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MED-GOLD

Turning climate-related information into added value for traditional **MED**iterranean**G**rape, **OL**ive and **D**urum wheat food systems

Deliverable 6.9

Climate Service Replicability Report

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Disclaimer

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EXECUTIVE SUMMARY

This document establishes the bases to exploring alternative markets where the services developed during the MED-GOLD project could be implemented by providing the opportunity to be applied on areas where the available resources are not enough for co-develop services adapted to end user needs.

Based on the experience acquired during the MED-GOLD project, the general idea of this document is focused on the study and analysis, of locations beyond the Mediterranean basin and the three sectors on which MED-GOLD lead its major effort.

Although this document is focused mainly to Colombian Coffee case, also other geographical regions in Africa and sectors beyond the agri-food sector are explored interacting with other initiatives, taking as starting point the Sustainable Development Goal number 13 (SDG13).

1. OBJECTIVES

No.	Objective	Yes
1	To co-design, co-develop, test, and assess the added value of proof-of-concept climate services for olive, grape, and durum wheat	
2	To refine, validate, and upscale the three pilot services with the wider European and global user communities for olive, grape, and durum wheat	
3	To ensure replicability of MED-GOLD climate services in other crops/climates (e.g., coffee) and to establish links to policy making globally	X
4	To implement a comprehensive communication and commercialization plan for MED-GOLD climate services to enhance market uptake	
5	To build better informed and connected end-user communities for the global olive oil, wine, and pasta food systems and related policy making	

2. IMPACT

No.	Expected impact	Yes
1	Providing added-value for the decision-making process addressed by the project, in terms of effectiveness, value creation, optimised opportunities and minimised risk	
2	Enhancing the potential for market uptake of climate services demonstrated by addressing the added value	This document explores the Climate Services market in Colombia. This provide a vision of feasibility to future market uptake.
3	Ensuring the replicability of the methodological frameworks for value added climate services in potential end-user markets	This document collects the experience of the MED-GOLD climate services applied in the Colombian coffee case.
4	To implement a comprehensive communication and commercialization plan for MED-GOLD climate services to enhance market uptake	
5	To build better informed and connected end-user communities for the global olive oil, wine, and pasta food systems and related policy making	

3. DEFINITIONS

Concepts and terms used in this document and needing a definition are included in the following table:

Concept / Term	Definition
Coffee bag	It is mainly made of jute and has a content of 60 kilograms (130 pounds), this type of bag originated in Brazil and became a worldwide standard.
Coffee berry borer	Coffee berry borer (*Hypothenemus hampei*) is a small beetle native to Africa. It is among the most harmful pests to coffee crops across the world. Spanish common names of the insect include barrenador del café, gorgojo del café, and broca del café.
Coffea Arabica	Also known as the Arabian coffee, "coffee shrub of Arabia", "mountain coffee" or "arabica coffee", is a species of Coffea. It is the dominant coffee crop specie representing about 60% of global production.
Coffea Robusta	Coffea *canephora*. Commonly known as robusta coffee, is a species of coffee that has its origins in central and western sub-Saharan Africa. It is a species of flowering plant in the family *Rubiaceae*. (https://es.wikipedia.org/wiki/Coffea_canephora)
ENSO	Is a recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean. On periods ranging from about three to seven years, the surface waters across a large swath of the tropical Pacific Ocean warm or cool by anywhere from 1°C to 3°C, compared to normal.
Geoportal	Website used to find and access geographic information (geospatial information) and associated geographic services (display, editing, analysis, etc.). Geoportals are important for effective use of geographic information systems (GIS) and a key element of Spatial Data Infrastructure (SDI).
Traviesa	Minor coffee harvest, called 'traviesa' or 'mitaca', commonly carried out 6 months after the main harvest.

4. ACRONYMS

Acronyms used in this document and needing a definition are included in the following table:

Acronym	Definition
AGROSAVIA	Colombian Corporation For Agricultural Research (acronym in Spanish)
C3S	The Copernicus Climate Change Service
CENICAFE	National Center for Coffee Research (acronym in Spanish)
CBB	Coffee Berry Borer
DNP	Planning National Department (acronym in Spanish)
ENSO	El Niño-Southern Oscillation
FEDECAFE	National Coffee Producers Federation of Colombia (acronym in Spanish)
FONADE	National Fund for Development Projects (acronym in Spanish)
GCMs	Global Climate Models
ICA	Colombian Agriculture and Livestock Institute (acronym in Spanish)
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies of Colombia (acronym in Spanish)
IRI	International Research Institute
OSS	Sahara and Sahel Observatory (acronym in French)
PDBM	Physiologically Based Demographic Modelling
RCM	Regional Climate Model
SANSA	South African National Space Agency
SLP	Sea Level Pressure
SST	Sea Surface Temperature
UPRA	Rural Agriculture and Livestock Planning Unit (acronym in Spanish)
WMO	World Meteorological Organization

5. REFERENCES

The following documents, although not part of this document, amplify or clarify its contents. Reference documents are those not applicable and referenced within this document. They are referenced in this document in the form [RD.x]:

Ref.	Title	Code	Version	Date
[RD.1]	WMO, State Of Climate Services – WMO 1242, 2019			2019
[RD.2]	FAO. 2019. Handbook on climate information for farming communities – What farmers need and what is available.			2019
[RD.3]	Understanding User Needs for Climate Services in Agriculture - World Meteorological Organization			2011
[RD.4]	Vivek Voora, Steffany Bermúdez, Cristina Larrea, Sofia Baliño Series. Global Market Report: Coffee. Sustainable Commodities Marketplace Series, 2019			2019
[RD.5]	DaMatta, F.M., Rahn, E., Läderach, P. et al. Why could the coffee crop endure climate change and global warming to a greater extent than previously estimated? Climatic Change 152, 167–178 (2019). https://doi.org/10.1007/s10584-018-2346-4			2018
[RD.6]	Ahmed S. et al.Climate Change and Coffee Quality: Systematic Review on the Effects of Environmental and Management Variation on Secondary Metabolites and Sensory Attributes of Coffea arabica and Coffea canephora,Frontiers in Plant Science v12 https://www.frontiersin.org/article/10.3389/fpls.2021.708013			2021
[RD.7]	World Economic Forum, 2022, video, https://www.linkedin.com/posts/world-economic-forum_meet-the-morettinos-sicilys-only-coffee-activity-6894248076186324992-dFhu			2022
[RD.8]	Factsheet Resilience Solutions for the Coffee sector in Colombia			2020
[RD.9]	Grüter R, Trachsel T, Laube P, Jaisli I (2022) Expected global suitability of coffee, cashew and avocado due to climate change. PLOS ONE 17(1): e0261976. https://doi.org/10.1371/journal.pone.0261976			2022
[RD.10]	European Commission, Directorate-General for Research and Innovation, Jacob, D., Runge, T., Street, R., et al., A European research and innovation roadmap for climate services, Publications Office, 2015, https://data.europa.eu/doi/10.2777/750202			2015
[RD.11]	Jörg Cortekara, Matthias Themesslb, Katja Lamicha. Systematic analysis of EU-based climate service providers, Elsevier. 2020			2020
[RD.12]	International Trade Centre (ITC) Climate Change and the Coffee Industry Geneva: ITC, 2010. vi, 28 pages (Technical paper)			2010
[RD.13]	Davis. A et al. High extinction risk for wild coffee species and implications for coffee sector sustainability, 2019 https://www.science.org/doi/10.1126/sciadv.aav3473			2019
[RD.14]	Área Sembrada, Área Cosechada, Producción Y Rendimiento Del Cultivo De Café Según Departamento 2015-2016 Agronet, 2016 http://www.agronet.gov.co/Documents/CAFE2016.pdf			2016
[RD.15]	Acción Sostenibilidad - Federación Nacional de Cafeteros, 2010 https://federaciondecafeteros.org/static/files/informe_sostenibilidad_esp.pdf			2010

[RD.16]	Criollo Escobar, H.; Benavides Arteaga, D.; Muñoz Belalcázar, J.; Lagos Burbano, T.C. 2019. Caracterización socioeconómica de fincas cafeteras del departamento de Nariño, Colombia Rev. U.D.C.A Act. & Div. Cient. 22(2):e1397. http://doi.org/10.31910/rudca. v22.n2.2019.1397			2019
[RD.17]	De Melo Virginio Filho, Elias & Astorga, Carlos. (2015). Prevención y control de la roya del café-Manual de buenas prácticas para técnicos y facilitadores.			2015
[RD.18]	Cure ,J.R., D. Rodriguez, A.P.Gutierrez, L.Ponti. The coffee agroecosystem: bio-economic analysis of coffee berry borer control (*Hypothenemus hampei*). Scientific Reports 10:12262 https://doi.org/10.1038/s41598-020-68989-x			2020
[RD.19]	Harry Suehrcke and Ross S. Bowden and K.G.T. Hollands, Relationship between sunshine duration and solar radiation, Solar Energy, 92, 160-171, 2013, https://doi.org/10.1016/j.solener.2013.02.026			2013
[RD.20]	Rodríguez D, Cure JR, Cotes JM, Gutierrez AP A coffee agroecosystem model. III. Parasitoids of the coffee berry borer (*Hypothenemus hampei*). Ecological Modeling 363: 96-110.			2017
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[RD.22]	Rodríguez et al. Cure JR, Cotes JM, Gutierrez AP, Cantor F A coffee agroecosystem model. I. Growth and development of the coffee plant. Ecological Modeling 222: 3626-3639.			2011
[RD.23]	Gutierrez AP, Villacorta A, Cure JR, Ellis CK (1998) Tritrophic analysis of the coffee (Coffea arabica) - coffee berry borer [Hypothenemus hampei (Ferrari)] - parasitoid system. Anais da Sociedade Entomológica do Brasil 27(3): 357-385.			1998
[RD.24]	Informe de la Misión De Estudios para la Competitividad de la Caficultura en Colombia Resumen Ejecutivo. Juan José Echavarría, Pilar Esguerra, Daniela McAllister, Carlos Felipe Robayo https://www.urosario.edu.co/Mision-Cafetera/Archivos/Resumen-Ejecutivo-version-definitiva/			2015
[RD.25]	Cavazos, T., Luna-Niño, R., Cerezo-Mota, R., Fuentes-Franco, R., Méndez, M., Pineda Martínez, L. F., & Valenzuela, E. (2020). Climatic trends and regional climate models intercomparison over the CORDEX-CAM (Central America, Caribbean, and Mexico) domain. International Journal of Climatology, 40(3), 1396–1420. https://doi.org/10.1002/joc.6276			2020

6. REPLICABILITY BEYOND THE MEDITERRANEAN REGION

6.1. STATE OF THE ART

To provide Climate Services for the Agri-food sector in a regional-national or even sub-national scale constitutes one of the challenges exposed in the 2019 WMO [RD.1], considering that climate information and associated services led to improved agricultural and food security outcomes and benefits for stakeholders. Several initiatives have been proposed to fill the gap between upstream providers and stakeholders or smallholders; however, these proposals and its implementation are still far from developing countries.

According to FAO [RD.2], over 500 million smallholder farms, producing more than 80% of the world's food in terms of value, and 750 million extremely poor people working in agriculture – normally as smallholder family farmers – are vulnerable to the effects of climate change. In this context, the agri-food sector is being threatened by climate change which affects the worldwide population despite they are not comparable depending on social and economic factors or development level.

Agriculture provides work in many sectors, including education, research, extension services, agro-industries and processing, commodities and trade, infrastructure, transport and pharmaceutical. Agricultural extension services provide technical guidance to farmers and are typically under the administration of each country (ie. agriculture ministry) [RD.3]. These extension services also provide useful climate information to farmers in coordination with National Meteorological and Hydrological Services (NMHSs).

A report by WMO and FAO identifies that 85% of the countries agree that agriculture, food security and water are in the top priority sectors for climate change adaptation. Climate services are a fundamental element for planning and decision making.

The MED-GOLD project aims to develop climate services for three Mediterranean sectors Grape/wine, Olive/olive oil and Durum wheat/pasta, however considering the wide approach of the climate services, this document is focused on the Colombian Coffee sector.

The coffee sector is the world's most important agricultural commodity and has high relevance to the worldwide economy [RD.4]. Currently, coffee crops are being threatened by the continuous changes in the climate conditions, due to damages caused on the tree and the grain and because climate conditions hold implications on plagues spreading [RD.5].

Paradoxically, the impact of the climate on coffee crops has caused, on the one hand, the need to plant on land at a higher altitude than usual with the consequences that this implies (deforestation, high investment, increased probability of losses, degradation of other activities economics, substitution of ancestral crops) as the Colombian case and on the other hand raise the need to research and implement the planting of species more resistant to climate change, sacrificing the "good will" that characterizes a distinctive brand.

