made, evaluating the calibration performance of different sets.

As in sub-activity 1 of Activity 1.2.1, for the calibration of crop models the following procedure will be followed: information generated in the different project plots will be used for additional validation and calibration processes, assembling some experimental crop plots with equipment for the measurement of climate variables and with special equipment to log a specific registry of growth and biomass accumulation by organ and throughout the entire crop cycle, phenology and definition of growth stages and development in the different sites. This includes growth parameters, as well as photosynthesis gas exchange, respiration and transpiration, and the definition of thermal thresholds as input for the development of the crop model. According to the primary data of each cycle, the climate and crop forecast models are validated and adjusted, as well as the performance of the integration of both models (climate and crop), which are denominated as agroclimatic models. The difference between these sub-activities consists of the crops being analyzed since in sub-activity 1 of Activity 1.2.1, work is done with crops that do not have this type of previous work, while in this activity, it is the complement of work already

[57] https://www.cenicana.org/category/clima/
[58] This is a lesson learned from the MADR-CIAT pilot since material by material calibration may result costly and inefficient.

developed, adding the variable of using a calibration methodology by genetic groups, which allows a more efficient calibration of materials. In the case of livestock, we will work with forage species models.

Capacity building of Gremio professionals is considered within the framework of this sub-activity, as well as in the development of calibration protocols of genetic material groups.

SA3. Calibration of simulation models under different agronomic (irrigation and fertilization) management conditions through the evaluation of water and nitrogen balance modules.

This Sub-activity is focused to generate and calibrate specialized modules within crop model related to water balance and nitrogen cycles. The procedure is equal to crop calibration processes, with the difference that it only focuses on variables and processes related to water and nitrogen cycles of the crop. In cases such as coffee crops, the modules have to be fully developed, but in the case of rice, models containing crop models are used. The first step in the collection of data or use of information collected in Big Data, is an initial validation and calibration step. After, a second validation and calibration process are made with plot information (which contains this level of detailed information), and finally, at experimental plots exclusively designed for this purpose.

SA4. Evaluation of performance of simulation models at commercial plots.

Pest and disease modeling are a new methodological development which generally is not included (or at least, not properly included) in crop models. In this case, we have considered a differential approach to traditional calibration models, based on experimental data under controlled conditions. This approach based on information from commercial plots becomes an initial step for the development of these models[59]. The first case includes the collection of historic data on the behavior of commercial plots, which will mostly result from information collected for the Big Data analysis. With entomologists and plant pathologists of the Alliance Bioversity-CIAT, Agrosavia and the Gremios, the initial theoretical models will be formulated with the behavior of pests and diseases according to climate variables. Model validations and calibrations will be done after (with historic information collected). Once a good performance of the models is reached, the Project plots managing this type of information will be tested, and the corresponding adjustments will be made. Finally, a record of information from these exclusively selected lots will be made, where the last validation and calibration process will be made before integrating them to the project's climate service platforms.

An additional product will be the use of these pest and disease behavior models considering climate variables, in order to analyze future dynamics regarding climate change scenarios.

SA5. Determine uncertainties resulting from climate, agronomic and articulation models.

The objective of this sub-activity is to evaluate and implement different methodologies to articulate climate and crop models, considering associated uncertainties and their implications in decision-making. To develop this, it will be required to have input generated from previous sub-activities. The first step consists of adapting the methodologies to connect with new inputs (NextGent), evaluate different agroclimatic forecast connection methodologies and implement the best

[59] The idea is to use statistical models instead of deterministic models, as in the case of crop models, as well as water/nitrogen cycle models.

performing methodology, showing result ranges according to the uncertainty (uncertainties in weather forecasting, crop modeling and their articulation). This work will help determine how Likelihood variations may impact the recommendations and guarantee that this uncertainty and error is taken into consideration in the communication of such recommendations, therefore establishing the forecast use criteria and its dissemination, based on the climate-crop forecast of performance and uncertainty.

These advancements will be included in the AClimateColombia and "Will it Rain or not?" platforms, to improve communication processes in the proper transmission of forecast to the MTAs. A previous analysis of the usability tests will be made to ensure the proper understanding of forecast-related uncertainties.

SA6. Analysis of climate and biophysical variables in cattle-farming areas.

An additional product for cattle-farming consists of bioclimatic characterization in the cattle-farming areas of Colombia. Most of the crops already have this information, but in the case of livestock, the information collected and generated in this project will be used to generate this basic product to support decision making. This work shall evaluate the availability and quality of climate data in cattle-farming areas, and will also identify information gaps, as well as the relation of climate variables with the productive and reproductive activities. This data will allow the identification and generation of new agroclimatic products or services which are useful for the Gremio in making decisions, as well as bioclimatic indicators that allow knowing environmental changes and their impact on the physiological performance of the animal. The first tasks consist of the evaluation of spatial and temporal availability of secondary meteorological stations and databases to later identify and evaluate the relation/impact of such climate variables with the physiology (physiological adaptation, reproduction). Once this information available, perform the bioclimatic characterization and/or zoning of prioritized cattle-farming areas.

Activity 1.2.3. Connect agroclimatic forecasts with artificial intelligence models (Result 1.1).

This activity considers the integration of agroclimatic forecasts in the design and commissioning of early alerts that through the generation of weather forecasts, the use of simulation models, and Big Data information, will provide true and timely information for farmers and technicians.

The goal of this activity is to evaluate and implement different methodologies to articulate climate and crop models, considering related uncertainties and its implications in decision-making.

All project information and some of the scientific and professional staff of the two institutions will be used for its development. It will also have the participation of an international partner, with sufficient experience and capacity to advise on the connection and training of forecasts (NextGen). This activity is formed by four (4) sub-activities that involve certain training costs for specific topics, as well as work meeting trips and coordination with the working team.

SA1. Develop connection methodologies between weather forecasts (i.e., conversion, monthly data integration) and the existing agroclimatic models.

This sub-activity includes adaptation of connection methodologies to new inputs (NextGent), evaluation of connection methodologies of agroclimatic forecasts, implementation of selected methodology for input generation processes for agronomic modeling and definition of new methods or improvements for platforms AclimateColombia and "Will it Rain, or not?", and improve communication processes for a better transmission of such forecasts to the MTAs.

SA2. Determine uncertainty resulting from the climate, agronomic and articulation modeling.

Therefore, it is necessary to establish the uncertainty of weather forecasts, agronomic modeling and the uncertainty of agroclimatic forecasts (articulation). The execution of this activity will start once the third year is ending, expecting to complete it by the middle of the fourth year. It has a strong component of statistical and agroclimatic simulation work.

SA3. Develop a methodology to integrate the uncertainty related to climate-crop modeling in the decision-making processes.

The first step is to determine how probabilities' variations may affect the recommendations and make sure that this uncertainty and error are taken into consideration when communicating such recommendations. Next, forecast use criteria and their dissemination according to their performance are established, as well as the climate-crop forecast uncertainty. Following is the process to integrate the established criteria in the agroclimatic forecast generation process. This sub-activity initiates at the end of the third year and is expected to be completed in the middle of the fourth year.

SA4. Develop a crop IT emulation as tool for the adoption of agroclimatic products by the producers.

An evaluation of national and regional crop emulators is made. Next follows the integration phase of the crop emulators with the climate services applications. Finally, the transfer and training of the simplified crop emulation is done. Its development is planned for the fourth year of the project, when a high percentage of information input will have been generated.

Activity 1.2.4. Strengthen mechanisms to disseminate agroclimatic information and transfer capacities.

This component will massively disseminate recommendations based on agroclimatic forecasts. It first approaches the training process for all users and the dissemination of the tool through socialization events and mechanisms. It later works on the improvement of information content in the current diffusion mechanism (i.e., Agroclimatic Technical Work Groups – MTA), and finally strengthens the MTA system as an expansion mechanism of the scope of results, and users of tools developed within the Project.

SA1. Design and implementation of a training, dissemination and socialization program on the use, requirements and advantages of the use of agroclimatic platforms, oriented to Gremio technicians, other professionals, producers and other relevant stakeholders.

This program considers a variety of training options for different users, including workshops and courses for producers and technicians, as well as digital farms and adaptation hubs as strategy for demonstration sites and producer-producer knowledge transfer. All this process will be planned and coordinated with professionals of Result 3.2, who will guide the generation of material and content for the different users, validating the material before its use.

Stakeholders and agroclimatic data will also be mapped in order to identify groups or communities with limited access. Special communication systems and networks according to the users' conditions and requirements will be used. The digital farms and adaptation hubs strategically located will allow having permanent training centers, where producers will directly learn the use of such tools by other producers, using producer-producer knowledge transfer. Producer groups receiving, but not using agroclimatic bulletins will use engagement tools, through courses using platforms such as Moodle or blackboard SA2. This will enhance co-production, translation, transfer, and use of information mechanisms.

SA2. Strengthening of the mechanisms for co-production, translation, transfer and use of agroclimatic information in the existing Agroclimatic Technical Committees (MTAs).

In Colombia, under the MADR-CIAT pilot, the formal initiation of Agroclimatic Technical Work Groups (MTAs) is implemented as a strategy for diffusion of results and recommendations, and to make available all methods and tools developed in the pilot program for all stakeholders in the working regions. However, all MTAs have recognized the need to improve and strengthen the diffusion and support processes in the implementation of recommendations.

Therefore, this sub-activity aims at building a participative strategy among professionals of the different Gremios and stakeholders participating in the MTAs to define the most adequate mechanisms for the dissemination of information to the different users, according to areas or types of producers, working on the design of instruments and materials for the diffusion of information, and on learning mechanisms for the use of recommendations. The strategy shall include different participative mechanisms that ensure the proper participation of different types of users. Once the strategy is constructed, the implementation phase will follow. Intermediate meetings will be held with participating stakeholders in order to analyze progress made on the implementation and results found, with the purpose of revising the potential adjustments required.

SA3. Operation and creation of new Agroclimatic Technical Work Groups (MTAs)

Within the Colombian goals (formally denominated "National Determined Contributions" o NDCs) negotiated under Paris Agreement 2015 in the United Nations Framework Convention on Climate Change (UNFCCC), Colombia undertakes the creation of an MTA network with participation of 15 departments, and a million producers receiving agroclimatic information. Currently, the goal increased to 27 departments during the updating of the NDC. The goal of this cross-sectional activity is to strengthen MTAs, incorporating technical-scientific information generated by the project, in the best manner (i.e., agroclimatic models, digital agriculture) in the decision-making of technicians and farmers, improving the mechanisms of information translation and transfer (i.e., agroclimatic bulletins), improvements in the design of measures to reduce crop losses through agronomic recommendations to farmers, monitoring and evaluation of agroclimatic information scope, and finally, escalating of work groups to other intervention territories of the project through strategic alliances with Gremios, farmer Gremios, public sector institutions, academia, research centers, meteorological services, international cooperation institutions, among other stakeholders.

During the last ten (10) years, scientists of the Alliance Bioversity-CIAT, the CCAFS program and strategic partners have developed, tested and broadened an approach to evaluate, co-produce, translate and transfer climate information in Latin America in order to allow agricultural decisions being made: the Agroclimatic Technical Work Groups - MTA (Giraldo-Mendez et al., 2019; Loboguerrero et al., 2018). MTAs foster open and clear dialogue about climate change in multiple timeframes, and how this can affect crops, as well as the design of measures to reduce crop losses, particularly providing agronomic recommendations to farmers.

The manual developed by CCAFS-CIAT[60] will be used for the creation and operation of MTAs.

Activity 1.2.5. Other activities related to producing, transferring or using agroclimatic information (automation of meteorological information, analysis of climate change signals, nutrient balance models).

SA1. Use information generated by Cenicafé and new research to model the inputs and losses of nutrients in coffee production systems facing climate change.

Cenicafé's database on research and registration of coffee nutrients balance will be used to generate conceptual nutrition balance models and will develop equations to represent such balances. A sub-set of data will be left for validation and calibration of the equations and once the proper performance of equations is obtained, will follow the programming phase of a tool that is compatible with other coffee modeling processes of this project.

SA2. Analysis of historical climate data in the sugar cane stations network.

The sugar cane Gremio mentions the need to study climate change signs in the Cauca River valley, to produce information for mitigating the effects of climate change in the entire sugar cane industry value chain.

Identified variables will be analyzed to build climate indicators. Historic information will be analyzed in order to measure changes according to variables and variance. Analysis of results and identification of measures which will become relevant due to climate change trends.

SA3. Evaluation of water balance and fertilization modules of rice crops in order to broaden their application in decision-making and optimization of natural and agroindustry resources.

Based on sub-seasonal climate services, work will be done to develop and evaluate water and fertilization balances in order to provide a package of options to producers, in accordance with different climate conditions, considering those of greater relevance or frequency in the zone, but leaving open the possibility of modifications or new modules, according to occurring circumstances. Initially, a historic data and agronomic data analysis will be done. For this, we will use Big Data platforms that allow the integration and analysis of multiple variables and crop management according to specific climate conditions. This information will be the base to define modules to be implemented in the field, as per climate conditions existing and forecasted, making the necessary adjustments before going to the producers testing phase.

Component 2. Genetic improvement, crop management techniques and other technological options and their scaling-up to increase climate resilience and promote low-carbon agricultural development.

Result 2.1. Strengthened germplasm bank, new climate resilient varieties developed and their seeds massively distributed.

[60] https://ccafs.cgiar.org/es/resources/publications/mesas-tecnicas-agroclimaticas-mta-manual-de-implementacion

Activity 2.1.1. Develop a state-of-the-art phenotyping platform designed to identify low carbon production and climate-resistant genetic resources.

SA1. Install, calibrate and test growth chambers designed to simulate future climate conditions through the manipulation of lighting, temperature and relative humidity.

The necessary equipment will be purchased and installed to evaluate controlled conditions that simulate environments resulting from climate change: water deficit, low nitrogen, and water loggings. Elite promissory genetic material will be multiplied through these types of stress. The multiplication technique will be according to the type of stress to be evaluated (i.e., in vitro, nitrogen stress evaluations; multiplication of buds for excess or deficit of water resources).

Evaluations under controlled conditions will be carried out for each of the stress types (lack of water and nitrogen, and excess water). The already established evaluation protocols and experimental designs will be used under controlled conditions for each crop. Outstanding materials will be selected from different types of stress and the seed will be reproduced to establish field validation tests.

SA2. Install and test the field equipment that admits capturing images and sensors' data.

Field validation tests will be established in areas with clear problems with the identified stress types. Evaluation protocols and experimental designs already established will be followed for field validation tests for each crop. Strict control and follow-up of plots will be followed to measure material behavior under field conditions, taking data and samples to make lab tests and the corresponding evaluations. The agronomic management of plots will be under the supervision of Gremio technicians to guarantee management according to usual management conditions for each location. The main variables previously identified as important by technicians and producers from each zone will be followed-up.

Equipment will be purchased and installed to follow-up the different crop variables in order to validate Big Data analysis results through images and sensors.

At this moment the materials with better performance in each area will be selected, in terms of tolerance or resistance to the evaluated stress factor, but also with respect to variables of interest (i.e., yield, quality, etc.), of each zone's technicians and producers.

SA3. Calibrate and test cameras and sensors to quantify the impact of abiotic stress over photosynthesis.

Before starting records that allow the determination of impact of different threats over production yield, it is necessary to purchase, install and calibrate the equipment to be used. Once their proper operation is tested and the validity of records is confirmed, the following phase of data registration and evaluation may be performed. This part is extremely important considering it determines the potential impact of different stress factors (water excess or deficit) over different genetic material. This will be the basis to determine the most promissory genetic material with greater potential to adapt to climate phenomena. It is necessary to clarify that these evaluations are made taking into consideration the analysis of the most limiting climate factors by zone and by crop.

SA4. Sequencing of parental genetic material

This sub-activity will include a combination of phenotype and genotype data to select individuals adapted to climate change conditions. Evaluation of elite parental materials that has been previously satisfactorily multiplied within water deficit/access or low nitrogen conditions.

SA5. Application of a genomic selection model

The first step is giving training on genomic selection models, which is done using phenotype information of each parental response in relation to water excess/deficit and low nitrogen conditions, collected in the previous sub-activities. The first analysis will help to identify genotypes with efficient use of nitrogen and water. After, the seed of promissory individuals is multiplied, collecting samples to extract DNA, following the established protocols, and finally make the genome sequencing. It is important to have in mind the storage and analysis capacity required to manage all information generated.

Activity 2.1.2. Identify heat, drought and excess water tolerant accessions for rice, maize, potatoes, musaceae, and livestock (forages).

SA1. Detection of physiological traits using phenotype platform established in Activity 2.1.1

Information shall be analyzed to detect which are the genetic material physiological traits that allow a better adaptation to certain climate stress conditions. Information generated in the previous activity is used to structure plant adaptation mechanisms hypotheses which are later registered and evaluated in tests under controlled conditions.

SA2. DNA sequencing to identify genome regions that control evaluated traits.

Sequencing will also be made to the most promising material progeny. The sequencing will be made following strict protocols already established for this type of activity. The information will also serve for the genomic selection model.

SA3. Identification of characteristics to increase crop resiliency

All information generated by the previous steps will be used and analyzed to better describe the genetic material characteristics that increase adaptation to different climate factors. This information will be the fundamental basis to save time and resources when obtaining resilient material. This information will be fundamentally shared through publications, seminars and congresses that allow world-wide researchers to enhance and guide their improvement processes on climate change resiliency.

Material characterization will be complemented with all information resulting from evaluations under controlled and semi-controlled conditions. It is important to understand inheritance mechanisms of characteristics that increase tolerance to different stress conditions. This information will be decisive to make and optimize material crossing and selection processes.

SA4. Selection and evaluation of controlled conditions in case of water deficit, low nitrogen and water loggings of elite parentals.

Genetic material with higher potential of facing climate challenges will receive different tests, initially by multiplication of promissory material, and then taking the material to different facilities assembled in order to evaluate high temperatures, high CO2 concentrations, water deficit, logging and low radiation. According to material to be evaluated and evaluation method to be used, the seed reproduction method will be selected to guarantee material quality for each crop, as well as the type of stress to be evaluated, and that the evaluation method has all the corresponding protocols of experimental designs, management and procedure to collect and register the information.

Evaluation of lines and varieties with high CO2 concentration on the field with Face system and under controlled conditions in greenhouses or special chambers to perform this work. Evaluate consequences of abiotic stress in the production yield and other relevant variables for crops (i.e., variables related to pests, diseases and quality). For tolerance of high nighttime temperature under controlled (growth chamber of the Alliance Bioversity-CIAT) and semi-controlled conditions (Four season greenhouse of the Alliance Bioversity-CIAT) and during different experimental stations of the Gremios; otherwise, in farms having the necessary infrastructure and conditions to make evaluations of commercial lots and that are commonly used for this purpose, following all established protocols. Infrastructure under controlled conditions will also be used for low radiation, (growth chamber of the Alliance Bioversity-CIAT), and some semi-controlled conditions in different experimental fields. To analyze water stress, we will use the infrastructure under controlled conditions for water stress (greenhouse with protection against precipitation and humidity control, Rainout-shelter of the Alliance Bioversity-CIAT).

Activity 2.1.3. Development of new varieties based on advanced[61] lines for climate change adaptation and mitigation for rice, maize, livestock, banana (varieties that are tolerant or resistant to water deficit and diseases that demand high use of chemical fungicides, such as black Sigatoka) and sugarcane (water deficit, waterlogging and greater efficiency in nitrogen use).

While performing the previous materials characterization, this will be of great assistance for future technological developments, and can even be considered and included in the development process of new varieties within this project, according to information and timeframes generated[62]. Parallel to this process, we will continue advancing on the development of new varieties based on advanced lines available when the project starts.

SA1. Establishment of experimental plots for the evaluation and selection of materials.

Plots will be established under controlled conditions to evaluate materials under different types of stress (related to climate)

SA2. Characterization and selection of lines, hybrids or varieties with tolerance to high night temperatures, low radiation and high CO2 concentrations

[61] With regards to the development of new varieties, this project strives to generate the highest impact possible. In this case, considering the extense periods of time required to develop a new variety, it was decided to work with the available advanced lines so that at the end of the five (5) years of the project, being able to have materials (varieties or hybrids) adopted in the field by the producers. Advanced lines are the genetic material resulting from previous years of research that demonstrate certain desirable characteristics for the development of new varieties.

[62] Regardless of the fact that rsults of the genetic material characterization results cannot be used in this project due to time schedules, it will practically be used as soon as it is available, since the Gremios will be the main users and they are anxious to get this information and knowledge to immediately put it at the service and application of the new variaties development process. This means there have been plans made with Gremios so as soon as the information is available, it will be used by their researchers.

SA1 plots will be monitored and evaluated in order to identify the materials with the greatest potential for tolerance to different types of stress.

SA3. New crosses with promising lines

Crosses of cultivated varieties will be made with the new promising materials in order to transfer the desired characteristics to the characteristics already achieved in the cultivated materials and to develop new materials that comply with the characteristics of the market and incorporate the new characteristics of tolerance to the different types. stress (associated with climatic variables).

SA4. Validation and performance evaluation of materials developed in other countries but that have not been tested in Colombia

The performance in Colombia of promising banana materials developed in other latitudes will be evaluated.

