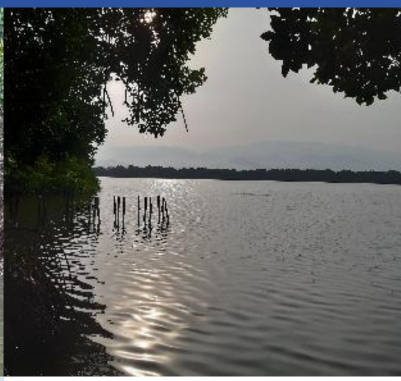
Jul 27, 2022

Evaluation of the current state of the Río Frío and Río Sevilla basins

Water resources baseline assessment, analysis of data gaps, and water governance analysis in the Magdalena region

Final report 1a/1b



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Executive summary

The Río Frío and Río Sevilla basins in the Magdalena region of Colombia increasingly face challenges between different water users in terms of both water quantity and quality. The Río Frío and Río Sevilla originate in the Sierra Nevada de Santa Marta (SNSM) and flow into the Ciénaga Grande de Santa Marta (CGSM), a Ramsar wetland. Within these basins, the largest share of the available water is predominantly used for irrigation purposes in oil palm and banana plantations. The sustainability of these production systems is threatened by water shortages and inefficient irrigation practices, alternating availability of water (floods & droughts) due to climate change, and other environmental problems such as salt intrusion and soil erosion. Lower river discharges in the dry season also mean that access to water is restricted. The two rivers are essential to sustain the ecosystems along the rivers and the wetland at the outlet of the basins, and also to provide water for domestic use. When looking at the water balance for both catchments, it is evident that during the dry season water demand far exceeds the available intake water. Due to water scarcity, several stakeholders have started initiatives to support sustainable use of water resources in the Magdalena region. To improve water allocation amongst all users and the development of a decision-support system for water allocation, this report presents a stakeholder assessment of the Río Frío and Río Sevilla basins highlighting the complexity of the water governance, combined with a baseline assessment of the basins water resources and management to assess the status of identified water sources, water availability, water demand and water quality. Key knowledge gaps remain on the catchment boundaries, landcover and irrigation production systems and the environmental flow requirements.

Colophon

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List of abbreviations

ADR	Rural Development Agency (*Agencia de Desarrollo Rural*)
ASR	Aquifer Storage and Recovery
AUNAP	National Authority for Aquaculture and Fisheries (*Autoridad Nacional de Acuicultura y Pesca*)
BOD	Biological Oxygen Demand
CGSM	Ciénaga Grande de Santa Marta
CORMAGDALENA	The Regional Autonomous Corporation of the Río Grande de la Magdalena *Corporación Autónoma Regional del Río Grande de la Magdalena*
CORPAMAG	The Regional Autonomous Corporation of Magdalena *Corporación Autónoma Regional del Magdalena*
DHI	Drought Hazard Index
DO	Dissolved Oxygen
DSS	Decision Support System
ENSO	El Niño-Southern Oscillation
ETm	Maximum Evapotranspiration
FOG	Fats, Oils and Grease
GDP	Gross Domestic Product
GIS	Geographic Information System
ICTs	Information and Communication Technologies
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies *Instituto de Hidrología, Meteorología y Estudios Ambientales*
INVEMAR	Marine and Coastal Research Institute *Instituto de Investigaciones Marinas y Costeras*
IUA	Water Use Index factor
IWRM	Integrated Water Resources Management
MADR	Ministry of Agriculture and Rural Development (*Ministerio de Agricultura y Desarrollo Rural*)
MADS	Ministry of Environment and Sustainable Development (*Ministerio de Ambiente y Desarrollo Sostenible)*
MAR	Managed Aquifer Recharge
masl	Meter above sea level
MCBM	Magdalena-Cauca Macrobasin
MVAP	Essential Minimum Potable Water (*Mínimo Vital de Agua Potable*)
MVCT	Ministry of Housing, City and Territory (*Ministerio de Vivienda, Ciudad y Territorio*)
OECD	Organisation for Economic Co-operation and Development
PCA	Plataforma Custodia del Agua
PNGIRH	National Policy for the Comprehensive Management of Water Resources (*Política Nacional para la Gestión Integral del Recurso Hídrico)*
PNN	National Natural Parks (*Parques Nacionales Naturales*)
PNR	Regional natural Parks

	(Parques Naturales Regionales)
POMCA	Watershed Planning and Management Plan (*Plan de Ordenamiento y Manejo de Cuenca)*
POMIUAC	Integrated Management and Ordination Plans of the Environmental Coastal Units (*Planes de Ordenación y Manejo Integrado de las Unidades Ambientales Costeras*)
PvW	Partners for Water
RGU	General Registry of Users (*Registro General de Usuarios)*
RVO	The Dutch Enterprise Agency
SDE	Secretary of Economic Development (*Secretaría de Desarrollo Económico*)
SFFCGSM	*Santuario de Flora y Fauna de Ciénaga Grande de Santa Marta*
SNPAD	National system for disaster prevention and response *sistema nacional para la prevención y atención de desastres*
SGC	Colombian Geological Survey (*Servicio Geológico Colombiano*)
SNSM	Sierra Nevada de Santa Marta
UBN	Unsatisfied Basic Needs Index
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNGRD	National Unit for Disaster Risk Management *Unidad Nacional para la Gestión del Riesgo de Desastres*
UPRA	Agricultural Rural Planning Unit (*Unidad de Planificación Rural Agropecuaria*)
WWF	World Wildlife Fund
ZB	Zona Bananera

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1 Introduction

1.1 Background

The Río Frío and Río Sevilla basins in the Magdalena region of Colombia increasingly face challenges between different water users in terms of both water quantity and quality. The Río Frío and Río Sevilla originate in the Sierra Nevada de Santa Marta (SNSM) and flow into the Ciénaga Grande de Santa Marta (CGSM), a Ramsar wetland. The two rivers are essential to sustain the ecosystems along the rivers and the CGSM wetland at the outlet of the basins. Water from the two river basins also provides fresh water for the livelihood of the approximately 185,000 inhabitants of the surrounding municipalities. The middle and lower section of the river basin is in use to produce agricultural crops such as bananas, oil palm, and coffee, and water from the Río Frío and Río Sevilla is in use for irrigation.

The water users in the Río Frío and Río Sevilla basins face challenges related to water scarcity, and the ecosystems face many environmental threats. Recent studies carried out by WWF, together with IDEAM (National monitoring agency) and CORPAMAG (environmental authority of Magdalena region), highlight that in the current situation, the discharge of both rivers is not sufficient to meet environmental flow requirements downstream causing serious damage to the mangrove system and fish population in the Ciénaga (WWF Colombia & CORPAMAG, 2020).

Within these basins, the largest share of the available water is predominantly used for irrigation purposes in oil palm and banana plantations. The sustainability of these production systems is threatened by water shortages and inefficient irrigation practices, alternating availability of water (shortage during dry seasons vs frequent flooding in the wet seasons) due to climate change, and other environmental problems such as salt intrusion and soil erosion. Lower river discharges in the dry season also mean that access to water (which is provided by the irrigation associations ASOSEVILLA and ASORIOFRIO) is restricted. The unpredictability in water supply poses difficulties in farm planning and decreases the efficiency of operations. Not only agricultural producers suffer from these issues, but also the rural population and natural ecosystems, since the rationing of water during the dry season does not only affect water utilized for irrigation purposes, but also water destined for domestic use and environment.

1.2 Objectives

In order to address these issues, The Dutch Enterprise Agency (RVO) has funded activities that aim to improve water efficiency in the banana and oil palm sectors in the Magdalena region. Several stakeholders have started initiatives to support sustainable use of water resources in the Magdalena region, and most notably is the Water Stewardship Platform (*Plataforma Custodia del Agua*, PCA), which brings together a large group of stakeholders to support sustainable use of the water resources. Building on these efforts, the next step is to improve water allocation amongst all users, by adjusting governance practices and develop a decision-support system (DSS) in collaboration with key stakeholders from both the management and the users' side.

In this project the consortium will make a first step to develop a DSS that will support the water users of the Río Frío and Río Sevilla basins towards sustainable and equitable water allocation. For sustainable water management, a good knowledge base and insight into the water balance is necessary. At the moment, water balances for the Río Frío and Río Sevilla are developed only on theoretical water demand of the users, and measured discharge at the main irrigation water intake of the water districts. There are several ongoing monitoring initiatives (Annex 1) in the river basins, but data collection is scattered across several organizations. The DSS will combine ongoing monitoring initiatives to support sustainable water management.

To support the development of the DSS, this report presents a stakeholder assessment of the Río Frío and Río Sevilla basins, combined with a baseline assessment based on literature review and data collection to assess the status of identified water sources, water availability, water demand and water quality for the Frío and Sevilla River Basins. This report also identifies knowledge gaps on these subjects.

1.3 Approach

For this water resources baseline and water governance analysis, available literature and data was collected. Collected biophysical baseline data includes relevant studies and materials already produced by the counterparts in the recent past, as well as relevant spatial data. Data was collected to improve insights of the water balance and water management of the river basins. A GIS database was developed by open source global and Colombian government databases, and data shared by stakeholders, to support the biophysical assessment (fact check literature), mapping exercises and DSS development.

Figure 1-1 Multi stakeholder workshop in Santa Marta, Colombia on the 5th of April 2022, as part of the round tables session of the Plataforma Custodia del Agua.

For the water governance analysis, data was collected for the project area compiling information from various sources, notably:

- the available literature;
- a round of interviews and a workshop session with the key stakeholders;
- field visits with Cenipalma, ASORIOFRIO and ASOSEVILLA in April 2022;
- and interpersonal communications.

A first step in the water governance assessment is to identify relevant stakeholders and governance mechanisms. To start, 14 Stakeholder interviews were held as part of the water governance analysis and helped to investigate the water resources related issues that trouble different stakeholders. For the second step, a complete stakeholder identification, mapping and profiling in terms of who the stakeholders are, at what level they operate, and their roles, responsibilities and capabilities, interests and concerns in relation to general development and project activities. To this end, several categories of stakeholders have been identified (water users: domestic, industry, agriculture, environment), different levels of government, service operators, civil society groups, finance institutions, which will be compared to the groups already actively participating in the PCA.

1.4 Reader's Guide

Chapter 2 presents the context of the Río Frío and Río Sevilla and provides an overview of the water basins.

2 Context assessment in the Río Frío and Río Sevilla basins

2.1 Overview of the water basins

The Río Frío and Río Sevilla basins are in the Magdalena region of Colombia. The Río Frío and Río Sevilla originate on the western flank of the Sierra Nevada de Santa Marta (SNSM), a UNESCO-declared Biosphere reserve. From there the rivers flow into the Ciénaga Grande de Santa Marta, a Ramsar wetland. The protected national park, SNSM covers a part of the Sierra Nevada mountain complex which is an isolated mountain complex encompassing approximately 17,000 km^2 and reaching 5,775 meters above sea level (masl) (Kaune et al., 2020a and Deltares, 2021a). The hydrological basin areas (1400 km^2) of the Frío and Sevilla rivers are located south of the departmental capital Santa Marta and cover multiple municipalities of the Magdalena department: Zona Bananera, Ciénaga and to a lesser degree Pueblo Viejo (Parada et al., 2015; Figure 2-1).

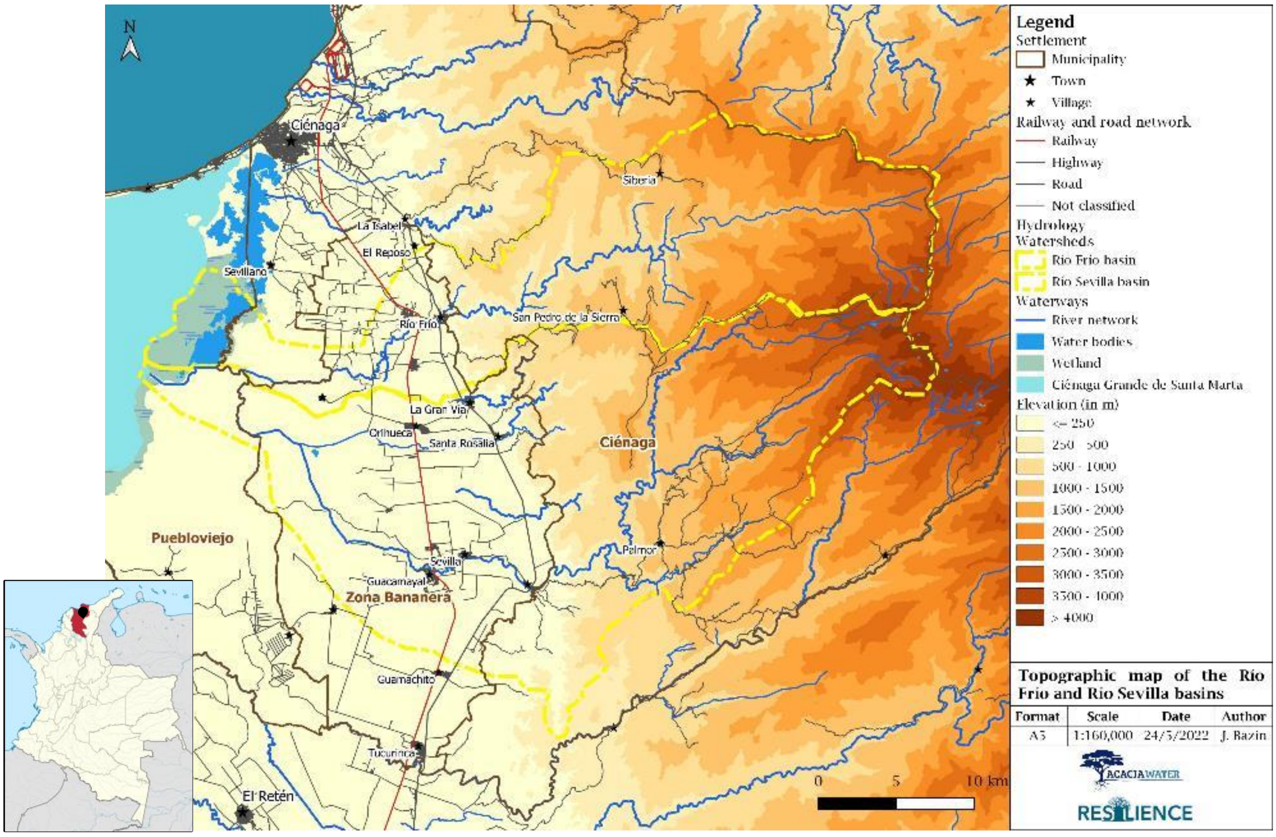


Figure 2-1: The Río Frío and Río Sevilla basins and the municipalities of Zona Bananera, Ciénaga and Pueblo Viejo in the Magdalena region (area in dark red in the map of Colombia, with location of basins indicated by a black dot). The main population centers are indicated on the map.

2.1.1 Hydrology and sub-catchments

The Magdalena-Cauca Macrobasin (MCBM) is the primary river basin system in Colombia, draining an area of around 257,000 km^2. It has its headwaters in the Colombian Andes at the Magdalena Lagoon (3,700 masl). The mean annual river discharge at Calamar, which is the gauging station closest to the mouth before the diversion of the Canal del Dique, is approximately 7200 m^3/s, with mean maximum discharges occurring in November (10,200 m^3/s), and minimum average flows in March (4050 m^3/s) (Kaune et al., 2020a).

The Sierra Nevada complex feeds 36 watersheds, making it the major regional 'water tower' supplying 1.5 million inhabitants with an approximate flow of 10,000 million cubic meters of water annually. The Río Frío and Río Sevilla basins are two of the 36 watersheds flowing from the Sierra Nevada complex and are located in the Bajo Magdalena hydrographic zone (lower MCMB) in the northeast of Colombia.

The Río Sevilla is approximately 89 km long, with an area of 713 km^2 and including about 41,562 hectares. The main tributaries are El Chorro, Cebolleta, Venado, Gallina river, Sevillita river, Caño Mocho, Cherua river and Maquencal (Kaune et al., 2020a).

The Río Frío is 65 km long and is fed by a system of ravines and lagoons located in the upper part of the basin between 4,200 and 1,800 masl. The basin has an area of 379 km^2, a drainage network of 580 km long and hosts around 14,000 inhabitants (Parada et al., 2015). The Río Frío formerly flowed into the Ciénaga del Chino. In the 1980s it was channelled and redirected to meet the Sevilla River.

2.1.2 Geology and aquifer systems

The Ciénaga-Fundación Aquifer is located in the municipalities of Zona Bananera, Pueblo Viejo, El Retén, Aracataca and Fundación (Findeter, 2018), as shown in Figure 2-2.
The RECARBA project improved the understanding of the aquifer system. In this project, the aquifer extent (Figure 2-3) was determined to slightly differ from the aquifer extent as shown in Figure 2-2. The different delineations of the aquifer show that there is not yet a common understanding of the exact aquifer boundaries.

The field measurements from the RECARBA project indicate the presence of different textural layers overlying each other. Field measurements show an upper clayey layer, followed by sandy strata of different thicknesses interspersed with other clayey layers resulting in a high spatial variability of transmissivity values (Figure 2-4, Figure 2-5). This indicates a highly heterogenous aquifer with differences in local water availability and recharge rates.

In the La Aguja sector, profiles were used to assess the aquifer. According to the lithological columns and the design of the wells, the aquifer seems to have a total thickness of permeable strata of about 40 m. The transmissivity in this area is 400 m2/d and the pumping flows are 22 or 25 l/s (Deltares, 2021c).

