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UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

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INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

ASSESSMENT OF ECOLOGICAL AND SOCIO-ECONOMIC IMPACTS OF METEOROLOGICAL AND HYDROLOGICAL DROUGHT IN COLOMBIAN MOJANA REGION

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A mis amigos, compañeros, profesores, que representan una fraternidad de países con un interés común de hacer de este planeta un universo sostenible que cambie los paradigmas de mercantilización de la vida, del ambiente, de los ecosistemas, de las relaciones humanas.

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A las comunidades de Ayapel y de San Marcos, generosas, alegres, abiertas, ejemplo de una Colombia marginada que se resiste al olvido, que con su "aguante" y capacidad de resilencia mitiga la desigualdad aferrada a una cosmogonía de lo mágico y de creer posible lo imposible.

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A mis padres, que son mi inspiración.

A nuestros caminos y a tu mano…

TABLE OF CONTENTS

TABLES

ILLUSTRATIONS

PHOTOGRAPHYS

APPENDIX

ABSTRACT

The Mojana region, located in the north of Colombia, is considered a macro-ecosystem of wetlands and floodplains, with a hydrological dynamic that is determined by the flood pulse of the Magdalena, Cauca, and San Jorge rivers. Productive periods and daily activities of the inhabitants are closely linked to the hydrological cycle; rural population shifts its livelihood activities from crop cultivation to fishing by following the course of this cycle. The social setting of the region is characterized by a subsistence economy where currently most of the population lives under the poverty line. Therefore, this population is potentially vulnerable to suffer the effects of extreme weather events. In recent years, the study of floods has gained special recognition, given the magnitude of the impacts generated during *La Niña* phenomenon from 2010 and 2011. However, the study of droughts had been underrated as drought impacts tend to manifest slowly over time, which make them significantly less visible than flood effects. Given the global context of increasing climatic variability, how to cope with drought hazard, minimizing the likelihood of obtaining negative livelihoods outcomes by reducing the system´s vulnerability, is a subject that needs to be addressed. The present study conducted an assessment of drought impacts on the natural resources that sustain the rural livelihoods, and the key factors that define the occurrence of these impacts by applying a vulnerability approach (the *sustainable livelihoods framework* – SLF). Multiple variables were integrated into the analysis by coupling the socio-economic and ecologic systems, identifying linkages through the use of complementary quantitative and qualitative methods. Consequently, this study provides entry points for risk managers and decision makers to address drought vulnerability in the Mojana-region.

Key words:

Mojana region; vulnerability; drought impacts; livelihoods; and flood pulse.

RESUMEN

La región de la Mojana, ubicada al norte de Colombia, se considera un macroecosistema de humedales y llanuras de inundación, cuya dinámica hidrológica está condicionada al pulso de inundación de los ríos Magdalena, Cauca y San Jorge. Tanto los períodos productivos como las actividades generales y cotidianas de los habitantes están altamente vinculadas al ciclo hidrológico; la población rural complementa sus medios de vida siguiendo este ciclo, alternando entre la agricultura y la pesca. La dinámica social de la región se caracteriza por una economía de subsistencia para la mayoría de la población que vive actualmente por debajo del umbral de pobreza; por lo tanto, esta población es potencialmente vulnerable ante los efectos de eventos climáticos extremos. En los últimos años, el estudio de las inundaciones ha tenido un reconocimiento especial, asociado a la magnitud de los impactos generados por el fenómeno de *La Niña* del 2010 y 2011. Sin embargo, el estudio de las sequías se ha subvalorado ya que sus efectos tienden a manifestarse lentamente con el tiempo, lo que los hace significativamente menos visibles que los efectos causados por una inundación. Por lo tanto, dentro de un contexto global de creciente variabilidad climática, abordar el tema sobre cómo enfrentar el peligro de la sequía, minimizando la probabilidad de obtener resultados de medios de vida negativos, mediante la reducción de la vulnerabilidad del sistema es una prioridad. El presente estudio permitió evaluar el impacto de la sequía en los recursos naturales junto con el flujo de servicios ecosistémicos que sustentan los medios de vida rurales así como los factores clave que definen la ocurrencia de estos impactos aplicando un enfoque de vulnerabilidad (*Sustainable livelihoods framework*- SLF). Se integraron múltiples variables en el análisis al asociar los sistemas socioeconómicos y ecológicos, identificando los vínculos a través del uso de métodos complementarios, cuantitativos y cualitativos. En general, este estudio proporciona puntos de entrada a los gestores del riesgo y a los encargados de la toma de decisiones para abordar la vulnerabilidad a la sequía en la región de la Mojana.

Palabras clave:

Región de la Mojana; vulnerabilidad; impactos de la sequía; medios de vida; y pulso de inundación.

1. INTRODUCTION

1.1 Background

Drought definition varies broadly among diverse fields of study (Yevjevich, 1967), reflecting the multiple and different perceptions around this subject, which affects, either directly or indirectly, almost all regions and climates of the world (Wilhite, 1992). Therefore, is considered one of the most complex and least understood natural hazards (Wilhite, 2000).

For this study, drought is understood according to Van Loon, Van Huijgevoort, & Van Lanen, (2012) definition: *“a sustained and regionally extensive period of below-average natural water availability”*. Whether this deficit will be observed on precipitation, soil moisture or streamflow will depend on the evolution of drought signal through the hydrological cycle (Van Loon, 2013). Thus, drought is grouped into three types: (1) Meteorological; (2) Agricultural or Soil moisture and, (3) Hydrological (Wilhite & Glantz, 1985). Most environmental impacts are related to agricultural and hydrological drought because ecosystems and human activities rely more on forms of water storage than on direct precipitation (Van Loon & Laaha, 2015).

Within the context of climate change, drought impact assessment becomes highly relevant, since the occurrence of extreme climatic events is expected to increase in frequency, severity, and duration (Wilhite, Sivakumar, & Pulwarty, 2014). Especially in the tropics and subtropics, highest temperatures and lowest precipitations have influenced the variation of droughts intensity, duration and affected area, since the 1970s (Li, Ye, Wang, & Yan, 2009). Only for the period 2001-2010, droughts affected more people around the world than any other natural hazard because of its large scale and duration (Sivakumar, 2013).

Bachmair et al., (2016) defined drought impact as *“an observable loss or change that occurred at a specific place and time because of drought.”* Impacts are categorized as direct or indirect, and often, the latter ones can be more significant than the former ones (Shiferaw et al., 2014). Further, drought effects on a specific region or economic sector, are determined by their environmental, technological, economic and political system (Liverman, 1990).

Accordingly, drought impacts result from the interaction between the occurrence of the natural event and the socioeconomic characteristics of the exposed area (Li et al., 2009). This is, the system`s vulnerability (Wilhite, Svoboda, & Hayes, 2007). Hence, the vulnerability of a system is in function of: (1) the hazard exposure; (2) the sensitivity to that hazard; and (3) the adapting capacity of the system to cope or recover from the disturbance (Adger, 2006; Reed et al., 2013).

Through the impacts of climate change on ecosystem services, livelihood options can be reduced, and poverty increased (Reed et al., 2013). For instance, it has been proved that recent droughts have contributed to worsening the food security situation in developing countries from sub-Saharan Africa and South-Eastern and Western Asia (FAO, IFAD, UNICEF, WFP, & WHO, 2017). Hence, drought is considered to be a significant constraint to livelihoods (Solh & van Ginkel, 2014), especially for rural communities whose subsistence is highly dependent of soil and water resources (Khayyati & Aazami, 2016).

Most studies have assessed drought trough single standardized indices, which are insufficient to characterize drought impacts (Liverman, 1990). Nevertheless, the integration of multiple and often contrasting variables into the analysis, remains to be a challenge (Nazari, Rad, Sedighi, & Azadi, 2015). A more comprehensive understanding of drought impacts that will lead to its effective mitigation will require approaching drought as a coupled interaction between environment and society (Bachmair et al., 2016). This will require both quantitative and qualitative data and the use of mixed modeling approaches (Van Loon et al., 2016).

The sustainable livelihoods framework is considered a useful tool to face the drought assessment challenge because enables the understanding of vulnerability and provides a basis for the detection of actions and strategies to build adaptive capacity (Reed et al., 2013). This framework has been used in previous studies to assess vulnerability of extreme climatic events (Keshavarz, Maleksaeidi, & Karami, 2017; Khayyati & Aazami, 2016; Reid & Vogel, 2006), which have proved its effectiveness.

1.2 Justification

The Mojana region is located in the north of Colombia within an area of approximately 10869.26 km^2, and comprises eleven municipalities from the Antioquia, Bolívar, Córdoba and Sucre Departments. This region is considered a Macro-ecosystem of wetlands and floodplains (Aguilera, 2009), which hydrological dynamic is conditioned to discharge variations of the Magdalena, Cauca, and San Jorge rivers (Caraballo & Ossa, 2011). As a result, plays a significant part in the local and national hydrologic regulation by buffering floods and facilitating the decantation and accumulation of sediments (Aguilera, 2004).

The present study has a special focus on the San Marcos and Ayapel Municipalities, located at the west side of this region. Both Municipalities cover an area of nearly 2901.75 km^2 (equal to 26.70% of the total Mojana extension), between the geographical coordinates 8º03'to 8º44'North latitude and 75º20 to 74º48'West longitude, and an average elevation of 34 m above sea level (Illustration 1).

Wetlands role in sustaining livelihoods is well recognized around the world (Mccartney, Masiyandima, & Houghton-Carr, 2005). In the study area, most of the population has a strong dependence on the ecosystem goods and services which they provide (Aguilera, 2004). Furthermore, productive periods and general and daily activities of the inhabitants are highly linked to the hydrological cycle; rural population shifts its economic activities from crop cultivation to fishery by following this cycle (CVS, 2007).

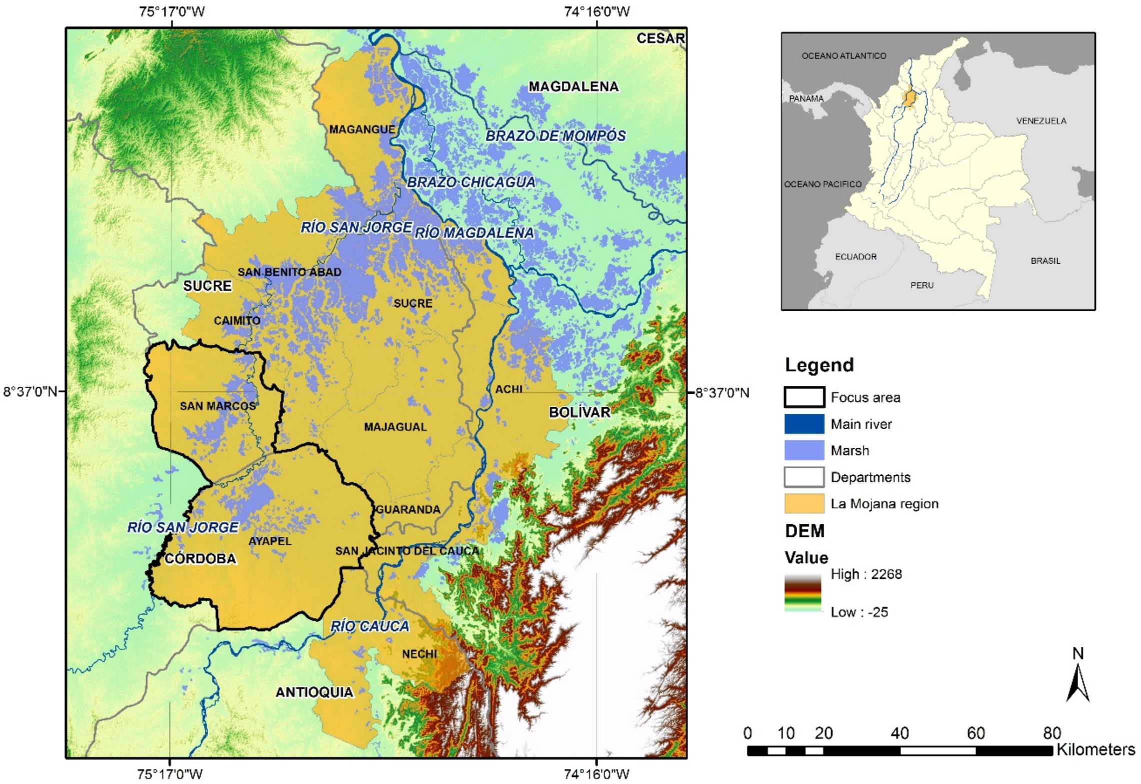


Illustration 1 Location of the study area (Mojana region) and the focus area (Ayapel and San Marcos Municipalities)

The social dynamic of the region is characterized by a subsistence economy where most of the population currently lives under the poverty line. The land tenure measured through a Gini index of 0.87, shows the high level of inequity in income distribution (Porras, 2014), enhancing the dependence of landless population on natural resources. According to Reed et al., (2013): *"Those who depend most on natural resources are likely to be most severely affected by climate change"*. Therefore, the rural population from the Mojana region is potentially vulnerable to suffer the effects of extreme weather events.

In recent years, the study of floods has gained special recognition, given the magnitude of the impacts generated by floods during *La Niña* phenomenon from 2010 and 2011: around 48.1% of the total Mojana population and 38.4% of the houses, were affected by this event (CEPAL, 2012). These damages exposed the high level of vulnerability of the region to extreme events, especially for the agricultural sector, which leads to the creation in 2012 of the Adaptation Fund (*Fondo de Adaptación*), to face the recovery of the affected areas and to establish future adapting measures (CORPOICA, 2014).

On the other hand, the study of droughts had been underrated as drought impacts tend to manifest slowly over time, which make them significantly less visible than flood effects (Van Loon, 2015). However, during the most recent *El Niño* event (El Niño Southern Oscillation), recorded between 2015 and 2016 -characterized in the study area by a high deficit of precipitation and temperature increase, especially in late 2015 and early 2016 - navigability restrictions, agricultural losses and, water supply shortages, were reported. At the national level, historical minimum discharges were recorded in the Magdalena and Cauca rivers, making this ENSO, the second most intense event after the one recorded in 1950 (IDEAM, 2016). Hence, within the context of increasing climatic variability, higher efforts should be conducted to approach drought impacts at a national level, especially in those regions whose income sources majorly come from provisioning services of the ecosystems, such as the Mojana region.

1.3 Objetives

How to cope with drought hazard, minimizing the likelihood of obtaining negative livelihoods outcomes by reducing the system´s vulnerability, is a subject that needs to be addressed. The present study provides a useful tool for risk managers and decision makers of the Mojana region, given that enables the understanding of how exposure to drought, and the population sensitivity and adapting capacity, determine drought impacts in their livelihoods. This was possible through the accomplishment of the following objectives:

- To characterize meteorological and hydrological drought events in the study area, during the period 1981-2015.

- To identify drought impacts on rural population livelihoods, during the previously identified drought events (from 1981 to 2015).

- To define which factors of sensitivity and adapting capacity have a greater or lesser influence on the livelihoods vulnerability.

- To signal entry points that contribute to the reduction of drought vulnerability in the Mojana region.

2. CONCEPTUAL FRAMEWORK

2.1 Coupling ecological and societal systems to address drought impacts

The most common understanding of drought includes only natural factors with humans as receptors. Nevertheless, natural and socio-economical systems are coupled (Illustration 2). Thus, human activities influence inputs, outputs and water storage in the hydrological cycle, modifying drought propagation (Van Loon et al., 2016) .

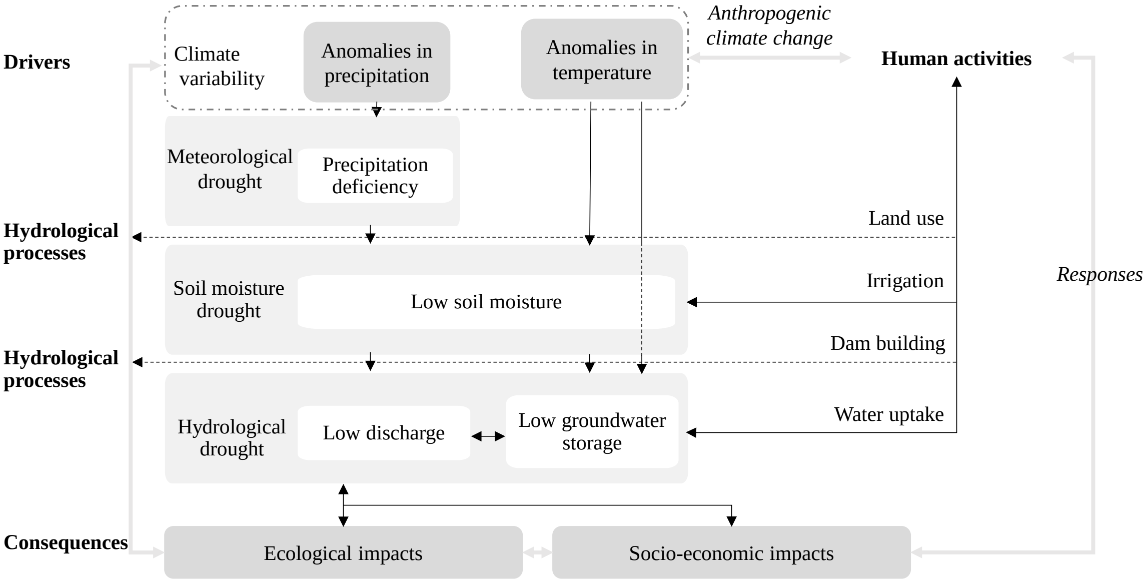


Illustration 2 Drought propagation including natural and human drivers and feedbacks; black arrows indicate direct influences and grey arrows indicate feedbacks
Source: Modified from Van Loon, (2015; 2016)

As previously stated, given that socio-economic and ecologic systems rely more on forms of water storage rather than on direct precipitation, the propagation of drought over the hydrological cycle hinders the identification of its impacts. Moreover, the influence of anthropogenic factors on the development of drought is little known and scarce studied (Wanders & Wada, 2015).

Meteorological drought is usually triggered by a prolonged moisture deficiency (Palmer, 1965), often related with large-scale atmospheric or ocean patterns such as ENSO, and sea surface temperatures (Van Loon, 2015). When this deficit is associated with high temperatures, low relative humidity and high solar radiation, the levels of evaporation and transpiration increase, and thus the moisture deficit in the soil limiting crops increases; this stage is known as agricultural or soil moisture drought, and can last from one to several months (Núnez, Muñoz, & Reyes, 2007). Finally, hydrological drought occurs when these conditions persist, causing the decreasing of groundwater recharge and levels, followed by the decrease of river discharge (Tallaksen, Hisdal, & Van Lanen, 2006).

Human factors can potentiate or attenuate drought characteristics (duration, severity, timing and spatial extent (Hisdal & Tallaksen, 2000)). However, the influence of water inflows and outflows are usually better recognized than the influence of other anthropogenic factors like land use and water storage modification (Van Loon et al., 2016). Wada, Van Beek, Wanders, & Bierkens, (2013), identified that the reduction of streamflow due to human consumption in Europe, North America and Asia had intensified the magnitude of hydrological drought from 10 to 500% while increasing the global frequency of drought by 27 (± 6)%.

The influence of land use and land cover (LULC) changes, on the alteration of the hydrological response of watersheds, especially over streamflow is widely accepted (Gashaw, Tulu, Argaw, & Worqlul, 2017). Nevertheless, a quantitative relationship between the land use changes and the runoff generation mechanism is little understood (Hundecha & Bárdossy, 2004). Further, few efforts to quantify the effect of LULC change on climate has been made, whit no conclusive results. For instance; Taylor et al., (2002), found that agricultural extensification, with deforestation and other land use changes in the Africa Sahel region since the late 1960s, were not the leading cause of drought, even though the climate of the region is somewhat sensitive to small changes in albedo and leaf area index.

Regarding future droughts, Wanders, Wada, & Van Lanen (2015), project a severe impact of climate change on streamflow and drought characteristics and its magnitude will be comparable to the impact caused by human activity. An increase of population with the consequent increase in water demand and land use change, are other aspects of high relevance in the development of future drought. Besides, it is foreseen that human influence will be responsible for 100% of future changes of hydrological drought in regions of Asia, the Middle East, and the Mediterranean, where high rates of water extraction are recorded (Wanders & Wada, 2015).

So far, the human influence on the characteristics, occurrence, and development of drought events has been recognized. However, the assessment of drought effects poses an additional challenge, since drought impacts vary in time according to the ecological, social and economic dynamics of the exposed area (Sivakumar, 2013). Thus, drought impacts are determined by the level of vulnerability of the affected system in a specific moment of time, which means that vulnerability is dynamic in response to the changes of the system (Wilhite et al., 2007). In this sense, the concept of vulnerability is originated from “human ecology” and attempts to establish relations between nature and society (Zarafshani et al., 2012).

2.2 Drought impact assessment through a vulnerability approach – The SLF framework

A vulnerability approach will enable the identification of social, economic, and environmental causes of drought impacts. Accordingly, The Sustainable Livelihoods Framework (SLF), developed by the Department for International Development of British (DFID, 2001), is applied to address this subject. The SLF frames a system within a context of vulnerability enabling the identification of the impact degree of potential stressors and the capacity of the system to cope with this potential threat (Žurovec, Čadro, & Sitaula, 2017).

The livelihood definition used by the DFID, states that *"a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living"*. Hence, the SLF provides a structured approached for stakeholders to manage this assets (natural, physical, economic social and human), through strategies that achieve positive livelihoods outcomes (DFID, 2001). Within this approach, vulnerability may be seen as the result of an external dimension determined by the system´s exposure to shocks, seasonality or resource trends, and an internal dimension defined by the system´s sensitivity to those external forces and its capacity to adapt.

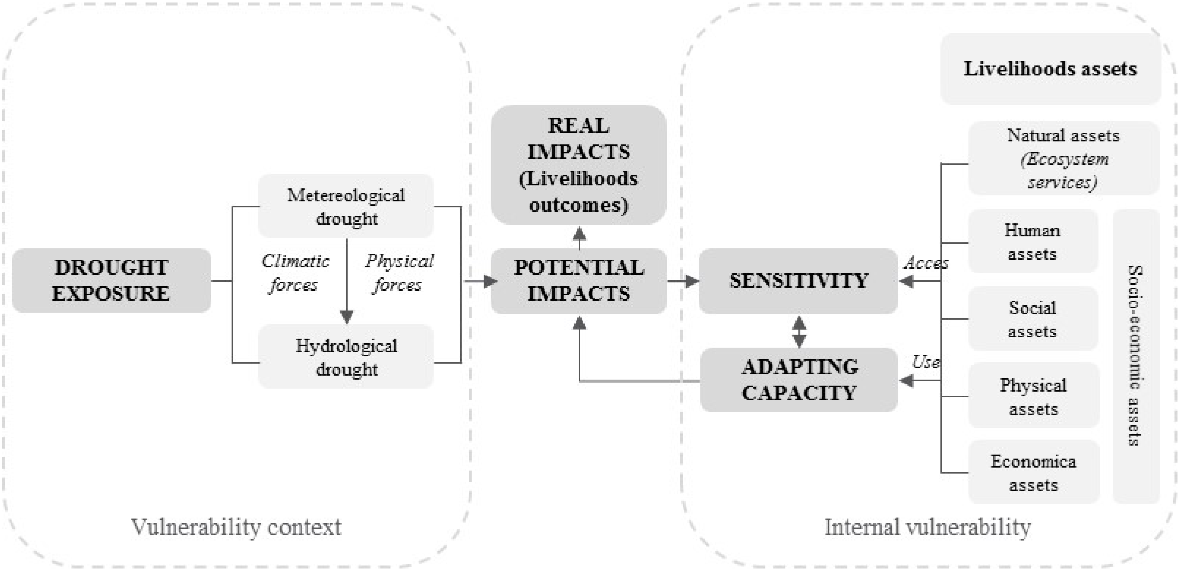


Illustration 3 Assessment of drought impacts through a vulnerability approach – The SLF framework

This framework is considered a useful tool for studying communitarian vulnerability to climatic change (Reid & Vogel, 2006), because:

I. Identifies the system´s response to shocks, seasonality or resource trends.
II. Promotes participatory people-center research approaches; and
III. Exposes entry points to build adaptive capability (Reed et al., 2013).

Previous studies have acknowledged that the main problem with this framework is that does not consider integrative socio-ecological systems (Adger, 2006). For instance, Reed et al., (2013), argues that the SLF emphasizes on the stock of assets rather than in flow of services provided by them, which may be a concern, especially for developing countries, who are highly dependent on provisioning services. Therefore, the present study introduces Reed´s perspective to the SLF by addressing natural assets in terms of Ecosystem services.

2.2.1 Vulnerability context - Drought exposure

"Exposure describes the degree of climate stress upon a particular unit of analysis" (Mohmmed et al., 2017). As drought signal moves through the terrestrial part of the hydrological cycle, the stressed component of the system changes. Further, only severe meteorological droughts or the pooling of frequent events will finally develop into soil moisture or hydrological droughts. This lag often last

from months to years since catchment characteristics act as an attenuator of the climatic forces (Hisdal & Tallaksen, 2000). Thus, drought exposure varies through the propagation process according to this climatic and physical forces.

2.2.1.1 Climate forces

Van Loon & Van Lanen, (2012), grouped hydrological drought into five categories and related each type with the climatic parameters that drive its propagation process. Overall, droughts of equatorial (A), arid (B), and temperate (C) climates are always controlled by temperature and precipitation. On the other hand, droughts of continental (D) and polar (E) climates are more dependent on temperature control because over the winter season precipitation in the form of snow inhibits feeding the water content in the soil (Table 1).

Table 1 Drought propagation processes per hydrological drought type and occurrence in Köppen-Geiger major climate types

Hydrological drought type	**Governing process (es)**	***P-control/ T-control***	**Climate types**
Classical rainfall deficit drought	Rainfall deficit (in any season)	*P-control*	A, B, C, D, E
Rain to snow season drought	Rainfall deficit in rain season, drought continues into snow season	*P and T-control*	C, D, E
Wet to dry season drought	Rainfall deficit in wet season, drought continues into dry season	*P and T-control*	A, B, C
Cold snow season drought	Low temperature in snow season, leading to:		
Subtype A	Early beginning of snow season	*T –control*	D, E
Subtype B	Delayed snow melt	*T –control*	D, E
Subtype C	No recharge	*T -control*	C, D
Warm to snow season drought	High temperature in snow season, leading to:		
Subtype A	Early snow melt	*T -control*	D, E
Subtype B	In combination with rainfall deficit, no recharge	*P and T-control*	C, D
Composite drought	Combination of a number of drought events over various seasons	*P and/or T-control*	A, B, C, D, E

Source: A. F. Van Loon & Van Lanen, (2012)

H. A. Van Lanen, Wanders, Tallaksen, & Van Loon, (2013), proved that regarding the climatic classification of Köppen, climates type B and E, record the least number of hydrological droughts but have greater durations and deficit volumes, because in these areas low discharges are expected for prolonged periods, increasing drought duration. On the contrary, climates of type A and C, exhibit short-term hydrological droughts because they receive precipitation on a regular basis. Finally, in climates of type D (continental), the duration may be longer if it began previous to the winter season.

The importance of including seasonality when modeling the effect of drought on its related impacts was proved by Stagge et al., (2015). Seasonality has a significant influence on drought characteristic; thus, in a constant climate drought is mainly related to precipitation abnormalities while in strong seasonality climates additional processes influence drought development (Van Loon, 2015). For instance, in a warm seasonal climate when a hydrological drought develops over the wet season, there is a little chance of recovering during the dry season because over this season evapotranspiration tends to exceed precipitation. These long multiseason droughts result in larger duration and deficit volumes (Van Loon et al., 2014).

- Weather pattern

The weather pattern governs the influence of precipitation, temperature or both, in the development of drought. A. Van Loon, (2013) found that in semi-arid climates, where a high variability of precipitations is expected, dry periods can last from years to decades. Additionally, they found that in some catchments, drought events tend to cluster over time. This clustering has important implications for the propagation process given that an isolated meteorological drought event might be attenuated in the catchment, but successive meteorological droughts decrease water storage, and a severe hydrological drought can develop. Therefore, high precipitation events should also be considered in the propagation process, as they modify the catchment storage stopping or preventing the development of drought.

Huang et al., (2017), showed the influence of precipitation and temperature according to seasonal variations in a continental monsoon climate zone. They identified differences in the time of drought propagation according to the seasons. Thus, spring and summer were the seasons with less time of propagation (from 3 to 9 months); this was attributed to high temperatures, while autumn and winter recorded relatively long times (6 to 12 months), probably as a result of the previous soil moisture conditions.

- Large-scale atmospheric or ocean patterns

Precipitation and temperature are affected by large-scale circulation patterns (Perlwitz, Knutson, Lossin, & LeGrande, 2017). These patterns may influence the intensity and duration of rainfall as well as abnormalities in temperature, which are the major climate controls for drought development. Huang et al., (2017), found that climatic anomalies such as El Niño-Southern Oscillation (ENSO) and Atlantic Oscillation (AO), affect evaporation, modifying the propagation time from meteorological to hydrological drought.

El Niño-Southern Oscillation is considered to be the dominant phenomenon in the variability of tropical climate, whose variations have impacts on weather, ecosystems, and in some populations around the world (Boucharel et al., 2011). The changes in the temporality of the ENSO have been studied in detail, obtaining that there is a change in the amplitude of the decadal occurrence, which affects the global climate (Ogata et al., 2013). It is estimated that this variability, will impact the occurrence of future droughts events (Wang & Kumar, 2015) since it has been suggested that there is a teleconnection of the impact of the ENSO and the severity of the hydrological drought (Talaee, Tabari, & Sobhan Ardakani, 2014).

- Climatic variability

Globally, drought-affected areas have significantly increased since the 1970s, especially in the tropics and subtropics. In these sown regions an increase in severity, frequency, duration and affected area of droughts is expected. The southeast of North America, southern China, Central America, the Mediterranean and southern Brazil are considered hotspots for future droughts (Li et al., 2009).

According to Krishnamurthy, Lewis, & Choularton, (2012), important production areas are likely to present future yield reductions due to climate variability. Alcamo et al., (2007) modeled different climatic scenarios to address the impact of changing frequency and spatial heterogeneity of extreme climate events in some food-producing regions of Russia. The results showed a doubled in the rate of food production shortfalls in the 2020s and triple in 2070s, that will affect the future food security of this country.

Similarly, future climate change scenarios along with socio-economic variables were integrated by Li et al., (2009) to predict cropland drought disaster risk. Results suggest that this risk will double by the end of the 21st century, with further implications for sorghum and maize-sown areas and for regions that are already under high drought-disaster risk. An important portion of this land is located in sub-Saharan Africa and parts of South Asia; developing regions with the highest level of chronic undernourishment that will suffer the increase of instability of food production (Schmidhuber & Tubiello, 2007).

2.2.1.2 Physical forces

In general, during a drought event, catchment streamflow depends more on groundwater discharge than in surface runoff or direct precipitation, given that these fast pathways are limited (Van Loon, 2015). In regions with relatively uniform catchment conditions, an even distribution of meteorological drought is expected due to its dependence on large scale atmospheric drivers. In contrast, a patchy hydrological drought distribution is determined by local catchment conditions; but this may change from region to region (Van Loon, 2015)

Henny A. Van Lanen, (2006) found that catchments characteristics such as storage capacity, aquifer transmissivity and drainage network, determine the propagation of drought at the subsurface level. Furthermore, A. F. Van Loon, (2015) recognizes the storage capacity of a catchment as the most important characteristic for hydrological drought development; this capacity is determined by topographic, geologic, climatologic, hydrologic factors, among others.

Peters et al., (2006) studied the propagation of drought in groundwater demonstrating the importance of large groundwater systems in the attenuation and delay of drought. However, they found a differential response of droughts frecuency and severity in recharge, discharge and hydraulic heads. Thus recharge and discharge zones exhibit more frequent but less severe droughts than droughts in hidraulic heads. These results are considered to be valid for the Pang catchment but may be applied for catchments with a large groundwater system and a non-linear groundwater discharge relationship.

Similarly, Barker, Hannaford, Chiverton, & Svensson, (2016), proved that in catchments with low storage capacity, hydrological drought and propagation characteristics are strongly correlated with the average annual precipitation, while the catchment characteristics describing their storage capacity, have a higher influence on drought characteristics (frequency, duration and severity) .

H. A. Van Lanen et al., (2013), recognized the importance of the control that the groundwater system has for the development of the hydrological drought in all types of climates, but particularly for the climates type A, C and D, due to the higher recharge. Hydrological drought events in arid and polar climates (type B and E) are expected to be more influence by their larger climate variability. They also found that quickly responding groundwater systems have more frequent drought events than slowly responding systems, but with shorter duration. Finally, a larger influence of groundwater system in drought development was proved, in comparison with the soil system.

Van Loon & Laaha, (2015) studied the influence of climate and catchment characteristics on the duration and the deficit volume of hydrological droughts, obtaining that the groundwater recharge measured through the base flow index (BFI), is the dominant factor to characterize the duration of hydrological drought, whereas the average precipitation and the elevation determine the deficit. Elevation plays a major role in the development of snow-related drought types because of its influence in temperature which determines the freezing and thawing season.

2.2.2 Internal vulnerability

Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli and adapting capability is the ability of a system to adjust to those stimuli (IPCC, 2001). From this perspective, access to limited resources determines the system sensitivity, and adaptation is determined by the capacity of the actors to mobilize those resources to reduce that sensitivity. The factors that influence a system´s sensitivity and adapting capacity are called assets or capitals.

Five types of assets or capitals forms are recognized: Human, Financial, Social, Physical and Natural (DFID, 2001). Ellis (2000), describes Human assets as the education level and health status of the population; Financial assets as the available cash or credits forms to purchase or acquire either consumption goods or services; Social assets as the social linkage of a community to achieve common goals and Physical assets as the existent tools and equipment used in productive processes. Finally, Natural assets, from the perspective of ecosystem services are defined as *“the aspects of ecosystems utilized (actively or passively) to produce human well-being”*(Fisher, Turner, & Morling, 2008).

2.2.2.1 Socio-economic assets

A higher influence of societal vulnerability to drought impacts, when compared with the physical drought characteristics, has been proved for several authors (Zarafshani et al., 2012). For instance, Nkedianye et al., (2005) showed that livestock resilience to drought in Maasailand – Africa, had been decreasing due to changes in social behavior and economic activities and weakening of social networks. The pastoral mobility that used to be practiced in this region during drought events proved no longer work with high mortality rates of the cattle.

Zarafshani et al., (2012), assessed drought vulnerability of wheat farmers in Western Iran, obtaining that agricultural income, farmers land size, investment and crop insurance, were the major sources of economic vulnerability among wheat farmers. Decreasing farmers' income during drought events proved to have a high influence on vulnerability mitigation. Furthermore, the level of education exhibit an inverse relation with the level of social vulnerability; the literacy rate has proved to influence the adaptive capacity to drought, because a population with lower literacy level is likely to have greater dependence on agriculture and are associated with marginalized conditions (Mohmmed et al., 2017). Finally, high reliance on governmental help, enhanced by the low participation of the community in drought mitigation, increase the socio-cultural vulnerability towards drought.

In a similar study conducted in rural Iran, Keshavarz et al., (2017), identified that between farms, different factors influence livelihoods vulnerability to drought, the main findings were:

- Higher economic capacity translate in lower livelihoods vulnerability to drought; moreover, available workers and job opportunities are also important to reduce vulnerability.
- Moderate or high levels of access to physical capital (road access, farm structures, and farm size), reduce vulnerability to drought.
- Mechanical inputs significantly decreased livelihood vulnerability to drought.
- Social networks can empower farm families and help them to mitigate the livelihoods vulnerability in the context of drought.

2.2.2.2 Natural assets

Global climate change is considered to be a major driver of ecosystem services loss, with severe impacts on livelihoods, especially from poor communities (Bhatta, Eric, Van Oort, Stork, & Baral, 2015). A high dependence on natural resources is very often related with poor households, whose limited infrastructure represents an obstacle to cope with drought. This may be enhanced by recurrent drought events because adaptation and resilience capabilities are weakened (Keshavarz et al., 2017).

Keshavarz et al., (2017), proved the importance of access to adequate natural resources in reducing livelihood vulnerability to drought. The most studied and clear direct drought impact on agriculture is the productivity loss in crops, which will depend on the ecological conditions of the crops. Lesk, Rowhani, & Ramankutty, (2016), demonstrated a reduction on the harvested area and an overall decreasing of national cereal production by 9-10% between 1964 and 2007 in the world. Cereal crops exposed to high temperatures exhibit significantly lower grain yields; this can be linked to particular developmental stages and can be effective over short time periods (Porter & Semenov, 2005). Other factors influencing crops yields and quality are: The sensibility of each crop to water stress; the water source reliability; the onset of drought relative to the stage of crop development; and soil water holding capacity (Rey, Ian Holman, & Jerry Knox, 2017). Accordingly, actions that influence the adaptation to deal with crops vulnerability include shifting crops, changing planting dates, use of climatic information, access to crop insurance and farming knowledge (Mohmmed et al., 2017).

Zarafshani et al.,(2012), showed the importance of access to water resources in the farmer’s vulnerability to cope with drought. However, not only the access to irrigation systems but the efficiency of irrigation methods and irrigation strategies during drought events, influence farmers vulnerability. Additionally, adaptation measures that lead to more efficient water use are often dependent on financial resources, implying an obstacle for poor farmers.

3. STUDY AREA

The Mojana region is located between the geographical coordinates 9º28' to 7º46' North latitude and 75º20 to 74º20' West longitude, and an average elevation of 34 m above sea level (this correspond to the administrative boundary). Its natural boundaries are delineated by the Magdalena River (north), the Cauca River (east), the San Jorge River (west) and the highlands from Ayapel and Caucasia municipalities (south) (Illustration 1). The confluence of this three rivers shapes an inland delta which response to the flooding pulses, enabling flooding damping and sediments deposition and accumulation (Díaz-Granados, Camacho, & Maestre, 2014). Even though the study area description corresponds to the whole region, specific information is shown for the San Marcos and Ayapel municipalities (focus area).

3.1 Physical system

Physiographically, the Mojana Region is located within an extensive area of floodplains at the North of Colombia, named *La Depresión Momposina* (The Momposina Depression). Two functional units define the geomorphology of the region. (1) The alluvial plain (Lowlands), which represents the dominant landscape, is continuously subject of the flooding pulses, comprising major and minor ridges, active riverbanks, active flood plain, marshes and streams; and (2) The Highlands or emerged zones formed by tertiary terraces of varying thickness, and by hills and foothills of the Perijá, Ayapel and Montes de María mountain ranges (DNP & FAO, 2003).

The predominant type of climate is the warm-humid-tropical, with constant temperatures close to 28ºC (J. F. Torres, Pinilla, & Bogotá, 2011). It is influenced by the Intertropical Convergence Zone (ITCZ) movement from south to north, which defines a unimodal pattern of rainfall; with a rain period of eight months between mid-April and November and a dry period of four months between December and March. During June and July, a small decrease of rainfall is observable; this phenomenon has locally being called *"Veranillo de San Juan"* (CORPOICA, 2014).

Based on the map of Climatic Zones of Colombia (IGAC, 1998), and the Caldas-Lang climatic classification, three climate types were recognized within the focus area (San Marcos and Ayapel Municipalities): Warm Semi-arid; Warm Sub-humid and Warm Humid (Illustration 4 and Appendix 1).

Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS), for the period 1981-2016 were used at a monthly level to analyze rainfall behavior for each climate type in the focus area. In general, rainfall pattern does not vary between climates; however, average annual precipitation differ between climate types (Table 2). The spatial distribution of this variation increases in the direction North-west to South-east.

Table 2 Climate types in the study area according to Caldas-Lang classification

Climate	Elevation (m.a.s.l)	Temperature (ºC)	Lang factor (P/T)	Area (Km^2)	Area (%)	Precipitation (mm)
Warm Semi-arid	0 - 900	≥ 24	20.1 – 40.0	534.76	18.43	1837.01
Warm Sub-humid	0 - 900	≥ 24	60.1 - 100	1940.04	66.86	2455.30
Warm Humid	0 - 900	≥ 24	100 - 160	426.95	14.71	3045.32

Source: Own elaboration, based on IDEAM, 2018

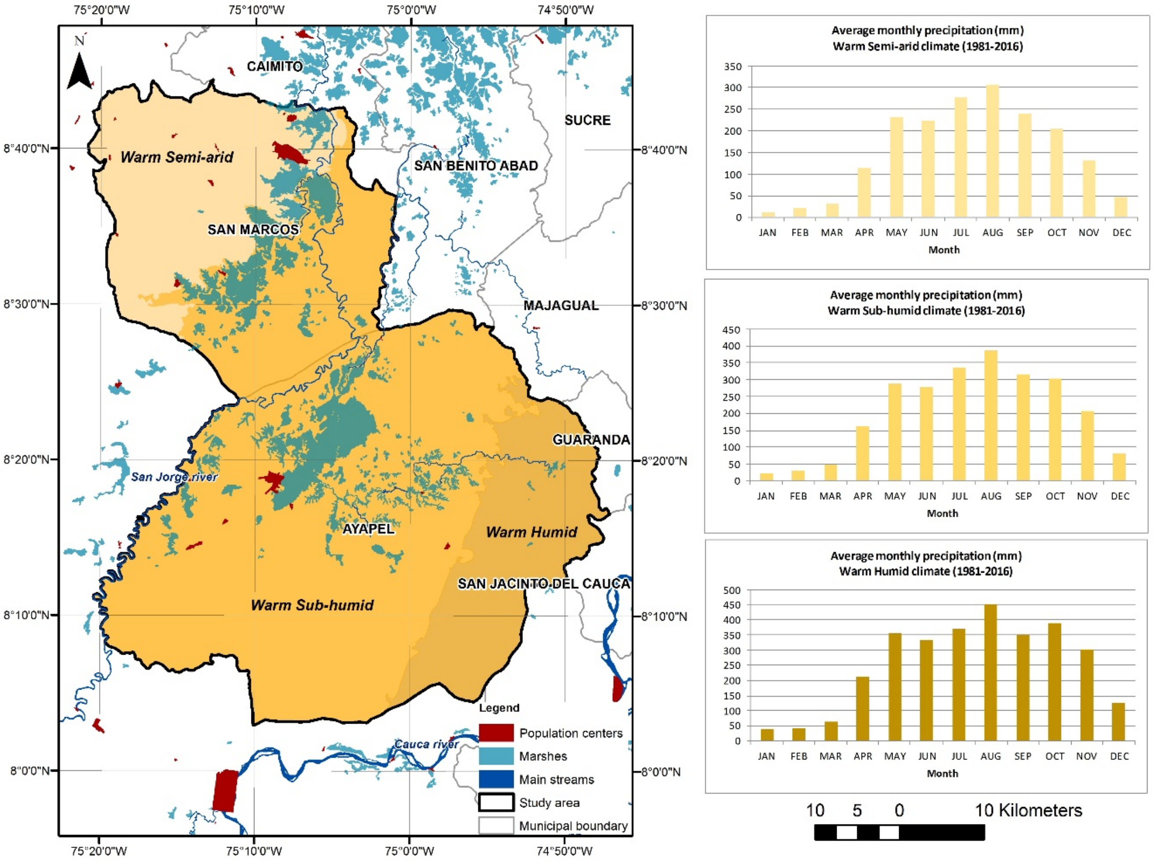


Illustration 4 Climatic zones and average monthly precipitation within the focus area (1981- 2016)

The soils from the alluvial plain derived from recent alluvial sediments that form a thick layer of unconsolidated materials of varying particle size (CORPOMOJANA, 2003). In their pass through fertile lands of the inter-Andean valleys; the Magdalena, Cauca and San Jorge rivers, collect and transport the sediments to this area. Both the nature of these sediments (organic or inorganic), and the level of flood exposure influence the degree of fertility of the soil. Thus, in flooded areas, moisture saturation hinders nutrient cycling, generating high levels of eutrophication. The same applies to temporal flooding areas during the rainy season; however, when the water level drops over the dry season, the accelerated decomposition of organic matter triggers nutrient cycling, increasing their availability (CVS, 2007).