SA5. Selection of lines with better performance

Advanced lines will be subject to different climate stress conditions identified for each of the zones and crops. Many of these materials will be evaluated under controlled conditions, later reproducing the seed of promissory materials, to then make the decentralized evaluation of each zone under semi-controlled conditions, and afterwards evaluating lots in the data bases of Gremios or producers' farms. All these evaluations already have the respective protocols for seed multiplication, equipment installations, implementation of plots and crop management, data collection and registration. In this case, it is important to consider the different locations and climate threats approached in the project, and therefore, the dimension of this sub-activity.

SA6. Evaluation of greenhouse gas emissions of different genetic material

In this project, most of the genetic improvement process will be oriented to adaptation. However, it is necessary to evaluate the potential mitigation of genetic material. Work is initially oriented towards materials that have been evaluated with regards to adaptation, identifying if some of these materials may have a benefit with regards to lower emissions, or even discard materials which may have elevated levels of gas emissions. Another item to evaluate is whether materials with high mitigation potential are identified, and in such case, this relevant information shall be included and considered in long-term improvement processes to achieve desired characteristics in the future advanced lines.

SA7. Materials registration process and release of new materials

Best materials identified will go through field evaluation processes and will then be registered before competent authorities, so the new varieties are later launched and released.

Activity 2.1.4. Massive seed multiplication for coffee, sugarcane, panela sugarcane, potato, banana and plantain through in vitro culture or the buds method for distribution to farmers.

Technology adoption processes are slow in principle and for that reason, many Producers do not want to the be pioneers in sowing and putting their investments at risk; something which in case of failure for different reasons[63], could cause their bankruptcy. For that reason, the project includes an important multiplication component, delivering seeds and providing technical support to Producers in an initial delivery with massive implementation, to help accelerate the adoption process, and to serve as training center for thousands of Producers which will become adopters or indirect beneficiaries of the Project. The latter will have to cover costs to implement technology and cover the corresponding advisory work. The selection of direct beneficiaries will be crucial, taking into consideration the locations in order to have good area distribution and coverage. It will also consider vulnerability conditions of Producer families, giving priority to more vulnerable families and differentiating users to identify beneficiaries of varieties and hybrids[64]. A fundamental aspect is the history of Producers in the management of new technologies since those having a good record of the introduction of new technology will initially be selected, since those Producers will be a reference in their regions and a role model to be followed by other Producers.

Seed quality is fundamental for all crops and therefore, all protocols will be followed to ensure highest purity of materials delivered to Producers. Some crops will require additional processes to reach such purity, or because they have considerably high risk of acquiring certain diseases.

SA1. Establishment of a thermotherapy protocol

A thermotherapy camera will be used at a defined temperature, with a photoperiod and permanence time according to the crop. Once the thermotherapy process is concluded, the plants are trimmed and the foliage is eliminated, conserving the stems. These stems are taken to the in vitro culture laboratory.

SA2. Cleaning by cryo-conservation

Material will be cleaned through a cryo-conservation technique, in this case focused on potato crops. Technological advances reached until now by Alliance Bioversity-CIAT and Agrosavia will Protocols established will be followed.

SA3. Material multiplication

Multiplication using the individual bud extraction system. This multiplication system consists on cutting or extracting individual buds from stems cultivated in clean seedbeds, previously diagnosed for systemic diseases (LSD, RSD, SCYLV), and with an age range between 7 and 9 months. With this system, plants are delivered and ready in 90 days. To establish seedbeds to multiply the varieties using the individual bud system, we follow common tasks following in the management of sugar cane commercial lots. For the production of plants, complete stems of variety to be multiplied are cut (10-15 buds per stem) in the selected lot. It is estimated that in order to produce plants for a hectare of land (8,500 to 9,000 plants) approximately 1,000 stems are needed, which is equivalent to two (2) tons of sugar cane. The extracted buds receive thermal treatment before being sown, in order to eliminate bacterial diseases such as leaf scald and ratoon

[63] Not related to technology perfomance which was previously sufficiently evaluated and validated, passing field testing processes in the registration of material, but that can occur due to poor technology implementation and management and for not following the established protocols. In many occasions the Producers adopt a new technology and continue using the old technological package, generating terrible results. An example of that is the change of variety from hybrids in rice crops, going from using approximately 200 kgs of seed, to 20 kgs. In this case, the sowing system, weed management and fertilization plan radically changes, so not applying such changes results in a technological failure.

[64] This is of great importance because some Producers do not have sufficient resources to purchase seeds and inputs demanded by hybrid materials, and in varieties it shall be considered that materials will be develioped with different requirements of inputs, taking into consideration the seed users.

stunting, eliminate residual pest eggs and larvae which may be present. After germination of the buds, the transplantation and maintenance processes take place.

Plant in vitro multiplication of sugar cane starts by cleaning the buds of each sugar cane stem. In this multiplication process, individual buds from the stems are cleaned with soap and used. These buds receive a hot water treatment and are sown in Styrofoam cups with the soil being previously pasteurized. Temporary immersion systems such as RITA® and SIT bioreactors are used.

It is expected to have a cloning, escalation and hardening protocol for coffee hybrids with differentiated response to climate and broca, using the somatic embryogenesis technique in bioreactors and a solid crop system. The development of these hybrids will represent an important help for farmers where due to climate condition of their farms, broca negatively affects their crops, but additionally, although this technology has been used in other coffee-growing countries of Central America and Brazil, it has not been evaluated in Colombia, precisely due to the limitations in the production of plants that are not able to be reproduced with seeds. Due to the above-mentioned benefits of these materials, it is convenient that coffee-growers of Colombia start using other coffee propagation sources, which like in the case of these materials, could be considered as having excellent characteristics.

The first step is to determine the type of explants having greater embryogenic tissue induction capacity (TE) and non-embryogenic callus (CNE), as well as disinfection conditions. The basal media and growth regulator (type, dosage, and combination among growth regulating groups - RC) are then determined vs. the frequency of CE and CNE. Next is the determination of growth conditions (temperature, photoperiod, type of lighting and light quality) by stages, and the determination of embryo (E) conversion to plant (P). Histologic analyses of ES regeneration in coffee hybrids are finally made.

In the escalation protocol using bioreactors for the cloning of hybrids, the steps are the following: 1) Implementation of RITA and MATIS bioreactors in the clonal escalation of three (3) coffee hybrids. 2) determination of the type, concentration and relation of RC in the liquid culture media, immersion frequency, and management of the bioreactor type. 3) Adjustment of embryo to seedlings conversion in RITA and MATIS-type bioreactors. 4) Comparison of small-scale conversion efficiency in liquid-solid systems vs. Bioreactors. y el ajuste de las condiciones de conversión Embriones a Plántulas en biorreactores tipo RITA y MATIS.

The hardening and transference protocol to ex vitro conditions with differential response to climate and broca uses the ES technique in solid cultivation. The first step consists of adjusting times and desiccation to induce maturity and conversion of somatic embryos in three (3) coffee hybrids. Then, the nursery conditions to harden in-vitro material coming from a solid system and bioreactors system is determined to define the substrate type and quality, the type of container, humidity percentage and irrigation frequency, type and frequency of fertilization in the hardening phase of three (3) coffee hybrids, with potential differential response to climate and broca. Finally, the efficiency rate in the hardening phase and transplantation of three (3) cloned coffee hybrids is determined (for solid system and system).

Finally, the determination of broca tolerance of new hybrids and the determination of these plants' agronomic characteristics takes place. This requires the collection of seeds, elaboration of artificial diets, and assembling of field seeds and plants with artificial broca infestations. The broca population and mortality rates of broca in the hybrids are evaluated, as well as the agronomic characteristics of the material.

In potato crops, the optimization of the production of pre-basic seeds in Phase I (minitubers) is made by determining fertilization by variety groups, establishing the methodology to program the sprouting of minituber seeds in storage, performing the field evaluation of storing methods. An economic analysis is then made by comparing the traditional system vs. This technology, in order to compare their benefits. Work is then made with Producers to train their organizations in the production of good quality seeds in learning plots, accompanied by organizational, financial, and market strengthening. It is important to support this with an awareness program on the use of good quality seeds.

In the case of “panela” sugar cane, the project will identify materials with good performance in case of climate events, purifying the variety using in vitro techniques to guarantee sanitation of material to be sown in basic seedbeds for the production of seedlings. Plant material (seedlings) will be delivered to nursery managers to establish commercial seedbeds, making agronomic and sanitation follow-up to basic and commercial seedbeds established.

A material conservation and production program will be implemented for flocculant and binding species. In this case, sexual and asexual seeds of the flocculant materials are in the production zone(s) to be intervened, implementing a species production system in nurseries and increasing the population of flocculant species in the “panela” manufacturing areas. A proposal is presented for an inclusive business/production chain for the generation and offer of these flocculant and/or raw material/bark species’ sowing material.

SA4. Detection of viruses, diseases

Some material may have serious virus-related problems. Therefore, an additional test will be made in order to guarantee that delivered seeds are in optimal condition, not representing any risk for the material’s performance. With this procedure, and crop management support given to the Producer, the goal is to reduce to the maximum any type of risk associated to the presence of crop viruses.

SA5. Implementation of the in-vitro technique of Somatic Embryogenesis (SE).

Obtain the Cloning Protocol for coffee hybrids with differential response to climate and CBB using the somatic embryogenesis technique in a solid culture system, as follows: i) determination of the type of explants with a greater capacity to induce embryogenic tissue (TE) and non-embryogenic callus (CNE) and disinfection conditions, ii) determination of basal mean and growth regulator (type, dose and combination between groups of growth regulators RC) VS. CE & CNE frequency, iii) determination of growth conditions (temperature, photoperiod, lighting type and quality of light) by stage, iv) determine embryo (E) to plant (P) conversion conditions, and v) histological analysis of the ES regeneration pathway in coffee hybrids.

SA6. Implement the use of bioreactors for scaling up

In the escalation protocol using bioreactors for the cloning of hybrids, the steps are the following: 1) Implementation of RITA and MATIS bioreactors in the clonal escalation of three (3) coffee hybrids. 2) determination of the type, concentration and relation of RC in the liquid culture media, immersion frequency, and management of the bioreactor type. 3) Adjustment of embryo to seedlings conversion in RITA and MATIS-type bioreactors. 4) Comparison of small-scale conversion efficiency in liquid-solid systems vs. Bioreactors. y el ajuste de las condiciones de conversión Embriones a Plántulas en biorreactores tipo RITA y MATIS.

<u>Result 2.2. More efficient use of water resources, restoring soil properties, and improving GHG mitigation practices by farmers and gremios through the adoption of new climate smart practices and technologies.</u>

Activity 2.2.1. Quantifying the baseline water footprint in six (6) crops (potato, sugarcane, panela sugarcane bananas, plantains, and livestock) and in the industrial phase of sugar production.

SA1. Definition and/or installation of crop lots to perform measurements

An important step is to define what and where measurements will take place. This is a fundamental decision because it defines the reference systems in relation to water management. It is not an easy task because it includes multiple variables that impact crop water consumption (varieties, location, climate change, management, etc.). Measurements will be made in areas with greater problems in terms of water availability, as per crops risk analysis. For this reason, the number of zones varies by crop.

The first task is to analyze predominant production information available in each zone and after a series of meetings with experts on the crop and the efficient use of water, who participate in the project, deciding over systems to be used as reference to measure the baseline. In cattle-farming areas, measurements will be made in three (3) sites, while in potato and "panela" sugar cane crops, measurements will be made in four (4) sites each, and for musaceae, in eight (8) sites.

After comes the definition of lots to be used as reference in each measurement zone and negotiation with Producers to obtain installation permits and the entire data collection and registration procedures. An agreement shall be subscribed with the Producer in order to establish the crop management protocol, as well as an authorization for the use of data obtained.

Once the sites are identified, the characterization of work areas shall be done, including climate, soils, gradients and other variables of interest.

SA2. Equipment purchase, installation and calibration

The necessary measuring equipment will be purchased and installed for making the respective calibrations of such equipment, in order to guarantee their proper operation. In the pilot project MADR-CIAT, measurement equipment was identified, generating protocols for their installation and calibration. Equipment required includes flow measuring equipment, humidity sensors, and lysimeters, considering there is a close-by meteorological station, or failing this, the installation of basic equipment for measurement of climate variables.

SA3. Collection and registration of data and other variables of interest

Data collected and registered during the entire crop cycle is taken from the equipment, including other variables such as management and some behavior variables, costs and production yield. Protocols for collecting and registering data from the different irrigation systems were established in the MADR-CIAT pilot program.

Samples for water quality will be taken at water inlets and outlets in order to measure grey water footprint.

SA4. Measurement of water consumption for different technologies and crop management techniques of prioritized crops in the Project.

To keep an adequate registration and measurement of water consumption, a flow diagram of the productive system is developed, registering each of the crop's stages, from the pre-sowing stage, until its harvest. The times to make measurements and register information of each variable are clearly defined for each of these stages. Once measurement equipment is installed, records are kept as established in the flow diagram.

SA 5. Collection of complementary data

To measure water consumption and quality, as well as measuring water footprints, it is necessary to define the system's limits in which the footprint will be measured, which in our case is Product (in reference to an agricultural product at the farm entrance), and in some cases, industrial processes (sugar cane).

The necessary complementary information will be collected to make calculation of green, blue and grey water footprint.

SA6. Measurement of water footprint for different production model crops.

Green, blue and grey water footprint will be measured using Water Se Footprint Network WFN methodology, promoted by Twente University, from The Netherlands.

Activity 2.2.2. Quantifying the baseline carbon footprint for seven (7) crops (rice, potato, sugarcane, panela cane, bananas, plantain, and livestock), fertilizer use and industrial processing in sugarcane cultivation.

SA1. Definition and/or installation of crop lots for measurements

An important step is the definition of what is going to be measured, and where. This is a fundamental decision since this defines the reference systems to be used in terms of greenhouse gas emissions (GEI for its acronym in Spanish) and the capture of carbon. This is not an easy task because there are multiple variables that have incidence in the generation of emissions and the capture of carbon (soil, climate change, management, etc.). Measurements will be made in the main productive areas of each crop, and where the project will be present for water footprint measurements, as well as other components in order to optimize displacement resources and other expenses.

The representative production systems identified for the measurement of water footprint will be used, working on the same lots to reduce operating costs. In cattle-farming, measurements will be taken in three (3) sites, for potato and "panela" sugar cane in four (4) sites each, and for musaceae in eight (8) sites.

Characterization of work areas resulting from the water footprint measurement point will guarantee having all variables of interest included, as well as the risk mitigation process.

SA2. Purchase, installation and calibration of equipment to measure Greenhouse Gas Emissions (GHG).

All necessary measurement equipment will be purchased, installed and calibrated to guarantee their proper operation. The protocols for the installation of equipment for the measurement of Greenhouse Gas Emission and carbon capture will be revised and adjusted in accordance with the MADR-CIAT pilot since variables are required, according to crops being analyzed. It is important to consider equipment needs, depending on the crops. Once protocols are ready, the installation and calibration of equipment will follow.

SA3. Data collection and registration of GHG and other variables of interest.

A flow diagram will determine sample taking times. Materials needed to collect and transport samples to laboratories, guaranteeing their quality is maintained, will be purchased. Once samples arrive in the laboratories, their gas chromatography processes will be performed. This equipment will be strategically distributed, according to crops and working areas, Gremio facilities, the Alliance Bioversity-CIAT and the different Agrosavia venues.

SA4. Quantification of GHG for different genetic materials, technologies, and management of crops prioritized by the project

Once lab results are obtained, emission levels of different systems and work areas will be calculated. This information will be revised along with IDEAM personnel who are in charge of generating GHG inventories for Colombia, in order to include these emission factors within the gas emission calculation for the country. Results will be published and may be very useful, being used as reference by other countries in the region, or even other countries all over the world.

SA5. Collection of complementary data

To calculate carbon footprint, as in the case of water footprint, it is necessary to establish the analysis unit to be used, which in our case is the same unit used to calculate the water footprint. For this purpose, information collected in the water footprint collection will be used, making sure to have included all variables required to calculate the carbon footprint. As a matter fact, it is only a procedure since the required information for calculating both footprints is revised for both calculation processes, establishing a single form and procedure to collect information.

SA6. Quantification of carbon footprint for different crops, under various production models.

Calculation of carbon footprint will follow the methodology structure in standards ISO 14040 y 14044 (ISO, 2006a, b), which are based on four (4) stages, or working steps: 1) Objective and scope; 2) Life cycle inventory; 3) Impact assessment, and 4) Interpretation of the life cycle. As in the case of the water footprint, the analysis will be made until the point where the main Product generated is sold at the farm; this is to say, “from the cradle to the gate of the farm”, as this type of scope is traditionally denominated in agribusiness systems.

Activity 2.2.3. Water basins modeling to determine water harvesting sites

SA1. Mapping of spatial and hydroclimatic information in the water basin.

Information on the water basin's biophysical data is searched, including data distributed at spatial level in the water basin, searching for the major spatial and temporal resolution of the information (maximum and minimum temperatures, precipitation, solar radiation, relative humidity, and wind speed), of soils (texture, hydrologic group, depth, apparent density, etc.), vegetation coverage and management practices, as well as a recent base map that allows verifications during the process (DEM – Digital Elevation Map, use of soils, vegetation coverage, water networks, basins, protected zones, etc.). Initially map information will be projected in the system of reference denominated MAGNA Colombia which is the most adjusted one, and in the event soil and coverage data is broken down by departments (as IGAC usually does), a partnership will be initiated before doing the coding and characterization processes.

With respect to hydrometeorological information, once stations having a satisfactory number of good quality data and continuous information on precipitation and temperature are selected, the missing data will be filled out using the most appropriate methodology. In some cases, it is recommended to use satellite information, such as climatologic database denominated CHIRPS for its acronym in English - "The Climate hazard infrared precipitation with stations". This type of information has already been interpolated for Colombia and satisfactorily represents the behavior of daily precipitation in a large part of the territory. Additionally, it is necessary to prepare the registration of water flow in the selected stations, were it is expected to have a comprehensive record that matches the period selected for precipitation and temperature data.

SA2. Construction and validation of the hydrological model and generation of scenarios of changes of coverage and weather forecasts.

A sensitivity analysis, calibration and validation of the hydrological model will be performed with the SWAT model. After the calibration and validation of the model, the initial or baseline modelling will take place in order to know the HRU water balance, as well as the water contribution represented by the main affluent, which will be translated in the reference water flow. Reference scenarios are generated, both for changes in coverage, as well as in the climate scenario to see flow responses. Special attention will be paid to water intake sites in irrigation districts, but also in the water balance of particular areas of interest, due to water deficit problems previously identified in crop risk analyses. An additional exercise will be executed to identify specific points or parts inside the sub-basins in order to analyze water needs of the crops, as well as water storage needs during specific times of the year.

SA3. Mapping, identification and validation of water harvesting points

The above-mentioned analysis will be fundamental to determine sites necessary to measure water harvesting required by Producers, as well as calculation of such needs.

SA4. Generation of water conveyance routes

With information provided by Producers on water requirements and the identified water harvesting sites, the water conveyance optimal routes are established.

SA5. Construction of water reservoirs (for "panela" sugar cane, plantain, and coffee crops).

The first step necessary is to subscribe written agreements with Producers in order to define conditions under which water reservoirs will be established, document installation permits and future commitments of the Project and Producers, as well as processing permits required for water conveyance. Once permits are obtained, the detailed design of reservoirs and water pipeline systems are made, continuing with the administrative phase to obtain the required environmental permits. Once these procedures are completed, water reservoirs and pipelines will be constructed.

SA6. Training workshops for Gremio professionals.

It is important that the entire process methodology is properly registered and documented, but especially that Gremio professionals are duly trained to replicate such methodology in other working areas. Therefore, workshops to reinforce tool knowledge and management are planned, since such professionals will be involved during the entire process. The main goal of these workshops is to reinforce the weakest areas, especially to apply the methodology in other practical cases in areas having the same problems, which are managed by the Gremio professionals.

SA7. Efficient water usage planning at irrigation districts

Results of hydrological modeling at basin level will emphasize their use for planning of Producers water supply by the irrigation districts. Work will be done with professionals managing the irrigation systems, so they know the entire modeling procedure and become familiar with the analysis and results, but especially so they support the result validation process. Once models demonstrate good performance and the irrigation district managers approve it, planning exercises will be carried out to validate their implementation. The process will be supported during the project's life cycle to guarantee its proper operation and an eventual adjustment and calibration, according to the circumstances.

Training of professionals managing the irrigation districts will be emphasized until they dominate the use of tools, guaranteeing their future use. IT and operational knowledge of entities managing the irrigation districts will be considered, leaving operation manuals to cover potential gaps occurring with personnel changes in the institutions. Installed capacity will also be left within the Gremios of interest (participating in district work) in order to leave a support copy and capacity to train new personnel.

Activity 2.2.4. Evaluation of efficient water use practices in the agronomic management and transformation processes (e.g., milling of panela cane) in potato, panela cane, plantain, banana, coffee crops and livestock.

SA1. Identifying and formulating agronomic management practices and industrial transformation.

One of the most important steps in the efficient use of water within the project will be the identification of the most competitive technologies for Producers, requiring low water consumption. This decision is fundamental since it defines systems to promote water consumption reduction in crops, and efficiently use water to increase crop resiliency. As with the baseline, measurements will be taken in areas with more water availability problems, according to crop risk analyses. That is why the number of areas will vary according to the crop. The first work will be to analyze available information in each zone with respect to new technologies implemented by some Producers, which may have a great potential to reduce water usage. This will be one (1) of the discussions to be held with strict caution and consulting a great number of expert people on crops and efficient water management. At the end, the most promissory technologies will be selected, considering other relevant variables for the Producers (investment, maintenance costs, quality, etc.).