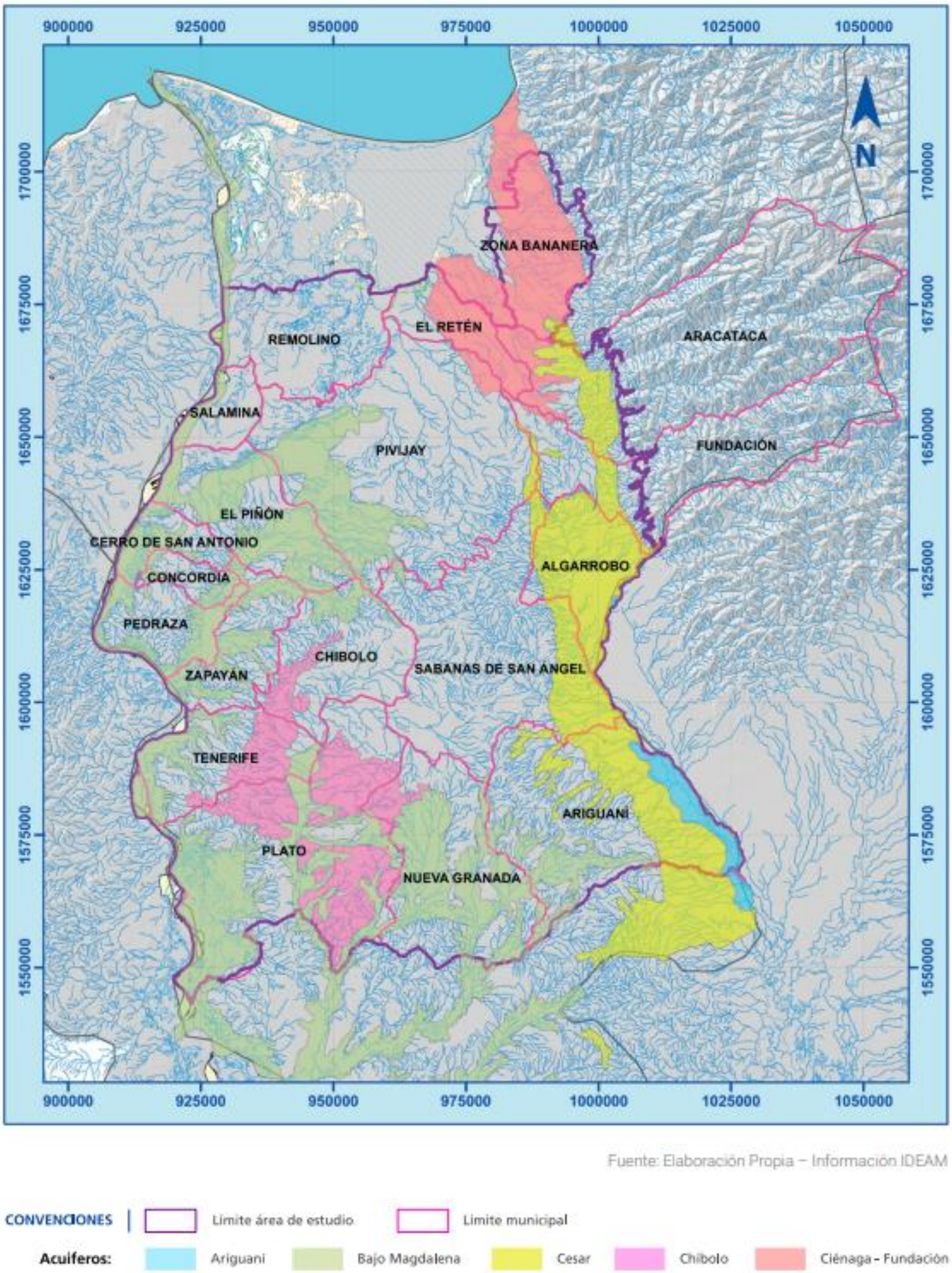


Figure 2-2: Aquifer systems in the project area, with on the top right, the Ciénaga-Fundación Aquifer indicated on the map. Source: Elaboración Propia – Información IDEAM. Source: Findeter (2018).

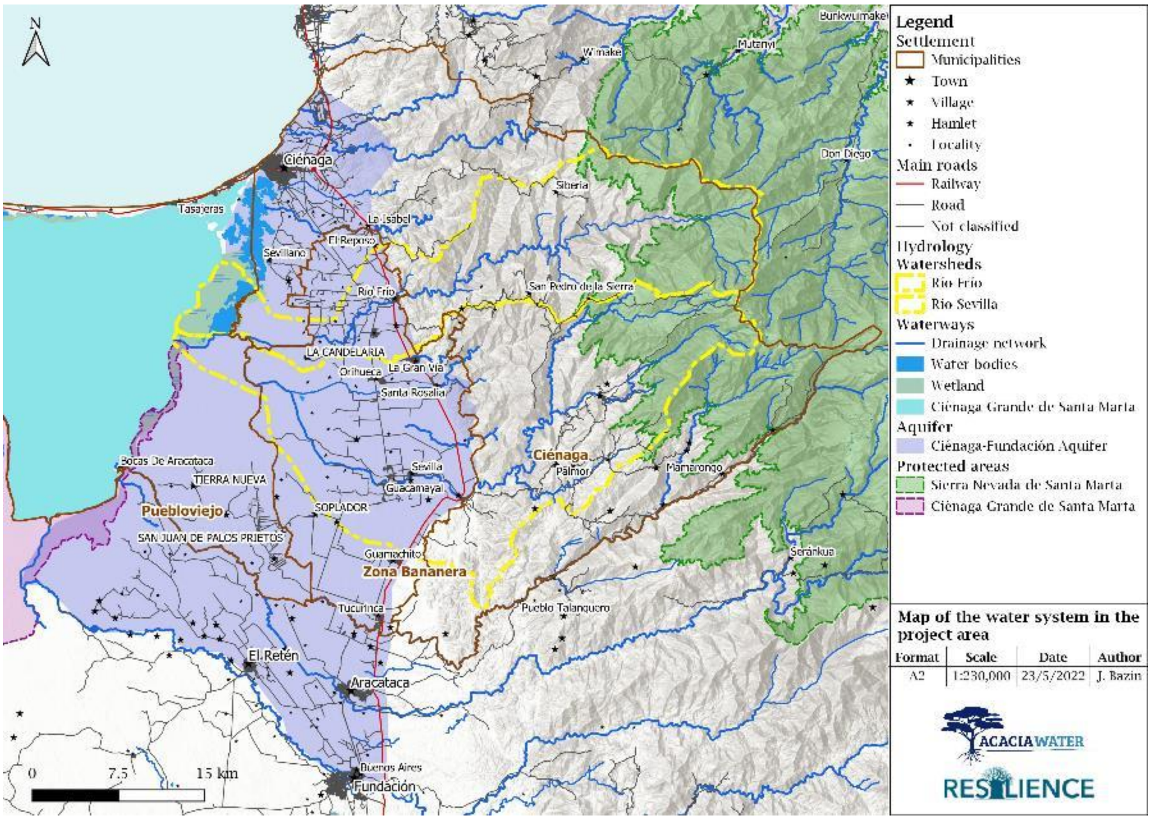


Figure 2-3. Aquifer system. The Ciénaga-Fundación Aquifer indicated on the map as delineated by the RECARBA project.

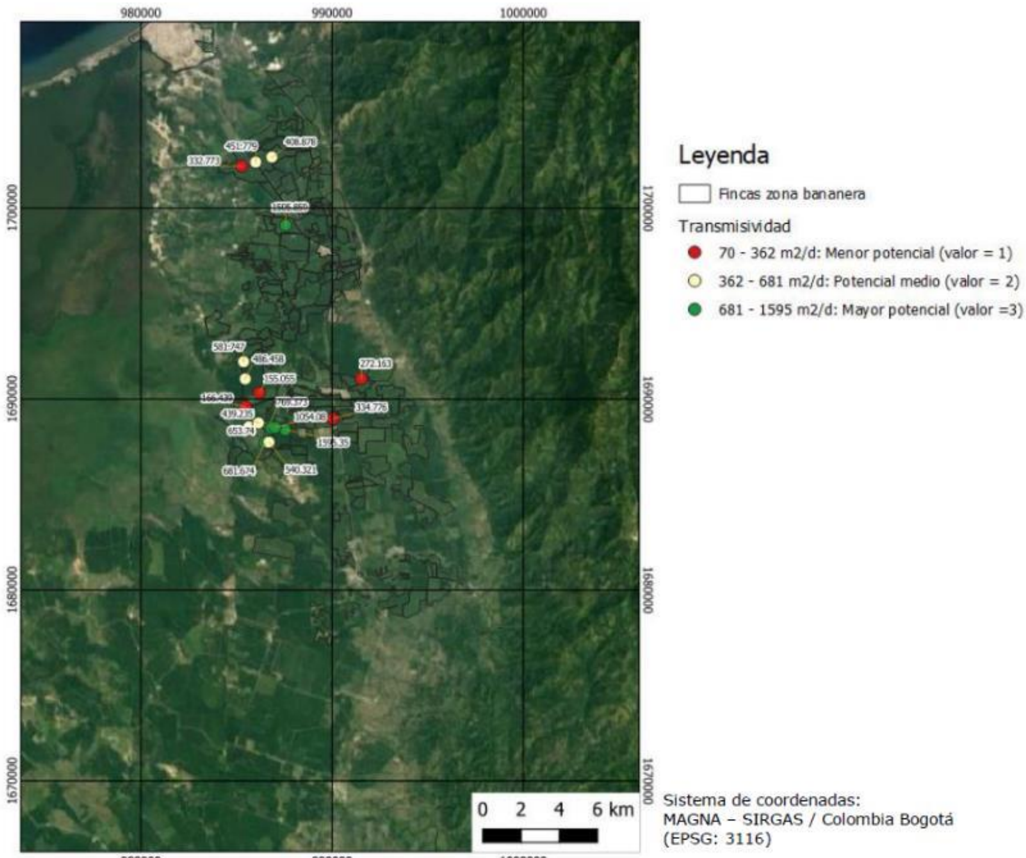


Figure 2-4 This map shows the available transmissivity values (in m²/d). These vary spatially, not observing any specific trend. This gives indication of the high heterogeneity of the aquifer. Source: RECARBA project, Deltares (2021b).

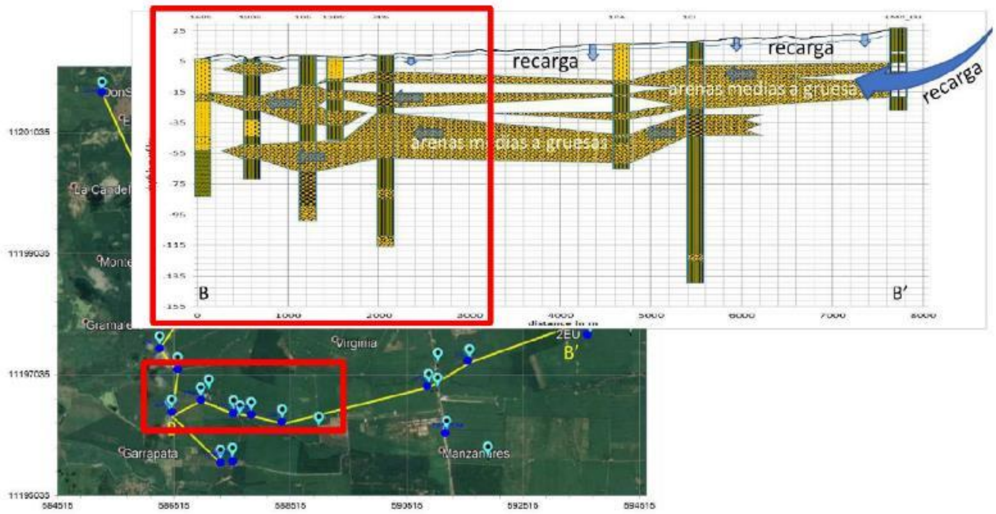


Figure 2-5. This figure indicates the field information for the Don Said farm based on well information. In this zone, the depth at the static level is between 3.3 m to 12.8 m, while the electrical conductivity varies between 79 to 753 µS/cm. Expected recharge flows are indicated in the figure. Source: RECARBA project, Deltares (2021b).

2.2 Biophysical environment

2.2.1 Topography

The catchment areas of the Río Frío and Río Sevilla have high and steep slopes in the upland area and relatively gentle slopes in the plains. As the catchment areas both originate in the Sierra Nevada mountains, elevation goes up to approximately 4000 masl, all the way to sea level near the Ciénaga Grande de Santa Marta (Figure 2-1).

2.2.2 Climate conditions

Temperature and relative humidity

The basins of Río Frío and Río Sevilla are characterized by a hot and dry to very dry climate. In a single location, monthly average temperatures show little variation, though between locations in the catchment annual average temperatures differ between 20˚C and 34˚C (Parada et al., 2015), with minimum values in the Sierra Nevada mountains as low as 3.4˚C (Kaune et al., 2020a). The relative humidity presents minimum values between January and April, close to 70% in the lower and middle basin, while the remainder of the year the humidity remains constant with values close to 90% (CORPAMAG, 2016).

Rainfall

The project area shows high variation in the temporal and spatial distribution of rainfall. The temporal distribution is marked by two distinct seasons: a wet season between April and November and a dry season between December and March (Figure 2-6). From August to November frequent floods tend to occur, while the month of March is the month with critical minimum flow (Parada et al., 2015). Within the wet season, the temporal distribution may vary from year to year.

The spatial distribution of rainfall results in high difference between upstream and downstream sections in both basins (Figure 2-7). In the wet season rainfall varies from 565 mm/season in the downstream coastal section of Sevilla basin, up till 2128 mm/season in the upstream and mountainous regions. In the dry season, rainfall in the downstream and upstream of Sevilla basin comes down to 31 mm/season and 250 mm/season respectively (Kaune et al., 2020a). The total average annual precipitation in Río Frío basin is estimated at 1675 mm, showing similar spatial and temporal variations as with the Sevilla basin (Parada et al., 2015).

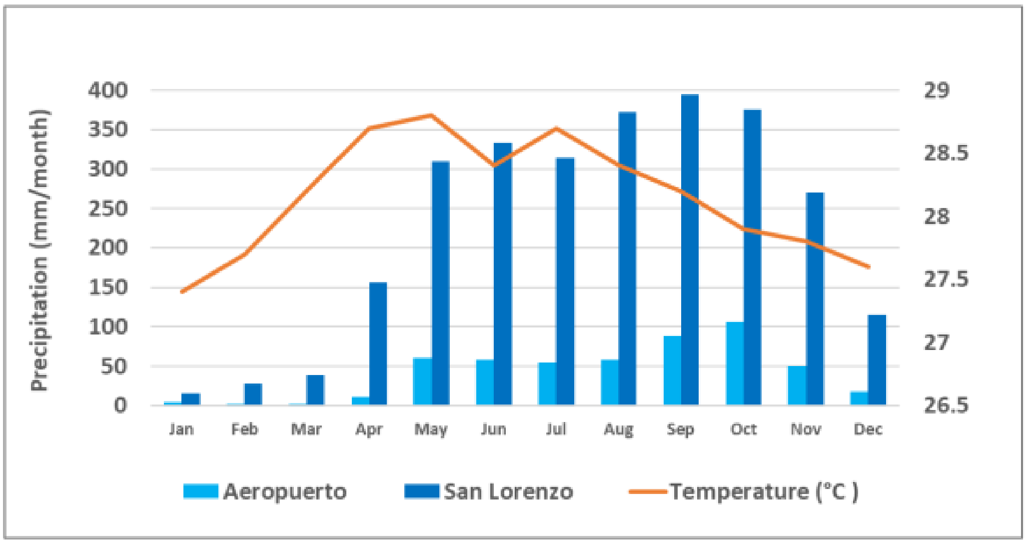


Figure 2-6: Average monthly precipitation and temperature (timeframe unknown) as recorded in stations Aeropuerto Simón Bolivar (coastal plain) and San Lorenzo (20km inland) located close to the Sevilla basin (Source: GSI, 2015). Unclear in Kaune et al. which timeframe has been used to calculate the averages. Source: Kaune et al. (2020a).

Colombia is one of the regions affected by the El Niño-Southern Oscillation (ENSO) phenomenon in its cold ("La Niña") and warm ("El Niño") phases. The "La Niña" phenomenon is characterized by an increase in rainfall in the study region, unlike the "El Niño" phenomenon that brings a decrease in the rainfall in the area. These regular and natural cyclical phenomena accentuate the extremes already existing, causing significant damage to environments and livelihoods (Parada et al., 2015).