The flood pulse is the driving force that modulates the annual changes in the biotic and abiotic variables that take place in the main river course and in all water bodies, associated with a floodplain (Montoya, Castillo, & Sánches, 2011). Flooding pulses for the Magdalena, Cauca and, San Jorge rives, usually presents a high seasonality generated by the rainfall regime from the upper and middle parts of the basin; thus, within the Mojana region, the flooded area varies around 80% among periods of low-water levels and high-water levels (DNP & FAO, 2003). Although the flooding pulse is rather predictable in large tropical rivers (Schöngart and Junk, 2007), its variability may be prompt by the El Niño Southern Oscillation (ENSO), which drives precipitation anomalies (deficit and excess), in the country.

The focus area is subject of annual flooding pulses from the San Jorge River, and in extreme events from the Cauca River (almost every 15 to 18 years) (CVS, 2007). The San Jorge River basin has a total area of 18784 km, with a main course of 512.4 km; it is born within the mountain ranges from the *Nudo de Paramillo*, at 3000 meters above sea level, and flows from south to northeast through the Departments of Antioquia, Córdoba, Sucre, and Bolívar, before its arrival to the Magdalena River (MINAMBIENTE & CORPOMOJANA, 2000).

Water level variations for the Ayapel marsh and San Marcos marsh can be observed in the Illustration 5; this information corresponds to the historical hydrological data from the Beirut (station code 25027340) and the San Marcos (station code 25027220) limnimetric stations. Maximum and minimum historical levels were recorded for both cases in the years 2010 and 1980, respectively. As may be seen, the recharge period responds to rainfall increase between April to September, while the period of discharge goes from October till March as rainfall decrease.

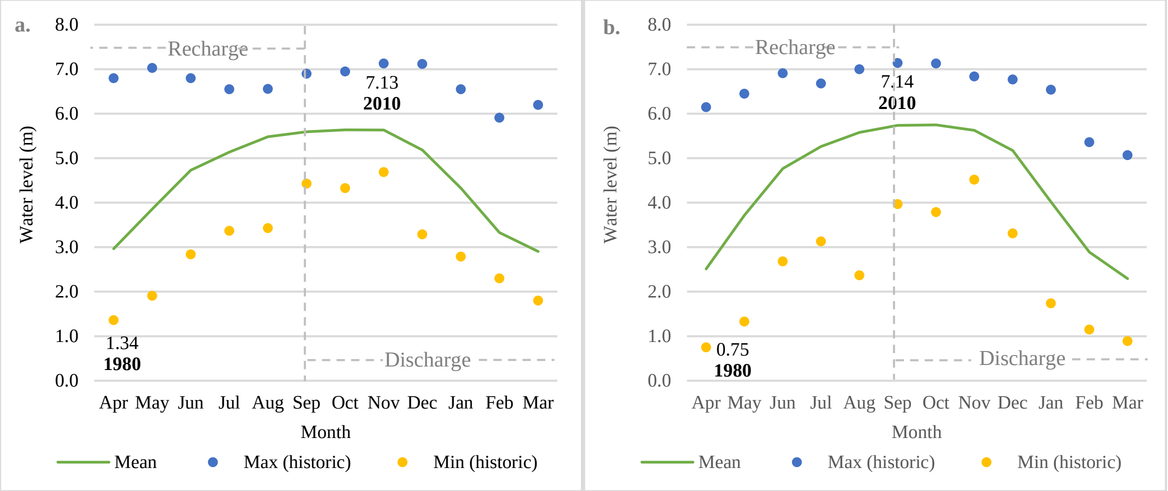


Illustration 5 Monthly water levels (1980-2015); average, maximum (historical), and minimum (historical). a. Ayapel marsh and b. San Marcos marsh

Within the system, the streams have a bidirectional flow that changes according to water level differences between the river and the marshes (CVS, 2007). In the Ayapel basin, the San Jorge River discharge to the marshes through a bifurcation of its main course called *Caño Grande*. This stream runs for approximately 5.6 Km (from north to south), before its confluence with the *Caño Fistola* –which carries out marshes discharge (from south to north)–, forming the *Caño Virola*. The latter, flows from south to north, to its mouth into the San Jorge River. At the beginning of the rainy season, the flow of the *Fistola* stream change direction, triggering water level increase of the marshes, and expansion of the flooded area (Illustration 6 a.).

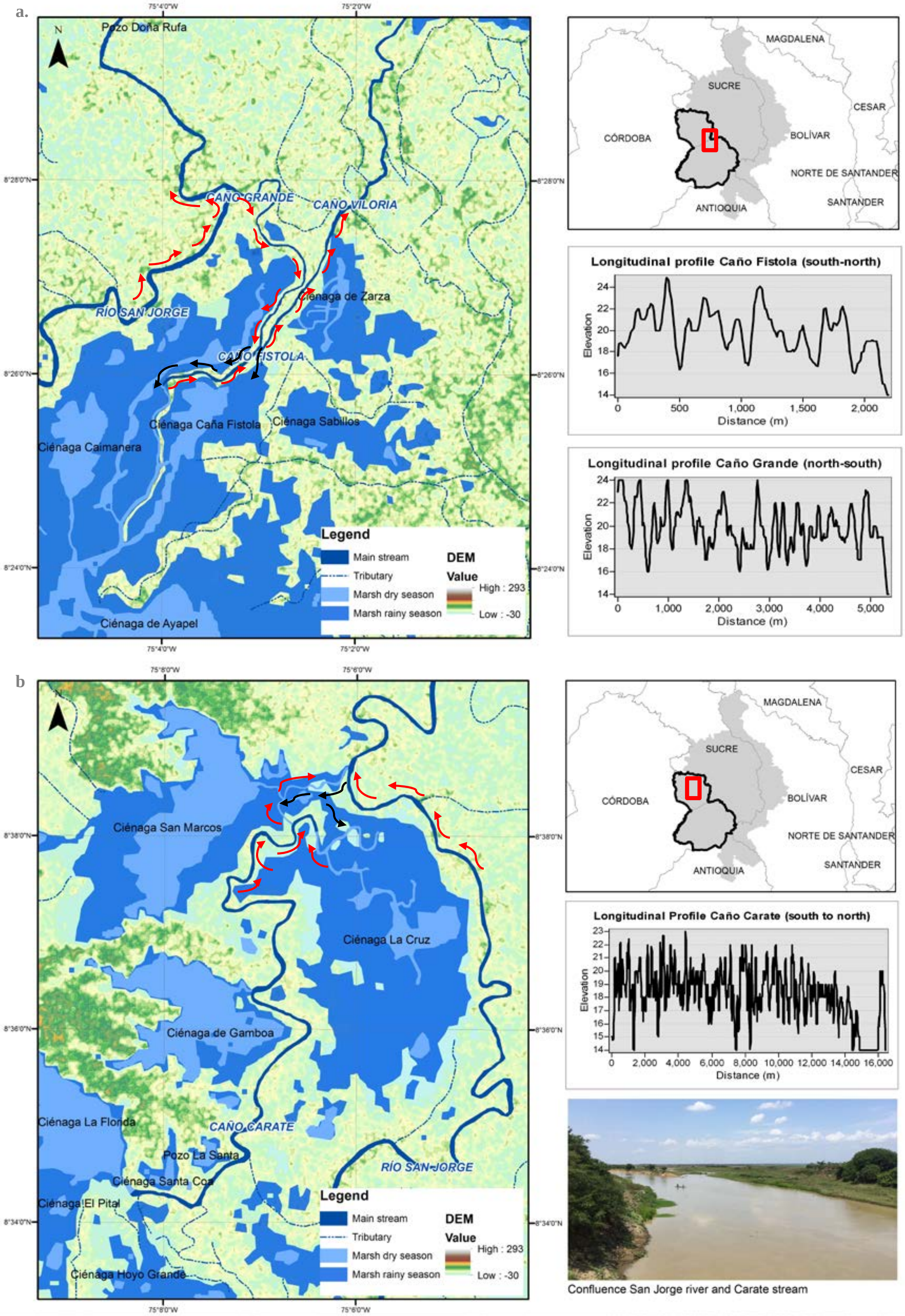


Illustration 6 Recharge and discharge communication streams between: a. The San Jorge river and Ayapel marshes; and b. The San Jorge river and San Marcos marshes

Red arrows indicate the dominant flow direction, while black arrows indicate flow change at the beginning of the rainy season. Longitudinal profiles are presented on the right side, to show elevation differences that regulate the main direction of the flow.

On the other hand, within the San Marcos municipality, the primary interaction between the San Jorge river and the marshes occurs through the *Caño Carate*, which intercommunicates the vast complex of wetlands located at the left side of the river. This stream, exhibits a defined channel in some parts of its course, while in others merge into the marshes such as La Cruz and San Marcos marshes, prior to the discharge over the river (MINAMBIENTE & CORPOMOJANA, 2000). During the rainy season overflows its banks, flooding its influence area (Illustration 6 b.)

3.2 Biotic system

Four ecosystems of great importance (Table 3), are recognized in the Mojana region, given the environmental services which they provide, these are: (1) Marshes; (2) Active floodplain; (3) Water streams; and (4) Flooded forest (DNP, PNUD, & DPAD, 2008).

Table 3 Matrix of importance values of ecosystem services by type of wetland

ECOSYSTEM	**SUPPORTING SERVICES**	Habitat for species	Maintenance of genetic diversity	**PROVISIONING SERVICES**	Crop cultivation	Aquaculture	Fishing	Freshwater	Raw materials (plants for fuel and energy)	**REGULATING SERVICES**	Local climate regulation	Air quality	Waste-water treatment	Regulation of water flow	Erosion prevension	Sediment regulation	Maintenance of soil fertility	Moderation of extreme events	Pollination	Biological control	**CULTURAL SERVICES**	Local ecological knowledge	Recreational activities and nature tourism	Aesthetic value of landscapes	Cultural identity and sense of belonging	Existence value
Marshes	█	█	█	█	░	█	█	█	░	▓	█	█	█	▓	█	█	▓	█	▓	▒	█	█	█	█	█	█
Water streams	█	█	█	█	▓	█	█	█	░	▓	█	▒	█	█	█	▓	█	█	▓	▒	█	█	█	█	█	█
Active floodplain	█	▓	█	█	█	▓	▓	▒	▒	█	▓	▓	█	█	█	█	█	█	░	█	█	█	█	█	█	█
Flooded forest	█	█	█	▒	▓	░	█	▓	█	▓	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█

Importance █ Very high ▓ Hihg ▒ Moderate ░ Low

Source: Modify from Jaramillo, Cortés-Duque, & Flórez, (2016)

(1) Marshes (*Ciénagas*): Shallow water bodies or saturated areas dominated by herbaceous plants (Hammer, 1988), connected either directly or indirectly to the rivers, being subject of its level fluctuations. Within this ecosystem, three ecological zones can be differentiated: Area of open water of variable depth; areas of bays, usually shallow; and marginal vegetation zones (Vélez, Montoya-Moreno, Aguirre, & Jordan, 2016).

Marshes enable the retention of large amounts of water, regulating river discharge and enhancing the processes of decanting and deposition of solids. Additionally, the exposure of large areas of water to air currents allows vertical mixing, improving oxygenation conditions (DNP & FAO, 2003). Finally, aquatic vegetation such as macrophytes species, act as retainers of nutrients and pollutants and provide shelter to aquatic fauna, favoring high biological diversity and high levels of fish production (Montoya-Moreno & Aguirre, 2013).

(2) **Active floodplain (*Playones*):** Fluctuating flood zone around the water bodies. Enables nutrient storage and cycling through the exchange of organic matter between the marshes and its adjacent areas during the flood pulse, which in turn contributes significantly to sustain the high biological productivity, species diversity and water quality of the floodplain (Craft, Casey, & Jones, 2000).

(3) **Water streams (*Caños*):** Biological corridors that intercommunicate water bodies and may have bidirectional flow. They constitute the main path for water and for aquatic organisms like fish, who migrate during the initial periods of the recharge and during the final phases of discharge (DNP et al., 2008).

(4) **Flooded forest (*Zapal)*:** Understory and shrub layers, from the Tropical Humid Forest (BHT) biome, that are resistant to prolonged periods of flood. Among the most common species can be found: Freshwater mangrove (*Symmeria paniculata)*; baygrape (*Coccoloba uvifera*); carper (*Capparis baducca L.*); and ice-cream bean (*Inga edulis*) (CVS, 2007).

The importance of this ecosystem is recognized for its high biomass production, providing organic matter to nearby aquatic systems (MINAMBIENTE & CORPOMOJANA, 2000). This high primary productivity is strongly linked with the flooding pulse, given that seasonally flooded forest have greater production than permanently flooded areas (Clawson, Lockaby, & Rummer, 2001). Additionally, they occupy a key role in the food chain by granting shelter, and shade to the fish, and the organisms from which they feed.

Annual timing, duration, and rate of rise and fall of the flood pulse influence the life cycles of the biota within a floodplain. Therefore, predictable and prolonged flood pulse, typical of large rivers, allows the adaptive response (anatomical, morphological, physiological and/or ethological), of the terrestrial and aquatic organisms who colonize this Aquatic-terrestrial transition zones (ATTZ) (Junk, Bayley, & Sparks, 1989).

One of the essential adapting measures developed in the study area, is the cycle of migration of some species of fish, including those with the highest commercial value, that move from the marshes to the streams and rivers, to avoid adverse conditions during low water periods (Sousa & Freitas, 2008). It has been found that fishes who exhibit this type of behavior, usually dominate fisheries, biomass and the production in the river-floodplain systems (Bayley, 1983). Further description of this cycle will be presented below, given the implications for the inhabitants of the region that depend on it for its subsistence.

Flood pulse also sustains the high geomorphological complexity of these systems (which in turn leads to a high heterogeneity of habitats), important biodiversity and differences of community structure (Montoya et al., 2011). In the case of the Ayapel marsh, Montoya-Moreno & Aguirre, (2013) observed composition, abundance and diversity variations of the epiphytic algal assemblage, through the flood pulse and between lentic and lotic environments. Similarly, Vélez et al., (2016) argue that this changes of structure favor the high richness of the species identified for the Ayapel marsh.

In their analysis of Ayapel marsh biodiversity, Vélez et al., (2016) found that producers dominate over consumers since they constitute the base for the ecosystem sustainability. In the Illustration 7 it is showed the number of taxa in a biological group with the most representative genres.

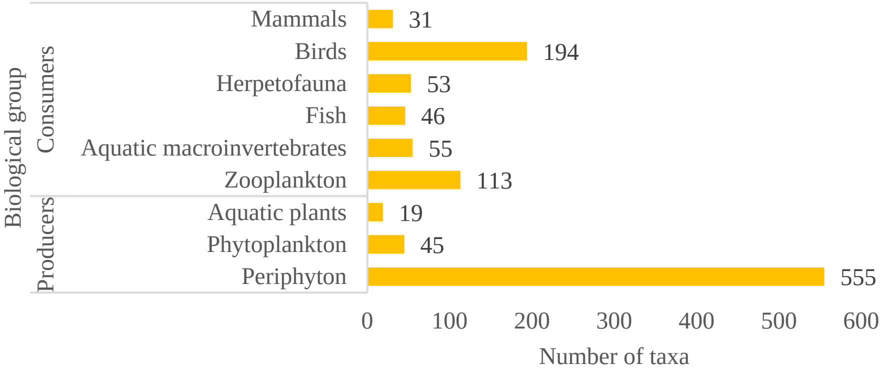


Illustration 7 Distribution by the number of taxa show in a trophic order
Source: Modify from Vélez et al., (2016)

3.3 Socioecological interactions

Official data from the last national census (2005), registered a population of 369,621 inhabitants in the eleven municipalities of the Mojana region (DANE, 2005). For the reference year; 52.25% of the population was located in the rural area. According to the projections, it is estimated that by 2018 the population has increased to 417,631, with a higher percentage in the urban area (50.07%). Within the focus municipalities, a rural population decrease was also expected; nevertheless, this could be underestimated given that the flooding disaster of 2010 and 2011, generated larger migrations than expected.

Water resources from the Mojana region are the main natural asset which sustains the livelihoods of its inhabitants. Thus, the regional economic dynamic is based in primary sector activities: crop cultivation, fishery, mining, hunting and livestock (Aguilera, 2004). This association between the community and their environment was sociologically studied by Fals Borda, (2002), who developed the term of "*Amphibian Man*" to describe the man whose continuous movement is between the land and the water, offering a characterization of the traditional lifestyle of the peasantry in the Momposina Depression.

Rural areas in Colombia are often characterized by its marked marginalized conditions (DNP et al., 2008). In the Mojana region, landholding inequities measured through a Gini index of 0.87 (Porras, 2014), limit the capacity of production of the rural population to a subsidence economy, which reinforce the dependence on biological resources. This low-income economy generates a high level of basic unmet needs, where most of the population lives under the poverty line (Sánchez Jabba, 2013).

According to Martínez-Reina, (2013); the mixed system (crop cultivation-livestock), is the dominant productive system of the region. Rice is the most important agricultural product, followed by maize, cassava, watermelon, coconut, and rubber. The type of cattle breeding is bovine, mainly of the Zebu specie (*Bos taurus indicus*), used for the production of both meat and milk.

In pre-Hispanic times, the indigenous communities (*Zenues* and *Malibues*), diversified its economic activities from food cultivation to fishing and hunting according to the flood pulse. This production strategy remains in force to this day; however, the limited access to the land inhibits the complementarity of activities, triggering indiscriminate hunting and fishing (Aguilera, 2004).

The productive cycle of small producers generally stars at the beginning of the rainy season (April-May); here the main crops (rice and corn) are sown, to be harvested between August and October. Subsistence fishing is practiced as a complementary activity along this process. With the decrease of water levels from November to January, the most important fish species migrate, which enables its capture for commercial purposes. Finally, as water bodies reach the minimum levels (February-April), hunting of birds and reptiles is practice (Ortiz Guerrero, Pérez Martínez, & Muñoz Wilches, 2007).

Seasonal changes do not exclusively influence productive activities. The Geographic distribution of the rural population among Highlands (emergent areas) and Lowlands (temporally flooded areas), defines variations in the level of interaction of people and water bodies (CVS, 2007). Consequently, a closeness to water bodies determines a higher vulnerability to floods; in turn, Highlands are more prone to the effects of rainfall deficits. Lowland population tends to use the active floodplain as temporal croplands during the dry season, while in Highlands permanent crops are sown. These spatial differences apply to a lesser extent to fishers, who tend to move across all the water bodies.

Means of transport also varies according to the spatial distribution. Water transport is especially important for the Lowlands inhabitants of Ayapel, who communicate through the marshes and streams, due to the precarious land connectivity; an only highway connects this zone with other municipalities (Illustration 8). In the case of San Marcos, the road network presents a higher development and connectivity, decreasing water transport dependence.

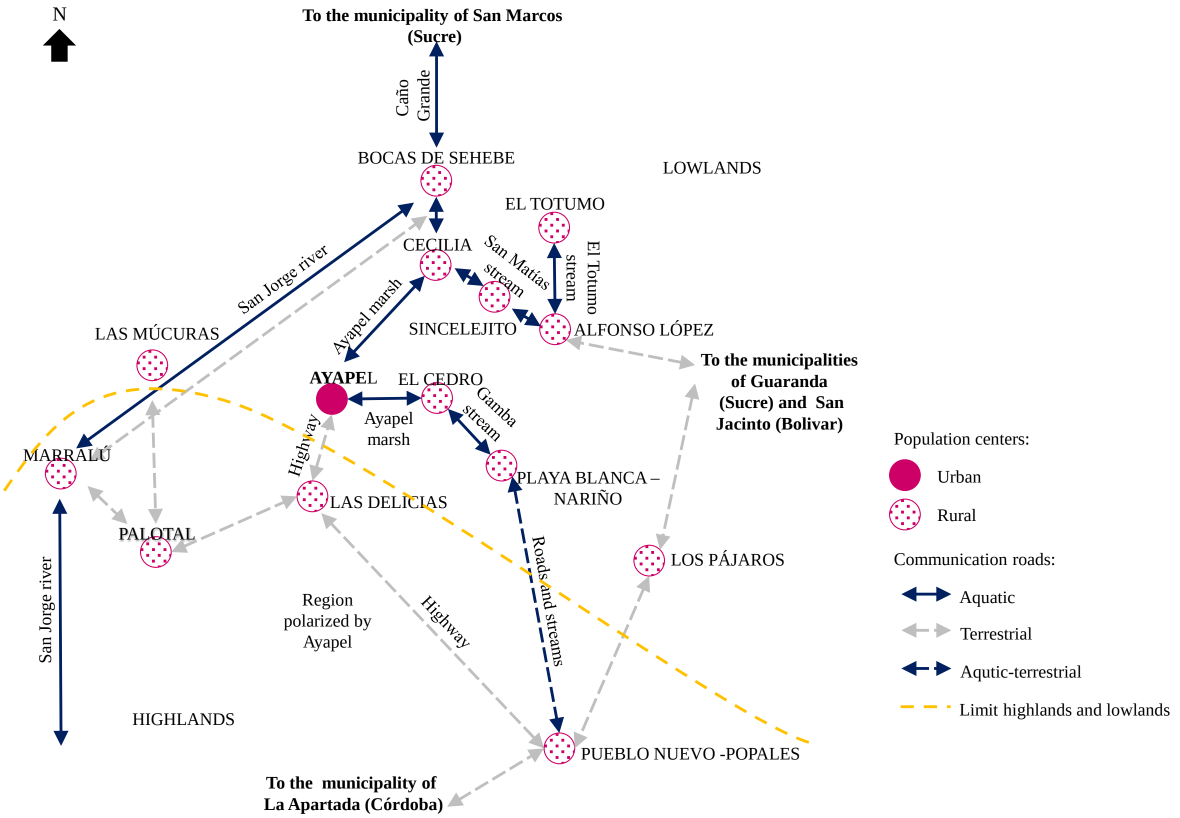


Illustration 8 Spatial connectivity in the Ayapel municipality
Source: Modified from Alcaldía Municipal de Ayapel, 2005

3.4 Rural livelihoods sources

According to Ellis (1998), rural households generate a living from several income sources. Three primary categories are recognized: farm; off-farm; and non-farm. Farm income involves both consumption-in-kind of own farm output and cash income from products sold. Off-farm refers to exchange labor or wage between farms, and non-farm refers to non-agricultural income sources. The development of farm-related activities characterizes the study area (Photography 1); for 2012 it was estimated that around the 45% of the productive areas were used for mixed systems of livestock and crop cultivation, 20% exclusively dedicated to crop cultivation, 16% to fishing, 8% to fishing and livestock, and the remaining percentage (7%) exclusively to livestock (Martínez-Reina, 2013).

Photography 1 Livelihoods sources in the Mojana region: a. Crop cultivation; b. livestock, and c. fishing
Source: D. Torres, (2018)

In developing countries, agriculture is the primary source of livelihoods for approximately 2.5 billion people (World Bank, 2017). Given its intrinsic characteristics, it is one of the most prone sectors to suffer the impacts of extreme climatic events (Mohmmed et al., 2017; Shiferaw et al., 2014). During the period 2003-2013, the agricultural sector accounted for nearly 84 percent of the total economic losses caused by drought (FAO, 2015). Consequently, the occurrence of drought events represents a major hazard to rural livelihoods (Keshavarz, Maleksaeidi, & Karami, 2017).

3.4.1 Crop cultivation

Within the study area, rainfed agriculture is practiced for either commercial or subsidence crop cultivation. Traditional subsidence crops include corn, rice, cassava, yam, and tropical fruit trees (cocoa, coconut, mango, guava, among others), planted in the yards of the houses. Commercial crops mainly include mechanized systems of rice and corn production (Aguilera, 2004). New crops for commercial purposes have recently being introduce, these include: winter squash, cocoa, sugar cane, rubber, coconut, beans, guava, lemon, traditional dry corn, technified dried corn, mango, yam, pineapple and zapote (Martínez-Reina, 2013).

Paddy rice is the main crop; near 6 to 10 rice varieties are used, mostly of non-certified seeds (FEDEARROZ, 2017). It is the primary income source and an essential product in the diet of the inhabitants of the region. According to the rice census of 2007 and 2016, the Mojana produces around 185 thousand of tons per year, with an average participation in the regional (Bajo Cauca) and in the national production of 72.96% and 6.84%, respectively (Illustration 9).

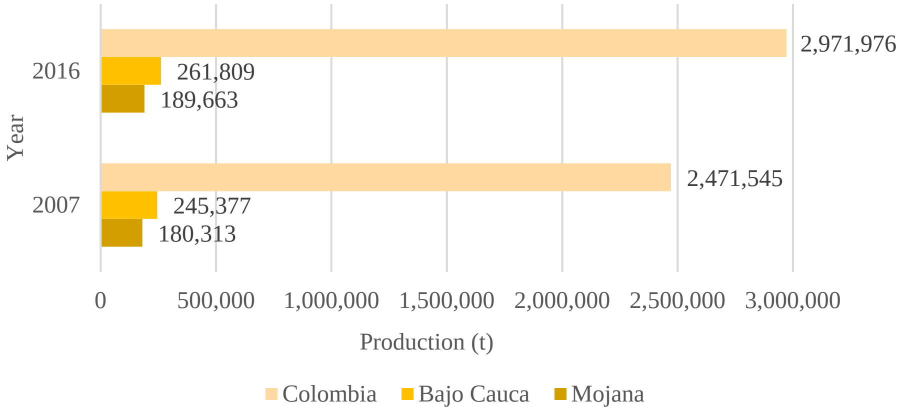


Illustration 9 Participation of the Mojana in the national and regional rice production for 2007 and 2016
Source: Own elaboration, based on FEDEARROZ (2008, 2017)

3.4.2 Fishing

The San Jorge River is one of the most productive fishing areas of the Magdalena River basin, given that the marshes contribute with nearly 55% of the catches (MINAMBIENTE & CORPOMOJANA, 2000). For the Magdalena basin, 190 species belonging to 29 families have been registered, of which 42 species are reported for the floodplains. In the Ayapel marsh basin Ríos-Pulgarín, Jiménez-Segura, Palacio, & Ramírez-Restrepo (2008), identified 40 species distributed in 23 families.

Historically 26 species of high commercial value have been recognized in the study area (Lasso et al., 2011); 13 of them have been captured between 2012 and 2017 in the municipalities of Ayapel and San Marcos (Illustration 10). The migratory species *Prochilodus magdalenae* is the most important with 29.54% of total annual catches, followed by *Leporinus muyscorum* (13.01%), *Oreochromis niloticus* (11.52%) and *Plagioscion magdalenae* (10.10%). Abundance, biomass, and diversity of the species variation is triggered by migrations, adverse conditions, and change of ecosystems connectivity during the flood pulse (Ríos-Pulgarín et al., 2008).

A species response to water levels fluctuation can be either active or passive throughout its life cycle. Usually, upstream migration is an active response, drive by the fish necessity to search for optimal conditions for spawning, while downstream migration is an active/passive response of juveniles and eggs to reach nursery areas (BOBP, 1997). Accordingly, the patter of migration in the study area comprises two movements: the upstream movement (*Subienda*) during the discharge season (from November to March); and the downstream movement (*Bajanza*) at the beguining of the recharge season (from April to June) (MINAMBIENTE & CORPOMOJANA, 2000).

Given that species of considerable commercial importance as *Prochilodus magdalenae* and *Pseudoplatystoma magdaleniatum* are rheophilic (flowing fish); its migration influences the quantity and composition of the landings. Thus, the upstream movement constitutes the best season of the year for fishing, with a significant increase of landings over the water streams and rivers. On the other hand, marshes landings increase during the downstream movement, but to a lesser extent. Minimum landings are reached from July to October, related with maximum levels of water, which hinders fishes catchings (Illustration 10).

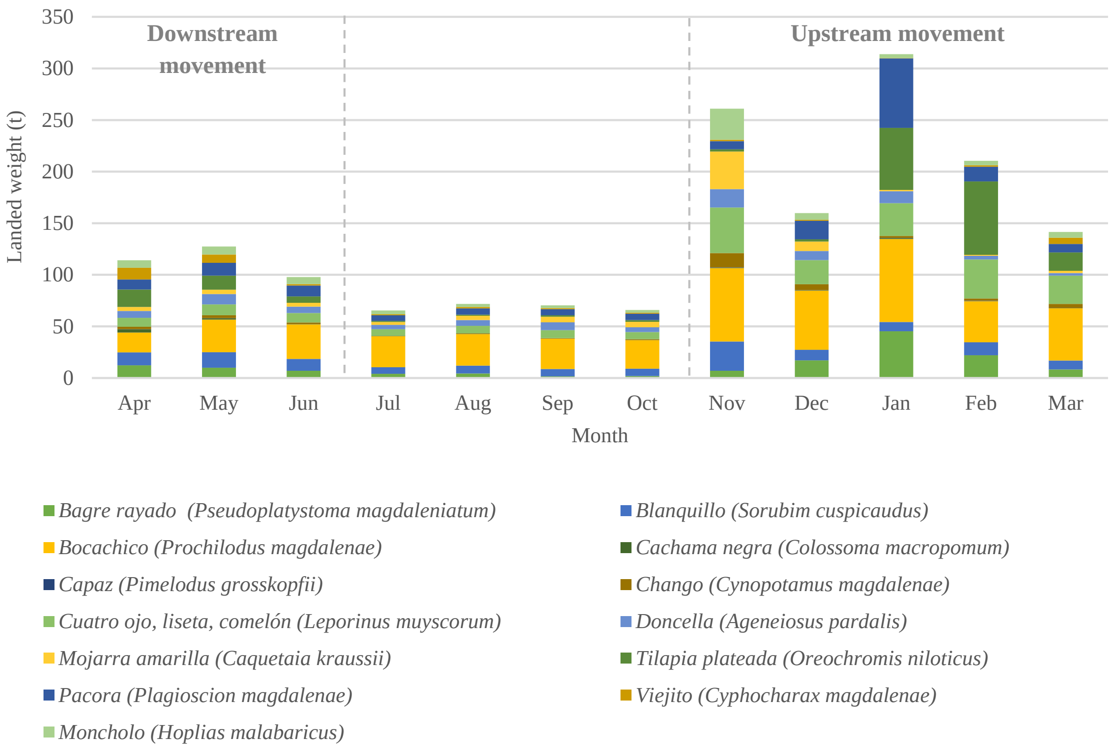


Illustration 10 Average landed weight per month (2012-2017) – Ayapel and San Marcos municipalities
Source: Own elaboration, based on SEPEC, (2018)

According to Aguilera (2004), the fishery is developed mainly by landless population, located around the water streams, rivers and marshes, characterized by its low levels of social linkage and organization. The type of fishing is artisanal; thus, productivity and income rely on the manual labor and productive seasons. The fish supply chain is made up of several intermediaries so that the fisherman's profit only reaches around 25% of the final price of the product.

3.4.3 Livestook production

Low technical level and very low profitability characterize the extensive livestock farming that occupies the largest part of the region (CORPOMOJANA, 2003). Transhumance or translation of livestock has been traditionally practiced during the dry season, to benefit from the available biomass exposed by the decreasing flooded area. This condition overlaps with a strong drop of the highlands productivity due to water stress conditions.

Livestock has contribute to the modification of the landscape, with the reduction of the forest area and the increase of the natural savanna (MINAMBIENTE & CORPOMOJANA, 2000). The naturalized forage has a low protein value and low digestibility, which in combination with the low availability of herbaceous species, make livestock production an unsustainable activity over the dry season (DPN, 2012).

Historically, the Mojana region has been characterized by unequal distribution of the land. Large land extensions for livestock production are property of a few elite groups whereas most farmers and daily laborers rent and work the rural land. Just in the Cordoba department, for 2010, it was estimated that 12% of the population possessed 80% of the land (Defensoría del pueblo, 2010). Illegal appropriation of communal and productive areas of the floodplain by stockbreeders have generated many social conflicts, such as population displacement, unemployment, and peasant movements for the recovery of these territories (CNRR, 2010). Landless population put an additional pressure over fishery resources because they are unable to develop the cultural model of complementarity between fishery and agriculture according to the hydrological cycles. Landowners, in their majority, are foreign people from the Antioquia department, who employ few of the local population to work in their lands (CVS, 2007).

During the last decade, large economic investments have allowed diversifying livestock, through the introduction of buffalo (a foreign species), which occupy the active floodplain and marshes (CNRR, 2010). The stockbreeders state that the buffalo introduction generates larger profits since buffalos are a more productive species, better adapted to conditions of water deficit and excess. However, the livestock of this species in the wetland areas is a growing threat to the ecological functioning of these complexes, especially concerning water flow and the loss of the functions of the soils and the active floodplain (Jaramillo et al., 2016).

4. METHODOLOGY

The applied methodology followed the principles and central components of the SLF. Illustration 11 summarizes the methods and tools used for the assessment of each component. The methods comprise systematic procedures to approach the SLF components and the study objectives; therefore, widely known and already proved methods were applied, sometimes developed within complementary frameworks. Finally, the used tools include a wide range of instruments which enabled from the field research to the data processing and analysis.

Objective	**Component SLF**		**Methods**	**Tools**
To characterize meteorological and hydrological drought events in the study area, during the period 1981-2015.	Vulnerability context - Drought exposure		Calculation of Standardized Precipitation Index (SPI) and Streamflow Drought Index (SDI)	DrinC and Arc-gis softwares.
To identify drought impacts on rural population livelihoods, during the previously identified drought events (from 1981 to 2015).	Livelihoods outcomes - Drought impacts	Potential impacts	Theoretical identification according to the Western Drought Coordination Council guide: *How to reduce drought risk?*	Impacts checklist, information gathering and causal chain
		Real impacts	Fieldwork according to the phase 2 of the Detailed Livelihood Assessment (DLA) approach.	Information gathering, semi-structured interviews, filed visits, workshop, literature review
			Quantitative analysis based on historical data	Statistical analysis through the software SPSS Statistics 19
To define which characteristics of sensitivity and adapting capability have a greater or lesser influence on the livelihoods vulnerability.	Livelihoods assets and strategies- Internal vulnerability	Sensitivity	Qualitative Ad-hoc approach for the ranking of sensitivity level of the livelihoods assets	Sensitivity indicators
		Adapting capability	Qualitative adaptation and vulnerability assessment, based on the *Conceptual framework for the vulnerability of socio-ecological systems* proposed by Berrouet, Machado, & Villegas-Palacio, (2017)	Identification of substitution capacity and coping capacity
To signal entry points that contribute to the reduction of drought vulnerability in the Mojana region.		Total internal vulnerability		Matrices for the estimation of total internal vulnerability by combining variables

Illustration 11 Study methodology; methods and tools applied regarding each SLF component and addressed objective

As previously stated, inside the study area (the Mojana region), a focus area was chosen; this corresponds to the Ayapel and San Marcos municipalities. Factors such as available information, accessibility, regional importance, security conditions, the presence of government institutions, administrative jurisdiction, and general differences and similarities were considered for selecting this two municipalities as the representatives of the study area conditions. Both the fieldwork and the data calculation were developed for these municipalities.

4.1 Drought exposure

For the definition of meteorological and hydrological drought events, the Standardized Precipitation Index (SPI) and the related Streamflow Drought Index (SDI), were calculated. The SPI was used to identify precipitation deficits affecting crop cultivation, while the SDI was related with discharge deficits affecting fishery production. To establish the best correlation between index and production, five averaging periods of drought were calculated (2, 3, 4, 6, and 12 months); this assessment periods were chosen according to the production cycles, and rainfall and water level variations (Table 4). Hydrological drought was defined according to the hydrological year, which starts in April of the year 1 with the beginning of the rainy season and finish in March of the year 2 with the end of the dry season; thus year 1 comprises 9 months and year 2 comprises 3.

Table 4 Drought indicators for the assessment of Livelihood exposure

Drought type	**Drought index**	**Exposed Livelihood**	**Entry data**	**Averaging periods**				
				2	**3**	**4**	**6**	**12**
Meteoro-logical	SPI	Crop cultivation	Monthly data series of the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) from 1981 to 2016.	Apr-May Jun-Jul Aug-Sep Oct-Nov	Jan-Mar Apr-Jun Jul-Sep Oct-Dec	Apr-Jul Aug-Nov Dec-Mar	Jan-Jun Jul-Aug	Jan-Dec
Hydrolo-gical	SDI	Fishing	Monthly data series of streamflow data from the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) from 1981 to 2015*. *2016 data were not available	Apr-May Jun-Jul Aug-Sep Oct-Nov Dec-Jan Feb-Mar	Apr-Jun Jul-Sep Oct-Dec Jan-Mar	Apr-Jul Aug-Nov Dec-Mar	Apr-Sep Oct-Mar	Apr-Mar

The SPI is one of the most commonly used drought indicators. It enables the study of precipitation at different temporal scales, which is useful in the monitoring of drought early signal (Sivakumar, Motha, Wilhite, & Wood, 2011). The SPI is based on the conversion of the precipitation data to standardized series with an average of 0 and a standard deviation of 1 (Vicente-Serrano et al., 2012). It also gives an approximation to the severity and likelihood of a drought event, with increasingly negative values indicating a more severe, but less likely drought (Barker, Hannaford, Chiverton, & Svensson, 2016). On the other hand, the SDI shares the same principles of calculation of the SPI but for monthly river discharge data instead of rainfall (WMO, 2016).

The most significant restraint for the use of this indexes is that requires a single input (precipitation or streamflow), excluding the interactions that define the water balance and water use of a region (WMO, 2016). Within this study, that problem will be addressed by coupling quantitative results with qualitative data throught the vulnerability assessment. Another known disadvantage is that the probability distribution, may not be appropriate in all environments. Finally, since the estimation allowed missing data, a high proportion of blank spaces can become problematic (Barker et al., 2016).

The software Drought Indices Calculator (DrinC) was used for the estimation of SPI and SDI; this software process monthly, annual or seasonal data, allowing the calculation of different accum ulative periods (Tigkas, Vangelis, & Tsakiris, 2015). Results can be classified according to the values of Table 5.

Table 5 Severity classification according to the SPI and the SDI

SPI/SDI	**Classification**		
	Severity	**Dry (-)**	**Wet (+)**
0 to ± 0,99	Mild		
± 1,0 to ± 1,49	Moderate	🟨	🟦
± 1,5 to ± 1,99	Severe	🟨	🟦
± 2,0 or less	Extreme	🟧	🟦

Source: Mckee, Doesken, & Kleist,(1993)

4.1.1 Meteorological drought

Monthly precipitation data series, for the period 1981-2016, were obtained from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS). CHIRPS are a high resolution daily, pentadal and monthly data series that integrate 0.05° resolution satellite images with in-situ recorded data, and global climatology to generate gridded rainfall time series (Funk et al., 2015). According to Shukla, Mcnally, Husak, & Funk, (2014), CHIRPS provide better estimates of precipitation means and variation than other data sets; likewise, Katsanos, Retalis, & Michaelides, (2016) found a good correlation between CHIRPS values and locally recorded precipitation.

Monthly precipitation values were extracted from the CHIRPS per climate type within the focus area, and for the San Jorge basin using ArcGIS interpolation tools (Appendix 1 and Appendix 7). This dataset was selected above local stations data, as the following advantages were acknowledged: (1) represented both temporal and spatial variations; (2) the information covered a period beyond 30 years; and (3) the information did not present gaps.

It was hypothesized that might be a difference between the SPI results obtained per climate type (Warm Semi-arid, Warm Sub-humid, and Warm-Humid). The analysis of variance (ANOVA) was used to prove or deny the existence of a statistical difference, with a level of significance of 0.05.

4.1.2 Hydrological drought

The hydrological dynamic for the study area is mainly governed by the flood pulse of the San Jorge river (Illustration 6). Accordingly, some fish species migrate between the river and the marshes as the flood pulse varies; this migration defines the life cycle of these species; thus, their productivity (DNP

& FAO, 2003). To characterize the flood pulse from the San Jorge river, six hydrometric stations were identified in its main course; however, only one of them contained river discharge data (*Montelibano automatica*). Consequently, monthly data for the *Montelibano* station between 1981 and 2015 was obtained (Appendix 8), from the Colombian Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). Montelibano was adopted as the reference station, from which the SDI was calculated.

Since drought propagation process defines the occurrence of hydrological drought. The annual SPI and SDI results where linearly correlated through the Pearson coefficient (*r)* with a significance level of 0.05, in order to establish the probability that a meteorological drought will eventually result in a hydrological drought. CHIRPS were used to obtain precipitation and characterize meteorological drought for the Montelibano station sub-basin (Illustration 12).

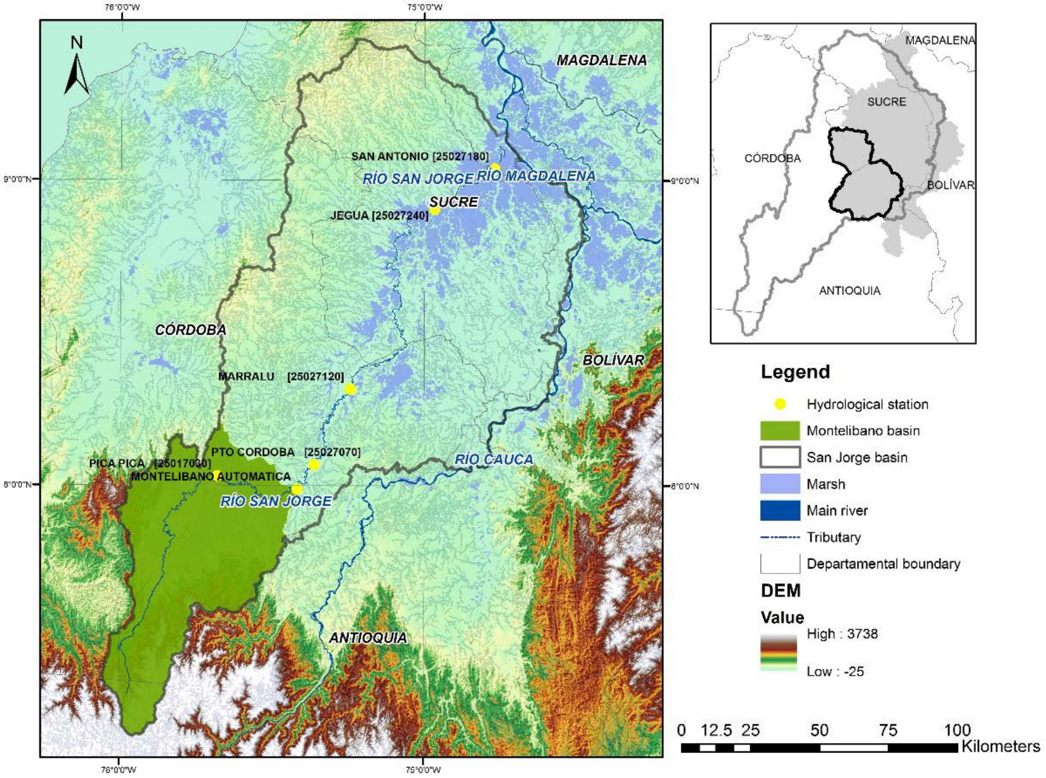


Illustration 12 Montelibano station sub-basin for the estimation of hydrological drought

4.2 Drought impacts

Impact assessment involved the identification of both Potential and Real impacts on rural livelihoods sources, more specifically on crop cultivation and fishing. This stage included a theoretical work and field participatory research developed during April 2018 in the Ayapel and San Marcos municipalities

4.2.1 Potential impacts

Potential drought impacts were defined as the likely outcomes of a drought event in the study area. Based on the drought impacts checklist developed by the Western Drought Coordination Council (1998), a theoretical identification of potential impacts was conducted for the Mojana region. Then, a causal chain was built to differentiate between direct or indirect impacts. Required data for the assessment of causes and consequences of the potential impacts along with likely sources, was listed. Field information gathering was made to obtain the necessary data; this included visits to public, academic and private sources.