SA2. Selecting and implementing conventional productive plots with efficient use practices.

Lots to be used as reference in each area where measurements will be taken are defined and negotiations with Producers are made to obtain installation permits, as well as authorization to collect and register data. An agreement shall be subscribed with the Producer in order to have authorization to use collected data. Once such sites are identified, the characterization of working areas shall be made, including climate and soils, gradients and other variables of interest, in coordination with baseline characterization work.

SA3. Installing equipment to monitor moisture balance.

The initial step will be to purchase all equipment necessary for taking measurements. The respective installations and calibrations will follow, in order to guarantee their adequate operation. The MADR-CIAT pilot project already identified the types of equipment for measurements and generated the protocols for the installation and calibration of such equipment. Equipment required includes flow measuring equipment, humidity sensors, and lysimeters, considering there is a close-by meteorological station, or failing this, the installation of basic equipment for measurement of climate variables.

SA4. Creating moisture balance and monitoring water quality.

Data collected and registered during the entire crop cycle is taken from the equipment, including other variables such as management and some behavior variables, costs and production yield. Protocols for collecting and registering data from the different irrigation systems were already established in the MADR-CIAT pilot. Samples for water quality will be taken at water inlets and outlets in order to measure grey water footprint.

The collected water information will be used to calculate water balances in crops.

SA4. Measurement of water consumption for different technologies and crop management techniques of prioritized crops in the Project.

To keep an adequate registration and measurement of water consumption, a flow diagram of the productive system is developed, registering each of the crop's stages, from the pre-sowing stage, until its harvest. The times to make measurements and register information of each variable are clearly defined for each of these stages. Once measurement equipment is installed, records are kept as established in the flow diagram.

SA5. Quantifying the water footprint in conventional systems and efficient water use practices.

To measure water consumption and quality, as well as measuring water footprints, it is necessary to define the system's limits in which the footprint will be measured, which in our case is Product (in reference to an agricultural product at the farm entrance), and in some cases, industrial processes (sugar cane).

The necessary complementary information will be collected to make calculation of green, blue and grey water footprint.

SA6. Training workshops on monitoring and managing efficient water use systems.

Meetings will be held with different stakeholders to share the results of the measurements of the water requirements and the water footprint of different technologies to disseminate the benefits of the different technologies.

Activity 2.2.5. Evaluation of GHG emission mitigation practices in agronomic management and transformation processes in rice, maize, potato, panela cane, plantain, banana, coffee, sugarcane crops, and livestock.

SA1. Definition and/or installation of crop lots to make measurements

One of the most important steps in the mitigation work within the project will be the identification of the most competitive technologies for Producers having a high mitigation potential. This decision is fundamental since it defines systems to promote the reduction of greenhouse gas emissions or the capture of carbon. Measurements will be taken in the same areas where water metrics are taken, but probably in different farms. The first work will be to analyze available data in each zone with respect to new technologies implemented by some Producers, which may have a great potential to reduce greenhouse gas emissions or capturing carbon. This will be one (1) of the discussions to be held with strict caution and consulting a great number of expert people on crops and mitigation. At the end, the most promissory technologies will be selected, considering other relevant variables for the Producers (investment, maintenance costs, quality, etc.).

Lots to be used as reference in each area where measurements will be taken are defined and negotiations with Producers are made to obtain installation permits, as well as authorization to collect and register data. An agreement shall be subscribed with the Producer in order to have authorization to use collected data. Once such sites are identified, the characterization of working areas shall be made, including climate and soils, gradients and other variables of interest, in coordination with baseline characterization work.

SA2. Purchase, installation and calibration of GHG gauging equipment

The necessary gauging equipment will be purchased and installed for making the respective measurements. Equipment will be installed and the corresponding calibration of equipment will be done in order to guarantee their proper operation. The protocol for the installation and calibration of GHG gauging equipment generated in the MADR-CIAT pilot project will be revised and adjusted, since variables according to crops to be used, are required. It is important to consider equipment needs, depending on the crops. Once protocols are ready, the installation and calibration of equipment will follow.

SA3. Data collection and registration of GHG and other variables of interest.

A flow diagram will determine sample taking times. Materials needed to collect and transport samples to laboratories, guaranteeing their quality is maintained, will be purchased. Once samples arrive in the laboratories, their gas chromatography processes will be performed. This equipment will be strategically distributed, according to crops and working areas, Gremio facilities, the Alliance Bioversity-CIAT and the different Agrosavia venues, taking into consideration carbon footprint baseline measurements.

SA4. Quantification of GHG for different genetic materials, technologies, and management of crops prioritized by the project

Once lab results are obtained, emission levels of different systems and work areas will be calculated. This information will be revised along with IDEAM personnel who are in charge of generating GHG inventories for Colombia, in order to include these emission factors within the gas emission calculation for the country. This task is more difficult than baseline work, since statistical registration mechanisms for the implementation of new technologies for indirect beneficiaries of the project will have to be revised. Results will be published and may be very useful, being used as reference by other countries in the region, or even other countries all over the world.

SA5. Collection of complementary data

To calculate carbon footprint, as in the case of water footprint, it is necessary to establish the analysis unit to be used, which in our case is the same unit used to calculate the water footprint. For this purpose, information collected in the water footprint collection will be used, making sure to have included all variables required to calculate the carbon footprint. As a matter fact, it is only a procedure since the required information for calculating both footprints is revised for both calculation processes, establishing a single form and procedure to collect information. However, measurements of both water and carbon footprints will be taken for all lots.

SA6. Quantification of carbon footprint for different crops, under various production models.

Calculation of carbon footprint will follow the methodology structure in standards ISO 14040 y 14044 (ISO, 2006a, b), which are based on four (4) stages, or working steps: 1) Objective and scope; 2) Life cycle inventory; 3) Impact assessment, and 4) Interpretation of the life cycle. As in the case of the water footprint, the analysis will be made until the point where the main Product generated is sold at the farm; this is to say, "from the cradle to the gate of the farm", as this type of scope is traditionally denominated in agribusiness systems.

Activity 2.2.6. Landscape restoration in sugarcane cultivation and livestock systems

SA1. Identification of potential intervention areas and landscape units

A landscape scale analysis will be performed within prioritized areas to identify sites demanding greater intervention by the Project. The aim is to generate the highest positive impact possible. Summons will be made through Gremios, local institutions, and community leaders so interested Producers may be candidates to participate in the program. One of the first selection criteria will be their location with respect to the previously mentioned zones, as well as other criteria, such as family vulnerability conditions, income, and plot sizes. Once the list of interested Producers is ready, they shall present the required documentation to ensure compliance with the previous and MADR requirements (to be in an adequate area for the crop according to UPRA maps, having land ownership support documentation, not appearing in lists of people having legal problems with the Colombian Government, etc.). This Project designates an official per site in order to support the most vulnerable Producers to obtain the required documentation. If high priority Producers do not comply with the above-mentioned requirements, Producers following in the list will start being considered.

SA2. Implementation of nursery for dissemination of native species

The most favorable sites to install native species dissemination nurseries shall be identified, considering their location, access roads, costs and previous experiences. An inventory of the amount, type and timing required for obtaining the required material will be made, with a production schedule with an additional 10% margin to cover any contingency. Nursery personnel is trained and agreements are subscribed with land owners for the installation of a temporary infrastructure to install the nurseries. Seeds are purchased and/or collected, according to species flowering calendar. Material dispatch planning and delivery is made.

SA3. Coverage mapping

With the zoning information, selected farms and information on species to work with per farm, two (2) maps will be made; one (1) with the initial situation, and another one with the expected situation after the Project's intervention. This last map includes a prospective analysis of what is expected after the life cycle of the Project is concluded. These maps will be used as reference for the project assessment process.

SA4. Implementation

Once the farms to be intervened are selected, farm plans are made in accordance with the Producer. Once the intervention agreement is subscribed, a work plan indicating intervention times, and the required inputs and labor is made, clearly establishing the Project's contribution and the Producer's responsibilities. Secondly, an agreement minute is subscribed with the Producer, including the above-mentioned information, to initiate the implementation process.

Activity 2.2.7. Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development in rice, maize, potato, sugarcane, plantain, banana, and livestock production.

SA1. Selection of farms and beneficiary lots

Summons will be made through Gremios, local institutions, and community leaders so interested Producers may be candidates to participate in the program. Within potential candidates, the families that are most vulnerable, having low income and small plots, will be identified. Once the list of interested Producers is ready, they shall present the required documentation to ensure compliance with the previous and MADR requirements (to be in an adequate area for the crop according to UPRA maps, having land ownership support documentation, not appearing in lists of people having legal problems with the Colombian Government, etc.). This Project designates an official per site in order to support the most vulnerable Producers to obtain the required documentation. If high priority Producers do not comply with the above-mentioned requirements, Producers following in the list will start being considered.

SA2. Producer Training

Selected Producers will be initially trained to be aware of the implications of new technologies, in terms of investment, costs, expected yields, but especially in relation to crop management implications. This is important for Producers to identify changes to be implemented in crop management and to confirm Producers' interest in the technology, ensuring they have sufficient information to decide on making such technological changes.

SA3. Implementation of sustainable production in seven (7) prioritized crops.

Once the farms are selected, the Producer will have all necessary information to understand technological changes and their implications. An agreement is then subscribed, including a work plan that established both parties' (Project and Producer) commitments and responsibilities.

SA4. Generating dissemination material.

Material with technical information will be generated to support SA2 trainings.

SA5. Implementing sustainable systems/practices at the regional level.

The technological change is then implemented after achieving SA3, being the Project in charge of payment of part of the change investments, providing permanent technical support.

Component 3. Innovative and inclusive business models through modernized innovation systems and a more engaged financial sector.

Result 3.1. Improved business models that provide farmers with reasonable profits and improved GHG mitigation practices

Activity 3.1.1 Strengthen gremios capacities to use digitally enabled tools that improve the provision of services to farmers with emphasis on profitable production system that also reduce GHG emissions and increase climate-resilience.

SA1. Assessment of gremios capabilities and needs, as well as, opportunities to better-inform their allocation of resources (human, financial) to respond to farmers demands and help them to manage climate to their advantage.

This activity supports growers' associations efforts to enhance their extension and knowledge transfer functions by using, inter alia, digitally enabled tools to increase the understanding and provide more appropriate response to farmers demands while strengthening processes of allocation of resources to provide services to farmers. These activities are conceptually aligned with an innovation systems approach.

SA2. Co-design of implementation plans for gremios to the decision-making processes to cost-effectively enhance their provision of climate-related services to farmers.

As part of the modernization of gremio's innovation systems, collaborative work with gremios will be needed to identify the best and more efficient mechanisms to use digitally enabled tools for providing farmers tailored extension services. As a result of such collaborative work, implementation plans will be designed in order to take advantage of new data and information generated through the Project to enhance provision of climate-related services to farmers. These plans will also be developed considering specific characteristics of each gremio and their associated farmers.

SA3. Co-develop feedback loop mechanisms to provide information to the gremios to inform allocation of resources/efforts (human, financial) for climate-related services provision to farmers.

Modernization of innovation systems need to happen involving actively the farmers part of each gremio, thus ensuring mechanisms for two-way dialogue between gremios, their technicians and farmers will be key to incentivize the generation of knowledge, as well as use and validation of climate-resilient and low-carbon options developed in the project. Such mechanisms will also allow gremios to identify areas and effectively prioritize their resources to support dynamization of innovation and extension system enhancement process.

Activity 3.1.2. Implement inclusive climate-resilient and low-carbon business models for agricultural products and services.

SA1. Systematization of the results generated by the components of the project on digital agriculture, climate-smart and low-carbon practices to guide its inclusion into business models.

The climate-resilient and low-carbon options derived from component 1 and 2 will be identified and assessed in the light of their potential to be adopted by gremios, farmers and other value chain actors. This will allow designing tailored ideas for most promising novel and inclusive business models that will guide following steps into formulating and implementing pilot cases studies.

SA2. Coordinate producers, gremios, buyers and other actors in the value chains, to prioritize opportunities for improvement, as well as barriers that limit the escalation of climate resilience and low emission practices

Mapping of key stakeholders and their roles in order to have a clear vision of their participation, or not, in the Project, as well as expectations and scope. This will identify new actions and cooperation means, or new users of data and technologies developed by the Project. Moreover, through a series of interviews, surveys, and focus groups, value chain- information will be updated. This analysis will provide a general vison of the supply operations, especially in the working areas of the Project.

SA3. Design of an escalation strategy (with gremios, producers and other actors) that allows the integration of digital agriculture elements and climate services to the value chains, to increase climate resilience and mitigate GHG emissions

Identification of barriers and opportunities for the adoption and scaling of climate-smart and low-carbon will be a key analysis of the Project to design the scaling strategies, playing a fundamental role for indirect beneficiaries of the Project. A better understanding of barriers and opportunities may represent the transition from the conservative scenario to an optimist one in relation to technology adoption.

Apart from knowing the barriers and opportunities, it is necessary to develop a series of actions to promote the adoption of technologies. However, with limited resources, it is necessary to reach an agreement about main actions which will increase adoption levels. The Project also considers an exercise with gremios to optimize knowledge transfer after the Project is concluded. This means that considering the limited resources of the Gremios, a strategy will be reached with them to allow the promotion of technologies developed in the Project. This will enable reaching a large number of users, with relatively low costs. Although this is a relatively easy exercise, in many cases the workload and commitments to be covered by Gremios do not allow Gremios to do this customarily. This is an additional commitment acquired by the Gremios and their commitment is to maintain the Project’s actions, especially through the massive expansion of the adoption of technologies.

SA4. Implement business models for producers and buyers, to enhance climate mitigation practices and evaluate market opportunities for differential products.

The diagnosis and design of inclusive business models adapted to climate and low carbon will be done using the LINK methodology. The prioritized business models will be implemented through field actions that generate adjustments to the analysis and integrate buyers in the transformation process, making agreements and potential commitments that allow scaling the adoption of climate-resilient and low-carbon strategies considering each actors role while ensuring the participation of farmers in the market.

SA5. Evaluate changes in the business models of producers and buyers, and identify lessons learned and success factors in scaling up digital agriculture mechanisms and low-carbon practices in the value chains.

The entire support process will be documented to make an assessment of impact reached in the business models process, and identifying lessons learned that allow orienting the implementation of similar processes with other Producers, crops and/or regions.

Activity 3.1.3. Enhance financial sector engagement with farmers and their needs and efforts on climate-resilience and climate mitigation activities.

SA 1. Implementation of a capacity building program to raise awareness of financial sector institutions (banks, MFIs, financial cooperatives, insurance companies, etc.) on mid and long-term de-risking mechanisms that the project will implement throughout its components (e.g. DCIPs, climate-smart practices and technologies).

Financial institutions at both local and national level need to be aware of the progress of gremios in reducing their risks associated to climate change and variability, this war they will explore and identify potential opportunities for developing tailored financial products to support the transformation towadrs a more climate resilient and low-carbon agricultural sector. In order to achieve this, a program to inform financial and credit officers, as well as key staff in financial institutions and insurance companies will be developed so that they understand the alternatives and opportunities for the sector to grow and de-risk. This program will be set mostly online with some in-person workshops and will be connected to the MTA, which at the same time, will facilitate the dialogue between financial institutions and other agricultural sector stakeholder participating in the MTA.

SA2. Facilitate participation and involvement of financial institutions in the MTAs for accessing local and tailored information on climate-smart actions implemented by the agricultural sector to reduce climate risks, which will reduce uncertainty and may incentivize the design of tailored financial products for the agricultural sector.

Through the capacity building program, through periodic communications and during MTAs' meetings, financial institutions will receive relevant information from the project, as well as relevant information to inform their business decision making processes. Such communications and participation in relevant meetings and events will allow ensuring that they are receiving updates of key information on the progress of the project that could facilitate the identification of opportunities for making improvements to their portfolio of products that could support the transformation into a climate-resilient and low-carbon agriculture.

SA3. Identify opportunities with financial institutions and prioritize cases studies to provide technical support for incorporating climate-resilient and low-carbon criteria to their agricultural financial products in compliance with the environmental, social, and governance (ESG) criteria.

Two case studies will be identified together with gremios and financial institutions to assess the design of novel and tailored financial products thatcould support adoption of climate-resilient and low-carbon options in Colombia. This assessment will serve as input for financial institutions to develop further their product portfolio beyond the duration of the project.

Activity 3.1.4. Fostering agri-digital entrepreneurship ecosystems.

SA1. Explore and identify potential opportunities for new ventures.

A qualitative assessment of potential opportunities for agri-digital entrepreneurship on climate-resilient and low carbon agriculture will be done, so that it serves as a basis for future business opportunities led by gremios and/or farmers as this is a growing market area in the country. The assessment will include interviews to relevant stakeholders, as well as information gather through the MTA in order to understand the state of the art of these business models and the use by farmers. The analysis will also identify main barriers and relevant actors to dynamize this market in the country. The analysis will be done to value chains with the highest potential for agri-digital entrepreneurships considering the data, information and results of the project.

SA2 Support creation of new ventures and transforming existing businesses by developing new digital technologies

Our team will provide expertise and time to support two cases for developing new ventures on agri-digital business. Moreover, the team will provide data and methodologies useful for those new ventures or enhanced existing business to implement their novel idea to bring digital tools as services for farmers. However, success of the business will be beyond of the control of the project.

Result 3.2. Modernized technical assistance and agricultural extension services with multi-tool strategies, differentiated and adapted to specific environmental, social, gender and productive contexts at the national level.

Activity 3.2.1. Foster inclusion of two-way digitally enabled tools for enhancing models for technology transfer technical assistance within an innovations system approach

SA1. Linking plans directed by Agrosavia, for Musaceae, potato and panela sugarcane; HUB innovation model applied by CIMMYT for maize; Knowledge Management Model in Sustainable Livestock by Fedegan; Dissemination campaigns of the National Extension Service of the National Federation of Coffee Growers; AMTEC mass adoption model in rice; The technical cooperation and technology transfer service (SCTT) with the network of Technology Transfer Groups (GTT) in sugarcane; Rural School Methodology (ECAS) by Asohofrucol – Musaseas;

This strategy is based on the profiling of learning methods and formulation of technology transfer plans. The strategy will be focused on generating changes in the beneficiaries, applying the wide array of experiences, methods and media so all approaches are enrichened by lessons learned from each other. To achieve this goal, it is necessary to have both public and private institutions working together in an articulated manner, with the objective of overcoming barriers which limit agricultural transformation and competitiveness of agricultural production chains.

SA2. Experience exchange

Experience exchange will be promoted, mainly using a Producer-Producer diffusion strategy. Target user groups will be identified, programming a series of visits to direct beneficiaries' farms to deliver first-hand information from other Producers regarding progress made in the implementation and results obtained, as well as discussing implications represented by technological changes to Producers, and the lessons learned.

SA3. Use of voice (IVR) and text (SMS) messaging, WhatsApp networks and chatbot

This is an important strategy to strengthen actions included in component 1. The goal is to massively reach thousands of Producers, after making the usability tests. Once the design and adjustments are made to the development, the Project focuses on escalation of diffusion means.

SA4. Producer association digitally enabled platforms or available mobile applications

The goal is to close the digital gap, taking advantage of professionals and technicians offering extension services with new and improved communication and facilitation abilities, and with new knowledge to convincingly facilitate and promote the appropriation of technologies, expecting Producers and the sector may decrease their vulnerability with respect to climate threats and reduce greenhouse gas emission to the atmosphere. This demands capacity building for thousands of users of these technologies.

Activity 3.2.2. Capability development on innovation systems approach and its inclusion into updated technology transfer plans.

SA1. Carry out events to disseminate the project and its content.

It is important to disseminate the scope of the Project to different stakeholders, through different media; particularly to stakeholders within work areas. Strong work will be done during the initiation of the Project in order to socialize de project in work areas, with different local stakeholders, and identify potential partnerships and cooperation means that enhance the Project's activities. Events will also be programmed to socialize progress and final results, receive feedback and review and answer, if possible, requests made by local stakeholders.

SA2. General training sessions by Output..

It is important to support working teams in the training of different stakeholders, mainly the Project's direct beneficiary Producers. Since this is a continuous process focused on "learning by doing", it is important that the capacity building team reviews all training contents and support the evaluation of changes in knowledge, attitudes, abilities, and skills of the participants. This team shall also review the content, making the necessary adjustments to guarantee the content is in agreement with direct beneficiaries.

SA3. Work meetings.

This sub-activity focuses on the empowerment of Gremio processes. The capacity building team shall attend work meetings held between researchers of the Alliance Bioversity-CIAT, Agrosavia, and the Gremios, in order to follow-up changes in knowledge, attitudes, abilities and skills of Gremio professionals, and especially verifying the empowerment level achieved throughout time. This will highlight adjustment required to guarantee that the Gremio gradually and properly assumes the control of activities. Training contents will also be reviewed to assure proper understanding of all users.

SA4. Development of written material, in physical and digital form.

The technical content will be requested from teams of components 1 and 2, which will be used to produce written material (hard copy and digital material), guaranteeing the generation of key issues for different types of users, guarantee an adequate coverage and participation of the different stakeholders involved and interested in the process. All material will go through an edition, diagramming, and design process.