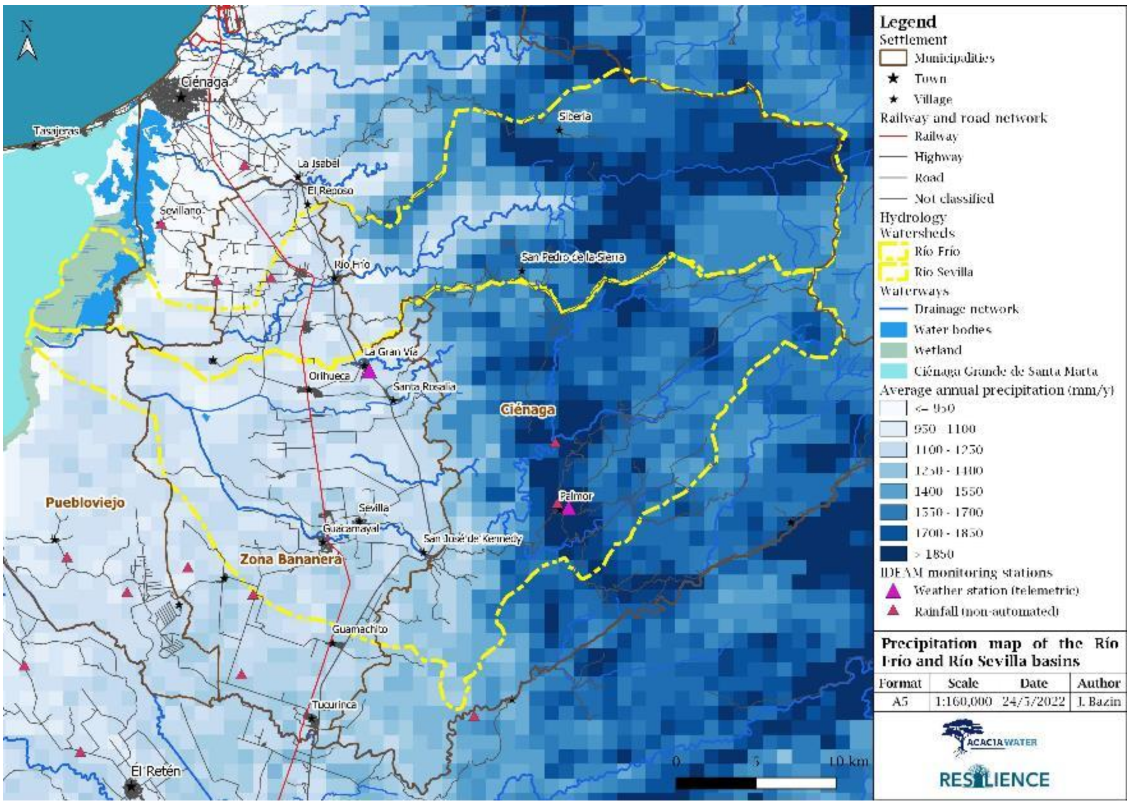


Figure 2-7. Precipitation map representing average yearly climate data for 1970-2000, showing the spatial variability of precipitation (data source: WorldClim).

Evapotranspiration

The actual evapotranspiration in the Río Frío and Río Sevilla basins show an opposite pattern to the temporal and spatial rainfall distribution. High evapotranspiration values occur in the downstream part of the basins during the dry season, while lower evapotranspiration values are present in the upstream area. This has mainly to do with the irrigation of oil palm and bananas in the coastal plain. For the Sevilla Basin, actual evapotranspiration varies between 35 mm/season in the upstream region, to 477 mm/season in the downstream section. During the dry season evapotranspiration goes up to 739 mm/season in the downstream region (Kaune et al., 2020a; Figure 2-8).

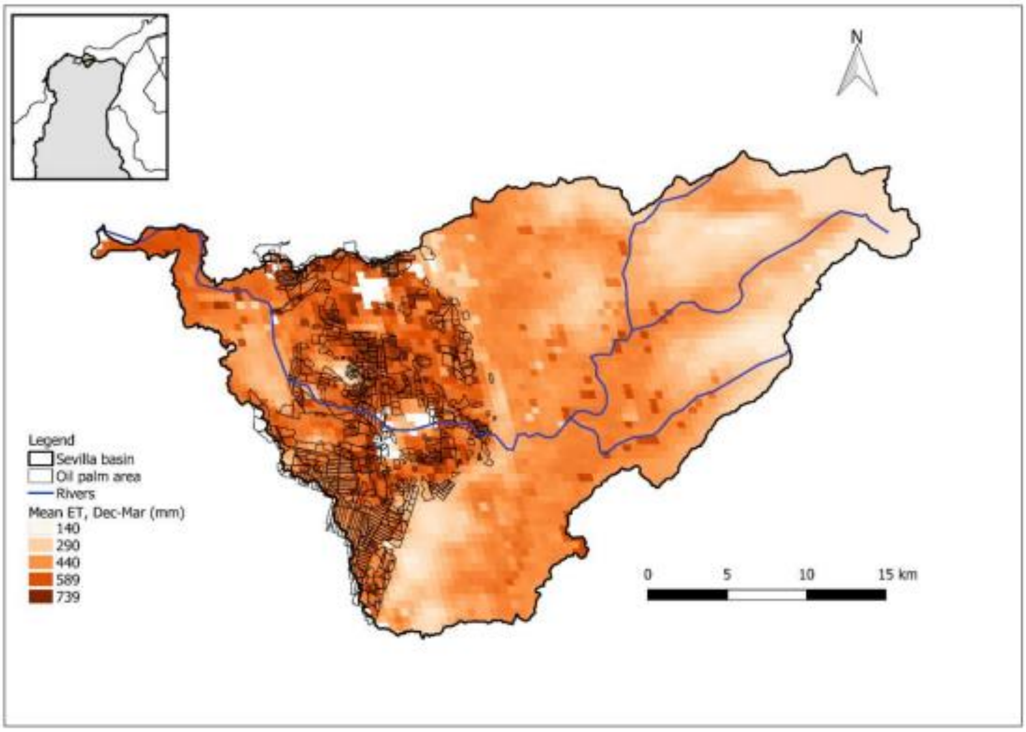


Figure 2-8: Mean total ET from December to March (dry season) in the Sevilla basin, Colombia, period 2010-2019 (Source: MODIS). Rio Frio basin was not included in this study. Oil palm area is delineated in light black (Source: CENIPALMA). Retrieved from Kaune et al. (2020a). Legend from 140 to 739 mm Mean ET.

Hazardous events

The seasonality in the region's rainfall pattern brings about extreme flood events, mainly between August and November, and drought periods between December and April. These events tend to intensify due to the ENSO phenomenon. In the period 2010-2015 the registered drought and flood events have significantly increased. During La Niña (2010-2011) about 800 hectares of Banana in Zona Bananera were lost and 20,000 hectares were flooded, causing regional adverse impacts to communities and infrastructure. El Niño (2014) caused the loss of 600 hectares of banana due to a lack of water. The monetary loss of both events for the study area were estimated to be 13 million dollars and 10 million dollars for La Niña and El Niño respectively (Parada et al., 2015).

Future droughts can affect water harvesting potential and availability of water for irrigation and urban areas in the project area. Kaune et al. (2020a) evaluated the drought hazard index (DHI) for the Sevilla Basin for the wet and the dry season. They found that for both seasons, the highest drought hazard was found in the lower part of the basin. This corresponds to the rainfall and crop growth patterns of the region.

Future climate trends

Climate change projections for the Department of Magdalena for the year 2100 show that the recurrence of extreme events is estimated to bring a 30% decrease in runoff and a severe surplus of water up to 40%, for El Niño and La Niña respectively. During the period between 2011 and 2040 rainfall is expected to reduce with 24.6%.

The impacts of climate change are also expected to have a high impact on natural inland water bodies in the Caribbean region and in particular in Magdalena by 2040. 80% of the continental water bodies show high and very high vulnerability, whereas the ecosystem areas of the Caribbean coast (such as mangroves and coastal lagoons) show very high vulnerability (Parada et al., 2015).

Currently, the average rise in sea level in the Colombian Caribbean is 3.5 mm/year. In the report, IDEAM presents two scenarios of future sea level rise, a rise of 0.3 m by 2030, and a rise of 1m by 2100 (Figure 2-9). If there is a sea level rise of 1m, it is estimated that between 1.1 and 1.4 million inhabitants would be affected in the Caribbean region, within which the Zona Bananera and Ciénaga would be included in its limits with the Ciénega Grande de Santa Marta. The decrease in precipitation and the rise in sea level will have repercussions on the salinization (and therefore also biodiversity) of swamps and other water bodies (IDEAM, 2021a and Parada et al., 2015).

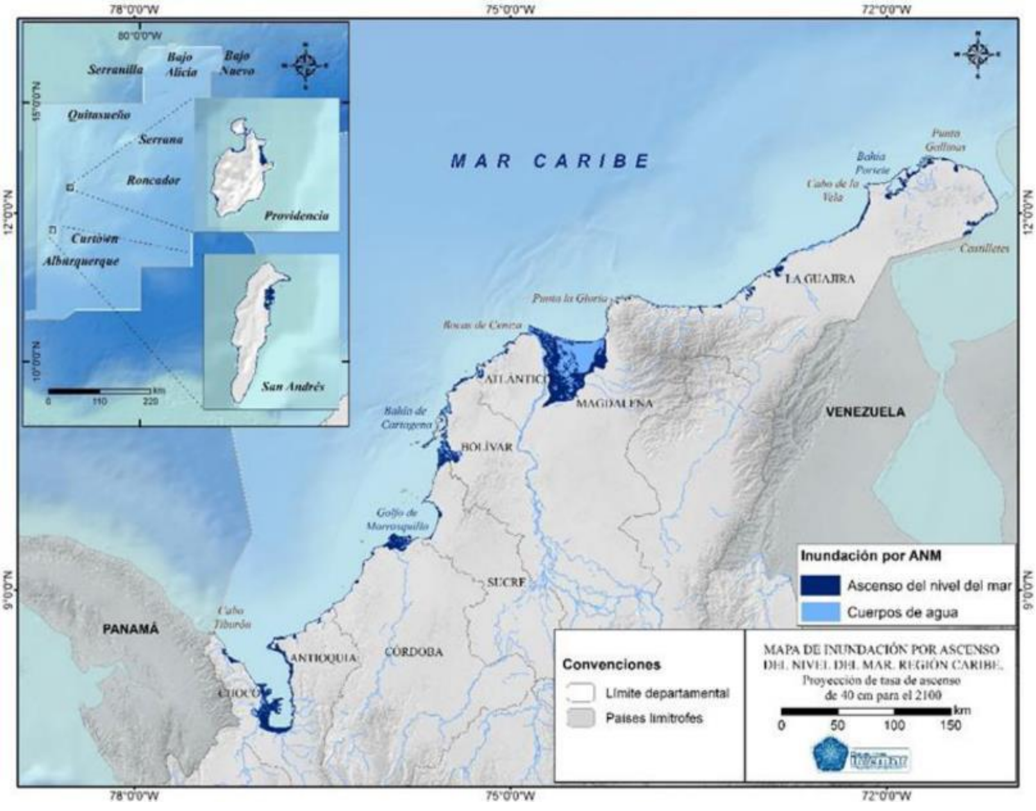


Figure 2-9. Sea level rise scenario of 40cm for the year 2100 in the Colombian Caribbean coast. Retrieved from IDEAM, 2021a. The projections show that the dark blue areas will be inundated in 2100. Source: INVEMAR-IDEAM (2017).

2.2.3 Vegetation and ecosystems

Sierra Nevada ecosystem

The Sierra Nevada and the ecosystems that come with it, generate water supply to the entire region. The fact that this mountain has been geologically formed independently of the Andes and that it has various thermal floors, has allowed the evolution of various ecosystems that contain a high number of unique (endemic) species. The Sierra Nevada ecosystem is protected through the System of National Natural Parks (Parque Nacional Natural, PNN), by the Regional Natural Parks (PNR), starting above the 2,000 masl, and partly overlaps with the indigenous reserve “Kogui-Malayo-Arhuaco”. The indigenous are represented in four groups, who have large community territories in the high basins, with rights over the sacred sites that are located throughout the entire Sierra Nevada, even into the Ciénaga Grande (Deltares, 2021a). Management of the protected area takes place in a mutual agreement between the System of National Natural Parks and the indigenous communities. The ecosystem is under pressure due to deforestation and burning for coffee production and extensive livestock ranching, mainly occurring in the middle part of the basins (Deltares, 2021a). This accelerates the process of erosion. Additionally, the ecosystem is under threat due to the expansion of agriculture which leads to contamination and sedimentation because of the excessive use of agrochemicals, bad agricultural practices and aggravated soil erosion (Parada et al., 2015). Most of these practices are unregistered and in conflict with the regulations of the System of National Natural Parks.

Ciénaga Grande de Santa Marta ecosystem

Both the Río Frío and Río Sevilla, originating in the Sierra Nevada, discharge into the Ciénaga Grande de Santa Marta (CGSM) and together with rivers Tucurinca, Aracataca and Fundación contribute for 40% of the incoming waters to this wetland area (Kaune et al., 2020a). The remainder 60% flows from the Magdalena-Cauca river basin. The CGSM is the largest complex of coastal wetlands in the Colombian Caribbean and one of the most productive in the estuarine deltas in the continent and has an estimated area of about 450 km^2 (Deltares, 2021a and Parade et al., 2015). The CGSM hosts 195 different bird species, 35 of these being migratory birds. The wetland generates a high fishing production which is estimated at 6,200 tons/year (Deltares, 2021a). It is a source of various ecosystem services (food, materials, tourism) and also has a regulatory function (salt cycle, hydrologic buffer, climate and air regulation, sink) (Parada et al., 2015).

Like the Sierra Nevada, the CGSM is also protected through the System of National Natural Parks. Furthermore, the CGSM has been declared a Ramsar site, which makes it of global importance, and the area is designated as a priority ecoregion by WWF. As with the Sierra Nevada, also the CGSM suffers from changes in the biophysical environment, resulting in increased sedimentation, reduction of biodiversity and affecting populations of migratory birds (Parada et al., 2015).

Figure 2-10. Picture of the mangroves in the Ciénaga Grande de Santa Marta with a fishing boat and fish net visible in orange behind the boat. (Picture: Acacia Water, April 2022).

2.2.4 Land use

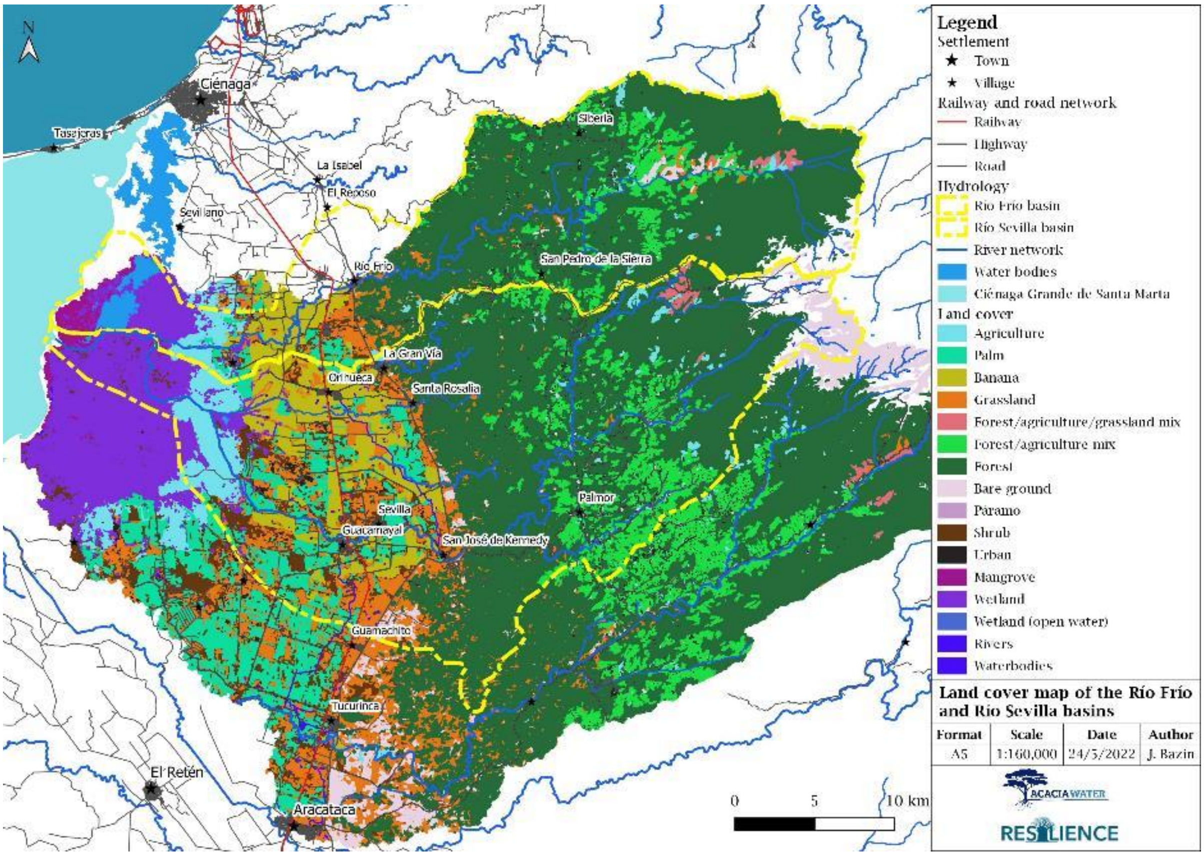


Figure 2-11. Landcover dataset as produced by the EO4Cultivar Mapping project, published 2020. The EO4Cultivar project covers most, but not all areas of interest for the Rio Frio and Rio Sevilla basins. A crosscheck with Hoyos et al. (2019) indicates that the Forest/agriculture mix (light green) is mostly coffee production systems. In general, the forest/agriculture/grassland mix upstream is mostly paramo rangelands and pastures of the indigenous communities. The map is clipped to the hydrological boundaries of the river basins, but the area north of this map is also of interest as this

region receives service of the water district of ASORIOFRIO. Source: (https://jncc.gov.uk/our-work/eo4c-colombia-mapper/).

Land use in the study area varies from closed forest in the upland areas to cultivated/agricultural lands in the lowland plains. The lowland plains are dominated by palm oil and banana cultivation as being the major water consuming crops. The middle section is a mix of forest and agriculture, mainly being coffee (Figure 2-11). Based on actual information from Cenipalma, the total area of oil palm fields in the Sevilla basin is 101 km². This represents 14% of the Sevilla basin area (Kaune et al., 2020a). Parada et al. (2015) indicate the total agricultural area in Ciénega and Zona Bananera to be 105,000 hectares (30% of total lands), of which 6.8%, 10% and 11% is covered by banana, oil palm and coffee respectively. Pasture areas with partial livestock use represent 69% of the total area destined for agricultural use for the two municipalities. Paramo grasslands are found above ~3100 masl. (Hoyos et al., 2019).