There is no doubt that climate variations not only affect production (planting, harvesting, soil management, treatment, etc.) itself, but also quality in terms of physical properties of coffee such as taste and aroma, as explained by Ahmed S., et al. (2021) [RD.6]. Under this scenario, the entire value chain around coffee is affected and will be even more so in the future. Another phenomenon that revolves around this climatic situation is the modification of the role in the value chain: countries or regions which have been mainly importers of coffee beans, have become coffee producers to try to minimize the effects of climate change in the world market. This is the case of the company Morettinos (Italy) which have been coffee roasters for 4 generations [RD.7] and now is producing its own coffee.

According to the Interamerican Development Bank [RD.8], Colombian coffee represents a significant staple of the country's diet and economy. Coffee is also among the country's most exported products. In 2018, the value of annual coffee exports reached USD 2.6 billion. Coffee plays a significant role in generating employment, as more than 785,000 people are directly involved in the sector, representing 26% of the total employment in agriculture. Due to the importance for the economy and the diet, some actions to increase the resilience of coffee crops need to be implemented. The climate risks associated to each process of the coffee value chain (site preparation, crop management, post-harvest management) can be monitored using climate services and/or weather forecasting were identified.

The Colombian National Climate Agency (IDEAM) is a public institution of technical and scientific support to the National Environmental System, which mainly provides services that focus on weather forecasting. Some initiatives also provide services for the coffee sector such as AgroClima (https://agroclima.cenicafe.org/) but services do not provide climate information based on predictive models (seasonal forecasting or long term projections) to allow decision making for the future management of the crops. Colombia prepared the National Plan of Adaptation to Climate Change (PNACC in Spanish), which supports the preparation of the country to face extreme climatic events, and the gradual transformation of the climate. This draws attention to the opportunities of climate services for the Colombian coffee sector, and in the same way shows the need for this sector to have tools that allow it to improve decision-making to be resilient to climate challenges.

The growing demand for agro-food products due to factors commonly known as the increase in population and the global economy, means an enormous pressure in political, economic, ecological and sustainable terms with a view to guaranteeing food security. Some plantations like avocado and cashew, have a "high socio-economic importance in many tropical smallholder farming systems around the globe. As plantation crops with a long lifespan, their cultivation requires long-term planning. The evaluation of climate change impacts on their biophysical suitability is therefore essential for developing adaptation measures and selecting appropriate varieties or crops" [RD.9].

The necessity to count with a tool focused on Climate services to help in decision making to guarantee the food security is evident as well as work in the conservation of forest into the frame of the silviculture. In a wide range, the main source of climate information is the National Service which owns and operates most of the national infrastructure needed to provide the weather, climate and water services. However, many countries lack the infrastructure and technical, human and institutional capacities to provide high quality climate services that allow the adoption of policies to be resilient against climate change.

In the last years, the Climate Services market has increased its presence to supply and support the growing demand to adapt to the impacts of climate change (Figure 1)[RD.10]. In EU there are about 371 providers of climate services who are filling the gap between data and end-users [RD.11]. However, this market is concentrated on the most developed countries meanwhile the climate impact and its consequences are global. Projects like MED-GOLD, which has developed climate services based on the needs of each sector, can play an interesting role to supply support to different sectors and beyond the Mediterranean region on where it is focused.

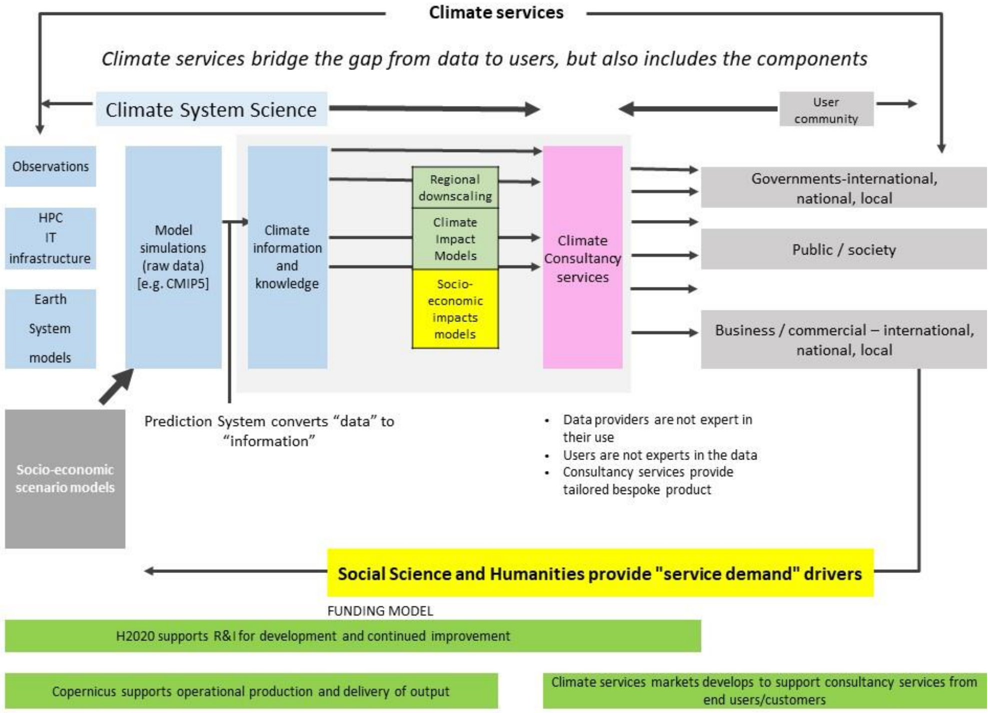

Figure 1. The essence of Climate Services.

6.2. COLOMBIA COFFEE OVERVIEW

Climate change will affect coffee producers, particularly smallholders who are least equipped to cope with it. Areas of intervention include aspects such as changing agricultural practices, creating social organization, and participating in new market strategies. Strategic support areas include improving access to information, establishing financial mechanisms and investing in social capital [RD.12].

The International Coffee Organization considers that Climate Change will influence global coffee production, and will mainly affect smallholders (who produce the majority of the world's coffee) and who are the most vulnerable group. Currently, the majority of initiatives to reduce the extent of global warming lead to finding a way to limit further warming, not to reverse it quickly.

The global coffee production can be affected due to prolonged droughts, rising temperatures, biodiversity loss and heavy rains. A recent study found that 60% of wild coffee species are under threat of extinction due to climate change [RD.13].

It is commonly accepted that climate change will affect both *arabica* and *robusta* producers, although it is difficult to precise it. Rising temperatures are expected to degrade some producing areas, making them less suitable or even unsuitable for coffee growing. Production may have to shift to alternative crops that will have to be identified.

The coffee quality will suffer due to the increase of pests and diseases limiting the viability of the current high quality producers. The pressure on water resources will increase because coffee may need to be grown under irrigation. Under this scenario, the cost of production will increase whereas in the future fewer parts of the world may be suitable for coffee production. If so, then the concentration could grow, bringing with it an increased risk of high volatility in the market.

In 2013, Central and South America were affected by coffee rust. In that year, the devastation caused by this fungus was the worst since 1970. Countries like Guatemala declared a national emergency and several events were reported from Nicaragua, El Salvador and Mexico. Countries like Colombia declared an emergency to take actions against the coffee rust.

Colombia is the third largest coffee producer in the world. According to the National Coffee Producers Federation of Colombia (FEDECAFE, acronym in Spanish), in 2018 Colombia produced around 13.6 million bags, being the coffee crops a strategic sector in the national economy.

Colombia's coffee region is increasingly vulnerable to climate-change-induced disasters like flooding, drought and invasive pests. Traditionally, the country has been known as a top producer of coffee arabica, an emblematic Colombian crop that is cultivated at middle altitudes between 1000 m and 2000 m in the Colombian Andes (Figure 2). The ideal production conditions are at altitudes between 1,200 and 1,800 meters above sea level, with temperatures ranging between 17° and 23°C. However, it is possible to produce quality coffee at marginally higher altitudes and under different rainfall regime/ seasonal distribution of rainfall. The production levels and crop success depend critically on weather conditions in the flowering stage, notably temperature precipitation, and solar radiation. There are different harvest seasons depending on the rainfall regime of specific crop areas. In areas with two rainy seasons, there is a main harvest followed by a mid-crop of lower production called the traviesa or mitaca, which produces about a third of the main crop. These characteristics allow growers to offer the world fresh coffee throughout the year. Areas with one rainy season have only one harvest per year. Harvesting is conducted under dry conditions between rainy seasons.

Unusual weather events related to climate change (Figure 3) have direct and indirect impacts on coffee *arabica*. A different species not widely cultivated in the country, coffee *robusta*, seems to be a suitable alternative that, despite being affected by climate extremes, can tolerate higher temperatures and is more resistant to pests and diseases. Therefore, this species could expand the production to other areas to counteract the *arabica* yield reductions with new planting in warming regions. These are usually flat places located below 1.200 m., which in Colombia are named: "Orinoquía", "Pacífico", "Caribe" and two specific zones in the Amazonía ("Caquetá" and "Putumayo"). *robusta* does however require heavier rainfall, which, because of the increased likelihood of prolonged droughts, means that irrigation is likely to become an increasingly essential requirement.

In a recent visit from a MED-GOLD partner to a particular producer (Finca el Ocaso in Salento, Quindío) a series of situations related with climate change that concern coffee growers were revealed:

- The "normal" lower altitude to plant coffee trees was around 1200 m – 1400 m, however currently is necessary to start higher than before.

- To use higher regions to plant coffee imply deforest and damage native ecosystems (i.e. Wax Palm forest)The precipitation events in dry seasons bring as consequence the use of greenhouse for the drying coffee process increasing costs.
- The preparation and planting of new plots involves costs of about $100M per hectare (€22k approx), however the first harvest takes 5 years and there is no guarantee of business success under current conditions.
- The added problem is the "good will" of the Colombian coffee brand which is oriented to "Coffea arabica" to keep the quality and worldwide recognizing. The Colombian Coffee Growers Federation only admits this variety.

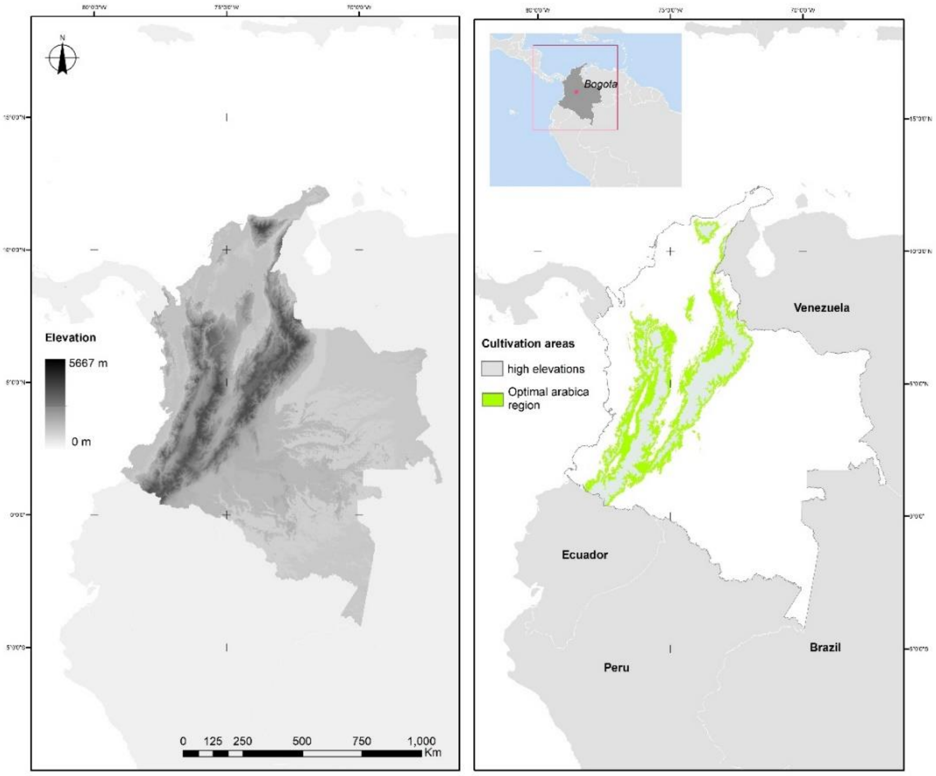

Figure 2. Optimal Region for Coffee Arabica Cultivation

Figure 3. Greenhouse adapted for occasional rainfall in dry seasons (postharvest management)

6.2.1. COFFEE SECTOR VALUE CHAIN

The coffee value chain [RD.7] builds on five main processes from input selection to transportation and distribution to supply the market. Each process involves specific activities, which are conducted by direct actors and engage identified indirect actors. Climate has a major influence in all process-related decisions, from when to plant to when to collect, and the time frame for these decisions. There are several value chains for the coffee sector depending on the size of the farm, what processes occur in the farm and customer preferences, among other variables. The most relevant processes are shown in Figure 4, each of which involves a series of activities that are influenced by climate. Is relevant to note that the influence of the climate involves not only the actions on the crop and its phenology process but also other aspects, which have significance in the value chain.

