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Bridging the gap between climate science and farmers in Colombia

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ABSTRACT

Agriculture is highly sensitive to variations in both weather and climate. Farmers face uncertainty in the weather patterns over the short term, and climate over the longer term. The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) has promoted a system of Local Technical Agro-Climatic Committees (LTACs)[4] in two Colombian regions to explore means of creating dialogue between researchers and farmers that would provide farmers with options in the face of both short- and longer-term variations in climate. The article uses a case study approach to describe how the original LTACs were established, the benefits obtained from the LTAC system, and the expansion of the system to areas outside Colombia.

The basic premise behind the LTAC approach is: If farmers and the local rural community at large can access and understand weather and climate forecasts and the responses of their crop production, processing, and marketing options under local conditions, they can make better decisions on how to manage their farms and businesses.

There are six basic components that are required to implement the LTAC approach to bridging the gap between climate science and farmers: (i) Establishment of the LTAC with alignment of local parties interested in managing variation in the climate and definition of their roles; (ii) local climate and monthly climate forecast; (iii) crop modeling and understanding of climate variation on crop production, processing and marketing and the impact this will have on management; (iv) dialogue between scientists, experts, and farmers; (v) dissemination and socialization of the dialogue; and (vi) local capacity building, which cuts across all the other five components.

The regular monthly meetings of the LTACs are the focal point of the overall process, bringing together information from various sources, organizing the ideas and thoughts, and then disseminating the information. A feature of the committees was their diversity. The committees required specific inputs, particularly on climate and the crop response before each meeting. Research organizations provided climate forecasts and crop response data. The forecasts proved closer to reality than long term means and the crops models that were used to predict crop

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response to changes in management and climate variation were relatively simple and unsophisticated. The committees gained confidence in these prognoses, which then formed the basis for dialogue on how best to manage climate variation. The production-side participants appreciated the opportunity to present their own points of view and the move from top-down recommendations, coming from the researchers and extension agents, towards a menu of options which they discussed. At the same time, it was evident in the early meetings that many of the participants came ill-prepared to grasp concepts related to managing climatic variation, thus highlighting the need for capacity building within the LTACs themselves.

LTACs actively promulgated their findings through bulletins, social networks, extension services, farmers' organizations radio, TV, and the press. In the dry El Niño year of 2015, many farmers used the information generated by the LTACs to better manage their crops, increasing yields, and reducing losses.

More LTACs are now being established in Colombia, Honduras, Guatemala and Nicaragua. These countries have understood the value of creating mechanisms through which researches and farmers can exchange ideas, with the farmers choosing options to improve their management based on better weather and climate forecasts and an understanding of how the weather and climate affects their crops.

1. Introduction

Agriculture is highly sensitive to variations in both weather and climate. In this paper, we use the National Oceanic and Atmospheric Administration (NOAA) definitions in which weather reflects short-term conditions of the atmosphere while climate is the average daily weather for an extended period of time at a certain location. Succinctly, climate is what you expect, weather is what you get (NOAA accessed, 2018). More than one-third of yield variation on a global basis is due to variation in climate and weather, and in large areas of the breadbaskets of the world, more than 60% of yield variation is associated with climate variation (Ray et al., 2015). Farmers face uncertainty in the weather patterns over the short term, and climate over the longer term. If individual farmers are to manage their enterprises well, they need to know future weather and climate scenarios for their farm and region and how these will impact their activities. Generalities on mean climate patterns over many years are not sufficient; growers need to know which crops are likely to do well and how to manage them on their farm at a specific moment in time. The conundrum has always been that farmers traditionally do not know, before they plant a given crop, the climatic or weather conditions that it will be subject to. In Western Australia, it has long been proposed that farmers should change their mix of crops according to expected climate conditions (see for example Kingwell, 1992) and farmers do change their practices according to the climate as witnessed by the comments of Peter Rowe, a farmer from Western Australia: "If there's no rain in sight we'll probably park up and leave the rest out" (Prendergast, 2017, ABC News, Australia). Changes in practices related to climate patterns are not restricted to large modern agriculture systems. In Indonesia, small farmers recognize that a late start to the rains may indicate an El Niño year and low rainfall. The area sown to rice declines in these years, whilst maize, which requires less water, increases (Naylor et al., 2002). More accurate advanced forecasting of El Niño events could mitigate the effects of varying climate patterns (Falcon et al., 2004).

Climate science has advanced markedly over the past two decades, with international coordination and collaboration, and it is now possible to predict both short-term weather and longer-term climate patterns at specific sites with a certain degree of confidence (Klemm, 2017; IPCC, 2014). Coupled with climate and weather analyses, crop models have improved to the point that a realistic prediction of crop performance under a range of climate conditions and management is possible (Challinor et al., 2018; Manatsa et al., 2012; Stone and Meinke, 2005). Thus, it is now possible to combine weather and climate prognosis with crop models and farmers' knowledge so that farmers can evaluate cropping options in light of likely weather and climatic conditions. To achieve this, a systematic approach is required so that farmers not only have access to information on probable climate patterns and crop responses, but also with growers participating in the discussion of how to best use the results of the climate prognosis and the crop production predictions (Meinke et al., 2013). In India, following this approach, farmers now select the most appropriate crop (sorghum, peanut or cotton) and plant density based on climate forecasts (Meinke et al., 2013). Similarly, Mishra et al. (2008) developed SARRA-h, a crop monitoring system for better risk forecasting, which uses rainfall forecasts to evaluate the likely yield of sorghum in Burkina Faso.

The scale of the predictions and models must be local so that farmers can make decisions on crop cultivation, land conservation, fertilizer and other inputs, and planting dates that relate specifically to their livelihoods and their farms (Ndiaye, 2010; Takle et al., 2014; Tall et al., 2014). Farmers prefer information that relates to what works on their farm, rather than blanket generalizations, especially when environmental conditions are extremely variable.

Colombia is an extremely heterogeneous country with an important agricultural sector that represents 6.3% of national GDP (World Bank, 2015). Livestock, sugarcane, coffee, rice, plantain, maize, and potato are important crops given their contribution to the country's economic development and food security (The World Bank, CIAT and CATIE, 2015). We also note that flowers and bananas make a major contribution to economic development, and, through increased incomes, to food security. Furthermore, as would be expected in a heterogeneous landscape, many crops that are not considered important on a national scale are of great significance at a local level.

Colombia has been categorized as highly vulnerable to climate change due to its specific biophysical and socioeconomic characteristics (DNP and BID, 2014). Furthermore, future climate change scenarios suggest that this vulnerability could rise as extreme events become more frequent and of greater intensity (IDEAM, 2013). Moreover, as Colombia is socially and ecologically heterogeneous, one-size-fits-all solutions are not realistic. Furthermore, farmers generally prefer making their own decisions in the context of local socio-economic, environmental, and technological conditions (Vanclay, 2004; Benson and Jafry, 2013) and through group meetings, rather than individualized technical assistance (Guerin and Guerin, 1994; Swanson, 2006; Vanclay, 2004; Araya et al., 2010).