- Impacts checklist

The Western Drought Coordination Council guide (1998), aimed to provide a tool for individuals and organizations of all regions, to reduce drought risk by identifying drought impacts; examining the underlying environmental, economic, and social causes of these impacts; and then choosing actions that will address these underlying causes. This guide includes a drought impacts checklist that classifies impacts as economic, environmental, or social as well as their description. Potential impact identification was made by following this approach (Appendix 2).

- Causal chain

"Theory-based evaluation, which means examining the assumptions underlying the causal chain from inputs to outcomes and impact, is a well-established approach" (White, 2009). The mapping of drought impacts through a causal chain enabled the visual identification of direct and indirect impacts, helping to understand its interactions. Overall, this contributed to establishing essential points to address for the diagnosis of impacts causes and consequences (Appendix 3).

- Information gathering

Multiple sources of data were considered, including governmental, academic and productive organizations. The collected information comprised: the characterization of the study area, territorial planning instruments, risk management plans, and specific data regarding agricultural, and fishing activities. This phase required internet search, e-mail communication and direct visits to most of the organizations, located between the municipalities of Montería, San Marcos, Ayapel, Medellín, and Bogotá. Meetings with public servants also helped to shape an overview of the problems and most relevant aspects of the region.

4.2.2 Real drought impacts

Real drought impacts were defined as those potential impacts that could have been recognized during previous drought events within the study area. The identification of drought impacts on livelihood sources comprised of two steps: (1) fieldwork and (2) quantitative data analysis.

4.2.2.1 Fieldwork

The Fieldwork was conducted according to the phase 2 of the Detailed Livelihood Assessment (DLA) approach. The DLA provides a guide for the exhaustive assessment of the impact of a disaster on livelihoods (FAO & ILO, 2009). This phase included the application of semi-structured interviews, field observations, field visits, a workshop and collection and analysis of data in the field so that a picture of the situation could gradually be built up (Illustration 14).

Based on the DLA, the fieldwork was intended to answer the next questions: (1) What are the livelihood sources in the region?; (2) What are the socio-economic and natural assets that sustain this sources?; (3) How this sources had been affected by previous drought events?; (4) How drought events have affected the lifestyle of the rural population?; (5) What adaptation measures and livelihood strategies have different people/ households developed and how effective/damaging are these?; and (6) What types of activities are needed for vulnerability reducing livelihood recovery of the different people, households, and communities ('building back better')?. To answer this questions, four levels of inquiry were established. Key informants were identified within each level; accordingly, different approaching strategies were defined to interact with these actors and acquire the information.

Table 6 Fieldwork inquiry levels, key informants, and strategies to approach them

Inquiry level	Key informants	Addressed questions	Approaching strategy
Regional/local	Governmental institutions	(1), (3) and (6)	Information gathering and interviews
Communitary	Farmers parnerships Community group	(1), (2), (3), (4) and (6) (1), (3), (4) and (5)	Semi-structured inteviews and field visits Workshops
Household	Womens	(4) and (5)	Interviews
Secondary data	Academic, governmental and private institutions	(1), (2), (3), (4) and (6)	Literature review

Since the information gathering stage that included the Regional Research and Secondary Data levels was previously described, the research at the Community and Household level is described in detail below.

- Communitary inquiry level

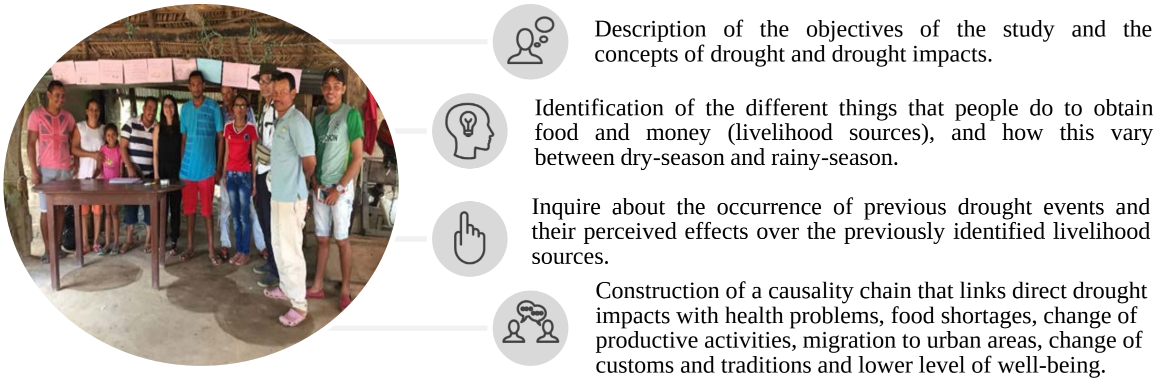
The core tool in the DLA is semi-structured interviewing (SSI) using checklists. SSI was used to approached farmers partnerships. These actors were considered the focus group regarding the livelihood sources information. Agricultural, livestock and fishing associations were included in the study; in almost all cases the interview process was accompanied with guided visits to the productive areas. The content of the applyied SSI is described in the Table 7, and the fieldwork form is available in Appendix 4.

Table 7 Semi-structured interview content

Section	Description
I. Identification of the farmer partnership	General data: Name, creation date, number of partners and location
II.Characterization of the productive activity	Description of the activities (crop cultivation, fishing or livestock): Product description, annual yields, dates of the activity, used techniques, objective of the production, water sources, practices for water and soil conservation, support infrastructure, conservation practices and sustainable management, natural phenomena that affect the area and land tenure system.
III. Drought impacts	Drought definition, the frequency of drought events, drought intensity, activities affected by drought events, drought impacts identification.
IV. Responsiveness and coping capacity to drought events	Identification of drought risk management systems, community capacity to cope with drought events, adapting measures to drought.

The interviews were directed mainly to associations of small and medium producers (are considered to bee more prone to suffer drought effects), from different rural areas, of both High and Low lands. In total, nine interviews were conducted with an average duration of 2.5 hours. The meetings included the participation of the legal representatives of the productive associations and in many cases, of other associates. Complementarily, eleven guided field visits were made to deepen the subjects covered in the interviews, recognizing the productive areas and observing the activities developed. The field track sought to obtain high representativeness of the study area, comprising a considerable extension and including heterogeneous zones (Illustration 14).

Drought impacts on the rural population lifestyle were identified from a community participation approach through a workshop held in the rural community of El Paso de Carate, in the municipality of San Marcos. A workshop is a planned event intended to achieve high levels of interaction among participants as they addressed a common issue (Sanoff, 2000). The composition of the participating community included the two genders, distributed in an age range ranging from children to senior adults. The activities developed during this workshop are listed below:



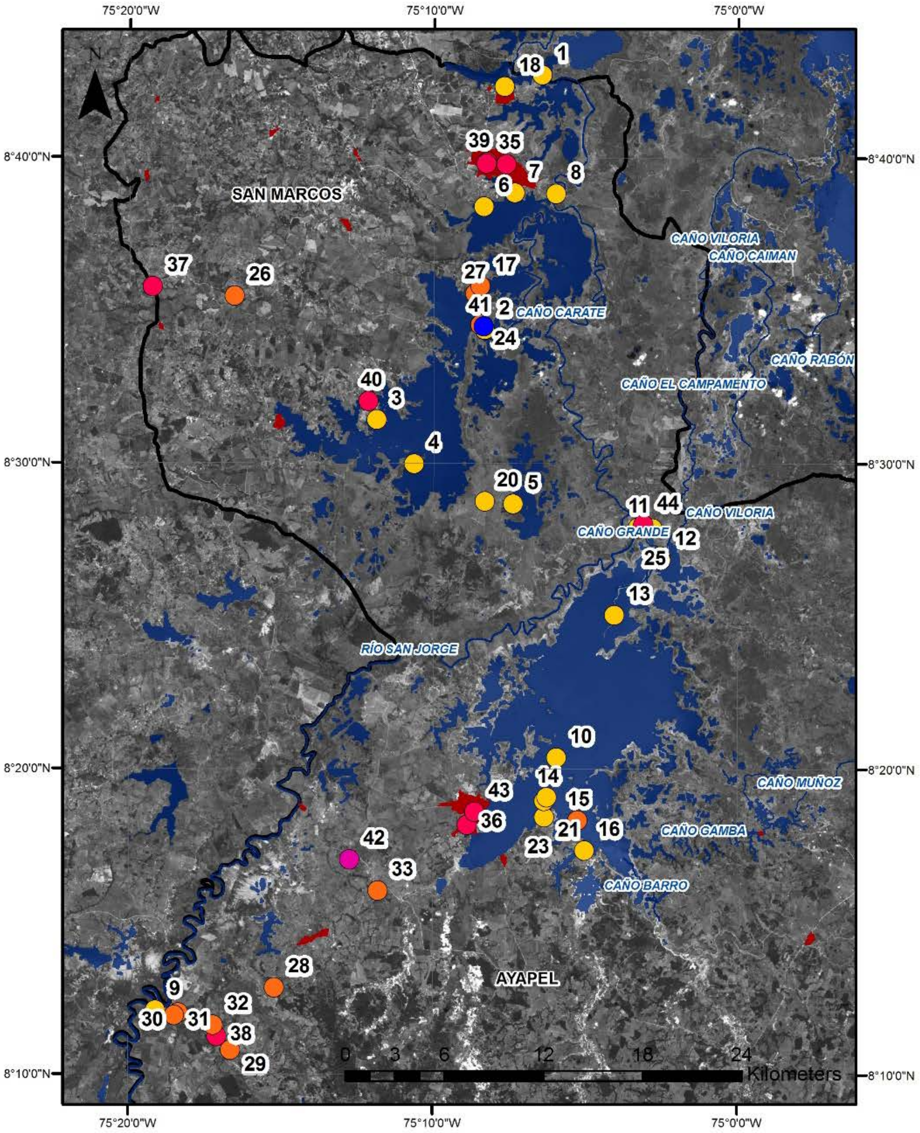
Description of the objectives of the study and the concepts of drought and drought impacts.

Identification of the different things that people do to obtain food and money (livelihood sources), and how this vary between dry-season and rainy-season.

Inquire about the occurrence of previous drought events and their perceived effects over the previously identified livelihood sources.

Construction of a causality chain that links direct drought impacts with health problems, food shortages, change of productive activities, migration to urban areas, change of customs and traditions and lower level of well-being.

Illustration 13 Workshop activities



Activity	Symbol	Component	ID	Description
Field observation	●	Ecosystem	1	San Jorge river
			2	Carate stream
			3	Las Flores marsh
			4	Old course Carate stream
			5	La Caimanera marsh
			6	San Marcos marsh - dry season
			8	Confluence San Jorge-Carate
			9	San jorge river
			10	Ayapel marsh
			11	Confluence San Jorge - Grande stream
			12	Viloria stream
			13	Fistola stream
			14	Barro stream
			16	El Quemado marsh
			17	Research center CORPOMOJANA
		Fishing	7	Fishing San Marcos marsh
			18	Fishing Palo Alto marsh
			19	Temporary housing for fishing
		Livestock	20	Buffalo farm
			21	Livestock in the active floodplain - dry season
		Agriculture	22	Stream banks agriculture
			23	Mango crop
Field visit	●	Fishing	15	Fishing Barro stream - dry season
			24	Fishing in La Florida marsh - dry season
		Fishing-Agriculture	25	Productive area Seheve
		Agriculture	26	Productive area Calle Larga
			27	Productive area El Paso de Carate
			28	Yam crops
			29	Agroforestry system; rubber crops
			30	Rice crops
			31	Fertile soils
			32	Household
			33	Mango plantations
Interview	●	Fishing	34	Association of Fishermen Producers of San Jorge and La Mojana
			43	Association of Small Agricultural Producers and Fishermen of Ayapel
		Livestock	35	Association of Agricultural Producers of San Marcos
		Agriculture	36	Association of Small Ecological Producers of Mangoes, Fruits, Vegetables and Tubercles of Ayapel
		Agriculture-Livestock	37	Association of Fish Farmers and Field Producers of Calle Larga
			38	National Association of Peasant Users of Colombia
		Fishing-Agriculture	39	Peasant and Producers Association of El Paso de Carate
			40	Association of Fishermen and Farming Producers of Las Flores
			44	Association of Fish Farmers and Agricultural Farmers of Seheve
Workshop	●	Fishing-Agriculture	41	Workshop El Paso de Carate
Training	●	Ecosystem	42	Soil pit

Illustration 14 Fieldwork activities and location

- Household inquiry level

Within the study region, a distinction of gender roles was identified; while men are the main providers of the income, women administrate the assets inside the household. Therefore, three interviews aimed at women were carried out at the household level; two in the municipality of Ayapel and one in the municipality of San Marcos. The interviews consisted of open questions, lasting approximately one hour. The objectives that this level of research seeks to address were:

- To establish the impact of previous drought events on livelihood assets, activities, and outcomes at the household level.
- To find out about the households strategies to cope with the damage / loss of assets.
- To establish what are the main short and longer-term priorities, needs and opportunities.

4.2.2.2 Quantitative analysis

Productivity decrease is one of the most recognized direct effects of drought (Western Drought Coordination Council, 1998), and a straightforward way to characterize drought impacts through historical data. The Pearson`s correlation coefficient (*r*) was calculated to establish the strength of the relations between drought events identified through the SPI and the SDI indices, and the historical variation of the crop cultivation and fishing productivity. This coefficient has a value between +1 and −1, where 1 is a total positive linear correlation, 0 is no linear correlation, and −1 is an absolute negative linear correlation (Table 8).

Table 8 Strength of the associations according to the Pearson coefficient (r)

Rank	Strength of association	Simbol
0	No association	🟩
0 to ± 0.24	Negligible association	🟩
± 0.25 to ± 0.49	Weak association	🟩
± 0.50 to ± 0.75	Significant association	🟩
± 0.75 to ± 1	Very strong association	🟩
± 1	Perfect association	🟩

The Pearson`s coefficient is an indicator of the existence of a association between two variables. Whether this relation is defined due to causality or it is real, was determined by a linear regression test, obtained through the use of the SPSS Statistics 19 software. A level of significance (α) of 0.05 was defined for all the estimations. The probability that the linkage between the variables can predict the outcome better than chance (ρ value) is reported. If the ρ value is lower than the level of significance, it means that the correlation between the variables is statistically significant.

The assessment was conducted for the most representative product within each livelihood source. Historical data regarding annual production variation was gathered and processed. However, in all cases, it embodies a higher area since historical registers are not recorded at the municipal level or exclusively for the study area (Table 9).

Table 9 Main livelihoods sources and available data for their characterization

Livelihood source	Representative product	Source of the historical data	Data coverage		Representativeness of the study area		
			Region	Period	Mojana	Ayapel	San Marcos
Crop cultivation	Paddy rice	FEDEARROZ	Bajo cauca region	1981-1992 2000-2016	72.96%*	4.84%*	4.77%*
Fishing	*Prochilodus magdalenae*	INPA, INCODER, CCI, SEPEC	Magdalena basin	1981-2009 2012-2016	87.03%***	24.70%**	8.67%**

*Average annual production participation to the total Bajo Cauca region for 2007 and 2016 (FEDEARROZ, 2008, 2017)
**Average annual landed weight participation to the total Magdalena basin within 2012 and 2017 (SEPEC, 2018).
***Value reported for 1999 (DNP & FAO, 2003)

4.3 Internal vulnerability

4.3.1 Defining sensitivity

A vulnerability approach is intended to identify drivers of drought impacts. Within the livelihood framework, five core asset categories or types of capital are recognized, upon which livelihoods are built (DFID, 2001). Thus, sensitivity is considered as the access to those forms of capital, and adaptive capacity as the use strategies of this resources to achieve positive livelihoods outcomes.

Table 10 provides a guide for the identification of the five type of assets. The assets characterization for the chosen livelihoods sources (Rice and *Prochilodus magdalenae*), was made supported on hard data from specialized organizations, and on the soft data collected during the fieldwork.

Table 10 Determinants of sensitivity and Indicators to measure them in rural farms

Assets	Description	Indicators
Economic assets (E)	Financial resources such as cash, credit, and productive resources.	Income Saving Unemployment Farm size Livestock
Physical assets (P)	Access to good infrastructure and to technology.	On-farm-structures Access to roads
Human assets (H)	Educational experiences, knowledge, skills, and expertise of a person.	Education Age Household size Illiteracy ratio Adults ratio
Social assets (S)	Collective resources and capacities that support and multiply individual efforts.	Social integrity Social linkage
Natural assets (N)	Basic ecosystem services	Regulating services Provisioning services Supporting services Cultural services

Source: Modified from Keshavarz et al., (2017) Ranking the contribution of each assessed indicator to the total internal vulnerability was defined through an ad hoc approach. Four categories of sensitivity were defined; each one was assigned a value, where high values are associated with high levels of sensitivity (Table 11).

Table 11 Criteria definition for the rating of sensitivity

Vulnerability aspect	**Category**	**Rating**
Sensitivity	I. Low	1 – 1.74
	II. Medium	1.75 – 2.49
	III. High	2.5 – 3.24
	IV.Very high	3.25 – 4

Sub-categories were established for each indicator, given that one category was not enough to represent the reality of the study area. This variation (measure in percentage), was related to the sensitivity rating, obtaining the weight for each category. The sum of the weights resulted in the sensitivity per indicator and the average of indicators resulted in the total sensitivity per asset (Table 12).

Table 12 Definition of sensitivity per indicator and asset

Indicator name (1)	**Category (2)**	**Portion (3)**	**Sensitivity rating (4)**	**Weight (5)**
Type of asset: P/H/E/S/N				
$N_1...N_n$	Indicator category	(%)	(1-4)	(3) x (4)
	Total sensitivity per indicator			$\sum(\mathbf{5})$
Total sensitivity per asset				$\frac{\sum(\mathbf{5})}{\#\boldsymbol{N}}$

Finally, the average sesitivity per type of asset was calculated. The assets pentagon (DFID, 2001) was used to show schematically the variation in the sensitivity of livelihoods sources. The center point of the pentagon, represents very high sensitivity while the outer perimeter represents low sensitivity.

4.3.1.1 Indicators definition for the assessment of sensitivity

Table 13 to Table 14 present the description and categorization of the indicators stablished to assesst the sensitivity of each livelihood source. Those indicators were selected according to Table 10, complementing literature review, and field recognition of the key points to addres regarding drought sensitivity in the study area.

4.3.2 Defining adaptation

Adaptations to climate change depend on using capital assets in different ways or substituting between capital assets (Reed et al., 2013). In other words, adaptation is a function of both the coping capacity (CC) and the substitution capacity (SC). Based on the Berrouet, Machado, & Villegas-Palacio, (2017) proposal to addressed adaptation, the capacity of substitution was evaluated by the combination of two factors: (1) availability of substitute sources, and (2) feasibility of substitution. Within this approached, substitution capacity is ranked according to Illustration 15.

Table 13 Indicators categories for the assessment of sensitivity in rice cultivation

Indicator	Description	Category
Physical assets		
Rice production system	Set of principles and a set of mostly biophysical mechanisms for rice production (Stoop, Uphoff, & Kassam, 2002).	Mechanized Manual
Water supply system	Mechanism of crops irrigation	Rainfed Irrigated
Human assets		
Level of education	Grade of education obtained among rice producers.	No education Primary education Secondary education Higher education
Workforce	Ranking ages of the producers.	0-19 20-29 30-39 40-58 ≥60
Economic assets		
Rice productive unit (RPU) extention	Area that a producer uses for rice sowing (FEDEARROZ, 2017).	≤5 ha 4.99 – 49.99 ha ≥50 ha
RPU Land tenure	The relationship, whether legally or customarily defined, among people, as individuals or groups, with respect to land property rights (FAO, 2018).	Own Rented Other
Social assets		
Level of partnership	Grade in which the producers agree to cooperate to advance in their mutual interests.	High Medium Low
Natural assets		
Regulating services – Moderation of drought events	Capacity of the rice production system to moderate the effects of drought events, measured through the growing phases.	Vegetative phase Reproductive phase Maduration phase
Provisioning services – Crop productivity variation	It is considered an indirect indicator of the ecosystem productivity	0.97-1.46 t/ha 0.49-0.96 t/ha ≤0.0-0.48 t/ha

Table 14 Indicators categories for the assessment of sensitivity in Prochilodus magdalenae fishing

Indicator	Description	Category
Physical assets		
Used fishing gear	The instrument employed for the catches, measured through the percentage of time that was used.	Trammel net Cast net Seine net Other
Property rights over the fishing gears	Legal ownership over the used fishing gears, estimated through the percentage of fishers that belong to each category.	Shared Individual Rented Borrowed
Human assets		
Level of education	Grade of education obtained among the fishers	No education Primary education Secondary education Higher education
Yearly dedication to the fishing activity	Proportion of the time within a year, in which the fishers dedicate to the fishing activity.	Total Parcial Occasionally
Economic assets		
Income	Daily wage obtained from the fishing activity, for each member of a fishers household, measured according to the used fishing gear.	Trammel net Cast net Seine net Other
Social assets		
Level of partnership	Grade in which the producers agree to cooperate to advance in their mutual interests, defined by the percentage of fishers that belong to a partnership.	Partnership members Not associated
Natural assets		
Supporting services – Habitat for species	Loss of the flooded forest, which grant shelter, and shade to the fish, and the organisms from which they feed.	>90% 61-90% 31-60% 0-30%
Provisioning services – Fishery resources	Loss of *Prochilodus magdalenae,* defined according to the threat category.	Critically endangered (CR) Endangered (EN) Vulnerable (VU) Near Treatened (NT)

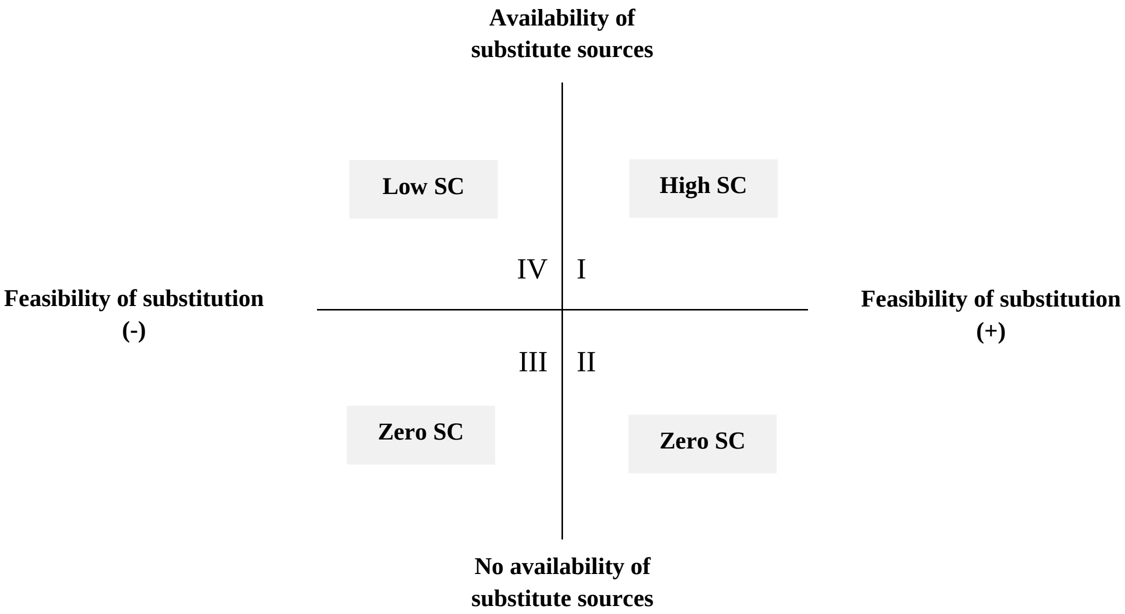


Illustration 15 Substitution capacity (SC) according to the availability of substitute assets and their feasibility of substitution

Source: Modified from Berrouet et al.,(2017)

Based on fieldwork and information gathering, the assessment of the coping capacity (CC) resulted from the identification of either one of these three factors or its combination: (1) Existence of early warning systems of drought; (2) Existing measures that have increase the capability of the population to face drought events and (3) Economic possibilities of the community to make the necessary investments for adaptation.

4.3.1 Defining total internal vulnerability

Through the following matrices, adopted and modified from Berrouet et al., (2017), the sensitivity was related to the substitution capacity (SC), and coping capacity (CC), obtaining the total internal vulnerability for each source of livelihoods.

Table 15 Matrices for the estimation of total internal vulnerability by combining variables

Sensitivity vs. substitution capacity

Sensitiv. **SC**	**Low**	**Medium**	**High**	**Very high**
II-III (Zero)	Low	Medium	High	Very high
IV (Low)	Low	Medium-low	High	Very high
I (High)	Low	Low	Medium-High	High

Sensitivity vs. coping capacity

Sensitiv. **CC**	**Low**	**Medium**	**High**	**Very high**
Zero	Low	Medium	High	Very-high
Low	Low	Medium-low	Medium-high	High
High	Low	Low	Medium-High	High

Assets color code	P	H	E	S	N
Crop cultivation	🟨	🟪	🟦	🟧	🟩
Fishing	🟨	🟪	🟦	🟧	🟩

Source: Modifyied from Berrouet et al., (2017)

5. RESULTS AND DISCUSSION

5.1 Drought exposure

5.1.1 Meteorological drought

No significant statistical differences of the $SPI_{3,4,6,12}$ results were obtained between climate types according to the results of the ANOVA test (Appendix 6). Consequently, an equal level of exposure to drought is expected within the three climatic zones that comprise the focus area (Illustration 4).

From the SPI_{12} it was possible to identify that during the analyzed period (1981-2016), the occurrence of wet and dry years showed a similar behavior: nine years were classified under the moderately to extremely wet conditions and nine years under the moderately to extremely dry conditions (Illustration 16). Thus, drought events represent a potential natural hazard, which has affected on average every 3.75 years the study area. However, not a real frequency could be established since the occurrence of drought has been highly variable (from 1 to 11 years).

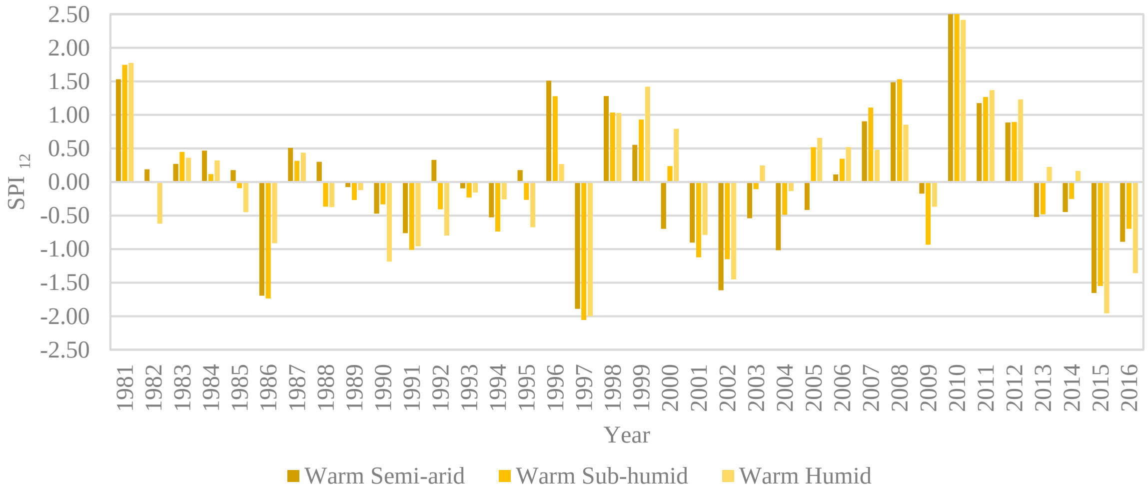


Illustration 16 SPI_{12} results according to climate type – Focus area (1981-2016)

An increasing frequency over the last years as expected within the context of global increasing climatic variability, it is not observable; moreover, the most prolonged period without droughts was recorded between 2004 and 2015. Frequencies of 1 year were recorded for the periods 1990-1991; 2001-2002; and 2015-2016. Results vary among averaging periods and climate types; the complete SPI results are presented in Appendix 5. On the other hand, an increased frequency of wet years can be recognized; for the period 2007-2012, the incidence was of 1.25 years.

In Colombia, *El Niño* phenomenon has proved to be strongly coupled with precipitation anomalies showing negative values on the central, northern, and western regions of the country, indicating a clear reduction of precipitation over these regions (Poveda, Álvarez, & Rueda, 2011). In the study area, both extremes; dry and wet years are highly related with the ENSO cycle (Table 16). These results suggest that *El Niño* could be considered one of the main drivers of drought occurrence in the study area.

Table 16 Relation of dry and wet years with El Niño y La Niña events (1981-2016)

Dry years				**Wet years**			
	Climate (Caldas-Lang)				**Climate (Caldas-Lang)**		
Year	**Warm Semi-arid**	**Warm Sub-humid**	**Warm Humid**	**Year**	**Warm Semi-arid**	**Warm Sub-humid**	**Warm Humid**
1986*	-1.69	-1.73	-0.91	**1981**	1.53	1.75	1.77
1990	-0.47	-0.33	-1.19	**1996**	1.51	1.28	0.27
1991*	-0.76	-1.01	-0.96	**1998****	1.28	1.03	1.03
1997*	-1.89	-2.06	-2.00	**1999****	0.55	0.93	1.42
2001	-0.90	-1.12	-0.79	**2007****	0.90	1.11	0.48
2002*	-1.61	-1.15	-1.45	**2008****	1.49	1.53	0.85
2004	-1.02	-0.49	-0.13	**2010****	2.52	2.52	2.42
2015*	-1.65	-1.55	-1.96	**2011****	1.18	1.27	1.37
2016*	-0.89	-0.70	-1.36	**2012****	0.89	0.90	1.23

🟨	Moderate	🟦	Moderate
🟧	Severe	🟦	Severe
🟥	Extreme	🟦	Extreme

**El niño year and **La niña year*

Overall, the combination of droughts and floods has affected the vulnerability of the ecological and socioeconomic systems. 2010 was recorded as the most extremely wet year during the analyzed period (1981-2010), flooding unexpected areas and maintaining some others inundated for nearly four years. A dry spell from March to July 2014 followed this period, which was locally recorded as a period of precipitation deficit, causing high losses of rice crops (FEDEARROZ, 2014). Finally, *El Niño* phenomenon of 2015-2016, was characterized by a high deficiency of precipitation and temperature increase, especially in late 2015 and early 2016; being the second more intense event after the one recorded in 1997.

As previously mentioned; the study area presents a strong seasonality, characterized for an extended period of rainfall from April to November and a short period of low rainfall from December to March. However, the rainy season can be divided into two periods: the first one with moderate precipitation from April to July, followed by a period of stronger rainfall from August to November (CORPOICA, 2014). Accordingly, the SPI_4 is considered the best averaging period to characterize drought within the study area (Table 17); the results show that the dry season (Dec-Mar) does not have recorded any droughts. Contrary, most extreme droughts are identified within the rainy season, especially in the Warm Semi-arid climate, while the Warm humid climate presents mostly moderate droughts.

Table 17 Meteorological drought events for climate type, according to the SPI_4

Climate	Warm Semi-arid			Warm Sub-humid			Warm Humid		
Year	**Apr-Jul**	**Aug-Nov**	**Dec-Mar***	**Apr-Jul**	**Aug-Nov**	**Dec-Mar***	**Apr-Jul**	**Aug-Nov**	**Dec-Mar***
1986	-1.02	-2.05	-0.26	-1.29	-1.89	-0.13	-0.74	-0.70	-0.31
1990	-1.04	0.10	-0.14	-0.80	-0.15	-0.02	-1.06	-1.84	-0.03
1991	-0.72	-0.16	-0.82	-0.58	-1.00	-0.66	-0.51	-1.16	-0.32
1997	-0.89	-2.45	-0.10	-0.80	-2.99	-0.08	-1.08	-2.57	-0.48
2001	-1.48	-0.22	0.47	-1.71	-0.81	0.46	-1.22	-1.05	0.55
2002	-0.76	-2.24	-0.22	-0.76	-1.06	-0.37	-1.20	-1.22	-0.53
2014	-2.10	1.42	0.07	-1.60	1.31	0.24	-0.78	1.38	0.36
2015	-2.22	-0.80	-0.19	-2.33	-0.77	-0.14	-2.58	-1.47	-0.14

🟨 Moderate 🟧 Severe 🟥 Extreme

*Estimation according to the hydrological year

A sustained three months period of meteorological drought is generally considered to have an adverse effect on soil moisture, causing water stress to plants. Regarding the local precipitation pattern and the rice water requirements through its growing stages, SPI_4 is considered to be adequate to define water deficit periods roughly. These results will be coupled with the vulnerability analysis and historical yield variations data, to establish the periods where drought impacted rice production.

5.1.2 *Hydrological drought*

Regarding the study of hydrological drought, it is important to remind that the results are recorded for the San Jorge river basin at the level of the Montelibano station. Both SPI and SDI were calculated for this point (Appendix 9), so confusions concerning the previous results of meteorological drought must be avoided. Similarly, in this case, the years were defined according to the hydrological cycle, considering April as the beginning month and March as the end month (numeral 4.1 Drought exposure).

According to the results of the Pearson correlation coefficient (0.75); there is a very strong association between the SPI_{12} and SDI_{12}. Furthermore, the linear regression analysis shows that this relationship is statistically significant, given a significance level of 0.05 and a ρ value of 0.00 (Appendix 9). These results indicate that for the study area the occurrence of hydrological drought is highly determined by meteorological drought. The hydrological years 1999-2000 and 2015-2016 were excluded from the analysis due to missing data; nevertheless, its study was possible regarding other SPI averaging periods.

By comparing the SPI_{12} and SDI_{12}, could be established that both meteorological and hydrological drought exhibit a similar behavior over time (Illustration 17). Overall, both wet and dry periods were recorded within the same hydrological year. However, an attenuation of the meteorological forces in the terrestrial part of the hydrological cycle can be observed, given that there is a lower variability in the distribution pattern of the SDI. This also could be expressed in terms of variance; 1.01 for the SPI, and 0.50 for the SDI.

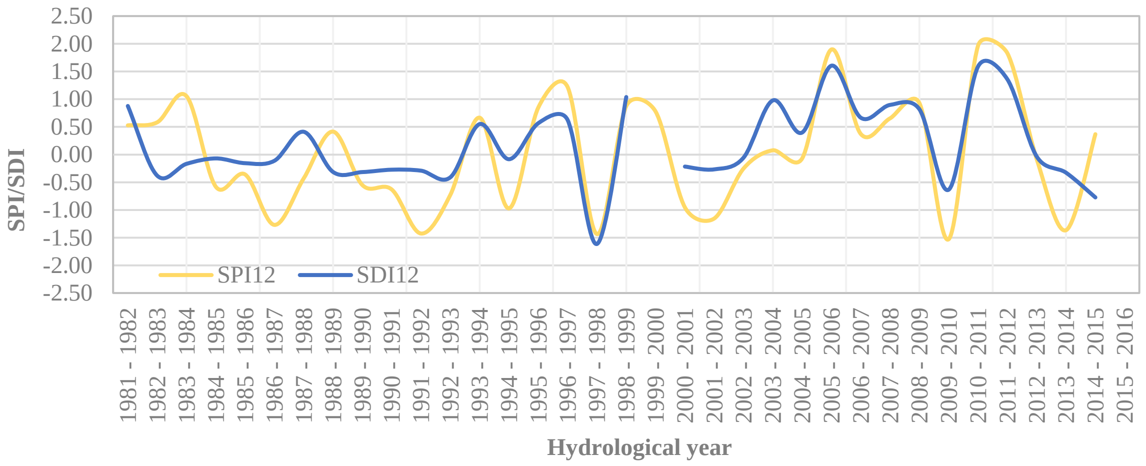


Illustration 17 SPI$_{12}$ and SDI $_{12}$ results for the San Jorge river - Montelibano station (1981-2015)

Five periods were identified as moderately dry according to the SPI$_{12}$; these are 1986-1987, 1991-1992, 1997-1998, 2001-2002, and 2013-2014, while just one was recorded as extremely dry (2009-2010). Although dry periods of the SPI$_{12}$ and SDI$_{12}$ showed to be temporally related, only the hydrological year 1997-1998 recorded a hydrological drought regarding the SDI$_{12}$ results. Furthermore, 1997-1998 showed to be a severe hydrological drought, but the related meteorological drought was classified as moderate; this year coincide with the second strongest *El Niño* event recorded at a national level (IDEAM, 2016). These results suggest that in spite of the strong correlation found between precipitation and streamflow, the characteristics of the basin, seem to have an important role in determining the drought propagation in the San Jorge river; factors such as groundwater recharge should be integrated to conduct a more detailed analysis.

The complete results for SDI are available in Appendix 10. A deeper analysis of SDI$_{2,}$ SDI$_{3,}$ and SDI$_4$ is presented here considering that these were identified as the main periods to address the impacts of hydrological drought in fishing since overlap with the fishing cycle and enable the study of the spawning season; this is deeply explained in numeral 5.3.2.1. Within the period of study (1981-2016), droughts occurred only during the rainy season; more specifically from April to July (Table 18). According to the SDI$_2$, both April-May and Jun-July exhibit five recorded events each, but just the first one showed extreme droughts; however, both periods combined generated the extreme hydrological droughts of 2014 and 2015. The frequency of droughts has been very variable (from 1 to 12 years); thus, it could not be established with certainty an increasing tendency over the last years.

Table 18 Hydrological drought events, according to the SDI$_{2,}$ SDI$_{3,}$ and SDI$_4$

Hydrological year	SDI$_2$		SDI$_3$	SDI$_4$
	Apr-May	Jun-Jul	Apr-Jun	Apr-Jul
1984 - 1985	-2.19	-0.54	-2.12	-1.38
1985 – 1986	-1.94	-0.40	-1.44	-1.18
1990 - 1991	0.05	-1.49	-0.55	-1.19
1997 - 1998	-1.45	-0.50	-1.09	-1.07
2001 - 2002	-0.41	-1.90	-0.81	-1.34
2013 - 2014	-0.22	-1.21	-0.79	-0.85
2014 - 2015	-2.02	-1.54	-1.51	-2.02
2015 - 2016	-1.86	-1.86	-2.07	-2.15

🟨 Moderate drougth 🟧 Severe drought 🟪 Extreme drought

5.2 Drought impacts

5.2.1 Potential impacts

The exposure analysis results showed that in the study area, moderate to extreme meteorological and hydrological drought events were identified for the reference period (1981-2016), always during the rainy period. Hence, the potential impacts were defined as those who could have affected the study area, according to the checklist developed by the Western Drought Coordination Council (1998). Accordingly a causality chain was built in order to identify direct and indirect impacts Appendix 3.

5.2.2 Real drought impacts

According to the results of the semi-structured interviews (Appendix 11), could be identified that most of the farmer's partnerships (44.4%), relate drought with the annual dry season, and another 33.3% describes drought as a fairly common event that occurs between one to two years. The remaining percentage (22.2%), recognized drought as an uncommon (every 3 to 4 years) or very rare (≥ 5 years) event. Overall, farmers highlight that both the rainy and the dry seasons have intensified in recent years (5-10 years); they state that extremely rainy periods are followed by extremely dry periods. Consequently, during the dry season, an abnormal increase in temperatures and decrease of rainfall is perceived, which they associate with a drought event.

A gap of knowledge in the way that people perceive drought and relate it with the dry season was recognized. SPI_4 results indicate that between 1981 and 2016, meteorological drought events only occurred during rainy seasons and not a single drought event was recorded for the dry season (December-May). To consistently argue with the people’s perspective, a study that couples rainfall and temperature is missing. In any case, the interpretations of the semi-structured interviews results should remain conservative and be considered a general perception of water scarcity impacts rather than just drought impacts.

Regarding the farmers perception of drought severity; the category severe obtained the highest representativeness with 55.6%, while the extreme and moderate categories obtained 22.2% each. This perception varies according to the objectives of the partnerships. Therefore, ranking the adverse effects of drought from 1 to 5 (lower to higher) was asked. The results show differences among livelihoods sources; where livestock was valued as the most impacted activity, followed by crop cultivation and fishing (Illustration 18). Droughts obtained a higher average ranking when compared with floods, whose impacts have been profoundly recognized in the study area; this is linked to the facts that some fishers considered floods beneficial and that the interviews included highlands partnerships, where floods

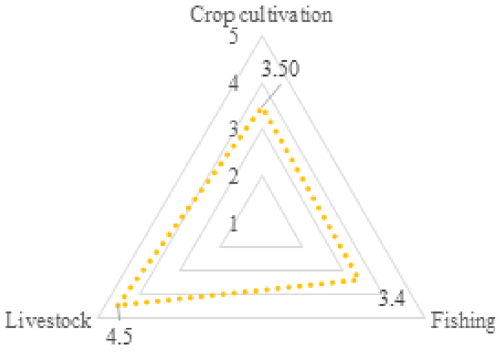
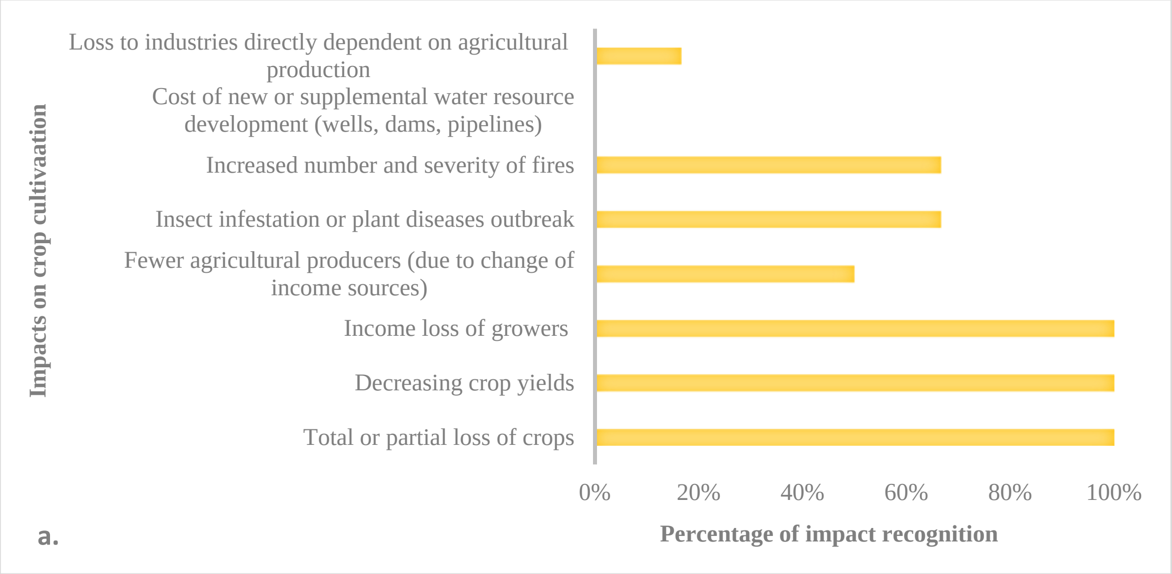
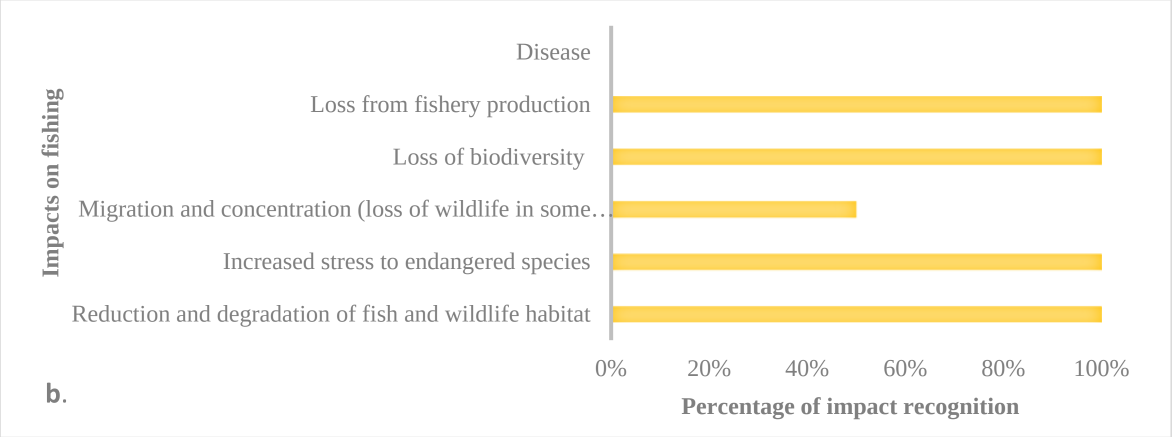


Illustration 18 Results of drought adverse effects ranking according to livelihoods sources

are not a significant hazard. This result suggests that droughts are a more extended hazard which affects both highlands and lowlands population.