SA5. Development of videos with the project topics.

Likewise, videos will be generated along with the technical content and help from the different groups. These videos will help disseminate the Project's activities, and especially its results.

Videos will be generated having in mind the different types of users, and the different communication means expert-expert, technician-technicians, Producer – Product and different combinations. Video formats will allow massive diffusion, mainly through WhatsApp.

SA6. Follow-up and joint work with the Agroclimatic Technical Committees.

Agroclimatic Technical Work Groups (MTA) emerged from the MADR-CIAT pilot program as an alternative to share knowledge with other stakeholders in working areas, and are oriented towards the socialization of information that assist Producers in reducing climate change impact. (https://ccafs.cgiar.org/es/events/mesa-tecnica-agroclimatica-de-cordoba). These MTA strengthened and new MTAs were created in other regions, for a total of thirteen (13) MATs currently established in Colombia. This has become one of the Colombian NDC goals. For this reason, the Project includes to continue strengthening the MTAs, support their operation and continue with capacity building in order to create new MTAs in the Project's work areas that still do not have this work mechanism.

Activity 3.2.3. Strengthen gremios and farmers capacities on climate adaptation and mitigation and nurture knowledge exchanges across farmers groups.

SA1. Specific workshops by topic.

Technical teams will be supported in the development of training workshops and result dissemination. Training processes will be supported in order to assess changes in knowledge, attitudes, abilities and skills of the participants. This team will also review the content and will make the necessary adjustments to guarantee contents are in accordance with the Project's direct beneficiaries.

SA2. Operation planning meetings.

Increase participation in the planning meetings and verify a common understanding of activities, procedures, implementation times, and acquired commitments.

SA3. Workshops to create procedures, carry out experiments and analyze results jointly.

This is a very specific sub-activity oriented towards a group of expert professionals on Project topics in component 2. The idea is to have capacity building activities for the Gremios, but especially guaranteeing protocols and procedures are understood, and verify their proper application by users (experts).

SA4 Three Communities of Practice on Digital Agriculture and Data Analysis, Climate Forecasts, and Communication and Outreach.

Practice communities is an important capacity building strategy. In this case, they will especially relate to component 1. This is a new component for most beneficiaries. A basic principle of digital upgrading is digital literacy for the different beneficiaries, within different development levels and use of technologies. This action is not only focused on disseminating information, but also allows to close the digital knowledge gap existing in different regions. This is something the Colombian national Government has been promoting with its program denominated "the digital future belongs to all"; a program that has been adopted in development plans at municipal and regional level.

SA5. Open training courses on specific topics on virtual education platforms.

Virtual training activities allow access to many users located in different locations, who benefit from receiving all the Projects information and capacities, especially expanding its scope to multiple regions. The strategy of having virtual courses will especially be used to disclose basic concepts and strengthen general capabilities.

SA6. Strengthening academic programs, thesis, and internships

The project will consider interaction with different universities located in the regions of intervention, searching for active participation of the above-mentioned students, as well as interaction through its research groups by means of seminars, lectures or workshops to strengthen research capabilities in the regions and the academia.

Activity 3.2.4. Develop a strategy that allows the dissemination, access and use of the Project's results by public and private key stakeholders.

SA1. Holding management meetings together with national institutions

The objective is that Project results go beyond the technical area. Therefore, result socialization events will be generated in a more managerial format to be presented to key institutions which may be indirect users and/or beneficiaries of information generated by the project (i.e., UPRA, Finagro, ICA, IDEAM, DNP etc.).

SA2. Preparing executive reports for producer associations on the progress and needs to support service sustainability

This is a very important activity to guarantee the sustainability of designed and implemented measures, long after the Project is completed. In this case, taking as input information on sub-activity 3 of Activity 3.1.1, executive reports will be generated to review Gremio directors and analyze advancements in capacity building and empowerment processes. Advance made in the implementation of activities of each component will be revised, as well as commitment compliance by the parties. This kind of information and discussions will allow the identification of difficulties and/or necessary modifications, always with the intention to guarantee long-term sustainability of this Project's activities.

SA3. Promoting communication through traditional and digital media, social networks, project website

The Project will have a communications plan which will publicize the Projects, its scope, and results, taking into consideration the diversity of its audience.

SA4. Developing infographics on the Project Identity

This material, aimed at the different public, will summarize in a concrete manner the scope of the Project, its progress and final results.

Impact assessment and MRV

Baseline development.

- ***Collection of primary and secondary data***

The information collection instrument and the sample will be designed, after discussions are held with a group of professionals from different Gremios. This will be followed by the validation of the instrument in the field and the required adjustments. Finally comes the training phase for surveyors who will go to the field to collect data.

- ***Baseline construction***

Collected information is organized in databases and reviewed for analysis and quality control. Once there is a clean database, a descriptive analysis is made and the Project's baseline is constructed. The presentation and validation of results will be done with key stakeholders. A data consolidation platform will be created to have record of the baseline, which will be used to record the Project's progress.

The monitoring strategy with reports every six (6) months will be applied during the development of the Project.

- ***Collection of primary and secondary data***

For collection of information based on questionnaires collecting baseline variable data, focal groups will be formed with Producers and Gremios for an initial general assessment. Later, field work will be executed to collect information on beneficiary samples, which will later feed the dashboard with key indicators in the platform.

- ***Generation of analysis and monitoring report***

Collected information is organized in databases and reviewed for analysis and quality control. Once there is a clean database, data is analyzed and reports are prepared. Likewise, results are disseminated so the involved institutions know progress made and the Project's impact. If necessary, such institutions will take corrective actions or the corresponding adjustments. The presentation and validation of results will be done with key stakeholders. Data will also be uploaded in the platform generated in the baseline sub-activity.

The intermediate line for the Project's direct beneficiaries will be developed in the third year.

- ***Collection of primary and secondary data***

The baseline data collection instrument will be revised. Work will be done jointly with a group of Gremio professionals to revise the instrument and make the necessary adjustments according to actual conditions. The instrument will be validated on the field and the corresponding adjustments will be made. Surveyors will be trained and will perform the field work.

- ***Generation of an intermediate line***

Collected information is organized in databases and reviewed for analysis and quality control. Once there is a clean database, data is analyzed and an intermediate baseline is constructed. This baseline will be used to make a mid-term analysis of the Project's progress and impact. The presentation and validation of results will be done with key stakeholders. Intermediate line results will be uploaded in the platform and will have a visual interface to observe progress achieved with respect to the baseline, and the expected figures.

- ***Report preparation***

A report of intermediate line results will present the Project's progress, and will generate the possibility to review difficulties and challenges found by the different participating institutions, as well as the positive aspects. The required adjustments will be made, and recommendations will be given to the different work groups.

The final line will be developed during the last year in order to assess the final impact of the Project.

- ***Collection of primary and secondary data***

The data collection instrument used for the intermediate line will be revised. Work will be done jointly with a group of Gremio professionals to revise the instrument and make the required adjustments, according to the actual conditions. The instrument will be validated in the field, and the corresponding adjustments will be made, if necessary. Surveyors will be trained and will perform the field work.

- ***Generation of impact assessment***

Collected information is organized in databases and reviewed for analysis and quality control. Once there is a clean database, data is analyzed and the final results of the Project and its impact are reported to the internal and external Project users. The presentation and validation of results will be done with key stakeholders. Intermediate line results will be uploaded in the platform and will have a visual interface to observe progress achieved with respect to the baseline, and the expected figures.

- ***Report preparation***

A report of the Project's final results will be presented, making a general balance of work done, and identifying lessons learned and recommendations for future project. This report will also be used to socialize the work done and the impact achieved.

Monitoring, reporting and verification of emission reduction

- ***Search of secondary data***

Secondary data will be searched and updated of MRV procedures will be revised. Based on that, a protocol for monitoring emissions according to each of the productive systems is built. Excel matrices are established to have spread sheets to record activity data, and another spread sheet for calculation of emission factors to be used. Spread sheets will also be established with formulas to make the respective emission reduction calculations or the different interventions made.

- ***Organization of databases and field consolidated data***

Activity data will be received from the different equipment making field mitigation implementations. These shall have site geo-references and the defined polygon of the intervened surface, as well as a description of the intervention made and the implementation timeframe. A description of the type of intervened system and conditions found at the time of intervention will also be delivered. Emission factors will be obtained from GHG and carbon capture measurements. These will be direct measurements in the field vs. conventional systems and sustainable production alternatives oriented to mitigation. This information will be used to feed the activity's databases and the emission factors, and will be compared vs. conventional systems, to later make the necessary adjustments on emission factors being used.

- ***MRV Calculation***

Calculation of project emissions and data collection will be made from two (2) information sources generated within the Project, which are organized in databases mentioned in the previous sub-activities. This will be done using technology implementation statistics and emission factors generated in Result 2.2. The achieved reduced emissions or carbon captures are estimated in the Project, and compared vs. the baseline.

- ***Verification***

There will be several verification actions; these include field monitoring and routine controls in the technology implementation follow-up. A comprehensive revision of reported data will be executed every six (6) months, controlling the number of selected farms randomly, to verify their compliance with implementation protocols. Part of the project's resources will be used to cover costs of a third party's verification made to a sub-sample of implemented actions for all crops in the Project. All data will have transparency, consistency, completeness, comparability and accuracy criteria (TCCCA for its acronym in English).

- ***Final Report***

A final report will inform emissions reduced by the Project. A registration of these actions and mitigation impact will be registered in the RENARE[65] system.

<u>Implementation of the Environmental, Social and Gender Plan</u>

Implementation of the Gender Action Plan

In general terms, the Gender Action Plan (PAG for its acronym in Spanish) will have a comprehensive data diffusion strategy on agroclimatic risk production forms, a plan for women's training on production resilient to climate change, a support plan and seed money for entrepreneurships and sustainable production business plans for organizations and/or groups of women, a water management plan oriented towards women in some areas with greater water deficit, a political empowerment strategy and participation in decision-making instances for women, as well as an education and training strategy on equality and gender approaches.

- ***Implementation of actions to reduce access barriers to agroclimatic information for women from the rural sector***

In the group of direct beneficiaries of Component 1, a particular group of Producers' homes will be selected to work with emphasis on female participation in production decision-making, having information technologies, communication and connectivity available. This implies having a differential gender approach during the training processes.

- ***Strengthen rural women's capabilities in a sustainable agriculture and livestock production, resilient to climate, which guarantees their food security, as well as their homes' safety.***

[65] This is the System of the Colombian Government which registers mitigation actions and their mitigation potential.

A particular group of Producers' homes will be selected as direct beneficiaries of component 2, working with emphasis on female participation in the implementation of technologies and sustainable production systems implementation to promote climate resiliency, efficient use of water, and low carbon agricultural development. This implies that training and implementation processes will have a differential gender approach.

- ***Revise, analyze and reduce structural barriers that hinder the access and full participation of women in rural areas, in agricultural and livestock value chains.***

The Project shall generate periodical discussion of gender topics with different gender institutions, entities and offices in the country. This will allow data and lessons learned to provide feedback to such institutions and that gender topics are considered when formulating projects and programs, especially in public policy matters.

Implementation of Environmental and Social Management Framework

- ***Implement an environmental and social management plan to manage risk and minimize potential adverse impact of the Project on the environment, communities and Project beneficiaries.***

Environmental and social procedures of the project are oriented towards the management of matters related to compliance of measures and actions established in the MGAS, and establish guidelines for the proper implementation of the measures, documentation of processes, and traceability registration. The Project will have a risk management plan associated to security, a strategy for knowledge social appropriation, a communications plan, a natural disaster and environmental emergencies risk management plan, an integrated solid waste management plan, and the development and implementation of road maps, updating of occupational health and safety, measures and protocols for the use of pesticides and agricultural chemical products, and economic and financial training for small Producers of agriculture and livestock products.

Due to their specificity, these plans and strategies will be developed during the Project's implementation phase. For its formulation and implementation, a methodology, as well as technical formats and annexes will be defined. These shall allow their traceability analysis, validation and registration of compliance of processes and procedures established by the MGAS of the Project.

- ***Implement a system for registration, reporting and resolution of petitions, claims, complaints, suggestions and accusations (PQRSD for its acronym in Spanish).***

An online platform of the Project will be designed and implemented. This platform will include a section to receive this type of communications. Such reports may also be sent by physical mail, telephone calls and/or direct communication with field teams. In such case, the person in charge of documentation management within the Environmental, Social, and Gender Team shall register data in the platform (all PQRSDs will have a file number and will be systematized in the platform). The communications registry shall preferably include the name, contact information, gender and ethnic group (if applicable). However, anonymous communications will also be managed. All PQRSDs will be filed in the PQRSD and incidents registrations of the CSICAP Project.

6.4 ASSESSMENT OF FINANCING OPTIONS

Annex 3 presents the Projects **economic and financial analysis,** which is supported by a complete model including all relevant data and assumptions. **Annex 4** presents a **detailed budget disaggregated** by activity and item. Likewise, different financing sources considered in the proposal, are presented. It is important to note that the model considers Gremio contributions to guarantee the development of the Project's activities. However, it is important to have in mind that after the Project is concluded, the Gremios will assume the operation and maintenance costs of implemented actions, being responsible for continuing escalating the measures. This is part of the agreement and institutional arrangement reached during the entire negotiation process. Post-project amounts are not reflected in the budget, but make part of leveraging achieved by the Project.

6.5 IMPLEMENTATION ARRANGEMENTS

Timetable for Implementation

El timeline for the implementation of sub-activities is presented in **Annex 5. Implementation Timeline.**

Project Sponsor and Implementation Partners

The Government of Colombia, through the Ministry of Finance and Public Credit (MHCP, for its acronym in Spanish) will be the entity responsible for the Project resources, including credits and donation made by the Green Climate Fund (GCF), as well as CAF financing resources. The MHCP shall guarantee the proper resource programming incorporated to the General Budget of the Nation with a credit source, following guidelines established by the Directorate of Public Credit and Treasury of the MHCP. On the other hand, the Ministry of Agriculture and Rural Development (MADR) will be in charge of the execution of resources and the Project's technical implementation through the Directorate of Innovation, Technological Development and Health Protection.

The Ministry of Agriculture and Rural Development (MADR) will be responsible for the execution of resources and technical implementation of the project through the Directorate of Innovation, Technical Development, and Health Protection (DIDTPS) before the Ministry of finance and CAF. Therefore, it will have a Project Executing Unit formed by a work team reporting to the leadership of the Director of DIDTPS.

MADR will directly contract an procured party which will be in charge of the operational, technical and administrative execution of the Project. The procured party selected by MADR is the Alliance Bioversity-CIAT. Direct contracting will be made in accordance with the Colombian national provisions in item (e) numeral 4 of Article 2 of Act 1150 of 2007, through which efficiency and transparency measures in Act 80 of 1993 are established, and where general provisions on public resources contracts are found. It is also in agreement with provisions in Article 2.2.1.2.1.4.7 of Decree 1082 of 2015, Articles 2 and 17 of Executive Order 591 of 1991, and Article 33 of Act 1286 of 2009.

The Directorate of Innovation, Technical Development, and Health Protection (DIDTPS) will have the following roles within the Project's implementation framework:

Table 12. DIDTPS Functions

To the Ministry of Finance	To CAF	To the procured party (CIAT)
Request disbursement of credit resources. Send reports of the technical execution of the Project in terms of the use of credit resources. Send reports on the Project's financial execution in terms of the use of credit resources. Answer any requests made by the Ministry of Finance in relation to the Project.	Request disbursement of donation resources. Send reports of the technical execution of the Project in terms of the use of donation resources. Send reports on the Project's financial execution in terms of the use of donation resources. Answer any requests made by the Ministry of Finance in relation to the Project.	Approval of reports on technical execution progress Approval of financial execution progress Approval of report on results compliance No objection to reference terms and contracting processes Technical supervision of the Project's execution Financial supervision of the Project's execution Approval of operational plans (POA) and the Annual Procurement Plan (PA) Support resource management and financial-accounting management of the Project Approve the execution of formulated activities and procurement processes according to POA and PA, after being approved by the Steering Committee. Approve arrangements for the development of strategic agreements, as well as TDRs and contracts for tender processes and procurement of materials and equipment. Supervise the development of activities executed and goods and services provided by third parties, ensuring their quality and compliance of procedures and requirements of GCF, CAF and MADR. Make technical recommendations and/or observations to the ¨Project.

Other responsibilities and functions of this Unit are the following:

- Coordinate the general implementation of the Project
- Guarantee achievement of results and Products, based on the Project's scope and guaranteeing a greater productivity and quality of services provided.
- Prepare a summary matrix of technical and financial advancements of the Project, and the compliance of results.
- Request and revise reports on technical execution progress and compliance of results to be presented to the Follow-up Committee.
- Revision of the Project's budget adjustments.

Proposed procured party.

The International Center for Tropical Agriculture (CIAT) is an agricultural research institution that aims to achieve ecoefficient agriculture, improving resource management to be more competitive and achieve sustainable productivity, with minimum ecological footprint. Its mission is to "reduce hunger and poverty, and improve human health in the tropics through research to increase agriculture ecoefficiency". Supported by the Colombian Government and the Rockefeller, Ford and Kellogg Foundations, CIAT was officially established in1967, starting its research work in 1969.

Impact analysis of CIAT's results have been published in more than 250 journal articles and other documents published since the 70s. The production of CIAT's material has increased exponentially, at an annual rate of approximately 10%, starting with nine (9) publications during the first decade of the Center, and approximately 170 publications during the last decade. In the last years, many of these publications (almost 40% of them) have analyzed the impact of crops for which CIAT is responsible within CGIAR. Almost 1/3 of the studies have informed about new tools and methods for impact assessment. The rest have focused on the impact of research on climate change, soil fertility, biofortification of crops, participatory research, and other topics. For additional information about our work during the last years, visit: http://annualreport2015.ciat.cgiar.org/.

CIAT is a member of the CGIAR Consortium, a global Gremio that brings together organizations dedicated to research for future food security. Its research includes the reduction of rural poverty, improvement of human health and nutrition, and guaranteeing a more sustainable management of natural resources, which is performed by the fifteen (15) member centers of CGIAR Consortium, in close collaboration with hundreds of related organizations, including national and regional research institutes, civil society organizations, the academic world, and the private sector.

In Colombia, CIAT has close relations with national research programs for different crops, with organizations such as FEDEARROZ, FENALCE, FEDEGAN, CENICAÑA, ASBAMA, AGROSAVIA, CIPAV, and working together with international research centers of CGIAR, such as CIMMYT.

On December 31, 2012, MADR and CIAT subscribed Agreement N° 20120382, which established their interest in working together in order to "joint efforts, resources, and capabilities to strengthen the adaptation capacity of the agricultural sector to climate change and variability, and improve the efficiency of the use of resources in productive systems within prioritized areas, according to Science, Technology and Innovation (CTI) instruments of the Parties subscribing the Agreement", in an amount of $22,200,000,000 Colombian pesos.

The Project was designed with four (4) components: (a) agroclimatic risk management, (b) site-specific agriculture, (c) testing new adaptation technologies, and (d) evaluation of sustainable production systems. This included work with rice, maize and bean crops along with Fedearroz and Fenalce. During this first stage, progress was made in the development of weather forecast models and their validation in some of the prioritized areas, as well as the first analyses of Site-Specific Agriculture. Advanced lines with tolerance to droughts and water logging were evaluated in rice, maize and beans. Water footprint was measured for different production systems (rice, maize and oil palm). The Gremios have found a great potential in data and tools generated during the two (2) years of work. A capacity building process was started with Gremio technicians and on some specific topics, the information was also delivered to Producers. The Project also included other topics, such as carbon footprint metrics in oil palm, intensive silvopastoral systems and fruit trees. Soil loss was measured in potato crops, evaluating extended cassava harvests. This agreement delivered Products with a high climate change adaptation potential in the agricultural and farming sector. Therefore, great expectations have been generated in the sector with the implementation of measures identified by data and tools generated within the agreement framework.

In 2015, MADR and CIAT continued with the development of objectives established in the first agreement, and initiated a second phase by subscribing Agreement N° 20150291. This work phase emphasized on capacity building of technicians in the different Gremios: rice (Fedearroz), maize (Fenalce), sugar cane (Cenicaña), cattle-farming (Fedegan) and oil palm (Cenipalma). Technical information on specific topics was delivered to Producers, in an amount of $10,500,000,000 Colombian pesos.

Work with MADR continues during 2019 under Agreement No. 20190458, whose objective was to strengthen the agriculture and farming sector on sustainable production adapted to climate. Another of the objectives of the Project was to multiply the offer of rice hybrid seeds for sowing in 2020, and strengthening the sector through the use of climate services to improve available data and increase the adaptation capacity of Producers.

In terms of the cattle-farming sector, along with Fedegan, agroclimatic forecasts for the last quarter of 2019 and first quarter of 2020 were generated and socialized for five (5) departments, and eleven (11) municipalities in order to generate knowledge and capabilities in the sub-sector (cattle farming) and take wise decisions during climate-related phenomena.

In 2020, a new agreement was subscribed to continue with work initiated in 2012 and massify 2019 results, which include rice germplasm commercial crops adapted to different climate conditions and tolerant to various plant stress-generating abiotic factors.

At the same time, a team was formed by MADR, CAF Latin American Development Bank, and CIAT to work on the CSICAP Project, in which MADR acts as the initiative leader, CAF as the agency accredited before GCF, and CIAT as the technical leader of the Project.