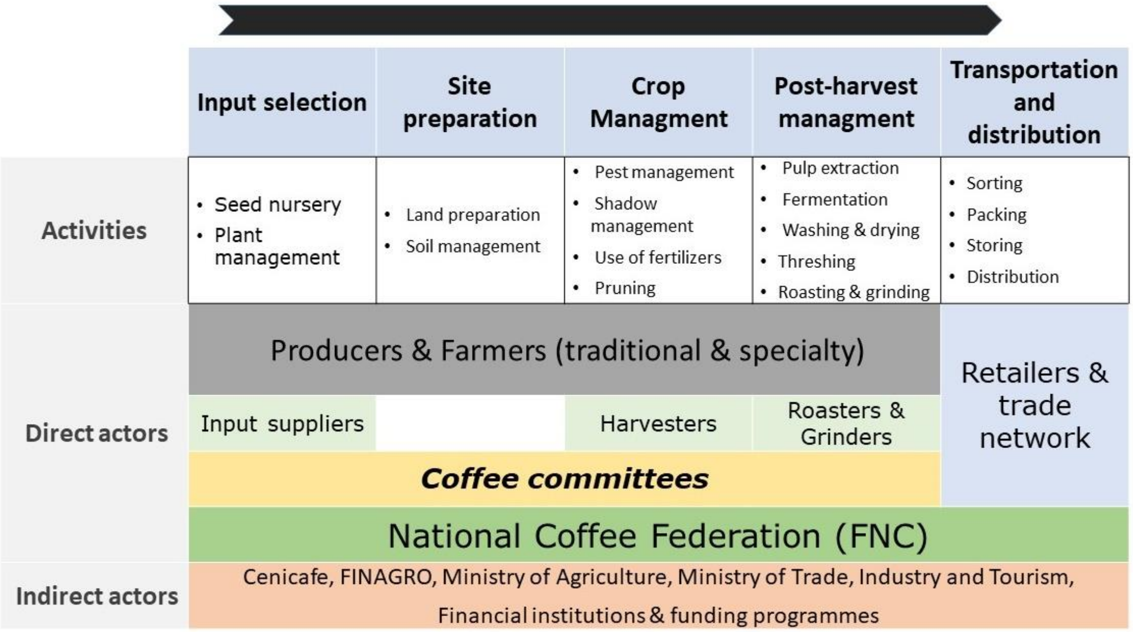

Figure 4. Colombian Coffee Industry Value Chain

6.2.2. COLOMBIAN COFFEE GROWING REGIONS

Coffee needs specific climatic conditions for its production, such as soil conditions, temperature, precipitation and altitude above sea level. As previously mentioned, the ideal conditions for cultivation are between 1,200 and 1,800 meters above sea level, with temperate temperatures that range between 17 and 23 degrees Celsius and with rainfall close to 2,000 millimetres per year, ideally well distributed throughout the year. At present, the cultivation of coffee in Colombia is located, for the most part, on the profile of the slopes of its three mountain ranges and there are specific areas where special coffee crops are planted.

During the last years a renewal of coffee plants has been performed focused on minimize damages by diseases: from the 974,000 hectares planted, 60% is planted in young technified resistant to rust, 20% is young technified coffee planted in other varieties. The remaining 20% is an aging technified coffee growing, on which the eyes should initially be directed to direct the areas to be renovated as a priority.

The main producing departments are Huila, Antioquia, Tolima, Cauca and Caldas [RD.14]. The coffee production is present from the provinces that limit with Ecuador, in the South, up to those that border the Caribbean Sea in the North (Figure 5). Along nearly 3,000 kilometres of inter Andean valleys, from the extreme South to the extreme North of Colombia, live those producers in different coffee growing regions [RD.15]

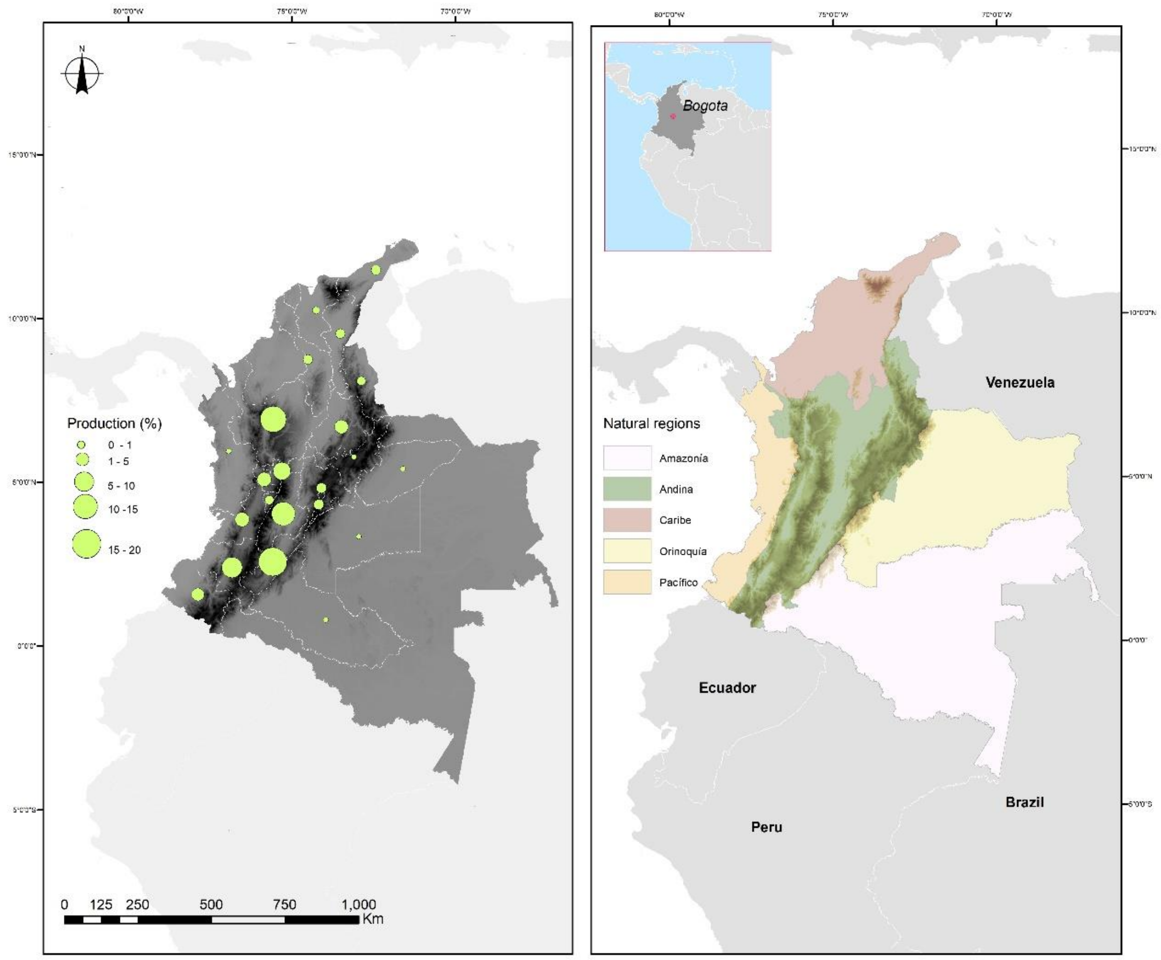

Figure 5. Distribution of Coffee production

6.2.3. SOCIAL AND ECONOMIC ANALYSIS

The annual production of coffee is around 834,000 tons, with a yield of 0.9 tons / ha. Production takes place in 20 departments of Colombia; there are more than 563,000 families producing coffee in Colombia. Most Colombian coffee growers live in small farms whose coffee cultivation plots are on average smaller than 2 hectares, while only 5% of Colombian coffee producers have coffee plantations of a size larger than 5 hectares. It was found that 89% of coffee growers correspond to the category "peasant economy", while the remaining 11% is in the smallholder category (Criollo et al., 2019)[RD.16]. The reduced dimensions of their coffee plots have allowed maintaining an essentially family oriented activity to the Colombian coffee growing industry. Around coffee in Colombia surged a number of social networks with a diversity of cultures and features, including different indigenous, afro descending communities and the heirs of the settlers of white or mestizo origin, all of them with diverse cultural manifestations between the regions.

This coffee culture has passed from generation to generation; however, the aging of the coffee producer is evident, since less than 20% of people are under 40, with an average age of 53-54 years, which may indicate a lack of generational Turnover.

However, there is a growing trend towards labor shortages in the field associated with aging population, migration and less participation of young people in activities in agriculture and the offer of alternative labor in sectors such as mining and construction, which has raised the labor cost of harvesting reaching more than 50% of the total production costs.

On the other hand, more than half of coffee families are made up of four or fewer people, presenting a tendency to decrease in size. The average years of formal education for coffee growers is 5 years; 70% of coffee growers have complete or incomplete primary education, 16% have secondary education and only 9% have a university or technological education. The above aspects may constitute a barrier in the acquisition of modern production technologies. However, the participation of women in the administration and decision making in coffee farms has been increasing; about one third of coffee growers correspond to the female gender.

6.3. Climate Impact and Climate Services for Colombian coffee Crop

The climate variability has a relevant impact including growth limitations, lower bean quality, pests and disease, flowering delays, and harvest failure. The level of the impact depends on their timing in relation to the phenology stage. Coffee flowering and fruit maturing can be widely affected by climate, dry periods synchronize flower-bud initiation that will open with the rains, concentrating the flowering and harvest, increasing production, but at the same time concentrating the attack of the coffee berry borer (CBB), the main pest of coffee in the Americas. In addition, an estimated 30% of coffee production areas consist of varieties that are exposed to rust.

The most meaningful parameters that affect coffee production are temperature, precipitation and solar radiation. The higher temperatures and lower precipitation have a negative impact on the density of coffee grains and promote the development of diseases.

Surplus rainfall combined with lower solar radiation and reduced temperature adversely affect the production by decreasing the number of flower buds and reducing growth rates.

The soils become more acidic, reducing their ability to retain nutrients when there is water excess. Prolonged rainfall affects the drying process and increases quality risks. Soil erosion has been highlighted as a risk in most coffee areas.

El Niño and La Niña have significant impacts on the coffee sector. During La Niña events, rainfall can increase by 20-40%, coupled with a decrease in solar brightness and temperature [RD.8]. La Niña provokes large periods with heavy rains benefiting the reproduction of the fungus *Hemileia vastatrix*, which is the cause the coffee rust disease. During El Niño events, there is an increase in water deficit during dry seasons, affecting the development of the coffee fruit and negatively affecting production.

Coffee production is further threatened by climate variations in the three first steps of the value chain, which is related to the plant behaviour and the grain quality. Other factors external to the plant suffer the climate impact affecting the post-harvest steps (coffee quality) and the distribution to international markets or internal consumption:

- Post-harvest, including storage and transportation to collection centres, are affected by environmental conditions. Particularly, excess humidity affects product quality in these processes.
- Product transportation routes are vulnerable to landslides and climate-related disruptions on rural roads, often increasing the cost of getting products to markets.

Some of the climate impacts identified above open the need for all agents involved in the value chain to have access to tools that support decision-making beyond the weather forecast. For example, some studies suggest that an effective method to combat coffee rust involves quick actions by farmers to prevent the spread of the fungus [RD.17] that is related to heavy rains. Having services that provide enough information to anticipate which regions will have a significant increase in precipitation will help prevent or minimize the impact by acquiring the necessary material (fungicides) to minimize the impact on the coffee crop or increase the stock in case of losses in production.

Considering the experience of the MED-GOLD climate services, some potential benefits were identified to this sector for the Colombian case.

Table 6-1 MED-GOLD Services for Coffee Sector

Time scale	Decision area	Challenge	Climate service	Benefits
Mid-term (e.g., 6 months)	Agro-management	• Optimize pest treatment • Anticipate best timing for harvesting	• Temperature • Precipitation • Solar radiation • Relative humidity • Physiological-demographic modelling for pests and productivity	• Reduce pest damage while protecting the environment • Maximize crop yield and quality
	Stock management	• Better estimation of coffee production • Improve the selling process		• Improve stock and selling planning
Long-term (e.g.,5-10 years)	Long-term strategy	• Select production areas • Assess incidence of coffee berry borer • Select appropriate species according to production areas (Robusta vs Arabica) • Select time of crop renovation • Define plant density	• Temperature • Precipitation • Solar radiation • Relative humidity • Physiological-demographic modelling for pests and productivity	• Future productivity per production area • Regional recommendations for improved crop management strategy • Cost-benefit analysis per production area • Exploitation adaptation and investment evaluation

Access to medium-term (seasonal) climate predictions

Climate services integrating physiological-demographic models for the coffee agroecosystem will provide growers with the capacity to use scientifically generated information for its decision-making: harvesting, phytosanitary products stock.