Given these challenges, the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) promoted a system of Local Technical Agro-Climatic Committees (LTACs) in two Colombian regions, the mountainous Andean region (Cauca) and the coastal plain (Córdoba) (see Annex A). Local agricultural sector institutions and technicians tailor agro-climatic forecasts based on context-specific conditions to provide farmers with relevant information that they can analyze in the monthly meetings of the LTACs. The farmers then use the knowledge generated to make better, informed decisions on how to manage their farms. This paper describes the LTAC approach, how it was implemented in the two distinct socio-ecological environments, as well as the reaction of farmers to it and some of the benefits they perceived from using the approach. We discuss the lessons learned and how the process may be improved. Finally, we draw some general conclusions on both potential pitfalls and factors we deem to be critical for successful implementation of LTACs, with success defined as the LTACs being seen as a source of relevant information at the local level and farmer acceptance and use of the outputs of the LTACs. We share these experiences using a case study approach and hope that this will provide guidelines to others who follow the LTAC methodology, adapting it to their own circumstances.

2. The approach: Local Technical Agro-climatic Committees (LTACs)

The basic premise behind the LTAC approach is: If farmers and the local rural community at large can access and understand weather and climate forecasts and the response of their crop production, processing, and marketing options under their local conditions, they can make better decisions on how to manage their farms and businesses.

The LTAC approach, inspired by a successful Agro-climatic Early Warning System established in Cauca, Colombia and experiences observed in villages in Senegal[5] (UNEP, 2014), initially generates weather and climate forecasts and reports on the likely crop response to the climate for specific conditions in time and space. These forecasts are tailored to local conditions and needs. The forecasts, produced by local agricultural sector institutions and technicians, are used as an input for monthly meetings, where growers and personnel from state and other local agencies and the community at large discuss and analyze them with a view to helping farmers and other members of the community make better decisions. A basic premise in the process is that knowledge-intensive practices require learning through interaction and shared understandings, rather than through one-way directed knowledge transfer or recommendations (see for example Ingram, 2008). To put it simply, farmers prefer to understand what they are doing, rather than blindly follow recommendations from a faceless expert or committee. Hence, the LTAC involves active participation of local stakeholders, farmers and the private sector, as well as research organizations and national and local government institutions, in discussions on how best to manage crops and farms in a specific location at a specific moment in time. Distinct entities provide critical inputs into the discussions. Organizations, such as the government meteorological agency and international/national technical agencies, provide the LTAC with information on likely climate scenarios. Through crop models and both local farmer and expert knowledge, crop choice and management options are assessed in the light of the likely climate scenarios. These appraisals include not only climate, but also markets for the produce and availability of inputs. Farmers then use these appraisals to help them decide what crops to grow and how to manage them.

There are six basic components that are required to implement the LTAC approach to bridging the gap between climate science and farmers: (i) Establishment of the LTAC with alignment of local parties interested in managing variation in the climate and definition of their roles; (ii); local climate and monthly climate forecast; (iii) crop modeling and understanding of climate variation on crop production, processing, and marketing and the impact this will have on management; (iv) dialogue between scientists, experts, and farmers; (v) dissemination and socialization of the dialogue; and (vi) local capacity building, which cuts across all the other five components.

3. Establishment of two LTACs

The first step in establishing a LTAC is alignment of interests of distinct segments of society related to managing agro-climatic risk. Bringing distinct agencies together so that they all work towards a common goal over an extended period is not a trivial task. As part of the alignment process, we first had to create interest in the idea of the LTACs.

3.1. The germination of the idea

In 2013, the CCAFS research program established a Climate Smart Village in the Cauca department in conjunction with a local non-governmental organization (NGO), Fundación EcoHabitats (Aggarwal et al., 2018). At the same time, an existing scheme to alert small farmers and indigenous groups of Amerindians to climate variability was indentified. This scheme was established by

[5] More information on Senegal experience is available at: https://ccafs.cgiar.org/blog/climate-change-and-social-networks-senegals-peanut-basin#.VqfAJvnhBdg.

international, national, and local agencies and was led by the Procuenca Río Piedras Foundation and the local water company, Acueducto y Alcantarillado de Popayán S.A. E.S.P. These two agencies brought together local town and municipal councils, small farmers associations, community action groups, and leaders of the Amerindian reservations, who were all integrated into the local seed conservation scheme and the Participatory Agro-climatic Early Warning System (SAATP). The SAATP focused on monitoring local climatic conditions and the use of good environmental practices for water and associated risk. The Procuenca Río Piedras Foundation expressed the need for better information on climate change and its effects on livelihoods. The Foundation needed information on how to adapt the agricultural production systems used by the local communities to climate change in the short, medium and long term. The Foundation emphasized the importance of production alternatives which would improve the management of the watersheds and the water supply to Popayán, the capital city of the Cauca Department. CCAFS provided the Río Piedras Foundation with information on the Climate Smart Agriculture Prioritization Framework (CSA-PF) (CCAFS, 2015), which they began to use in their discussions with the local communities. This methodology was more directed to long-term climate change rather than to short-term variation in weather and climate patterns, which were the main concern of the growers.

Simultaneously, in 2013, the Colombian government, through the Ministry of Agriculture and Rural Development (MADR), began a joint program with CCAFS and the International Center for Tropical Agriculture (CIAT) to mitigate the effects of climate change and climate variability in the country. As part of this initiative, an interchange was organized with the Climate Smart Village in Senegal. Personnel from the government (IDEAM, the Colombian national meteorological service), universities (Universidad Nacional-the National University), producers' associations (FENALCE-cereal growers association and FEDEARROZ-rice growers federation) and scientists (CCAFS-CIAT) visited the newly established program for the Climate Smart Village in Senegal (Sanogo et al., 2016).

The Senegalese program aimed at empowering farmers to make better decisions by putting climate information in their hands. The Colombian entities found the Senegalese idea attractive, and CCAFS organized a meeting with representatives from the MADR, FENALCE, FEDEARROZ, IDEAM and CIAT. At this meeting, the MADR manifested its support for the LTACs and later pledged the establishment of 15 LTACs by 2030 during the Paris COP21 meeting in 2015. The representatives decided to initiate this support in Cauca, where there was already valuable experience working with small-scale producers and the Río Piedras Foundation, and in Córdoba, where FENALCE was active and FEDEARROZ was likely to support activities in this area. Consequently, financial support was provided for the setting up of the first two LTACs through an agreement.

Subsequently, CCAFS invited a Senegalese delegation to Colombia to share experiences. This delegation met with high-level local and national government agencies, producers and farmers associations, and other agencies. The positive reaction to this meeting provided further impetus to the development of an initiative that would put climate information in the hands of farmers so that they could make better decisions. Conceptually, the focus was to bring information and knowledge from multiple sources, including much of the tacit knowledge of the farmers, so that they themselves could combine expert knowledge with their own experiential knowledge to make better decisions.