Increased adverse outcomes of the dry season have felt in recent years. Nonetheless, farmers recognize that the capability to cope with the dry season has dropped with the loss of environmental services. Illustration 19 summarized the results of the drought impacts checklists, included in section III (questions 10 to 12) of the semi-structured interview. Each partnership identify which of the listed impacts have affected its livelihoods sources during drought events. The impacts percentage refers to the number of the interviews where the impact was recognized above the total interviews aimed at that livelihood (6 for crop cultivation; 5 for fishing and 2 for livestock). 2014 and 2015 were signal as the years in which most of the impacts were observable; for some cases, the farmers stated that these impacts have consistently affected their livelihoods since 10 to 4 years ago. The complete results are presented for each partnership in Appendix 11.





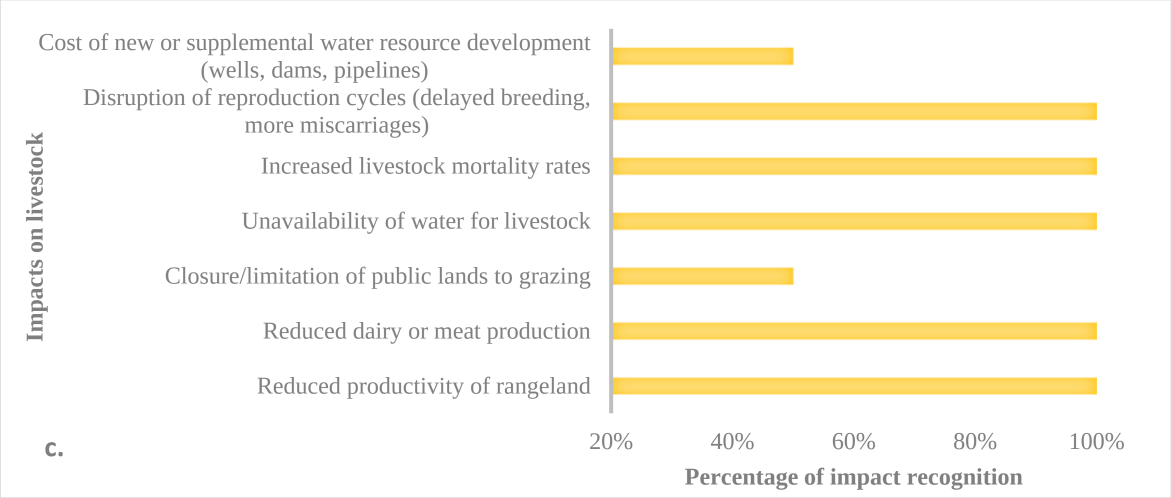


Illustration 19 Identified drought impacts on livelihood sources through the use of checklists: a. Impacts on crop cultivation; b. Impacts on fishing; and c. Impacts on livestock

The identification of drought impacts on fishing posed a significant challenge, given the difficulty to differentiate if the impacts were triggered by drought events or by other factors such as overfishing and habitat loss. In all cases, it is essential to highlight the cumulative nature of fishing impacts.

The most common impacts within the three assessed livelihood sources were those related with a decrease in productivity and associated income losses; the temporal productivity variations were assessed through the quantitative analysis presented below. Another drought impacts recognized by farmers that were not considered within the checklists, include:

- Increase of the uncertainty in the grower's decisions regarding new cultivation seasons.
- Decreased of the sown area in the next cultivation seasons.
- Increased demand for food purchased in the urban area.
- Increase pressure over provisioning services (fishing resources)
- Increased debts, related with income losses.
- Increased vulnerability to predation (from species concentrated near water).
- Increased level of exposure of the fish species to captures.
- Decreased stock weights.
- Increased cost/unavailability of feed for livestock

5.2.2.1 Crop cultivation

Within the study area, rainfed cultivation is practiced. Thus, the rainfall pattern defines two planting seasons; in the first semester of the year, the rice-sowing season begins around April and May. Likewise, in the second semester; mostly between September and October, initiates the second sown season, majorly relevant for mechanized producers. From germination to tillering as well as from flowering to filling, are considered critical stages for rice productivity, being highly susceptible to water deficit (Numeral 5.3.1.4). Accordingly, periods that could characterize this stages were considered for the estimation of the SPI and its subsequent correlation with the annual rice yields.

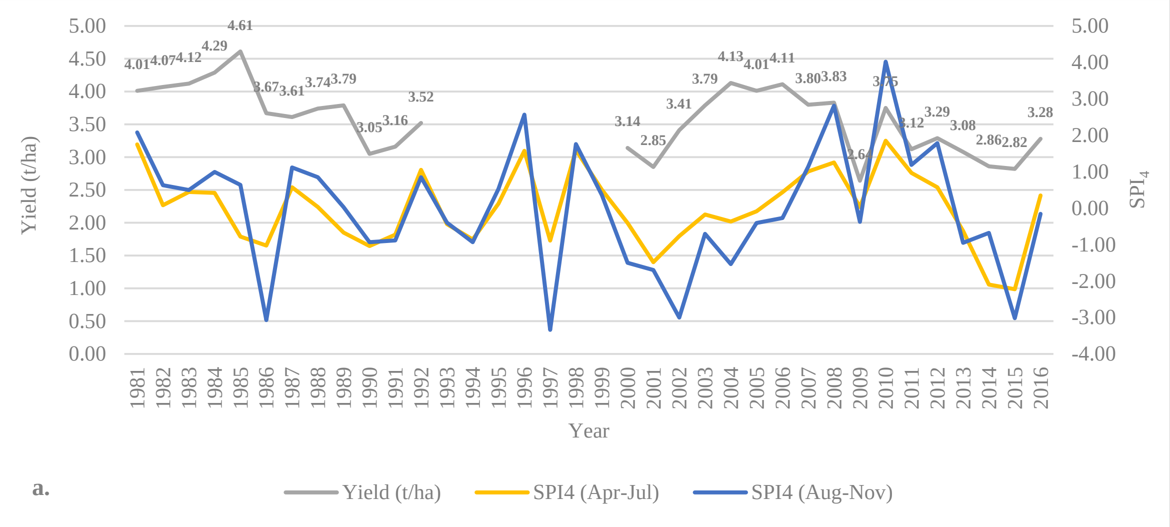
Table 19 shows the results of the Pearson correlation coefficient. The strength of the association between rice yields and the different SPI cumulative periods between 1981 and 2016, proved to be either negligible or weak. For all the climatic categories, the averaging period with the strongest association was the SPI_4 between April and July; within this period the relationship proved to be statistically significant, which is confirmed by the SPI_2 for the period June-July. These results establish that annual yield variations are influenced for water excesses and deficits during the first cultivation semester, especially for the flowering and filling stages. Nevertheless, this association is not clear for the second sowing semester of the year. Overall, the annual SPI for Warm Semi-arid and Warm Sub-humid climates proved to be significantly related with the rice yields.

Table 19 Pearson coefficient (r) and ρ value results for the correlation between $SPI_{2,\,3,\,4,6,12}$ and rice yields (1981-2016)

Climate	**Statistic**	**SPI_2**		**SPI_3**		**SPI_4**		**SPI_6**		**SPI_{12}**
		Jun-Jul	**Oct-Nov**	**Apr-Jun**	**Jul-Sep**	**Apr -Jul**	**Aug-Nov**	**Jan-Jun**	**Jul-Dec**	**Jan-Dec**
Warm Semi-arid	*r*	0.44	0.19	0.27	0.29	0.42	0.2	0.2	0.29	0.34
	ρ	0.02	0.32	0.16	0.13	0.02	0.31	0.29	0.13	0.07
Warm Sub-humid	*r*	0.47	0.26	0.24	0.38	0.44	0.31	0.17	0.4	0.37
	ρ	0.01	0.17	0.21	0.05	0.02	0.1	0.38	0.03	0.05
Warm Humid	*r*	0.36	0.38	0.14	0.32	0.36	0.28	0.07	0.36	0.29
	ρ	0.05	0.04	0.48	0.1	0.05	0.14	0.73	0.05	0.13

🟩 Negligible association 🟩 Weak association

The weakness in the associations can be due to multiple variables, including changes in agricultural practices, the information gap between 1993 and 1999, yields decreasing during extremely wet years, or proliferation of pests and diseases, among others. Further, certain conclusions about the influence of drought on yields can be obtained through the observation of the annual variations (Illustration 20).



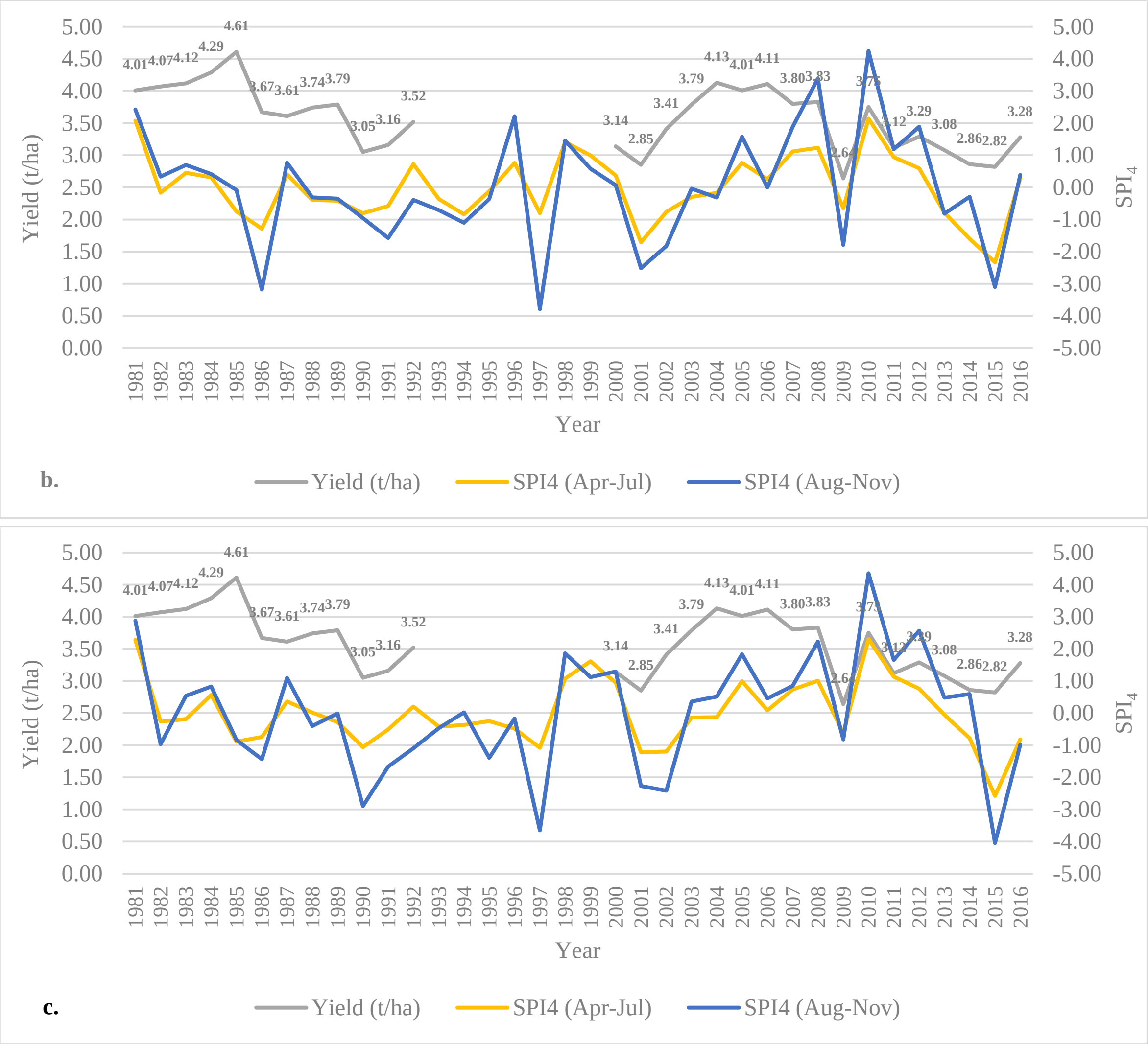


Illustration 20 Yields vs. SPI_4 for the period 1981-2016. a. Warm Semi-arid climate; b. Warm Su-humid climate; and c. Warm Humid climate
Source: Own elaboration, based on FEDEARROZ (1993, 2018)

Illustration 20 shows that rice yields for the years 1986, 1990, 1991, 2001, 2014 and 2015, were below the historical average of 3.6 and responded to the drought events identified with the SPI_4. The lowest yield values were determined for 2011, 2014 and 2015 with 2.85 t/ha, 2.86 t/ha, and 2.82 t/ha respectively, coinciding with the years that presented the most severe drought events during the period April to July in all climates. The period August-November of 2002, which was locally recorded as an extremely dry period for the Warm-Semi-arid climate, exhibited normal yields.

The Colombian National Federation of Rice Growers (Federación Nacional de Arroceros - FEDEARROZ), also related the yields decrease of 1986, 2014 and 2015 with drought events (FEDEARROZ, 1993, 2014b, 2017). Further, field observations of FEDEARROZ, during the year 2014, in the Mojana region, showed that 73.4% of the rice sown areas were affected with partial or total losses of the crop. Locally, yields even decreased to 1.25 t/ha.

From the semi-structured interviews, could be established that crop losses and quality damage often accompanied a yield decrease; these were identified as direct drought effects on crop cultivation. Linking the consequences of these primary drivers through a causality chain was possible by the workshop and the household's interviews. Accordingly, the identification of drought direct and indirect impacts on crop cultivation is presented in Illustration 21; the distinction between the economic, ecologic or social nature of the impacts is also pointed out. . These results are considered applicable to small and medium growers since it was the population group to which the interviews and the workshop were directed. Additionally, large producers have the option to ensure their crops against possible losses.

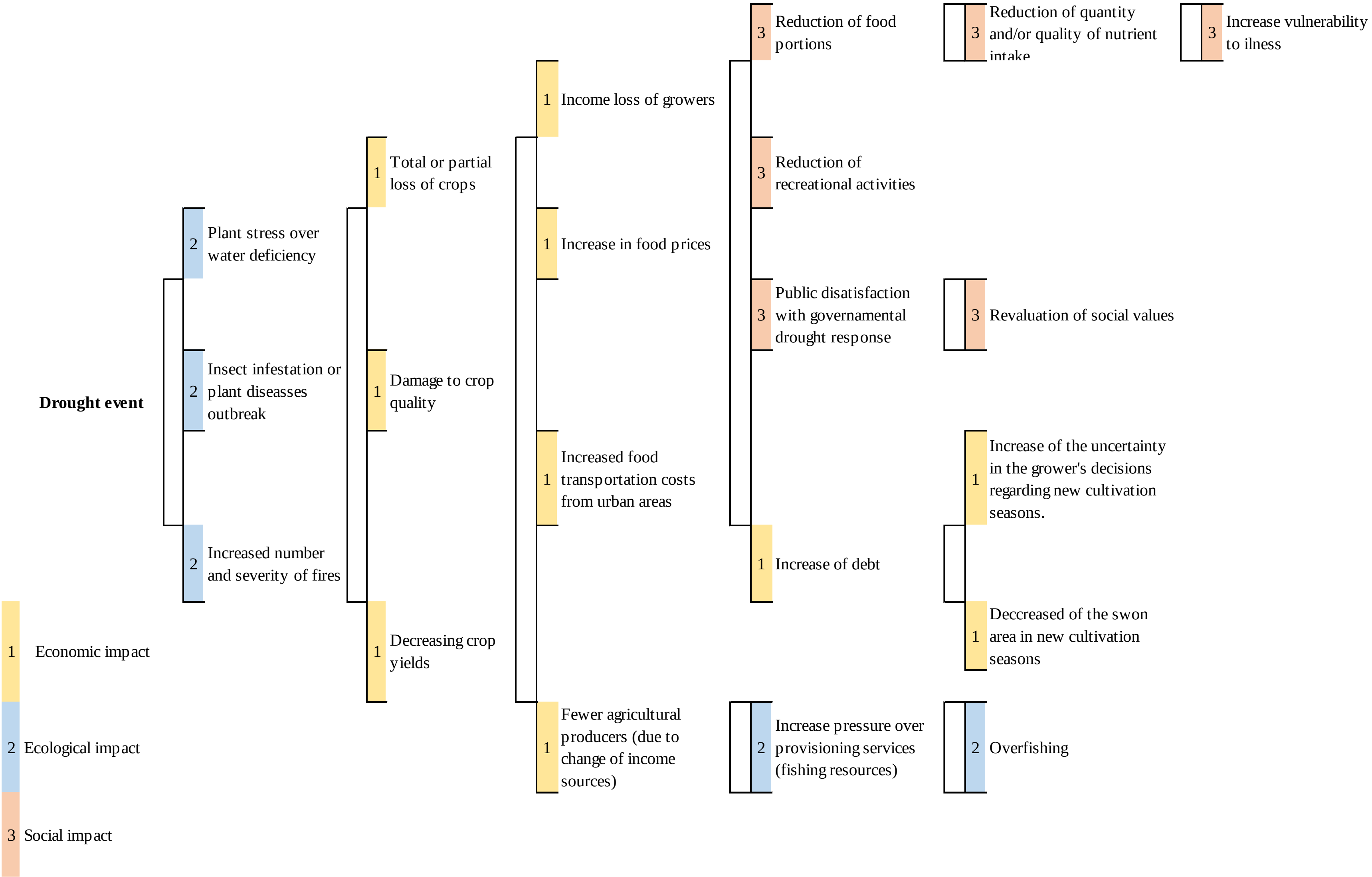


Illustration 21 Drought direct and indirect impacts on crop cultivation

5.2.2.1 Fishing

As previously established, hydrological drought events have been recorded within the first months of the hydrological year (April-July), overlapping with the spawning season of *Prochilodus magdalenae*. According to with Atencio G (2017), the water temperature plays a significant role in the gonadal maturation and in the hatching of the eggs, where temperatures between 26º and 30º C need to be secured. Additionally, it has been proved that spawning only takes place when the fishes feel the adequate environmental stimuli, mainly of the water level variations at the beginning of the rainy season. Thus, a hydrological drought event during this period could potentially influence the productivity of the species. Accordingly, the values of SDI$_2$ SDI$_3$, and SDI$_4$ for the beginning of the rainy season were correlated with the landed weight per hydrological year (Appendix 12), which may be considered a measure of the productivity of *Prochilodus magdalenae*. The results presented in Table 20 shows a weak or negligible association between the related variables; likewise, the ρ value indicates that these variables are not statistically related.

Table 20 Pearson coefficient (r) results and ρ value for the correlation between SDI$_{2,3,4,}$ and Prochilodus magdalenae landed weight (t/year)

Statistic	**SDI$_2$**		**SDI$_3$**	**SDI$_4$**
	Apr-May	**Jun-Jul**	**Apr-Jun**	**Apr-Jul**
Correlation coefficient	0.16	0.25	0.27	0.23
ρ value	0.34	0.15	0.12	0.20

🟩 Negligible association 🟩 Weak association

The obtained results indicate that the variation in fishing productivity is trigger by a combination of ecological and anthropogenic factors. Welcomme (1995) by citing Valderrama (1993), stated that the factors that influence the severe reduction in catches of *Prochilodus magdalenae* include fishing, climatic change, and environmental stress. Accordingly, is difficult to establish the possible influence of drought regarding this variation. It is possible to observe a rather constant decrease of the landed weight between 1981 and 2015 (Illustration 22). However, by comparing the historical data of landed weight per hydrological period, and the drought events defined for the SDI$_2$, it is shown that the drought periods of 1984-1985, 2001-2002, and 2015-2016 were related with an increase of the landed weight compared to the antecedent year, while 1985-1986, 1990-1991, 1997-1998, were associated with a decrease. For 2013-2014, and 2014-2015, missing data were reported, so its decreasing tendency cannot be considered.

The previous results are inconclusive regarding the feedback of drought events on spawning. Under controlled conditions, such as fish ponds, and according to the interviewed fish farmers, drought is related to weight loss and delayed sexual maturation of the individuals. Similarly, low water levels enhance fish predation and capture since they are more available. Consequently, a negative impact of drought on the fishing of *Prochilodus magdalenae* is suggested. However, variables like hydrological drought characteristics, the life cycle of the fishes, variation of monthly captures, accumulated impacts in the basin that have caused overexploitation and habitat loss, among others, require to be coupled to address this issue through a more detailed study.

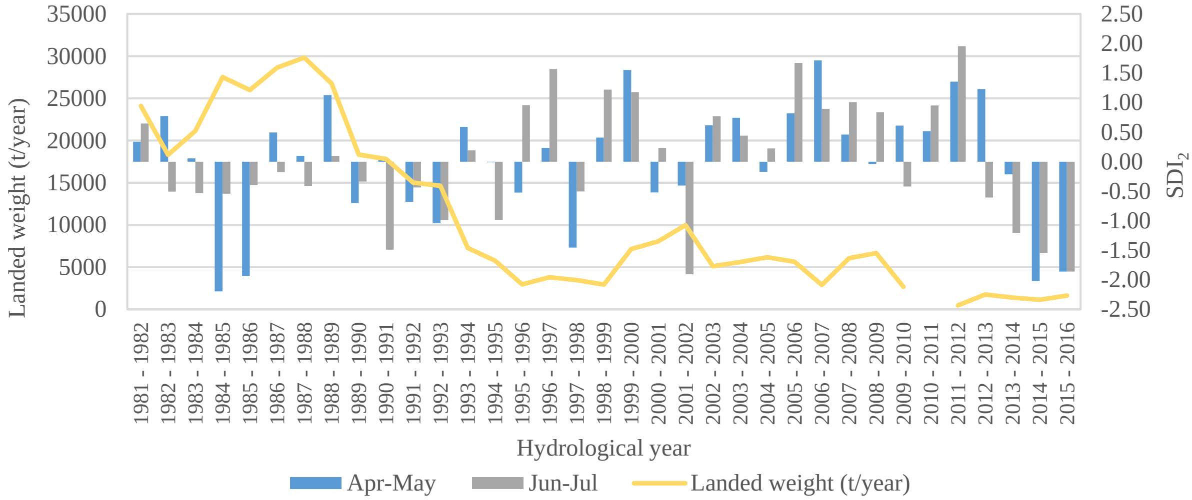


Illustration 22 Landed weight per hydrological year vs. SPI$_2$ for April-Jul

5.3 Sensitivity

5.3.1 Crop cultivation

Results of the assessment of rice cultivation sensitivity through indicators for each asset type are summarized in Table 21. Economic assets present the highest level of sensitivity with a value of 3.5. Physical assets (3.24), social assets (3.00), and natural assets (2.8) were ranked with high sensitivity. Finally, human assets obtained a medium sensitivity qualification (1.99). Further data that support the results along with the discussion for each asset and indicator are presented below.

Table 21 Assessment of sensitivity in rice cultivation

Indicator	Category	Portion (%)	Sensitivity rating	Weight
Physical assets				
Rice production system	Mechanized	73.87%	2	1.48
	Manual	26.13%	4	1.05
	Total sensitivity			2.52
Water supply system	Rainfed	98.19%	4	3.93
	Irrigated	1.81%	2	0.04
	Total sensitivity			3.96
Total sensitivity physical assets			High	3.24
Human assets				
Level of education	No education	12.20%	4	0.49
	Primary education	52.70%	3	1.58
	Secondary education	27.10%	2	0.54
	Higher education	8.00%	1	0.08
	Total sensitivity			2.69
Workforce	0-19 years	0.50%	3	0.01
	20-29 years	7.90%	2	0.16
	30-39 years	19.10%	1	0.19
	40-59 years	53.00%	1	0.53
	≥60 years	19.50%	2	0.39
	Total sensitivity			1.28
Total sensitivity human assets			Medium	1.99

Indicator	Category	Portion (%)	Sensitivity rating	Weight
Economic assets				
Rice productive unit (RPU) extention	≤5 ha	61.30%	4	2.5
	4.99 – 49.99 ha	35.70%	3	1.1
	≥50 ha	3.00%	1	0.0
	Total sensitivity			3.6
RPU Land tenure	Rented	71.50%	4	2.9
	Other	1.30%	3	0.0
	Own	27.20%	2	0.5
	Total sensitivity			3.4
Total sensitivity economic assets		Very high		3.50
Social assets				
Social linkage	Low	0		0
	Medium	100.00%	3	3
	High	0		0
	Total sensitivity			3
Total sensitivity social assets		High		3.00
Natural assets				
Regulating services - Moderation of drought events	Vegetative phase	45.83%	4	1.83
	Reproductive phase	29.17%	3	0.88
	Maduration phase	25.00%	2	0.50
	Total sensitivity			3.21
Provisioning services -Crop productivity variation	0.97-1.46 t/ha	75.90%	3	2.28
	0.49-0.96 t/ha	2.04%	2	0.04
	≤0.0-0.48 t/ha	22.02%	1	0.22
	Total sensitivity			2.54
Total sensitivity natural assets		High		2.87

The sensitivity estimation was assessed by following the methodology of Numeral 4.3.1, further information regarding the indicators is also available there.

5.3.1.1 Physical assets

Based in the 2016 rice census (FEDEARROZ, 2017) it was possible to establish that approximately 98.19% of the rice croplands in the Mojana region correspond to rainfed (manual and mechanized) production systems. Thus, the rainfall pattern defines two planting seasons; in the first semester of the year, the rice-sowing season begins around April and May. Likewise, in the second semester; mostly between September and October, initiates the second sown season, majorly relevant for mechanized producers. Rainfed agriculture is significantly susceptible to drought events considering that rely on direct precipitation while irrigated systems rely on forms of water storage less likely to be affected by drought events.

Mechanized rainfed production represents the major percentage of the total sown area (approximately 73.87%) (FEDEARROZ, 2008). However, the rainfed manual output is considered of high importance for small producers of the Mojana region because most of its production is for self-consumption. The manual cultivation activity requires a large quantity of physical effort, starting in February, with the chopping or undermining of the land with ax and machete (this lasts about a month). In March the land is burned, and around April or May with the first rains, the rice is sown. Rice requires near four months to growth; thus, in September or October is harvested (CVC, 2007). The low levels of technological development and the small average production areas (around 1.6 ha) generate low yields (Table 22).

Table 22 Rice harvested area and yields for the first and second semester of 2007 and 2013 or 2016 – Manual and mechanized rainfed production in Ayapel and San Marcos municipalities

Municipalities	Year	Manual				Year	Mechanized			
		1st semester		2nd semester			1st semester		2nd semester	
		Harv. area (ha)	**Yield (t/ha)**	**Harv. area (ha)**	**Yield (t/ha)**		**Harv. area (ha)**	**Yield (t/ha)**	**Harv. area (ha)**	**Yield (t/ha)**
Ayapel	2007	36	2.1	120	2.3	2007	740	5.1	1117	4.3
	2013		2.4		2.3	2016	370	3.2	2029	3.68
San Marcos	2007	224	2.6	28	2.4	2007	1190	4.4	432	3.9
	2013		2.3		2.3	2016	21	3.9	2427	4.18

Source: Own elaboration, based on FEDEARROZ,(2008, 2017)

The yields obtained by the manual rainfed production in the San Marcos and Ayapel municipalities were similar for the first and second semester of 2007 and 2013, with an average of 2.34 t/ha. In comparison, yields from mechanized production were higher but exhibited a more significant decrease between 2007 and 2016, even though the cropped area increased.

Historically, the Mojana region has been characterized by a low infrastructure for the reception and threshing of the rice, which along with the difficulties of transportation, represents a significant challenge for the rice commercialization. Long journeys of the rice by waterway, with high moisture conditions, affect the quality of the product (FEDEARROZ, 1993). The San Marcos municipality is better connected by land than the Ayapel municipality; however, in both areas navigation remains highly relevant, since the associated transportation costs are usually lower.

5.3.1.1 Human assests

Rice croplands over the Mojana region are characterized by a low level of technical assistance (Martínez-Reina, 2013). Based on the results of the rice census (FEDEARROZ, 2017), it is possible to identify 5492 rainfed mechanized rice producers for the Bajo Cauca (approximately 5061 belong to the Mojana); among them, the dominant level of schooling is the primary education (52.7%), followed by secondary education (27.1%) and no education (12.2%). Only the 3.4% has a technical education and 4.6% has a university education. The level of education exhibit an inverse relation with the level of social vulnerability; the literacy rate has proved to influence the adaptive capacity to drought, because population with lower literacy level are likely to have greater dependence on agriculture and are associated with marginalized conditions (Mohmmed et al., 2017).

The major workforce is concentered within the age group from 40 to 59 (53%). Over 60 years old producers have a higher representation (19.5%), compared to the age ranges of 20 to 29 (7.9%) and 30 to 39 (19.1%) (FEDEARROZ, 2017). Probably, as in the case of the global tendency, the younger generation does not see its future in the rurality. In the particular situation of the Ayapel municipality, the public officials state that young people prefer to do illegal but more profitable activities such as mining and joining the illegal armed groups, which generates high rates of school dropouts and drugs consumption.

Farmers' productivity can change through the age according to factors like experience, physical strength, investment capacity in land and agricultural inputs, and willingness to change or stay in the activity (Guo, Wen, & Zhu, 2015). Investment capacity and experience are strengthened with aging, while physical strength is more related to youth. According to Tauer (1984), farmers under the age of 25 and over the age of 65 show lower productivity compared to farmers between 35 and 45 years where maximum productivity is reached. Facing drought hazard requires both knowledge and manual labor; thus, rice producers below 29 years and above 60 years are considered to be more sensitive to drought impacts.

5.3.1.2 Economic assets

According with the rice census of 2016 (FEDEARROZ, 2017), in the Bajo Cauca region, the rice productive unit (RPU) is on average smaller than 10 hectares; where small producers, who have less than 5 hectares represent the 61.3% of the RPU`s with the 11% of the total production, while big producers with areas over 50 hectares represents the 3% of the RPU`s, with the 42% of the output. Generally, higher yields are linked with higher land extensions. In addition, for the mechanized rice, the 27.2% of the RPU`s belong to the owners while 71.2% are rented, making visible the inequity in the land distribution. The results for the focus area according to the census of 2007 and 2016 (FEDEARROZ, 2008, 2017) are presented in Table 23.

Table 23 Sown area and rice productive units according to land tenure in Ayapel and San Marcos municipalities -2007 and 2016

Land tenure	**Ayapel**				**San Marcos**			
	Sown area		**Rice productive unit (RPU)**	**Average area per RPU (ha)**	**Sown area**		**Rice productive unit (RPU)**	**Average area per RPU (ha)**
	(ha)	**%**			**(ha)**	**%**		
2007**								
Own	504	64.9%	66	7.6	405	28.6%	60	6.8
Rentend	268	34.5%	35	7.7	1010	71.4%	91	11.1
Other*	5	0.6%	3	1.7		0.0%		
Total	777	100.0%	104	5.7	1415	100.0%		8.9
2016***								
Own	689	24.9%	136	5.1	459	22.5%	56	8.2
Rentend	1997	72.3%	225	8.9	1555	76.2%	133	11.7
Other*	78	2.8%	12	6.5	27	1.3%		
Total	2764	100.0%	373	6.8	2041	100.0%	189	9.9

* Includes sharecroppers, invaders, settlers and others
** Includes total sown area (manual and mechanized production)
***Includes only mechanized production

Source: Own elaboration, based on FEDEARROZ (2008, 2017)

The results of Table 23 show that for all cases the RPU´s extension in Ayapel and San Marcos municipalities were less than 10 hectares; in most cases, the biggest proportion of sown areas (70-75%) was rented. During the field visit and according to the local producer's interviews, it was possible to recognize the unequal distribution of the land. Small producers lease the land per harvest season; very often the rented extension does not exceed one hectare per producer, because of the land costs and the limited manual labor. Historically, the occupation by large farms dedicated to extensive livestock has caused many social conflicts, such as population displacement, unemployment, and farmer's movements for the recovery of their territories (CNRR, 2010).

Within this context; it is possible to establish that landholding inequities have enhanced rural systems vulnerability because landless population put additional pressure on fishery resources since they are unable to develop the cultural model of complementarity between fishery and crop cultivation according to the hydrological cycles (CVS, 2007). Likewise, the reproduction of these inequalities in terms of control, use and resource access, may discourage the efforts for collective action, most of all when elites monopolized the use of common resources (Baker, 1998).

5.3.1.3 Social assets

According to the field observations, recently associativeness of agricultural producers have been increasing, stimulated by the governmental politics which establish that individual producers cannot apply for support to developed productive projects. Very often, these associations only exists for the period of the project, partly because the governamental help does not respond to the real necesities of the population and partly because of the loss of interes of the participants and low reinvestment rates of the profits, making the projects unsustainable over time. Often, new associations may form to apply for new resources. This high dependence on governmental help, enhanced by low population participation in drought mitigation, has proved to increase the socio-cultural vulnerability towards drought (Zarafshani et al., 2012),

On the other hand, according to the Colombian Planning National Department (DPN, 2012), within the study region, there is an evident lack of articulation between policy makers from high government institutions and actions coordination from the local government. Failed coordination efforts between governmental institutions have caused inefficient representation of the population interests, breading a culture of mistrusts in local authorities. Thus, governmental institutions likelihood to successfully drive collective action is considered to be low.

5.3.1.4 Natural assets

Rice is considered to be particularly susceptible to soil water deficit; for instance in Thailand, rainfed rice yields have declined until 45% during drought events (Xangsayasane et al., 2014). Yields of rainfed lowland rice are highly shaped by its phenology, especially flowering stage, therefore, efforts to enhanced drought resistance should consider variations in flowering time (Fukai, Pantuwan, Jongdee, & Cooper, 1999). The Illustration 23, shows the phenological rice stages, for paddy rice of four months during the first and second sowing semester, and signals the periods of higher water demand, where the deficit is more likely to affect crop yields.

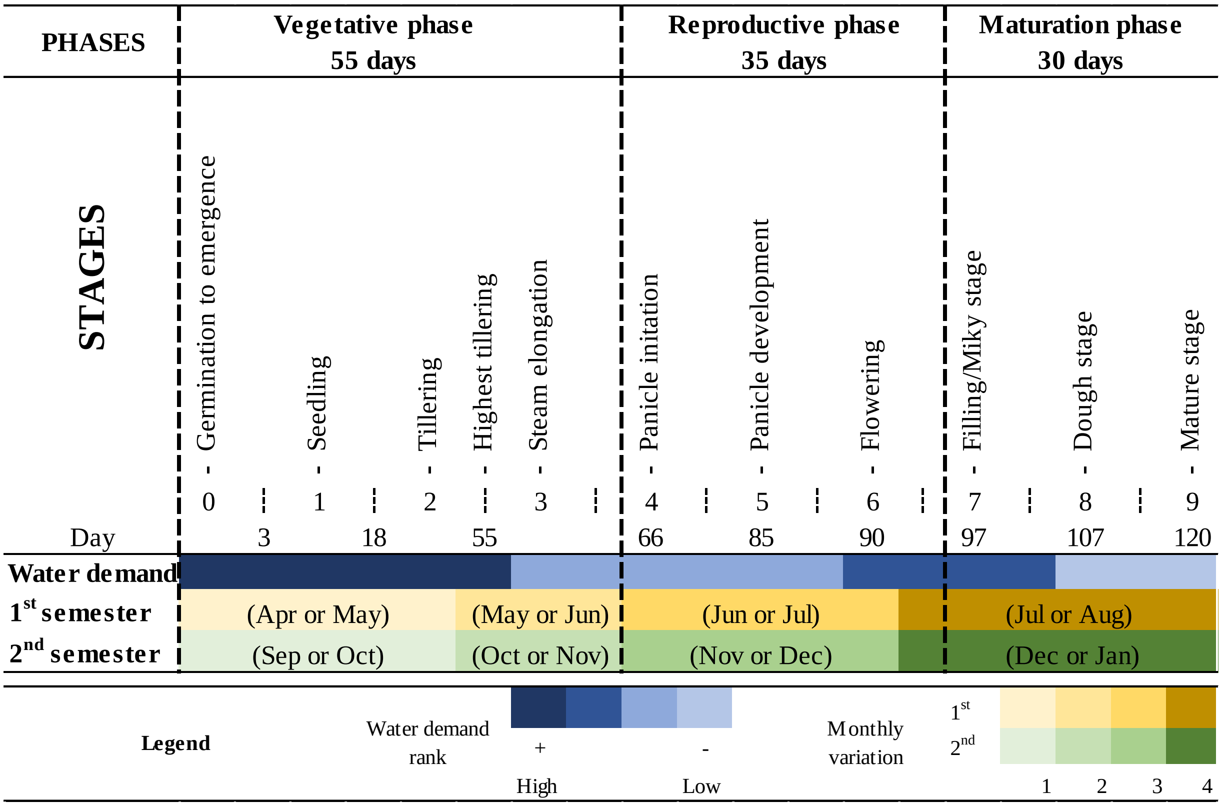


Illustration 23 Phenological rice stages and water demand for the first and second semester
Source: Own elaboration, based on CIAT (1980)

According to the interviews with local producers, in the growing stages (Germination to tillering) and the stage 6 (flowering) and 7 (filling), crop water demand increase. Thus, rainfall anomalies or delayed rainfall periods during the sowing months could generate crop losses. During the stage 0, the respiration rate is high; while the seed absorbs water the metabolism of their reserves of starch and protein starts, initiating the growth of the embryo. From the seventh or eighth-day on, the seedling starts nutrient absorption and photosynthesis, becoming independent of the seed. Around the eighteen-day, the tillering starts; the tillers emerge sequentially and the root system is expanded (CIAT, 1980).

Generally, optimum flowering time for high yields is related to water availability (Fukai, 1999). Both wet and dry winds influence pollination, generating yield losses during the flowering stage. After the fertilization of the flowers, the carbohydrates are transferred to the spikes to fill them with a milky liquid; therefore, this process requires that precipitation exceeds evapotranspiration (CIAT, 1980). At the local level, these stages can coincide with rainfall decrease between the months of June and July (*Veranillo de San Juan*) or November and December, presenting a threat to crop yields.

As previously stated, there has been a general decreasing of rice crop yields for the Bajo Cauca region in the period 1981-2016. For ten of the eleven municipalities of the Mojana region (excluding Caimito), it was possible to identify yield variations for the first and second semester of 2007 and 2016 respectively. The results on Table 24, show an average decrease of 1.1 t/ha and a harvested area decline of 26.1% between the first semester of 2007 and 2016; while the second semester only shows an average decrease on 0.2 t/ha but a sown area rise of 50.8%. Overall, annual mean crop variations ranged from -0.75 to 1.46 t/ha; where 22.02% of the area changed less than 0.048 t/ha, and 75.90% changed more than 0.97 t/ha.

Table 24 Harvested area and yield variations for the Mojana municipalities in the first and second semester of 2007 and 2016

Department	Municipality	Harvested area (ha)				Yield (t/ha)						Mean
		2007*		2016		2007*		2016		Δ2007-2016		
		I	II	I	II	I	II	I	II	I	II	
Antioquia	Nechí	1133	1615	787	2514	5.0	5.5	3.1	4.55	2.0	0.96	1.46
Bolívar	Achí	1062	3459	622	3664	4.0	3.8	3.8	3.52	0.2	0.31	0.28
	Magangué	225	425	50	402	4.4	3.9	5.5	4.34	-1.1	- 0.41	- 0.75
	San Jacinto del Cauca	2142	2836	3016	4502	4.9	4.5	3.4	3.78	1.5	0.69	1.11
Córdoba	Ayapel	776	1237	370	2029	5.0	4.3	3.2	3.68	1.8	0.65	1.24
Sucre	Guaranda	2854	4213	3381	7964	4.7	4.0	2.7	3.58	1.9	0.41	1.16
	Majagual	4003	9818	2853	12422	4.8	3.6	2.5	3.88	2.3	- 0.29	1.00
	San Benito Abad	2004	1092	417	3213	4.5	4.0	4.0	3.83	0.5	0.21	0.34
	San Marcos	1414	460	21	2427	4.0	3.9	3.9	4.18	0.1	- 0.24	- 0.09
	Sucre	65	1431	73	950	4.8	3.1	2.7	3.57	2.1	- 0.49	0.81
	Total	**15678**	**26586**	**11590**	**40087**	**4.6**	**4.1**	**3.5**	**3.9**	**1.1**	**0.2**	0.66

*Includes mechanized and manual production

Source: Own elaboration, based on FEDEARROZ (2008, 2017)

A yield decreasing of rice beyond 1 t/ha is considered high, given that the Bajo Cauca is the least prolific area of rainfed mechanized production in Colombia. According to the census data (FEDEARROZ, 2008, 2017), at a national level, 2007 yields were 5.3 t/ha and 4.4 t/ha for the first and second semester respectively. For the first period of 2016 a decrease of rice yields in the Bajo Cauca and the Central region was observed, diminishing the national value to 3.5 t/ha; however, within the three remaining rainfed important areas of the country (Costa norte, Santanderes, and Llanos), the average yield was of 4.6t/ha (24.5% higher than the average Mojana value). The second semester of 2016 exhibited a national yield increase reaching 5.3 t/ha (26.6% higher than the average Mojana value).

5.3.2 Fishing

The results of the assessment of fishing sensitivity through indicators for each asset type are summarized in Table 25. Economic, human and social assets obtained the highest vulnerability classification, while natural and physical assets classify under the high category. Overall, a higher level of vulnerability is related to this livelihood, when it is compared to rice cultivation. Further data that support the results along with the discussion for each asset and indicator are presented below.