Execution Scheme

The procured party will form a project coordinating team that will be directly responsible for interaction and response to technical and administrative requirements of the executing unit. The Project Coordinating Team (ECP for its acronym in Spanish) will include (1) a Project Manager, (2) a technical associate, (3) a research assistance, (4) a project analyst, (5) a logistics assistant, and (6) two emeritus technical advisors on climate and agriculture.

This team will be responsible for the implementation of the Project, orienting the six (6) thematic leaders and eight (8) crop coordinators. The team will work with the different administrative areas of MADR, CIAT, the strategic partners and any other institution, entity or person contracted to provide a service or supply a good. This team will be responsible for institutional relations under the Project Manager, and therefore will report to MADR, who will ensure the proper execution of the Project and the adequate use of resources. The team will be responsible for preparing the technical reports to be presented to MADR, as well as the financial report. The operations venue of CIAT, as procured party, will be in the city of Palmira, Valle del Cauca. All equipment from the Project's Execution Unit will be covered by the Project's resources.

Interaction between MADR, as the entity responsible for the financial execution and implementation of the Project before MHCP and CAF, and the procured party (CIAT) will be articulated by the Execution Unit (MADR) and the Coordination Team of the Project (CIAT).

The procured party will form a work team that guarantees the development of each of the components for all prioritized crops in the CSICAP Project. It will have main thematic coordinators and leaders on cross-sectional topics. The Project will have six (6) thematic leaders formed by CIAT personnel in the city of Palmira, Valle del Cauca. These will be PhD experts and renowned experts with at least ten (10) publications. These leaders will be responsible for the implementation of activities for each of the Project components. Each one will have a budget allocated according to the Project's financial plan and procurement plan approved by the execution unit.

Each one will be responsible for the implementation of activities for each Project component, and guarantee the achievement of their respective products and scopes.

- Main theme leader 1. Coordinator of agroclimatic forecast and digital agriculture.
- Main theme leader 2. Coordinator of technologies for efficient water management and low GHG emissions
- Main theme leader 3. Coordinator of technologies for improvement and strengthening of germplasm bank
- Cross-sectional theme leader 1. Coordinator of knowledge management and capacity building
- Cross-sectional theme leader 2. Coordinator of environmental, social and gender topics
- Cross-sectional theme leader 3. Coordinator of impact assessment

The Project will also have eight (8) crop coordinators (one for each type of crop). These coordinators are renowned experts on each of the crops, with PhD and minimum ten (10) crop publications in indexed international journals.

These professionals will be in charge of integrating each of the crop topics in order to achieve coherence, efficiency and coordination in the implementation processes. These coordinators will be responsible for making improvement recommendations and proposals, the required adjustments or coordination activities to be covered by resources managed by the main and cross-sectional theme leaders, as applicable, since there will not be a budget allocation different from that allocated to their time dedication to the Project.

This team will be formed by CIAT personnel (cattle-farming, rice, musaceae), CIMMYT (maize), Agrosavia ("panela" sugar cane and potato), Cenicafe (coffee) and Cenicaña (sugar cane). Personnel of CIAT and CIMMYT will be based in the city of Palmira, Valle del Cauca, Agrosavia in Bogotá, at their venue of Tibaitata, Cenicafé in Chinchiná (Caldas) and Cenicaña in the municipality of Candelaria, Valle del Cauca. Time (25%) dedicated to coordinate the different crop themes will be covered by the Project's resources.

Illustration 14~~Illustration 14~~ shows the organization chart of the procured party's working team.

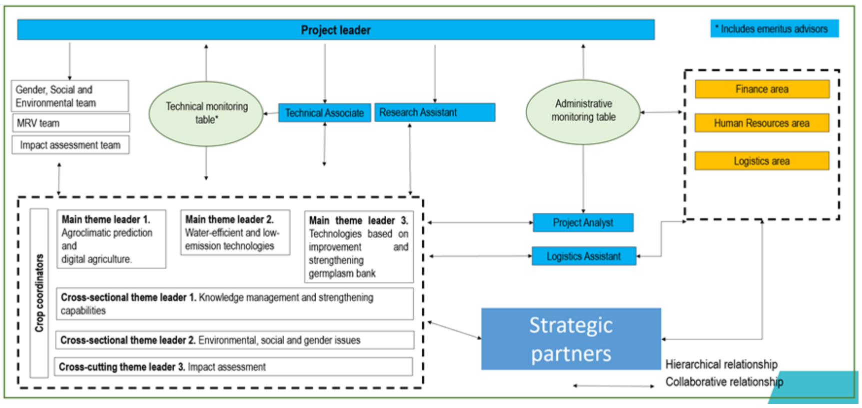


Illustration 14. Organization chart of the procured party's Work Team for the CSICAP Project

Strategic Partners

The Project will have thirteen (13) strategic partners for the implementation of the Project. For the execution of the CSICAP Project, CIAT will work jointly with the following sector Gremios: Fedearroz (rice), Fenalce (maize), Fedegan (cattle farming), Fedepanela (panela sugar cane), Fedepapa (potato), Federación Nacional de Cafeteros - Cenicafe (coffee), Asocaña - Cenicaña (sugar cane), Augura, Asbama and Aohofrucol (musaceae). Additionally, Corporación Colombiana de Investigación Agropecuaria (Agrosavia) for agriculture and cattle-farming research, and institutions such as Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), for improvement of maize and wheat, and Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria (CIPAV), for research of sustainable systems in agriculture and cattle farming of Colombia, will be strategic partners for the implementation of the Project (See Figure 6).

These strategic partners will play an important role in the implementation of activities. Therefore, they will be allocated a budget that will be subject to products and deliverables. The importance of these partners increases considering they are the institutions that will give continuity and sustainability to the Project's actions once this Project is concluded.

These are national institutions having presence in the different production regions of each of the crops, with high recognition and links with producers, as well as broad technical knowledge on production systems prioritized in the Project. These strategic partners are entities with financial resources and will assume part of the Project's implementation costs.

Program supervision scheme

Two (2) groups will be in charge of supervising the technical and financial execution of the Project: The Follow-up Committee and the Steering Committee. Following is the execution scheme, configuration, and roles of the different entities:

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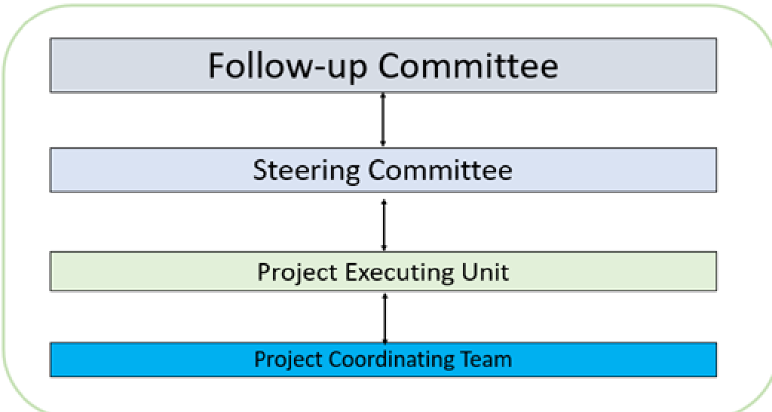

Illustration 15. Governance scheme of the CSICAP PROJECT

Table 13. Description of configuration and role of the Project's committees

	Follow-up Committee (Primary Level)	**Steering Committee (Secondary Level)**
Participating entities	MADR (2 delegates: Vice-Minister of Agricultural Affairs or his/her delegate and the Director of Innovation, Technological Development and Health Protection) CAF (1 delegate: Country representative or its delegate) DNP (2 delegates: Director of Sustainable Rural Development and Director of Environment and Sustainable Development) Ministry of Finance (1 delegate)	MADR (2 delegates: Director of Innovation, Technological Development and Health Protection, or his/her delegate, and the Project Coordinator) DNP (2 delegates: Delegate from the Directorate of Sustainable Rural Development and the delegate of the Directorate of Environment and Sustainable Development, or its Delegate) Alliance Bioversity-CIAT (1 delegate: Project Leader)
Guests*	MADS: Director of Climate Change IDEAM: Director	
Functions	Approve the technical execution advancement Approve the financial execution advancement Approve result compliance Make recommendations, observations and/or request adjustments	Revision of the annual operational plan Give strategic orientation to the Project Make recommendations on actions and initiatives to achieve synergies with other projects, programs and policies. Identification and recommendation of strategic alliances to escalate the Project's actions. Revision of technical and financial execution advancements, compliance of results to be presented to the Follow-up Committee.
Meeting frequency	Annual	Semi-annual

* Other guests may attend after being approved by the Follow-up Committee.

The execution unit is the tertiary level instance, while the procured party is of fourth level. The functions of the units were previously mentioned.

7. RISKS AND MITIGATION MEASURES

7.1 ASSESSMENT, ASSUMPTIONS AND MITIGATION MEASURES

The six (6) most relevant risks for the Project are initially presented. In principle, the main risk is having a low technological adoption (risk #1). Although calculations from indirect adopters were made with the most conservative scenario, it is necessary to make some actions to help minimize the risk.

Selected Risk Factor 1		
Category	**Likelihood**	**Impact**
Technical and operationalTechnical and operationalTechnical and operational	MediumMediumMedium	MediumMediumMedium
Description		
Stakeholder Risks: In general, the community of agriculture and cattle-farmers tends to be very conservative when adapting to new technologies, varieties, or crops, being passively resistant to the introduction of new profitable procedures or systems.		
Mitigation Measure(s)		
This risk can be mitigated by establishing close relations with relevant stakeholders, including the Government and stakeholders at the end of the productive chain. These measures decrease the Likelihood of occurrence of this risk.		

A second risk (risk #2), would be failures in the established protocols, or failures by those applying such protocols. The Project supervision and coordination mechanisms are fundamental and shall operate in order to identify problems on a timely manner and take the necessary corrective actions.

Selected Risk Factor 2		
Category	**Likelihood**	**Impact**
Technical and operationalTechnical and operationalTechnical and operational	LowLowLow	MediumMediumMedium
Description		
Technical performance risk: This risk refers to potential incorrect design or management of trials or pilot projects, or breaching of Gremio agreements or institutions configurations. The occurrence Likelihood of these risks is very low, in spite of their high level of impact.		
Mitigation Measure(s)		
To mitigate this risk, CIAT will have a Project Coordination Team with capacity to travel, in order to follow-up the Project's progress and make early detection of risks caused by poor management and non-compliance, and take timely measures.		

The third risk (risk #3), are potential delays in the operation, especially at the beginning of activities. In this case, the Project's supervision and coordination mechanisms will be fundamental to identify issues or delays and make corrective actions in a timely manner

Selected Risk Factor 3		
Category	**Likelihood**	**Impact**
Technical and operationalTechnical and operationalTechnical and operational	MediumMediumMedium	MediumMediumMedium
Description		
Risk of delays and cancellations causing cost increases: A delay inherent risk exists in the scheduled work planned, including the acquisition of inputs, human resources, materials and tools. It is probable that this risk occurs, with a medium impact. In case of occurrence of time delays, a possible result would be an increase in costs.		
Mitigation Measure(s)		
Contingencies shall be included in the Project's budget estimates, as a mitigation measure for this risk. Another measure is making a strict budget and financial follow-up to avoid possible delays or cancellations. A CIAT Coordinator will be in charge of operational aspects in order to make early detection of risks in order to take timely corrective actions.		

Risk #4 relates to failures in the identified and agreed mechanisms for the Project's operation sustainability. Gremio commitment letters approved by their Board of Directors have been subscribed. In some cases, these have to be approved by the Committees led by MADR. A very powerful tool is available to guarantee the necessary and sufficient resources for the Project's operation. Likewise, once the Project is concluded, a minute is written certifying the equipment and infrastructure transfer from the MDR to the Gremios, who commit to maintain and operate the entire technological development investment made on the Project.

Selected Risk Factor 4		
Category	**Likelihood**	**Impact**
GovernanceGovernanceGovernance	MediumMediumMedium	MediumMediumMedium
Description		
Sustainability Risk (Risk #4: The lack of governance or existence of mechanisms which hinder the Project's sustainability is a medium Likelihood and high impact risk.		
Mitigation Measure(s)		
From the beginning of the Project, each stakeholder will assume the assigned responsibilities from the execution phase, until the Project is concluded. The strengthening of Producers' Gremios will help mitigate this risk, since technical and economic support will be provided to its members. Once the Project ends, maintenance and operation plans will be established in order to properly maintain the infrastructure and guarantee a long-lasting life cycle.		

Risk #5 related to the location of intervention sites and the derived problems. Very important measures have been taken to manage this risk, such as the inclusion of this type of criteria within work site prioritization. Depending on the Project's progress and investments made, the possibility of evaluating some adjustments in the locations may be possible.

Selected Risk Factor 5		
Category	**Likelihood**	**Impact**
Technical and operationalTechnical and operationalTechnical and operational	LowLowLow	MediumMediumMedium
Description		
Location risk: The Project will have activities in remote and difficult access areas, representing the risk of having delays and increased costs in the execution of the Project.		
Mitigation Measure(s)		
To mitigate risk, location will be a criterion for the selection of pilots, preferring those closer to the logistic structure. CIAT will have the capacity to supervise all implementation sites through visits and regular reports.		

The risk of currency exchange fluctuations (risk #6), is a latent risk frequently found, especially in long-term projects. However, the risk of having a lower currency exchange that will represent a negative impact for the Project, has a lower Likelihood of occurrence, but if happening, it could affect the Project's scope.

Selected Risk Factor 6		
Category	**Likelihood**	**Impact**
ForexForexForex	MediumMediumMedium	MediumMediumMedium
Description		
Currency exchange rate risk: Financial planning may be affected by future fluctuation in the currency exchange rates.		
Mitigation Measure(s)		
Coverage and good financial planning are used to help mitigate this risk. This would not change the Likelihood of occurring, but would mitigate the impact of changes in currency exchange rates on Project costs.		

The risk #7 refers to the probability and impact for money laundering, terrorist financing and prohibited practices risks.

Selected Risk Factor 7		
Category	Probability	Impact
ML/FT	Low	High
Description		
Probability and impact for money laundering, terrorist financing and prohibited practices risks.		
Mitigation Measure(s)		
CAF has established an AML program, customer screening, monitoring and related due diligence procedures that are designed to prevent doing business with entities and/or persons that engage in illegal activities, sanctions screening which includes lists of sanctions and restricted persons issued by		

countries or by international organizations (UE, UN, US- OFAC, UK, France, Canada, World Bank, Inter-American Development Bank, and a designated Compliance Officer. The contract (legal agreement) signed among CAF and executive agency and other relevant parties, there are obligations to comply with AML and FT regulations and to prevent prohibited practices. Additionally, the business manager performs due diligence through the AMLCFT risk profile and KYC checklist. They also carry out the screening of the MHCP, MADR and related parties against the international sanctions lists. The information is updated according to the risk profile, once a year for low-risk clients and twice a year for medium risk.

The risk #8 refers to the volatility of agricultural commodities prices.

Selected Risk Factor 8		
Category	Probability	Impact
Other	Medium	Medium
Description		
Volatility of agricultural commodities prices.		
Mitigation Measure(s)		
As part of its implementation, the CSICAP project will contribute to the reduction of crop price volatility, often associated with climatic events, with the improved information from big data, agroclimatic services, and improved crop management, which will allow farmers to improve decision making, lowering uncertainty and better coupling production with markets to reduce crop price variation. Regarding the prices of the supplies, in the event of a high increase of the prices of them, it is possible to reach an agreement with the producers´ association (which are strategic partners of the project) who usually have stock and the quantity required by the project is quite small.		

The risk #9 refers to the ability to find suitable contractors to undertake the work at the expected prices.

Selected Risk Factor 9		
Category	Probability	Impact
Technical and operational	Low	Medium
Description		
The ability to find suitable contractors to undertake the work at the expected pricepoint.		
Mitigation Measure(s)		
There is a pool of human talent that has worked in previous/similar experiences as the CSICAP project in Colombia so the risk to find suitable contractors to undertake the work at the expected price point is low. The risk will be mitigated by using this pool of human talent, as well as pursuing new talent from qualified rosters of candidates that can meet the minimum experience and the expected price point. Additional mitigation measure considered was during the formulation process of the project because the producers´ associations were active actors and they will be strategic partners for the implementation, so their human talent skills have been considered in the whole process.		

The risk #10 refers to the aspects identify in the impact assessment of the pilot about the vertical dissemination and how has been considered in the project.

Selected Risk Factor 10		
Category	Probability	Impact
Technical and operational	Low	High
Description		
Vertical dissemination to farmers of the technologies and good practices under components 1 and 2.		
Mitigation Measure(s)		
During the formulation process of the CSICAP project with the farmers associations (gremios) and the MADR, it included the transfer of technology and dissemination as key aspect in each component of the project considering the lessons learned from the pilot. As a result, there are dissemination and training activities with the technicians and with farmers in each component to strengthen the adoption of the technologies and its use by the farmers. In addition, there will be signed agreements between Gremios – Farmers/ producers based on previous experiences of projects between MADR-CIAT-Gremios that involve technology transfer to producers. These agreements will include three main sections: (i) protocol for technology delivery, control, and follow-up; (ii) guideline for the implementation and use of the technology and (iii) certificate of Delivery which will be signed by the producer and gremio including a photographic record.		

Following, and in a complementary manner, risks are shown in more detail, especially the effect they have on certain specific components of the Project. In this case, risk assessment can change to the previous one since the first one is related to the entire project, while the one following relates to specific Project components, or other risks that were not mentioned previously, of lower cost or concern. The most relevant measure identified ex ante or ex post actions for each situation are mentioned y finally, one (1) or several institutions responsible for risk management or handling the situation, are introduced. Table 15. Low risks identified in the Project~~Table 15. Low risks identified in the Project~~ shows risks assessed as high and medium, which are the ones demanding more attention.

Tabla 14. Identified high and medium risks of the Project

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of Mitigation Activities	Responsible
Resources managed by Gremios and work teams	Drastic drop of currency exchange rate (TRM)	1. High	2. Medium	1. High	Adjust the operational plan and obtain approval from the corresponding entities.	Alliance, Gremios, Agrosavia, MADR, CAF
Gremios, Agrosavia, CIMMYT or CIPAV	One (1) or several Gremios or partners breach deliverable's schedules	2. Medium	2. Medium	2. Medium	Establish a stricter follow-up and supervision protocol especially for those cases in which institutional capabilities were assessed as low.	Alliance

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of Mitigation Activities	Responsible
Field personnel	Public Order Factors (security)	2. Medium	2. Medium	2. Medium	This criterion was basically considered to define working sites. If selected areas have this problem, and depending on the time of execution of the Project and investments made, the possibilities of moving activities to other regions will be considered.	Alliance, Gremios, Agrosavia, MADR, CAF
Result 1.1. Digital Agriculture Result 1.2. Climate services	Desertion of professional who have performed most of the capacity building process of the program once the Project ends.	1. High	3. Low	2. Medium	All documentation of protocols, databases, methodologies, and results will be sorted in a repository in order to facilitate the seamless Project conveyance process.	Gremios
Result 2.1. Genetic improvement	Delays in registration of new varieties by competent authorities.	2. Medium	2. Medium	2. Medium	Detailed follow-up of the registration process and make the required processes before competent authorities in order to comply with the planned timeframes. In case of excessive delays, ask MADR to mediate the situation.	Alliance, Gremios, Agrosavia y MADR
Result 1.1. Digital agriculture Result 1.2. Climate services Result 2.1. Genetic improvement	Logistic problems with timing to acquire equipment and inputs, preparation, execution of derived agreements, personnel hiring and consultancies.	2. Medium	2. Medium	2. Medium	Project planning considering average time taken for processes within each of the institutions. However, there will be a logistics assistant who will follow-up the different processes and will generate delay alerts caused by non-compliance of timing established in the supply chain and contracting area.	Alliance, Gremios and Agrosavia

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of Mitigation Activities	Responsible
Result 2.1. Genetic improvement	Assays losses	2. Medium	2. Medium	3. Medium	There are protocols for each crop and experiments which will be adequately performed.	Alliance, Gremios and Agrosavia

Table 15. Low risks identified in the Project

~~Table 15. Low risks identified in the Project~~ lists a series of minor risks that shall also be considered, knowing that in case of occurrence, an action shall be taken, especially those that in spite of having a low Likelihood of occurrence, if they occur will represent a high impact on the development of the Project

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Table 15. Low risks identified in the Project

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of risk mitigation activities	Responsible
All Components	One (1) or several Gremios or partners decide to withdraw from the project for reasons related to the Project's development, or for exogenous reasons	1. High	4. Very low	3. Low	Hold meetings among the different Project managers of the Gremio and escalate the issues. If the situation is not resolved, ask for intervention of MADR to mediate in a potential conflict.	Alliance
Result 1.2. Agroclimatic services	New models' performance is not satisfactory.	1. High	4. Very low	3. Low	Consultancy services of an internationally recognized institution have been included to support the revision of validation procedures and recommendation of methodological alternatives which allow exploring new working routes.	Alliance
Result 2.1. Genetic improvement	Normal climate conditions over the duration of the Project, without climate phenomena, such as droughts, excessive rainfall, and/or high	1. High	4. Very low	3. Low	If this is the case during the first years of the project, climate forecast information will be used to analyze the possibility of changing locations.	Alliance, Gremios and Agrosavia

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of risk mitigation activities	Responsible
	temperatures in all work sites.					
All Components	Restrictions due to health emergencies, or others	2. Medium	3. Low	3. Low	The strategy is to have field personnel in the different Project sites. In case of strong mobility restrictions, the teams will be reinforced through travelling and per diem expenses.	Alliance, Gremios and Agrosavia
All Components	The proper action coordination planned in the Project is not achieved.	2. Medium	3. Low	3. Low	Thematic leaders and crop coordinators have been appointed to achieve an adequate articulation of actions in each crop, as well as different actions among Gremios.	Alliance
Result 1.2. Agroclimatic services	Loss of trust of Producers and Technicians due to improper agroclimatic forecasts/recommendations.	2. Medium	3. Low	3. Low	Capacity building exclusively focused on understanding the uncertainty concept, which will be reinforced wherever improper forecasts are made.	Alliance, Gremios and Agrosavia
Result 1.1. Digital agriculture Result 1.2. Climate services	Desertion of Project's professionals with high degree of expertise/education or those who have participated in great part of the capacity building program.	2. Medium	3. Low	3. Low	The Project has all protocol documentation, databases, methodologies and results filed in a repository in order to facilitate a seamless conveyance of the Project. It also has several experts on each topic in the institutions, which guarantee the provision of support during the transition.	Alliance, Gremios and Agrosavia
Result 2.1. Genetic improvement	Low yield in seed multiplication processes.	2. Medium	3. Low	3. Low	Protocols are established for each crop and experiments to be duly performed.	Alliance, Gremios and Agrosavia

Project/Component/Product	Risk	Impact	Likelihood	Risk Level	Description of risk mitigation activities	Responsible
Result 1.1. Digital agriculture Result 1.2. Climate services Result 2.1. Genetic improvement Result 2.2. Water and carbon footprint	Theft or intentional damage of equipment	3. Low	3. Low	3. Low	Equipment security will be one of the criteria considered when selecting work lots,	Alliance, Gremios and Agrosavia
Result 1.1. Digital agriculture Result 1.2. Climate services	Assay loss	3. Low	4. Very low	3. Low	Protocols are established for each crop and experiments to be duly performed.	Alliance, Gremios and Agrosavia
Result 2.2. Water and carbon footprint	Program withdrawal or breach by Project beneficiaries	3. Low	2. Medium	3. Low	Commitment minutes will be written with beneficiaries in order to register the Project's conditions. If the situation continues, depending on time and investment made, substitutes will be searched for.	Alliance, Gremios and Agrosavia

8. MULTI-STAKEHOLDER ENGAGEMENT

8.1 KEY RESULTS OF MULTI-STAKEHOLDER CONSULTATIONS

A total of 24 group work plenary sessions (See Table 8) were held with participation of decision-makers and different work teams to present advancements in formulations reached at bilateral meetings among different teams. A total of 86 officials from fourteen (14) national institutions directly related to climate change adaptation and mitigation in the Colombian agriculture and cattle farming sectors participated, along with 39 CGIAR experts on different crops and topics.