3.2. Formalization of LTACs in two regions of Colombia

After the visit of the Senegalese delegation and the political support from the MADR, CCAFS organized an informal meeting with multiple agencies to promote the initiative. There was a consensus that a formal agreement and commitment by the people and the agencies involved was necessary for each LTAC if they were to be successfully implemented. In both cases formal agreements were signed among the multiple agencies involved.

3.3. Definition of roles

CCAFS began a process of aligning the interests of the multiple agencies and individuals interested in the LTAC approach (Fig. 1). Of vital importance was defining which agencies should take the lead role of the initiative. In the Cauca department, the Fundation Río Piedras took the lead with CCAFS-CIAT in promoting and organizing the LTAC. The Foundation Procuenca Río Las Piedras is an autonomous nonprofit organization with experience in watershed administration and integrated water management. The Río Piedras

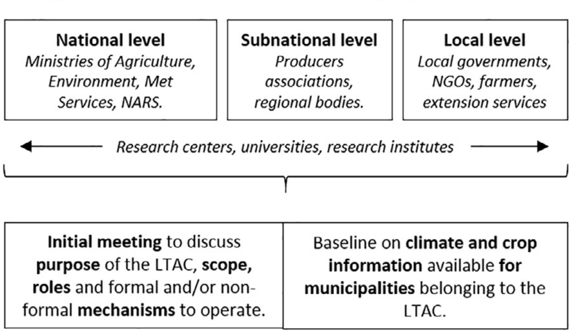

Fig. 1. Alignment of interests.

Foundation's clear vision of sustainable development, with a view to improving the quality of life while at the same time preventing and mitigating environmental damage, was closely aligned with the overall strategies that the newly formed LTACs wished to follow. Nevertheless, the principal focus of the Río Piedras Foundation was not agriculture; it was watershed management and sustainable provision of water to Popayán. Recognizing the Río Piedras Foundation's excellent record of "*getting things done,*" the founders who signed the formal establishment of the LTAC system decided unanimously that the Río Piedras Foundation should take a lead role, with emphasis on the local organizations, while at the same time CCAFS would coordinate the activities with national organizations. In contrast with Córdoba, no strong growers' organizations or associations tied to one specific crop were involved in Cauca LTAC.

In Córdoba, FEDEARROZ and FENALCE were assigned the lead role. CORPOICA (Colombian National Agriculture Research Institute) would provide expertise and logistical support, with FENALCE and FEDEARROZ providing contacts directly with the producers, necessary local crop information, and some logistical support. Thus, in Córdoba, the specific crop growers' organizations played a major role with FENALCE for maize, FEDEARROZ for rice, and CONALGODON for cotton. Crops such as cassava, which are mainly grown by the smaller producers who rent land, were not well represented by crop-specific growers' organizations.

IDEAM indicated that they could provide the basic meteorological information, but that they had neither the resources to attend the LTACs on a regular basis nor the capability to provide precise, locally-tailored climate predictions nor real weather data in real time. The clear recognition of their own strengths and limitations by IDEAM was critical to the success of the LTACs. If IDEAM had agreed, but later failed, to provide the local climate predictions at the scale required, the LTACs would not have functioned effectively. CCAFS, as part of the agreement with the MADR, agreed to provide the locally-relevant climate information, much of which was based on information supplied by IDEAM.

A concern expressed by the participants from Córdoba was the need to evaluate and validate the course of action suggested by the LTACs. CORPOICA and FENALCE took on this responsibility, although in most cases there was not enough time to validate recommendations for handling climate variation over the short term via field trials.

The Municipal Agricultural Technical Assistance Units (UMATAs) in Colombia are charged with providing technical assistance to the small and medium sized producers with a view to improving their productions systems, their income, and their welfare. The UMATAs took on the responsibility of divulging the results of the LTACs and also of providing feedback on the farmers' appreciation of their performance.

4. Committee meetings: Dialogue between scientists, experts and farmers

The meetings of the LTACs are the focal point of the overall process, bringing together information from various sources and diverse points of view, organizing the ideas and thoughts, and then disseminating the information. The committees require specific inputs before each meeting and the mechanisms to make the results of their deliberations available to anyone who needs them. In addition, the success of the LTACs depends on the capability of the committee members to understand and interpret the information made available to them and, as they develop, the ability to produce more relevant information in-house, rather than depending on external agencies.

4.1. The initial meetings

In the first meeting, stakeholders who become LTAC members formalized their participation through signed agreements that they themselves defined (see section Formalization of LTACs in two regions of Colombia). Once the LTAC was established, the next meeting named the coordinating or lead agency. The coordinators organized monthly encounters, including sending the invitations, writing the minutes, and keeping members up-to-date with pertinent information. Subsequent meetings reviewed and refined the roles of distinct entities (see section Definition of roles). Often, the roles were divided into technical supporters (e.g., universities, research centers) with specific skills in one or more of the knowledge areas and the actors in the field who make the decisions on how to manage the farms.

The initial meetings highlighted the distinct socio-economic dynamics of the two zones. In Córdoba, the growers' organizations and official agencies, such as CORPOICA, took a lead role with the power to make decision for the whole region and to manage pooled resources. On the other hand, in Cauca community leaders and farmers themselves became the lead figures. Thus, in Córdoba, there was a technical slant to the discussions, whereas in Cauca the growers and community leaders brought their own personal opinions and tacit knowledge to the table. In both cases discussions from the beginning concentrated on production problems, with less recognition of the importance of markets and price variations.

The LTAC members rapidly appreciated the idea of open fora for the presentation of ideas and discussion of novel opportunities. Furthermore, the participants engaged in production, rather than those from the research and technical agencies, appreciated the opportunity to present their own points of view and to be heard. At the same time, it was evident in the early meetings that many of the participants came ill-prepared to grasp concepts related to managing climatic variation, thus highlighting the need for capacity building within the LTACs themselves.

Much discussion in the initial meetings centered on who should do what, and which crops should be the focus of attention. As the meetings progressed, the emphasis shifted to how the growers in the regions could better manage their crops and farms.

4.1.1. Inputs for the meetings

To help farmers and growers manage their enterprises in the face of variations in climate patterns, the LTACs required access to specialized information on the likely climate and weather scenarios and options to make the best of these scenarios. Currently, the committees are more concerned with the short-term stochastic fluctuations in weather and climate than the long-term trends associated with climate change.

4.1.1.1. Climate-weather predictions. Expert opinion suggested that the main seasonal variations in climate relative to long-term averages in Colombia are associated with the El Niño-Southern Oscillation (ENSO). The climatic effects of ENSO over tropical South America and Colombia have been widely examined by Hastenrath (1976, 1990), Hastenrath et al. (1987), Montealegre (1996, 2009), Montealegre and Pabón (2000) and Poveda et al. (2006). Information on ENSO was obtained from public sources including NOAA[6], IDEAM[7], International Research Institute for Climate and Society[8] (IRI), and the Bureau of Meteorology – Australia[9]. Climate forecasts were generated using various tools including the Climate Predictability Tool (CPT) (Mason and Tippet, 2016). Historical data on precipitation and maximum and minimum temperatures was provided by IDEAM and sea surface temperatures forecast from the CFSv2 model. CCAFS used this information to adjust the models for the Colombian environment. Local forecasts for temperature and precipitation were built with a horizon of 6 months and were classified by terciles defining the categories below normal, normal and above normal rainfall (Fig. 2).