Table 25 Assessment of sensitivity in fishing

Indicator	Category	Portion (%)	Sensitivity rating	Weight
Physical assets				
Used fishing gear	Trammel net	86.50%	4	3.46
	Cast net	9.00%	4	0.36
	Seine net	4.00%	2	0.08
	Other	0.50%	2	0.01
	Total sensitivity			3.91

Indicator	Category	Portion (%)	Sensitivity rating	Weight
Property rights over the fishing gears	Shared	79.00%	2	1.58
	Individual	11.50%	2	0.23
	Rented	7.90%	4	0.32
	Borrowed	1.60%	3	0.05
	Total sensitivity			2.17
Total sensitivity physical assets			High	3.04
Human assets				
Level of education	No education	22.00%	4	0.88
	Primary education	53.59%	3	1.61
	Secondary education	24.41%	2	0.49
	Higher education	0.00%	1	0.00
	Total sensitivity			2.98
Yearly dedication to the fishing activity	Total	76.00%	4	3.04
	Parcial	8.00%	3	0.24
	Occasionally	16.00%	2	0.32
	Total sensitivity			3.60
Total sensitivity human assets			Very high	3.29
Economic assets				
Income	Trammel net	86.50%	3.5	3.0
	Cast net	9.00%	3	0.3
	Seine net	4.00%	4	0.2
	Other	0.50%	4	0.0
	Total sensitivity			3.48
Total sensitivity economic assets			Very high	3.48
Social assets				
Social linkage	Partnership members	31.50%	2	0.63
	Not associated	68.50%	4	2.74
	Total sensitivity			3.37
Total sensitivity social assets			Very high	3.37
Natural assets				
Supporting services – Habitat for species	>90%	100.00%	4	4.00
	61-90%		3	0.00
	31-60%		2	0.00
	0-30%		1	0.00
	Total sensitivity			4.00
Provisioning services – Fishery resources	Critically endangered (CR)		4	0.00
	Endangered (EN)		3	0.00
	Vulnerable (VU)	100.00%	2	2.00
	Near Treatened (NT)		1	0.00
	Total sensitivity			2.00
Total sensitivity natural assets			High	3.00

The sensitivity estimation was assessed by following the methodology of Numeral 4.3.1, further information regarding the indicators is also available there.

5.3.2.1 Physical assets

Fishing is artisanal; the fishing gears have a relevance of use depending on the season and the water body (Illustration 25). During the season of high water levels, fishing is carried out in the marshes, and the most commonly used gears are trammel nets and cast nets. In the season of decreasing water levels, the concentration of fishers on the rivers and its tributaries rises, and trammel nets are used as barrier gears to capture the fishes in their upstream movement. Finally, as water level reaches its minimum, the used of seine nets and cast nets increase in pools and riverbeds (Photography 2).

Photography 2 Commonly used fishing gears: a. Use of seine nets in the Carate Stream (San Marcos municipality); and b. Use of cast nets in a fish pond (Ayapel municipality)
Source: D. Torres, (2018)

In the lower San Jorge, 79% of the fishers share the fishing gear; 11.5% are sole proprietors; 7.9% rent them and 1.6% fish with a borrowed gear (MINAMBIENTE & CORPOMOJANA, 2000). Salas-Jiménez, (2015), showed that the dominant fishing gear is the trammel net, used in 86.5% of the catches, followed by the cast net used in 9%, and the seine net used in 4%. According to Barreto et al., (2010), the cast net is considered a highly efficient fishing gear for the capture of *Prochilodus magdalenae* in six-hour fishing operations, in comparison with the stationary gears (trammel nets and seine nets), which require longer fishing operations (more than 12 hours), to obtain representative catches. However, the use of trammel nets has been extended by replacing the traditional use of cast nets, due to the reduction of costs when bought in company, and by allowing the capture of fish below the minimum permitted size. The fishing vessels are mostly wooden canoes driven with oar, and in smaller proportion, with outboard engines brand Yamaha 40HP; used by its high efficiency and low fuel consumption (DNP & FAO, 2003).

The use of trammel nets is considered to threaten the aquatic fauna since it is a little selective method which allows the capture of fishes below the minimum maturation size, and of non-targeted species. On average, it has been found that the *Prochilodus magdalenae* capture size by using this gear is 24.1 cm (CCI, 2009); being the recommended capture size of 26 cm and the minimum of 25 cm according to the Resolution 0595 of 1978 (AUNAP-UNIMAGDALENA, 2013).

5.3.2.1 Human assets

It is estimated that about 7,000 habitants of the Mojana region are fishermen; the income generated by its activity directly sustain nearly 35,000 persons, while another 4,000 depend indirectly, through the commercialization of products, inputs, and equipment (DPN, 2012). No specific data regarding fishers demographics was explicitly found for the Mojana region. Nonetheless, the results of the national fishery census of 2012 (AUNAP-UNIMAGDALENA, 2013), reported the next data for the entire Magdalena basin:

Table 26 Demographic statistics of fishers in the Magdalena basin

Variable	Values Magdalena basin (2012)	
Average age (years)	42	
Average time of experience in fishing activity (years)	21.5	
Ethnicity (%)	0	
	Secondary education	24.41%
Level of schooling (%)	Primary education	53.59%
	No education	22.00%
Yearly dedication to the fishing activity (%)*	Total	76.00%
	Parcial	8.00%
	Occasionally	16.00%
Dependants (#)**	5	

* National value

**Value DNP, (2012)

Source: Own elaboration based on AUNAP-UNIMAGDALENA, (2013)

In the Mojana region, the complementarity of activities between crops cultivation and fishing is essential for the subsistence of its inhabitants (Aguilera, 2004). In the 1970s, fishing was limited to the upstream migration season (MINAMBIENTE & CORPOMOJANA, 2000). However, the difficult access to arable lands by the most impoverished population has increased the percentage of annual dedication to the fishing activity, even in periods of low productivity where the species have not reached their maturation size.

The major workforce is concentrated in the age range from 40 to 49, which along with the average experience of the fishers that exceeds 20 years (AUNAP-UNIMAGDALENA, 2013), seems to indicate the low generational replacement, which at the long-term may endanger the food security of the region.

5.3.2.2 Economic assets

The most significant direct use value of aquatic ecosystems of the Mojana region is fishing; this activity constitutes the source of food for a large proportion of the population, especially for those with limited livelihoods options. Besides, allows obtaining additional income through local and regional marketing (Pereira, 2017). However, the fishing marketing chain has several intermediaries involved, reducing the income of the fishers to 25% of the final price (Aguilera, 2004).

González Porto, De la Hoz Maestre, & Manjarrés-Martínez, (2015), calculated the total profit (discounting variable costs), from the landings in the Magdalena basin by fishing operation (daily), according to the fishing gear and motorization of the fishing vessel, during the period July-December of 2016. The results for the three most representative gears used in the Mojana are summarized in Table 27. Profits include the total fish production, where *Prochilodus magdalenae* represents around 58.2% of the total value of the landings. Ayapel was identified as the fourth municipality with the higher monetary value within the entire Magdalena basin, with a representation of 7.9% of the total value of the landings. Together, the Mojana municipalities of Magangué, San Benito Abad, and Nechí, contributed with the 22.7%, which may be linked to the fact that the period of the study was developed for the months where fishes feed and grow in the marshes. In the case of the San Marcos municipality, the representation only reached 2.2%.

Table 27 Profit from the landings in the Magdalena basin by fishing operation

Fishing gear	Number of fishers	Profit (daily)		
		Mean (Colombian pesos)	**Per fisher (Colombian pesos)**	**Per fisher (US$)***
Cast nets with motor	2	$ 34,545.00	$ 17,272.50	$5.66
Cast nets without motor	1	$ 36,805.00	$ 36,805.00	$12.06
Seine nets with motor	6	$ 134,626.00	$ 22,437.67	$7.35
Seine nets without motor	6	$ 44,530.00	$ 7,421.67	$2.43
Trammel nets with motor	3	$ 49,523.00	$ 16,507.67	$5.41
Trammel nets without motor	3	$ 46,235.00	$ 15,411.67	$5.05

*Average dolar value in 2016 in Colombia ($ 3,050.98)

Source: Own elaboration based on González Porto, De la Hoz Maestre, & Manjarrés-Martínez, (2015)

The results display above show that the most profitable fishing gear is the cast nets without motor, with an earning of US$12.06 fisher/day, while seine nets without motor generate 79.8% fewer earnings with US$2.43 fisher/day. Results for cast nets with motor and trammel nets (both with and without motor) do not vary significantly, generating on average US$5.37 fisher/day. This results may change given that part of the months with the highest production (January-March), in which trammel nets are the most used gear for the fishing operations, are not included.

Taking into account that around 79% of the fishers in the country are either married or living under consensual union (AUNAP-UNIMAGDALENA, 2013); it is estimated that each fisher has around five dependents (Table 26). Thus, this earnings very often represent the total income of a household. Furthermore, profits are only obtained during labor days, which varies between seasons. No data regarding total labor days per month was found, in Table 28, estimations of fishery income at a household level assume that fishers work on average 20 days/month. The obtained results show that on average, the fishery income at a household level is US$0.84 per capita/day; 55.6% below the international poverty line threshold of US$1.90 per capita/day (World Bank, 2017).

Table 28 Estimation of fishing income at a household level

Fishing gear	Income (US$)			
	fisher/day	**fisher/month**	**member of the household/month**	**member of the household/day**
Cast nets with motor	$5.66	$113.23	$22.65	$0.75
Cast nets without motor	$12.06	$241.27	$48.25	$1.61
Seine nets with motor	$7.35	$147.08	$29.42	$0.98
Seine nets without motor	$2.43	$48.65	$9.73	$0.32
Trammel nets with motor	$5.41	$108.21	$21.64	$0.72
Trammel nets without motor	$5.05	$101.03	$20.21	$0.67
Mean	**$6.33**	**$126.58**	**$25.32**	**$0.84**

Source: Own elaboration based on González Porto, De la Hoz Maestre, & Manjarrés-Martínez, (2015)

5.3.2.3 Social assets

A low level of associativity among fishers is recognized; at a national level, it is estimated that only 31.5% of fishers belong to a partnership (AUNAP-UNIMAGDALENA, 2013). Participation and collective action have been disrupted by power accumulation in the hands of a few elite groups. According to Porras (2014), power forces in the Mojana region are shaped through two practices:

patrimonialism and clientelism. The local institutions respond to this practices, where the individual interest prevails over the public; thus, political power is not in function of the rights and necessities of the population rather than on the pursuit of the state income. This is reflected in the low presence of the state in the control or regulation of the fishery activities, which in turn enhance the impoverishment situation of the fishers and the loss of the biological resources (Galvis & Mojica, 2007).

Political power is linked to the possession of the land or the means of production, which is why its permanent appropriation is sought (Illustration 24). In the Mojana region, this process includes the dispossession of peasants and fishers from both land and water (marshes and active floodplain lands). For the expropriation, landowners have used methods such as obstructing the flow of water to dry out the marshes, enclosure of communal lands, fumigation of the peasants' crops, illegal modification of the limits of the plot in complicity with governmental institutions and use of violence against peasants with the help of illegal armed groups (Porras, 2014). The appropriation of flooding communal lands that used to be employed for subsistence farming by peasants and fishers has increased the dependence of the landless population in the fishing activities (Galvis & Mojica, 2007).

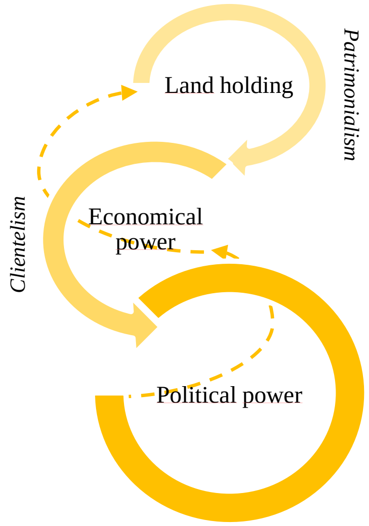


Illustration 24 Spiral of power accumulation in the Mojana region

5.3.2.1 Natural assets

Some species of Tropical fish migrate to avoid undesired conditions as an adaptive strategy to increase their productivity (Fernandes & de Merona, 1988). *Prochilodus magdalenae* (a migratory species), has been since the 1960`s the mainstay of the fishery in the Magdalena river basin (Galvis & Mojica, 2007). The life cycle of this species is closely related to the flood pulse; factors such as diet, growth, and reproduction are determined by the annual water level fluctuations. According to Ferguson, Ward, Ye, Geddes, & Gillanders, (2013), species that require flood pulses for successful reproduction are severely impacted by anomalies in seasonal flow patterns; further, they may be especially vulnerable to the combined impacts of diminished streamflow and fishing.

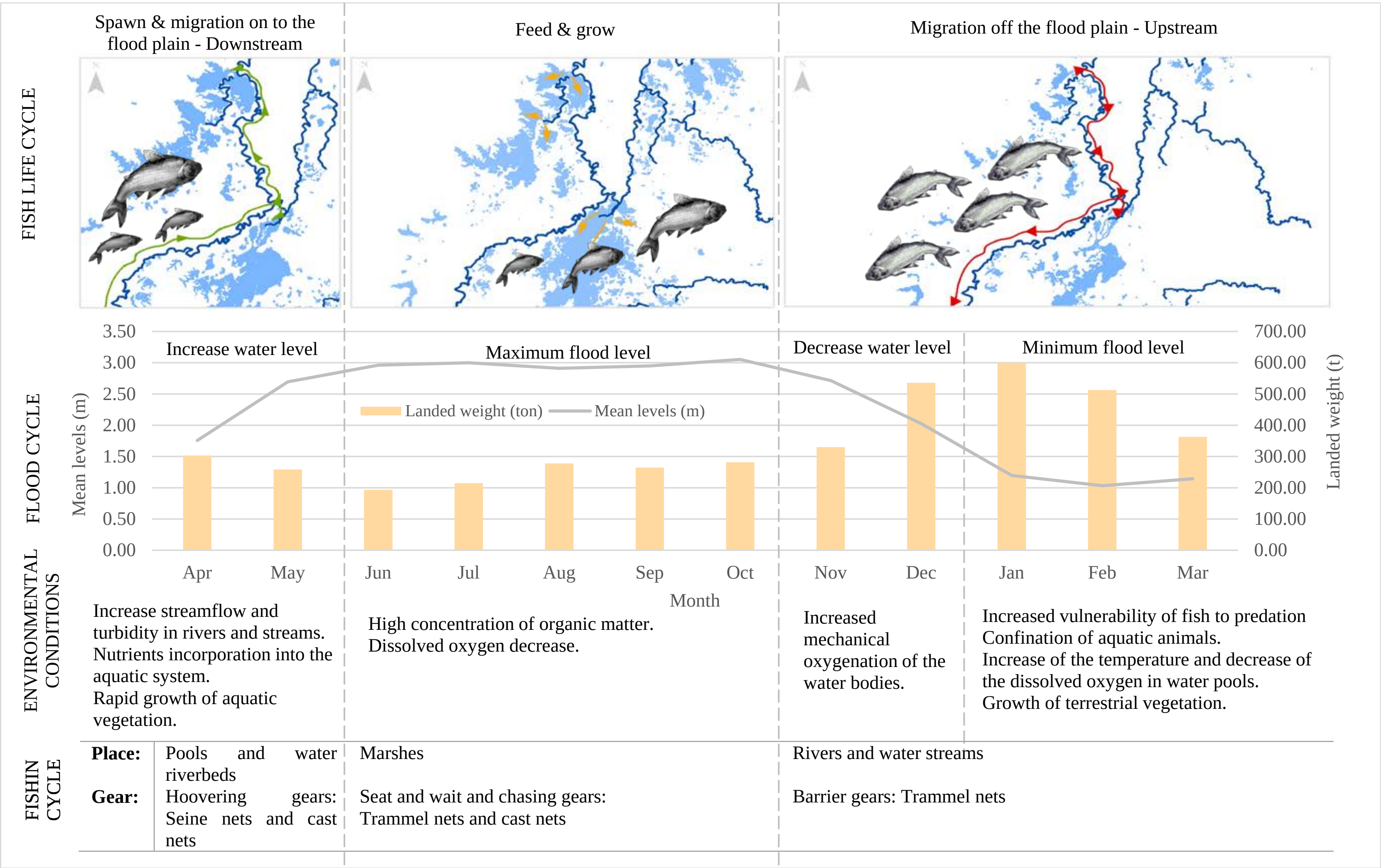
Changing environmental conditions through the flood pulse trigger *Prochilodus magdalenae* migration and in turn, this influences the fishery activity (Illustration 25). Thus, fishing places, fishing gears and landed weight vary through the year, being the period between November and March, the most productive season as the fish leave the marsh to go up the rivers in search of better conditions. According to Mójica, (2012), by the start of the rainy season between April and May, the fish return to the marsh with mature gonads. Sexual maturation is linked with weight loss caused by the energy expenditure from the upstream movement, along with the change of diet. During the downstream movement, spawning takes place in the riverbeds, and overflow waters are responsible for transporting the juveniles to the floodplains. Finally, during the season of maximum levels, individuals rapidly increase in biomass, since they feed on the abundant detritus from the decomposition of organic matter, especially of aquatic vegetation (macrophytes).

Intensive fishing in the Magdalena basin has led to the loss of this endemic biological resource. For the 2002 *Prochilodus magdalenae* was classified under the category of threat CR (Critically endangered), and for 2012 under the category VU (Vulnerable). The reduction of threat category during this period was considered the result of a joint effort between government authorities and fishers for the conservation of wetlands and improve fishing practices during the migrations (Mójica, 2012). However, the decrease in the threat classification is not reflected in the catches, which have reached the lowest historical levels in recent years, decreasing by approximately 72% between 2002 and 2017 (from 4940.9 ton/year to 1398.62 ton/year). Additionally, Barreto et al., (2010) found that for the lower basin approximately 72% of the catches are made below the average size of maturity of 27.49 cm; reached between an of age 1.1 to 1.2 years. The average size of capture is 25.79 cm, which inhibits the reproduction of the species.

Another factor that has contributed to the declination of fish populations in the Magdalena basin is the growing disappearance of the floodplain marshes (Welcomme, 1995); which constitute the breeding areas of *Prochilodus magdalenae*. The loss of this habitat has been related with the agricultural activities of the region. Egertson, Kopaska, & Downing, (2004) have proved that as agriculturally driven eutrophication increased, macrophyte communities change from a dominance of submergent, to floating-leaved, and to emergent macrophytes. The proliferation of emerging macrophytes in the marshes has generated their accumulation in large floating islands, which has intensified the eutrophication and clogging processes (J. F. Torres et al., 2011). Further, huge areas have been drained by land owner's, trough the construction of dikes during the dry season, blocking the connectivity between marshes and water streams (Galvis & Mojica, 2007).

The flooded forests locally called *Zapales*, which constituted the primary vegetation of the region has progressively disappeared; by the 90`s the estimation of the loss exceeded 90% (MINAMBIENTE & CORPOMOJANA, 2000). However, this percentage could have increased during the last decade, especially after the vast tree mortality triggered by the flooded disaster of 2010 and 2011. Part of the remaining forest was located in a natural reserve of 1,500 hectares called *La Caimanera*; field recognition in April 2018 allowed to observe the high degradation of this area, located in the municipality of San Marcos.

The extensive mining of nickel in the upper part of the San Jorge River, as well as the alluvial gold mining in the sub-basin of Ayapel, have transferred a large amount of sediments to the marshes, with high concentrations of heavy metals and other pollutants (Marrugo-Negrete, Pinedo-Hernández, & Díez, 2015). According to Gracia, Marrugo, & Alvis (2010), the mesure of mercury concentration in the population of Ayapel, have shown levels above those internationally allowed by the USEPA; it is suggested that this may be a consequence of the high consumption of fishes contaminated with mercury. Analysis of mercury in sections of the fish muscle, found that in illiophage species (sediment eaters) such as *Prochilodus magdalenae*, mercury concentrations are low, compared with concentrations in carnivorous species, and even detritivores, which present a considerable accumulation of metal mainly during the dry season of the year (J. F. Torres et al., 2011).



Increase streamflow and turbidity in rivers and streams. Nutrients incorporation into the aquatic system. Rapid growth of aquatic vegetation.

High concentration of organic matter. Dissolved oxygen decrease.

Increased mechanical oxygenation of the water bodies.

Increased vulnerability of fish to predation Confination of aquatic animals. Increase of the temperature and decrease of the dissolved oxygen in water pools. Growth of terrestrial vegetation.

Place:	Pools and water riverbeds	Marshes	Rivers and water streams
Gear:	Hoovering gears: Seine nets and cast nets	Seat and wait and chasing gears: Trammel nets and cast nets	Barrier gears: Trammel nets

Illustration 25 Linkage Prochilodus magdalenae life cycle-Flood cycle-Environmental conditions and Fishing cycle

Source: Own elaboration based on BOBP, (1997)

5.4 Adaptation

5.4.1 Crop cultivation

5.4.1.1 Substitution capacity

Illustration 26 summarized the results of substitution capacity for the assets of crop cultivation. While physical and social assets present a low qualification due to the difficulties that imply its substitution, human and natural exhibit a high level, which is more related with the feasibility rather than with the availability of substitution. For the economic assets the substitution capacity was null as it is related with land tenure and land concentration.

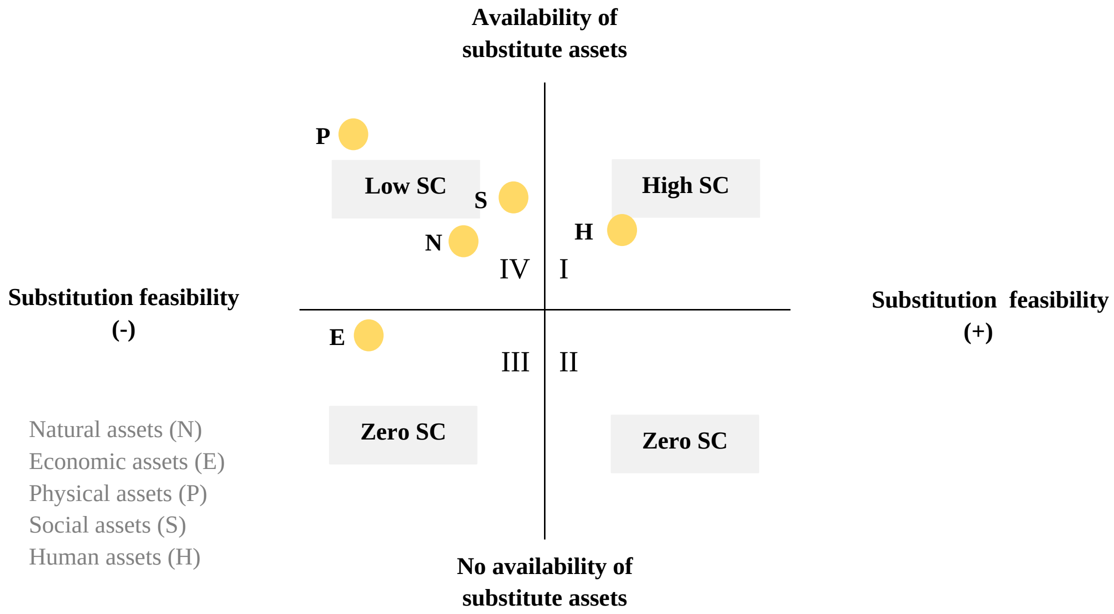


Illustration 26 Substitution capacity (SC) for crop cultivation

The conversion of traditional systems to more resistant production systems able to regulate the effects of drought is poorly extended in the study area. For 2016 the percentage of the sown area in the Mojana region under irrigated systems only reached 1.91%, represented by the Achí municipality. According to FEDEARROZ (2014), efforts for implementing irrigated systems are beginning in the Mangangué municipality through the mechanism of complementary irrigation. However, their extension is still not representative.

Between 2000 and 2017, the Bajo Cauca region exhibited an increase of 45.85% of the mechanized sown area. According to FEDEARROZ (2017), this could be explained due to the growth of rice prices in the market, the rising investor confidence after the introduction of crop insurances, and the conversion from manual to mechanized production. Nevertheless, this increase has not been constant over time so could only represent temporal conditions (Illustration 27). Furthermore, it is difficult to state that a mechanized area increase will equally beneficiate all the producers, given that the biggest part of them are manual, but they representativeness in terms of area is very low. For instance, in 2007 the percentage of manual producers within the total Bajo Cauca was of 71.90%; but only represented the 26.13% of the total sown area. Thus, historical data of the composition among mechanized and manual producers might be a better item to characterize the substitution capacity.

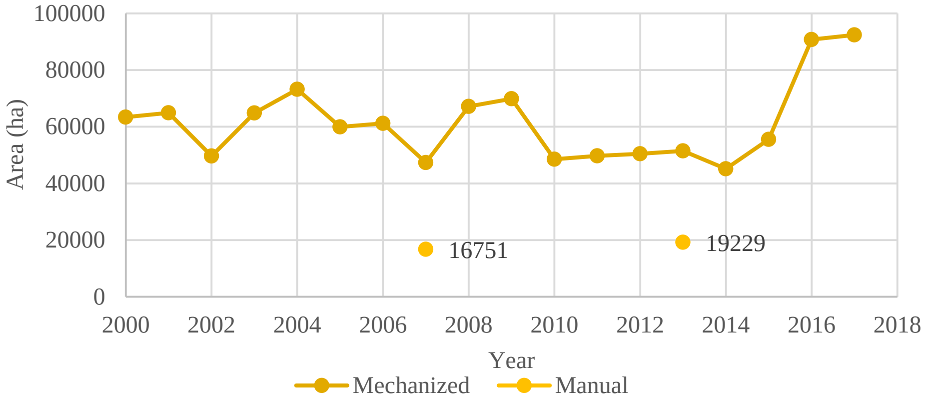


Illustration 27 Rice sown area in the Bajo Cauca region between 2000 and 2017
Source: Own elaboration based on FEDEARROZ, (2008, 2017, 2018)

A technological conversion imposes costs that limit the implementation of irrigated systems or the change from manual to mechanized production. However, the difficult access to croplands may be a more significant obstacle, as entails higher productions costs, lower yields and limited access to financing and crop insurance options.

The high land concentration and the inequities in land tenure determine limited access for the most part of the population to croplands; by 2010, it was estimated that in the Cordoba department 12% of the population possessed 80% of the land (Defensoría del pueblo, 2010). A similar behavior is expected for the Sucre department. In consequence, it is difficult to recognize a substitution capacity for these factors because historically have been sustained in the process of dispossession of the land and the water that remains in force. The Colombia National Commission for Repair and Restitution (CNRR, 2010), states that the dispossession of marshes and active floodplains has been a constant in the life of the peasantry of the Mojana region. This dispute over communal areas comes before the 70`s, extending in time to the present. Within this context, the peasants have been deprived of the daily activities of fishing and agriculture, and of the possibility to use spaces that were previously common goods.

An opportunity to initiate the democratization of the land is recognized in the land-restitution process that is taking place in the country within the framework of the peace treaties (CNRR, 2010). By July 2018; 511 requests of land-restitution for the Mojana region were under study (Unidad de Restitución de Tierras, 2018), where Nechí represented the highest participation with 328 of the applications (Illustration 28). However, the high informality in the land tenure that characterizes this region and the difficulty of determining formerly common areas pose limitations for the restoration of these rights.

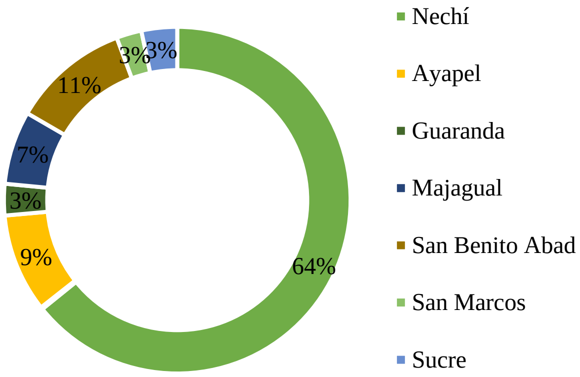


Illustration 28 Land restitution applications under study
Source: Own elaboration based on Unidad de Restitución de Tierras (2018)

As previously mentioned, the concentration of the land translates into political power through practices of power intermediation based on the clientelism and the patrimonialism (Porras, 2014). Within this logic, -which conceives the system as a business-, efforts of collective action are discouraged as an individualist way of thinking prevails. During the fieldwork, it was possible to recognize an increasing attempt to establish grower partnerships motivated by the government support to finance productive projects.

Even though the success of this recent associativeness remains unknown, it is essential to highlight the reactivation (during 2016), of the National Association of Peasant Users of Colombia (Asociación Nacional de Usuarios Campesinos de Colombia –ANUC), in the Ayapel municipality. According to CNRR (2010), the ANUC developed the most important peasant movement of the second half of the 20th century, not only in Colombia but perhaps in Latin America, achieving more than 800 land recoveries during the decade of the 70's in the departments of Córdoba, Sucre, and Bolivar. The current objective of the ANUC in the Ayapel municipality, - specifically in the community of Las Catas -, is to achieve the titling of property rights on behalf of 300 peasant families that have been occupying this territory for 12 years.

A decreased sensitivity was both perceived and described during the field recognition and interviews conducted in Las Catas, when it was compared with communities of landless fishers or growers. The access to land of this population has enabled the diversification of its livelihoods sources and the implementation of new productive systems. Within the four productive units visited, it was possible to observed crop diversification, livestock introduction, fish farming, chickens breeding, and initiatives to implement agroecological systems (Photography 3).

Photography 3 Livelihoods sources diversification in Las Catas. a. Banana crops, b. Fish pond, and c. Agroecosystem "El Desafio"
Source: Torres, D. (2018)

It is important to emphasize on the fact that, on its own, the land democratization does not lead to a vulnerability reduction; this process must be accompanied by other policies of promotion, sustainability, and viability of the peasant economies (CNRR, 2010). Accordingly, the support of governmental and non-governmental organizations has played a preponderant role in the improvement of the socio-economic conditions of Las Catas peasantry. Still, the absence of property rights imposes limitations to obtain state funding; coupled with this; there is widespread uncertainty about the future of the land. The success that obtaining the land titling would imply is not limited to winning in terms of access; furthermore, it signifies the consolidation of the peasant movement as a transforming political subject of the rural sector of the country.

According to the rice census data (FEDEARROZ, 2008, 2017), among the mechanized rainfed producers there was an increase of the concentration above the range age of 40 years, which went from 65.2% in 2007 to 72.4% in 2016. This factor, in combination with the decreasing tendency of the rural population, could indicate that there is a low level of substitution of the labor force. However, an increase of 82.8% in the producer's number was also identified for this period. Thus, although in relative terms the percentage of producers in the highest age ranges increases, there is a replacement of the rice producers in absolute terms. A more reliable analysis of the substitution capacity for the human assets will require further data regarding manual producers.

On the other hand, by comparing the level of education from the mechanized producers for 2007 and 2016, it was possible to observe a drop in the illiteracy rate by 33.0%. Likewise, the high education grew 40.1% (from 4.93% to 6.90%), and the biggest percentage of producers with primary and secondary education prevailed at 55% and 25%, respectively. In 2012, the Regional Educational Project for the Mojana (PERM) was formulated, proposing three lines of action or guiding axes: agricultural, environmental and cultural, to overcome structural poverty and violence in the territory (Porras, 2014). Information regarding the advances of this project could not be found; however, its implementation has been reported in the local means of communication and is considered a breakthrough to improve the education of the Mojana.

Finally, in response to the changing climatic conditions, efforts have been conducted for the research and evaluation of more resistant germplasm. Thought the collaboration of the Agriculture Ministry, the International Center of Tropical Agriculture and FEDEARROZ, simulation models had been applied for the selection of new varieties and for the identification of materials with high yield potential or low variability (MADR & CIAT, 2014). Varieties such a Fedearroz 473 and Fedearroz 733 have proved to be more resistant to high temperatures and water deficit in the Mojana region (FEDEARROZ, 2010).

5.4.2 Fishing

5.4.2.1 Substitution capacity

Illustration 29 summarized the results of substitution capacity for the assets of fishing. In this case, a low substitution capacity characterizes all the assets mainly due to the limited feasibility of substitution. Additionally, the number of fishers and their constant dedication to this activity have a negative connotation because trigger the overexploitation of the ecosystem. For the economic assets, the substitution capacity was null since it is related to the inequity in land tenure and concentration, enhanced by the dispossession processes of land and water.

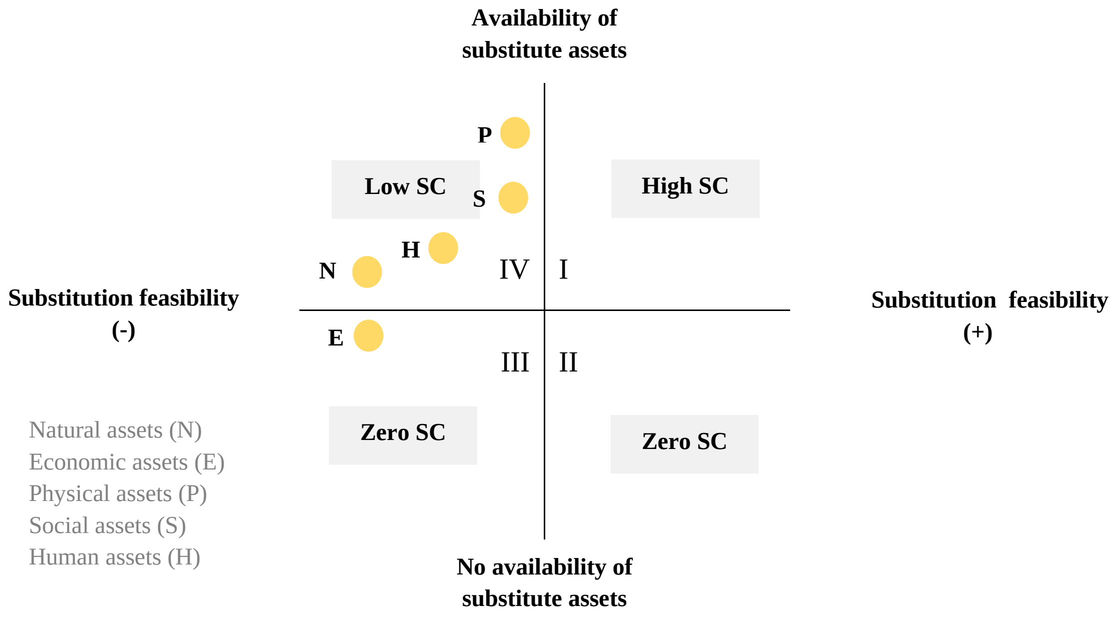


Illustration 29 Substitution capacity (SC) for fishing

The trammel nets constitute the main fishing gear of the Mojana region, but it is considered a main driver of sensitivity since it is a little selective method which allows the capture of fishes below the minimum maturation size, and of non-targeted species. There is a wide variety of fishing gears that can replace the use of the trammel nets. Historically, in the region, the main gear was the cast nets (Aguilera, 2004), which are considered less harmful for the ecosystem. Approximately 30 years ago, the trammel nets were introduced replacing this traditional gear. Not only the replacement but the securing of the regulatory conditions for the use of these gear could be considered a substitute asset. The normativity (Acuerdo 008 of 2008), allows the use of the trammel nets in the Magdalena basin, provided that its length does not exceed 400 m and that the size of its inner mesh is not below 8 cm (Puentes, Polo, Roldán, & Zuluaga, 2014). The annual dynamics of the landings, - in which the fishing resource tends to decrease with brief periods of recovery -, makes evident the lack of action of the fishing authorities to implement these regulations (Barreto et al., 2010).

Regarding the property rights over the fishing gears, the category Shared showed the highest proportion, which does not constitute a major driver of vulnerability. Furthermore, it is a cultural practice which increases during the upstream movement of the fishes (*Subienda*), through the establishment of stationary settlements close to the water streams which are considered the best spots for fishing. These settlements, locally called "*Ranchas*", are occupied by a group of fishers whose members or participants manage to have collective access to the necessary instruments for the fishing operations: canoes, fishing gears (cast nets, seine nets, harrow or trammel nets), and tools to build this temporal homes (CVS, 2007).

The spiral accumulation of land and power that has been previously described (Numeral 5.3.2.1 and 5.4.1.1), inhibits the traditional complementary of cultivation and fishing, as well as the likelihood for collective action, which in turn hinders the identification of a substitution capacity for economic, social and human assets. Accordingly, the low income rather than the used fishing gear is linked with the total yearly dedication to the fishing activity, even during seasons where this activity limits to subsistence. Inquiries conducted by Porras (2014) show that over the *Subienda* season, the wage can reach COP$800,000 to COP$1,000,000 per week, which for 2016 (reference year) was around US$262 to US$327 or US$7.5 to US$9.36 per household member per day, exceeding by far the previously estimated income of US$0.84, whose calculation included the variable costs but excluded three out of the four *Subienda* moths (January to March). Furthermore, fishing on the marshes outside the migration seasons, with inadequate gears, constitutes a treat to the aquatic fauna given that most of the catches are below the minimum size, enhancing the problem of overexploitation (Photography 4).

Concerning the educational level, it is possible to identify that fishers have a higher illiteracy rate (22.0%) than growers (12%). It is expected that educational projects such as the already mentioned Regional Educational Project for the Mojana (PERM) (Numeral 5.4.1.1), could also have a positive impact on these population. However, at that time is not possible to establish if there has been an improvement of this situation.

Photography 4 Fishing outside the migration seasons (April 2018). a. Use of seine nets in the Carate stream, b. Composition of the catches, and c, Prochilodus magdalenae capture size in the Palo Alto marsh (from 18 to 20 cm).
Source: D. Torres, (2018)

Finally, regarding the loss of the ecosystem services of habitat support and fishery provision, the DNP & FAO (2003), through the Sustainable development program for the Mojana region, identified the necessity to rehabilitate the fish habitats at strategic points, and the repopulation of commercial species, to recover the fishing levels. Given the importance of *Prochilodus magdalenae* in the catches of the Magdalena basin, several studies that contribute to its repopulation have been conducted. Among these studies, the addressed topics are: production of fingerlings, fertility rate, larval development, general biological aspects, spatial and temporal variations, and induced reproduction (Arias-Gallo, Jiménez-Segura, & Dorado, 2010; Atencio G, 2017; Avendaño, & Ramírez, 2017; Cordero C., Pertuz B., & Solano, 2003; Jaramillo-Villa & Jiménez-Segura, 2008; Olaya N., Solano P., Flórez A., Blanco V., & Segura Guevara, 2001) .

The *Prochilodus magdalenae* artificial fingerlings production is difficult, as the spawning only takes place when the fishes feel the adequate environmental stimuli, mainly of the water level rise at the beginning of the rainy season (Atencio G, 2017). Regardless of this limitation, and according to the experts of CORPOMOJANA, the successful stocking of six millions of fingerlings was conducted during 2017 within the marshes of the low San Jorge basin. Both the experts of CORPOMOJANA and the fishers state that the productivity of *Prochilodus magdalenae* was very high during the *Subienda* season of 2017-2018. However, this increase is not entirely attributed to the stocking actions, which are only considered to represent around 5% of the total catches.

On the other hand, actions for the rehabilitation of the natural forest have been carried out after the massive loss triggered by the flood event of 2010-2011. Regarding the CORPOMOJANA actions, during the period 2011-2015; 42 hectares were reforested with native species, and by the end of the period 2016-2018, it is expected that the reforestation of other 1312 hectares has concluded. In addition to public actions, private reforestation initiatives were recognized during the fieldwork. For instance, the NGO CORPOAYAPEL aims to plant one million trees of native species, mainly in the areas near Caño Barro and Caño Muñoz. This process has had an essential social component in which the community has contributed to the creation of a seed bank that by April 2018 had 17 different species. Likewise, for the planting of 40,000 individuals, which began in May 2018, it was expected to integrate the community, in order to build social cohesion and generate awareness about the protection of the environment. Ultimately, it is foreseen that this actions will contribute to the rehabilitation of the ecosystem.

Although the importance of the mentioned initiatives is recognized, the damage that over 400 years of deforestation have caused, - mainly for the introduction of livestock-, is extremely difficult to compensate. Further, initiatives that aim for the integrated stewardship of the basin had not been developed.

5.4.2.2 Coping capacity

Two initiatives to enhance the capacity of the socio-economic and ecological systems to cope with the effects of drought were recognized for the Mojana region, these are described in Table 29. Likewise, the role of the institutions involved in these initiatives is presented in Illustration 30.