Initially, Alliance Bioversity-CIAT presented the scientific formulation capabilities and the validation of mitigation and adaptation practices. On the other hand, each Gremio presented the existing gaps and needs in climate change adaptation and mitigation. Then, together, they identified the progress made in each crop, evaluating critical issues and potential alternatives to close such gaps.

In a second set of meetings held between Alliance Bioversity-CIAT and each Gremio, a technical proposal for the result was structured in order to respond to each sector's needs. Global activities, sub-activities and deliverables by crop were defined.

In a third work session, each of the proposed activities were defined in detail, including the execution sites, each activity's beneficiaries (Producers, Gremio and independent professionals, and entities) and an execution timeline by activity. Additionally, methodological approaches were established for the execution of each activity.

In a final round of meetings and with the level of detail obtained, the budget for each of the crops was determined, per year, item and activity.

Tabla 16. Plenary work sessions held with each of the Gremios

Gremio	Date	No. of Meetings	No. of Participants
Fedearroz	March 31, 2020	First	16
	May 13, 2020	Second	36
	July 31, 2020	Third	33
Augura / Asbama	September 30, 2020	First	42
	November 5, 2020	Second	32
Fedepapa	April 15, 2020	First	5
	October 23, 2020	Second	32
Fedepanela	March 11, 2020	First	12
	April 14, 2020	Second	4
	October 23, 2020	Third	38
Cenicaña	July 30, 2020	First	5
	November 11, 2020	Second	43
	November 26, 2020	Third	56
FNC / Cenicafe	July 27, 2020	First	5

Gremio	Date	No. of Meetings	No. of Participants
	August 11, 2020	Second	13
	October 29, 2020	Third	41
Fedegan / Cipav	February 11, 2020	First	15
	October 21, 2020	Second	40
	November 25, 2020	Third	40
Fenalce / Cimmyt	February 25, 2020	First	15
	May 20, 2020	Second	39
	September 3, 2020	Third	40
Agrosavia	June 24, 2020	First	6
	August 6, 2020	Second	18

The purpose of the first work session was to set topics and priorities, forming the different work teams for each topic from the different institutions, Alliance Bioversity-CIAT-Gremio-Agrosavia, with a topic leader and team coordinators from each institution. These teams will have multiple bilateral work meetings to discuss priorities in detail, technological options, and then the entire design of the Project, in detail. Following are some of the most relevant conclusions from the bilateral meetings.

RICE

Priorities according to rice census and previous research were established, especially considering results obtained in the pilot MADR-CIAT program. Direct beneficiaries' profiles were established according to the group of Gremio professionals, and considering the participation of universities which will benefit from training on different selection methodologies, as well as from receiving line characterizations developed by FEDEARROZ and accessions from the germplasm bank from the rice program of Alliance Bioversity-CIAT. Afterwards, the Gremio determined the areas with the highest technology transfer rate and areas more likely to have climate limitations which affect crop stability, according to variety adoption data. This data is established according to the joint research agenda of Alliance Bioversity-CIAT-FEDEARROZ-MADR, and the determined priorities for genetic improvement derived from joint projects in which climate and physiological modelling of the crop has been performed in different regions.

SUGAR CANE

The Project initially considered as priority the strengthening of the monitoring network of metric potential and water balance as platform for the planning of irrigation, drainage and efficient water use, and given the importance of this activity, to advance in the application of precision irrigation in this crop. When making this proposal, MADR prioritized this initiative to be finance with MADR's own resources in 2021. A project was structured, in which the Alliance Bioversity-CIAT leads the project and Cenicaña acts as partner through a derived agreement, as well as with partners from other crops (Agugura for bananas, Fedepanela for panela sugar cane), considering the generation of work mechanisms under the format implemented in the pilot program with these institutions, especially with Augura and Fedepanela, who are partners with whom this is the first time we work under a cooperation scheme. Another of the topics discussed, but finally was discarded due to the high costs of machinery and equipment required, was the implementation of a mitigation of greenhouse gas emissions in the sugar cane industry, which implied the Project to deliver eight (8) high cost machines to the sugar mills.

Discussions with the Gremios were made, analyzing the possibility of including actions in the Project that enhance cooperation and interaction with other institutions in the region, so they can benefit with the information, knowledge and capabilities of the Gremio. The possibility of having the Gremio lead the creation of the Agroclimatic Technical Work Group for Valle del Cauca, was discussed, considering that is the Department where the Gremio is mostly present. In this process, an agreement was reached with the Government of Valle del Cauca, MADR and Alliance Bioversity-CIAT, and the MTA was created for Valle del Cauca, which is currently jointly led by the Government of Valle del Cauca and Cenicaña.

MAIZE

Since 2018, the International Center for Maize and Wheat Improvement (CIMMYT) and Alliance Bioversity - CIAT have led the development of the maize strategic plan for maize in Colombia, with participation of different government levels, national and international research centers, civil society, Gremios of producers and the private sector, to design a better future for maize in the country, based on a common objective: increase cord productivity and profitability in a sustainable manner, preserving its biodiversity, and improving resource management. As a result of this participative process in which more than 49 stakeholders from the main public and private entities making part of the maize value chain were consulted. With them, objectives were established and strategies were aligned in order to increase national maize offer and strengthen resiliency and food security of Colombia, with special focus on climate change impact. Among the resulting strategies were having access to improved seeds, which set the basis for the current proposal. Three (3) of the stakeholders involved in the strategic plan, also participate in the component of the current project (Fenalce, Agrosavia and CIMMYT). Therefore, considering that the four (4) institutions (Fenalce, CIMMYT, Alliance Bioversity-CIAT and Agrosavia) led this initiative, it was agreed to identify and prioritize the most relevant topics of this initiative, which are aligned with this Project's framework. This was taken as benchmark for the detailed plan of activities and sub-activities of the Project.

TROPICAL FORAGE

The cattle farming Gremio represented by Fedegan, jointly working with CIPAV, expressed the relevance of this Project's proposed activities as a result of experiences obtained in the Sustainable Colombian Cattle Farming Project, and the technical and governance structure derived from that project. This structure includes local, regional, national and international stakeholders who have facilitated resources for sustainable practices in cattle farming. One of the conclusions of the first meeting was the importance of mapping the initiatives and rescue lessons learned from different projects (Tapasco et al 2019). Based on that, priorities and work sites were identified, considering how they can be complementary and have synergies with other initiatives.

COFFEE

The Project was broadly discussed in the Technical Management of the National Coffee-Growers Federation of Colombia and after, with the Research Committee of Cenicafé. With regards to seed multiplication, scientific personnel of Alliance Bioversity-CIAT and Cenicafé, specialized in clonal propagation and *in vitro* systems, discussed the most relevant matters to execute the proposed activities. The need to have coffee massive and in vitro clonal propagation forms became evident in these meetings. The relevance of developing material with excellent agronomic characteristics adaptable to climate change and less susceptibility to broca was also mentioned. This Gremio dedicates considerable time to the analysis of implications of each of the actions to be executed, maintaining the firm decision of keeping all initiatives in experimental fields or research farms of Cenicaña, until a sufficiently tested validation process that demonstrates stability in the results is complete, before starting the testing and validation phase with Producers.

POTATO

Fedepapa Gremio's participation was very limited in terms of personnel and time, in comparison with other Gremios. Prioritization of potato chain demands was made in the seven (7) departments with highest potato production (98% of potato production located in such area). One of the main demands of the potato supply chain is the improvement of seed production, which shall be of good quality, as well as the implementation of strategies to increase its use. This demand is a high priority in the departments of Cauca, Antioquia, Norte de Santander, Santander, Nariño, Boyacá and Cundinamarca. The different demands were analyzed during the seven (7) bilateral meetings held, leaving quality seeds as one of the priorities of the Gremio.

"PANELA" SUGAR CANE

The participation of this Gremio was low, including the short time dedication of its officials in the project formulation phase. In the socialization of the project to communities and institutions interested in the topic, the Project had a positive assessment as to objectives and impact achieved by these activities in productive, economic, environmental and social terms, for the development of the panela agroindustry in Colombia.

MUSACEAE

Main stakeholders of the musaceae Gremio in the public sector (Agrosavia), as well as the private sector (Augura, Asbama, Asohofrucol) were consulted. At least five (5) bilateral meetings were held with each of the Gremios, in order to: a) define priorities, b) co-design the necessary interventions, c) discuss execution strategies, d) identify direct and indirect beneficiaries, and d) calculate costs and availability to participate directly in the implementation of the project. Gremios recognized that proposed interventions, such as the evaluation of new varieties and the development of bio-products will allow better water resources management and reduce the use of chemical products causing high greenhouse gas emissions, contributing to mitigate climate change effects. Both the private sector (Augura), and the public sector (Agrosavia), as well as Alliance Bioversity-CIAT committed themselves to actively participate in the Project's implementation.

Additionally, 52 consultations and group sessions were held with extensionists, producers, ethnic groups and institutional stakeholders at territorial and national level, regarding their perceptions and recommendations for the implementation of the Project, having participation of 205 people, out of which 74 were women, and 18 from ethnic groups. The main conclusions of these consultations are in item 2.2.3. – Shareholders Views, included herein.

Capacity building of diverse stakeholders in the agriculture and cattle-farming sectors is a need shared by all Gremios and partners, being clearly aligned with the need to cover a broad spectrum of sector beneficiaries, producers at all production scales, technicians and professionals of the Gremios, municipal public entities, the academia, researchers and stakeholders from other supply chains, to modernize the sector towards resiliency against climate change effects. The objective is to enhance competencies and provide an important coverage of topics and technologies used and developed during the Project.

Meetings were also held for the construction of the M&E and MRV systems of the Project, concluding that several of the institutions involved (Agrosavia, Cenicaña, Cenicafe, and Fedearroz) actually know the methodologies to be used to develop these information systems and provide follow-up. For the other institutions, this was a great opportunity to know more about the topic and support the construction of indicators. All institutions are very interested in participating in the execution and implementation of the system.

For more information, see Annex 7.

9. Conclusions and Recommendations

9.1 Key Conclusions and Recommendations

The simple formulation of the Project has already shown an important result: reuniting the different agriculture and cattle-raising institutions to reflect about solutions required to face the serious challenges posed by climate to the crops. The mere fact of analyzing figures and the current of each region in relation to climate and challenges faced, as well as those in the future, represents an important input for researchers in charge of generating technologies for the next years and decades. Secondly, is being able to think about comprehensive and long-term solutions. The fact that each group of professionals from different institutions will analyze their own strengths and their role in the Project based on the identified needs and strengths, is an important step in terms of institutional synergies.

This is an innovative project from different perspectives. From a technological perspective, part of the main solution is the technological component, which connects an innovative solution to the needs of the Colombian agricultural and cattle farming sectors, which is becoming increasingly important at global level: the modernization of agricultural and cattle farming extension services and the increase in coverage. Implementation of Act 1876 of December 29, 2017 is currently being regulated. Its object is the creation and commissioning of the National System for Agricultural and Cattle Farming Innovation (SNIA), that also considers that one of the elements to be strengthened consists of services to advise Producers on climate change adaptation and mitigation. The Project conceives the installation of all the necessary infrastructure to massively cover Colombia, but also capacity building to guarantee its operation and maintenance; and here is the second innovative component of the Project, but in this case, it is related to institutional matters and resource leveraging. It is the involvement of Gremios as a key factor to be sustainable.

These Gremios are a unique global figure since they are institutions that represent agricultural and cattle farming producers before the national government and other entities. Many of these Gremios manage parafiscal resources, another unique figure, because these are public resources collected by a value withholding in the sale of agricultural and cattle-farming products, which are allocated to re-invest in the same crop which generated such payment. This investment shall cover research and extension services costs, among others. Gremios which do not have parafiscal payments rely on voluntary direct contributions (i.e., sugar cane).

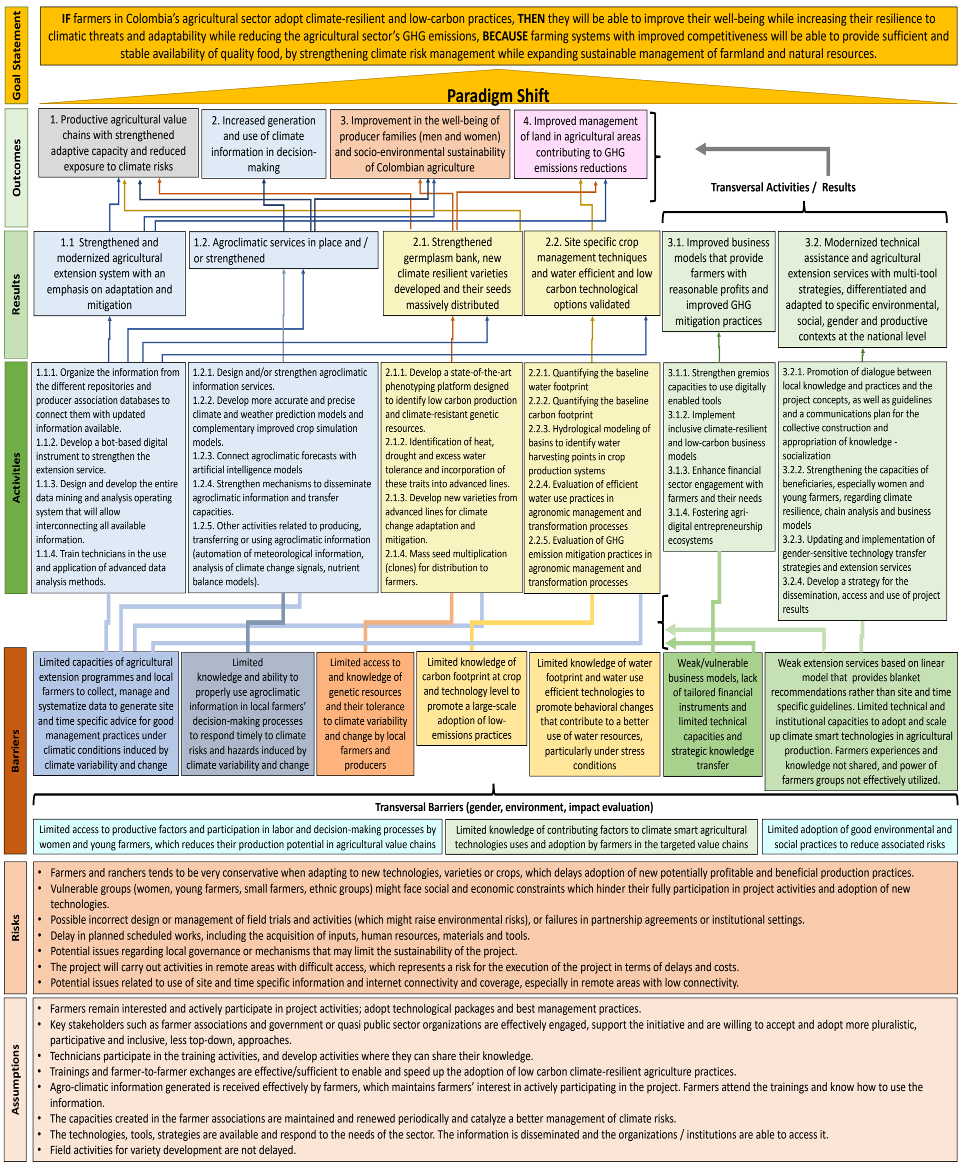
The strategy and scope of this Project is to invest to strengthen Gremios so they are prepared to face climate change, having the required information, knowledge, capabilities, and technologies for their associates. The Gremios will be in charge during the next decades, of operating and maintaining all the infrastructure and installed capacity, being responsible for the escalation of proposed technologies and the development of new technologies based on the new installed capacity.

The Project’s estimated investments are for the implementation of public services and assets. This means Big Data platforms, climate services, and new genetic material available for Producers, who will have easy and free-of-charge access to the generated information (but having the Gremios pay for operation and maintenance costs and paying costs related to seeds multiplication and distribution logistics). With regards to technologies to reduce water and carbon footprints, the Project considers that the group of direct beneficiaries, giving priority to vulnerable population, but strategically distributed, will be the strategy to massify this type of technologies, and allowing hundreds of thousands additional producers to implement them. This work will be accompanied by strengthening the analysis of supply chains and business models to expand the adoption possibilities under different promotion approaches and mechanisms.

Gender gaps and some social and environmental tensions, seem an important matter in the Colombian agriculture and cattle farming sectors. It is highly recommendable to maintain the gender action plan and the environmental and social management framework of the Project. Acknowledging gender topics in the Gremios and the sectors' institutions is still incipient and is not within institutional priorities. Therefore, these topics are of utmost relevance for the Project. Environmental issues are much better dominated and managed by the Gremios and their progress in terms of knowledge and actions implemented is evident. However, there are still some tensions, many of which are related to water resources. Result 2.2, which covers water footprint and has great relevance, looks for alternatives that allow reducing the stress, variability and climate change scenarios, which tend to increase such tensions. The potato crop and the moorland ecosystem appear as important matters because Colombia is strongly advocating for regulations to protect this eco-system. A large quantity of potato crops is sowed on this strategic ecosystem, where tensions are evident, enormous, and increasing, when there are no production or income alternatives for the farmers. Although the Project has decided not to make any direct intervention in potato crops located in moorlands, a serious discussion shall take place during the development of this Project, to establish mechanisms under which this Project could reduce such tensions, mainly because potato crops in Colombia have an intensive use of inputs and its irrational use of pesticides is widely known, especially considering that one of the technologies of the Project has to do with sustainable production of potato, using conservation agricultural techniques.

Project risks seem to be manageable. However, currency exchange fluctuations may significantly affect the Project's scope, especially in relation to operations of the Gremios and national institutions. The other risks are of operational nature. In this sense, there is broad previous experience in agreements between MADR-Alliance Bioversity-CIAT-Gremios, but at a minor scale. Therefore, it is important to entail the levelling at the beginning of the Project, of procedures, formats, financial management and other administrative and operational matters. Given the importance of this Project, a fundamental aspect will be the coordination and supervision mechanisms.