Producers can identify the incidence of dry and wet periods in coffee flowering, fruit set and harvest and the relative importance of CBB that are key to economic coffee production.

Prospective tool for policy-making

A coffee system model-driven by climate variables will be a very useful tool for policy-making. This will help growers' associations and authorities to understand the impact of climate and climate change on the coffee species. In this sense, they can set a number of measurements in order to promote the best option for the sector.

Coffee *arabica* is currently the most important coffee crop in Central and South America. This is, for example, an emblematic crop for Colombia, being cultivated at middle altitudes in the Andes. C. *robusta* is better adapted to warmer areas. This species can be a suitable option to expand production to the Magdalena river basin, the *Altillanura* Plains and the Caribbean Plains, among other possibilities.

6.4. MED-GOLD CASAS PDBM service applied to Colombian Coffee

6.4.1. Description

In this chapter, the applicability of the MED-GOLD Climate Service based on CASAS PBDM model is described, showing how it was replicated in the Case of Colombian Coffee from the scientific and technical point of view.

PBDMs are a comprehensive approach for understanding the relevant relationships in the agroecosystems. This analysis is important preliminary research for developing more specific management tools for policy makers. The role of MED-GOLD is to apply the same conceptual and computational framework using PBDM (Physiological Based Demographic Models) climate driven analysis for olive in Europe and coffee in Colombia (Figure 6).

The Weather data (temperature, precipitation, solar radiation, and relative humidity) collected from field, are used as driven variables to model the coffee plant growth and development in field conditions and the impact of its main pest, the CBB on coffee production. Impact of different control strategies, from chemical to cultural to biocontrol were examined in a tri-trophic simulation setup with climate as a background.

The objective to use the MED-GOLD CASAS PDBM model, is to study the dynamics of coffee production and its main pest via well parametrized models to examine the possibilities of different control strategies of the pest under a climate setup: *Cultural control, Chemical control, Entomopathogenic fungi, Entomopathogenic nematodes and Combination of different control components* [RD.18]

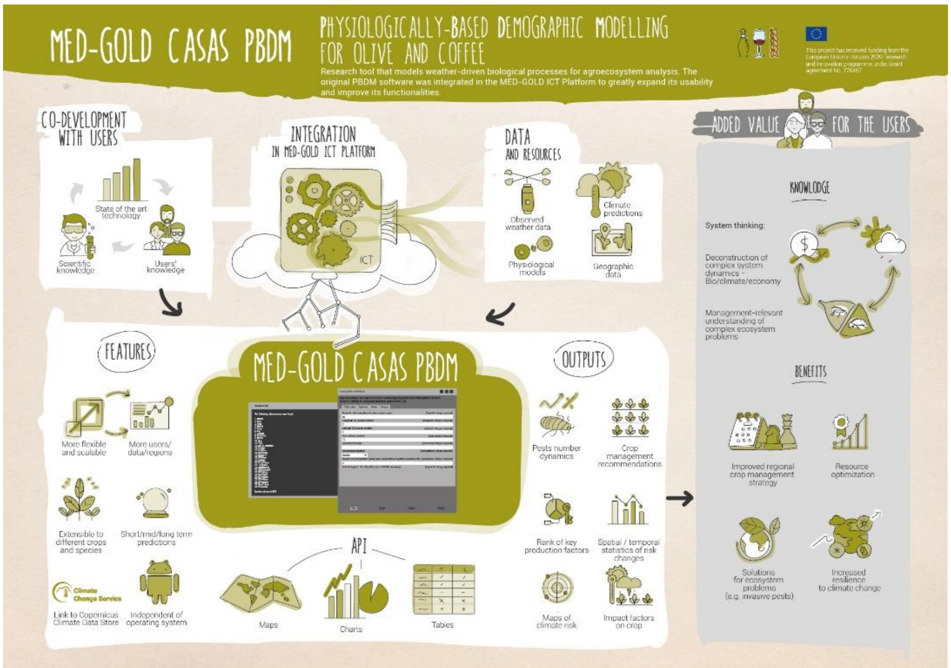

Figure 6. MED-GOLD CASAS PBDM for Coffee

6.4.2. Development

Daily maximum and minimum temperatures (°C), relative humidity (%), precipitation (mm), and hours of sunshine for Colombia were obtained from data published in the Anuario Meterológico Cafetero (CENICAFE 1995). Daily solar radiation ($MJ \cdot m^{-2} \cdot day^{-1}$) was estimated from recorded hours of sunshine using the relationship developed by Prescott (1940)[RD.19].

Parametrization of the model for *C.arabica* was done previously in successive works ([RD.20], [RD.21], [RD.22], [RD.23]). Parametrization for *C.robusta* is underway as a result of MED-GOLD. New field data (weekly data) were collected under MED-GOLD for C.*robusta* and CBB attack in San Francisco, Cundinamarca, Colombia (2018-2019) with the aim to extend the use of the model by parametrizing the same *C.arabica* model to be used with *C.robusta*.

Besides weather data provided in the Anuario Meterológico Cafetero, two sets of climate satellite data for Colombia were available through MED-GOLD: AgMERRA and AgERA5.

6.4.2.1. Technical - Data transfer

Climate data used are from the international data bases AgMERRA and AgERA5 provided by MED-GOLD in the appropriate format for the PBDM coffee model analysis.

6.4.2.2. Scientific

The following applied aspects of coffee production were analysed using the coffee PBDM model:

1. Intensive harvesting (H), cleanup (CU), and insecticide on CBB control.

2. Biopesticides of fungal pathogens (*Beauveria bassiana* and *Metarhizium anisopliae*).

3. Biopesticides of nematodes (Steinernema and Heterorhabditis).

4. The action of CBB parasitoids – The *bethylids Cephalonomia stephanoderis* (Cs), *C. hyalinipennis* (Ch) and *Prorops nasuta* (Pn) and the *eulophid Phymastichus* coffea (Pc) were studied via simulations.

The simulation results for Colombia that were published as part of the MED-GOLD project [RD.18] suggest poor control of CBB by parasitoids, entomopathogens, and chemical control, with average reductions being <15%. Additionally, antagonistic effects among these control tactics were found with the action of CBB parasitoids (P. nasuta and P. coffea). Positive coefficients for the interactions Pn·H, Pc·H and Pc·CU indicate detrimental effects to parasitoid efficacy of harvesting and cleanup because parasitoid life stages are removed, resulting in lower future CBB parasitization rates. Similar antagonistic effects were found between sprays of pathogenic fungi (B. bassiana) and cultural practices of harvests and cleanup as indicated by the positive sign interactions of Bb·H and Bb·CU. Another significant antagonistic interaction identified for Colombia was the positive sign interaction of the eulophid parasitoid P. coffea and B. bassiana (i.e. Pc·Bb).

In conclusion, despite some detrimental effects on biological control agents, periodic harvest of fruit and clean up were found to be the major control practice reducing CBB infestation levels in Colombia, with the efficacy of the practice decreasing as the time (T) between harvests (H) and cleanup (CU) increased from 15 to 60 days. The analysis for Colombia suggests that cleanup is the second most important control strategy for reducing the level of infestations. The result of this simulation agrees with Johnson et al (1990)[RD.18], who found that ground and tree raisins (dry overripe fruit) left after harvest, could be the main CBB reservoir in the inter-crop season in Hawaii.

6.5. Applicable services

Coffee prices, even for premium quality coffees, vary over time on the international commodities market (Atallah et al. 2018). In economic analyses, control tactics must enter not only as cost, but also as price enhancing attributes. For example, pest control based on sustainable periodic harvesting could be an important element in promoting and positioning select coffees on the international markets as unique, organic and highest quality. To this end, an in-farm mixture of shade grown, and sun grown coffees using organic cultural practices to control CBB has been proposed as a sustainable option for coffee production on small to medium properties (Hernandez-Aguilera et al. 2019)[RD.18].

C. arabica PBDM can easily be modified to include other species of coffee (e.g., C. robusta), and both models would have transferability enabling their use in a bio-economic analysis on larger, albeit global scale, and in the face of climate change.

6.6. Results and Conclusions of the MED-GOLD replicability for Colombian coffee

A team of experts appointed by the Colombian government to study sustainability of Colombian coffee production found that the policy of the Colombian Growing Association to mainly focus on C.arabica excelsior quality coffee must be revised: "… by refusing even to consider robusta coffees planting is a dogma that must be overcome, it closes options for participation in a promising coffee business." [RD.24]

With that in mind C.robusta field data was taken during MED-GOLD project through one year (2018-2019). Weekly samplings of plant growth, fruit development and CBB information were taken in a farm of an independent grower in an area which traditionally have been also planted with C.arabica cultivars. With that information and weather data information C.arabiga model was used as a frame and is being parametrized for C.robusta. These two species can be compared via modelling for different scenarios of climate including El Niño periods. Those are important climatic events that have influence on coffee production and CBB attack. Parametrization is still on their way, and this will allow a preliminary examination of the potentiality of planting C. robusta in a bigger scale in Colombia complementing C.arabica traditional planting.

The coffee simulations resulting from PBDM models are going to be a fundamental tool for policy making for the coffee sector in Colombia. This is not intended as a grower tool for productivity forecast.

6.7. Other Scientific Contribution for the Colombian Case

Within the frame of experimenting and scientific contributions, the MED-GOLD partner MetOffice has completed a preliminary evaluation of the performance of regional climate model simulations from the CAM-CORDEX initiative over Colombia. The objective was to see if any of the simulations were sufficiently realistic to be used to drive PBDMs or other crop models.

Under the Central American initiative CAM-CORDEX [RD.25], regional climate model (RCM) simulations were completed over an area which includes the southernmost parts of the USA, Mexico, Central America and northern parts of South America (Figure 7). Colombia is located close to the centre of the domain. No studies explicitly evaluating the CAM-CORDEX simulations over Colombia are known.

The CAM-CORDEX simulations fall into three groups, where the models were driven by ERA-Interim, a reanalysis product which represents "true" meteorology, simulations of recent climate by global climate models (GCMs), e.g., 1950-2005, and projections of future climate. The simulations in the first two groups have been compared with observed data and a summary is provided here.

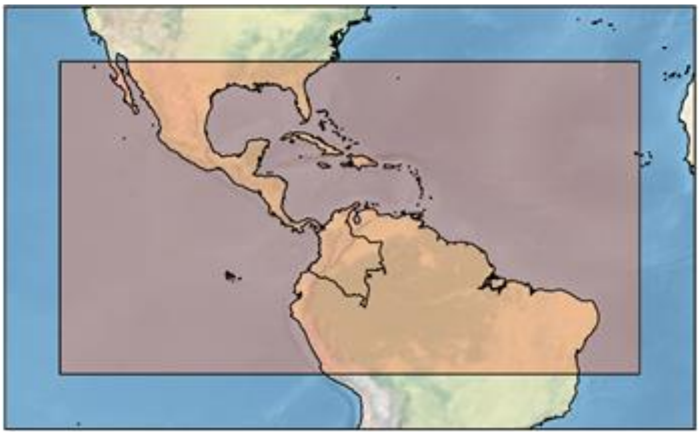

Figure 7. Outline of the CAM-CORDEX domain (light brown)

Climate data from three RCMs, RCA4, RegCM4.3 and CRCM5, are available for the CAM-CORDEX domain. Unfortunately, there is no single experiment for which data are available from all three RCMs. RCA4 and CRCM5 were driven by the ERA-Interim reanalysis. All three RCMs were forced by historical simulations from different global climate models. RegCM4.3 was used to downscale two GCMs, and CRCM5 was forced with one GCM, whereas RCA4 was forced by ten GCMs. Climate data from both the evaluation and historical simulations produced by the RCMs for a common period of 1981-2010 were compared with the AgMERRA dataset.

The RCM simulations were found to generally underestimate precipitation throughout the year over Colombia. For minimum temperatures, AgMERRA shows only small changes throughout the year, with a high of 21.5°C in April and a low of 20.4°C in July, giving a variation in minimum temperature of less than 1°C. The RCMs vary in whether they in general overestimate or underestimate minimum temperatures, with 11 models consistently predicting higher temperatures than observed, and 4 models consistently predicting lower temperatures than observed. The RCMs also tend to show a much greater variation between warmest and coolest months than is observed

Annual cycles for maximum temperatures show a similar pattern to those for minimum temperatures with AgMERRA showing only small changes throughout the year (Figure 7). The warmest month is February with an average maximum temperature of 30.5°C, and the coolest month is June with an average maximum temperature of 28.5°C. The variation in temperature throughout the year is 2.0°C.