According to Findeter (2018), FINAGRO indicates that of the agricultural lands in Zona Bananera, 55% is attributed to palm oil, 36% to banana, 4% to maize, 3% to Yuca and 2% to rice. However, during the fieldwork of 2022, all stakeholders indicated that there was currently no rice production. Findeter (2018) also reports that about 80% of the (agricultural) lands are individually owned, while 17% are rented.

2.2.5 Soils

In general, good quality soil type and soil texture maps depicting the soil diversity at a local scale are not available for Colombia. It is therefore that soil maps in previous projects were generated from low resolution (1km) global datasets. Only the RECARBA project presented a different soil map, providing information on the texture of the soil (Figure 2-12).

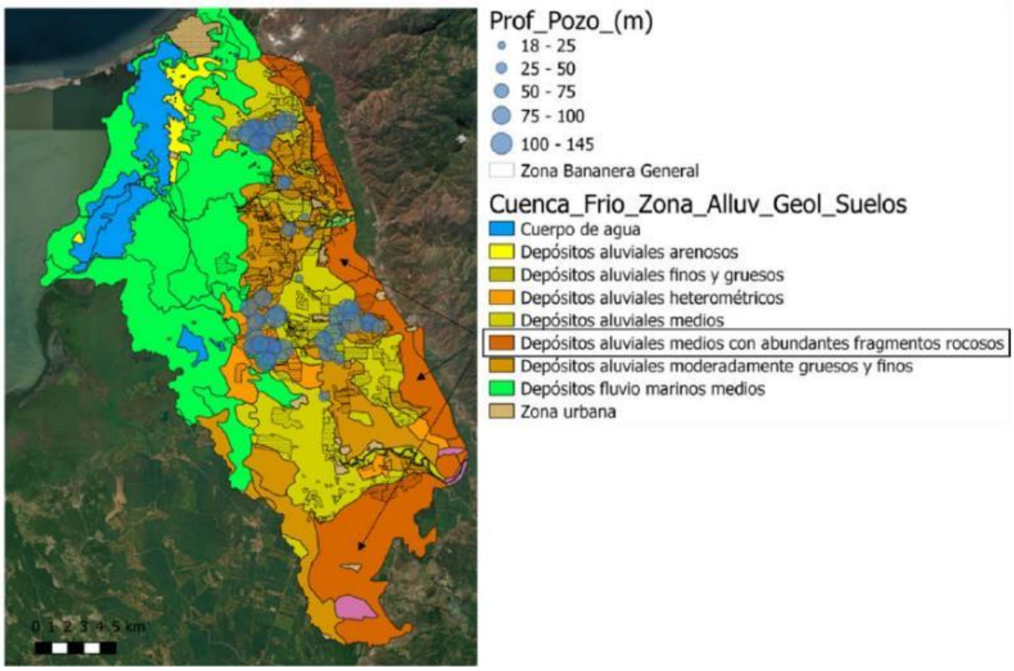


Figure 2-12. Soil map used in the RECARBA project (Deltares, 2021) providing information on the texture of the soil. The blue dots indicate the depths of wells in m.

Similar for the water holding capacity map (Figure 2-13) provides some insights in the retention capacity in both basins, based on global gridded datasets. At the eastern part of the agricultural plains, the water holding capacity is expected to be lower compared to the areas bordering the Ciénega Grande (Figure 2-13). It is reported that the natural fertility of the soils tends to be moderate to high. This reduces the amounts of nutrients that need to be applied to the agricultural fields.

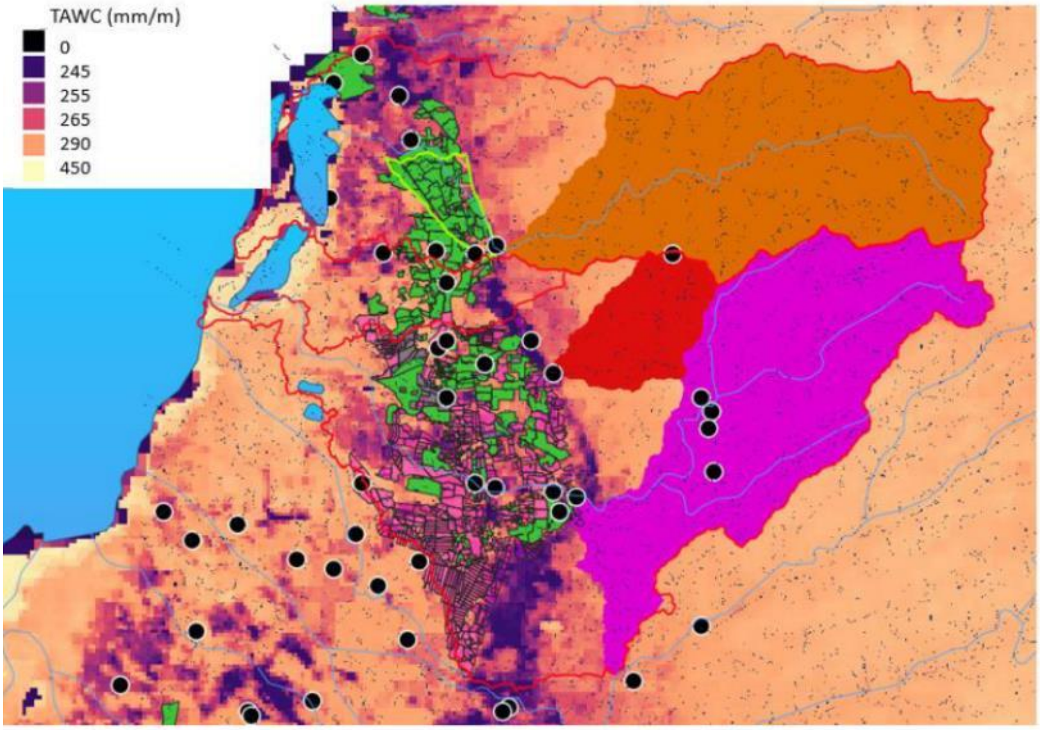


Figure 2-13. Soil water storage capacity (in mm/m) from the global HiHydroSoil product based on SoilGrids1km (Source: RECARBA project, Deltares, 2021).

Soil erosion risk and land degradation

Forest cover in the SNSM has been dynamic as a result of multiple processes, including forest clearing (1950s onwards) and cultivation of illegal crops. Specifically, the international trade of marijuana (Cannabis sativa) during the 1970s brought large-scale deforestation to the SNSM, with an estimated 70% of its forests (~150,000 ha) felled between 1975 and 1980. Forest recovery within the basin seems to have taken place from the mid-1980s onwards.

The forest clearing had a strong effect on the erosion risk and sedimentation downstream. The natural vegetation acts as a water buffer and stores precipitation in it leaves and soil. The soil is held together by the root systems. The EO4 Cultivar project made maps of soil risk and the ability to moderate surface water runoff (Figure 2-14 and Figure 2-15). Figure 2-14 shows patches of high risk area for soil erosion near the river network (this could f.e. be river banks, cultivated areas or inhabited areas). Also base soils on top of the SNSM show high risk for erosion.

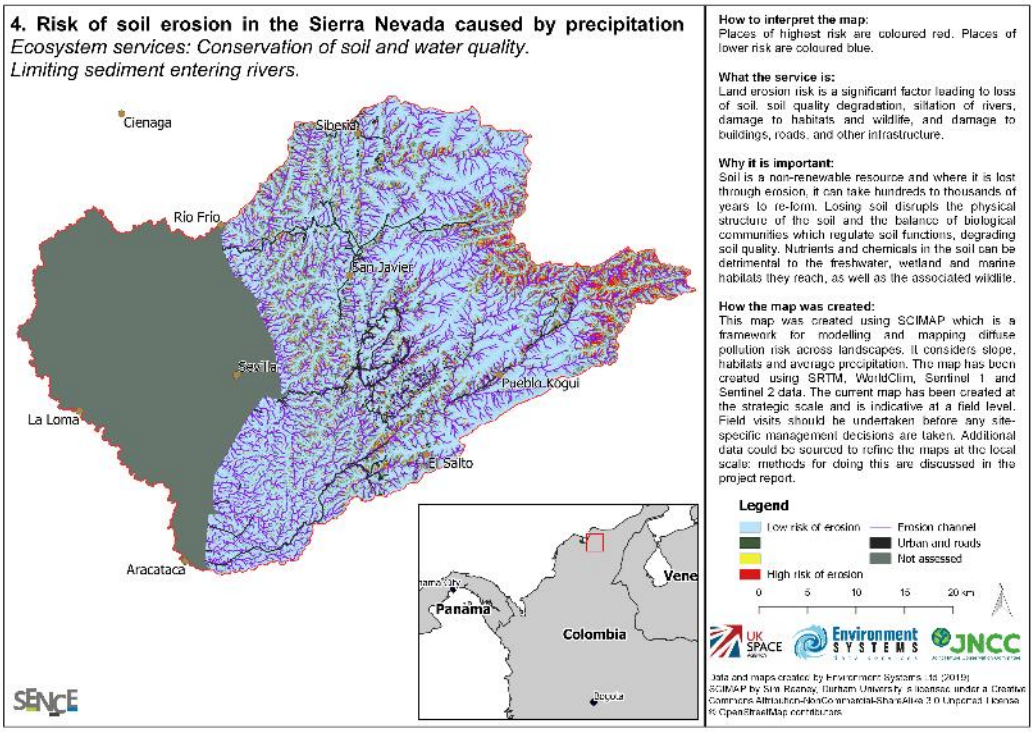


Figure 2-14 Map showing the risk of soil erosion in the Sierra Nevada (caused by precipitation events). Source: EO4 Cultivar project.

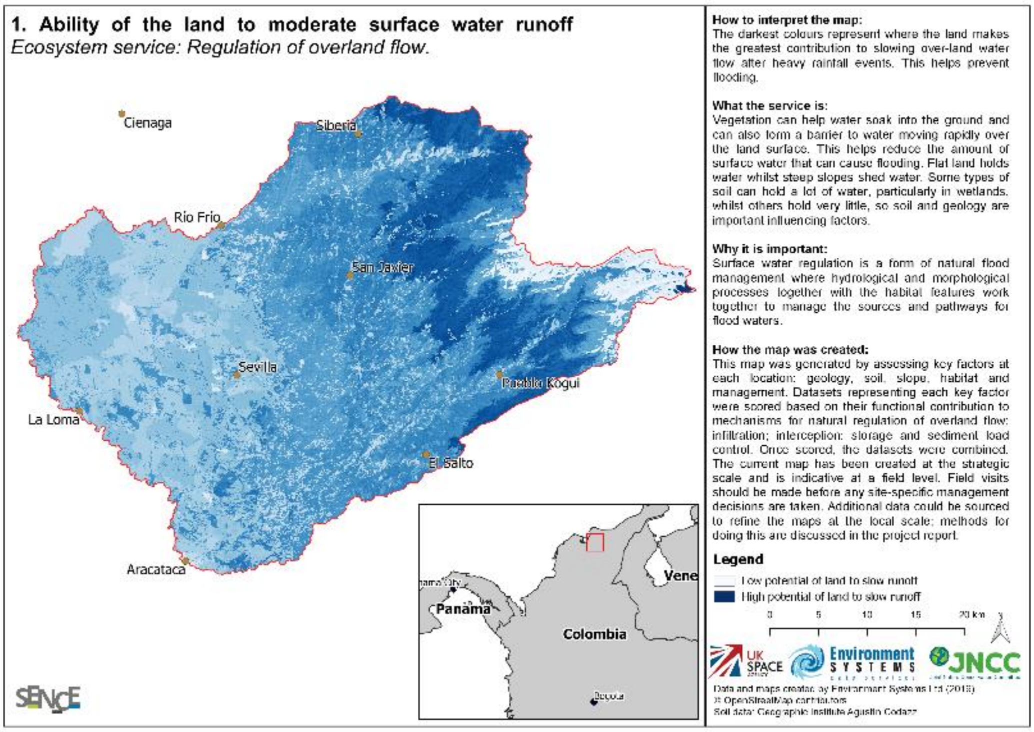


Figure 2-15. Ability of the land to moderate surface water runoff. The map shows that the natural vegetation in the upstream part of the catchment has the highest potential to slow down runoff. Source: EO4 Cultivar project.

2.3 Socio-economics environment

2.3.1 Population

The basin areas of the Frío and Sevilla rivers cover multiple municipalities of the Magdalena department: Zona Bananera, Ciénaga and to a lesser degree Pueblo Viejo. According to the 2018 National census, the municipalities of Zona Bananera and Ciénaga have a population of 66.802 and 118.435 inhabitants respectively (Dane, 2018) Kaune et al. (2020a) report about 145,000 people to live inside the Río Sevilla basin.

The Unsatisfied Basic Needs Index (UBN) is one of the indicators considered traditionally used to measure poverty in Colombia. The UNB of the municipality of Zona Bananera is 44.22%, which represents a high relative vulnerability level (i.e. municipalities with population exposed to the greatest flood potential with UBN between 27% and 56%) (Parada et al., 2015).

Indigenous communities

Historically, there is a certain level of cohabitation and coexistence between the different human groups that inhabit the Sierra Nevada massif. In recent years, though, it has been altered by the incursion of agro-industrial activities, the construction of large infrastructure projects and the alterations of public order, product of conflicts between armed groups operating in the area (Findeter, 2018).

Within the Sierra Nevada de Santa Marta National Natural Park, by indigenous oral tradition, four groups are recognized: Kogui, Sánha, Kankuama and Ika. Each one with its own territory and language:

- The Kogui, considered the strongest and largest group, are mainly inhabiting the northern slopes of the Sierra Nevada, the most wooded area receiving the largest pluvial rainfall. They are located in the valleys of the Don Diego and Palomino rivers.
- The Kankuamos show a high risk of extinction and live mainly on the eastern slope of the Sierra Nevade de Santa Marta, between the Badillo and Guatapurí rivers in the department of Cesar.
- The Sánha are a dispersed and very little homogeneous group, which maintained more contact with the settlers in the area.
- The Iká tend to be a homogeneous group, partly due to the process of integration and mixing with the new settlers in the area.

2.3.2 Key Economics activities & employment

Supplied by water from the Río Frío and Río Sevilla, agriculture forms the major economic and income generating activity in the study area. The agricultural activities, of which the highest revenue lies with banana, oil palm and coffee production, contributes substantially to the regional Gross Domestic Product (GDP) and employment. According to the Report of Regional Economic Situation (*Informe de Coyuntura Económica Regional*), for the department of Magdalena the GDP value was $8,550 billion COP in 2012, which equals 1.3% of the national GDP. Economic activity related to the cultivation of agricultural items other than coffee (including bananas and other crops) represented 7.5% of the department's GDP (Parada et al., 2015).

The specific crops are crucial for regional food security and dominate the export portfolio of the Magdalena and Cesar region (Kaune et al., 2020a). The oil palm is destined for oil extraction that is marketed locally for the production of biodiesel. Only a fraction is available for export. Palm oil production is a recent practice in Colombia, and is stimulated by grants / economic incentives and strong support from the national government in its efforts to replace at least part of the diesel use by biodiesel.

Banana production has existed in the region for more than a century. Contrary to oil palm, majority of the produced bananas are destined for direct export (Parada et al., 2015). Apart from oil palm and banana production, which heavily rely on irrigation water use, fully rainfed coffee production takes place on the hillslopes in the study area. Like with bananas, majority of the coffee produced is exported. Table 2-1 presents the production and value of the major crops cultivated in the municipalities of Zona Bananera and Ciénaga. The table shows the relative importance of banana production, as it equals 84% of the export sum of the three major crops (Parada et al., 2015).

Table 2-1: Comparative table of planted area, production and export for the main crops of the Zona Bananera and Ciénaga municipalities. Retrieved from Parada et al. (2015).

Producto	Área Sembrada[12]	Producción Regional	Exportación Regional[13]		Participación de la Respectiva Exportación Nacional
	(ha)	(ton)	(ton)	(US$)	
Café	10.624	5.770	4.127	20	1%
Aceite de Palma[14]	10.551	27.248	4.493	4,90	3%
Banano	7.095	259.374	248.999	116	15%

Apart from the agricultural practices, the ecoregion of Ciénaga Grande de Santa Marta hosts a variety of fishing communities. The INVEMAR (2020a) report states that since 1994 the whole of the CGSM system has produced an annual average of 6,063 tons of fish (mainly), shrimp, crab and clams. This generates a total average monthly between $778 and $1,509 million COP (resp. 0.18 and 0.36 million euro). Although fishing has been the main source of employment in the CGSM, it is important to highlight that the average income for this small-scale fishery is around 1500 euro per family/year (Rueda et al. 2011), which is below the poverty line (Roderiquez-Roderiquez, 2018)

The agricultural activities significantly contribute to the employment in the region. ASBAMA reports that banana production generates nearly 10,000 direct and 29,000 indirect jobs in the department of Magdalena, which equals to 8.3% of the total employment of the department (Parada et al., 2015). With respect to the employment in palm sector, in 2016 in DANE conducted the Great survey of direct employment in the Colombian palm sector where it managed to establish that this sector produces 67,672 jobs in Colombia, of which, 17,651 are generated in the northern part of the country comprising the following departments: Antioquia; Bolívar; Cesar ; Córdoba; La Guajira and Magdalena (Fedepalma, 2019).

According to information from the National Federation of Coffee Growers of Colombia, in the department of Magdalena there are 17,917 hectares of coffee, generating 11,350 direct jobs. The municipalities with the greatest importance in coffee growing are: Ciénaga, Santa Marta, Fundación and Aracataca.