APPENDIX 1. THEORY OF CHANGE



APPENDIX 2. CLIMATE CHANGE RISKS AND IMPACTS IN THE TARGETED AGRICULTURAL SUB-SECTORS, AND ADAPTATION AND MITIGATION INTERVENTIONS AND BENEFITS

<table>
<tr><th rowspan="2">Crop</th><th rowspan="2">Hazard[1]/ climate risk[2]</th><th rowspan="2">Impacts</th><th rowspan="2">Component 1. Digital agriculture and climate services (Outputs 1.1 y 1.2)</th><th colspan="3">Component 2. Genetic improvement, crop management techniques and other technological options and their scaling-up to increase climate resilience and promote low-carbon agricultural development</th><th rowspan="2">Adaptation and Mitigation Benefits [3]</th></tr>
<tr><th>Output 2.1. Strengthening the germplasm bank, developing new varieties and supporting the massive multiplication of seeds for adaptation and mitigation</th><th>Output 2.2. Crop management techniques and other technological options and their scaling-up to increase resilience and mitigation

Adaptación</th><th>Output 2.2. Crop management techniques and other technological options and their scaling-up to increase resilience and mitigation.

Mitigación</th></tr>
<tr><td rowspan="2">Rice</td><td rowspan="2">Low radiation/ low yields
High humidity/increased diseases
Dry periods/irrigation supply problems
High temperatures/low yields

See: Castro-Llanos et al. (2019), Ramirez-Villegas et al. (2012), FAO and MADR (2013), Cortés and Alarcón (2017)</td><td rowspan="2">For the dry Caribbean region, a 22% reduction in climatic suitability is estimated for 2050 at RCP 8.5 (Castro-Llanos et al.,2019).
For the humid Caribbean region, changes in crop phenology are expected by 2050 (Ramirez-Villegas et al., 2012).
In the central part of the country, an 80% reduction in climate suitability is expected by 2050 with RCP 8.5 (Castro-Llanos et al., 2019).
For the eastern plains region, a 25% reduction in yield is estimated for 2030 (FAO and MADR, 2013).
In some regions where it is possible to take advantage of better climatic conditions projected for the crop are the middle and upper parts of the Magdalena inter-Andean valley (Cortés & Alarcón, 2017, FAO and MADR, 2013) and the upper part of the Cauca inter-Andean valley (Castro-Llanos et al., 2019).</td><td rowspan="2">Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models)</td><td rowspan="2">New varieties tolerant or resistant to drought, water deficit, high temperatures and low radiation (Develop, validation, massive multiplication and deliver of seed to farmers)</td><td>Water resource planning at the basin level</td><td>Quantifying the carbon footprint</td><td rowspan="2">Adaptation:
Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.
Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of genetically improved varieties and efficient water use practices.

Mitigation: Direct emissions reductions 41,016 tCO2e</td></tr>
<tr><td colspan="2">Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development</td></tr>
<tr><td>Maize</td><td>Low radiation/ low yields
High humidity/increased diseases
Dry periods/irrigation supply problems
High temperatures/low yields/increased pests

FAO and MADR (2013(, Goavaerts et al (2019), CIMMYT and CIAT (2019), DNP-BID (2014).</td><td>Yield reductions are predicted in the main production areas throughout the country. Estimated yield reductions to 2030 for the humid Caribbean fluctuate between 12 and 28% (FAO and MADR, 2013, Goavaerts et al., 2019, CIMMYT & CIAT, 2019).
In the inter-Andean valleys, the yield reduction to 2030 is estimated to be between 6 and 62% (Goavaerts et al., 2019, CIMMYT & CIAT,2019, FAO and MADR, 2013).
For the eastern plains region, yield reductions to 2030 are estimated to be between 1 and 20% (Goavaerts et al., 2019, CIMMYT & CIAT,2019, DNP-BID, 2014).
At the local level, in Cereté (Córdoba) a decrease in yield of between 13% to 28% is expected, in Espinal (Tolima) between 6% to 8%, and in Uribe (Meta) from 1% to 3%.</td><td>Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models)</td><td>New varieties tolerant or resistant to drought, water deficit, high temperatures and disease resistance (Develop, validation, massive multiplication and deliver of seed to farmers)</td><td colspan="2">Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development</td><td>Adaptation:
Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.
Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of genetically improved varieties and efficient water use practices.

Mitigation: Direct emissions reductions 15,965 tCO2e</td></tr>
<tr><td rowspan="2">Cattle</td><td rowspan="2">Waterlogging-rainy season/Forage rot
Dry periods/low forage production
High temperatures/animal stress

(DNP-IDB, 2014)
CIAT and CORMACARENA (2018)</td><td rowspan="2">For cattle farming, the economic impacts of climate change in Colombia show that the departments experiencing the greatest reductions in cattle production are Nariño (18.5% reduction in production when compared to the 1970-2010 baseline scenario), Casanare (6.0%), Córdoba (5.4%), Caquetá (4.6%), Guaviare (3.6%) and Cundinamarca (3.5%) (DNP-IDB, 2014).</td><td rowspan="2">Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recomendations) for ranchers</td><td rowspan="2">New forrages varieties tolerant or resistant to drought, water deficit and excces (Develop, validation, massive multiplication and deliver of seed to farmers)</td><td>Quantifying the water footprint
Evaluation of efficient water use practices</td><td>Quantifying the carbon footprint</td><td rowspan="2">Adaptation:
Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.
Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of efficient water use practices.

Mitigación: Direct emissions reductions 208,220 tCO2e</td></tr>
<tr><td colspan="2">Landscape restoration and Trasferencia tecnológica y escalamiento (implementación de modelos de ganadería sostenible: sistemas silvopastoriles, rotación de potreros, mejoramiento de praderas, cercas vivas)</td></tr>
<tr><td rowspan="2">Panela sugarcane</td><td rowspan="2">High temperatures/increased pest infestation
Excess of water/plant rot
Dry periods/low yields

Since there are no specific studies on this crop, the risk comes from the experts opinion from the guild, Agrosavia, Cenicaña and CIAT who are part of the formulation of the project.</td><td rowspan="2">This is a crop of great social importance in Colombia, as it is the basis for the livelihoods of some 160,000 families of smallholder farmers. However, little has been studied and there is practically no research related to climate.</td><td rowspan="2">Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recomendations) for panela sugar cane producers</td><td rowspan="2">New varieties tolerant or resistant to drought, water deficit and high temperatures (Develop, validation, massive multiplication and deliver of seed to farmers)</td><td>Quantifying the water footprint
Water resource planning at the basin level
Evaluation of efficient water use practices</td><td>Quantifying the carbon footprint</td><td rowspan="2">Adaptación:
Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.
Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of efficient water use practices.

Mitigation: Direct emissions reductions 78,799 tCO2e</td></tr>
<tr><td colspan="2">Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development</td></tr>
</table>

Crop	Hazard[1]/ climate risk[2]	Impacts	Component 1. Digital agriculture and climate services (Outputs 1.1 y 1.2)	Component 2. Genetic improvement, crop management techniques and other technological options and their scaling-up to increase climate resilience and promote low-carbon agricultural development			Adaptation and Mitigation Benefits [3]
				Output 2.1. Strengthening the germplasm bank, developing new varieties and supporting the massive multiplication of seeds for adaptation and mitigation	Output 2.2. Crop management techniques and other technological options and their scaling-up to increase resilience and mitigation Adaptación	Output 2.2. Crop management techniques and other technological options and their scaling-up to increase resilience and mitigation Mitigación	
Potato	Dry periods/low yields Excessive rainfall/increased diseases Frosts/crop loss High temperatures/increased pests, displacement of production DNP-BID (2014), FAO and MADR (2013)	The areas for this crop are concentrated in the high zones of the mountains of the Andean region, and the estimated yield reduction to 2030 is estimated at between 10% and 40% (DNP-BID, 2014, FAO and MADR, 2013). DNP-BID (2014) estimates that Nariño and Cundinamarca will have the greatest reductions in yields. The drop in yields compared to those simulated in the baseline scenario are related to the higher expected occurrence of irregular precipitation periods (rainfall concentrated in short periods and long periods without rain) and increases in air temperature that affect various physiological processes of the crop. In Cundinamarca, a decrease in yields ranging from 5% to 35% when compared with those estimated for the 2000-2010 period is expected. In addition, in the case of Boyacá, there would be a downward trend ranging from 7% to 12% for yields between the period 2041 and 2070.	Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recomendations) for potato producers	New varieties tolerant or resistant to drought, water deficit and high temperatures (massive multiplication and deliver of seed to farmers)	Quantifying the water footprint Evaluation of efficient water use practices	Quantifying the carbon footprint	Adaptation: Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption. Increase productivity from the use of efficient water use practices. Mitigation: Direct emissions reductions 34,324 tCO2e
					Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development (conservation tillage models)		
Coffee	Excessive rainfall/low yields High temperatures/berry borer infestation Ramirez-Villegas et al. (2012), (CIAT-USAID-FNC, 2017).	This crop is distributed in the mid-mountain zone across the entire mountain geography of the Andean region. Here, changes in the phenology of the crop are expected by 2050 (Ramirez-Villegas et al., 2012), a gradual loss of climatic suitability and decrease in yields by 2050, above 1500 masl (Ramirez-Villegas et al., 2012), and an intensification of problems related to pests and diseases (below 1500 masl) by 2050 (Ramirez-Villegas et al., 2012). In a specific study in Colombia's 'coffee-growing region' as it is known, it was reported that by 2030, 22% of the current suitable coffee-producing area is expected to have been lost (CIAT-USAID-FNC, 2017).	Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models)	New varieties tolerant or resistant to pest resistance (massive multiplication and deliver of seed to farmers)	Water resource planning at the basin level Evaluation of efficient water use practices		Adaptation: Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption.
Sugarcane	Waterlogging/crop loss Dry periods/irrigation supply problems FAO and MADR (2013). Ramirez-Villegas et al., (2012).	Higher temperatures, higher dioxide concentration, and higher yields 12.5% (FAO and MADR, 2013). Gradual loss of climate suitability and decrease in yields by 2050 (Ramirez-Villegas et al., 2012).	Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic information services improved (climate and crops predictions and pest and disease alert prediction models)	New varieties tolerant or resistant to drought, water deficit and exces (Develop, validation, massive multiplication and deliver of seed to farmers)	Quantifying the water footprint	Quantifying the carbon footprint	Adaptation: Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption. Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of genetically improved varieties.
					Landscape restoration (aislamiento y protección de rondas de quebradas y rios)		
Musacese	Dry periods/low yield	Banana crop is concentrated in two regions of the country, one near the humid Caribbean zone and the other near the dry Caribbean. Changes in crop phenology are expected by 2050, changes in pest and disease incidence (below 500 masl) by 2050 and gradual loss of climatic suitability and decrease in yields by 2050, below 500 masl (Ramirez-Villegas et al., 2012). Plantain crop is found throughout much of the national geography and in different thermal floors. By 2030, problems are expected with high temperatures and therefore loss of climatic suitability in the lower parts, especially in the dry humid Caribbean and the Orinoquia (CIAT, 2014).	Adaptación: Big Data platforms using remote and non-remote sensors and agroclimatic services (information and recomendations) for banana and plantain producers	New varieties tolerant or resistant to drought, water deficit and high temperatures (validation, massive multiplication and deliver of seed to farmers)	Quantifying the water footprint Water resource planning at the basin level Evaluation of efficient water use practices	Quantifying the carbon footprint	Adaptation: Increase productivity, loss reduction, lower costs and increased profitability resulting technologies for agroclimatic risk management and digital agriculture adoption. Increase productivity, loss reduction, lower costs, Increased profitability resulting from the use of efficient water use practices. Mitigation: Direct emissions reductions 53,973 tCO2e
	High temperatures/ low yields and increased pest infestation				Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development		

1. IDEAM. 2015. http://documentacion.ideam.gov.co/openbiblio/bvirtual/022963/escenarios_cambioclimaticodepartamental/Estudio_tecnico_completo.pdf
2. See the bibliographic references within each box
3. For benefits data see Annex 3 financial and economic analysis , and tables D1.1 y D1.2 (FP) to see details of beneficiaries and mitigation info

Appendix 3. Initial Criteria for the Selection of Beneficiaries, Areas and Eligible Interventions

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
Component 1. Digital agriculture and climate services for rural modernization with an emphasis on adaptation and mitigation.	Result 1.1. Strengthened and modernized agricultural extension system with an emphasis on adaptation and mitigation.	Activity 1.1.1. Organize the information from the different repositories and producer association databases (public and free-access systems) to connect them with updated information available from existing free-access platforms through remote sensing or other sources. Activity 1.1.2. Develop a bot-based digital instrument to strengthen the extension service Activity 1.1.3. Design and develop the entire operating system of data analysis and mining which will allow the interconnection of all available information. It will also develop systems which allow the automation of analysis and modelling processes to have more robust recommendations and agile and efficient processes. Activity 1.1.4. Train technicians in the use and application of advanced data analysis methods.	The municipalities in which the project activities will be implemented have been identified, but the producers who will be beneficiaries have not yet been selected. Producers will be selected during the first 6 months of the project. For the selection of the beneficiary producers of the project, the following procedure will be followed. This process is based on requirements that the MADR requests in the different programs and projects that are developed with public resources. 1. A procedure and schedule is established for a call for interested parties to participate in the project. 2. Project socialization workshops are held to present the scope and other relevant	Component 1 activities will be carried out in 179 municipalities in 6 agricultural sub-regions (Dry Caribbean, Humid Caribbean, Inter-Andean Valleys, Foothills / Mid-mountain, High Mountain, Eastern Plains) in 3 regions of the country (Caribbean Region / North, Andean Region / central-south and Orinoquia Region / East) - for more information see page 93 of section 6.2 PROJECT OBJECTIVE AND TARGET SITES. The focus regions are those that correspond to the highest production and productive potential for each crop that are also exposed to climate hazards. A summary of the key climate hazards per region is provided below, with mention of the most economically important affected systems. <u>Dry and Humid Caribbean:</u> High temperatures and dry periods (low yields in rice, maize and *musa* crops, animal stress for cattle, problems for irrigation supply with rice and banana, low forage production for cattle). <u>Inter-Andean Valleys:</u> Dry periods (irrigation supply problems with rice, maize, sugarcane), gigh temperatures (low yields/increased pest infestation with maize) flood and waterlogging (crop loss sugarcane) <u>Foothills/Mid- mountain:</u> High temperatures (increased pest infestation with panela sugarcane and *musa* crops, low yields in *musa* crops, berry borer infestation with coffee), excess of water (plant rot with panela sugarcane) dry periods (low yields panela sugarcane and *musa* crops), excessive rainfall (low yields and quality in coffee) <u>High Mountain:</u> Dry periods (low yields in potato and low forage production for cattle), excessive rainfall (increased disease potato), frosts (crop loss for potato), increased temperatures (increased pests, displacement of production in potato and animal stress for cattle)	Big Data system (Output 1) for each of the crops, which considers the entire process; of organizing existing databases, capturing missing information through different methods, ranging from surveys, collecting information from technicians, tools for reporting from producers, instrumentation with sensors in the field, and analysis with remote sensing, among others. All these systems will have capture, reporting and storage devices and mechanisms connected to centralized databases to make this process more efficient. Script/algorithms will be developed to analyze large databases and the different processes will be automated to achieve greater efficiency and lower costs for the Guild. All the necessary systems infrastructure will be acquired to set up a platform that will automate the entire data capture, storage and analysis reporting process, and will have interfaces and systems for disseminating information and recommendations to technicians and producers through different mechanisms, according to the conditions of the beneficiary producers and work areas. The result is the delivery of recommendations to producers with site-specific information at the farm, or even lot level. This entire process will be carried out with an emphasis on strengthening the Guilds' capacities. In this regard, all the infrastructure and equipment required, as well as personnel and training needs, were planned with the Guild. The Guild will be involved from the beginning with the implementation of the technological option and will be responsible for its operation during and after the project.
	Result 1.2. Agroclimatic services in place and/or strengthened.	Activity 1.2.1. Design and/or strengthen agroclimatic information services. Activity 1.2.2. Develop more accurate and precise climate and weather prediction models and complementary improved crop simulation models by using new-			Climate services (Output 2) involves improving the climatological network, improving the performance of climate models and new generation forecasting systems, calibrating crop models and integrating them with climate forecasts, developing new early warning services such as the occurrence of pest and disease infestations, and sub-seasonal services such as weather forecasting services. The big leap at this

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
		generation climate models, improving the performance of climate prediction models, modeling crop physiological processes, including alerts for pests, diseases and other abiotic factors (for example, frosts), and irrigation planning and optimization. Activity 1.2.3. Connect agroclimatic forecasts with artificial intelligence models (Result 1.1). Activity 1.2.4. Strengthen mechanisms to disseminate agroclimatic information and transfer capacities. Activity 1.2.5. Other activities related to producing, transferring or using agroclimatic information (automation of meteorological information, analysis of climate change signals, nutrient balance models)..	information on the measures to be implemented, as well as the procedures and requirements requested and the means for receiving applications. 3. Written information on the call for applications is shared with interested parties through trade associations, technicians, local institutions, and community leaders in the project's areas of intervention.	Eastern Plains: Low radiation (low yields for rice and maize), high humidity (increased disease for rice and maize), waterlogging-rainy season (forage rot for cattle), dry periods (low forage production), high temperatures (animal stress for cattle). The selected municipalities were chosen by common agreement between the Guilds, scientists from the Alliance of Bioversity International and CIAT, Agrosavia, MADR and DNP, according to the information available on the greatest climatic risks for the crops to be worked on, or according to the mitigation potential and the synergies and complementarities with other projects, and the number of producers and/or area under production. In addition, some considerations on security aspects and operational capacity of the Guilds (e.g., personnel, logistical capacity) and other organizations with presence in the regions were also considered in the selection.	point is to be able to move from probabilistic information at the level of Colombia's major regions to deterministic predictions associated with crop damage thresholds at the level of localities (municipalities or even villages).
Component 2. Genetic improvement, crop management techniques and other technological options and their scaling-up to increase climate resilience and promote low-carbon	Result 2.1. Strengthened germplasm bank, new climate resilient varieties developed and their seeds massively distributed	Activity 2.1.1. Develop a state-of-the-art phenotyping platform designed to identify low carbon production and climate-resistant genetic resources. Activity 2.1.2. Identify heat, drought and excess water tolerant accessions for rice, maize, potatoes, musaceae, and livestock (forages). Activity 2.1.3. Development of new varieties based on advanced lines for climate change adaptation and mitigation for rice, maize, livestock, banana (varieties that are tolerant or resistant to water deficit and diseases that demand high use of chemical fungicides, such as black Sigatoka) and sugarcane (water deficit, waterlogging and greater efficiency in nitrogen use).	4. Information and documentation provided by interested producers is received. 5. An official is appointed per zone to accompany and support the process of onboarding producers who request it. 6. The list of interested parties is consolidated for each of the zones and by crop.	These activities will take place at CIAT's campus in Cali -Colombia and at experimental stations located in the six agricultural subregions (Dry Caribbean, Humid Caribbean, Inter-Andean Valleys, Foothills / Mid-mountain, High Mountain, Eastern Plains) since they must performed under controlled conditions.	The development of genetic materials (Output 3) tolerant or resistant to certain environmental conditions is undoubtedly one of the key elements in adaptation. However, the time taken for the whole breeding cycle extends far beyond the period of this and most projects. In the MADR-CIAT pilot, just as for this project, it has been decided to resort to the use of advanced lines and other mechanisms to reduce the breeding cycle, such as the phenotyping platform and the application of certain techniques. The other important aspect is to be able to reach producers with material available in a timely manner for planting. Here we will carry out mass multiplication of genetic material with good performance (in terms of stability), under different environmental conditions, and material with specific conditions that are tolerant or resistant to certain climatic phenomena. This material will be delivered according to the threats identified in each of the areas, and for some materials the recommendations of the agro-climatic forecasts will be taken into

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
agricultural development		Activity 2.1.4. Massive seed multiplication for coffee, sugarcane, panela sugarcane, potato, banana and plantain through in vitro culture or the buds method for distribution to farmers.	7. Verification of the location of the properties with respect to the areas suitable for cultivation according to the UPRA (unit attached to the MADR). Farms outside these zones will not be eligible for the project. 8. The property must have at least 20% of its land in production of the crop for which it wishes to receive support from the project, with a minimum area of half (0.5) hectare in this use. 9. The producer must declare that he/she is not involved in any illegal activity contemplated in the Colombian Penal Code - Law 599 of 2000 and its modifications. 10. It is verified that the owner of the property or the lessee is not reported in the Clinton List (officially called Specially Designated	Potato: this activity is located in four municipalities located in three strategic departments (Nariño, Cundinamarca, Boyacá) were the potato production is concentrated. In this department was estimated yield reduction to 2030 at between 10% and 40% (DNP-BID, 2014, FAO and MADR, 2013). DNP-BID (2014) estimated that in Nariño and Cundinamarca will have the greatest reductions in yields. The drop in yields compared to those simulated in the baseline scenario are related to the higher expected occurrence of irregular precipitation periods (rainfall concentrated in short periods and long periods without rain) and increases in air temperature that affect various physiological processes of the crop. In Cundinamarca, a decrease in yields ranging from 5% to 35% when compared with those estimated for the 2000-2010 period is expected. In addition, in the case of Boyacá, there would be a downward trend ranging from 7% to 12% for yields between the period 2041 and 2070. Sugarcane: these activities will be developed in 46 municipalities in the Cauca valley were the production of sugarcane is concentrated. Higher temperatures and higher dioxide concentration, result in 12.5% biomass yield increase (FAO and MADR, 2013), but may result in lower sugar yield (Ramirez-Villegas et al., 2012) Musa crops: these activities will be implemented in 7 municipalities through all Caribbean region specially were musaceae production is concentrated. Banana crop is concentrated in two regions of the country, one near the humid Caribbean zone and the other near the dry Caribbean. Changes in crop phenology are expected by 2050, changes in pest and disease incidence (below 500 masl) by 2050 and gradual loss of climatic suitability and decrease in yields by 2050, below 500 masl (Ramirez-Villegas et al., 2012) Coffee: This activity will be implemented on two municipalities with mayor problems of berry borer infestation. Intensification of problems related to	account. To accelerate the process in the breeding cycle, state-of-the-art phenotyping and sequencing techniques will be used to identify the adaptation potential of new materials to environments with water deficit or excess, and low nitrogen availability. New varieties produced through conventional breeding or assisted by genomic selection models, adapted to climate change conditions, will provide technological options for climate change adaptation and mitigation.