Most models overestimate maximum temperatures, with average positive biases ranging from +1.2°C (+4%) to 4.8°C (+16%). The RCA4 RCM exhibits a much greater variation in maximum temperatures than observed, with peaks in March and October, and a low in May-June that is not present in AgMERRA.

7. TARGET MARKET ANALYSIS BY INCLUDING DETAILS ON THE ADDRESSABLE AND THE STRATEGIC PRIORITISATION OF THE SERVICES

In this chapter, a research shows how the Colombian Coffee sector works and what is the position of the Climate Services in this particular industry considering the direct and indirect actors along of the value chain.

Continuing with the exposed in the section 6.2.1, the target market is separated according to the most critical stage and the time scale in which the Climate Services are relevant in decision-making. The target market is analysed independently taking into account the actors whom plays a relevant role in three general stages, Productive (input selection, site preparation, and crop management), Post-harvest and Transportation and distribution.

The productive stage is a relevant stage into the value-chain because it is the most vulnerable to Climate Conditions and is the support for the following stages. In addition, this stage provides the employment and supports the economy of hundreds of small farmers and producers. The climate services as a tool to decision-making needs to be scalable from to all actors involved in this stage, however this scalability needs to pass by organisations (privates or public), regional associations, cooperatives, until reach the small grower farmer.

Colombian Coffee industry has the particularity that its structure works around of Coffee maker Colombian Federation (FEDECAFE), which controls many of the activities related to the coffee value chain see Figure 8. Although there are independent coffee cooperatives, they are focused on buying the production of small growers. Basically, the support in decision making for growers depend on Public sector initiatives through government institutions, private sector (FEDECAFE), or international programs.

The particular structure of the Colombian coffee industry lead to consider in both directions (competitor – client) the same actor, which is developed in the following chapters.

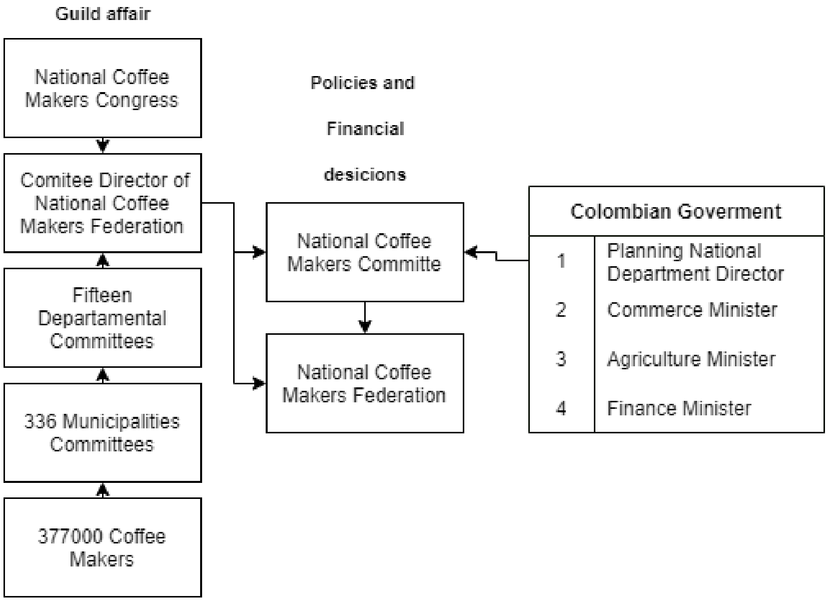

Figure 8. FEDECAFE structure

The researching activity identified the main actors that potentially can be customers of Climate Services for coffee sector having into account the nature (public or private) and its relation with the coffee value chain, putting more attention on the Productive stage (Figure 9)

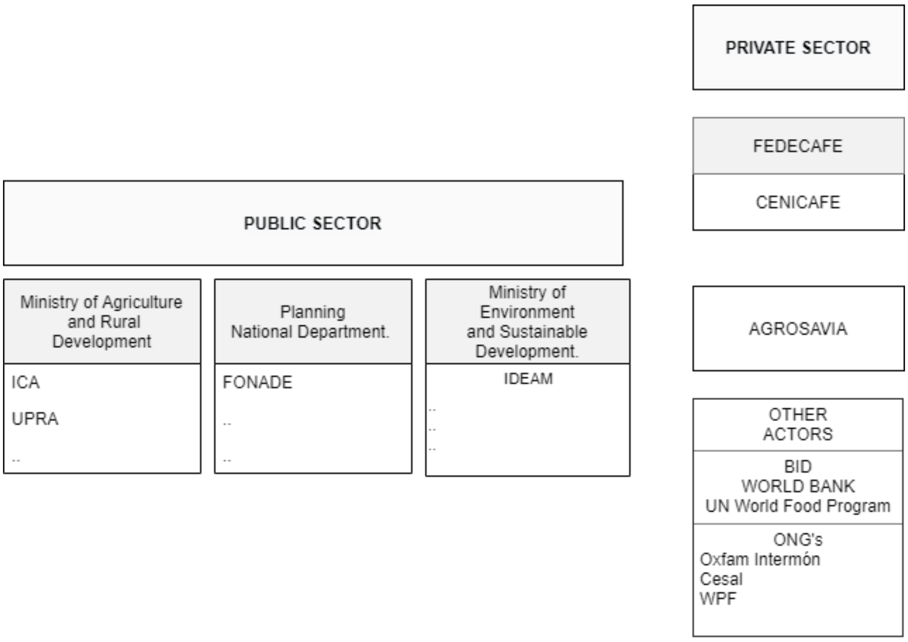

Figure 9. Main actors for potentially use Climate Services for coffee sector

7.1.1. Public Sector:

Colombian Agricultural Institute (ICA in Spanish) is a public entity of the National Order with legal status, administrative autonomy and independent patrimony, belonging to the National System of Science and Technology, attached to the Ministry of Agriculture and Rural Development (https://www.ica.gov.co/)

ICA provides some services (accessible from ICA but hosted in http://herramientas.datos.gov.co/) leaded to support activities for agriculture and livestock however do not count with a service that allow interactive experiences and/or filter the solution depending on particular crop, Area of Interest, Climate variable, or Climate index. There are limitations considering modern services based on mapping and updated solutions (Figure 10).

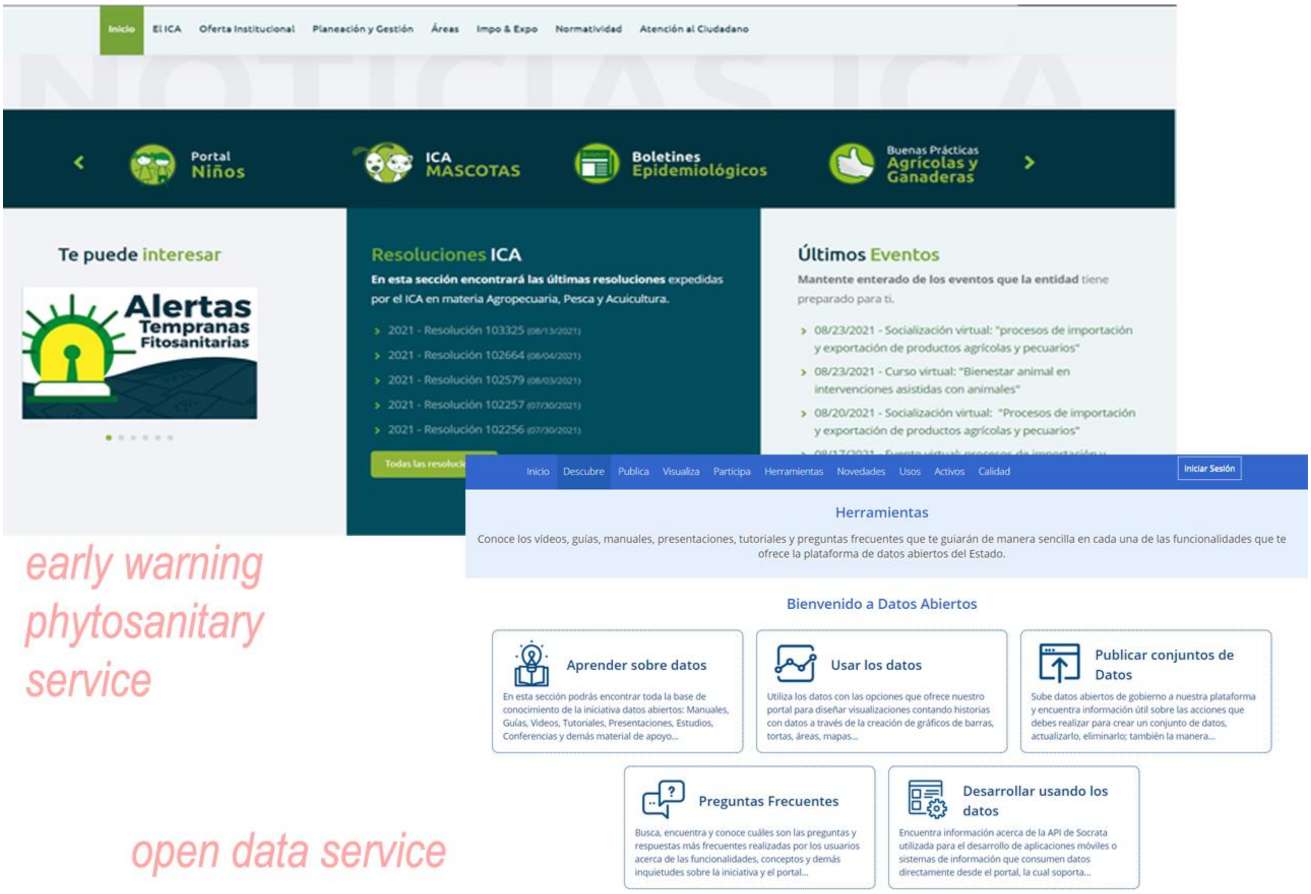

Figure 10. Agricultural Colombian Institute Service Overview

7.1.1.1. RURAL AGRICULTURE AND LIVESTOCK PLANNING UNIT (UNIDAD DE PLANIFICACIÓN RURAL AGROPECUARIA - **UPRA**)

UPRA generates criteria, guidelines and instruments for decision-making related to agricultural planning and comprehensive rural development (Figure 11). (https://www.upra.gov.co)

The services are oriented to supply information mainly documents and news related to agriculture and livestock farming and territorial planning. An interesting demo based on a commercial GIS platform was explored. It provides statistical data and information related to regional management such as planting schedule, harvest schedule or production of the main Colombian crops.

Figure 11. UPRA documentation service

This dashboard is not fully operational but could share useful information to different agriculture and livestock farms. There is a repository to use python scripts for vector-data management, however this is not can be considered as easy use service and is directed to particular user whom manage the specific commercial GIS package (Figure 12).

https://experience.arcgis.com/experience/1a5c7c59ed354e98a36c56b4729041d9/page/home

Figure 12. UPRA experimental dashboard for agriculture

In addition UPRA provides the tool SIPRA (https://sipra.upra.gov.co/) an operational GIS based solution (Figure 13) that provides low-scale (National or Regional) information related to land planning: (agriculture border, productive chain, irrigation management, statistics).

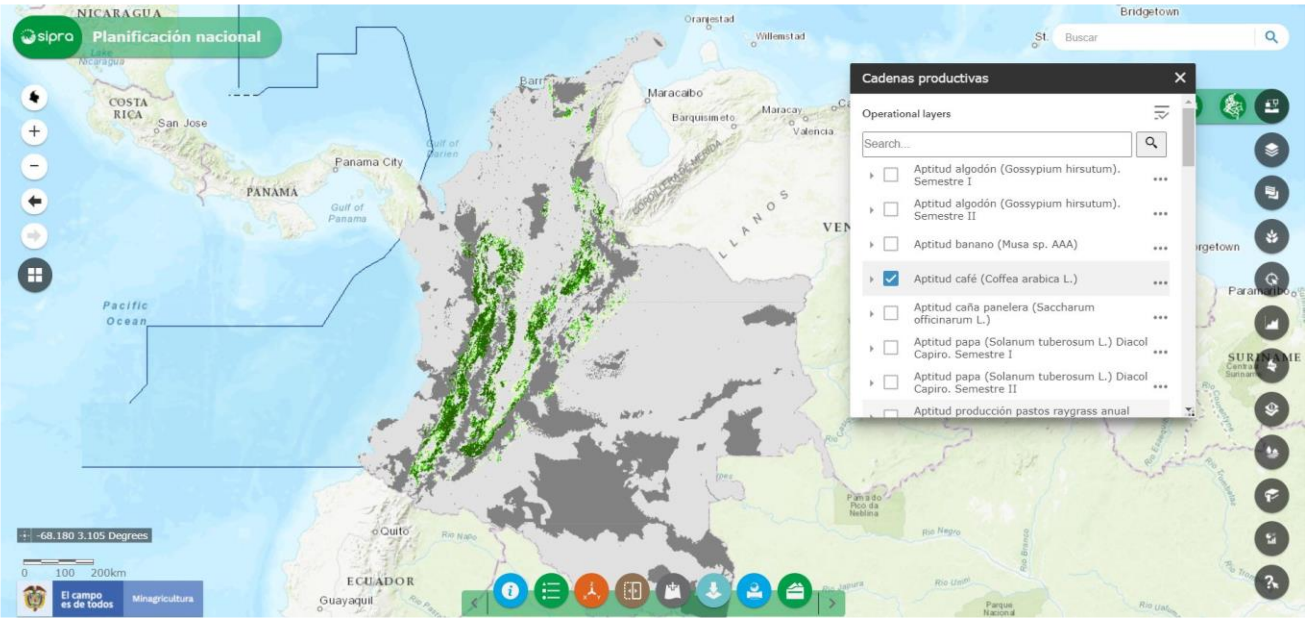

Figure 13. SIPRA map server service

Planning National Department (DNP) is the executive administrative agency of Colombia in charge of defining, recommending and promoting public and economic policy. The National Fund for Development Projects (FONADE) is a government financial institution of Colombia that provides grants and lines of credit to support feasibility and pre-feasibility studies of development projects in the public sector, especially those entities undergoing privatization. This public consultancy do not provide services itself, however is a strategic contact to know the projects where the Climate Services can be used.