2.4 Conflicts and stresses

2.4.1 Environmental impacts

Climatic events like La Niña and El Niño impact the livelihoods and food security of people in the study area and have led to significant economic losses. With the 2010-2011 floods, 20,000 hectares of land in Zona Bananera were affected as well as 230 homes, 337 families and a total of 1,475 people. The Association of Banana Growers of

Magdalena – ASBAMA (*Asociación de Bananeros del Magdalena*), for their command area reported that 1,522 banana plantations were affected by floods. The economic reduction of banana exports for the department of Magdalena was estimated at US$57 million and US$ 29 million for 2010 and 2011 respectively. Additionally, it was estimated that the 2010-2011 floods caused the loss of 5,070 jobs in the area and about US$ 1.6 million for damages to homesteads (Parada et al., 2015).

Droughts in turn have significantly impacted the productive sector, the ecosystem of swamps and wetlands and communities in Zona Bananera. The irrigation districts enforce strict rationing of water supply. The most critical rationing occurred in March 2014 with 24 hours of service for 74 hours of drying up (Workshop, April 2022). To counter these restrictions, some users form dikes and extract water illegally. This results in very low levels of water in the riverbeds, up to the total drying of the Río Frío before the confluence with the Río Sevilla for example. According to ASBAMA, 1,200 hectares of banana were affected by the 2014 droughts, of which 300 hectares were severely affected and 30 hectares were abandoned. ASBAMA estimated a decrease in the yield of about 30% (from 48-50 bunches/ha/week to 34-36 bunches/ha/week in the dry period).

The economic losses from the 2014 drought event were estimated at US$ 10 million in Zona Bananera (Parada et al., 2015). Besides, droughts also affect the CGSM system and the fishing communities. Indeed, this ecosystem has negative water balance in the dry season, since the evaporation of the water mirror is greater than the entry of water from the Magdalena and from the Sierra Nevada. The increase in salt concentration in this body of water causes mortality of fish, reduction of fishing and impacts on mangrove ecosystems. Fishing is a minor economic activity, but of great importance for families in the area, especially in the municipality of Pueblo Viejo. However, the activity is declining and it generates over-exploitation of the fishing resource

2.4.2 Water Quality

Surface water quality

Parada et al. (2015) report that the mouth of the Río Frío is completely sedimented and desilting works are carried out up to about 10 km upstream of the confluence of the Río Frío and the Río Sevilla. The sedimentation problems, which are also present in the Río Sevilla, are reported to limit the water supply in the dry season. During flood periods the sediments cause diversions of the channel affecting agricultural lands and settlements in the vicinity of the riverbeds. Figure 2-16shows the various sediment flows towards the Ciénega Grande de Santa Marta wetland area. INVEMAR (2021a) indicates that during dry periods, sediment influx from the Sierra Nevada de Santa Marta complex is reduced with 50%. ASORIOFRIO, ASOSEVILLA and different producers indicate that continues efforts must be made to maintain sedimentation tanks.

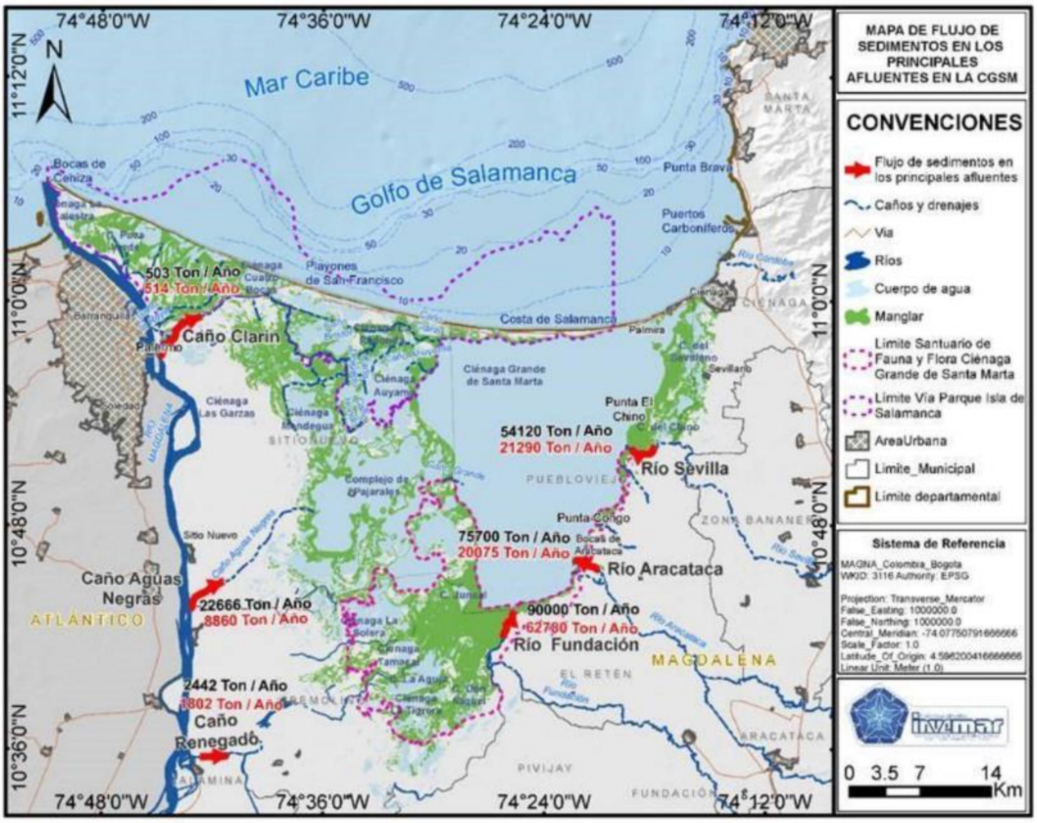


Figure 2-16. Sediment flow (ton/year) in the main tributaries of the CGSM. Values in red represent dry condition and values in black normal condition. In a dry condition, sediment transport is reduced by approximately 50% on the side of the rivers of the SNSM and about 40% on the side of the channels that connect with the Magdalena River with respect to the average scenario (2013). Prepared by: LABSIS (2020). Source: INVEMAR, 2021a

The findings are supported by Kaune et al. (2020a) mentioning high levels of sediments, Biological Oxygen Demand (BOD), and organic matter in the Sevilla River. An analysis of other water quality parameters, reported by Kaune et al. (2020a), show that values of Dissolved Oxygen (DO) have decreased, while Fats, Oils and Grease (FOG) have increased between 2012 and 2014 in various parts of Río Sevilla (Table 2-2).

In an analysis of electrical conductivity in the Aguja creek, Orihueca creek, Río Frío and Río Sevilla, Deltares (2021c) reports that values are low, between 60 to 220 µs/cm indicating fresh water. In the mouth of the Sevilla River (Sevillano, Ciénaga Magdalena), the electrical conductivity is slightly higher (1260 µs/cm), which can be explained by its proximity to the coasts and the influence of saline intrusion in the area. Likewise, it could also be influenced by other aspects such as calcite dissolution and nutrients.

Table 2-2: Quality indicators of three river section of the Sevilla Basin. Retrieved from Kaune et al. (2020a)

Quality indicators	Units	River source section (Palmor town)		Puente Sevilla – Guacamayal section (Zona Bananera municipality)		River mouth section (Zona Bananera municipality)	
		2012	2014	2012	2014	2012	2014
pH	U of pH	7.25	7.35	7.04	7.24	7.15	8.18
Dissolved Oxygen (DO)	mg/L	10.53	7.19	9.53	5.35	9.34	6.71
Suspended solids	mg/L	10.2	< 10	71.2	23.2	47.8	< 10.0
Biological Oxygen Demand (BOD)	mg/L	< 5	< 2.0	< 5	< 2.0	< 5	< 2.0
Fats, Oils and Grease (FOG)	mg/L	< 10	< 15.0	< 10	16.7	< 10	< 15.0
Total Coliforms	Most Probable Number (MPN) /100 mL	17230	16100	36540	26130	46110	15800
Escherichia Coli	Most Probable Number (MPN) /100 mL	200	200	3930	3640	3640	3100

Waste water treatment from towns in the area does hardly occur. Wastewater is frequently discharged into irrigation canals and accumulates at points of congestion and generating sources of pollution (Parada et al., 2015). Water quality issues are also related to the use of agrochemicals, especially from the coffee crop production. Also, at present the Ciénaga Grande is a threatened ecosystem. The large loads of pollution carried by the Frío and Sevilla rivers (BOD, coliforms, matter organic matter, sediments) reach the Ciénaga, further increasing the pressures it suffers (Parada et al., 2015).

There is little return flow or drainage water from the agricultural fields back towards the Río Frío or Río Sevilla, but some drainage water has been reported. The water quality of drainage water from banana fields and other agricultural fields pose concerns as the water is mix with agrochemicals. The presence of "Buchón de agua" (water bush) indicates that there is an excess of fertilizers.

Groundwater quality

Over the years, research showed layers with the presence of brackish water at shallow depths in the NW part of the aquifer, where it borders the Caribbean Sea and the Ciénaga Grande de Santa Marta; this except for the first campaign carried out in 2016. Figure 2-17 shows the vertical electrical soundings that have reported the presence of the salt wedge in the different acquisition campaigns (INVEMAR 2021a). The triangles in the figure indicate brackish water, but provides no further information about the level of salinity.

Due to saline intrusion, related to overexploitation, the general water quality and potential declines. (Parada et al., 2015). This results in higher salinity levels in some wells, which impacts agricultural production (Findeter, 2018).

Due to the lack of a waste and wastewater treatment system, pollution of the aquifer is also of concern.

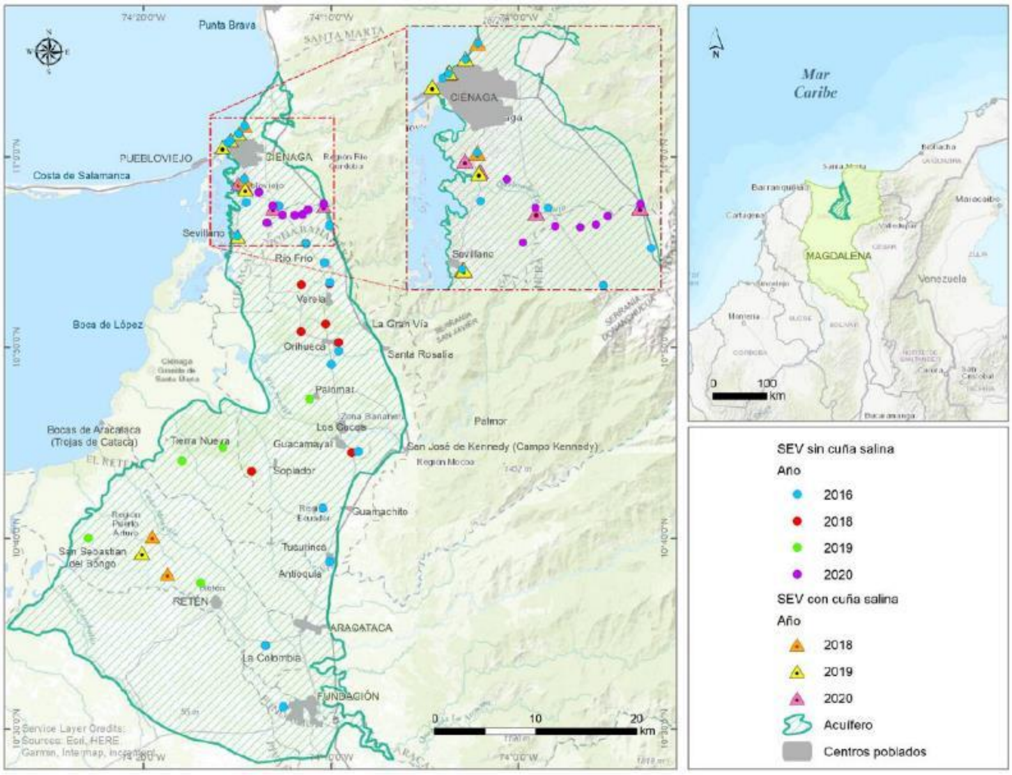


Figure 2-17. Location of Vertical Electrical Soundings of the different acquisition campaigns indicating in which the presence of layers with brackish water has been reported. The round dots indicate locations with freshwater as indicated by the VES measurement, the triangles indicate brackish water. (INVEMAR, 2021a)

2.4.3 Land tenure

In most of the municipalities in the Department of Magdalena, lend tenure problems occur. These problems originate from the existing informality in allocation and acquisition of lands, as well as from armed conflicts resulting in land restitution. The lend tenure problems especially hamper the advancement of agricultural activities, as majority of the small and medium-scale producers do not have ownership of the land. Currently this group enjoys the temporary right to the use and harvest of the property of another of the land, through tenure mechanisms such as sharecropping, leases and loans (Findeter, 2018).

3 Overview of the stakeholders in the Río Frío and Río Sevilla basins

3.1 Stakeholders assessment

This assessment builds on the foundation already laid by the *Plataforma de Custodia del Agua* (PCA). This (from origin) temporary platform brings together most relevant actors who all recently decided to renew their alliance for several more years and the intention is the embed the PCA in the water governance landscape for the future. This assessment includes all members of the PCA. More stakeholders were identified as being relevant to the water governance in the Frío and Sevilla river basins, and thus are included in this assessment.

3.1.1 Government agencies

Below is a brief overview that provides an introduction to the government agencies, their roles and responsibilities.

Overarching ministerial government bodies

- The Ministry of Environment and Sustainable Development (*Ministerio de Ambiente y Desarrollo Sostenible* – MADS) is the public entity in charge of defining the National Environmental Policy and promoting the recovery, conservation, protection, ordering, management, use and exploitation of renewable natural resources. The ministry also presides the joint commission of the Environmental Coastal Unit “Magdalena River – Canal del Dique complex – Ciénaga Grande de Santa Marta lagoon system” (*Unidad Ambiental Costera (UAC) del Río Magdalena complejo Canal del Dique – sistema lagunar de la Ciénaga Grande de Santa Marta*) that coordinates and harmonizes the planning and management process of the area, in particular to support the formulation of Integrated Management Plans of the Environmental Coastal Units (*Planes de Ordenación y Manejo Integrado de las Unidades Ambientales Costeras* - POMIUAC) (INVEMAR, 2020).
- The Agricultural Rural Planning Unit (*Unidad de Planificación Rural Agropecuaria* – UPRA) is attached to the Ministry of Agriculture and Rural Development (*Ministerio de Agricultura y Desarrollo Rural* – MADR), and is in charge of planning the efficient use of land, define relevant criteria and create the instruments required for this purpose
- The Rural Development Agency (*Agencia de Desarrollo Rural* – ADR) is attached to the MADR, and is in charge of structuring, co-financing and executing comprehensive agricultural and rural development plans and projects with a territorial approach to contribute to the transformation of the countryside
- The ADR is the owner of ASORÍOFRIO and their infrastructure, intake, irrigation channels, drainage canals, machinery and maintenance. The entity controls and provides technical supervision and financial tools to the irrigation association.

- The National Authority for Aquaculture and Fisheries (*Autoridad Nacional de Acuicultura y Pesca* - AUNAP) is attached to the MADR, and is in charge of running fisheries policy and aquaculture in the Colombian territory for research, management, administration, control and surveillance of fisheries resources and aquaculture. It recommends that the management strategies based on fishing quotas and optimal fishing effort should be based on concerted scenarios between the fishing communities, researchers and administrators of the resource (AUNAP, CORPAMAG and PNN).
- The Ministry of Housing, City and Territory (*Ministerio de Vivienda, Ciudad y Territorio* – MVCT) has established the single national dumping permit format that must be filled out by any natural or legal person who carries out economic activities of an agricultural or livestock nature that generate the discharge of polluting substances into water bodies, in accordance with the terms of Decreto 1076 of 2015 (Findeter, 2018).
- National Unit for Disaster Risk Management (*Unidad Nacional para la Gestión del Riesgo de Desastres* – UNGRD) – is the unit that directs, guides and coordinates Disaster Risk Management in Colombia, by strengthening the capacities of public, private, community entities and society through knowledge of risk, its reduction and the management of disasters. UNGRD directs the implementation of disaster risk management, in accordance with sustainable development policies, and coordinates the operation and continuous development of the national system for disaster prevention and response (sistema nacional para la prevención y atención de desastres) - SNPAD. They propose and articulate national policies, strategies, plans, programs, projects and procedures for disaster risk management, within the framework of the SNPAD and update the regulatory framework and management instruments of the SNPAD (UNGRD).
- The Regional Autonomous Corporation of the Río Grande de la Magdalena (*Corporación Autónoma Regional del Río Grande de la Magdalena* – CORMAGDALENA) has the mission of guaranteeing the recovery of the navigation and port activity of the Río Grande de la Magdalena. They are not an environmental authority, but is interconnected with environmental authorities, as they also work on the conservation of land, the generation and distribution of energy and use and preservation of the environment, fish resources and other renewable natural resources. Its jurisdiction is made up of 128 municipalities over 13 departments, including the department of Magdalena. Cormagdalena will participate in the process of planning and harmonization of policies and regulatory norms issued by the different competent authorities for the adequate and coordinated management of the Magdalena River basin

Environmental authorities

- The Regional Autonomous Corporation of Magdalena (*Corporación Autónoma Regional del Magdalena* – CORPAMAG) is the environmental authority with jurisdiction in the territory, in charge of managing the natural resources and promoting sustainable development of Magdalena. The entity grants permits, concessions and licenses to irrigation associations and municipalities. It also allocates and manages some concessions directly (Interviews; Workshop, April 2022). Besides, CORPAMAG has under its control and management the Ramsar wetland.
- The National Natural Parks (*Parques Nacionales Naturales* - PNN) is the entity in charge of the administration and management of the Natural Parks Systems, also including the Regional Natural Parks – PNR) the *Parque Sierra Nevada de Santa Marta* (SNSM) as well as the *Santuario de Flora y Fauna de Ciénaga Grande de Santa*

Marta (SFFCGSM) (Interviews; Findeter, 2018). PNN manages the public protected areas of the National Natural Parks System, and also, Protected Forest Reserves, Regional Natural Parks, Integrated Management Districts, Soil Conservation Districts and Recreation Areas.