Table 29 Initiatives to enhance the coping capacity of the livelihoods in the Mojana region

Initiative	Head actors	Description	Duration and coverage	Objectives	Achievements
Massive Technology Adoption Program (AMTEC)	National Federation of Rice Growers (FEDE-ARROZ) and Ministry of Agriculture and Rural Development (MADR)	The AMTEC program is a model of massive transfer of technology to increase yields and reduce production costs in rice cultivation. It is expected that the implementation of these technologies will improve the capacity of the rice productive systems to face adverse conditions such as climate change, bad agronomic practices, and market factors (FEDEARROZ, 2012).	It was initially planned for 5 years (2012-2017), but its implementation continues around the rice production regions of the country.	Implement pilot tests. Design programs of agronomic management adapted to each region. Socialize the AMTEC project to the producers. Provide financing for agricultural machinery. Train producers in the implementation of new technologies	The adoption of this program in the Mojana region is not widespread. Only for the Achí and Magangué municipalities, implementation of irrigated systems by the AMTEC program were documented by FEDEARROZ, 2014 and 2017. Its implementation is limited to large and medium producers who own arable lands.
Reducing risk and vulnerability to climate change in the region of La Depresión Momposina in Colombia	Minister of Environment and Sustainable Development (MADS) as project manager, and the United Nations Development Programme (PNUD) as project implementer, whit the financing of the National Adaptation Fund (FA Nal).	Reunite the efforts of multiple national and international institutions, to "*reduce the vulnerability of communities to the risks of flooding and drought associated with climate change and increase the resilience of ecosystems in this region*" (MADS & PNUD, 2012).	It was expected to last five years (2012-2017), but it was extended until 2019. Covers the municipalities of Ayapel, San Marcos, and San Benito Abad.	*"Strengthen existing hydro-climatological and environmental information systems.* *Rehabilitation of wetlands and their hydrology.* *Introduction of climate change-resilient agro-ecological practices.* *Relevant institutional and social structures strengthened for mainstreaming climate risk management"*. (MADS & PNUD, 2012).	According to the project performance report (Adaptation Fund, 2017), by March 2017 the advances of the project included: -Coverage of 15,555 beneficiaries. -Installation of eleven (11) automatic hydro-climatological stations. This information is used in the monthly bulletins prepared by Cordoba and Sucre`s agro climatic technical tables, and delivered to the producers every month. -Enabled the diffusion of the information about climate change to 50 stakeholders. -Restoration of 40 hectares for the recovering of the wetlands. -Application of 6 productive initiatives with an agro-ecological approach, including 729.33 hectares of native rice resistant to local climate, 3 rice mills for post-harvest management, vegetable gardens, and a fish pond. -501 houses and 14 educational centers have been adapted with rainwater capture and storage facilities, benefiting 2,505 people. -42 communities and 6 associations (3 women's associations) strengthen their climate and disaster risk management capacities. - Identification of 160 hectares for silvopastoral systems

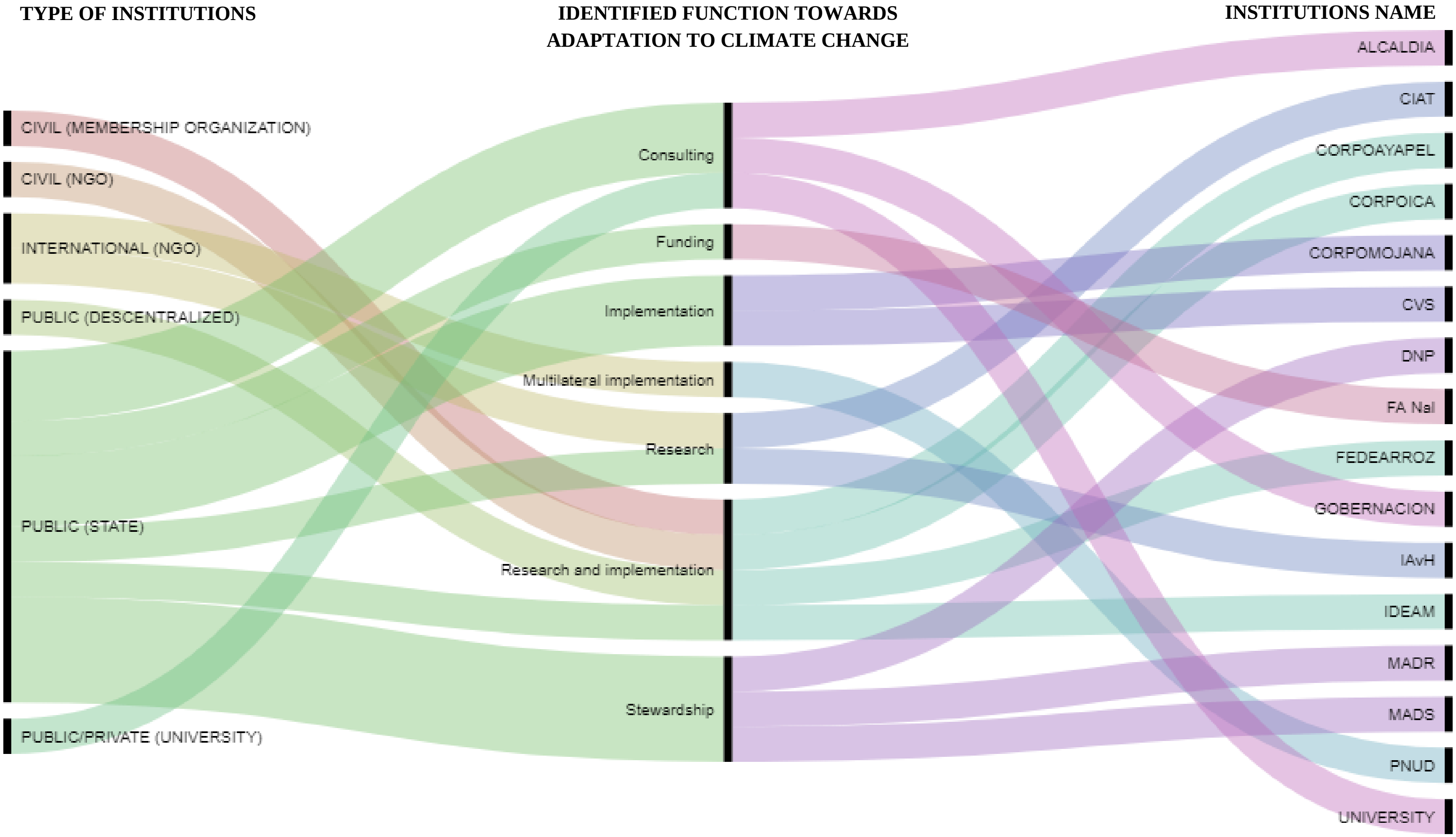


Illustration 30 Institutions and its functions towards climate adaptation in the Mojana region

Source: Own elaboration with RAWGraps

Acronym	**Name**	**Translation**
FA Nal	Fondo de Adaptación Nacional	National Adaptation Fund
MADS	Ministerio de Ambiente y Desarrollo Sustentable	Ministry of Environment and Sustainable Development
MADR	Ministerio de Agricultura y Desarrollo Rural	Ministry of Agriculture and Rural Development
DNP	Departamento Nacional de Planeación	National Planning Department
CORPOMOJANA	Corporación para el Desarrollo Sostenible de la Mojana y el San Jorge	Corporation for the Sustainable Development of La Mojana and San Jorge
CVS	Corporación Autónoma Regional de los Valles del Sinú y San Jorge	Regional Autonomous Corporation of the Sinú and San Jorge Valleys
IDEAM	Instituto de Hidrología, Meteorología y Estudios Ambientales	Institute of Hydrology, Meteorology and Environmental Studies
IAvH	Instituto de Investigación de Recursos Biológicos Alexander von Humboldt	Research Institute of Biological Resources Alexander von Humboldt
GOBERNACION	Gobernaciones Departamentales de Córdoba y Sucre	Departmental Governments of Córdoba and Sucre
ALCALDIA	Alcaldías de San Marcos, San Benito y Ayapel	Municipal Authorities from San Marcos, San Benito Abad y Ayapel
UNIVERSITY	Universidad de Córdoba, Sucre y Pontificia Universidad Bolivariana	University of Córdoba, Sucre and Pontificia Universidad Bolivariana
PNUD	Programa de las Naciones Unidad para el Desarrollo	United Nations Development Programme
CIAT	Centro Internacional de Agricultura Tropical*)*	International Center for Tropical Agriculture
CORPOICA	Corporación Colombiana de Investigación Agropecuaria	Colombian Agricultural Research Corporation
FEDEARROZ	Federación Nacional de Arroceros	National Federation of Rice Growers
CORPOAYAPEL	Corporación para el Desarrollo Integral de la Ciénaga de Ayapel	Corporation for the Integral Development of the Ayapel Marsh

Although the peasants recognize the institutional actions for the implementation of the *Reducing risk and vulnerability to climate change* project, they do not consider that these actions will lead to a significant change in their level of vulnerability, mostly concerning drought events. In many cases, it is difficult for them to perceive the direct benefits of these activities. Regarding the implementation of silvopastoral systems, the peasants argue that were established in areas that are not common property. They also express that in many cases, the farmers did not respect the agreements for the protection of the planted species by introducing the cattle ahead of time or using the wood to fence the farms. It is important to highlight that the acknowledgments presented here, only embody the perception of a few members of *Las Flores* (San Marcos) and *Seheve* (Ayapel) communities. Thus, do not represent the general opinion of the 42 communities and 15,555 beneficiaries of the project.

According to the Adaptation Fund (2017), within the 42 covered communities, 60% of the population has been benefited by the project. This percentage change drastically when it is compared to the total rural population of the Mojana region or even to the three involved municipalities. Table 30 presents the outcomes of the project that have enhanced the coping capacity to drought, by building early warning systems, implementing measures to reduce socio-ecological vulnerability, and strengthening the population capacities for the risk management.

Table 30 Outcomes of the MADS, PNUD & Adaptation Fond project, related with strengthening the coping capacity to drought and their representativeness for the Mojana region by March 2017

			Representativeness			
Outcomes	**Measure unit**	**Project coverage**	**Mojana region**		**San Marcos, Ayapel, and San Benito Abad**	
			Total	**(%)**	**Total**	**(%)**
Total beneficiaries	People	15555	208,530*	7.46%	71161*	21.86%
Installation of hydro-climatic stations, which allows preparing forecasts and warning bulletins.	People	12525	208,530*	6.01%	71161*	17.60%
Implementation of rainwater capture and storage facilities	People	2505	208,530*	1.20%	71161*	3.52%
Vegetable gardens (number of households beneficiated)	People	1333	208,530*	0.64%	71161*	1.87%
Croplands for the sowing of native rice resistant to local climate conditions	Area in ha of the croplands	729.33	49087**	1.49%	8228**	8.86%
Fish pond construction (number of fishers)	Number of fishers	48^	7000	0.69%		

*Rural population estimated for 2018, according to the DANE projections (DANE, 2005)

**Data extracted from the IV rice census (only includes mechanized production) (FEDEARROZ, 2017)

^Benefited families were assume to be equivalent to the number of fishers or rice producers who are the household heads

The previous results exhibit that the coverage of the project does not show high representativeness within the Mojana region, and this percentage does not increase above the 22% for the three municipalities where the project takes place. However, the implemented actions have shown to be socially oriented. Thus, acknowledge real needs of the population, generating in the process an intangible but significant achievement, which is the population’s recognition and appropriation of its vulnerability and the appreciation for the traditional peasant knowledge.

The weaknesses of the project regarding drought adaptation of rural livelihoods, are:

- Is focused mainly on reducing vulnerability to flooding; thus, the beneficiary communities are limited to areas where a high flood threat is recognized. This generates a bias concerning adaptation to drought, which has been identified as a more widespread hazard.

- The municipal and departmental government was only included as an agent of consultation and not as a decision-making actor. The same happens in the case of the regional environmental institutions (CORPOMOJANA and CVS), whose actions were limited to the implementation. Local and regional institutions should be integrated into the decision-making process since they are the referent of government action for most of the population.

- The diffusion of the project regarding drought impacts has been not extended to all the local institutions. Through community inquiries, the project identified the impacts of drought on the access to water for human consumption, food production, and livestock activities (Adaptation Fund, 2017). However, the fieldwork consultations to the CVS, and the Córdoba Risk Management Unit revealed that these regional institutions do not recognize the drought hazard within the focus area (Ayapel and San Marcos municipalities).

- The used of the information provided by the hydro-climatic stations is limited to some part of the population but has the potential to benefit a larger area. This might be linked to the poor access of the rural communities to the information sources and the reduced capacity of action of the local institutions. Overall, this reinforces the statement that the local institutions should be granted with a more active role in the decision-making and implementation processes of this projects.

- Outside the two communities included in the fieldwork, which coincide with the implementation of the project, the population did not recognized efforts to build adaptive capacity towards climate change. Furthermore, the peasants only acknowledge initiatives of adaptation regarding floods, even though the project aims to reduce the vulnerability of both climatic extremes.

- The implemented actions indicate that there has been a weak recognition of the livelihood sources of the population. Within the beneficiary communities, the main source of livelihoods is fishing, given that they inhabit nearby the flooded areas. However, the only action aimed at this source was limited to the construction of a fish pond that only involves 48 families.

- The Project has been mainly household oriented, where women's are considered key actors. By introducing agro productive practices, short-term results are visible at this level, regarding the strengthened of food security to climate change. Nevertheless, these initiatives have not approached the structural issues that shape the vulnerability. Furthermore, the implemented actions do not generate an added value which helps in overcoming the subsistence economy that characterizes the region.

5.5 Total vulnerability

5.5.1 Vulnerability context

Between 1981 and 2016, drought has been a recurrent, yet not a very frequent hazard, which has affected the focus area (Ayapel and San Marcos municipalities), mainly related with the occurrence of *El Niño* phenomenon. The most extreme ENSO events were recorded for 1997 and 2015, coinciding with periods of extreme meteorological drought. The semi-arid climate proved to have more severe events than the warm sub-humid and warm-humid climates. Still, none statistical difference in the distribution pattern of wet and dry years was observed, which suggest an equal level of exposure for the three climatic zones.

For the San Jorge basin at the Montelibano station, annual SPI and SDI proved to be strongly coupled; however, an attenuation of the meteorological forces was observed, given that only the meteorological drought of 1997 developed into a hydrological one. This situation changes according to the results of the SPI and the SDI for a cumulative period of four months, where both meteorological and hydrological drought events occurred during the years 1984, 1992, 1997, and 2001. The years 2009, 2014, and 2015 only recorded hydrological droughts while the years 1984, 1990, 1991, just recorded meteorological droughts.

An increasing frequency of drought events was not observed during the last decade. By including the wet years, it is possible to identify that 2008-2013 marked a period of water excess, reaching the highest historical levels in 2010, followed by a shorter period of water deficit between 2014 and the first trimester of 2016. Overall, during the last decade the occurrence of normal years has decrease. Recurrent extremes have weakened the vulnerability conditions of the socio-ecological system.

According to the above, it was proved that drought represents a natural hazard for the Mojana region, which has shown to have a negative impact on rice productivity. An influence of hydrological drought on fishing productivity was not possible to identify; but regarding the life-cycle of *Prochilodus magalenae*, it is suggested that drought might be related with a productivity change, if it is coupled with the spawning season.

The analysis of the vulnerability context would not be complete without understanding why the occurrence of drought events is linked with impacts on the livelihood sources of the population. Reed et al., (2013) established that the most reliant communities on natural resources are likely to be most severely affected by climate change. In the case of the Mojana region, its population is utterly dependent on ecosystem services, which according to the flood pulse defines an alternation between livelihood sources from cultivation to fishing. Consequently, the main adaptation of the population as amphibian men have consisted of interpreting the hydrological cycle and mobilizing its productive activities from the land to the water according to the water level fluctuations. Thus, anomalies in the hydrological cycle cause disruptions over the livelihood.

The high level of exposure to drought of the livelihoods in a region where drought impacts have been previously acknowledged, and water scarcity should not be a significant issue, has been influenced by the way that people faces adverse conditions. For the study region, this refers to the capability of the population to endure, which Fals Borda (2002) called “El *Aguante*.” This term defines a reactive form of response of the population that does not generate dynamics of transformation; thus, it cannot be considered a factor of sensitivity or adapting capacity. Overall, it is the ability of the population to survive, supported by its creativity, optimism, conformism, and their faith in God and destiny. This factor does not lead to the development, and it is related with rudimentary productive systems based on the low-productivity extractive practices, where there is no planning or hazard mitigation.

5.5.2 Internal vulnerability

Factors that shaped the relationship of drought exposure and drought impacts are included in the internal vulnerability analysis. By overlapping sensitivity with adapting capacity, the total internal vulnerability of the livelihood sources to drought, classify mainly under the Very-high and High categories (Table 31). Fishing showed a higher level of vulnerability in comparison to rice cultivation; this is related to the overpressure exerted on fishery resources and to the cumulative nature of the factors that generate its sensitivity. Accordingly, the (IPCC, 2007), have established that: *“non-climate stresses can increase vulnerability to climate change by reducing resilience and can also reduce adaptive capacity because of resource deployment to competing needs”*.

Table 31 Total internal vulnerability of livelihoods sources to drought within the Mojana region

Sensitivity vs. substitution capacity (SC)

Sensitiv. **SC**	**Low**	**Medium**	**High**	**Very high**
II-III (Zero)	Low	Medium	High	Very high
IV (Low)	Low	Medium-low	High	Very high
I (High)	Low	Low	Medium-High	High

Sensitivity vs. coping capacity (CC)

Sensitiv. **CC**	**Low**	**Medium**	**High**	**Very high**
Zero	Low	Medium	High	Very-high
Low	Low	Medium-low	Medium-high	High
High	Low	Low	Medium-High	High

Assets color code	P	H	E	S	N
Crop cultivation	🟨	🟪	🟦	🟧	🟩
Fishing	🟨	🟪	🟦	🟧	🟩

Physical assets (P)
Social assets (S)
Human assets (H)
Natural assets (N)
Economic assets (E)

The loss of supporting, regulating and provisioning ecosystem services defined a High level of livelihoods vulnerability to drought. This was linked with decreasing productivity in fishery and rice production and with the loss of the ecosystem capacity to moderate the impacts of adverse conditions. Accordingly, the effects of the natural seasonality felt more intense with recurrent inundations and agricultural failures, even when they are not related to climatic anomalies. Initiatives to reforest and rehabilitate the flooded forest were observed; still, the success of this actions will take time, since it is estimated that around 90% of the natural coverage has been lost.

The economic assets define a Very-high level of vulnerability, explained by the inequity in the access to croplands and to the low income generated by these livelihoods sources, limiting most of the population to a subsistence economy (Aguilera, 2004; Porras, 2014). These results are similar to the findings of Zarafshani et al., (2012), who assessed drought vulnerability of wheat farmers in Western Iran, obtaining that agricultural income and farmers land size, were among the major sources of economic vulnerability from wheat farmers. Additionally, within the mentioned study was acknowledge that decreasing farmers' income during drought events has a high influence on vulnerability mitigation.

Limited access to land could be considered the main driver of vulnerability since it has been sustained through the historical process of dispossession of peasants from land and water. Additionally, it feeds back with the other components of vulnerability. In agrarian-based communities, it has often been acknowledged an equivalence among land tenure and power (Baker, 1998). Powerful groups tend to discourage marginalized groups participation to have more control over common-pool resources management. In the Mojana region, violence has been used in the process of monopolization of power and natural resources (CNRR, 2010). This processes have impacted not only the likelihood of collective action but has influenced the ecosystem services loss because landless population put an additional pressure over fishery resources as they are unable to develop the cultural model of complementarity between fishing and crop cultivation.

The accumulation of power in favor of private interest was also observed by Adhikari & Lovett (2006), who established the existence of a tendency to political power concentration in a community-based forest management in Nepal. They found that elite groups used their political power to manipulate the elections to assure a high representation in the decision-making process accordingly to their economic interest and their desire for increased political power. Similarly, Ortiz, Pérez, & Muñoz (2004), demonstrate in a Mexican case study that powerful members, who hold authority positions in local common-pool resources, do not necessarily had more incentives to cooperate. In their studies of rural India Barker (1998), also found that in heterogeneous villages with essential differences in wealth distribution, community-based initiatives were likely to be threatened by local elites.

For the case of fishing, the high dependence of the population on this livelihood source defines a Very-high level of sensitivity. At the same time, the low income generated from it (outside the main migration season), limits the capability to diversify the livelihoods sources and assets. Thus, the capacity of adaptation is low, and this dependence is continuously reinforced. These results are comparable with the ones obtained by Sallu, Hubacek, & Paavola (2014). By applying the SLF framework, they found that vulnerability of fishery-based livelihoods in households of Padma and Kutubdia in Bangladesh, is determined by the high dependency on marine fisheries and the difficulties to alternate income sources, due to limited assets.

The lack of collective action and social cohesion hinders community response mechanisms that can generate transformation dynamics, unlike the weak state action. Keshavarz et al., (2017), identified that social networks empower farm families and help them to mitigate their livelihood vulnerability in the context of drought. Participation and collective action have been obstructed in the Mojana region by power accumulation in the hands of a few elite groups which favor private interests. Nevertheless, among the most significant achievements of the adaptation initiatives, it is possible to recognize the community recognition and appropriation of its vulnerability and the recovery of the traditional peasant's knowledge. This advances could lead to active participation.

According to Keshavarz et al., (2017), moderate or high levels of access to physical assets such as mechanical inputs reduce vulnerability to drought. For the Mojana region, both crop cultivation and fishing are characterized by a low level of technological development, which has been sustained for decades despite having demonstrated low levels of productivity. Although a high availability of physical assets substitutes is recognized, their substitution is almost null, showing a deficient finance investment in the region.

Illustration 31summarizes the main factors that shaped the vulnerability in the Mojana region and how they interconnect and feedback. Overall, two structural points of entrance to addressed drought vulnerability were identified: the inequitative land tenure and accumulation and the increasing dependence on fishery resources.

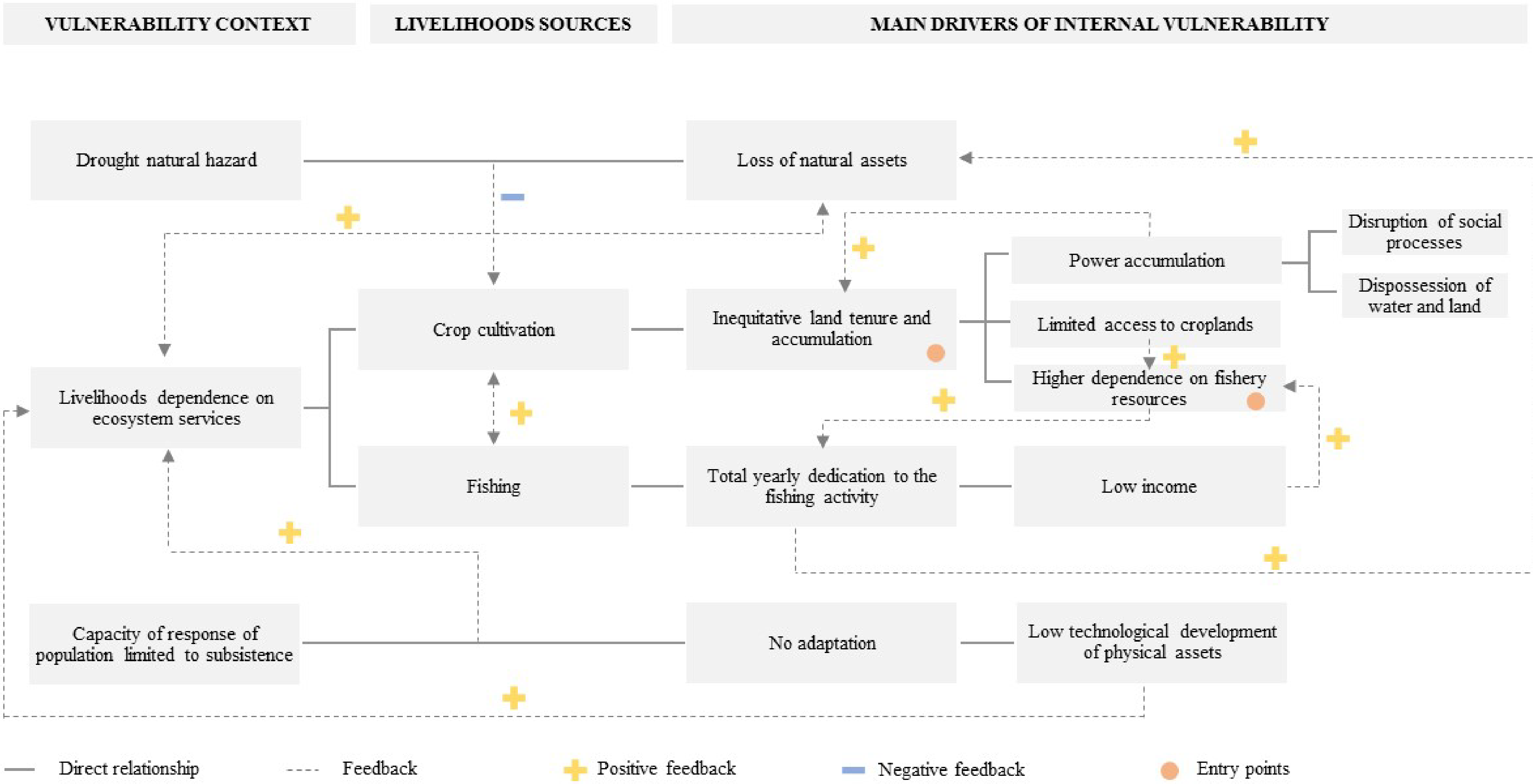


Illustration 31 Identification of entry points to reduce livelihoods vulnerability to drought

6. CONCLUDING REMARKS

The present study conducted an assessment of drought impacts on the natural resources that sustain the rural livelihoods, and the key factors that define the occurrence of these impacts by applying a vulnerability approach (the *sustainable livelihoods framework* – SLF). Multiple variables were integrated into the analysis by coupling the socio-economic and ecologic systems, identifying linkages through the use of complementary quantitative and qualitative methods. Consequently, this study provides entry points for risk managers and decision makers to address drought vulnerability in the Mojana-region.

Given the marked seasonality of climate and productive activities in the study area, the used of standardized drought indices demonstrated to be very useful for the assessment of drought impacts on livelihoods sources by enabling the definition of different accumulative periods. Accordingly, meteorological drought measure through averaging periods of four months proved to be related with rice yields variations, when was overlapped with the periods of cultivation. A similar linkage between the spawning season of *Prochilodus magdalenae* and hydrological drought is suggested. Nevertheless, the definition of drought impacts on fishing will require a more specific study that couples variables like hydrological drought characteristics, the life cycle of the fishes, variation of monthly captures, accumulated impacts through the basin, and habitat loss.

Inequities in land tenure and land accumulation, and an increasing dependence on fishery resources were identified as the main drivers of drought vulnerability in the Mojana region, shaping the processes that generate vulnerability. High sensitivity and weak capacity of substitution characterized this factors. Adaptation measures intended to approach this vulnerability factors exceed the local or regional scale. Furthermore, it poses the challenge to address national issues such as land democratization and integrated management of natural resources, in order to generate real sustainability in the adaptation toward climate change.

The importance of *Prochilodus madalenae* as the mainstay of fishery production in the Magdalena basin was recognized. Both the marshes and the rivers play a vital role in the life cycle of this species. Non-climate stresses were related with the representative decreasing of the catches. The Mojana region generates a pressure over this resource, and at the same time is a natural receptor of the accumulated impact on the San Jorge, Cauca, and Magdalena basins. Therefore, to secure the recovery of this species population and the dynamics of the ecosystem, an integrated water management starting with the San Jorge basin and gradually extending to cover the Magdalena basin is required.

From the fieldwork interviews, it was perceived that the peasants often related drought events with a temperature increase. It is suggested that future studies in the Mojana region include the temperature factor for the drought definition. Additionally, the importance to structure the fieldwork according to different inquiry levels was proved, to gradually build up a picture of the situation that covers a broad perspective from several actors.

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Appendix 1 CHIRPS precipitation results per climate type

Warm Semi-arid												
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1981	14.03	42.67	47.54	178.59	394.18	249.36	286.71	350.59	193.04	208.49	160.10	72.54
1982	16.60	26.45	13.58	115.13	252.90	161.30	318.70	238.94	320.73	253.26	123.81	21.59
1983	5.42	23.66	14.79	120.48	263.04	211.72	303.59	294.00	259.24	211.31	118.07	56.59
1984	12.14	59.47	8.48	74.55	128.60	344.05	348.17	298.50	265.79	260.76	114.20	13.37
1985	8.56	9.85	12.86	38.30	190.18	193.52	316.70	398.45	320.49	209.69	110.53	51.06
1986	6.86	25.29	26.11	127.88	179.39	222.58	180.17	156.65	194.28	236.55	98.53	23.48
1987	13.30	18.06	13.56	164.40	188.09	141.10	424.10	337.51	183.40	260.34	154.64	39.61
1988	3.62	12.37	1.64	102.25	143.06	240.01	356.35	378.87	235.49	155.90	196.74	62.48
1989	13.71	9.93	41.79	41.06	215.77	238.23	256.66	277.93	242.72	290.56	142.16	32.88
1990	18.35	25.15	35.21	113.41	232.42	175.26	187.08	316.63	270.34	193.25	107.80	42.94
1991	1.48	10.69	20.99	147.16	226.28	186.89	184.65	266.53	214.70	229.47	149.38	19.41
1992	7.63	10.73	4.43	98.11	260.59	213.44	418.73	316.56	227.11	158.60	153.74	26.17
1993	15.53	16.56	65.19	95.71	235.60	221.14	227.83	296.04	220.47	206.54	158.13	40.54
1994	16.85	11.11	65.89	102.70	232.48	178.30	215.92	346.99	245.58	168.77	107.58	14.12
1995	10.83	6.35	18.53	102.81	175.45	220.60	354.89	367.23	231.34	202.77	119.34	50.49
1996	5.52	34.22	46.39	121.39	343.08	304.76	308.27	407.56	268.60	204.27	107.37	40.62
1997	3.99	32.32	16.24	74.29	154.58	293.29	203.53	168.16	242.18	143.78	99.50	10.85
1998	3.11	33.73	31.18	74.16	418.63	291.17	297.54	339.03	289.47	137.39	128.56	86.74
1999	16.17	64.51	27.68	135.42	155.51	262.68	354.72	320.97	219.04	234.03	87.39	70.59
2000	13.29	15.94	24.29	103.62	238.23	216.46	225.65	275.30	230.57	173.13	90.45	63.82
2001	9.55	1.88	25.80	54.93	254.66	167.88	182.25	244.74	289.14	172.72	147.74	77.76
2002	4.57	7.39	38.75	117.24	196.70	202.76	223.49	164.14	228.35	186.57	91.61	31.09
2003	3.19	16.35	20.41	118.68	231.98	209.44	253.59	233.84	266.14	168.78	154.13	26.49
2004	9.57	6.60	4.23	96.00	278.59	162.24	252.46	302.04	187.15	142.69	130.55	34.11
2005	6.78	4.33	16.61	155.69	179.82	226.20	263.87	288.16	220.86	174.19	160.59	32.51
2006	14.14	13.20	49.55	168.27	296.40	224.33	208.88	283.12	206.59	210.07	105.90	65.20
2007	1.00	6.15	70.56	188.29	273.96	246.76	275.14	346.38	202.68	206.75	135.19	81.70
2008	7.05	15.57	56.97	136.51	247.97	252.08	387.47	355.15	268.54	268.84	164.00	25.53
2009	9.48	18.48	52.75	88.82	175.04	229.23	348.58	347.04	221.61	157.85	108.41	24.75
2010	5.19	42.37	44.57	135.14	214.66	351.31	425.43	372.19	331.26	234.18	199.79	126.00
2011	15.02	27.80	104.26	147.54	265.78	285.04	279.49	285.67	253.50	156.22	204.82	78.53
2012	11.34	15.13	33.15	136.45	254.17	245.84	280.97	401.99	280.86	232.23	99.14	39.35
2013	6.02	18.12	39.70	118.57	228.51	208.24	201.81	375.04	192.71	176.17	99.28	42.92
2014	20.03	13.86	10.84	100.25	144.01	180.72	172.44	460.23	238.77	209.04	131.57	41.17
2015	6.85	30.13	12.52	82.69	196.65	83.10	223.14	174.70	205.27	291.48	125.67	53.17
2016	10.97	4.98	3.81	107.54	286.34	230.35	261.16	270.36	175.06	238.54	141.52	

Warm Sub-humid

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	33.46	68.22	71.05	259.52	448.33	331.38	364.28	411.50	259.10	314.74	265.46	120.34
1982	53.94	36.86	15.24	164.09	327.19	188.51	352.20	338.58	436.95	317.25	177.55	25.24
1983	9.48	33.40	27.12	160.52	307.10	281.93	374.09	387.19	384.16	292.74	174.61	127.76
1984	31.52	79.04	12.86	96.35	180.80	397.42	427.46	374.74	334.10	324.58	188.38	21.93
1985	13.57	12.15	30.89	47.95	214.34	262.00	428.29	428.74	372.54	351.65	138.04	113.36
1986	16.35	35.01	33.77	185.96	191.88	272.84	234.87	243.02	271.18	336.49	154.96	42.93
1987	30.14	27.67	23.17	227.86	286.02	185.67	416.00	391.71	274.70	374.73	212.15	73.16
1988	8.03	17.64	6.92	108.58	221.98	276.08	394.39	399.57	305.96	228.51	284.50	90.89
1989	36.57	15.58	51.35	78.85	290.19	286.21	342.28	321.75	316.64	404.05	175.05	48.98
1990	36.58	31.83	75.21	163.70	303.37	233.72	245.26	405.03	295.68	285.54	205.26	70.14
1991	8.46	17.66	40.86	171.97	320.17	204.68	278.49	307.23	266.63	277.72	246.07	44.66
1992	16.96	7.76	7.01	123.26	317.04	251.02	475.33	355.43	276.01	230.75	222.33	49.42
1993	36.76	15.69	99.65	151.43	308.19	250.63	295.09	333.08	293.28	305.20	237.63	51.06
1994	20.95	11.57	74.75	146.33	275.82	281.47	237.63	452.94	289.58	226.54	209.88	22.59
1995	24.89	8.16	30.65	120.25	234.97	234.51	449.74	401.99	268.02	320.00	191.15	84.12
1996	16.13	62.61	82.50	165.40	319.15	325.76	361.77	536.19	355.81	321.52	179.85	74.44
1997	10.61	43.39	19.65	110.60	228.55	357.39	249.73	252.61	283.71	211.99	155.84	25.71
1998	7.49	43.41	53.09	116.03	473.04	295.59	396.37	401.99	347.57	237.85	227.09	128.66
1999	32.08	93.16	55.06	202.84	226.08	391.45	389.54	398.79	281.06	338.73	143.27	145.16
2000	34.35	34.99	31.42	162.51	315.91	292.21	340.40	394.76	353.06	296.69	130.00	115.15
2001	14.43	5.92	49.73	84.10	275.64	236.87	238.85	297.45	333.72	269.24	217.82	134.23
2002	10.11	16.78	52.08	185.92	252.33	208.33	304.92	234.94	384.10	308.57	162.97	30.21
2003	10.10	23.55	35.36	190.92	260.19	262.22	300.68	348.77	327.89	277.25	286.53	86.58
2004	17.72	6.28	15.55	150.00	356.75	221.57	303.04	413.17	274.98	295.29	209.14	48.60
2005	22.61	4.97	28.09	260.99	263.41	333.88	313.76	436.25	335.74	264.33	273.15	42.11
2006	34.98	18.92	74.27	211.47	354.49	273.95	253.26	372.92	297.96	304.88	204.63	129.65
2007	7.21	14.84	88.54	252.53	349.71	291.80	336.45	475.95	292.93	350.75	183.51	105.74
2008	12.82	27.30	63.29	178.89	291.00	294.97	485.79	419.38	379.35	443.42	249.72	33.23
2009	20.27	30.62	62.83	112.80	212.40	254.27	386.80	427.76	269.26	233.14	152.26	40.08
2010	6.62	40.52	56.19	239.40	284.94	405.49	485.71	443.03	425.36	339.18	277.72	203.87
2011	33.79	44.93	147.07	197.27	292.68	344.74	366.76	327.91	351.31	226.17	332.86	132.03
2012	21.49	25.79	51.10	213.64	320.01	297.88	313.89	528.77	346.98	336.57	159.84	71.11
2013	11.15	14.93	61.68	174.80	278.06	291.24	204.14	488.19	279.30	251.78	186.58	72.23
2014	24.07	15.86	22.69	139.01	186.87	279.67	242.52	562.78	327.41	232.47	251.24	87.69
2015	25.05	41.18	21.06	121.77	274.47	136.14	235.29	255.54	279.78	393.58	192.82	83.70
2016	24.26	7.71	7.66	144.90	371.64	268.73	311.34	356.55	237.07	427.46	201.72	

Warm Humid

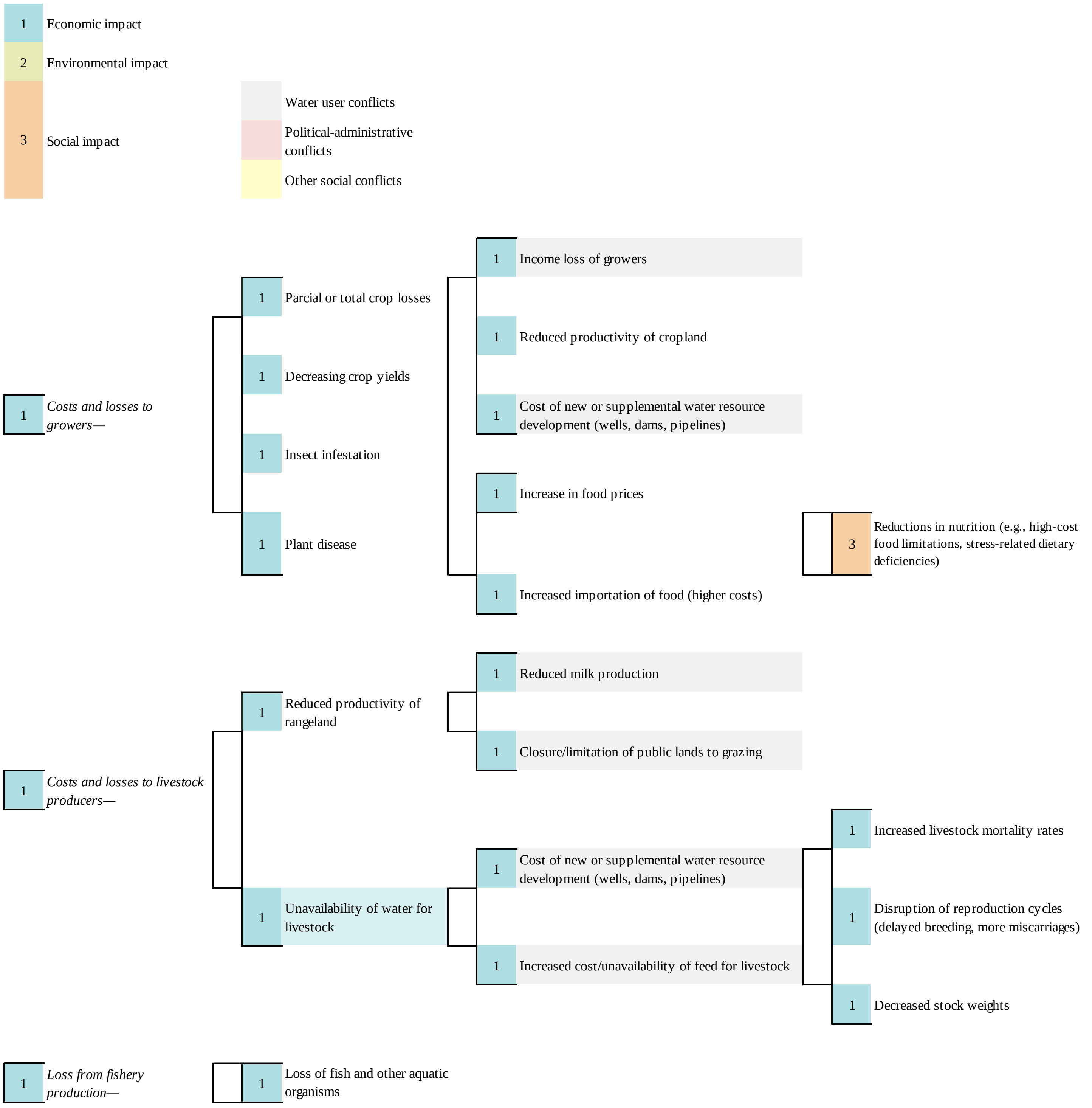
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	38.83	94.47	109.87	357.87	560.49	394.43	424.58	496.78	232.64	425.51	431.97	179.29
1982	105.53	46.17	16.93	240.88	403.86	220.77	355.58	340.09	437.76	387.73	217.00	23.49
1983	14.56	47.19	45.94	202.57	336.12	306.10	388.17	488.16	485.35	370.44	264.35	203.14
1984	70.77	109.63	21.89	167.05	288.17	452.57	461.24	428.16	349.53	465.85	288.41	34.06
1985	17.78	12.39	40.45	48.91	256.54	294.58	518.18	473.90	375.37	450.41	198.93	167.08
1986	25.69	43.54	44.18	303.29	284.83	299.38	254.45	369.21	327.32	446.79	241.16	58.23
1987	29.30	28.71	35.02	265.41	394.49	267.27	404.22	499.96	325.94	449.92	333.28	148.46
1988	11.26	32.64	8.69	125.69	377.91	359.76	405.99	376.18	343.28	295.37	410.44	134.29
1989	60.16	21.05	63.57	102.16	352.64	332.20	430.25	390.38	357.79	506.54	278.14	77.16
1990	48.60	33.83	98.24	183.61	352.63	278.78	277.60	375.68	249.24	329.92	273.10	108.14
1991	16.60	27.28	59.60	214.26	372.90	249.50	342.62	346.45	305.10	288.72	378.82	81.57
1992	24.48	9.46	10.37	167.14	365.90	319.75	449.01	401.88	276.43	330.04	291.31	90.58
1993	68.99	17.83	120.28	215.64	356.89	273.57	347.34	380.04	356.69	411.98	333.92	75.91
1994	23.35	16.53	93.39	188.42	345.38	378.98	289.89	585.99	337.48	316.59	312.09	34.47
1995	44.34	9.00	43.36	127.27	293.76	287.35	514.19	365.71	243.81	410.73	300.86	137.12
1996	49.55	112.58	115.97	173.33	299.73	342.49	367.89	559.59	331.04	401.90	247.82	114.97
1997	10.61	73.07	18.63	128.53	274.29	418.92	267.51	321.05	267.29	281.17	267.08	33.89
1998	10.97	53.96	76.15	146.29	546.20	325.56	452.32	524.86	388.02	349.86	355.46	190.34
1999	65.51	125.03	100.69	314.07	359.19	506.82	404.03	486.06	364.75	369.54	194.20	299.07
2000	57.52	71.56	51.64	226.27	417.39	404.58	396.00	530.41	452.70	400.70	161.42	153.30
2001	24.14	10.00	76.97	125.07	362.85	300.95	280.03	372.45	352.17	354.07	254.72	225.97
2002	15.31	26.30	61.30	248.11	289.51	226.25	307.69	291.44	417.01	356.76	245.60	40.96
2003	17.92	35.23	46.43	247.49	300.82	324.75	368.56	414.30	369.01	385.30	400.81	197.59
2004	32.35	8.03	21.00	209.62	446.95	241.96	345.31	503.36	332.63	453.17	304.24	68.64
2005	61.23	10.68	39.75	361.69	320.05	404.29	367.05	526.33	396.48	343.54	361.09	77.08
2006	52.06	33.65	96.18	240.55	429.11	326.88	284.95	462.06	365.59	407.65	313.16	202.31
2007	12.91	27.82	95.19	319.94	397.67	328.23	355.88	517.88	330.49	431.07	227.86	153.47
2008	30.78	42.94	79.84	217.58	373.03	328.77	536.63	506.70	319.99	488.07	378.72	45.52
2009	42.91	50.65	93.08	151.34	261.68	325.88	421.73	582.18	306.77	310.65	259.21	77.15
2010	10.07	51.07	81.41	349.81	380.80	481.02	532.20	495.01	436.31	455.74	461.43	317.39
2011	68.52	65.71	171.82	324.85	305.86	428.70	422.67	368.75	454.68	308.17	442.47	203.70
2012	36.35	35.96	85.00	295.76	401.97	349.69	359.83	618.06	453.58	449.80	279.12	141.09
2013	18.99	34.42	106.63	241.44	404.53	405.36	205.76	547.88	348.34	361.54	317.33	108.10
2014	29.23	15.70	42.75	188.50	285.84	372.74	288.00	639.66	405.51	298.15	378.26	133.17
2015	47.90	41.64	32.62	145.32	301.14	212.01	226.10	351.65	311.75	364.73	248.48	91.36
2016	34.33	11.65	14.31	138.60	375.80	296.21	318.91	370.21	265.67	564.90	263.04	