7.1.1.2. Institute of Hydrology, Meteorology and Environmental Studies of Colombia (**IDEAM**)

IDEAM is a government agency of the Ministry of Environment and Sustainable Development of Colombia. (http://www.ideam.gov.co/)

The services provided by IDEAM (Figure 14) are focused mainly on weather forecasting based on weather stations network (http://dhime.ideam.gov.co/atencionciudadano/).

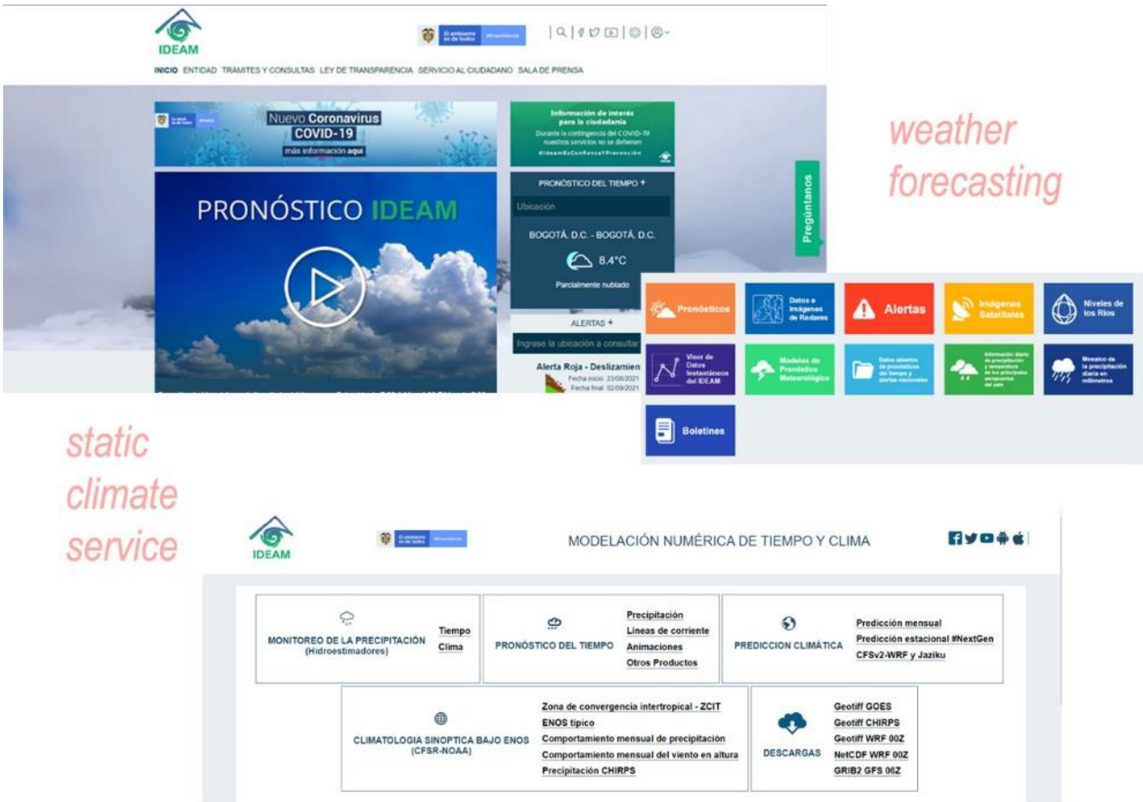

Figure 14. IDEAM weather service

In terms of Climate Services, IDEAM provides accessibility to historical, seasonal forecasting and monitoring tool based on mapping solutions hosted and developed by International Research Institute (IRI) (Figure 15) from Columbia University.

http://iridl.ldeo.columbia.edu/maproom/ACToday/Colombia/NextGen_Precip.html

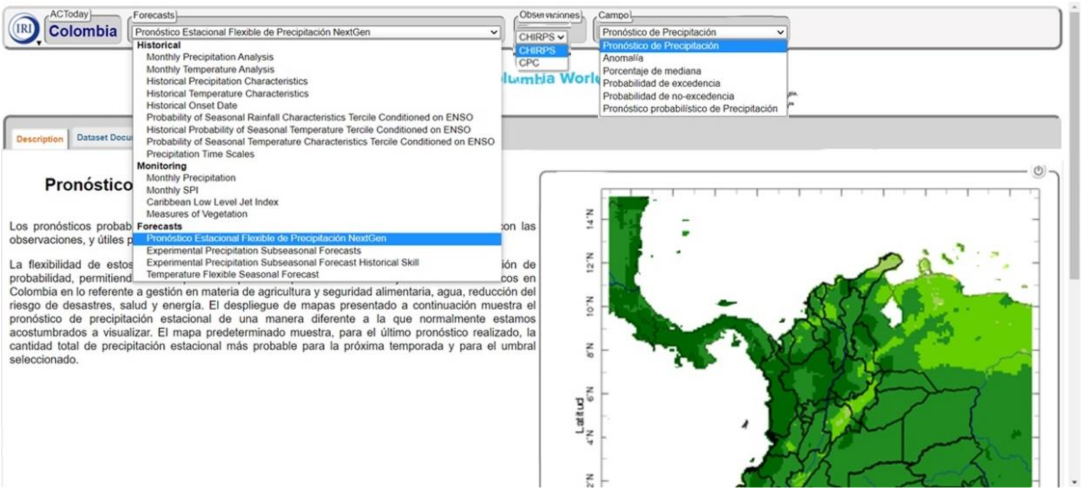

Figure 15. IDEAM - IRI seasonal forecast service

Considering the IDEAM nature, not strictly focused to the agriculture sector, however provide information which can be potentially exploited by other suppliers. Historically, Colombia has been affected by ENSO. In the 1990's a hard drought period affected the energy supply and the irrigation due to decrease of reservoirs level. The monitoring of the ENSO is p resent in this tool through the time series record. (Figure 16).

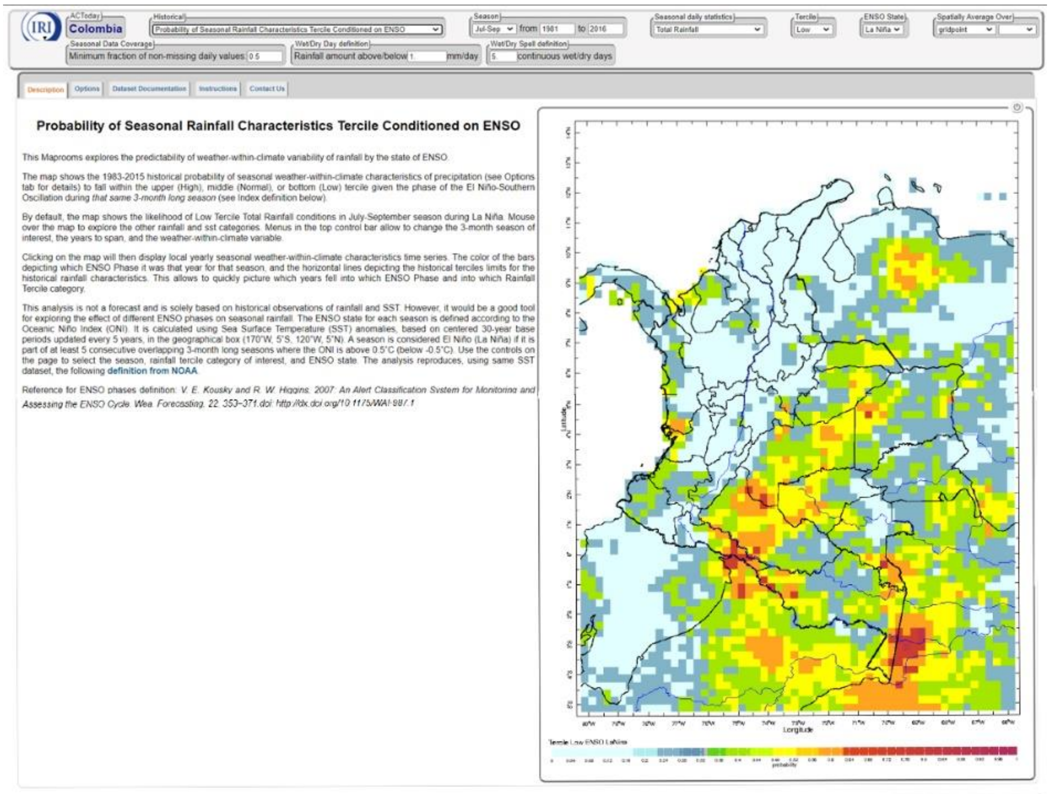

Figure 16. IRI - IDEAM ENSO Scenario Overview

The IRI tool provides an experimental sub seasonal and seasonal forecasting service, however the last update is for 2019 (Figure 17).

Considering the research related to Climate Services provided by IDEAM (weather station records and IRI Climate Service accessibility), some opportunities for MED-GOLD Climate services were identified. However it is relevant to indicate that IDEAM can play a role in two directions: client and competitor.

According to open available information, the IDEAM has invested in projects to improve and update some services which are not working adequately or are oriented to intermediate or high level end-user. In this sense IDEAM can be a customer for specific climate services for decision making in agriculture, environment and sustainable development within the frame of the Colombian Climate Change policies.

Concerning the coffee production and considering both the purpose of IDEAM and the kind of service offered by MED-GOLD beyond of climate variables (i.e. bioclimatic indices), IDEAM not represents a direct competitor.

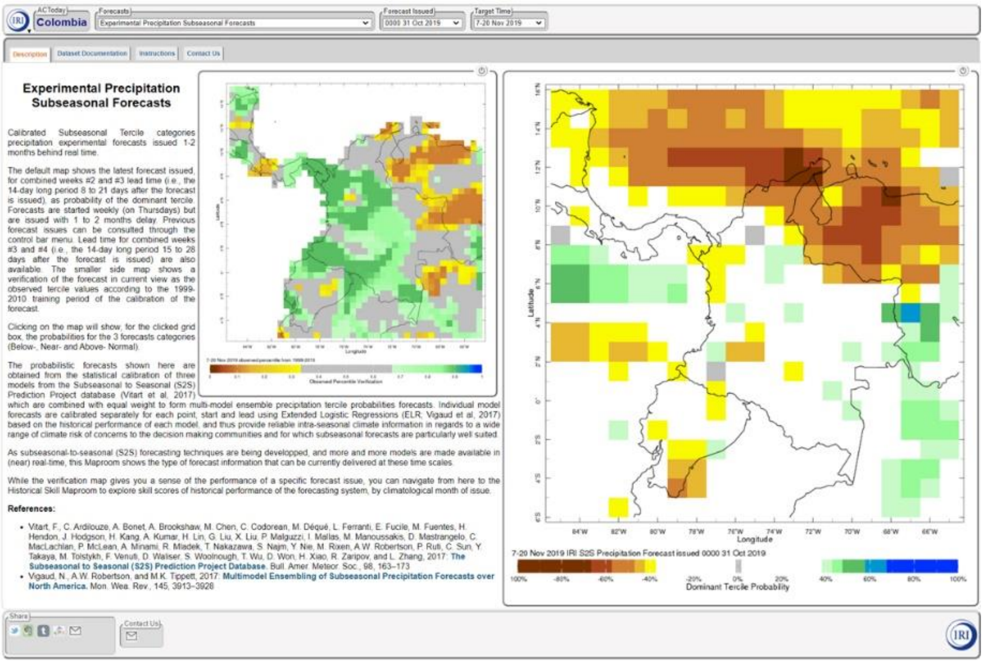

Figure 17. IRI - IDEAM Experimental Seasonal - Sub Seasonal Forecasting Overview

7.1.2. Private Sector Providers

7.1.2.1. National Center for Coffee Research (CENICAFE)

CENICAFE is a center created by the National coffee makers Federation (FNC, in Spanish) today FEDECAFE, with the objective to study aspects related to farm production, harvest, benefit, grain quality, management and use of by-products from coffee exploitation, and resource conservation natives of the Colombian coffee zone.