Local government

- The Government of Magdalena (*Gobernación del Magdalena*) is an entity in charge of promoting the socio-economic, cultural and environmental development of its territory, in order to satisfy the basic needs of the community. It has physical and human resources for the formulation, execution, monitoring and evaluation of policies, programs and projects aimed at improving the quality of life of its inhabitants, complying with legal provisions and framed in an institutional process of continuous improvement.
- The Municipality of Zona Bananera (*Alcaldía de Zona Bananera*) sits between the mountains of the Sierra Nevada de Santa Marta and the swamps of the Ciénaga Grande de Santa Marta, meaning that it covers essentially the agricultural production area. Its Secretary of Economic Development (*Secretaría de Desarrollo Económico* - SDE), is a particular body of the municipality of Zona Bananera that is responsible for ensuring the provision of water services to the local population
- The Municipality of Ciénaga (*Alcaldía de Ciénaga*) is located on the shores of the Caribbean Sea, at the northeastern end of the Ciénaga Grande de Santa Marta, and at the foot of the Sierra Nevada de Santa Marta.

From all the government agencies mentioned above, CORPAMAG, PNN and the Government of Magdalena are members of the PCA. Also community representatives and the Juntas de Acción Communal of San Pedro, Palmor, Carital, Julio Zawady and Josefina are also part of the PCA.

3.1.2 Water suppliers

Domestic water supplier

- Aguas del Magdalena S.A. E.S.P. is the departmental water company of mixed nature (90% owned by government, 10% owned privately) that ensures the collection, treatment and distribution of water for the urban and rural communities of the Department of Magdalena, through the feasibility and implementation of infrastructure works in sustainable water and sewerage, business strengthening to service providers, social management and integrated management of water resources, according to the needs of our customers and applicable regulations under the Departmental Plan for business management of water and sanitation services. Aguas del Magdalena is responsible for the drinking and potable water policy in the department of Magdalena, providing technical support and financial assistance to municipalities. The company executes infrastructure works, but the municipalities provide drinking water services and ensure its proper provision.

Irrigation associations

In the focus area, there are two large-scale irrigation associations for the agricultural exploitation of the Río Frío and Río Sevilla, respectively ASORÍOFRIO and ASOSEVILLA (Torres et al., 2019; Findeter, 2018).

- The Association of Users of the Large-Scale Land Adaptation District of the Río Frío (*Asociación de Usuarios del Distrito de Adecuación de Tierras de Gran Escala del Río Frío* - ASORÍOFRIO) is located in the town of Rio Frío in the municipality of Zona Bananera, Magdalena (Findeter, 2018). It is a legal entity under private law, of a corporate nature, with a special purpose and non-profit, constituted by those who meet the conditions (e.g. who has a water concession through ASORIOFRIO) to be taken into account as users of the land adaptation district. It is dedicated to providing the development, administration, operation, conservation and rehabilitation of the irrigation infrastructures that make up the district. ASORÍOFRIO has a contract with the Rural Development Agency (*Agencia de Desarrollo Rural* – ADR) to operate. The Association must keep a General Registry of Users (RGU), which will contain the list of its users with user information, location of the property, etc.

- ASOSEVILLA is the association of users of the irrigation district of Sevilla, also located in the municipality of Zona Bananera, Magdalena (Findeter, 2018). It is a legal entity of private law, of corporate nature, with special purpose and non-profit. The objective of the irrigation association is to operate, conserve and maintain the water works that make up the district. ASOSEVILLA bought the irrigation district from the state in 2010; unlike ASORÍOFRIO, the association is not under contract with ADR.

The origins of the irrigation associations go back to the establishment in 1900 of the United Fruit Company in the Zona Bananera, with the drilling of irrigation canals to support the growth in the export market of bananas to the United States (Visit to Cenipalma, April 2022; Brungardt, 1995). In the aftermath of the 1928 strike of the United Fruit Company workers and of the '*Masacre de las bananeras*' tragic event, the banana plantations were handed over to a few families while the administration of the irrigation network passed to the hands of the government. Later on the ownership of the irrigation district was given to the producers. Both ASORÍOFRIO and ASOSEVILLA come from the division in 1994 of the former Prado Sevilla district into 4 irrigation associations.

Both ASORÍOFRIO and ASOSEVILLA are members of the PCA.

3.1.3 Water users

Farmers and trade associations

The farmers and trade associations listed below came across as key stakeholders in the Río Frío and Río Sevilla basins:

- FEDEPALMA - *Federación Nacional de Cultivadores de Palma de Aceite*
- ASBAMA - *Asociación de Bananeros del Magdalena y La Guajira*
- AUGURA - *Asociación de Bananeros de Colombia*
- FNC - *Federación Nacional de Cafeteros de Colombia*
- Fedecacao - *Federación Nacional de Cacaoteros*

All the farmers associations mentioned above are members of the PCA, except for Fedecacao. The PCA comprises more companies and trade associations, including Tecbaco, Fundación BANASAN, Fundeban, Uniban Fundación, DAABON, Fundepalma and ASOCOOMAG; however, they will not be discussed in detail as they played less prominent role in the group discussion and stakeholder interviews of this study.

Local communities

- The campesinos are the rural communities who work the land, often in small plots, with the family constituting most or all of the labour. This includes agricultural wage laborers (jornaleros) and small landholders (minifundistas).
- The indigenous communities Kogui – Malayo – Arhuaco reside within the National Park of the Sierra Nevada de Santa Marta (Findeter 2018; Parada et al., 2015). As guardians of the mountains, the indigenous communities call for respect for nature and the use reasonable use of natural resources, especially water. On that matter,

they have expressed their concerns regarding several activities and deficiencies that have shown to threat the availability and quality of water.
- The fishermen communities of the Ciénaga. There are several communities located around the lake, with around 3,500 artisanal fishermen operate in the CGSM. They supply a good part of the food security of a growing population in the municipalities of Sitionuevo (stilt houses with ~33,100 inhabitants), Puebloviejo (~33,000 inhabitants) and Ciénaga (~105,500 inhabitants) (INVEMAR 2020a)

Only the campesinos are represented in the PCA, through the *Juntas de Acción Comunal* (JAC, see Section 3.1.4).

3.1.4 Civil society groups / Non-governmental organizations (NGOs)

- The *Plataforma de Custodia del Agua* (PCA)[1] is a public-private initiative that seeks to improve the water governance for the Río Frío and Río Sevilla basins by stimulating collective action through debate, consultation and articulation, generated in a space for plural and inclusive participation. The PCA was formed in 2015, through an agreement of wills between 19 institutions under the leadership of WWF Colombia. It was initially established for a 5-year period, but the alliance was renewed in 2019 and later in 2021 for 4 more years with the 19 pioneering institutions and 11 other community entities and organizations. The target of the PCA is to organize a roundtable once every 1 – 2 months.

More civil society groups and NGOs are members of the PCA as listed below, but less information is known about the role they play and their responsibilities

- *Juntas de Acción Comunal* (JAC) of the villages San Pedro, Palmor, Carital, Julio Zawady and Josefina. They are non-profit civic corporation made up of the residents of a place, who join efforts and resources to seek the solution of the most felt needs of the community
- *Fundación Mujeres Rurales Construyendo Futuro* is committed to the youth and the environment.
- *Red Ecolsierra* (Network of Eco-Friendly Producers from the Sierra Nevada de Santa Marta) is a supportive organization dedicated to increasing the profitability of organic coffee farming.
- *Fundación Herencia Ambiental Caribe* was created to promote peace and sustainable human development through the sustainable use and protection of the environment and natural, cultural and social resources, with an emphasis on community participation processes and the strengthening of identity and culture.
- ASOSANPEDRO ESP.

3.1.5 Research entities

Public institutions

- INVEMAR – *Instituto de Investigaciones Marinas y Costeras* – is a public institution that carries out basic and applied research on renewable natural resources, on the environment of coastlines and on marine and ocean ecosystems in order to provide the necessary scientific knowledge for policy formulation and decision making, to MADS in particular. Since 2014, INVEMAR's Marine and Coastal Geosciences program has been monitoring monthly oceanographic conditions in the department of Magdalena from 3 monitoring stations (INVEMAR, 2020).
- IDEAM - *Instituto de Hidrología, Meteorología y Estudios Ambientales* – is a public institution that provides technical and scientific support to the National

[1] http://plataformadecustodiadelagua.org/

Environmental System, which generates knowledge, produces reliable, consistent and timely information on the state and dynamics of natural resources and the environment. It facilitates the definition and adjustments of environmental policies and decision-making by the public and private sectors and the general public.

- AGROSAVIA - *Corporación Colombiana de investigación Agropecuaria* – is a non-profit, decentralized public entity with mixed participation of scientific and technical nature. Its purpose is to work on the generation of scientific knowledge and agricultural technological development through scientific research, the adaptation of technologies, transfer and advice in order to improve the competitiveness of production, equity in the distribution of the benefits of technology and sustainability in the use of natural resources.
- *Universidad del Magdalena* is a public, departmental, research university based in the city of Santa Marta, capital of Magdalena, Colombia.

Both AGROSAVIA and INVEMAR are members of the PCA, as well as the Universidad del Magdalena.

Research centers

- Cenipalma - *Corporación Centro de Investigación en Palma de Aceite* – works with palm growers to obtain better results and services that the sector requires, to contribute to the health, productivity and sustainability of this agribusiness through research, generation of inputs and guidelines for the implementation of best practices.
- The Humboldt Institute – *Instituto de Investigación de Recursos Biológicos Alexander von Humboldt* – is a non-profit civil corporation linked to the MADS. Within the framework of the United Nations Convention on Biological Diversity, ratified by Colombia in 1994, the Humboldt Institute generates the necessary knowledge to assess the state of biodiversity in Colombia and to make sustainable decisions.

Cenipalma is part of the PCA. The Humboldt institute is not part of the PCA.

3.1.6 Finance institutions

- FINAGRO - *Fondo para el Financiamiento del Sector Agropecuario* – is a financial entity that has encouraged the establishment of crops the central and northern region of the Department of Magdalena through its lines of credits (Findeter, 2018). It has granted credit for a total amount of $108,607 million Colombian pesos between 2013 and 2016, which were distributed in: oil palm (54%), banana (29%), cassava (10%), traditional corn (5%), mango and rice (1%).

3.2 Water governance assessment

3.2.1 National policy for water resources management and development

In the Colombian legal system, water resources are part of the public domain which means that the state is responsible for its permanent protection to ensure its fair access and efficient use in a proportional, equitable, equal and fair way (Restrepo-Medina & Nieto-Rodríguez, 2020). The Ministry of Environment and Sustainable Development (MADS) is the public entity in charge of defining the National Environmental Policy and of promoting the recovery, conservation, protection, ordering, management, use and exploitation of renewable natural resources. With that aim, the National Policy for the Comprehensive Management of Water Resources (*Política Nacional para la Gestión Integral del Recurso Hídrico* – PNGIRH) was formulated in 2010 to establish the objectives, strategies, goals, indicators and lines of strategic action for the management of water resource in the country (Findeter, 2018).

To further guide the formulation of action plans, the MADS developed instruments such as the Water Resource Management Plan (*Plan de Ordenamiento del Recurso Hídrico*) which sets out guidelines and procedures for proper use and management of water resources with the purpose of guaranteeing efficient water use for productive purposes (Workshop output; Restrepo-Medina & Nieto-Rodríguez, 2020; Findeter, 2018). It also addresses regulatory structures to control and administer (through concessions and permits granted) the anthropogenic discharge of polluting substances into water bodies in order to protect the environment from unsustainable economic activities.

In Colombia, the legislation regarding water determines that the Regional Autonomous Corporations must make plans for the ordering and management of hydrographic basins at a level of 396 divisions territorial watersheds defined for Colombia that may or may not coincide with the official subdivision of 316 hydrographic subzones (SZH) for the country (Parada et al., 2015).

At high government level, the Ministry of Agriculture and Rural Development (*Ministerio de Agricultura y Desarrollo Rural* – MADR) and the Ministry of Housing, City and Territory (*Ministerio de Vivienda, Ciudad y Territorio* – MVCT) also have a play in policies and regulations related to water resources management, in particular regarding the domestic water supply.

On a final note, local stakeholders recognize that the research institutes are a great support for articulating a national action strategy for river basins management plans in the territories (Workshop, April 2022).

3.2.2 Water governance at basin level

The implementation of the National Policy for the Comprehensive Management of Water Resources (PNGIRH), as developed by the MADS, is the responsibility of environmental authorities, mainly the regional autonomous corporations in their respective jurisdictions (Restrepo-Medina & Nieto-Rodríguez, 2020). The basins of the Río Frío and Río Sevilla together represent a level of subdivision of the hydrographic subzone (SZH), Ciénaga Grande de Santa Marta (code: 2906-01) prioritized by the Regional Autonomous Corporation of Magdalena (CORPAMAG) through the Watershed Planning and Management Plan (*Plan de Ordenamiento y Manejo de Cuenca* – POMCA) that is updated about every 10 years (Findeter, 2018; Parada et al., 2015). CORPAMAG is managing the natural resources in the department of Magdalena, in particular the water availability. To that effect, CORPAMAG grants permits, concessions and licenses.

As the Río Frío and Río Sevilla basins provide important services to the ecosystem in the area, interventions on water resources have a considerable impact on sustainability of the various ecosystems. In this regard, the National Natural Parks (*Parques Nacionales Naturales, PNN*) are a key player in the territory (Parada et al., 2015). The entity oversees the administration and management of the System of National Natural Parks (*Sistema de Parques Nacionales Naturales*) and the coordination of the National System of Protected Areas (*Sistema Nacional de Áreas Protegidas*). In the focus area, it manages the *Parque Sierra Nevada de Santa Marta* (SNSM) and the *Santuario de Flora y Fauna de Ciénaga Grande de Santa Marta* (SFFCGSM).

CORPAMAG also manages the Ramsar wetland Ciénaga Grande de Santa Marta (Parada et al., 2015), and therefore the management areas of CORPAMAG and PNN overlap. Besides, the entity promotes community participation and programs for environmental protection, sustainable development and proper management of renewable natural resources (Findeter, 2018; Parada et al., 2015). This community participation though governmental institutions is also prescribed by law. Local stakeholders reported that the government organizes rounds of prior consultation with the indigenous communities when a planning process or work includes their territories (Workshop, April 2022). Thus, the community leaders have been able to oppose development projects in the Sierra Nevada that were considered to disregard the environment and the customs and traditions of the communities

On a larger scale, the Regional Autonomous Corporation of the Río Grande de la Magdalena (CORMAGDALENA) also has a role in the environmental development of the focus area. The entity has the mission of guaranteeing the adequacy and conservation of land, and use and preservation of the environment, fish resources and other renewable natural resources in its jurisdiction, including the department of Magdalena.

According to Torres et al. (2019), both Río Frío and Río Sevilla are subject to future river basin management planning, indicating the local interest in improving water management in the region. To this day, however, the POMCA is not yet fully implemented in the context of the Río Frío and Río Sevilla basins. This will be described in greater detail in the next chapters.

3.2.3 Water governance at local level

Irrigation water supply

In the focus area, there are two large-scale irrigation associations for the agricultural exploitation of the Río Frío and Río Sevilla, respectively ASORÍOFRIO and ASOSEVILLA (Torres et al., 2019; Findeter, 2018). The irrigation associations allocate the water from the Río Frío and Río Sevilla to the different agricultural uses and they oversee that the concession (water allocation permit), as determined by the regional environmental authority CORPAMAG, is respected (Torres et al., 2019). As explained in an interview with a representative of Cenipalma (Visit to Cenipalma, April 2022), the board members of ASORÍOFRIO and ASOSEVILLA are appointed by the producers. Besides the water districts, CORPAMAG itself allocates and manages few concessions directly.

According to stakeholders (Santa Marta meeting, April 2022), about 80% of the land is owned by 20% of the producers among which Tecbaco and Banasan. Those important producers are reported to hold power in the decision-making relating to water allocation. Indeed, there are strong interests at stake concerning water allocation, especially for banana producers exporting to Europe. According to Cenipalma, their export contracts impose strict quality criteria for bananas which can be met provided that a specific volume of water is supplied (Visit to Cenipalma, April 2022).

According to Findeter (2018), both irrigation associations have efficient water resource saving policies or programs, an environmental management plan and a plan to recover losses, established by the environmental authority CORPAMAG.

Domestic water supply

With regard to domestic water supply, the Municipality of Zona Bananera directs the provision of public aqueduct, sewage, and sanitation services through special units or office secretariats (Findeter, 2018); in this case, the Secretary of Economic Development (*Secretario de Desarollo Economico* - SDE). The municipality is supported by Aquas del Magdalena, with technical support and financial assistance for the development of infrastructure. The municipality is certified by the Superintendence of Residential Public

Services (*Superintendencia de Servicios Públicos Domiciliaros*) for the direct management and allocation of the water resources, and it also holds a concession for the use of water resources.
The Municipality of Ciénaga was reported to also come into play in the water governance in the focus area by local stakeholders (Workshop, April 2022).