Weather and climate forecasts and the observed weather and climate patterns were used to evaluate the accuracy of the forecasts. Monthly climate forecast of precipitation and temperature were checked against observed local data from selected meteorological stations and satellite data from National Aeronautics and Space Administration (NASA) Tropical Rainfall Measuring Mission (TRMM[10]). The climate forecasts were evaluated statistically and by the LTAC members. The statistical analyses of true and false alarms were analyzed (Wilks, 2006; Jolliffe and Stephenson, 2003) and used to improve the accuracy of the forecasts by including information on other weather phenomena and climate processes including the Inter-Tropical Convergence Zone and the Madden–-Julian Oscillation. At the beginning of each monthly meeting, the weather and climate predictions of the previous month were analyzed and discussed. Local participants compared what they observed and perceived with the forecasts they had received. When predictions did not correspond with reality and what the local participants perceived, the reasons were discussed and decisions were made regarding which distinctive features of local weather and climate patterns meteorologists should include for future predictions.

The climate model was validated with at least 10 years of historical data and was considered by the LTACs to be useful when 70% of the forecasts for the following 6 months accurately predicted whether the rainfall would be normal, above normal or below normal. Thus, in 2015, for Córdoba (Cereté) the models accurately forecast lower than normal rainfall throughout the year, and in Cauca (Popayán), the models forecast lower than normal rainfall from June to September (Fig. 3). The forecasts approximated more closely to reality than the long-term averages, thus indicating the improved information basis for making decisions.

4.1.1.2. Crop response. The climate predictions *per se* are of use to farmers, but their value can be greatly increased if crop response to climatic variability can be evaluated. The committees faced two main challenges in looking at crop response. In the Córdoba LTAC, the main question was how to vary the management of the crops (maize, rice, cotton) or livestock enterprises, whereas in Cauca not only was variation in crop management considered, but also the possibility of changing crops according to the expected climate conditions.

For those cases where formal crop models existed and local information necessary to run them was available, these models were used to evaluate the effects of climate on the crops. For those instances when no crop models or necessary information existed, the explicit and tacit knowledge of CCAFS and local stakeholders was used.

Generalized crop models often need to be developed and validated for the local conditions and agronomic aspects of the locally-preferred crops or cultivars, local soils, and any anomalous aspects of the locality in question. Crop models for maize, rice, and potatoes were adapted to Colombian conditions. The maize, rice, and potato crop models were adapted using the adjustments suggested by Cortés et al. (2013a,b,c). Moreover, parameters of the models were adjusted for various varieties of local importance based on information provided by agricultural technicians, producers, local farmers, and experts from CCAFS. Models were also developed for cotton, oil palm, common beans, watermelon, and pastures. Models for sugarcane (panela) were based on the work of Cortés et al. (2013d).

The crop models were synchronized with the climate predictions to create crop performance probable future scenarios for the monthly LTAC meetings. The LTACs were aware that the effects of rainfall, the most important element of climate, do not directly impact crops, but mostly impact crops through indirect effects on soil water status. The soil water status itself is influenced by many factors, including soil physical characteristics, topography, and evapotranspiration. Furthermore, both excess and deficits of water may reduce crop performance. Temperature, in the tropics, in any spot shows little variation with seasonal variation in climate conditions (Legates and Willmott, 1990; Williams, 1994) and solar radiation, under the specific local conditions encountered, is intimately related to cloud cover and rainfall patterns. Nevertheless, extreme of temperatures were considered to be of importance for crop development and yield. In the higher-altitude Cauca region, the LTAC indicated that temperature should be included in the models. In addition, in Córdoba, local and expert opinion suggested that high temperatures during the dry period were associated with proliferation of insect pests. The high temperatures also affect flowering and pollination in maize and rice. Thus, although

6 http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml
7 http://www.ideam.gov.co/web/tiempo-y-clima/clima/fenomenos-el-nino-y-la-nina
8 https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/
9 http://www.bom.gov.au/climate/enso/
10 http://trmm.gsfc.nasa.gov/

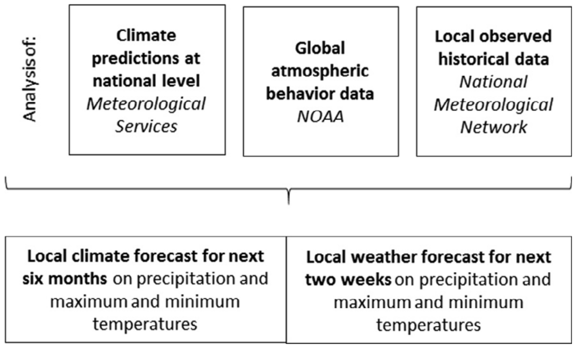

Fig. 2. Weather and climate forecasts.

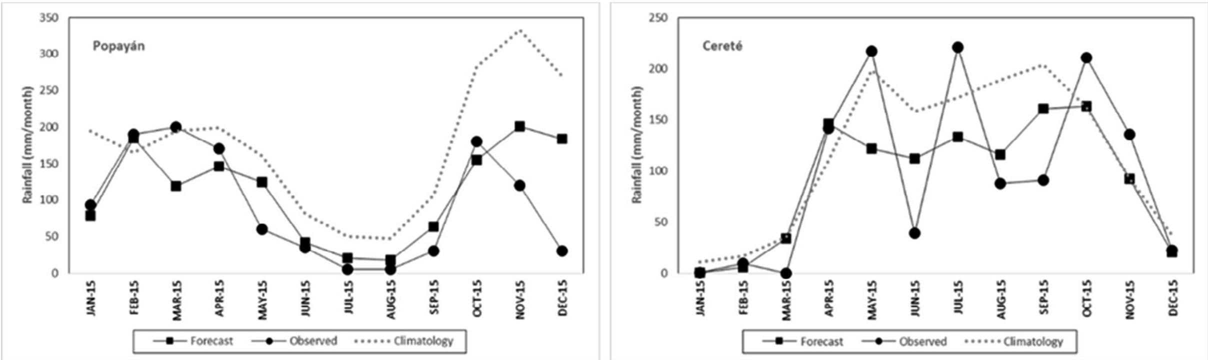

Fig. 3. Forecast, Observed and long term rainfall for Popayán, Cauca and Cereté, Córdoba for 2015.

temperature fluctuations are small, they may have large effects and were introduced into the models.