CENICAFE has 8 experimental stations distributed in the three mountain areas. These Experimental Stations meet the representative environmental conditions of most of the coffee farms in the country. The Center has researchers trained in the disciplines that constitute the most important areas of knowledge, to address the coffee ecosystem. CENICAFE has received the support of coffee growers and its challenge has been the development of appropriate technologies for coffee production in Colombia, in terms of economic, environmental and social sustainability.

CENICAFE provides different services into its agri-climatic platform (https://agroclima.cenicafe.org/home):

- Current weather conditions: presents the hourly records of rain (mm), temperature (°C) and relative humidity (%), recorded in the last 24 hours, in the Automatic Meteorological Stations installed in the coffee region of Colombia.
- Daily bulletin: contains the daily records of the temperature (°C), relative humidity (%) and rain (mm) of the Automatic Stations installed in the Colombian coffee region and that are active and transmitting information for the specific date of the query.
- Historic data: only for registered users
- Precipitation forecasting: Two days in advance forecasting based on IDEAM report, with spatial resolution of 10km.
- Seeding Times: In this application users can find the description of the adequate water condition for coffee planting based on the reference patterns of rain distribution and evapotranspiration historically recorded in the coffee region of Colombia. As a reference in Figure 18 is indicated the best time for seeding in Santa Marta Region for May.

Figure 18. CENICAFE Seeding Time Service

- Fights from "Broca": this application presents the number of adult borers captured weekly in 20 attractive traps at CENICAFE's Experimental Stations. With this information the user can identify the flight times of the CBB, relate them to weather events and the critical period of attack on the crop. Together with the infestation assessments users can make decisions for the integrated management of CBB

Geoportal Service

- Climate Atlas (GEOPORTAL): presents the trend of the climatic variables throughout the Colombian coffee zone according to the climatology (historical average) and under the El Niño Southern Oscillation (ENSO), El Niño, La Niña and Neutral variability scenarios.
- Vulnerability map to CBB (GEOPORTAL): is a tool that allows knowing the degree of vulnerability that coffee growing areas have to the attack of the coffee berry borer depending on the climate scenario. The Figure 19 show three degree of vulnerability in Boyacá department.

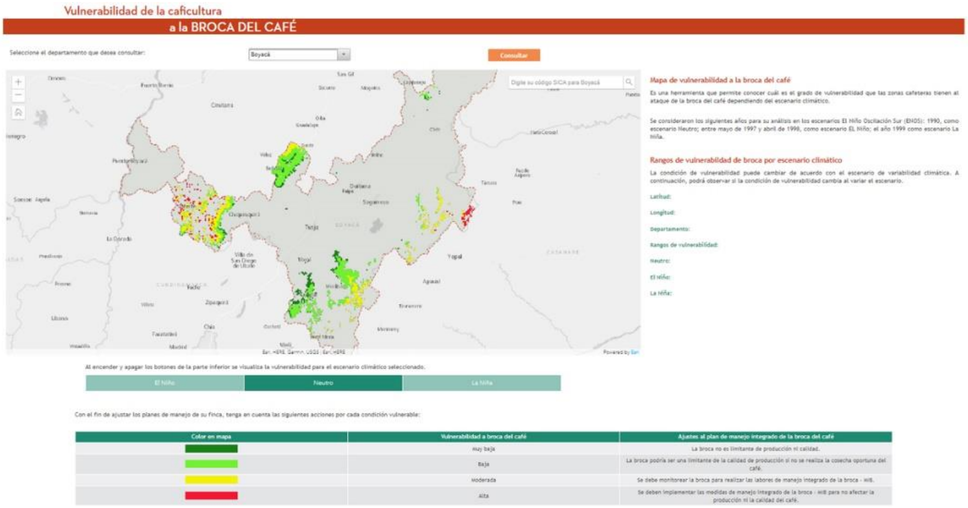

Figure 19. CENICAFE Coffee Berry Borer vulnerability Service

Early warning Services for Huila Department (Figure 20)

- Control of CBB based on flowering stage. The coffee berry borer is a pest that causes losses in production, therefore, it requires timely control. The period of greatest susceptibility to pest attack (critical period) is determined from the record of the main blooms. This application uses the dates of the main blooms of a productive year to define the critical period in which the control practices that will protect the harvest must be carried out, thus providing an early warning of the attack of the CBB
- Coffee rust Control based for flowering stage: Coffee rust is a disease that causes losses in coffee production in susceptible varieties, therefore, it requires timely and adequate chemical control. The rust epidemic is related to the physiology of the plant in coffee production, begins after flowering and is maximized before harvest. In this application, the dates of the main blooms are identified as an early warning to define the critical control period, starting 60 days after the main blooms have occurred and ending 180 days after they occur.
- Water deficit alert: this application provides info about water at 10-days time resolution for the last months, based on water balance for coffee crop. User can consult the information by locating the Automatic Station on the map or by searching by Station or Municipality.

Figure 20. Water deficit tool Overview

In general, the services provided by CENICAFE are mainly focused on weather forecasting, however seasonal forecasting and long term projections as decision making tool are not implemented. In this sense the MED-GOLD Climate Services can be a complementary service for CENICAFE adapting the critical indices and climate variables related to coffee crop to seasonal forecasting and Long term projections, thus CENICAFE - FEDECAFE can be considered a potential customer.

Considering the FEDECAFE is one of the most important actor in the Colombian Coffee Industry, the decision making for long term projections are necessary to guarantee the coffee production in the Climate Change scenario.

7.1.2.2. Colombian Corporation for Agricultural Research (AGROSAVIA)

AGROSAVIA is a public entity decentralized by services with a private regime, in charge of generating scientific knowledge and technological solutions through research activities, innovation, technology transfer and training of researchers, for the benefit of the Colombian agricultural sector.

Through the AGROSAVIA the user can find the tool MAPA (registration needed) which is a system to support the decision making based on weather forecasting data. According with the official website information, this tool "contributes with expert knowledge to increase the local capacity to make decisions aimed at improving the adaptation of cropping systems to climate change and climate variability. This tool is conceived as a learning platform with a climate-smart agriculture approach"

http://www.corpoica.org.co:8086/NetCorpoicaMVC/SEMapa/Inicio/

AGROSAVIA is leaded to all agri-food sectors, however the coffee and particularly the plague (CBB) and diseases (coffee rust) control is an opportunity for PDBM applications. Considering the objectives of this institution, the Climate Services can be offered as a complementary product for its offer, however the AGROSAVIA represents a direct competitor.

The Table 7-1 summarizes the identifiable services provided by the main actors involve in the Colombian Coffee industry to identify competitors, strategic partners or customers.

Table 7-1 Services offered by the main value chain actors

COMPLETING SOLUTION	PRODUCTS	CS solution	COVERAGE	TARGET GROUPS	SR	FORMAT SOLUTION
ICA	-Phytosanitary early warning service (info sheet)	N/A	National	- Farm growers -livestock farming	N/A	–read only. -document
	-Climate Information (static)	N/A	National	General	N/A	–read only.
UPRA	-Document		National			-read only
	-Sowing Calendar by crop -Harvest calendar by crop -Crop Distribution by region	N/A	Regional	-Farm Growers -Livestock Farms -General Public	N/A	UPRA based GIS dashboard usability: Med usr profile: Med accesibility: Low
	-Info sheet		National		N/A	-read only
	-Irrigation Management (risks, threats for hydric deficit by crops) -Productive Chain (land aptitude to agriculture products, eg. Coffee Arabica, potato, rice, etc) -Productitivy by municipality	N/A	Regional Municipality	-Farm Growers	N/A	SIPRA -usability: Med -usr profile: Med -accesibility: Low
IDEAM	-Metrological station data. Single variables by station	Weather	Local (Agri meteorological station distributed along the county)	General Public	N/A	GIS Web based -usability: Med -usr profile: Med -accesibility: Med
IRI climate service for Colombia accessible from IDEAM	**Historical Analysis -** *climatologies (1981-2010)* *and anomalies (1981-2016)* Monthly Precipitation Analysis	Climate	Grid Point Municipalities States	General Public	0.05º	Map Service – Interactive (Columbia University) International Research Institute -usability: Med -usr profile: High -accesibility: Med

	Monthly Temperature Analysis Historical Precipitation Characteristics Historical Temperature Characteristics Historical Onset Date Probability of Seasonal Rainfall Characteristics Tercile Conditioned on ENSO Historical Probability of Seasonal Temperature Tercile Conditioned on ENSO Probability of Seasonal Temperature Characteristics Tercile Conditioned on ENSO Precipitation Time Scales					
	Monitoring From 2010-current Monthly Precipitation from last 2 to 11 months *Monthly Standardized Precipitation Index (SPI) *Caribbean Low Level Jet Index *Measures of Vegetation MODIS based. (Last Year) NDVI EVI Reflectance Values				500m	
	Forecasts Seasonal Flexible Precipitation Forecast NextGen **Experimental Precipitation Subseasonal Forecasts Experimental Precipitation Subseasonal	Climate Observations CHIPS CPC			0.05º 1º	

	Forecast Historical Skill Temperature Flexible Seasonal Forecast					
CENICAFE	Current conditions based on agri meteorological stations	Weather	Local (Agri meteorological station distributed along the Coffee Region)	Coffee Growers	N/A	AGRICLIMA -usability: Med -usr profile: Med -accesibility: High
	Historical records based on agri meteorological stations					
	Daily Bulletin based on agri meteorological stations					
	Rainfall forecasting based on IDEAM service Hourly 2 days in advance	Climate	National	General Public	10km	
	Sowing Calendar based on rainfall and evapotranspiration	Climate	Local (Agri meteorological station distributed along the Coffee Region)	Coffee Growers	N/A	
	Coffee Borer Monitoring (8 experimental pitfall)	N/A	Local			
	Historical average of Climate Variables (precipitation, temperature, humidity and solar bright) in ENSO scenarios : La Niña, El Niño and Neutral	Climate	States on the Coffee Region		1Km	AGRICLIMA -usability: Med -usr profile: Low -accesibility: High
	Coffee borer Vulnerability mapping	Climate				
	Early warning for: Coffee Borer Coffee rust Water deficit		Huila State			
	Agri ecology zonification for coffee based on climate variables and phenology stages					
	Soils Mycorrhiza Quality	Related				

Table 7-2 Market Profile Identification and comparison with MED-GOLD product offer

Supplier	Competition Level	Strengths	Main Market	Weakness	Potential Users	Market Profile
CENICAFE	Medium	Main known Federation Control and decide almost on all value chain actors Consolidated federation with government delegated	All associated members	No Climate services based products	Coffee growers, coffee Farmers.	Client
ICA	Low	National Institution	Agriculture and Livestock	No digital solutions No provide products based on Climate Data	Growers and Livestock	Client
IDEAM	Medium	National Climate Authority. Weather data accessibility form in-situ weather stations network	N/A	Hgh dependency from NOAA and Uiversuty No specific products No Added value products Only provider weather data from small network	General Public	Competitor
IRI climate service for Colombia accessible from IDEAM	High	Consolidated Research Cente				Competitor
UPRA	Low	Institutional project GIS based solution Planning tool	Agriculture and Livestock	No implemented services No Climate services based solutions	Growers and Livestock	Client
MED-GOLD	N/A	Co-developed tool End user needs adapted solution	End User needs adaptation under the Climate	No weather forecasting service No GIS based solution No EO monitoring implemented in the current service	Educational, Industrial, growers	Climate services provider

Other segment of possible customer or competitors of Climate Services are the ONG's, Bilateral institutions, National or international research institution and funded Cooperation Programs interested in the agro-food security and poverty reduction, however this customer segment is variable and depends of funded projects.

The main advantage of the MED-GOLD services against the competitors exposed in the previous table is the co-developed and adaptive service based on climate data. The adaptation to the end user needs, covers specific requirements for the agri-food sector and its value chain, as was demonstrated with the PDBM model applied in the Colombian Coffee experience as well as the bioclimatic indices calculated for the three Mediterranean sectors whom participated in this funded project.

In the frame of global challenges against the climate crisis and the adaptation to climate change, the Colombian government trough the agricultural minister, environmental ministry and the Administrative Planning Department are promoting initiatives to reach the climate goals to adaptation. In this scenario, the MED-GOLD services find an opportunity from the technical and scientific support, to national or regional planning institutions to guarantee improvements oriented to the agri-food sectors and food security, this means that different sectors beyond of coffee industry could be beneficiaries of the climate services.