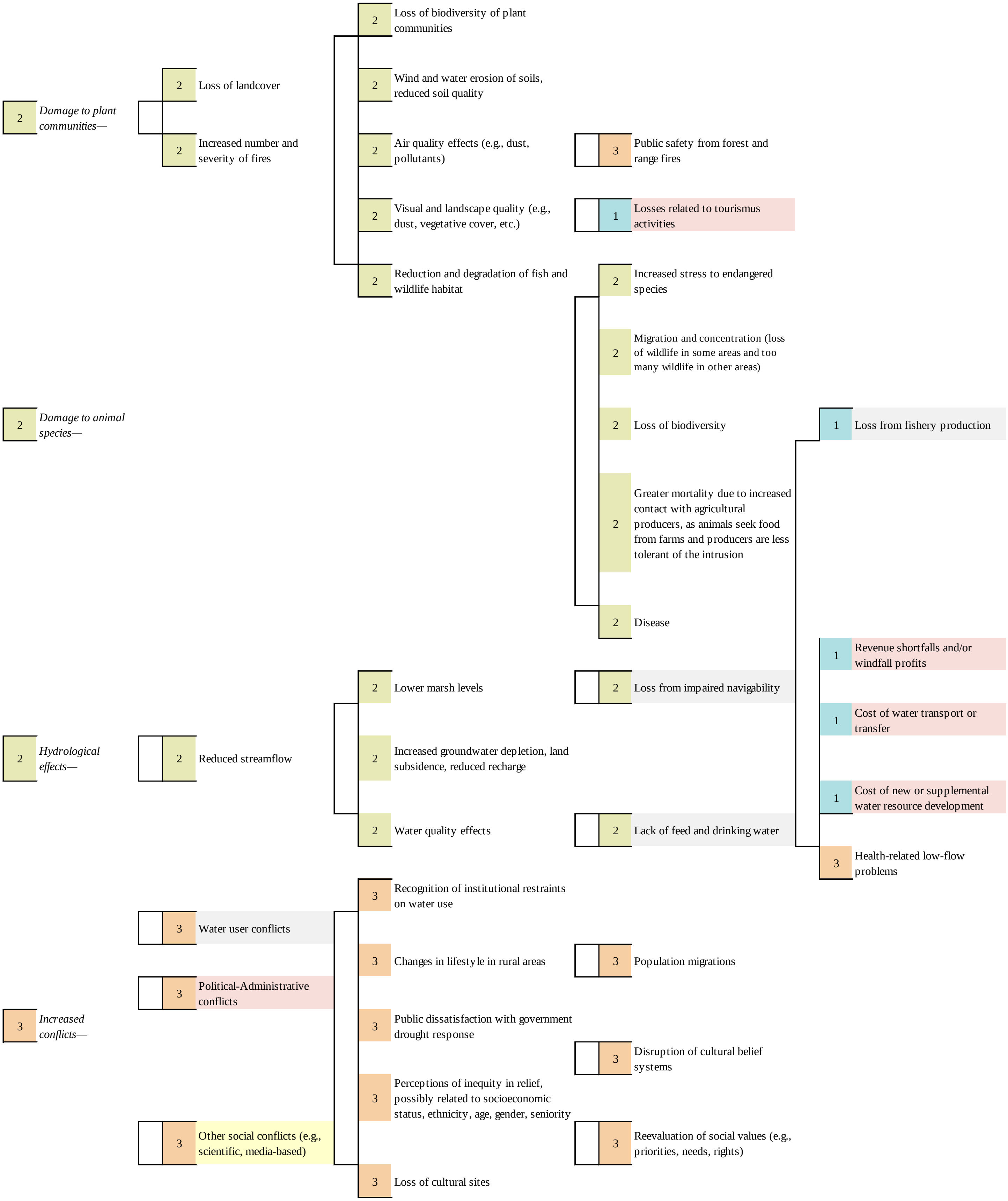
Appendix 2 Drought impacts checklist

Impacts	**Direct**	**Indirect**
Economic		
Costs and losses to growers—		
Parcial or total crop losses	▨	
Decreasing crop yields	▨	
Income loss of growers		▨
Reduced productivity of cropland		▨
Insect infestation	▨	
Plant disease	▨	
Cost of new or supplemental water resource development (wells, dams, pipelines)		▨
Costs and losses to livestock producers—		
Reduced productivity of rangeland	▨	
Reduced milk production		▨
Closure/limitation of public lands to grazing		▨
Unavailability of water for livestock	▨	
Cost of new or supplemental water resource development (wells, dams, pipelines)		▨
Increased cost/unavailability of feed for livestock		▨
Increased livestock mortality rates		▨
Disruption of reproduction cycles (delayed breeding, more miscarriages)		▨
Decreased stock weights		▨
Loss from fishery production—		
Damage to fish habitat	▨	
Loss from fishery production		▨
General economic effects—		
Decreased land prices		▨
Loss to industries directly dependent on agricultural production		▨
Unemployment from drought-related declines in production		▨
Reduction of economic growth		▨
Fewer agricultural producers (due to change of income sources)		▨
Rural population loss		▨
Loss to recreation and tourism industry—		
Losses related to tourismus activities		▨
Water suppliers—		
Revenue shortfalls and/or windfall profits		▨
Cost of water transport or transfer		▨
Cost of new or supplemental water resource development		▨
Transportation industry—		
Loss from impaired navigability		▨
Decline in food production/disrupted food supply—		
Increase in food prices		▨
Increased importation of food (higher costs)		▨

Impacts	**Direct**	**Indirect**
Environmental		
Damage to animal species—		
Reduction and degradation of fish and wildlife habitat	▨	
Lack of feed and drinking water		▨
Greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion		▨
Disease		▨
Increased vulnerability to predation (from species concentrated near water)		▨
Migration and concentration (loss of wildlife in some areas and too many wildlife in other areas)		▨
Increased stress to endangered species		▨
Loss of biodiversity		▨
Hydrological effects—		
Reduced streamflow	▨	
Lower marsh levels		▨
Increased groundwater depletion, land subsidence, reduced recharge		▨
Water quality effects		▨
Damage to plant communities—		
Loss of landcover	▨	
Loss of biodiversity of plant communities		▨
Increased number and severity of fires	▨	
Wind and water erosion of soils, reduced soil quality		▨
Air quality effects (e.g., dust, pollutants)		▨
Visual and landscape quality (e.g., dust, vegetative cover, etc.)		▨
Social		
Health-		
Mental and physical stress (e.g., anxiety, depression, loss of security, domestic violence)		▨
Health-related low-flow problems		▨
Reductions in nutrition (e.g., high-cost food limitations, stress-related dietary deficiencies)		▨
Loss of human life (e.g., from heat stress, suicides)		▨
Public safety from forest and range fires		▨
Increased conflicts—		
Water user conflicts		▨
Political-Administrative conflicts		▨
Other social conflicts (e.g., scientific, media-based)		▨
Reduced quality of life, changes in lifestyle—		
Changes in lifestyle in rural areas		▨
Population migrations		▨
Disruption of cultural belief systems		▨
Reevaluation of social values (e.g., priorities, needs, rights)		▨
Public dissatisfaction with government drought response		▨
Perceptions of inequity in relief, possibly related to socioeconomic status, ethnicity, age, gender, seniority		▨
Loss of cultural sites		▨
Increased data/information needs, coordination of dissemination activities		▨
Recognition of institutional restraints on water use		▨

Appendix 3 Causal chain of potential drought impacts




2 Damage to plant communities—
2 Loss of landcover
2 Increased number and severity of fires
2 Loss of biodiversity of plant communities
2 Wind and water erosion of soils, reduced soil quality
2 Air quality effects (e.g., dust, pollutants)
2 Visual and landscape quality (e.g., dust, vegetative cover, etc.)
2 Reduction and degradation of fish and wildlife habitat
3 Public safety from forest and range fires
1 Losses related to tourismus activities
2 Damage to animal species—
2 Increased stress to endangered species
2 Migration and concentration (loss of wildlife in some areas and too many wildlife in other areas)
2 Loss of biodiversity
2 Greater mortality due to increased contact with agricultural producers, as animals seek food from farms and producers are less tolerant of the intrusion
2 Disease
1 Loss from fishery production
1 Revenue shortfalls and/or windfall profits
1 Cost of water transport or transfer
1 Cost of new or supplemental water resource development
3 Health-related low-flow problems
2 Hydrological effects—
2 Reduced streamflow
2 Lower marsh levels
2 Increased groundwater depletion, land subsidence, reduced recharge
2 Water quality effects
2 Loss from impaired navigability
2 Lack of feed and drinking water
3 Increased conflicts—
3 Water user conflicts
3 Political-Administrative conflicts
3 Other social conflicts (e.g., scientific, media-based)
3 Recognition of institutional restraints on water use
3 Changes in lifestyle in rural areas
3 Public dissatisfaction with government drought response
3 Perceptions of inequity in relief, possibly related to socioeconomic status, ethnicity, age, gender, seniority
3 Loss of cultural sites
3 Population migrations
3 Disruption of cultural belief systems
3 Reevaluation of social values (e.g., priorities, needs, rights)

Appendix 4 Semi-structured interview form

CUESTIONARIO LA PARA TESIS DE MAESTRÍA:
"Assessment of ecological and socio-economic impacts of meteorological and hydrological drought in Colombian Mojana Region"

FORMULARIO DE ASOCIACIONES PRODUCTIVAS

UASLP Universidad Autónoma de San Luis Potosí
Technology Arts Sciences TH Köln

Confidencialidad: Los datos que se solicitan en este cuestionario son de uso académico, en ningún caso se emplearán con fines comerciales.

Fecha: ______ **Número form.:** ______
Lugar: ______

SECCIÓN I: IDENTIFICACIÓN DE LA ASOCIACIÓN PRODUCTIVA

1. Nombre: ______ **2. Fecha de conformación:** ______
3. Dirección sede principal: ______
4. Área en donde opera:
Departamento(s): ______ **Municipio(s):** ______ **Centro(s) poblados (s):** ______
Cabecera(s) municipal(es): ______ **Tierra(s) de comunidad(es) negra(s):** ______

SECCIÓN II: CARACTERIZACIÓN DE LA(S) ACTIVIDAD(ES) PRODUCTIVA(S)

5. ¿Cuáles de las siguientes actividades productivas busca favorecer esta asociación?:

a. Agricultura *(pregunta 6)* b. Ganadería *(pregunta 7)* c. Pesca *(pregunta 8)* d. Navegabilidad e. Turismo
f. Otra(s). ¿Cuáles?: ______

6. Descripción de la actividad agrícola:

6.1 ¿Cuáles cultivos y/o plantaciones fomenta esta asociación?

a. Cultivos permanentes. ¿Cuáles?: ______ b. Cultivos transitorios. ¿Cuáles?: ______
c.Plantaciones forestales. ¿Cuáles?: ______ e. Cultivos forrajeros y pastos. ¿Cuáles?: ______
d. Otro(s). ¿Cuáles?: ______

6.2 ¿En qué temporada se siembran y cosechan los cultivos que mencionó anteriormente? 1. Primer semestre; 2. Segundo semestre

a. Cultivos permanentes.	Siembra: ______	Cosecha: ______	b. Cultivos transitorios.	Siembra: ______	Cosecha:
	Siembra: ______	Cosecha: ______		Siembra: ______	Cosecha:
c.Plantaciones forestales.	Siembra: ______	Cosecha: ______	e. Cultivos forrajeros y pastc	Siembra: ______	Cosecha:
	Siembra: ______	Cosecha: ______		Siembra: ______	Cosecha:
d. Otro(s).	Siembra:	Cosecha:		Siembra:	Cosecha:

6.3 Mencione aproximadamente:

Número de socios que practican la agricultura: ______ Área sembrada: ______
Producción media anual: Cultivo: ______ Cantidad: ______ Unidad: ______
Cultivo: ______ Cantidad: ______ Unidad: ______
Cultivo: ______ Cantidad: ______ Unidad: ______
¿Se cuenta con registros históricos? Sí: No:

6.4 De acuerdo a los métodos empleados: ¿Qué tipo de agricultura se practica en los cultivos que mencionó anteriormente?

a. Tradicional b. Industrial c. Agroecológica d. Otra(s). ¿Cuál(es)?: ______
Cultivos: ______ Cultivos: ______ Cultivos: ______

6.5 El destino final de la producción es:

a. Autoconsumo b. Intercambio o trueque c. Venta a comercializador d. Venta a tienda o supermercado e. Venta a central de abastos
f. Venta a la industria g. Venta a mercado internacional h. Otro(s). ¿Cuál(es)?: ____________

6.6 ¿Cuáles son las fuentes de abastecimiento de agua para cultivar?:

a. Lluvia b. Río c. Aljíbe d. Ciénagas g. Otra(s). ¿Cuáles?: ____________

6.7 ¿Cuáles de los siguientes sistemas de riego utilizan?:

a. Asperción b. Goteo c. Gravedad d. Bombeo e. Manual f. Ninguna g. Otra(s). ¿Cuál(es)?: ____________

6.8 ¿Qué prácticas emplean para la conservación del agua y el suelo?

6.9 Califique: ¿Cuáles de los siguientes fenómenos naturales afectan más los cultivos? *Escala de 1 a 5, dónde 1 es el mínimo y 5 el máximo*

ı. Inundacione b. Heladas c. Sequías d. Lluvias a destiempo e. Incendios f. Plagas o enfermedades g. Otra(s). ¿Cuál(es)?: ____________

6.10 ¿Qué infraestructura de apoyo se tiene para el desarrollo de la actividad agrícola?

a. Centro de acopio b. Distrito de riego c. Planta trilladora h. Otro(s). ¿Cuál(es)?: ____________

6.11 ¿Cúal es la forma de tenencia de la tierra predominante entre los asociados dedicados a la agricultura?

a. Propia b. Arriendo c. Propiedad colectiva d. Aparcería e. Otra(s). ¿Cuál(es)?: ____________

7. Descripción de la actividad ganadera

7.1 ¿Qué tipo de ganado se cria?

a. Bovino b. Avicultura c. Porcino d. Acuicultura e. Otro(s). ¿Cuál(es)?: ____________

7.2 ¿Qué tipo de explotación se realiza?

a. Intensiva b. Extensiva c. Trashumante d. Nómada e. Otra(s). ¿Cuál(es)?: ____________
Ganado: ________ Ganado: ________ Ganado: ________ Ganado: ________ ____________

7.3 ¿Cúal es el propósito de la actividad ganadera?

a. Doble propósito b. Leche y sus derivados c. Carne d. Huevos e. Otro(s). ¿Cuál(es)?: ____________
Ganado: ________ Ganado: ________ Ganado: ________ Ganado: ________ ____________

7.4 Mencione aproximadamente:

Número de socios que practican la ganadería Área ocupada:
Producción media anual: Ganado: Actividad: Cantidad:
Ganado: Actividad: Cantidad:
¿Se cuenta con registros históricos? Sí: No: ¿Cuáles?:

7.5 ¿Cuáles son las fuentes de abastecimiento de agua para la ganadería?:

a. Lluvia b. Río c. Aljíbe d. Ciénagas g. Otra(s). ¿Cuáles?:

7.6 ¿Qué prácticas emplean para la conservación del agua y el suelo?

7.7 Califique: ¿Cuáles de los siguientes fenómenos naturales afectan más la actividad ganad Escala de 1 a 5, dónde 1 es el mínimo y 5 el máximo

. Inundacione b. Heladas c. Sequías d. Lluvias a destiempo e. Incendios f. Plagas o enfermedades g. Otra(s). ¿Cuál(es)?:

7.10 ¿Qué infraestructura de apoyo se tiene para el desarrollo de la actividad ganadera?

a. Silos b. Mataderos c. Fabricas de lácteos h. Otro(s). ¿Cuál(es)?:

7.11 ¿Cúal es la forma de tenencia de la tierra predominante entre los asociados dedicados a la ganadería?

a. Propia b. Arriendo c. Propiedad colectiva d. Aparcería e. Otra(s). ¿Cuál(es)?:

8. Descripción de la actividad pesquera

8.1 ¿En qué lugar se realiza la pesca?

a. Río b.Ciénaga c. Caño d. Quebrada e. Otro(s). ¿Cuál(es)?:
¿Cuál(es)?: ¿Cuál(es)?: ¿Cuál(es)?: ¿Cuál(es)?:

8.2 La pesca se realiza como una actividad:

a. Principal b. Complementaria c. Tenporal d. Ocasional e. Otro(s). ¿Cuál(es)?:
Época: Época: Época: Época: Época:

8.3 ¿Qué especies se extraen?

a. Peces b. Reptiles c. Mamíferos d. Otro(s):
¿Cuál(es)?: ¿Cuál(es)?: ¿Cuál(es)?: ¿Cuál(es)?:

8.4 ¿Cúal es el propósito de la pesca?

a. Autoconsumo	b. Comercial	c. Artesanal	e. Otro(s): ____
Especies: ____	Especies: ____	Especies: ____	Especies: ____

8.5 ¿Qué instrumento se utiliza para la pesca?

a. Arpón	b. Chinchorro	c. Trasmallo	d. Atarraya	e. Otra(s). ¿Cuál(es)?: ____
Época: ____	Época: ____	Época: ____	Época: ____	Época: ____
Especies: ____	Especies: ____	Especies: ____	Especies: ____	Especies: ____

8.6 Mencione aproximadamente:

Número de socios que practican la pesca: ____ Área ocupada: ____

Producción media anual:	Especie: ____	Cantidad: ____	Especie: ____	Cantidad: ____
	Especie: ____	Cantidad: ____	Especie: ____	Cantidad: ____
	Especie: ____	Cantidad: ____	Especie: ____	Cantidad: ____
	Especie: ____	Cantidad: ____	Especie: ____	Cantidad: ____

¿Se cuenta con registros históricos? Sí: No: ¿Cuáles?: ____

8.7 ¿Se aplican prácticas de conservación y manejo sostenible del recurso pesquero? Sí: No:

¿Cuál(es)?:

8.8 Califique: ¿Cuáles de los siguientes fenómenos naturales afectan más la pesca? *Escala de 1 a 5, dónde 1 es el mínimo y 5 el máximo*

ı. Inundacione b. Heladas c. Sequías d. Lluvias a destiempo e. Incendios f. Plagas o enfermedades g. Otra(s). ¿Cuál(es)?: ____

8.8 ¿Qué infraestructura de apoyo se tiene para el desarrollo de la actividad pesquera?

SECCIÓN III: IMPACTOS DE LA SEQUÍA

9. Generalidades de la sequía

9. 1 ¿Usted que entiende por sequía?: ____

9.2. ¿Qué tan frecuente es la sequía en su región?:

a. Muy frecuente (Entre 1 a 2 veces por año)	b. Medianamente frecuente (Cada 2 años)	c. Poco frecuente (Cada 4 años)	d. Se presenta muy raras veces (Mayor a 5 años)	e. Otro. ¿Cúal?: ____

9.3 ¿Cómo describiría las sequías que afectan la región?:

a. Extremas	b. Severas	c. Moderadas	d. Ligeras

9.4. ¿En cuáles actividades productivas se han percibido impactos por eventos de sequía?:

a. Agricultura *(pregunta 11)* b. Ganadería *(pregunta 12)* c. Pesca *(pregunta 13)* d. Navegabilidad *(pregunta 14)* e. Turismo *(pregunta 15)*
f. Otra(s). ¿Cuáles?: *(pregunta 16)*

11 Impactos en la agricultura

11.1 ¿Cuáles de los siguientes impactos han afectado a la actividad agrícola en la zona?

a. Disminución en el rendimiento de los cultivos	Sí:	No:	Cuándo:	Cultivos afectados:
b. Pérdida total o parcial de cultivos	Sí:	No:	Cuándo:	Cultivos afectados:
c. Cambio de actividad por parte de agricultores afectado	Sí:	No:	Cuándo:	Cultivos afectados:
d. Pérdidas económicas:	Sí:	No:	Cuándo:	Cultivos afectados:
e. Aumento de plagas y/o enfermedades	Sí:	No:	Cuándo:	Cultivos afectados:
f. Aumento en la frecuencia e intensidad de incendios	Sí:	No:	Cuándo:	Cultivos afectados:
g. Costos por la implementación de fuentes de abastecimiento alternas o suplementarias	Sí:	No:	Cuándo:	Cultivos afectados:
h. Pérdidas en otras actividades que dependen directamente de la agricultura	Sí:	No:	Cuándo:	Actividades agectadas:
i. Otros. ¿Cuáles?:				

11. Impactos en la ganaderia

11.1 ¿Cuáles de los siguientes impactos han afectado a la actividad ganadera en la zona?

a. Disminución en el rendimiento de los potreros	Sí:	No:	Cuándo:	Zonas afectadas:
b. Reducción en la producción de leche/carne/huevos/otr	Sí:	No:	Cuándo:	Zonas afectadas:
c. Cierre o limitaciones de tierras públicas para el pastor	Sí:	No:	Cuándo:	Zonas afectadas:
d. Falta de disponibilidad del agua para el ganado:	Sí:	No:	Cuándo:	Zonas afectadas:
e. Aumento de la mortandad del ganado	Sí:	No:	Cuándo:	Zonas afectadas:
f. Interrupción de los ciclos de reproducción (reproducción retrasada, más abortos espontáneos)	Sí:	No:	Cuándo:	Zonas afectadas:
g. Costos por la implementación de fuentes de abastecimiento alternas o suplementarias	Sí:	No:	Cuándo:	Zonas afectadas:
h. Otros. ¿Cuáles?:				

12. Impactos en la pesca

12.1 ¿Cuáles de los siguientes impactos han afectado a la actividad pesquera en la zona?

a. Degradación del hábitat de peces y fauna y flora en ger	Sí:	No:	Cuándo:	Especies afectadas:
b. Aumento del estrés de especies en peligro	Sí:	No:	Cuándo:	Especies afectadas:
c. Migración y/o concentración de la fauna	Sí:	No:	Cuándo:	Especies afectadas:
d. Pérdida de biodiversidad:	Sí:	No:	Cuándo:	Especies afectadas:
e. Disminución de la producción pesquera	Sí:	No:	Cuándo:	Especies afectadas:
f. Aparición de enfermedades	Sí:	No:	Cuándo:	Especies afectadas:
h. Otros. ¿Cuáles?:				

13. Impactos en la navegabilidad

13.1 ¿Cuáles de los siguientes impactos han afectado la navegabilidad en la zona?

a. Disminución en los niveles de los cuerpos de agua	Sí:	No:	Cuándo:	Zonas afectadas:
b. Pérdida de la navegabilidad	Sí:	No:	Cuándo:	Zonas afectadas:
c. Pérdidas económicas	Sí:	No:	Cuándo:	Zonas afectadas:
d. Incremento en los costos de transporte:	Sí:	No:	Cuándo:	Zonas afectadas:
e. Otros. ¿Cuáles?:				

14. Impactos en el turismo

14.1 ¿Cuáles de los siguientes impactos han afectado el turismo en la zona?

a. Pérdida de cobertura vegetal	Sí:	No:	Cuándo:	Zonas afectadas:
b. Aumento en la frecuencia de incendios	Sí:	No:	Cuándo:	Zonas afectadas:
c. Pérdida de la calidad visual del paisaje	Sí:	No:	Cuándo:	Zonas afectadas:
d. Disminución de la producción pesquera	Sí:	No:	Cuándo:	Zonas afectadas:
e. Otros. ¿Cuáles?:				

15. Impactos en otras actividades

15.1 ¿Qué impactos considera que se han evidenciado en otros sectores?

SECCIÓN IV: CAPACIDAD DE RESPUESTA Y ADAPTABILIDAD ANTE EVENTOS DE SEQUÍA

16. Organización para la gestión del riesgo

16.1 ¿Sabe usted si se cuenta con un sistema de gestión del riesgo en la zona? Sí: No:

¿Cómo se encuentra organizado?: ____________________

16.2 ¿Qué entidades reconoce usted en la gestión del riesgo por eventos de sequías o a quién ha acudido usted ante una sequía?

Califique su gestión (de 1 a

a. Alcaldía municipal ________

b. Consejo municipal de gestión del riesgo ________

c. Fondo de adaptación nacional al cambio ________

d. Programa de las Naciones Unidas para el desarrollo ________

e. Otras. ¿Cuáles?: ____________________

¿Cómo describiría su acción a. Preventiva b. Mitigativa c. Correctiva d. Otra. ¿Cuál?:

16.3 Califique de 1 a 5: ¿Cómo considera que es la organización comunitaria para hacer frente a los eventos de sequía?

¿Por qué?: ____________________

16.4 ¿Qué medidas de adaptación se han implementado para hacer frente ante nuevos eventos de sequía?

a. Sistemas de alerta temprana b. Recuperación sistema de canales Zenú c. Introducción de variedades de semillas resistentes a la sequía

d. Sistemas agroecológicos e. Otras.¿Cúales?: ____________________

¿Quién implementó estas medidas?: ____________________

OBSERVACIONES

Número de contacto: ____________________

Appendix 5 SPI results for averaging periods and climate type

2-month SPI	Wsa						Wsh						WH					
Year	**Jan-Feb**	**Mar-Apr**	**May-Jun**	**Jul-Aug**	**Sep-Oct**	**Nov-Dec**	**Jan-Feb**	**Mar-Apr**	**May-Jun**	**Jul-Aug**	**Sep-Oct**	**Nov-Dec**	**Jan-Feb**	**Mar-Apr**	**May-Jun**	**Jul-Aug**	**Sep-Oct**	**Nov-Dec**
1981	1.45	1.45	1.94	0.50	-0.75	1.03	1.70	1.49	2.29	0.48	-0.58	1.24	1.34	1.53	2.34	0.75	-0.90	1.40
1982	0.93	-0.17	-0.43	-0.12	2.09	-0.39	1.47	-0.27	-0.59	-0.18	1.64	-1.01	1.60	-0.02	-0.66	-0.94	0.92	-1.80
1983	0.20	-0.03	0.31	0.20	0.51	0.16	-0.08	-0.14	0.34	0.37	0.76	0.38	-0.22	-0.12	-0.47	0.45	1.21	0.48
1984	1.89	-1.43	0.28	0.56	1.41	-0.79	1.88	-1.69	0.21	0.67	0.54	-0.89	1.95	-0.83	0.54	0.54	0.82	-0.79
1985	-0.66	-2.83	-0.84	1.03	1.46	-0.07	-1.14	-2.63	-1.14	1.05	1.31	-0.26	-1.67	-2.79	-1.55	1.20	0.92	-0.36
1986	0.39	0.35	-0.59	-2.45	-0.19	-0.92	0.29	0.32	-1.32	-2.28	-0.12	-1.10	0.01	0.76	-1.13	-1.60	0.41	-1.05
1987	0.34	0.76	-1.66	1.32	0.05	0.48	0.54	0.70	-1.21	0.71	0.43	0.18	-0.35	0.38	-0.25	0.64	0.42	0.58
1988	-0.92	-0.79	-0.85	1.16	-0.95	1.36	-1.14	-1.53	-0.83	0.61	-1.16	1.14	-0.91	-1.72	0.51	-0.24	-1.14	1.00
1989	-0.19	-1.44	0.07	-0.31	1.51	0.17	0.32	-1.19	0.18	-0.41	1.27	-0.67	0.33	-1.18	-0.01	0.05	1.29	-0.46
1990	0.95	0.24	-0.51	-0.59	0.39	-0.28	0.88	0.56	-0.31	-0.53	-0.48	0.06	0.36	0.21	-0.59	-1.32	-1.92	-0.22
1991	-1.43	0.60	-0.44	-1.10	0.05	0.06	-1.11	0.22	-0.47	-1.12	-1.01	0.25	-0.91	0.13	-0.69	-1.00	-1.72	0.43
1992	-0.66	-0.83	0.30	1.16	-1.07	0.25	-1.22	-1.19	0.08	0.87	-1.60	0.01	-1.43	-1.00	0.00	0.27	-1.55	-0.21
1993	0.38	0.47	0.10	-0.41	-0.26	0.55	0.33	0.70	-0.03	-0.73	-0.24	0.22	0.47	0.67	-0.60	-0.68	0.35	0.03
1994	0.13	0.61	-0.47	-0.08	-0.50	-0.93	-0.65	0.33	-0.05	-0.19	-1.45	-0.54	-1.11	0.21	0.38	0.45	-0.95	-0.55
1995	-0.78	-0.34	-0.67	1.07	-0.13	0.08	-0.62	-0.76	-1.24	1.01	-0.38	0.05	-0.52	-1.10	-1.17	0.47	-0.94	0.26
1996	0.78	0.59	1.98	1.03	0.55	-0.34	1.17	0.66	0.97	1.31	0.77	-0.22	1.74	0.28	-0.47	0.79	-0.03	-0.39
1997	0.62	-1.18	-0.01	-1.99	-1.06	-1.22	0.39	-1.19	0.30	-2.00	-1.78	-1.40	0.39	-1.49	0.07	-1.95	-2.36	-1.03
1998	0.64	-0.75	2.47	0.49	-0.26	0.80	0.27	-0.44	2.19	0.64	-0.42	0.95	-0.12	-0.41	1.69	1.11	0.02	1.01
1999	2.11	0.51	-0.37	0.77	0.21	-0.14	2.13	0.78	0.67	0.57	0.04	0.22	2.06	1.22	1.65	0.54	-0.02	0.66
2000	0.21	-0.19	0.08	-0.61	-0.70	-0.21	0.91	-0.04	0.56	0.17	0.43	-0.35	1.27	0.17	1.28	0.78	1.19	-0.88
2001	-1.55	-1.51	-0.32	-1.35	0.37	0.94	-1.62	-1.11	-0.63	-1.63	-0.18	0.92	-1.42	-0.66	-0.23	-1.33	-0.33	0.57
2002	-1.46	0.38	-0.62	-1.80	-0.49	-0.90	-1.05	0.55	-1.38	-1.59	0.95	-1.18	-1.02	0.45	-2.01	-1.85	0.40	-1.20
2003	-0.54	0.05	-0.08	-0.74	-0.11	0.26	-0.58	0.40	-0.50	-0.54	-0.15	1.12	-0.53	0.32	-0.65	-0.23	0.20	1.33
2004	-0.90	-0.89	-0.09	-0.15	-2.31	-0.01	-1.28	-0.50	0.21	0.02	-0.63	-0.18	-1.08	-0.31	0.03	0.25	0.53	-0.30
2005	-1.60	0.67	-0.53	-0.17	-0.88	0.47	-0.99	1.11	0.43	0.29	-0.22	0.53	0.09	1.13	0.38	0.56	0.04	0.26
2006	0.09	1.35	0.81	-0.70	-0.45	0.10	0.39	1.07	0.79	-0.74	-0.18	0.73	0.44	0.67	0.69	-0.52	0.40	0.81
2007	-2.42	1.84	0.81	0.38	-0.59	0.82	-1.46	1.58	0.93	0.74	0.35	0.23	-1.06	1.22	0.40	0.43	0.27	-0.22
2008	-0.27	1.00	0.59	1.20	1.57	0.41	-0.22	0.60	0.30	1.36	2.35	0.15	0.14	0.35	0.16	1.50	0.75	0.15
2009	0.13	0.10	-0.56	0.90	-1.20	-0.66	0.27	-0.33	-1.29	0.76	-1.67	-1.20	0.62	-0.16	-1.09	1.27	-1.41	-0.65
2010	1.12	0.79	1.25	1.53	1.97	2.05	0.11	1.17	1.44	1.50	1.76	2.01	-0.24	1.32	1.61	1.41	1.54	2.23
2011	0.92	1.76	1.11	-0.06	-0.59	1.63	1.17	1.61	0.89	-0.15	-0.53	1.89	1.35	1.69	0.48	-0.17	0.29	1.59
2012	0.02	0.62	0.59	0.82	1.20	-0.54	0.12	0.85	0.67	0.95	0.84	-0.56	0.10	1.00	0.65	1.11	1.64	0.11
2013	-0.15	0.43	-0.14	0.04	-1.42	-0.46	-1.11	0.53	0.10	-0.17	-1.22	-0.16	-0.52	0.76	1.17	-0.46	-0.29	0.16
2014	0.49	-0.59	-1.74	0.46	0.12	0.13	-0.23	-0.57	-1.29	0.69	-0.78	0.78	-0.87	-0.31	-0.29	0.79	-0.36	0.79
2015	0.65	-1.04	-2.54	-1.68	0.94	0.23	0.82	-0.92	-2.18	-2.13	0.72	0.07	0.53	-0.99	-2.05	-2.07	-0.68	-0.61
2016	-0.92	-0.59	0.76	-0.34	-0.51	-4.11	-0.69	-0.73	0.92	-0.38	0.61	-3.40	-0.82	-1.39	-0.14	-1.00	0.97	-3.11

3-month SPI:	Wsa				Wsh				WH			
Year	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**
1981	1.27	2.19	0.12	1.03	1.48	2.38	0.03	1.32	1.38	2.34	-0.07	1.71
1982	0.09	-0.33	0.45	0.41	0.41	-0.38	0.65	-0.77	0.58	-0.20	-0.20	-1.66
1983	-0.41	0.34	0.30	0.21	-0.49	0.26	0.76	0.18	-0.39	-0.35	1.13	0.28
1984	0.76	-0.14	0.68	0.24	0.74	-0.43	0.70	-0.57	0.98	0.09	0.44	-0.13
1985	-1.07	-1.63	1.43	-0.03	-0.96	-2.06	1.27	0.27	-1.31	-2.44	1.16	0.10
1986	0.14	-0.33	-2.53	-0.25	-0.07	-0.66	-2.30	-0.58	-0.28	-0.05	-1.48	-0.50
1987	-0.36	-0.74	0.89	1.21	-0.18	-0.19	0.35	0.91	-0.71	0.22	0.39	0.99
1988	-2.18	-0.83	1.04	0.65	-2.16	-1.11	0.47	0.28	-1.95	-0.22	-0.25	0.30
1989	0.37	-0.72	-0.27	1.36	0.36	-0.61	-0.36	0.56	0.25	-0.78	0.08	0.47
1990	0.73	-0.42	-0.30	-0.50	1.07	-0.18	-0.62	-0.23	0.73	-0.57	-1.85	-0.82
1991	-0.95	-0.01	-1.19	0.40	-0.59	-0.21	-1.37	-0.14	-0.48	-0.41	-1.15	-0.47
1992	-1.68	0.11	0.99	-0.60	-2.22	-0.27	0.51	-1.01	-2.32	-0.29	-0.24	-0.82
1993	1.14	-0.09	-0.53	0.51	1.20	-0.09	-0.81	0.17	1.03	-0.34	-0.53	0.15
1994	1.07	-0.51	-0.04	-1.54	0.44	-0.15	-0.37	-1.64	0.07	0.12	0.29	-1.29
1995	-0.81	-0.67	0.94	-0.01	-0.70	-1.30	0.59	0.18	-0.62	-1.42	-0.27	0.36
1996	0.90	1.81	1.13	-0.36	1.33	0.77	1.41	-0.05	1.67	-0.56	0.56	-0.34
1997	-0.06	-0.41	-1.67	-2.36	-0.38	-0.22	-1.96	-2.72	-0.50	-0.52	-2.24	-2.17
1998	0.44	1.92	0.77	-0.35	0.37	1.34	0.76	0.16	0.20	0.79	1.15	0.73
1999	1.35	-0.08	0.56	0.30	1.57	0.85	0.26	0.55	1.77	1.69	0.53	0.48
2000	-0.02	-0.03	-0.63	-0.81	0.30	0.44	0.39	-0.48	0.73	0.97	1.22	-0.78
2001	-0.73	-0.93	-0.76	0.40	-0.49	-1.22	-1.22	0.48	-0.32	-0.77	-1.08	0.25
2002	-0.13	-0.47	-1.65	-1.16	-0.23	-0.70	-0.79	-1.02	-0.49	-0.96	-0.99	-1.50
2003	-0.59	-0.01	-0.46	-0.41	-0.52	-0.06	-0.39	0.80	-0.56	-0.15	-0.09	1.36
2004	-1.89	-0.25	-0.55	-1.19	-1.74	0.07	-0.28	-0.33	-1.61	0.03	0.10	0.18
2005	-1.30	0.01	-0.31	-0.10	-0.99	1.14	0.37	-0.01	-0.31	1.18	0.73	-0.19
2006	0.68	1.18	-0.91	0.13	0.83	1.00	-0.79	0.68	0.75	0.66	-0.34	0.93
2007	0.70	1.34	0.07	0.78	0.50	1.40	0.50	0.69	0.12	0.95	0.24	0.07
2008	0.75	0.73	1.29	1.26	0.36	0.39	1.58	1.58	0.38	0.17	1.14	0.85
2009	0.78	-0.74	0.71	-1.53	0.57	-1.41	0.36	-2.17	0.80	-1.17	0.85	-1.46
2010	1.03	1.28	1.94	2.49	0.36	1.66	1.96	2.44	0.22	1.85	1.65	2.88
2011	1.94	1.26	0.03	1.01	2.06	0.96	0.10	1.23	1.88	1.03	0.48	1.15
2012	0.19	0.72	1.00	-0.04	0.25	0.93	1.03	-0.15	0.43	0.96	1.49	0.53
2013	0.32	-0.06	-0.33	-0.98	0.00	0.21	-0.43	-0.89	0.47	0.98	-0.41	-0.14
2014	-0.37	-1.59	0.40	0.14	-0.74	-1.13	0.68	-0.11	-0.84	-0.33	0.97	0.05
2015	-0.17	-2.51	-1.78	1.42	-0.01	-1.96	-2.10	1.01	-0.12	-1.87	-1.96	-0.89
2016	-1.96	0.61	-0.84	-1.74	-1.73	0.56	-0.94	-0.63	-1.65	-0.60	-1.45	-0.66

4-month SPI	Wsa		Wsh		WH	
Year	**Apr-Jul**	**Aug-Nov**	**Apr-Jul**	**Aug-Nov**	**Apr-Jul**	**Aug-Nov**
1981	1.75	0.33	2.08	0.34	2.28	0.60
1982	0.08	0.55	-0.17	0.50	-0.26	-0.71
1983	0.44	0.05	0.45	0.24	-0.19	0.73
1984	0.42	0.57	0.31	0.10	0.56	0.27
1985	-0.78	1.42	-0.75	0.67	-0.89	0.06
1986	-1.02	-2.05	-1.29	-1.89	-0.74	-0.70
1987	0.57	0.54	0.40	0.37	0.36	0.73
1988	0.04	0.82	-0.39	0.08	0.02	-0.42
1989	-0.67	0.70	-0.42	0.07	-0.28	0.27
1990	-1.04	0.10	-0.80	-0.15	-1.06	-1.84
1991	-0.72	-0.16	-0.58	-1.00	-0.51	-1.16
1992	1.05	-0.20	0.73	-1.12	0.20	-1.30
1993	-0.44	0.04	-0.36	-0.35	-0.42	-0.04
1994	-0.86	-0.08	-0.84	-0.26	-0.37	0.39
1995	0.12	0.41	-0.12	-0.24	-0.25	-1.14
1996	1.57	0.99	0.76	1.45	-0.48	0.32
1997	-0.89	-2.45	-0.80	-2.99	-1.08	-2.57
1998	1.59	0.16	1.41	0.04	1.08	0.79
1999	0.51	-0.15	0.99	-0.41	1.61	-0.49
2000	-0.41	-1.09	0.37	-0.30	0.95	0.35
2001	-1.48	-0.22	-1.71	-0.81	-1.22	-1.05
2002	-0.76	-2.24	-0.76	-1.06	-1.20	-1.22
2003	-0.18	-0.53	-0.30	0.26	-0.14	0.50
2004	-0.36	-1.17	-0.17	-0.14	-0.13	0.64
2005	-0.08	-0.32	0.76	0.82	0.99	0.84
2006	0.44	-0.71	0.25	-0.25	0.09	0.37
2007	1.01	0.13	1.12	0.77	0.73	0.11
2008	1.26	1.55	1.24	2.15	1.01	1.22
2009	0.04	-0.41	-0.65	-1.14	-0.62	-0.20
2010	1.85	2.17	2.14	2.11	2.30	2.05
2011	0.97	0.22	0.94	0.24	1.13	0.52
2012	0.57	1.21	0.59	1.30	0.76	1.80
2013	-0.62	-0.33	-0.79	-0.03	-0.05	0.53
2014	-2.10	1.42	-1.60	1.31	-0.78	1.38
2015	-2.22	-0.80	-2.33	-0.77	-2.58	-1.47
2016	0.35	-0.50	0.28	0.11	-0.82	-0.17

SPI$_4$ (Dec-Mar)

Hydrological year	Wsa	Wsh	WH
1981 - 1982	0.48	0.52	0.76
1982 - 1983	-0.31	-0.42	-0.63
1983 - 1984	0.54	0.64	0.91
1984 - 1985	-0.76	-0.63	-0.92
1985 - 1986	0.28	0.38	0.42
1986 - 1987	-0.26	-0.13	-0.31
1987 - 1988	-0.47	-0.30	0.21
1988 - 1989	0.47	0.36	0.32
1989 - 1990	0.31	0.35	0.02
1990 - 1991	-0.14	-0.02	-0.03
1991 - 1992	-0.82	-0.66	-0.32
1992 - 1993	0.42	0.40	0.12
1993 - 1994	0.52	0.13	-0.31
1994 - 1995	-0.63	-0.53	-0.60
1995 - 1996	0.54	0.61	0.66
1996 - 1997	0.10	0.06	0.24
1997 - 1998	-0.10	-0.08	-0.48
1998 - 1999	0.96	0.86	0.91
1999 - 2000	0.43	0.61	1.03
2000 - 2001	0.19	0.30	0.18
2001 - 2002	0.47	0.46	0.55
2002 - 2003	-0.22	-0.37	-0.53
2003 - 2004	-0.70	-0.11	0.42
2004 - 2005	-0.38	-0.32	-0.11
2005 - 2006	0.28	0.21	0.04
2006 - 2007	0.60	0.59	0.45
2007 - 2008	0.74	0.44	0.38
2008 - 2009	0.25	0.05	-0.13
2009 - 2010	0.36	0.03	-0.13
2010 - 2011	1.35	1.22	1.08
2011 - 2012	0.56	0.54	0.58
2012 - 2013	0.22	0.14	0.22
2013 - 2014	0.03	-0.04	-0.03
2014 - 2015	0.07	0.24	0.36
2015 - 2016	-0.19	-0.14	-0.14

6-month SPI:	**Wsa**		**Wsh**		**WH**	
Year	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**	**Jan-Jun**	**Jul-Dec**
1981	2.21	0.46	2.42	0.62	2.32	0.84
1982	-0.31	0.49	-0.22	0.17	0.00	-0.92
1983	0.16	0.30	0.04	0.64	-0.46	0.87
1984	0.06	0.62	-0.13	0.29	0.41	0.21
1985	-1.73	1.18	-2.06	1.09	-2.45	0.82
1986	-0.29	-2.09	-0.62	-2.00	-0.18	-1.22
1987	-0.78	1.15	-0.26	0.65	-0.07	0.73
1988	-1.16	1.08	-1.47	0.46	-0.68	-0.04
1989	-0.56	0.30	-0.43	-0.04	-0.59	0.26
1990	-0.19	-0.46	0.22	-0.61	-0.21	-1.63
1991	-0.24	-0.81	-0.39	-1.12	-0.54	-1.01
1992	-0.23	0.63	-0.73	-0.04	-0.80	-0.57
1993	0.25	-0.26	0.35	-0.56	0.11	-0.29
1994	-0.12	-0.58	-0.03	-1.01	0.07	-0.41
1995	-0.82	0.76	-1.34	0.52	-1.42	-0.01
1996	1.77	0.82	1.07	1.08	0.32	0.20
1997	-0.42	-2.26	-0.34	-2.73	-0.63	-2.57
1998	1.75	0.50	1.18	0.64	0.65	1.10
1999	0.36	0.55	1.25	0.42	2.01	0.57
2000	-0.08	-0.84	0.41	0.07	0.98	0.48
2001	-1.03	-0.48	-1.22	-0.70	-0.78	-0.57
2002	-0.49	-1.81	-0.70	-1.09	-1.00	-1.41
2003	-0.18	-0.55	-0.25	0.06	-0.34	0.63
2004	-0.59	-0.91	-0.36	-0.40	-0.42	0.13
2005	-0.28	-0.32	0.70	0.26	0.84	0.39
2006	1.16	-0.70	1.05	-0.29	0.75	0.25
2007	1.31	0.33	1.27	0.67	0.76	0.17
2008	0.79	1.49	0.39	1.90	0.21	1.15
2009	-0.43	0.10	-0.98	-0.59	-0.62	-0.07
2010	1.35	2.49	1.44	2.58	1.54	2.53
2011	1.71	0.39	1.60	0.63	1.58	0.88
2012	0.63	0.81	0.80	0.73	0.87	1.24
2013	-0.01	-0.65	0.13	-0.75	0.90	-0.36
2014	-1.53	0.36	-1.21	0.46	-0.57	0.66
2015	-2.26	-0.75	-1.66	-1.00	-1.59	-1.73
2016	0.21	-1.34	0.08	-1.03	-0.97	-1.29

Appendix 6 ANOVA test for the estimation of variations among SPI results according to climate type