The crop models were based on CROPWAT and AQUACROP, both of which were developed by the Food and Agriculture Organization of the United Nations (FAO). AQUACROP simulates the yield response of herbaceous crops to water and is particularly well-suited to conditions in which water is a key limiting factor in crop production. CROPWAT estimates crop water requirements and irrigation requirements based on soil, climate, and crop data. The models were tested for efficacy in maize. CORPOICA and FENACLE planted observation plots at distinct planting dates. There was close agreement between the models and the field observations and consequently the LTACs were able to use the models with confidence.

In the Cauca region, the LTAC was particularly interested in exploring the likely response to irrigation in potatoes, maize, and common beans. The interest in irrigation led to information being collected on the frequency and intensity of rainfall, the probabilities of floods or rising river levels, and the possibility of controlling water movements. In the Córdoba area, the main interest was in assessing the advantages and disadvantages of distinct planting dates, with special reference to avoiding water deficit in the critical growth periods such as anthesis. This is especially important in the Córdoba region with the "canícula," a dry period which comes with varying intensity soon after the summer solstice.

The results of the crop simulations were assessed for technical consistency by field technicians before the official meetings of the LTACs. Moreover, when there were no crop models available, the field technicians drew on their own experience to assess possible

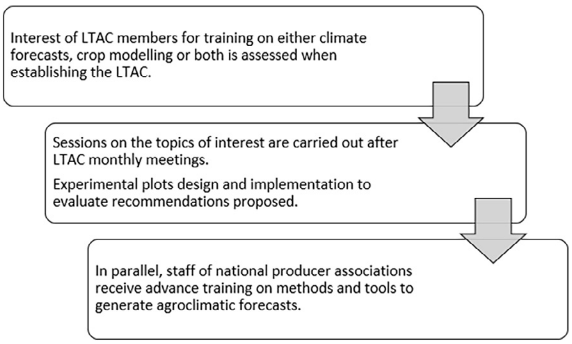

Fig. 4. Capacity building at the local level.

management options under distinct climate prognoses.

4.1.1.3. Capacity building. The capacity building program is designed by the LTAC members to meet their needs. In both Córdoba and Cauca, the committees decided to build capacity principally in the areas of climate forecasting and crop modeling to reduce their dependence on research organizations such as CCAFS (Fig. 4).

Training programs began with basic concepts of weather and climate and the causes of temporal and spatial variation. The participants were then introduced to climate and weather models and the key concepts on climate prediction and crop modelling. They learned how to use specialized software and how to interpret the output of both deterministic and probabilistic models. During the training sessions, a total of 15 institutions were trained, reaching approximately 40 people. Initially the LTACs depended on CCAFS scientists to elaborate the seasonal agro-climatic forecasts, but increasingly the forecasts are done by national or local institutions.

Moreover, as the initiative progressed, the LTAC members realized the importance of organizational skills. Teamwork was also improved through scientists-LTAC members' dialogue: the scientists had to downscale the complexity of the information and knowledge they wished to share so that everyone could understand. The local participants learned how to share their local knowledge with the scientists, often making tacit knowledge explicit so that it could be included in the discussions and the models themselves.

Apart from the more formal training, the LTACs themselves provided in-service training or learning on the job. The wide diversity of participants in the meetings, with diverse points of view and lifestyles, turned the meetings into a melting pot where all could learn something new. This was particularly noteworthy in Cauca, with the distinct view points of the Amerindian communities and their relationship with the land and the small farmers or "Campesinos" meeting and discussing with institutions like the national apprentice service (SENA), regional environmental agencies, and various departmental and government agencies.

4.2. Monthly meetings and dissemination

Participants at these meetings include producers, producers' associations, cooperatives, UMATA, universities, national agriculture research institutes, agricultural and environmental NGOs, departmental environmental regulatory organizations, multilateral organizations, ministries of agriculture, agricultural finance and credit agencies, traders, seed companies, intermediaries, and insurance companies among others. In Cauca, the suppliers of public services which provide drinking water to the local communities were key member of the meetings. It is noteworthy that even though the meetings emphasized production, entities with a wide range of interests attended the meetings.

At the time of writing the Cauca LTAC has met 19 times. As mentioned above, the meetings concentrated on crop choice and crop management as these were the areas deemed to be most important in the initial committee meetings. The procedure used was to develop the climate forecasts and the crop simulations at least two days before the routine monthly meetings. These forecasts and simulations then formed the basis for the dialogue between the scientific community and the local committee members (Fig. 5). The LTACs depended on the public sector organizations and the larger commercial entities for the information on climate and its effects on production, whereas the agricultural technicians and the farmers were more involved in planning how to manage the crops and the risks involved at the local level.

We note that there was intense dialogue between the scientists and the other members of the LTACs while appraising the management options open to the farmers in the region. Thus, it was not the scientists, as in the traditional top-down model, who decided what were likely to be the most appropriate management options, but rather a consensus was reached with all points of view considered. Together scientists and other LTAC members deliberated on the implications for crops and explored options that minimized associated risks while evaluating optimal strategies to face the current and future situation. These findings were recorded in the minutes of the meeting and were then used to develop bulletins that summarized the conclusions. As the meetings progressed, trust in forecasts as a tool to help manage uncertainty improved: farmers learned by their own experience that it is better to have a forecast, with all of its limitations, than to have no forecast at all.

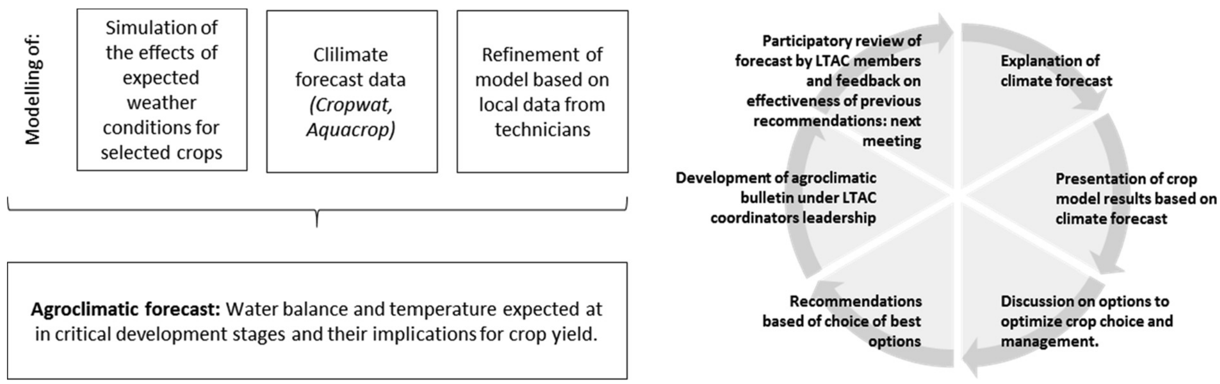

Fig. 5. The relation between crop modeling and the dialogue within the LTAC.

The scientists initially suggested that there would be little difference in the model results month to month, and consequently there was little point in monthly meetings. However, the majority of the members of the LTACs considered that, even though there was often little new model information to enlighten future decisions, it was useful to maintain monthly meetings to get feedback and ensure continuity. This view was later supported by the combining of longer-term climate forecasting with shorter-term weather forecasting, which highlighted the importance of more frequent meetings.