7.2. Business Model Canvass

MED-GOLD Business Plan (D6.10) takes advantage of the Business Model tool that serves to summarize the market uptake by showing in a glimpse the main actors and highlighting the challenges, strengths and weaknesses of the Business Plan. The figure below (Figure 21) is showing the building blocks of a Business Plan and the questions that will guide the collection of valuable information for each cell.

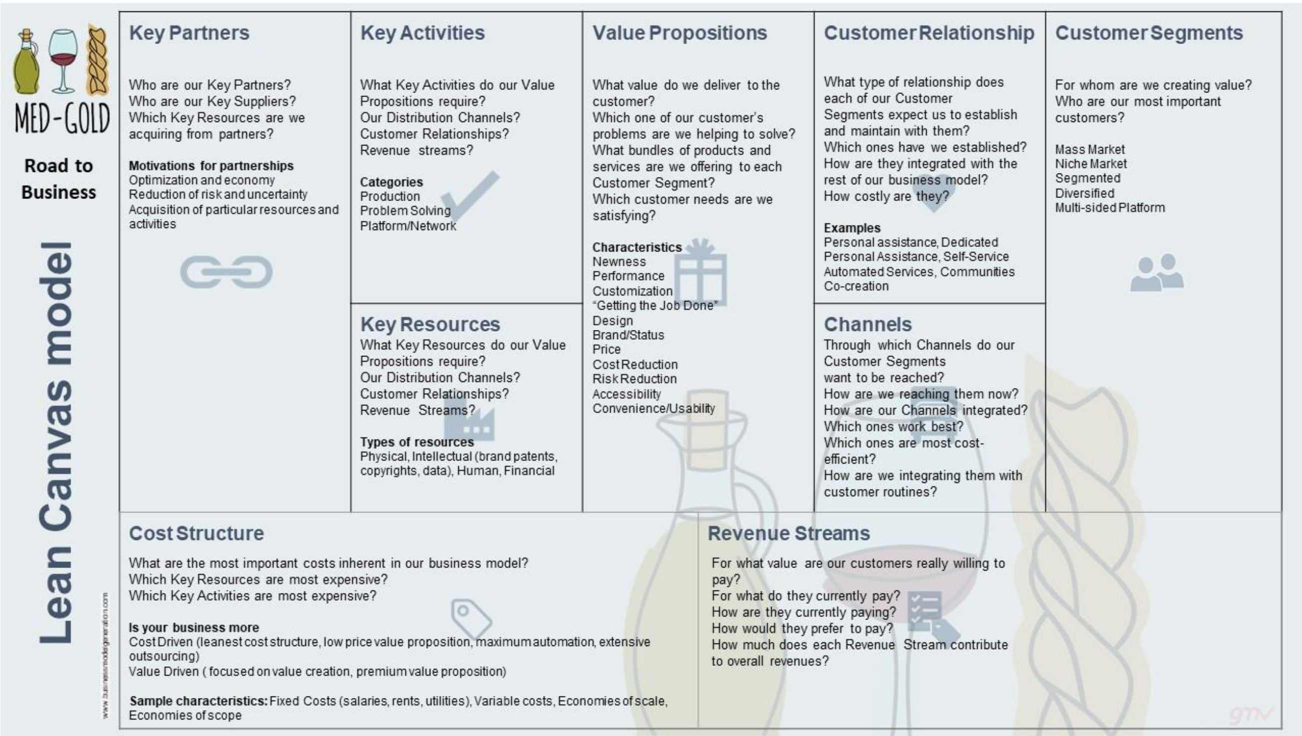

Figure 21. Business Canvas Model Template.

Source: http://www.businessmodelgeneration.com

In order to gather the key elements that will help MED-GOLD project to understand the Colombian Market (Table 7-3)

Table 7-3. MED-GOLD Business Canvas Model for Colombian Coffee Sector

Key Partners	Key Activities	Value Propositions	Customer Relationships	Customer Segments
Climate data providers Local data providers Sectorial partner, coffee High tech institutes Research institutes	Design end-user technology Commercialization planning Input request Models developing Output design	Climate Services (Downstream services) Contribute to improve productivity Enable to plant, harvest, etc. at optimum time Contribute to avoid cost of key commodities, land, insurance or losses Increase farmers' resilience to weather extremes Promote adaptation to climate variability Attractive tools to young farmers in order to transform agriculture labour from hard manual with poor margins to a more intellectually challenging activity. **PDBM**	The customer relationship could be continued through Workshops, specific sessions or webinars based in new developments. Through Newsletters with relevant information on the sector to engage if new products come along, tutorials or workshops. As the product matures it helps customers track it improvement. The cost must be affordable, and splitted b to the advances on the technology, as is not a task that will require a daily basis it's easy to add it to the work process	*Public: IDEAM* *Private: FEDECAFÉ - CENICAFÉ* *Non-Profit Organizations:* *AGROSAVIA*
	Key Resources Developers & Researchers IT Infrastructure Data availability		**Channels** Social media MEDGOLD community Direct contact with sectorial producers (associations, federations, cooperatives), distribution (guilds)	

Cost Structure	Revenue Streams
The cost structure is based on the cost of maintenance of the ICT platform, Dashboard, and further developments.	Freemium Demand-oriented Supply-oriented / inclusive model Open source

7.3. Climate Services from the vision of Colombian Coffee, OSS, SANSA and other projects beyond of Agriculture.

In this chapter are summarized the visions beyond of the three Mediterranean agriculture sectors (Olive/Olive oil, Grape/Wine, Durum wheat /Pasta) in the frame of the MED-GOLD final event.

Such as was mentioned in the previous sections the Colombian coffee is the core of this document. In the section 6.6, the experience of MED-GOLD in the coffee sector was described from the technical and scientific point of view. In this section we collect the most important comments from Mr. Ramón Vargas Rubio, honorary president of the National Association of Coffee Exporters of Colombia and collaborator of MED-GOLD in the activities related with replicability.

- "…The climate in one of the most important elements in an agricultural product, and coffee has a very special circumstance and condition for production that is that coffee blooms depending on the level of rain and the stress that can be caused by drought…"
- "…we have felt in this final period of the years 2020 and 2021 that climate change is so strong that, although it has not decreased coffee production, it has extended the coffee flowering periods and consequently has delayed harvesting, but it has also caused an effect that has been valuable to the *campesinos* (field workers) who pick the coffee…"
- "…It is important to start to thinking, not only about the climatic effect itself on the plant, but also about climate consequences on pests, altering that an excess of rain can creates a coffee rust problem and an excess of drought can create an problem of the coffee berry borer…"
- "… I have had that support for 2 years from MED-GOLD in my farm, who has made a permanent study on the production of my Robusta coffees and the climatic effects…"

Continuing with the exploration of MED-GOLD beyond of Euro Mediterranean region and the traditional agri-food sectors, the results of the project (dashboard) and its methodology were explained in the context of replicability and relation with other initiatives which. This is the case of the project Africulture.

Mr Louis Evence Zoungrana (Observatoire du Sahara et du Sahel) works in the development of agricultural and environmental surveillance tools and associated knowledge management systems. Observatoire du Sahara et du Sahel operates in Africa's Sahara-Sahel region. Key themes in the organization's work are aligned with the challenges facing this vulnerable region: land degradation, desertification, drought and the adverse impacts of climate change on ecosystems and populations. His impressions about the MED-GOLD project and Climate services were the following, indicating the possibilities of MED-GOLD:

- "The replicability of the MED-GOLD project's Climate services tool is well possible. The replicability lies on its interoperability (the tool is built in OGC standards which are interoperable). So, we believe that it could be extensible and customized according our needs…"
- "We do not use directly the Climate services tools. In general, we use to download the raw climate data (rainfall, temperatures, etc.) from relevant repositories (WorldClim, CHIRPS, TRMM, etc.), and to process these before generating the information and figures we need.

The mandate of the South African National Space Agency (SANSA) is to coordinate and integrate space science and technology programmes, conduct long-term planning and implementation of space-related innovations in South Africa, and ensuring the supply of cost-effective space-based EO data and products to support South Africa's policy, decision-making, economic growth and sustainable development. According from Mr. Mahlatse Kganyago, Remote Sensing Scientist at SANSA, the MED-GOLD Climate Services under a potential operational service would be perfectly adaptable to African context considering the threat that is supposing the climate change with longest droughts which affects sectors like Agriculture and Livestock

- "… for example services provided by MED-GOLD such as seasonal projections, climate change projections or maximum and minimum temperatures in extreme conditions will help us for making of decisions about management, pesticides applications…"

Dr Carlos Domenech is senior manager Climate Change and Sustainability Services at GMV (Spain). His main scientific expertise is on the fields of atmospheric physics and climate with an emphasis on the analysis of Earth Observation data and development of climate services. His impressions after to know the MED-GOLD services, the methodology and the applicability to other areas like disaster preventions (floods, droughts, etc) or sectors like silviculture

- “Climate services are key for climate change risk assessment and monitoring, to support climate change adaptation solutions, and to contribute to climate adaptation-mitigation synergistic approaches for land use and forestry regulation”
- “MED-GOLD is a great example of how both satellite-based EO and climate modelling can support resilient agriculture”. The approach taken by MED-GOLD is currently being promoted in our activities with the World Bank and the Asian Development Bank”

8. MAIN RESULTS

This document provided an overview of how climate services can be applied in a scientific and technical scenario to explore the possibilities of replicability in sectors other than those proposed in MED-GOLD. In the particular case of Colombian coffee, the use of climate information applied to PDBM will serve to explore the potential of the coffea *Robusta* crop as a response to the challenges that the coffea *Arabica* crop will have to face in view of the threat posed by imminent climate change. These results propose, based on the basis of scientific experimentation, alternatives by the authorities regarding the variety of coffee that can be implemented in coffee farms. On the other hand, this report on replicability reaffirms the spirit of co-development and collaboration between the different actors involved in a hypothetical tool adapted to the needs of a particular sector. The parameterization process that was exposed in this experimental phase will serve as a starting point for decision makers from coffee growers' federations and associations to make a transition towards new coffee varieties.

In experimental terms, the results of simulations based on CAM-CORDEX were also presented as an alternative in the PDBM inputs, however these did not yield acceptable results.

Additionally, this document presented the status of climate services aimed at providing services to the agriculture and coffee sectors and identified the different actors that play a relevant role for the coffee sector as well as for the agricultural sector in general. The result of the exploration of public, private or "public-private" institutions allows us to conclude that Colombia has an important way to go in terms of providing services based on Climate (seasonal, medium and long term time scales), for which can present as a potential market for co-developed tools as the case of MED-GOLD. Likewise, FEDECAFÉ was identified as the main actor in terms of decision-making regarding coffee policies, however, other private entities were identified, such as AGROSAVIA, with which it could work as a partner to provide climate services oriented to other cocoa sectors, fruits, livestock, etc.

From the governmental institutions point of view, IDEAM depends on the external services of the IRI program (Columbia University) to provide climate information, however, in a collaborative framework through the EU, C3S and projects such as MED-GOLD could be opened the possibility of providing an external provider service.

This document also justify how the Climate services could have a practical applicability on other sectors as the case of the silviculture and fishing and the possible applications from the perspective of OSS and SAMSA.

8.1.1. Challenges and barriers

The main challenge that arises after the preparation of this document is to be able to penetrate the Colombian market from the scientific and technical aspects to create alliances and collaborations to be able to launch a program based on climate services aimed at helping to combat the effects of climate change on coffea Arabica, which is predominant in the Colombian production, and/or contribute to the adoption of planting species that are more resistant to rising temperatures.

Establish an effective communication mechanism aimed at the Colombian coffee sector, highlighting the need for adaptation and the importance of having a centralized system with a clear objective, such as guaranteeing the proper functioning of the value chain, which must continue to function if the goals are to be achieved maintaining the stamp of quality that characterizes Colombian coffee worldwide.

8.1.2. Future steps

The steps to follow under the scenario of an operational tool is to initiate direct contacts that allow demonstrating the scope of climate services to establish the guidelines of a new coffee policy and in the same line extendable to other key sectors for the family economy and/or structural in Colombia.

9. EXPLOITATION OF THIS DOCUMENT

This document provided an overview of the Colombian Coffee Industry and the current position of Climate Services as a decision-making tool for the agricultural and agri-food sectors in the Colombian context.

The replicability of the MED-GOLD project through the PDBM leads us to think about the potential of Climate Services for the coffee sector, focused on the control of pests and diseases that are closely related to climatic factors.

This document can be used both by the general public and by policy makers, scientists and academics, economists and representatives of the agri-food industry as a basis to start a detailed study on coffee and other sectors and their relationship with the climate considering the challenges in the current scenario framed in Climate Change.

END OF DOCUMENT