3.3 Water governance and water allocation

Following the workshop session and field visits in Magdalena in April 2022, it became clear that decisions on water resources allocation intervene at different scales and time frames:

- The government, represented by the Ministry of Environment and Sustainable Development (MADS), sets the vision and deploys long-term strategies for the major river basins by means of ministerial decrees as found in the Water National Policy, and of guidelines as provided in the Water Resources Management Plan and other action plans.
- CORPAMAG manages the water availability in the department of Magdalena by granting concessions (water permits) for irrigation purposes and for domestic use over a long-term period ranging from 5 to 15 years. They also carry out field audits of water intake by agricultural producers and check the environmental flow. These are not environmental audits, but they are part of the monitoring and follow-up that the corporation has to do, as an activity that remains when a concession is granted.
- The irrigation associations, ASORÍOFRIO and ASOSEVILLA, and the municipalities of Zona Bananera and Ciénaga allocate the water resources to the actual water users on-the-ground, based on short-term water availability predictions.

4 Water supply in the Río Frío and Río Sevilla basins

4.1 Water concession

In 2015, CORPAMAG granted the irrigation districts a fixed water concession for the use of the properties registered in the district for a term of 10 years, based on the Watershed Planning and Management Plan (POMCA), fitting the national guidelines for environmental flow.

4.1.1 Potential extraction volumes

It was reported in several information sources that:

- For ASORÍOFRIO, the water concession amounts to 3.41 m3/s, which is equivalent to 8.84 Mm3/month. Besides, CORPAMAG grants 14 private users in the irrigation district of ASORÍOFRIO a water concession of 1.49 m3/s, or 3.87 Mm3/ month. In total, the total water concession for the irrigation district is 12.71 Mm3/ month.
- For ASOSEVILLA, the environmental authority grants a water flow of 4.41 m3/s, giving a total of 11.42 Mm3/ month. No private concession has been reported.

However, other information sources provide contradicting information on the potential extraction volumes, due to the fact that the extraction volumes for irrigation water depend on the environmental flow- and the minimal environmental flow is not clear. More information is provided in subchapter 5.5.

The reported official actual abstraction volumes for irrigation are usually lower than the potential extraction volumes, but in practice and during the dry season this might be different as there is not continuous monitoring. Also in the wet season, the intake of water is lower as there is a lower water demand for irrigation. The actual water intake by the water districts should fit the environmental flow requirements set by CORPAMAG, in the dry season field checks by CORPAMAG are carried out to see if the environmental flow is sustained.

4.1.2 Water tariffing

The water tariffing system in place was explained by local stakeholders joining the workshop as part of this project (Workshop, April 2022). Two billing systems coexist, one for domestic water supply using a volumetric rate and one for irrigation water supply using a fixed rate for services and volumetric rate for water use.

The domestic water supply is billed by the municipalities through a system of water, sewage and cleaning fees. There are national regulations on the provision of public services and likewise indicating how the rates should be depending on the number of users, the management and operation of each municipality. The domestic water supply system does not have fixed rates, but rather each operator does its analysis of services and sets the rates.

The irrigation districts charge their water users a fee for services which includes the rate for the water used, administration costs, maintenance costs of the infrastructure, and other costs. The water tariffing rates are set by MADR. In the case of ASOSEVILLA, as explained by various stakeholders, the irrigation district receives 60 pesos/m3 of fees from each water user recorded in the RGU, which amounts to 160,000 pesos/ha/year approximately (Visit to Cenipalma, April 2022; Santa Marta meeting, April 2022). All producers should have a mandatory water meter to monitor their water use and report to the water districts. In practice, not all producers have a water meter and some measure the water use based on pump statistics at the producers water intakes of the distribution network. ASORIOFRIO have more advanced data collection systems, so they charge the water used on a frequent basis. ASOSEVILLA charge semi-annual rates.
The irrigation districts then pay a fee of 60 to 70 *centavos*/m3 to CORPAMAG for the water concession. CORPAMAG is planning to increase its tariff to 5 pesos/m3 at least, or up to 12 pesos/m3 (Workshop, April 2022). One of the reasons suggested for this is to ensure improvements in water use efficiency are encouraged and implemented by the water users.

TARIFAS 2022			
TIPO TARIFA	**VALOR TARIFA**	**UNIDAD**	**PERIODICIDAD**
TARIFA FIJA (T.F)	$201,878.7	$/ha	Anual
TARIFA VOLUMETRICA (T.V)	$49.63	$/lps o $/m^3	Según consumo
TARIFA REPOSICIÓN DE MAQUINARIA (TRME)	$11,346.0	$/ha	Anual

Figure 4-1. Water tariffing system of ASORIOFRIO for 2022, according to the 'Resolución 000400 de 2021' of the Ministry of Agriculture and Rural Development.

As ASORÍOFRIO is a non-profit organization, they reinvest profits in infrastructure maintenance (f.e. weed cleaning) and development. Income is listed for ASORÍOFRIO, eventhough it is a non-profit organization. This income corresponds to loans of equipment (e.g. gauging equipment, *Equipo de aforo*) to private companies. The equipment is for free to district users.

4.2 Main water supply in the Río Frío basin

4.2.1 Water supplier in the Río Frío basin – ASORÍOFRIO

The large-scale land irrigation district of the Río Frío, operated by ASORÍOFRIO, is located in the north of the department of Magdalena, specifically in the municipality of Zona Bananera (Findeter, 2018). It covers 5,777 hectares in banana, oil palm, fruit trees and food crops (ASORIOFRIO, 2015). ASORÍOFRIO is in charge of the development, administration, operation, conservation and rehabilitation of the irrigation infrastructures that make up the district (see Figure 4-2). The water infrastructures and the irrigation association itself are owned by ADR. The government body also controls and provides technical supervision and financial tools to the irrigation association.

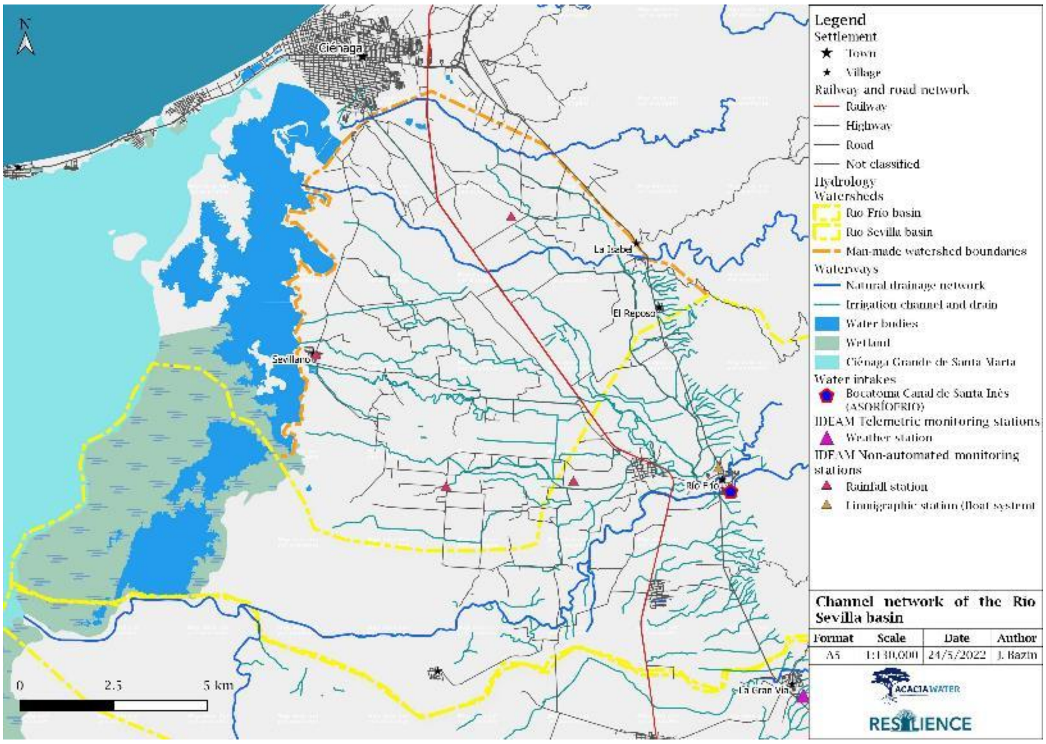


Figure 4-2: The channel network of ASORIOFRIO provides service to a large area situated north of the hydrological catchment of the Río Frío.

4.2.2 Irrigation network system

The infrastructure of ASORÍOFRIO is made up of the main intake (referred to as *bocatoma*), a sand removal tank, a primary canal (canal Santa Inés), three secondary canals (North, Centre, South) and 34 tertiary canals, to convey water to users (ASORÍOFRIO, 2022). These channels are sometimes referred to as aqueducts.

The bocatoma Canal de Santa Inés is the main water intake of the irrigation district (coordinates 10,89982060; -74,15110900). It is a weir structure with a total capacity of more than 5000L. CORPAMAG funded the concrete spillway, the valves and the door system, but the structure is operated by ASORÍOFRIO. The intake supplies water to the canal Santa Inés, as depicted in the figure below.

Figure 4-3. The Río Frío, at the village Río Frío, and the primary water infrastructures of ASORÍOFRIO, with the main intake (blue square), the weir structure (orange line), and canal Santa Inés (blue line), in zoom below, Bing maps Imagery.

The irrigation channel network has a total length of 79 km approximately (ASORÍOFRIO, 2015). Table 4-1 provides an overview of the main canals and their main properties.

Table 4-1. Information about the channel network of ASORÍOFRIO (ASORÍOFRIO, 2015), average flow unknown.

Channel	Length (in meters)	Flow (in m3/s)
	PRIMARY Canals	
Canal Santa Inés	1,300	/
	SECONDARY Canals	
Canal Norte	7,200	/
Ramal Centro	6,000	/
Canal Sur	4,492	/
	TERTIARY Canals	

Canal Lianos (Norte)	3,600	/
Canal Putumayo (Norte)	4,000	/
Canal Perro (Norte)	2,500	/
Canal Roble (Norte)	1,200	/
Canal Loco (Centro)	5,000	/
Canal Bovea (Centro)	6,000	/
Canal Maria Teresa (Centro)	3,600	/
Canal Pantoja (Centro)	3,600	/
Canal Pantoja 2 (Centro)	1,300	/
Canal Mayales (Centro)	1,000	/
Canal Desvio Nuevo (Sur)	1,800	/
Canal Desvio Viejo (Sur)	1,500	/
Canal Sur Nuevo (Sur)	3,200	/
Canal Olleta (Sur)	4,000	/
Canal Enano (Sur)	1,200	/
Canal Lucia (Sur)	4,000	/
Canal Permanente (Sur)	3,500	/
Canal Tablazo (Sur)	4,000	/
Canal Lola (Sur)	4,500	/
Canal Carital (Sur)	1,300	/

The main water intake from the river is connected to a sedimentation tank, just west of the highway 45. Between the main intake and the discharge monitoring station, a small water intake is located that serves a private concession of a producer arranged directly by CORPAMAG (Visit to ASORIOFRIO, April 2022). The three infrastructures are located on the satellite imagery in Figure 4-4.

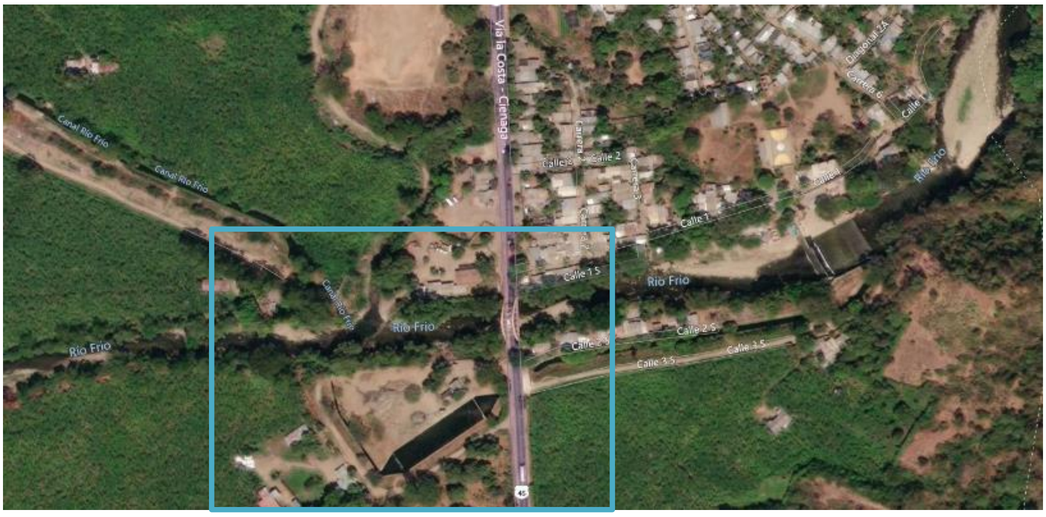


Figure 4-4. The Río Frío, at the village Río Frío, and the hydrological monitoring station of the ASORIOFRIO intake (blue dot), main channel (known as Santa Inés, blue line on the right) and intake of the private concession (orange dot) at ASORIOFRIO. Bing Maps Imagery.

4.2.3 Water allocation in the Río Frío basin

The total capacity of the weir structure is more than 5000L, but the water intake never exceeds the maximum volume of the water concession granted by CORPAMAG (3,41 m3/s). ASORÍOFRIO organizes the water supply. Producers are contacted by ASORÍOFRIO a day before the actual water supply to the irrigation channel to request how much water is required (e.g. how many hours the producers need to irrigate). After finishing irrigating, the producers contact ASORÍOFRIO to close the irrigation supply channel so that they are not charged more than they should. This practice also contributes to efficient water use of the water flowing through the channels. Therefore it is said that there is not much water that enters the ASORÍOFRIO main channel intake (Santa Inés) and eventually drains into the Ciénaga as 'residue water'. There is however some drained water from the banana fields; this water is also occasionally monitored in terms of quantity by ASORÍOFRIO.

In the wet period, ASORÍOFRIO opens the reliever (*aliviadero*) to increase the river flow downstream. At the same time, they open the weirs a little to reduce the risk of flooding by the Río Frío downstream. This, however, results in debris and sediments to enter the channel system, which requires maintenance.

ASORÍOFRIO carries out various monitoring activities, including the monitoring of the water surplus that is drained from the (banana) fields; it can range from 50% in the wet season to 0% in the dry season. The frequency of these measurements of the drainage system are unknown. Drinking the drainage water is strictly forbidden in ASORÍOFRIO (Workshop, April 2022).

Upstream from the main intake of ASORÍOFRIO, there is an intake for domestic use. The domestic water intake is a separate concession from the irrigation water intake. As the flow measurements are done just downstream of the domestic water intake, these volumes are already deducted from the water availability.

ASORÍOFRIO also reported on unregulated water intakes directly from the river. However, this practice is difficult to monitor, so there are no existing records.

4.3 Main water supply in the Río Sevilla basin

4.3.1 Water supply in the Río Sevilla basin – ASOSEVILLA

The large-scale land irrigation district of the Río Sevilla, administrated by ASOSEVILLA, is located in the north of the Magdalena department, specifically in the municipality of Zona Bananera (Findeter, 2018). ASOSEVILLA is privately owned, and has the objective to operate, conserve and maintain the infrastructures that make up the district. The board of the irrigation district includes 9 producers out of 366 local producers in total (Santa Marta meeting, April 2022). ASOSEVILLA gradually moves towards more efficient water allocation, however, some producers would like this shift to go faster.
According to figures shared by ASOSEVILLA, the district covers 8,475 ha under banana crops, oil palm, fruit trees and food crops, of which 7,018 ha can be potentially irrigated (ASOSEVILLA, 2022). By January 31st, 2022, ASOSEVILLA provided water to 380 users among the district as recorded in the General Registry of Users (*Registro General de Usuarios* - RGU). However, only 160 producers have been reported to pay ASOSEVILLA for their irrigation services.

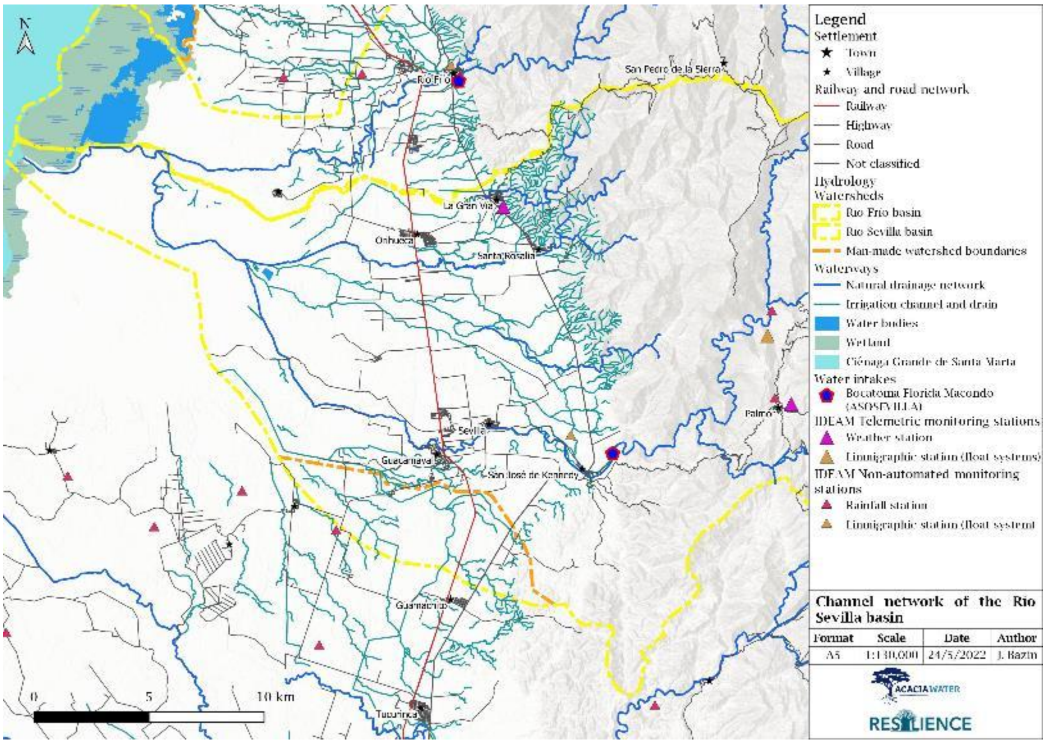


Figure 4-5 Channel network of the Río Sevilla basin.