Initially agro-climatic bulletins produced by CCAFS and the LTAC partners were circulated outside of the formal meetings of the LTAC. These bulletins contained information on the ENSO phenomenon, local climate prediction, implications of climate prediction in phenological phases of crops, and a set of recommendations to diminish negative impacts or to take advantage of opportunities given the forecast. Later the LTAC coordinators produced monthly bulletins generated from the information and discussions in the LTAC monthly meetings, including the information in the agro-climatic bulletins. The bulletins also highlighted good agricultural practices and general information on agriculture. These bulletins were written in an easy to understand vernacular.

Each LTAC member disseminated the bulletin through their network of farmers using email, social media, or in some cases printing copies to give to those with no access to electronic media. A FEDEARROZ participant printed copies to put in places frequented by farmers so they could pick them up and obtain the information when they passed by. In addition, the LTAC members of Córdoba set up a WhatsApp group, managed by CORPOICA, which is exclusively used to share the bulletin and other information on climate, weather, and the crops of interest for the members (Fig. 6).

In Cauca, the results of the LTAC meetings were not only disseminated through the bulletins, but also via workshops with the local communities (Fig. 7). In the El Niño year of 2015, these workshops and the bulletins kept the communities informed of the evolution of the El Niño event, recommendations and techniques for efficient use of water, alternative planting dates of crops to mitigate the effects of reduced rainfall, and forest fire prevention practices and drills. In addition, the local radio, television, and press actively disseminated the information from the LTAC meetings and the government web-based agricultural information service, AgroNet, placed information from the LTAC on their website.

5. The LTAC experience and innovative management of climate variation

The climate forecasting confirmed the initial premise that variations in temperature were small and could be predicted accurately. The variation in rainfall in any one locality was large; however, the monthly rainfall forecasts for the following 6 months were closer to the real rainfall than estimates based on long-term averages. Thus, the LTACs could confidently plan with more reliable information on likely climate scenarios than before.

The crops models that were used to predict crop response to changes in management and climate variability were relatively simple and unsophisticated. Nevertheless, the expected yield from models and the real yield obtained in experimental plots in Córdoba that were not used to develop the models were similar. Thus, the LTACs had confidence in the scenarios created through the forecasts and the models, which they then used to appraise distinct climate scenarios and management options.

We suggest that the best criteria for evaluating the success of the LTAC approach is through the perceptions of those involved, its influence on how farmers' manage their enterprises in the face of climate and weather variation and uncertainty, and farmers' degree of satisfaction with the results. It is not possible to document either all the perceived benefits of the LTACs or all of the management decisions attributable to the LTACs. However, a few examples illustrate some activities that helped farmers manage weather and climate variations, their degree of satisfaction, and also some of decisions that farmers made based on the LTACs.

5.1. Cauca

The evaluation of the impact of the LTAC in Cauca is largely based on the doctoral thesis of one of the authors (Recaman, 2017). The Participatory Agro-Climatic Early Warning System of the upper reaches of the Cauca River watershed states it has been more effective since it became integrated with the LTAC. The LTAC has expanded from the original eight institutions to include smaller farmer organizations, state and departmental agencies, educational institutes, and research organizations. The members of the LTAC

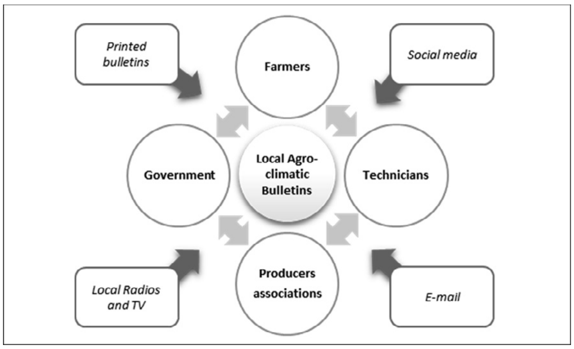

Fig. 6. Dissemination scheme.

Fig. 7. Dissemination of information in Cauca.

have observed improved articulation between organizations, more agreements based on trust, freer interchange of ideas and communication, and greater capacity to use knowledge. This in turn has led to adaptive and transformative governance with greater participation of many actors, tolerance of risk, and a more equitable distribution of power. These factors contributed to the LTACs ability to make more timely recommendations to the Amerindian communities and the small farmers' organizations. The recommendations were well-received as the very same communities were involved in the development of the LTAC.

In 2015, the Cauca LTAC met 12 times, with agencies and communities actively participating. During the year, the Australian Meteorological Service officially recognized the existence of an El Niño event. This was expected to accentuate the rainfall deficit that occurs in the middle of the year. Thus, in Cauca with a dry forecast for 2015, the CROPWAT model was used to assess *ex ante* the likely response to supplementary irrigation for potatoes, maize, and beans. The estimated response and the economic consequences in terms of both increased costs and returns were also evaluated. Based on these climate predictions and the agro-climatic models, the LTAC proposed a joint plan of action coordinated by the local institutions and the communities. The plan was oriented to both guarantee water supply for human consumption and for farming. Based on the appraisal, farmers adopted a range of management strategies to mitigate the effects of the expected lack of rainfall. These strategies included protection of springs and streams, improved water conduits, altering planting dates to avoid the worst of the drought, planting varieties from the local seed banks thought to be more drought-tolerant, establishment of small water reservoirs, and in one case a more efficient micro-aspersion irrigation scheme. Many of the practices adopted served not only to guarantee crop production, but also to ensure an adequate supply of water for household use. Of 81 farmers interviewed, 38% indicated that they had increased yields and reduced losses as a result of the LTACs activities (Recaman, 2017). Ramírez (2015) also reported that farmers in Cauca perceived average yield increases as a result of the early warning of the El Niño event.

The influence of the LTAC reached beyond the agriculture sector and the rural areas. The contingency plan for the Popayán water company (Acueducto y Alcantarillado de Popayán S.A. E.S.P) designed to mitigate the negative effects of climate variability over both the long and the short term used information from the LTACs. The perceived performance of the LTAC in Cauca has been sufficiently promising that the Departmental Secretariat for Agriculture of Cauca, accompanied by the FAO and other organizations, agreed to increase the area of influence of the LTAC, to incorporate more institutions, and to add other products that are important for the economic development of the region.

5.2. Córdoba

In Córdoba the monthly meetings provided information that was used by growers. Thus, the crop models indicated the potential benefits of modifications to the planting date of rice, maize, and cotton to avoid water deficits and higher temperatures at critical crop growth stages. Edinson Salgado, a technician with UMATA of Chimá in Córdoba, referring to the 2015 maize crop stated that: "*The recommendation in the bulletin was to plant maize during the second half of the month instead of the first half, which is what we usually do. We shared this information with the farmers and the ones that followed the recommendation said that their crops grew better with the recommended planting date*" (AGROSAVIA, 2015).