ANOVA SPI_{12}

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	0.00	0.00	1.03
Wsh	36	0.00	0.00	1.03
WH	36	0.00	0.00	1.03

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	7.84E-10	2.00E+00	3.92E-10	3.81E-10	1.00E+00	3.08E+00
Within the group	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI_6 (Jan-Jun)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	3.60E+01	1.63E-04	4.52E-06	1.03E+00
Wsh	3.60E+01	1.04E-04	2.90E-06	1.03E+00
WH	3.60E+01	1.22E-04	3.38E-06	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	4.97E-11	2.00E+00	2.49E-11	2.42E-11	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI_6 (Jul-Dec)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	3.60E+01	-4.09E-05	-1.14E-06	1.03E+00
Wsh	3.60E+01	-1.82E-04	-5.06E-06	1.03E+00
WH	3.60E+01	1.35E-04	3.75E-06	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	1.40E-09	2.00E+00	7.01E-10	6.82E-10	1.00E+00	3.08E+00
Within the group	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI_4 (Apr-Jul)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	-7.73E-05	-2.15E-06	1.03E+00
Wsh	36	-2.65E-04	-7.36E-06	1.03E+00
WH	36	1.17E-04	3.24E-06	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	2.02E-09	2.00E+00	1.01E-09	9.83E-10	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI_4 (Aug-Nov)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	-1.99E-04	-5.53E-06	1.03E+00
Wsh	36	-3.28E-04	-9.11E-06	1.03E+00
WH	36	-4.53E-05	-1.26E-06	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	1.11E-09	2.00E+00	5.56E-10	5.40E-10	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI_4 (Dec-Mar)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	35	5.18E+00	1.48E-01	2.47E-01
Wsh	35	5.37E+00	1.53E-01	1.86E-01
WH	35	5.19E+00	1.48E-01	2.46E-01

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	6.81E-04	2.00E+00	3.41E-04	1.50E-03	9.98E-01	3.09E+00
Within the groups	2.31E+01	1.02E+02	2.26E-01			
Total	2.31E+01	1.04E+02				

ANOVA SPI$_3$ (Jan-Mar)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	1.06E-05	2.94E-07	1.03E+00
Wsh	36	-2.82E-05	-7.84E-07	1.03E+00
WH	36	3.78E-06	1.05E-07	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	2.39E-11	2.00E+00	1.19E-11	1.16E-11	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI$_3$ (Apr-Jun)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	-2.79E-04	-7.75E-06	1.03E+00
Wsh	36	-1.92E-04	-5.34E-06	1.03E+00
WH	36	-1.17E-05	-3.26E-07	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	1.03E-09	2.00E+00	5.16E-10	5.01E-10	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI$_3$ (Jul-Sep)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	8.77E-05	2.44E-06	1.03E+00
Wsh	36	1.38E-05	3.83E-07	1.03E+00
WH	36	-1.35E-04	-3.75E-06	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	7.14E-10	2.00E+00	3.57E-10	3.47E-10	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

ANOVA SPI$_3$ (Oct-Dec)

SUMMARY

Group	Count	Sum	Average	Variance
Wsa	36	-1.08E-04	-3.01E-06	1.03E+00
Wsh	36	1.36E-05	3.76E-07	1.03E+00
WH	36	2.28E-05	6.33E-07	1.03E+00

ANOVA

Origin of variations	Sum of squares	Degrees of freedom	Average of squares	F	Probabilility	Critical value for F
Between groups	2.98E-10	2.00E+00	1.49E-10	1.45E-10	1.00E+00	3.08E+00
Within the groups	1.08E+02	1.05E+02	1.03E+00			
Total	1.08E+02	1.07E+02				

Appendix 7 CHIRPS precipitation results for the Montelibano station

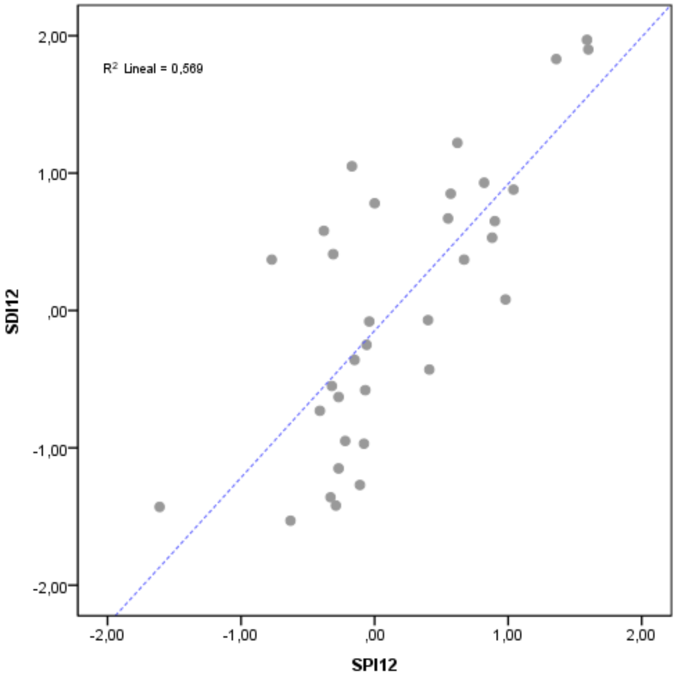
Hydrological year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1981 - 1982	320.07	498.00	354.67	422.67	339.00	359.47	284.65	240.53	170.78	50.83	86.63	47.27
1982 - 1983	386.54	416.85	333.79	452.04	354.28	401.47	404.47	200.88	97.33	26.30	40.84	73.85
1983 - 1984	240.87	392.26	363.53	407.83	380.62	360.50	364.74	310.99	259.90	44.31	139.60	47.92
1984 - 1985	132.57	277.89	347.52	422.34	430.46	393.60	401.45	267.57	81.82	18.78	58.94	69.40
1985 - 1986	133.41	342.50	419.84	437.60	385.52	400.62	325.08	210.31	100.20	49.39	49.62	100.66
1986 - 1987	298.69	273.62	416.14	292.94	286.73	294.58	410.77	213.48	107.88	62.76	52.71	34.51
1987 - 1988	271.24	360.83	247.58	407.36	429.83	297.15	421.31	259.52	142.16	20.05	44.16	36.87
1988 - 1989	166.29	310.82	346.77	450.79	444.90	347.38	372.06	366.79	134.32	83.75	48.90	72.95
1989 - 1990	169.38	368.08	296.28	386.29	302.33	390.47	361.82	214.07	102.82	109.07	79.28	129.38
1990 - 1991	212.87	378.40	298.42	318.37	390.03	283.39	365.17	379.63	117.67	23.68	23.68	99.29
1991 - 1992	194.83	347.76	347.76	306.31	337.23	349.93	340.92	316.38	79.56	42.23	22.81	24.65
1992 - 1993	156.03	361.76	270.44	422.69	355.51	330.80	320.88	240.88	143.88	121.80	26.48	116.87
1993 - 1994	250.35	372.68	333.29	437.65	271.25	401.47	404.47	402.40	162.44	35.14	37.58	101.54
1994 - 1995	211.98	400.76	312.83	305.75	448.52	312.86	314.70	305.05	80.31	43.30	15.18	60.66
1995 - 1996	234.13	364.25	430.68	450.06	349.90	303.91	444.40	160.39	151.23	88.73	111.19	169.43
1996 - 1997	244.56	416.85	430.58	454.91	478.27	443.10	329.40	227.98	124.26	34.51	142.08	30.82
1997 - 1998	222.40	367.12	360.26	328.17	315.85	295.73	337.64	260.34	51.39	19.21	74.93	75.08
1998 - 1999	181.26	422.43	305.31	438.34	354.05	319.11	308.39	246.10	278.05	71.90	193.05	147.62
1999 - 2000	333.07	325.32	367.01	420.52	419.63	338.08	464.26	199.07	211.72	37.40	79.47	44.04
2000 - 2001	192.99	347.38	337.35	408.19	355.50	356.33	335.41	136.67	163.03	55.94	27.44	99.79
2001 - 2002	193.90	296.94	306.30	268.05	357.59	308.23	361.69	326.09	162.46	33.57	40.91	114.82
2002 - 2003	251.79	380.37	359.78	354.51	337.98	327.48	319.58	283.46	123.17	123.17	47.16	71.97
2003 - 2004	302.58	385.57	393.21	311.70	351.06	316.54	321.67	368.56	199.14	45.15	20.54	45.25
2004 - 2005	222.13	442.41	374.22	320.67	365.37	402.52	302.67	330.67	95.09	62.53	15.68	91.04
2005 - 2006	289.22	411.82	491.07	379.40	367.79	359.40	475.58	375.40	92.00	59.76	54.19	191.49
2006 - 2007	240.50	461.75	350.89	421.67	382.05	340.94	299.86	284.79	150.95	29.78	17.84	153.70
2007 - 2008	267.43	374.40	426.68	319.57	474.07	361.71	424.26	256.67	110.01	48.70	67.94	76.06
2008 - 2009	235.78	341.94	392.84	433.59	386.88	385.89	448.58	279.27	74.66	77.27	70.49	151.98
2009 - 2010	194.35	383.60	365.33	347.02	291.48	244.13	317.56	271.88	85.20	19.90	35.18	132.52
2010 - 2011	269.87	360.58	417.59	443.71	472.96	447.76	331.40	309.30	248.87	59.36	69.50	136.45
2011 - 2012	246.26	515.00	426.05	448.72	448.72	389.34	281.48	326.27	213.33	39.27	27.21	165.61
2012 - 2013	339.99	307.26	355.66	374.68	398.39	322.56	367.87	257.56	94.99	15.47	30.76	156.15
2013 - 2014	215.17	297.20	316.44	335.08	403.27	337.86	311.27	230.96	129.90	51.32	35.72	59.42
2014 - 2015	287.79	268.02	377.40	318.38	472.11	362.93	382.92	344.99	155.47	61.66	57.77	44.37
2015 - 2016	249.60	368.21	312.12	369.37	341.51	345.18	412.32	413.93	224.07			

Appendix 8 River discharge data for the Montelibano station

Hydrological year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1981 - 1982	153.8	292.6	330.1	379.3	337.6	407.9	336.9	342.6	126.7	161.1	116	57.5
1982 - 1983	254.8	270.6	229.2	290.9	186.5	190.9	290.9	189.3	100.5	74.7	53	36
1983 - 1984	194	207.4	259.4	257.6	228.2	240.1	210.2	235.4	131.6	183.5	85.7	61.94
1984 - 1985	48.54	124.1	205.8	309.5	348.8	470.9	332.4	237.9	176.8	33.46	34.11	34.24
1985 - 1986	65.5	124.5	270.7	265.4	294	349.1	352.3	215.2	141	89.04	80.9	54.82
1986 - 1987	255.6	217.9	292.1	277.1	176	168.4	367.1	200.8	95.96	137.8	109.3	31.7
1987 - 1988	130.9	277.2	260.8	273.3	320.5	239	385.3	307.9	224.4	110.2	85.9	67.5
1988 - 1989	244	356.3	265.9	346.7	365.8	309.7	222.1	129.7	74.5	89.13		
1989 - 1990	79.45	223.2	244.1	300.4	277.3	303	266.4	181.7	144.9	64.4	65.46	54.62
1990 - 1991	82.83	317.6	196.2	203.1	265.3	207.1	272.3	327.9	164.9	65.19	51.27	76.88
1991 - 1992	81.43	223.1	283.4	246.9	277.1	276.9	295.3	255.5	161.6	53.1	50.9	14.7
1992 - 1993	22.7	243.1	208.3	249	307.3	277.2	282.1	179.1	139.9	114.6	80.1	46
1993 - 1994	168.4	322	227.4	400.3	222.7	252	309.3	413.3	333.8	63.7	31.7	40.8
1994 - 1995	96.3	295.6	228.3	229.2	365.2	293	332.7	332.2	96.7	34.12	22.72	21.37
1995 - 1996	110	213.1	365	406.4	330.9	294.2	452.4	202.3	157.3	75.34	65.06	125.5
1996 - 1997	132	297.3	382.2	527.4	376.4	408	285.8	177.6	91.74	41.31	74.15	47.64
1997 - 1998	64.84	163	281.9	238.7	185.1	194		279.6	94.71	43.29	63.13	44.24
1998 - 1999	126.3	331.7	381.6	446.6	341	345.4	289.8	271.8	260.4	102.1	133	147.7
1999 - 2000	306.6	397.1	393.6	425.6							99.25	90.23
2000 - 2001	79.06	244.5	278.5	356.7	277.4	250.1	293.8	163.7	129.2	69.97	44.66	77.19
2001 - 2002	59.24	278.5	216	141.1	205.2	229.9	399.1	484	169.8	82.56		67.7
2002 - 2003	243.7	251.8	427.6	306.1	263.6	260.6	218.9	208	101.8	36.36	23.51	23.35
2003 - 2004	179.5	340.1	348.2	323.2	327.7	371.6	367.3	471.8	271	64	30.65	31.04
2004 - 2005	84.27	284.6	404.7	228.7	303.6	375.6	327.4	380.3	123.3	68.5	55.08	37.63
2005 - 2006	168.6	366	529.8	405.3	403.6	381.2	538.9	545.3	134	67.14	55.36	106.7
2006 - 2007	218.6	529.4	378.8	379.8	317.1	301.6	253.6	215.7	145.6	52.82	20.89	58.96
2007 - 2008	158.3	308.9	467.1	315.1	419.2	340.6	502.9	296.5	95.45	56.21	49.18	48.85
2008 - 2009	128.5	259.2	338.6	408.6	345.1	360.7	489	278.1	121.1	67.12	60.49	136.3
2009 - 2010	161.1	333.2	320.8	211.9	189.9	146	167.5	207.8	77.55	47.41	41.52	119.5
2010 - 2011	155.6	321.8	386.5	384.2	586.5	618.1	422.9	223	354.5	95.04	55.16	85.94
2011 - 2012	230.2	423.3	484.5	524.8	397.1	388.2	246.6	315	247.4	81.28	51.62	72.8
2012 - 2013	332.5	291	256.8	249.7	383.4	298.7	221	195.5	83.44		37.77	127.2
2013 - 2014	150.5	212.2	193	238.1	300.3	388.4	231.7	181.1	151	60.78	45.01	45.94
2014 - 2015	66.18	118.1	267.7	125.8	217.8	292.3	301	261.9	152.2	49.84	58.27	37.62
2015 - 2016	84.91	110.9	188.6	172.9	138	108.6	225.5	181.9	135.1			

Appendix 9 SPI_{12} and SDI_{12} results for the Montelibano station

Annual SPI:		
Hydrological year	**SPI_{12}**	**SDI_{12}**
1981 - 1982	0.53	0.88
1982 - 1983	0.58	-0.38
1983 - 1984	1.05	-0.17
1984 - 1985	-0.58	-0.07
1985 - 1986	-0.36	-0.15
1986 - 1987	-1.27	-0.11
1987 - 1988	-0.43	0.41
1988 - 1989	0.41	-0.31
1989 - 1990	-0.55	-0.32
1990 - 1991	-0.63	-0.27
1991 - 1992	-1.42	-0.29
1992 - 1993	-0.73	-0.41
1993 - 1994	0.67	0.55
1994 - 1995	-0.97	-0.08
1995 - 1996	0.85	0.57
1996 - 1997	1.22	0.62
1997 - 1998	-1.43	-1.61
1998 - 1999	0.88	1.04
1999 - 2000	0.78	
2000 - 2001	-0.95	-0.22
2001 - 2002	-1.15	-0.27
2002 - 2003	-0.25	-0.06
2003 - 2004	0.08	0.98
2004 - 2005	-0.07	0.40
2005 - 2006	1.90	1.60
2006 - 2007	0.37	0.67
2007 - 2008	0.65	0.90
2008 - 2009	0.93	0.82
2009 - 2010	-1.53	-0.63
2010 - 2011	1.97	1.59
2011 - 2012	1.83	1.36
2012 - 2013	-0.08	-0.04
2013 - 2014	-1.36	-0.33
2014 - 2015	0.37	-0.77



Correlations

		SDI_{12}	**SPI_{12}**
Correlación de Pearson	SDI12	1.000	.754
	SPI12	.754	1.000
Sig. (unilateral)	SDI12	.	.000
	SPI12	.000	.
N	SDI12	34	34
	SPI12	34	34

Model resume

Modelo	**R**	**R cuadrado**	**R cuadrado corregida**	**Error típ. de la estimación**	**Estadísticos de cambio**				
					Cambio en R cuadrado	**Cambio en F**	**gl1**	**gl2**	**Sig. Cambio en F**
1	.754[a]	.569	.555	.66959	.569	42.217	1	32	.000

a. Variables predictoras: (Constante). SPI12

ANOVA[b]

Modelo		**Suma de cuadrados**	**gl**	**Media cuadrática**	**F**	**Sig.**
1	Regresión	18.928	1	18.928	42.217	.000[a]
	Residual	14.347	32	.448		
	Total	33.275	33			

a. Variables predictoras: (Constante), SPI12

b. Variable dependiente: SDI12

Appendix 10 $SDI_{2,3,4,6,\text{ and }12}$ results for the Montelibano station

	2-month SDI					
Hydrological year	**Apr-May**	**Jun-Jul**	**Aug-Sep**	**Oct-Nov**	**Dec-Jan**	**Feb-Mar**
1981 - 1982	0.34	0.64	0.39	0.36	0.48	0.59
1982 - 1983	0.77	-0.51	-0.22	0.05	0.10	0.11
1983 - 1984	0.05	-0.53	-0.03	-0.02	0.55	0.47
1984 - 1985	-2.19	-0.54	0.48	0.20	0.24	-0.08
1985 - 1986	-1.94	-0.40	0.26	0.20	0.31	0.41
1986 - 1987	0.50	-0.17	-0.31	0.20	0.32	0.44
1987 - 1988	0.10	-0.41	0.13	0.38	0.59	0.50
1988 - 1989	1.13	0.10	0.30	-0.24	0.05	
1989 - 1990	-0.70	-0.34	0.17	-0.02	0.24	0.33
1990 - 1991	0.05	-1.49	-0.02	0.25	0.31	0.37
1991 - 1992	-0.68	-0.44	0.12	0.17	0.26	-0.11
1992 - 1993	-1.04	-0.99	0.17	0.01	0.39	0.36
1993 - 1994	0.59	0.19	-0.02	0.42	0.73	-0.04
1994 - 1995	-0.01	-0.98	0.28	0.34	-0.12	-0.40
1995 - 1996	-0.52	0.96	0.23	0.33	0.32	0.66
1996 - 1997	0.23	1.57	0.44	0.02	-0.11	0.34
1997 - 1998	-1.45	-0.50	-0.22	-0.84	-0.08	0.25
1998 - 1999	0.41	1.22	0.32	0.19	0.66	0.94
1999 - 2000	1.55	1.18				0.65
2000 - 2001	-0.52	0.23	0.08	0.00	0.20	0.34
2001 - 2002	-0.41	-1.90	-0.10	0.60	0.38	
2002 - 2003	0.62	0.77	0.07	-0.06	-0.08	-0.35
2003 - 2004	0.74	0.44	0.33	0.56	0.60	-0.15
2004 - 2005	-0.17	0.22	0.31	0.40	0.17	0.14
2005 - 2006	0.82	1.67	0.44	0.79	0.21	0.54
2006 - 2007	1.71	0.89	0.22	0.03	0.20	0.03
2007 - 2008	0.46	1.01	0.41	0.51	-0.01	0.18
2008 - 2009	-0.04	0.84	0.34	0.47	0.16	0.68
2009 - 2010	0.61	-0.42	-0.33	-0.18	-0.15	0.54
2010 - 2011	0.52	0.95	0.83	0.32	0.82	0.44
2011 - 2012	1.35	1.95	0.44	0.19	0.58	0.35
2012 - 2013	1.23	-0.61	0.31	-0.08		0.55
2013 - 2014	-0.22	-1.21	0.32	-0.09	0.25	0.13
2014 - 2015	-2.02	-1.54	0.05	0.19	0.21	0.16
2015 - 2016	-1.86	-1.86	-0.61	-0.10		

	3-month SDI:			
Hydrological year	**Apr-Jun**	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**
1981 - 1982	0.36	0.80	0.30	0.77
1982 - 1983	0.26	-0.66	0.01	0.21
1983 - 1984	-0.20	-0.43	0.00	0.77
1984 - 1985	-2.12	0.81	0.23	-0.16
1985 - 1986	-1.44	0.20	0.18	0.46
1986 - 1987	0.31	-0.87	0.12	0.63
1987 - 1988	-0.15	-0.04	0.41	0.59
1988 - 1989	0.74	0.53	-0.27	
1989 - 1990	-0.85	0.11	0.02	0.31
1990 - 1991	-0.55	-0.63	0.25	0.34
1991 - 1992	-0.60	-0.15	0.19	-0.04
1992 - 1993	-1.34	-0.04	0.04	0.52
1993 - 1994	0.09	0.09	0.54	0.07
1994 - 1995	-0.41	0.13	0.25	-0.37
1995 - 1996	-0.06	0.56	0.30	0.59
1996 - 1997	0.51	1.23	-0.03	0.21
1997 - 1998	-1.09	-0.89	-0.65	0.15
1998 - 1999	0.63	0.82	0.31	0.88
1999 - 2000	1.56			-0.25
2000 - 2001	-0.52	0.12	0.02	0.34
2001 - 2002	-0.81	-1.08	0.53	-0.70
2002 - 2003	0.96	-0.05	-0.08	-0.32
2003 - 2004	0.75	0.53	0.58	0.01
2004 - 2005	0.35	0.20	0.32	0.20
2005 - 2006	1.45	0.96	0.66	0.48
2006 - 2007	1.65	0.47	0.06	0.05
2007 - 2008	1.00	0.67	0.39	0.17
2008 - 2009	0.13	0.78	0.38	0.59
2009 - 2010	0.53	-1.22	-0.21	0.40
2010 - 2011	0.73	1.77	0.49	0.50
2011 - 2012	1.68	1.23	0.30	0.39
2012 - 2013	0.80	0.27	-0.13	-0.50
2013 - 2014	-0.79	0.26	-0.02	0.15
2014 - 2015	-1.51	-0.80	0.19	0.12
2015 - 2016	-2.07	-1.98	-0.05	

4-month SDI			
Hydrological year	**Apr-Jul**	**Aug-Nov**	**Dec-Mar**
1981 - 1982	0.53	0.35	0.51
1982 - 1983	0.16	-0.07	0.17
1983 - 1984	-0.32	-0.02	0.51
1984 - 1985	-1.38	0.33	0.20
1985 - 1986	-1.18	0.22	0.37
1986 - 1987	0.15	-0.02	0.38
1987 - 1988	-0.22	0.24	0.54
1988 - 1989	0.70	0.08	
1989 - 1990	-0.61	0.08	0.31
1990 - 1991	-0.82	0.12	0.36
1991 - 1992	-0.67	0.14	0.21
1992 - 1993	-1.19	0.09	0.39
1993 - 1994	0.41	0.21	0.52
1994 - 1995	-0.60	0.29	-0.08
1995 - 1996	0.33	0.26	0.46
1996 - 1997	1.07	0.24	0.15
1997 - 1998	-1.07	-0.43	0.13
1998 - 1999	0.92	0.24	0.71
1999 - 2000	1.54		
2000 - 2001	-0.16	0.04	0.29
2001 - 2002	-1.34	0.29	0.06
2002 - 2003	0.75	0.02	-0.04
2003 - 2004	0.64	0.42	0.42
2004 - 2005	0.00	0.33	0.22
2005 - 2006	1.41	0.58	0.37
2006 - 2007	1.50	0.13	0.20
2007 - 2008	0.81	0.43	0.14
2008 - 2009	0.46	0.38	0.40
2009 - 2010	0.09	-0.23	0.22
2010 - 2011	0.81	0.57	0.66
2011 - 2012	1.86	0.30	0.50
2012 - 2013	0.44	0.14	-0.17
2013 - 2014	-0.85	0.14	0.25
2014 - 2015	-2.02	0.12	0.25
2015 - 2016	-2.15	-0.30	

6-month SDI		
Hydrological year	**Apr-Sep**	**Oct-Mar**
1981 - 1982	0.78	0.42
1982 - 1983	-0.43	0.06
1983 - 1984	-0.53	0.23
1984 - 1985	-0.19	0.17
1985 - 1986	-0.59	0.25
1986 - 1987	-0.53	0.26
1987 - 1988	-0.20	0.45
1988 - 1989	0.75	-0.66
1989 - 1990	-0.41	0.10
1990 - 1991	-0.89	0.27
1991 - 1992	-0.53	0.15
1992 - 1993	-0.78	0.16
1993 - 1994	0.04	0.46
1994 - 1995	-0.19	0.16
1995 - 1996	0.36	0.37
1996 - 1997	1.24	0.03
1997 - 1998	-1.39	-0.41
1998 - 1999	0.93	0.47
1999 - 2000	-0.72	
2000 - 2001	-0.24	0.10
2001 - 2002	-1.39	0.39
2002 - 2003	0.44	-0.11
2003 - 2004	0.76	0.49
2004 - 2005	0.27	0.30
2005 - 2006	1.49	0.62
2006 - 2007	1.24	0.06
2007 - 2008	1.01	0.35
2008 - 2009	0.65	0.43
2009 - 2010	-0.61	-0.04
2010 - 2011	1.84	0.49
2011 - 2012	1.83	0.32
2012 - 2013	0.58	-0.17
2013 - 2014	-0.26	0.03
2014 - 2015	-1.54	0.18
2015 - 2016	-2.80	-0.88

Appendix 11 Semi-structured interview, drought results

Section II-questions 6.9, 7.7, and 8.8

Crop cultivation

Natural hazard	Peasant and Producers Association of El Paso de Carate	Association of Fishermen and Farming Producers of Las Flores	Association of Fish Farmers and Agricultural Farmers of Seheve	National Association of Peasant Users of Colombia	Association of Fish Farmers and Field Producers of Calle Larga	Association of Small Ecological Producers of Mangoes, Fruits, Vegetables and Tubercles of Ayapel	Average
Floods	1.00	5.00	5.00	2.50	1.00	1.00	2.58
Droughts	2.00	4.00	5.00	3.00	4.00	3.00	3.50
Untimely rains	2.50	3.00	5.00	2.00	5.00	4.00	3.58
Fires	3.00	3.00	1.00	1.00	1.00	2.00	1.83
Pests or diseases	4.00	3.00	5.00	3.00	1.00	2.00	3.00

Fishing

Natural hazard	Peasant and Producers Association of El Paso de Carate	Association of Fishermen and Farming Producers of Las Flores	Association of Fishermen Producers of San Jorge and La Mojana	Association of Small Agricultural Producers and Fishermen of Ayapel	Association of Fish Farmers and Agricultural Farmers of Seheve	Average
Floods	1.00	1.00	5.00	3.00	5.00	3.00
Droughts	5.00	5.00	3.00	2.00	2.00	3.40
Untimely rains	1.00	4.00	4.00	3.00	2.00	2.80
Pests or diseases	1.00	1.00	1.00	1.00	1.00	1.00

Livestock

Natural hazard	Association of Agricultural Producers of San Marcos
Floods	3.50
Droughts	4.50
Untimely rains	1.50
Fires	3.00
Pests or diseases	2.50

Section III - questions 9.2 and 9.3

Livelihood source	**Farmers Partnership**	**Drought frequency**	**Drought severity**
Fishing	Association of Fishermen Producers of San Jorge and La Mojana	Fairly common (every 2 years)	Moderate
	Association of Small Agricultural Producers and Fishermen of Ayapel	Fairly common (every 2 years)	Severe
Livestock	Association of Agricultural Producers of San Marcos	Very frequent (Between 1 to 2 times per year)	Extreme
Agriculture	Association of Small Ecological Producers of Mangoes, Fruits, Vegetables and Tubercles of Ayapel	Very rare (more than 5 years)	Extreme
	Association of Fish Farmers and Field Producers of Calle Larga	Very frequent (Between 1 to 2 times per year)	Moderate
Agriculture-Livestock	National Association of Peasant Users of Colombia	Very frequent (Between 1 to 2 times per year)	Severe
Fishing-Agriculture	Peasant and Producers Association of El Paso de Carate	Very frequent (Between 1 to 2 times per year)	Severe
	Association of Fishermen and Farming Producers of Las Flores	Fairly common (every 2 years)	Severe
	Association of Fish Farmers and Agricultural Farmers of Seheve	Uncommon (every 3 to 4 years)	Severe

* Frequency in the last years, aproximately since 2014

Section III - question 10.1

Drought impacts on crop cultivation	Productive partnership																	
	Peasant and Producers Association of El Paso de Carate			Association of Fishermen and Farming Producers of Las Flores			Association of Fish Farmers and Agricultural Farmers of Seheve			National Association of Peasant Users of Colombia			Association of Fish Farmers and Field Producers of Calle Larga			Association of Small Ecological Producers of Mangoes, Fruits, Vegetables and Tubercles of Ayapel		
	Yes	No	Year	Yes	No	Year	Yes	No	Year	Yes	No	Year	Yes	No	Year	Yes	No	Year
Total or partial loss of crops	x		2014	x		2014	x			x		2014	x		2014	x		2015
Decreasing crop yields	x		2014	x		2014	x			x		2014	x		2014	x		2015
Income loss of growers	x		2014	x		2014	x			x		2014	x		2014	x		2015
Fewer agricultural producers (due to change of income sources)	x		2014		x			x		x		2014	x		2015-2016		x	
Insect infestation or plant diseases outbreak		x		x			x			x		2014	x	x	2014	x		2015
Increased number and severity of fires	x		2014	x		2018		x		x		2014		x		x		2015
Cost of new or supplemental water resource development (wells, dams, pipelines)		x			x			x			x			x			x	
Loss to industries directly dependent on agricultural production		x			x			x			x					x		2015
Affected crops:	Rice and corn			Rice and corn			Rice and corn			Rices, casava and corn			Corn and casava			Mango		
Others	Increase of the uncertainty in the grower's decisions regarding new cultivation seasons. Decrease of the sown area in the next cultivation seasons.						Decrease of the sown area in the next cultivation seasons. Increased demand for food purchased in the urban area Increase of debts									Decrease of mango quality		

Section III - question 11.1

Drought impacts on fishing	Productive partnership														
	Peasant and Producers Association of El Paso de Carate			Association of Fishermen and Farming Producers of Las Flores			Association of Fish Farmers and Agricultural Farmers of Seheve			Association of Fishermen Producers of San Jorge and La Mojana			Association of Small Agricultural Producers and Fishermen of Ayapel		
	Yes	No	Year	Yes	No	Year	Yes	No	Year	Yes	No	Year	Yes	No	Year
Reduction and degradation of fish and wildlife habitat	x			x			x		2014-2015	x			x		
Increased stress to endangered species	x			x			x		2014-2015	x			x		
Migration and concentration (loss of wildlife in some areas and too many wildlife in other areas)		x		x			x		2014-2015		x		x		
Loss of biodiversity	x			x			x		2014-2015	x			x		
Loss from fishery production	x			x			x			x		2015-2016	x		
Disease		x			x			x			x			x	
Other:	Increased vulnerability to predation (from species concentrated near water) Increased level of exposure of the fish species to captures														

Section III - question 12.1

Drought impacts on livestock	Productive partnership					
	Association of Agricultural Producers of San Marcos			National Association of Peasant Users of Colombia		
	Yes	No	Year	Yes	No	Year
Reduced productivity of rangeland	x		since 2008	x		since 2014
Reduced dairy or meat production	x		since 2008	x		since 2014
Closure/limitation of public lands to grazing	x				x	since 2014
Unavailability of water for livestock	x		since 2013	x		since 2014
Increased livestock mortality rates	x		since 2010	x		since 2014
Disruption of reproduction cycles (delayed breeding, more miscarriages)	x		since 2008	x		since 2014
Cost of new or supplemental water resource development (wells, dams, pipelines)	x		since 2008		x	
Others:	Decreased stock weights Increased cost/unavailability of feed for livestock					

Appendix 12 Landed weight Prochilodus magdalenae (1981-2015) – Magdalena basin

Landed weight *Prochilodus magdalenae* per month (1981-2015) - Magdalena basin

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Information source
1981	**3743.12**	**3198.42**	**2401.95**	**1992.42**	**1678.60**	**1243.58**	**1437.27**	**1847.62**	**1751.57**	**1849.17**	**2104.04**	**3545.24**	26793.00	Lasso et al. (2011)
1982	**2665.02**	**2277.20**	**1710.14**	**1418.56**	**1195.12**	**885.40**	**1023.30**	**1315.46**	**1247.07**	**1316.56**	**1498.03**	**2524.13**	19076.00	
1983	**2362.13**	**2018.40**	**1515.78**	**1257.34**	**1059.30**	**784.78**	**907.00**	**1165.96**	**1105.34**	**1166.93**	**1327.78**	**2237.26**	16908.00	
1984	**4060.25**	**3469.40**	**2605.46**	**2161.23**	**1820.82**	**1348.94**	**1559.04**	**2004.16**	**1899.97**	**2005.83**	**2282.31**	**3845.60**	29063.00	
1985	**3440.66**	**2939.97**	**2207.87**	**1831.43**	**1542.96**	**1143.10**	**1321.13**	**1698.32**	**1610.03**	**1699.74**	**1934.03**	**3258.77**	24628.00	
1986	**3981.74**	**3402.31**	**2555.07**	**2119.44**	**1785.61**	**1322.86**	**1528.89**	**1965.40**	**1863.23**	**1967.05**	**2238.17**	**3771.24**	28501.00	
1987	**4034.69**	**3447.56**	**2589.05**	**2147.62**	**1809.35**	**1340.45**	**1549.22**	**1991.54**	**1888.00**	**1993.20**	**2267.94**	**3821.39**	28880.00	
1988	**4416.22**	**3773.57**	**2833.88**	**2350.71**	**1980.45**	**1467.21**	**1695.72**	**2179.86**	**2066.54**	**2181.69**	**2482.40**	**4182.75**	31611.00	
1989	**2472.78**	**2112.94**	**1586.78**	**1316.24**	**1108.92**	**821.54**	**949.49**	**1220.58**	**1157.12**	**1221.60**	**1389.97**	**2342.06**	17700.00	
1990	**2725.23**	**2328.65**	**1748.78**	**1450.61**	**1222.13**	**905.41**	**1046.42**	**1345.18**	**1275.25**	**1346.31**	**1531.88**	**2581.16**	19507.00	
1991	2048.92	1750.76	1314.79	1090.62	918.83	680.71	786.73	1011.35	958.78	1012.20	1151.72	1940.60	14666.00	*Instituto Nacional de Pesca y Acuicultura* - INPA
1992	2193.37	1874.19	1407.48	1167.51	983.62	728.71	842.20	1082.66	1026.37	1083.56	1232.92	2077.42	15700.00	
1993	1645.46	1041.69	1726.45	1260.10	617.53	262.81	215.91	612.34	407.63	560.81	351.27	1626.53	10328.53	
1994	527.65	452.70	376.21	703.99	498.41	467.51	528.62	640.43	633.81	466.50	322.79	439.20	6057.82	
1995	412.91	400.64	262.84	94.84	159.08	108.75	159.39	121.55	149.34	265.68	241.03	487.23	2863.28	
1996	482.33	415.14	263.97	120.00	259.01	129.26	107.06	164.76	319.90	233.74	492.74	463.53	3451.45	
1997	624.76	663.70	237.41	143.45	283.27	199.45	164.16	195.70	206.81	81.67	67.85	141.24	3009.47	
1998	360.00	880.00	740.00	600.00	185.04	20.03	31.43	169.75	224.67	313.45	140.57	483.07	4148.01	
1999	255.68	344.75	177.08	182.23	255.13	276.35	397.80	837.95	664.70	372.59	766.37	1432.70	5963.33	
2000	**783.62**	**669.59**	**502.85**	**417.11**	**351.41**	**260.34**	**300.89**	**386.80**	**366.69**	**387.12**	**440.48**	**742.19**	5609.10	*Corporación Colombia Internacional* - CCI
2001	**1771.71**	**1513.89**	**1136.91**	**943.06**	**794.52**	**588.62**	**680.29**	**874.52**	**829.06**	**875.26**	**995.90**	**1678.05**	12681.80	
2002	**690.27**	**589.82**	**442.94**	**367.42**	**309.55**	**229.33**	**265.05**	**340.72**	**323.01**	**341.00**	**388.01**	**653.78**	4940.90	
2003	**759.30**	**648.80**	**487.24**	**404.17**	**340.51**	**252.26**	**291.55**	**374.79**	**355.31**	**375.11**	**426.81**	**719.16**	5434.99	
2004	**828.10**	**707.59**	**531.39**	**440.79**	**371.36**	**275.12**	**317.97**	**408.75**	**387.50**	**409.09**	**465.48**	**784.32**	5927.46	
2005	**929.74**	**794.45**	**596.61**	**494.89**	**416.94**	**308.89**	**357.00**	**458.92**	**435.07**	**459.31**	**522.62**	**880.59**	6655.03	
2006	823.40	492.40		294.20	134.50	105.70	221.90	197.90	139.00	194.20	110.10	144.10	2857.40	
2007	746.29	445.22	165.71	221.01	242.37	241.70	279.54	277.14	275.39	599.70	748.00	622.61	4864.68	
2008	1135.50	907.80	505.80	399.80	487.40	399.70	333.40	287.70	381.60	461.60	665.60	1216.30	7182.20	
2009	789.04	615.53	624.31	374.48	348.74	321.13	398.06	357.18	245.57	230.01	148.34	249.15	4701.54	
2010														
2011														
2012	174.82	152.05	151.45	51.76	71.39	54.18	42.83	50.54	48.25	86.95	392.22	431.05	1707.49	*Servicio Estadístico Pesquero Colombiano* - SEPEC
2013	323.41	201.58	4.82	61.16	153.91	85.56	125.48	83.24	82.30	129.66	119.34	137.01	1507.47	
2014	102.94	168.00	156.36	160.61	168.18	129.08					293.32	392.16	1570.65	
2015			0.54	125.36	174.09	190.36	221.42	152.16	153.71	155.25	201.97	262.57	1637.43	

nual, according to the historical average percentages of participation per month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
13.97%	11.94%	8.96%	7.44%	6.27%	4.64%	5.36%	6.90%	6.54%	6.90%	7.85%	13.23%

Landed weight *Prochilodus magdalenae* per hydrological year (1981-2015)

Hydrological year	Year 1									Year 2			
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Total**
1981 - 1982	1992.42	1678.60	1243.58	1437.27	1847.62	1751.57	1849.17	2104.04	3545.24	2665.02	2277.20	1710.14	24101.86
1982 - 1983	1418.56	1195.12	885.40	1023.30	1315.46	1247.07	1316.56	1498.03	2524.13	2362.13	2018.40	1515.78	18319.96
1983 - 1984	1257.34	1059.30	784.78	907.00	1165.96	1105.34	1166.93	1327.78	2237.26	4060.25	3469.40	2605.46	21146.80
1984 - 1985	2161.23	1820.82	1348.94	1559.04	2004.16	1899.97	2005.83	2282.31	3845.60	3440.66	2939.97	2207.87	27516.39
1985 - 1986	1831.43	1542.96	1143.10	1321.13	1698.32	1610.03	1699.74	1934.03	3258.77	3981.74	3402.31	2555.07	25978.63
1986 - 1987	2119.44	1785.61	1322.86	1528.89	1965.40	1863.23	1967.05	2238.17	3771.24	4034.69	3447.56	2589.05	28633.17
1987 - 1988	2147.62	1809.35	1340.45	1549.22	1991.54	1888.00	1993.20	2267.94	3821.39	4416.22	3773.57	2833.88	29832.38
1988 - 1989	2350.71	1980.45	1467.21	1695.72	2179.86	2066.54	2181.69	2482.40	4182.75	2472.78	2112.94	1586.78	26759.83
1989 - 1990	1316.24	1108.92	821.54	949.49	1220.58	1157.12	1221.60	1389.97	2342.06	2725.23	2328.65	1748.78	18330.15
1990 - 1991	1450.61	1222.13	905.41	1046.42	1345.18	1275.25	1346.31	1531.88	2581.16	2048.92	1750.76	1314.79	17818.80
1991 - 1992	1090.62	918.83	680.71	786.73	1011.35	958.78	1012.20	1151.72	1940.60	2193.37	1874.19	1407.48	15026.59
1992 - 1993	1167.51	983.62	728.71	842.20	1082.66	1026.37	1083.56	1232.92	2077.42	1645.46	1041.69	1726.45	14638.56
1993 - 1994	1260.10	617.53	262.81	215.91	612.34	407.63	560.81	351.27	1626.53	527.65	452.70	376.21	7271.49
1994 - 1995	703.99	498.41	467.51	528.62	640.43	633.81	466.50	322.79	439.20	412.91	400.64	262.84	5777.65
1995 - 1996	94.84	159.08	108.75	159.39	121.55	149.34	265.68	241.03	487.23	482.33	415.14	263.97	2948.33
1996 - 1997	120.00	259.01	129.26	107.06	164.76	319.90	233.74	492.74	463.53	624.76	663.70	237.41	3815.88
1997 - 1998	143.45	283.27	199.45	164.16	195.70	206.81	81.67	67.85	141.24	360.00	880.00	740.00	3463.60
1998 - 1999	600.00	185.04	20.03	31.43	169.75	224.67	313.45	140.57	483.07	255.68	344.75	177.08	2945.52
1999 - 2000	182.23	255.13	276.35	397.80	837.95	664.70	372.59	766.37	1432.70	783.62	669.59	502.85	7141.88
2000 - 2001	417.11	351.41	260.34	300.89	386.80	366.69	387.12	440.48	742.19	1771.71	1513.89	1136.91	8075.56
2001 - 2002	943.06	794.52	588.62	680.29	874.52	829.06	875.26	995.90	1678.05	690.27	589.82	442.94	9982.32
2002 - 2003	367.42	309.55	229.33	265.05	340.72	323.01	341.00	388.01	653.78	759.30	648.80	487.24	5113.20
2003 - 2004	404.17	340.51	252.26	291.55	374.79	355.31	375.11	426.81	719.16	828.10	707.59	531.39	5606.73
2004 - 2005	440.79	371.36	275.12	317.97	408.75	387.50	409.09	465.48	784.32	929.74	794.45	596.61	6181.18
2005 - 2006	494.89	416.94	308.89	357.00	458.92	435.07	459.31	522.62	880.59	823.40	492.40	0.00	5650.03
2006 - 2007	294.20	134.50	105.70	221.90	197.90	139.00	194.20	110.10	144.10	746.29	445.22	165.71	2898.82
2007 - 2008	221.01	242.37	241.70	279.54	277.14	275.39	599.70	748.00	622.61	1135.50	907.80	505.80	6056.56
2008 - 2009	399.80	487.40	399.70	333.40	287.70	381.60	461.60	665.60	1216.30	789.04	615.53	624.31	6661.98
2009 - 2010	374.48	348.74	321.13	398.06	357.18	245.57	230.01	148.34	249.15				2672.66
2010 - 2011													
2011 - 2012										174.82	152.05	151.45	478.32
2012 - 2013	51.76	71.39	54.18	42.83	50.54	48.25	86.95	392.22	431.05	323.41	201.58	4.82	1758.98
2013 - 2014	61.16	153.91	85.56	125.48	83.24	82.30	129.66	119.34	137.01	102.94	168.00	156.36	1404.96
2014 - 2015	160.61	168.18	129.08					293.32	392.16			0.54	1143.89
2015 - 2016	125.36	174.09	190.36	221.42	152.16	153.71	155.25	201.97	262.57				1636.89