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
			Narcotics Traffickers or SDNT list). 11. Each producer may only receive incentives for the implementation of measures in one crop. 12. Once all the information has been corroborated,	pests and diseases (below 1500 masl) by 2050 (Ramirez-Villegas et al., 2012). Panela sugarcane: this activity will be implemented on the 18 municipalities located on four of the most important panela production zones. This is a crop of great social importance in Colombia, as it is the basis for the livelihoods of some 160,000 families of smallholder farmers. However, little has been studied and there is practically no research related to climate. However, it is expected to have similar behavior as sugarcane, and may experience decreased sucrose yield by 2050 (Ramirez-Villegas et al., 2012).	
	Result 2.2. More efficient use of water resources, restoring soil properties, and improving GHG mitigation practices by farmers and gremios through the adoption of new climate smart practices and technologies.	Activity 2.2.1. Quantifying the baseline water footprint in six (6) crops (potato, sugarcane, panela sugarcane bananas, plantains, and livestock) and in the industrial phase of sugar production.	producers are selected in order of priority: women heads of household, small producers, medium producers. 13. The project executing unit will be responsible for reviewing	The measurement of consumptive use of water and the water footprint will be carried out in systems that use irrigation water (potato, sugar cane, musaceae and livestock) and areas with very marked dry periods. In the case of potatoes, four zones (Cundinamarca, Boyacá, Antioquia and Nariño) were selected, for panelera cane also four zones were prioritized (Valle del Cauca, Risaralda, Cundinamarca and Hoya del Río Suárez); five for musaceae (Uraba, Magdalena, La Guajira, Quindío and Valle del Cauca)), and three for livestock (La Guajira, Cauca, Nariño)	the water and carbon footprints (Output 4) of different crop management techniques and technologies. At this point, it is specifically proposed to generate information on water consumption and GHG generation for conventional systems in the first two years, and also to measure the same variables for the crop management technologies or practices, that have been identified by the working groups and prioritized by experts in the field. All these techniques or management practices are available and implemented at a commercial level. In this sense, the lots are located to make the respective measurements, the equipment is purchased and installed, all the measurement records are kept, and finally a comparison is made, not only of the reduction values in water consumption and/or emissions, but also in changes in key variables for the producer such as yield, costs or product quality. Subsequently, the entire scaling-up process is carried out, for which project resources will be used to implement technologies at the farm level. Although this is a massive scaling up of the technology, the farms where the implementations are being carried out will still be considered as training centers for producers and technicians in each area.
		Activity 2.2.2. . Quantifying the baseline carbon footprint for seven (7) crops (rice, potato, sugarcane, panela cane, bananas, plantain, and livestock), fertilizer use and industrial processing in sugarcane cultivation.	compliance with the established criteria and validating the final lists of beneficiaries. The executing unit may invite the guild to participate in the preparation of the final lists of beneficiaries. Once the producers have been selected, they must sign a	For the measurement of GHG and carbon footprints, the crops that generate the most emissions (rice, potatoes, panela cane, sugar cane, musaceae and livestock), and the areas that use crop management practices, technologies and / or processing were prioritized. In the case of rice, four locations were prioritized (rice under irrigation in: Tolima, La Guajira, Sucre and Huila), potato three (soil removal: Boyacá, Cundinamarca and Nariño), maize two (supplementation of animal feed: Córdoba and Cesar), sugarcane three (stoves: Hoya del Río Suárez, Cundinamarca and Risaralda), sugarcane one (processing: Valle del Cauca), musaceae two (use of nitrogen fertilizers: Uraba and Magdalena), and livestock three (Caquetá, Nariño, Sucre).	
		Activity 2.2.3. Water basins modeling to determine water harvesting sites.	commitment agreement to actively participate in the training provided by the project, to use and	The planning of irrigation water use at the farm level will be carried out in watersheds with water regulation problems and that provide water to irrigation systems for crops with high water demand, rice in Tolima, sugar cane in the Hoya del Río Suarez and banana in Magdalena	

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
		Activity 2.2.4. Evaluation of efficient water use practices in the agronomic management and transformation processes (e.g., milling of panela cane) in potato, panela cane, plantain, banana, coffee crops and livestock.	apply the technology, it is strictly forbidden to sell any material, input or equipment received as a project incentive, and the agreement will contain a special clause in which the producer acknowledges that the management of natural resources such as water or timber is his sole responsibility, and the project team will only be responsible for guiding actions focused on the legal and sustainable management of these resources. At the time of signing this commitment, the producers will also sign a data privacy policy specifically designed to comply with the Habeas Data law of Colombia.	The measurement of consumptive use of water and water footprints for alternative technologies with low water consumption will be carried out in the same areas of activity 2.2.1.	
		Activity 2.2.5. Evaluation of GHG emission mitigation practices in agronomic management and transformation processes in rice, maize, potato, panela cane, plantain, banana, coffee, sugarcane crops, and livestock.		For the measurement of GHG and carbon footprints for alternative technologies low in emissions and greater carbon capture, they will be carried out in the same areas of activity 2.2.2.	
		Activity 2.2.6. Landscape restoration in sugarcane cultivation and livestock systems.		Sixteen (16) implementation zones were chosen in different livestock ecoregions of the country, reconciling with other works that have already been carried out (sustainable livestock program, connected landscapes in Caquetá, Vision Amazonia, Biocarbon Fund and livestock reconversion plan). The 16 are located in the following livestock ecoregions, the dry Caribbean (2), the humid Caribbean (2), Hoya del Patía (2), the Nariñense Altiplano (2), the foothills of the Llanero (4), Caquetá (2) and Magdalena Medio (2).	
		Activity 2.2.7. Massive implementation of agronomic management technologies and transformation processes that enable more efficient use of water and promote low-carbon development in rice, maize, potato, sugarcane, plantain, banana, and livestock production.		The implementation of low carbon and low water consumption alternatives will be carried out in 33 locations, as follows: Rice (Tolima, Casanare, La Guajira, Sucre and Huila), Corn (Tolima, Valle del CaucaX2, Cesar and Meta), Papa (Cundinamarca , Boyacá, Antioquia and Nariño), Panela (Valle del Cauca, Cundinamarca, Risaralda and Hoya Rio Suarez), Musaceae (UrabaX4, MagdalenaX3, La GuajiraX2, Cesar, Caldas, Córdoba, Meta, Quindío and Valle del Cauca), under the criteria previously exposed in the previous activities related to water footprints and carbon footprints (2.2.1, and 2.2.2, respectively).	
Component 3. Innovative and inclusive business models through	Result 3.1. Improved business models that provide farmers with reasonable profits and	Activity 3.1.1 Strengthen gremios capacities to use digitally enabled tools that improve the provision of services to farmers with emphasis on profitable production system that also reduce GHG emissions and increase climate-resilience		Since all these activities are transversal and will be supporting and supporting the implementation of the first two components, component 3 will be implemented in all the previously prioritized locations.	It will work with the unions to identify new opportunities that allow potential for the scaling of technologies.
		Activity 3.1.2. Implement inclusive climate-resilient and low-carbon			

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
modernized innovation systems and a more engaged financial sector	improved GHG mitigation practices.	business models for agricultural products and services.			
		Activity 3.1.3. Enhance financial sector engagement with farmers and their needs and efforts on climate-resilience and climate mitigation activities.			
		Activity 3.1.4. Fostering agri-digital entrepreneurship ecosystems.			
	Result 3.2. Modernized technical assistance and agricultural extension services with multi-tool strategies, differentiated and adapted to specific environmental, social, gender and productive contexts at the national level.	Activity 3.2.1. Foster inclusion of two-way digitally enabled tools for enhancing models for technology transfer technical assistance within an innovations system approach			This component is transversal therefore it will work hand in hand and in coordination with the first two components. The activities considered here have to do with the accompaniment of all training processes and activities to reinforce and expand coverage, as well as review of methodologies, communication pieces and materials of all processes related to training, technology transfer and extension.
		Activity 3.2.2. Capability development on innovation systems approach and its inclusion into updated technology transfer plans.			
		Activity 3.2.3. Strengthen gremios and farmers capacities on climate adaptation and mitigation and nurture knowledge exchanges across farmers groups.			
		Activity 3.2.4. Develop a strategy that allows the dissemination, access and use of the Project's results by public and private key stakeholders.			
Monitoring and evaluation	Impact assessment and MRV.	Baseline development.			Data collection for project monitoring and evaluation, surveys, interviews, data monitoring, database review, report preparation
		Monitoring and biannual reports.			
		Development of mid-term project evaluation.			
		Development of final project evaluation.			
		Monitoring, reporting and verification of emission reduction.			
Environmental, Social and Gender	Implementation of the Environmental,	Implementation of the Gender Action Plan.			Preparation of protocols and plans related to environmental, social and environmental aspects in order to guide the different work teams of the guidelines that must be followed in order to comply with the Gender Action Plan, social and environmental management plan. Accompaniment

Component	Output	Activity	Final Beneficiaries' selection criteria	Project Area selection criteria:	Eligible interventions / activities
	Social and Gender Plan.				to the work team, participation in the preparation of the work methodology and strategy in order to ensure compliance with the environmental, social and gender plans. Development of actions identified in the action plans in order to contribute to closing gender, social and environmental gaps

Appendix 4. List of Departments and Municipalities in the CSICAP Project

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
1	Antioquia	1	Ándes
1	Antioquia	2	Apartadó
1	Antioquia	3	Campamento
1	Antioquia	4	Carepa
1	Antioquia	5	Carmen de Viboral
1	Antioquia	6	Caucasia
1	Antioquia	7	Chigorodo
1	Antioquia	8	Jardín
1	Antioquia	9	Jericó
1	Antioquia	10	La Unión
1	Antioquia	11	Medellin
1	Antioquia	12	Nechi
1	Antioquia	13	San Vicente
1	Antioquia	14	Santuario
1	Antioquia	15	Sonsón
1	Antioquia	16	Támesis
1	Antioquia	17	Turbo
1	Antioquia	18	Venecia
1	Antioquia	19	Yolombó
2	Arauca	20	Fortul
2	Arauca	21	Tame
3	Boyacá	22	Belén
3	Boyacá	23	Chitaraque
3	Boyacá	24	Cómbita
3	Boyacá	25	Motavita
3	Boyacá	26	Saboyá
3	Boyacá	27	Samacá
3	Boyacá	28	Santana
3	Boyacá	29	Toca
3	Boyacá	30	Togüí
3	Boyacá	31	Tunja
3	Boyacá	32	Tutazá

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
3	Boyacá	33	Ventaquemada
4	Caldas	34	Anserma
4	Caldas	35	Belalcazar
4	Caldas	36	Chinchina
4	Caldas	37	Manizales
4	Caldas	38	Risaralda
4	Caldas	39	San José
4	Caldas	40	Viterbo
5	Caquetá	41	Albania
5	Caquetá	42	El Docello
6	Casanare	43	Agua Azul
6	Casanare	44	Pore
6	Casanare	45	San Luis
6	Casanare	46	Yopal
7	Cauca	47	Balboa
7	Cauca	48	Buenos Aires
7	Cauca	49	Caloto
7	Cauca	50	Corinto
7	Cauca	51	El Tambo
7	Cauca	52	Guachene
7	Cauca	53	Miranda
7	Cauca	54	Padilla
7	Cauca	55	Patia - Bordo
7	Cauca	56	Popayan
7	Cauca	57	Puerto Tejada
7	Cauca	58	Santander de Quilichao
7	Cauca	59	Timbio
7	Cauca	60	Villarica
8	Cesar	61	Aguachica
8	Cesar	62	Codazzi
8	Cesar	63	La Jagua de Ibirico
8	Cesar	64	La Paz
8	Cesar	65	La Paz
8	Cesar	66	Manaure
8	Cesar	67	Puerto Bello

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
8	Cesar	68	San Alberto
8	Cesar	69	San Juan
8	Cesar	70	San Martín
8	Cesar	71	Urumita
8	Cesar	72	Valledupar
9	Córdoba	73	Cereté
9	Córdoba	74	Ciénaga de Oro
9	Córdoba	75	Cotorra
9	Córdoba	76	Monteria
9	Córdoba	77	Moñitos
9	Córdoba	78	Santa Cruz de Lorica
9	Córdoba	79	Tierra Alta
10	Cundinamarca	80	Bogotá
10	Cundinamarca	81	Caparrapí
10	Cundinamarca	82	Chipaque
10	Cundinamarca	83	Cogua
10	Cundinamarca	84	La Peña
10	Cundinamarca	85	Pasca
10	Cundinamarca	86	Sibaté
10	Cundinamarca	87	Subachoque
10	Cundinamarca	88	Tausa
10	Cundinamarca	89	Ubaté
10	Cundinamarca	90	Une
10	Cundinamarca	91	Villapinzón
10	Cundinamarca	92	Zipaquirá
11	Guajira	93	Dibulla
11	Guajira	94	Fonseca
11	Guajira	95	Rioacha
11	Guajira	96	Urumita
11	Guajira	97	Villanueva
12	Huila	98	Aipe
12	Huila	99	Campo Alegre
12	Huila	100	Garzón
12	Huila	101	Gigante
12	Huila	102	Neiva

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
12	Huila	103	Palermo (Juncal)
13	Magdalena	104	Aracataca
13	Magdalena	105	Cienaga
13	Magdalena	106	Fundación
13	Magdalena	107	Puerto Berrio
13	Magdalena	108	Puerto Parra
13	Magdalena	109	Santa Marta
13	Magdalena	110	Zona Bananera
14	Meta	111	Acacias
14	Meta	112	Ariari
14	Meta	113	Fuente de oro
14	Meta	114	Granada
14	Meta	115	Lejanías
14	Meta	116	Puerto Gaitan
14	Meta	117	Puerto Lleras
14	Meta	118	Puerto López
14	Meta	119	San Juan de Arama
14	Meta	120	San Martín
14	Meta	121	Villavicencio
15	Nariño	122	Aldana
15	Nariño	123	Consacá
15	Nariño	124	Cumbal
15	Nariño	125	Guachucal
15	Nariño	126	Iles
15	Nariño	127	Ipiales
15	Nariño	128	Pasto
15	Nariño	129	Potosí
15	Nariño	130	Sandoná
15	Nariño	131	Sapuyes
15	Nariño	132	Tangua
15	Nariño	133	Túquerres
16	Norte de Santander	134	Arboledas
16	Norte de Santander	135	Convención
16	Norte de Santander	136	Cúcuta
16	Norte de Santander	137	El Zulia

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
16	Norte de Santander	138	Sardinata
16	Norte de Santander	139	Toledo
17	Quindio	140	Armenia
17	Quindio	141	Buenavista
17	Quindio	142	Buenavista
17	Quindio	143	Montenegro
17	Quindio	144	Quimbaya
18	Risaralda	145	Belen de Umbria
18	Risaralda	146	La Virginia
18	Risaralda	147	Marsella
18	Risaralda	148	Pereira
18	Risaralda	149	Santuario
19	Santander	150	Bucaramanga
19	Santander	151	Carmen de Chucurí
19	Santander	152	Cimitarra
19	Santander	153	Curiti
19	Santander	154	Floridablanca
19	Santander	155	Mogotes
19	Santander	156	Páramo
19	Santander	157	Pinchote
19	Santander	158	Sabana de Torres
19	Santander	159	San Benito
19	Santander	160	San Gil
19	Santander	161	Socorro
19	Santander	162	Valle de San José
19	santander	163	Yondó
20	Sucre	164	Chalán
20	Sucre	165	Coloso
20	Sucre	166	Guaranda
20	Sucre	167	Los Palmitos
20	Sucre	168	Majagual
20	Sucre	169	Morroa
20	Sucre	170	Ovejas
20	Sucre	171	Palmito
20	Sucre	172	San Marcos

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
20	Sucre	173	San Onofre
20	Sucre	174	Tolú
21	Tolima	175	Alvarado
21	Tolima	176	Ambalema
21	Tolima	177	Armero - Guayabal
21	Tolima	178	Espinal
21	Tolima	179	Flandes
21	Tolima	180	Guamo
21	Tolima	181	Ibague
21	Tolima	182	Libano
21	Tolima	183	Planadas
21	Tolima	184	Saldaña
21	Tolima	185	San Luis
21	Tolima	186	Valle de San Juan
21	Tolima	187	Venadillo
22	Valle del Cauca	188	Andalucia
22	Valle del Cauca	189	Anserma Nuevo
22	Valle del Cauca	190	Argelia
22	Valle del Cauca	191	Bolivar
22	Valle del Cauca	192	BUGA
22	Valle del Cauca	193	Buga La Grande
22	Valle del Cauca	194	Caicedonia
22	Valle del Cauca	195	Cali
22	Valle del Cauca	196	Candelaria
22	Valle del Cauca	197	Cartago
22	Valle del Cauca	198	El Cerrito
22	Valle del Cauca	199	Florida
22	Valle del Cauca	200	Ginebra
22	Valle del Cauca	201	Guacarí
22	Valle del Cauca	202	Jamundí
22	Valle del Cauca	203	La Unión
22	Valle del Cauca	204	La Victoria
22	Valle del Cauca	205	Obando
22	Valle del Cauca	206	Palmira
22	Valle del Cauca	207	Pradera

List of Deparments/ Provinces and Municipalities in the CSICAP Project

Columna1	Department/ Province	Total Municipalities	Municipalities
22	Valle del Cauca	208	Rio Frío
22	Valle del Cauca	209	Roldanillo
22	Valle del Cauca	210	San Pedro
22	Valle del Cauca	211	Sevilla
22	Valle del Cauca	212	Toro
22	Valle del Cauca	213	Trujillo
22	Valle del Cauca	214	Tulua
22	Valle del Cauca	215	Tulua
22	Valle del Cauca	216	Vijes
22	Valle del Cauca	217	Yotoco
22	Valle del Cauca	218	Yumbo
22	Valle del Cauca	219	Zarzal

APPENDIX 5. AREA OF INDIRECT INTERVENTION ACCORDING TO % OF TECHNOLOGY ADOPTION

	FEDEARROZ	FENALCE	FEDEPAPA	FEDEPANELA	A. FEDEGAN	B. FEDEGAN	FEDECAFE	MUSACEAS	ASOCAÑA	TOTAL
Adoption Rate	100%	100%	91%	67%	100%	100%	0%	95%	100%	
Year										
2024	5.312	2.779	1.215	2.463	83.400	83.400	-	466	-	179.035
2025	50.460	22.927	8.508	13.548	166.800	83.400	-	3.646	-	349.289
2026	95.608	43.075	15.801	24.633	250.200	83.400	-	6.827	-	519.543
2027	140.757	63.222	23.094	35.717	333.600	83.400	-	10.007	-	689.798
2028	185.905	83.370	30.387	46.802	417.000	83.400	-	13.189	-	860.054
2029	185.905	83.370	30.387	57.887	500.400	83.400	-	13.189	-	954.538
2030	185.905	63.222	23.094	68.971	583.800	83.400	-	13.189	-	1.021.582
2031	185.905	43.075	15.801	80.056	667.200	83.400	-	13.189	-	1.088.626
2032	185.905	22.927	8.508	68.971	750.600	83.400	-	13.189	-	1.133.501
2033	140.757	2.779	1.215	57.887	834.000	83.400	-	10.007	-	1.130.045
2034	95.608	-	-	46.802	834.000	-	-	6.827	-	983.237
2035	50.460	-	-	35.717	834.000	-	-	3.646	-	923.823
2036	5.312	-	-	24.633	834.000	-	-	466	-	864.410
2037	-	-	-	13.548	834.000	-	-	-	-	847.548
2038	-	-	-	2.463	834.000	-	-	-	-	836.463
2039	-	-	-	-	834.000	-	-	-	-	834.000
2040	-	-	-	-	834.000	-	-	-	-	834.000
2041	-	-	-	-	834.000	-	-	-	-	834.000
2042	-	-	-	-	834.000	-	-	-	-	834.000
2043	-	-	-	-	834.000	-	-	-	-	834.000
2044	-	-	-	-	834.000	-	-	-	-	834.000
2045	-	-	-	-	750.600	-	-	-	-	750.600
2046	-	-	-	-	667.200	-	-	-	-	667.200
Total	1.513.800	430.745	158.013	580.098	15.178.800	834.000	-	107.836	-	18.803.293

ANNEXES

The list of annexes referred to in the document following the numbering of the Funding Proposal. Annexes 1 and 2 are not included in this document considering at the date of this document the letter of No Objection (Annex 1) is course at the Colombian DNA and Annex 2 refers to this feasibility study.

- Annex 3 Economic and financial analysis
- Annex 4 Detailed budget
- Annex 5 Schedule
- Annex 6 Environmental, social and gender assessment
- Annex 7 Stakeholder participation

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