Nelson Lozano, Coordinator of the Climate Change and Sustainability Unit of the MADR, observed that since the LTAC in Córdoba was established, "*the volume of requests for support in losses due to climate variability has significantly reduced.*" This view was supported by a local insurance agent, who stated that in the dry year of 2015 the number of claims was comparatively less in those areas of the North Coast of Colombia served by the LTACs.

The perceived benefits of the LTAC in Córdoba led to the establishment of another LTAC in the neighboring department of Sucre. Rice growers in the region, who have already modified planting dates, are now considering moving from upland production systems to irrigated paddy rice. In the wetlands of the Mojana district, the small farmers association, based on recommendations of the LTAC, are now planting yams and maize and they have reported excellent results. Saavedra (2018) interviewed 263 rice farmers in the region; 76% used the climate information to determine when they planted their crop and 59% chose the most appropriate variety.

Córdoba LTAC has also been source of South-South knowledge, with Central American countries having participated in the LTAC meetings as observers. These countries have taken and adapted to their own contexts a similar model to understand and use climate information to identify best practices to reduce the negative effects of short- and long-term climate variability on their crops (see lessons learned and discussion section below for more detail).

6. Lessons learned and discussion

Our experiences support the view that the LTAC approach of using climate and agronomy models, validated for local contexts, coupled with strengthened local capacity to understand climate and its impact on agricultural processes helps farmers manage climatic risk. Adaptation measures need to be based on local knowledge and experience that is then shared with farmers so they can implement the measures, not only to minimize the effects of weather and climate variability, but also to take advantage of the opportunities that climate change might offer.

The LTAC approach requires the participation of multiple agencies, with a range of skills, all working together with the common goal of improving the well-being of those that live in the locality. This is not a trivial task. In our case the alignment of multiple agencies and the decision to use the LTAC approach was triggered by the exchange between Senegal and Colombia, which included participation from the Ministry of Agriculture and Rural Development of Colombia. We believe that this high-level support and backing was fundamental for the establishment of the LTACs in the socio-political context of Colombia.

Once the high-level support had been obtained, a lead agency was required to align the interests of the multiple agencies; an international agency, CIAT/CCAFS, acted in this catalytic role in Colombia. Recently, in Honduras, Guatemala and Nicaragua, LTACs have been established based on the Colombian experience. The principle catalysts have been the Secretariat of Agriculture and Livestock (SAG) in Honduras, the Commonwealth of Copán Chorti' in Guatemala, and Heifer International (an NGO dedicated to the eventual elimination of poverty and hunger) in Nicaragua.

In Honduras, the implementation of LTACs is a national initiative designed to cover the whole country. At the time of writing there are seven LTACs in seven regions. SAG decreed how LTACs should be formalized and provides guidelines on how they should be organized. Honduran LTACs do not meet as often as those in Colombia; they have prioritized meetings around the three main seasons for planting in the country. Consequently, only three bulletins per year per region are developed and disseminated.

In Chiquimula, Guatemala, in the northern part of Copan, a group of institutions led by the Commonwealth of Copán Chorti' expressed interest in managing the agro-climatic risks of the farmers in its area of influence, but lacked the knowledge, information and skills to establish a system to support the farmers. CCAFS, CIAT, Bioversity, and CATIE (The Tropical Agricultural Research and Higher Education Centre) were already involved in Guatemala with projects helping farmers cope with climate and weather variability (Agroclimas and Climate Smart Village in Olopa). Together, they decided to provide technical support to establish the first Guatemalan LTAC under the leadership of the Commonwealth of Copán Chorti'. This LTAC is supported by the Ministry of Agriculture, Livestock and Food (MAGA), the Ministry of Environment and Natural Resources (MARN), and Insivumeh (the national meteorological institution). The LTAC meets every 4 to 6 weeks with the participation of a wide range of local actors, including ANACAFE (coffee producers' organization), CUNORI (local university), CATIE, and local authorities among others.

In Nicaragua, through a FONTAGRO-funded project, Heifer International and CIAT have supported the implementation of two LTACs used to create local capacities to understand climate and weather implications on crops and test the recommendations given in farmers' fields. The main driving force comes from local organizations and associations, including suppliers of agricultural inputs. Government institutions are aware of the project but have not yet played a major role. The low level of government support required for the establishment of the two Nicaraguan LTACs suggests that LTACs may spontaneously arise from local initiatives in the future, with the impetus to establish them not directly coming from the government.

Once the agencies have been aligned, the LTACs need to be formalized with a lead or coordinating agency. In the Córdoba case, the lead was shared jointly by CORPOICA and FENALCE, both of which are agricultural organizations with an interest in increasing agricultural productivity and rural well-being. At the time of writing, the Córdoba LTAC continues to function well and two more LTACs have been established in the North Coast region of Colombia, one in Sucre department and the other covering the three departments of Magdalena, Cesar and the Guajira using a similar model. The departments of Santander, Caldas, Tolima, and Nariño have also established LTACs (see Annex A). In Cauca the lead agency, the Río Piedras Foundation, is not primarily an agricultural organization and there was an inactive period for that specific LTAC. However, currently the Secretariat of Agriculture of Cauca has assumed leadership of the LTAC and is supported by a variety of organizations that include IDEAM, CRC (Environmental Authority of Cauca Department), Fundación EcoHabitats, the Río Piedras Foundation, Cauca University, and FENALCE, among others. This effort is being linked to implementation of the Participatory Integrated Climate Services for Agriculture (PICSA) methodology in the Climate Smart Village in the northwest of Popayán. We note that support from agencies of the central government, such as the national agricultural research agency and the national meteorological service, in terms of services facilitate the activities of the LTACs. In the case of Colombia, the LTACs would probably never have been established without the support of the Ministry of Agriculture and Rural Development, whereas in Nicaragua the government was not directly involved.

A strength of the first two LTACs in Colombia has been the diversity of the agencies involved and the move from top-down recommendations, coming from the research agencies in the form of instructions to farmers transmitted by extension agents, towards a menu of options which growers and extension agents discuss with the researchers. This process is well illustrated by the use of supplementary irrigation in Cauca. The researchers showed the likely benefits of irrigation to potatoes, maize, and beans in a dry year; however, the growers worked out how they could capture and store rainwater to use for supplementary irrigation and selected crop varieties adapted to dry conditions from their own communal seed banks.

Although the diversity of agencies is a strength of the LTAC approach, the dependence on many organizations can be a threat to its effectiveness. For example, the constant updating of the climate forecasts is optimized when there is access to real weather information in real time and this would normally be provided by the national meteorological service. However, IDEAM does not have the resources to work directly with the individual LTACs. To address this challenge, a working group of meteorologists from the LTACs and IDEAM meets every month to evaluate the national and regional climate and weather forecasts. The LTAC meteorologists then use this information, coupled with other sources including satellite data, to make the information relevant to local needs.

The LTACs and the dissemination of their deliberations through the agro-climatic bulletins and other mechanisms have become an important source of guidelines for producers and decision makers, positively influencing production systems and food security, and facilitating the sharing of local, often tacit, knowledge with scientific information based in mutual respect and trust.

The climate forecasts based on publicly-available information adapted to local conditions were acceptably accurate, and when combined with relatively unsophisticated crop models provided information to the LTACs that enhanced their ability to assess distinct scenarios and management options. However, crop models are not available for many crops, particularly those that are not important globally but may be of great importance locally. This limits the ability of LTACs to help farmers make decisions regarding such crops. In Cauca, the local stakeholders identified this deficiency and proposed the collection of the agricultural data necessary to feed the current and future models so as to cover all areas of interest of the producers. This suggests that there is a need for improved monitoring of what is happening on the farms themselves so that local capacity can be increased to not only use, but also to develop and validate simple models for locally-important crops. Furthermore, the importance of monitoring is reflected in the perceived need to expand the network of meteorological stations in the Cauca region from 25 to 37 to improve the early warning systems.

The official dissemination of the LTACs findings and suggestions for improved management were through the bulletins and the UMATAs. In Córdoba, CORPOICA played an important role in dissemination when it established the LTACs WhatsApp group. Furthermore, the strong crop growers' federations, FENALCE and FEDEARROZ, played a fundamental role in disseminating information. In both Córdoba and Cauca, many informal channels evidently developed and helped spread the knowledge generated by the LTACs. Nevertheless, we suggest that in the future more structured means of communication may enhance the effectiveness of the LTACs.

In Colombia few small-scale producers keep farm records (Howland et al., 2015), hence their capacity to evaluate the consequences of their management decisions is limited. Moreover, we envision a virtuous circle with the LTACs offering a menu of options to farmers, with farmers choosing options and then providing feedback on their effectiveness, which in turn improves the LTAC's ability to continuously refine and improve the options offered. The lack of farm records limits the possibility of providing feedback and evaluating the effectiveness of LTACs. While writing this paper, we found many testimonies to the efficacy of the LTACs, but little hard data to support these views. We suggest that the performance of the LTACs could be greatly increased if better means of monitoring farm management practices and performance were routine. This would allow farmers and their representatives at the LTACs meeting to provide: (i) improved feedback on the consequences of decisions based on the LTACs deliberations; (ii) inputs into the refinement of the crop models used to determine response to climate variation; and (iii) discussions with facts and figures rather than purely subjective opinions about the effects of varied management on farm and crop performance.

The LTACs in Colombia have concentrated almost entirely on managing crop production in the face of climate variation. Prices of agricultural products are also influenced by the climate. Moreover, supplies to shops and supermarkets are often disrupted by adverse climate conditions. We suggest that in the future the LTACs should not only look at the supply side, but also at the demand for agricultural products and how it is to be satisfied under variable climate conditions.

Up to now the LTACs have concentrated on climate variation rather than long-term trends associated with climate change. This approach is rational: the same techniques and procedures used to manage short-term climate variation can be used to manage long-term trends associated with climate change. However, to handle climate change over a long period of time will almost certainly require bringing alternative crops into the system. Currently the LTACs are not looking at these alternatives. The strong presence of specific crop federations, such as the rice and cereal growers' federations in the LTAC of Córdoba, may hinder the search for alternatives.

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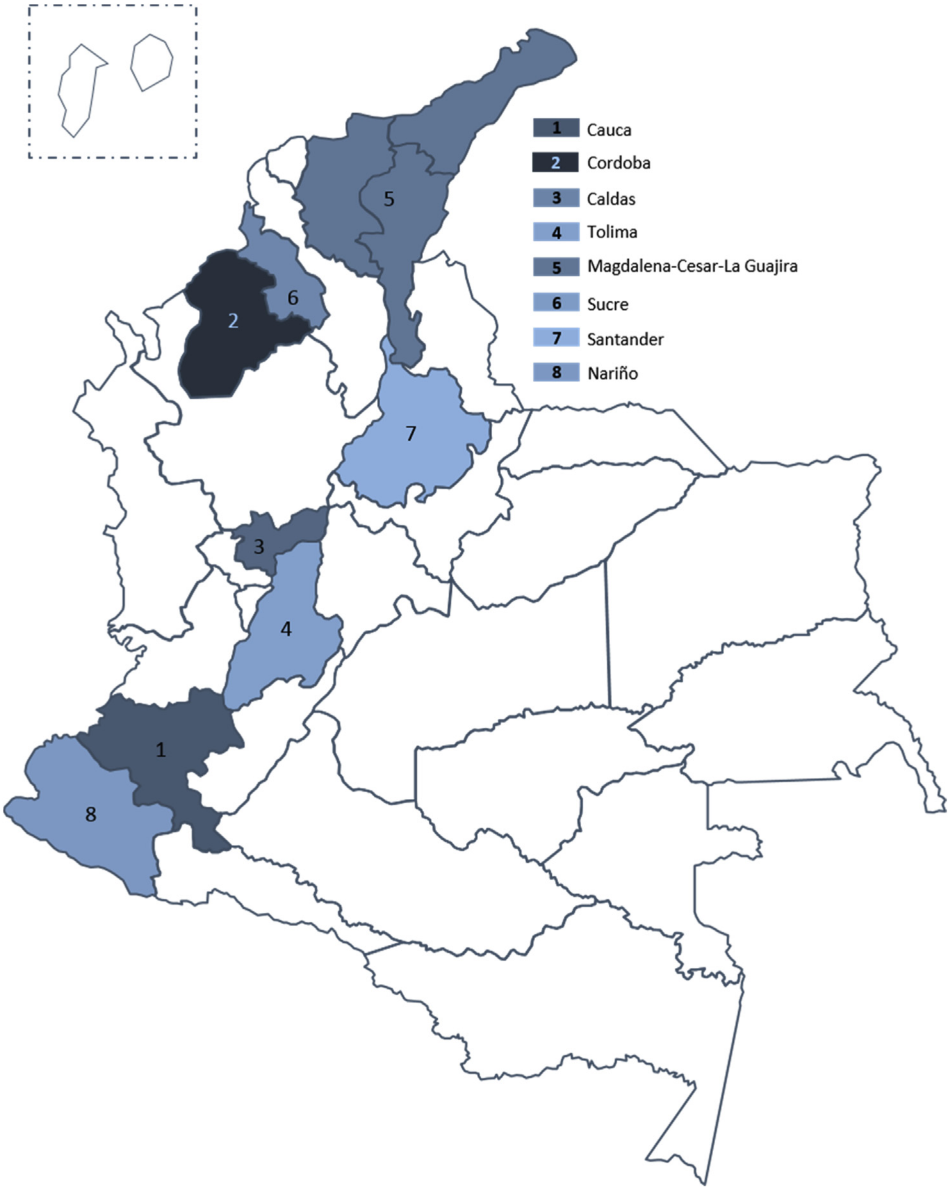
Appendices

Annex A: Current Local Technical Agro-climatic Committees in Colombia



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