4.3.2 Irrigation network system

The infrastructure of the district is made up of the Florida-Macondo intake, a sand removal tank, two main canals (canal Florida and canal Macondo), seven secondary canals and five tertiary canals, to convey water to users. The irrigation channel network has a total length of 70km approximately (ASOSEVILLA, 2022). Most of the canals are lined. Table 4-2 provides an overview of the main canals and their main properties.

Table 4-2. Overview of the main canals and their main properties of ASOSEVILLA (ASOSEVILLA, 2022).

Channel	Length (in meters)	Average flow (in m3/s)
	PRIMARY Canals	
Canal Florida	6,325	7.5
Canal Macondo	1,938	1.4
	SECONDARY Canals	
Canal Susana	10,120	0.7
Ramal Florida	8,471	2.8
Canal Marconia	3,100	2.3
Canal Gabriela	3,312	0.8
Canal Sacramento	4,180	Unknown
Canal Macondo 1	4,897	0.6
Canal Macondo 1	7,116	0.8
	TERTIARY Canals	
Canal Abarca	2,015	Unknown
Canal Gloria	4,283	Unknown
Canal Campo	6,417	Unknown
Canal Garcia	5,270	Unknown
Canal Los Colonos	1,300	Unknown
	DRAINS (*drenajes*) AND CREEKS (*quebradas*)	
Dren. Sacramento	7990	/
Dren. Manzanares	7630	/
Dren. Marconia	11857	/
Dren. Union	5550	/
Dren. Abarca	2317	/
Quebrada La Tal	16050	/
Quebrada Orihueca	14040	/
Quebrada Guaimaro	13600	/

The irrigation channel network dates back from 1900. ASOSEVILLA maintains the canals annually, especially to remove sediments. However, the network is partially damaged at present as ASOSEVILLA reported. A big flood in 2021 caused the concrete walls of the sedimentation basin to break and led to erosion of the river bank (see Figure 4-6). At the time of the field visit to the irrigation district, the intake was congested with debris.

Figure 4-6 Damage to the river bank of Río Sevilla just south of the main intake of ASOSEVILLA, damage caused by the 2021 flood. (picture of Acacia Water, April 2022).

4.3.3 Water allocation and monitoring in the Río Sevilla basin

ASOSEVILLA divides the water over the channels based on the command area (hectares) served by the channel. In times of drought, all producers receive less water. The reduction in water is calculated based on the hectares owned of the producers, and proportionally distributed accordingly. So, if the available water is 20% less than normal, the allocated water to the producers is also 20% lower. The volume is corrected by ASOSEVILLA to account for the travel time of the water from the intake to the field and associated conveyance losses.

In their service area, about 80% of the palm producers are practicing surface irrigation according to Cenipalma (pers. Comm. 2022). Overall, the total efficiency of the irrigation system network – defined as the product of the operational, conveyance and application efficiencies – is estimated to be 51%. This figure roughly indicates that around 50% of what is demanded from the Sevilla river is lost in the transfer to the users and in the application on the farm (Parada et al., 2015). Considering the stakeholder comments on unlined channel sections and numerous leakages, the efficiency might even be lower in practice. Switching to another irrigation system is said to be difficult, due to thefts of sprinklers and due the inadequacy between the return on investment (7 years) and the repayment term of the loan (5 years) for a drip irrigation system (Cenipalma). Currently, mostly banana producers are equipped with drip irrigation systems.

ASOSEVILLA indicates that there is some return flow from the channels to the Río Sevilla and Ciénaga, but this is not monitored.

4.4 Other water sources and water infrastructure

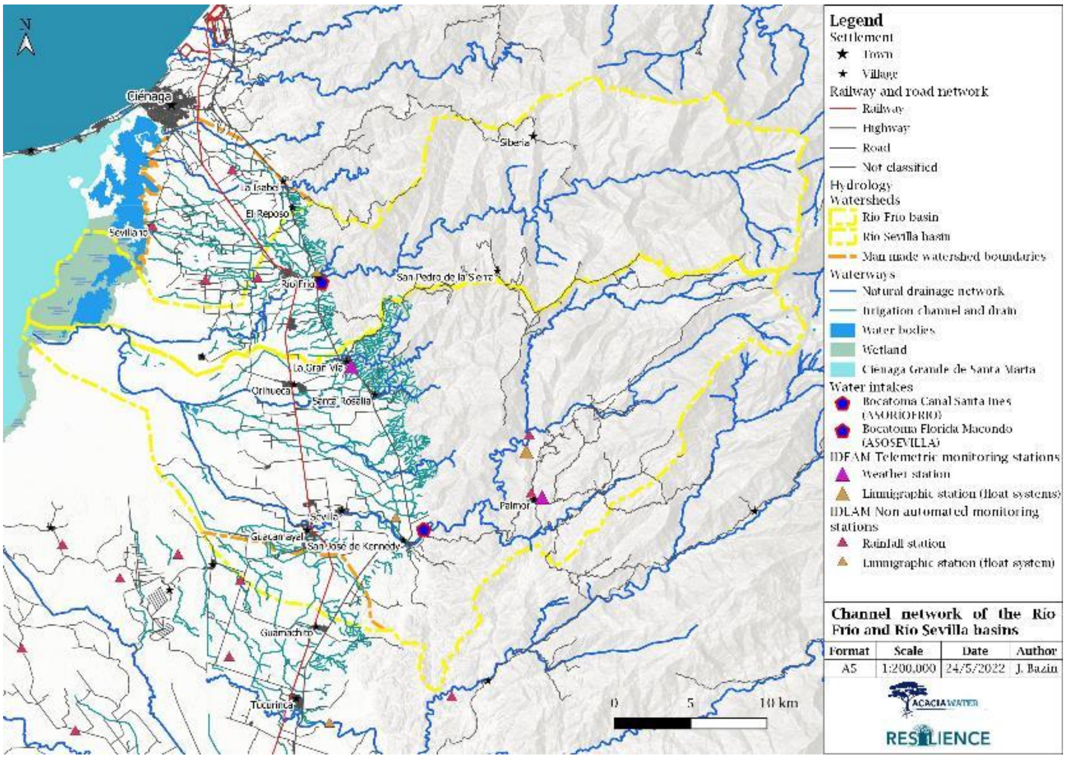


Figure 4-7: Overview of the Rio Frio and Rio Sevilla basins surface water infrastructure.

Reservoirs / ponds

ASORÍOFRIO and ASOSEVILLA reported the existence of a multitude of private reservoirs of all sizes; these have been confirmed based on Google Earth Imagery. According to ASBAMA most of the reservoirs are filled with rainwater, and water from the reservoirs is used during the dry season. Since they are private-owned, there is little control and monitoring of those infrastructures.

According to Parada et al. (2015), ASORÍOFRIO initiated a pre-feasibility study for the construction of reservoirs that retain flood peaks and provide water in the dry season. However, ASORIOFRIO indicated that they are not owning reservoirs, and are not planning to do so in the near future.

Aqueduct system for domestic water supply

According to the study carried out by Findeter (2018), the municipality of Zona Bananera has a regular aqueduct system to ensure water supply to the local communities. However, the study mentions that the system shows signs of deterioration and that the poor provision of the service has been evidenced, as well as the lack of coverage for the entire population of each village and the poor quality of the water not being suitable for human consumption despite some improvements (see Figure 4-8). In San Jose de Kennedy permissions were provided by ASOSEVILLA for domestic water use to 1,100 families from the ASOSEVILLA water system.

MUNICIPIOS	2007 URBANO	2008 URBANO	2009 URBANO	2010 URBANO	2011 URBANO	2012 URBANO	2013 URBANO	2014 URBANO	2015 URBANO	2016 URBANO

Zona Bananera (Sevilla)	83.8			49.3	59.6	36.56	54.86	55.3	63.36	

PORCENTAJE %	0% - 5%	5.1% - 14%	14.1% - 35%	35.1% - 80%	80.1% - 100%
Categorización	Sin Riesgo	Riesgo Bajo	Riesgo Medio	Riesgo Alto	Inviable Sanitariamente

Fuente: Elaboración propia .

Figure 4-8: Results of water quality in aqueduct infrastructures in the years 2007 – 2016 following the IRCA (*Índice de Riesgo de la Calidad del Agua para consumo* humano – Index of risk (riesgo) of the quality of the water for human consumption). Retrieved from Findeter (2018). No clear improvement can be seen in the assessments from 2010 onwards.

In practice, only ASORÍOFRIO reports that there is a functional and dedicated water intake to domestic water use, upstream the Bocatoma weir. According to local stakeholders, the downstream users of ASORÍOFRIO do not have an aqueduct or piped water system; they are supplied with water by the river (Workshop, April 2022). ASORÍOFRIO also reported on unregulated water intakes directly from the river (for domestic and irrigation water use). However, this practice is difficult to monitor, so there are no existing records (Visit to ASORIOFRIO, April 2022).
Regarding ASOSEVILLA, there is no domestic water intake or piped water system for the villages in the Río Sevilla catchment. There is however, the permission to use water from the Water supply system of ASOSEVILLA San Jose de Kennedy. According to ASOSEVILLA (pers. comm. 2022), the people living in the service area of ASOSEVILLA use water from the river and the channels. The estimation is that out of a population of 80000 people, about 20-30% take up water unofficially from the irrigation canals (daily 0.2 L/s) and 80-70% from the river.

4.4.1 Groundwater abstraction

Boreholes

Many boreholes are reported to be present in both Río Frío and Río Sevilla basins, but there is not a complete inventory present for the region. According to Deltares (2021), groundwater is supplied to local communities for domestic use in the irrigation district of ASOSEVILLA.
Sustainable potential abstractions depend on the recharge of the aquifer and the presence of layers with brackish to saline groundwater layers. Looking at Figure 4-9 groundwater recharge is very low in the productive areas of the catchments, but it increases on the slopes of the Sierra Nevada.

Domestic water supply in the Zona Bananera through boreholes, unfortunately have collapsed and nonfunctional. In Valera, a well of 16 l/sec is needed, but the 80 m deep well provided a yield of only 1.5 l/s.

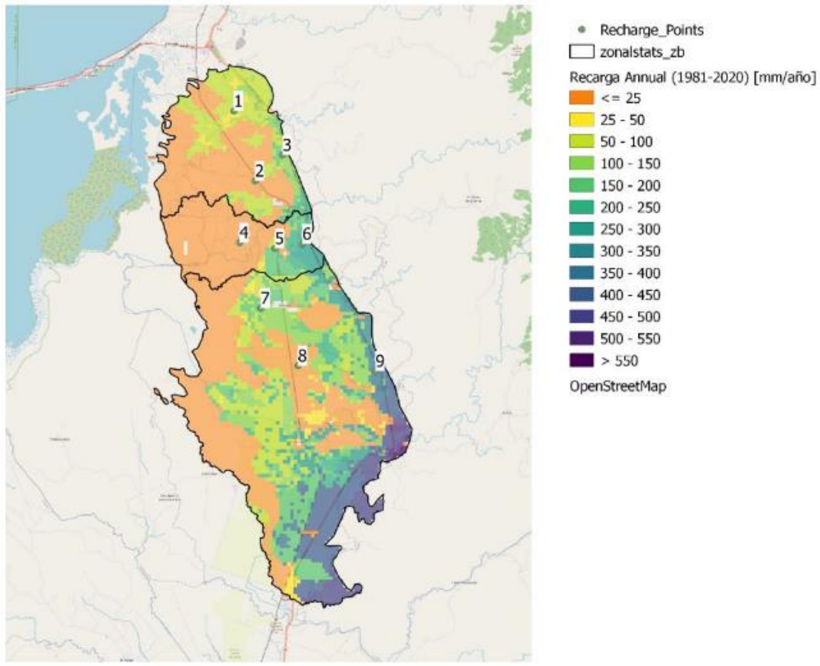


Figure 4-9. Distribution of diffuse recharge in the Zona Bananera (in mm/year as a multiannual average for the period 1981-2020). Retrieved from Deltares, 2021b.

4.5 Monitoring system

4.5.1 Monitoring activities in ASORÍOFRIO

As reported by some representatives, ASORÍOFRIO has a permanent monitoring station 360 meters downstream the Bocatoma weir (Visit to ASORÍOFRIO, Apr 2022). At this location, ASORÍOFRIO measures the flow velocity and the water level. ASORÍOFRIO also has a small weather station near their main office. All the data is collected in a private online system called lynks.web.

Besides, ASORÍOFRIO performs a weekly flow measurement at several points upstream of the intake with a Sontek instrument called FlowTracker, which is a mobile tool with a handheld set. Prior to the measurement, the irrigation association also measures the width and depth of the river at different points. By doing so, ASORÍOFRIO verifies that the minimum ecological flow requirement of 20% is met. If this is not the case, the irrigation association adjust the weirs to rectify the situation.

4.5.2 Monitoring activities in ASOSEVILLA

ASOSEVILLA performs two flow measurements in the sedimentation tank and upstream, as reported by some representatives. The irrigation association has a technical team of 22 people that measure the water levels of the channels on a regular basis at almost every water intake.

- In the banana field plots, producers have flow meters to measure the water flow; this is obliged by the certification from Globalget.
- In the palm field plots, water districts use what is called '*canaleta aforadora sin cuello*', a sand-clock shaped weir where there is a '*reglilla*' measuring tape and the dimensions are controlled. This is checked daily by the person in charge of the canals ('*canalero*'). The operator reads the water level in centimeters and report the measurements to the registry office where the value is converted into volumes,

based on conversion formulas that have been in use for a long time. The invoices to the water users are established based on those reported volumes.

All the measurements are entered in a private system called SIFI that is licensed by the state. Twice a year, ASOSEVILLA reports to CORPAMAG on the records of water flows and water use. About 80% of the irrigation water use is monitored according to representatives of ASOSEVILLA; the remainder is used for pastures, lemon and other small crops, but it is not monitored.

4.5.3 Other monitoring activities

There are many precipitation stations, some of IDEAM (telemetric stations and conventional station). Less sophisticated rain gauges are often also located at some of the larger producers in the area.

Cenipalma also reports to carry out monitoring activities on experimental fields of palm oil located in the irrigation district of ASOSEVILLA (Visit to Cenipalma, April 2022). Their research focuses on different types of irrigation, yields and palm species to assess the optimal irrigation. They also study the impact of a dry period on the palm tree, as this is not directly visible. For this, they have their own weather station and an automatic water flow meter. However, their research is hampered by power cuts of the local network, so they are unable to operate the pump. They are also troubled by the high turbidity of the river water quality. When turbidity is high (usually associated with heavy rains), the sand trap has to be cleaned 3 times per day to prevent damage. Besides, data sharing with ASOSEVILLA is challenging since the irrigation association only accepts one specific type of measurement units, namely the number of hours that water has been pumped at a specific rate m3/h. This does not coincide with the unit of measurement of the water meter of Cenipalma.

Two other important monitoring stations are located in the focus area:

- an IDEAM station about 300 m upstream of the inlet of ASOSEVILLA.
- an INVEMAR station at the outlet of Río Frío and Río Sevilla (Río Negro).

4.5.4 Challenges of the monitoring system

By law, the local producers have to write a plan to ensure the efficient use of water for their crops with a consideration for the recommended irrigation provision per hectare (Workshop, April 2022). Once approved by CORPAMAG, the water users must implement the plan and the environmental authority must audit them. When the concessions are delivered, the water users are obliged to have an automated measurement system. In practice, more than 50% of the concessionaires do not have automated measurement systems, mostly due to the lack of financial capacity to cover the investment. Some water users report that an automated measurement system according to ASOSEVILLA is not required, which is opposite to the environmental authority directives. This allows for inconsistencies in the invoices and excessive use of water. When CORPAMAG grants a concession for groundwater use or other use, an automated water meter is required by CORPAMAG.

Yet, field officers of CORPAMAG visit the water users occasionally to check the water intakes and the water use (Pers. Communication PCA). These are no environmental audits, but these audits are part of the monitoring and follow-up that the corporation has to do after a concession is granted. There were multiple illegal water abstraction connections to channels in the Río Sevilla catchment for instance. A few years ago, the informal intakes were removed as a result of an audit. According to Cenipalma, the water availability subsequently improved. Now the situation got worse again, so they expect that some of these illegal connections have returned, but this has not been confirmed.

In general, local stakeholders express the need for a more robust and unified system of measurements and data collection (Workshop, April 2022). This would require a database with equivalent measurements units and frequency of measurements. In particular, monitoring is lacking in the upstream part of the catchment, so there are no early warning systems of floods to help prevent disasters. The local stakeholders try to mitigate those risks themselves, for instance via WhatsApp communication.

5 Water demand in the Río Frío and Sevilla basins

5.1 Priorities for water allocation

According to local stakeholders that attended the workshop session in April 2022, priorities for water allocation are by law, from most (1) to lower importance (3):

1. Domestic supply
2. Ecosystem (i.e. environmental flow), irrigation and forestry
3. Other uses: watering hole, industrial use, thermal or nuclear generation, exploitation of money, investment, hydroelectric generation, synergic generation, mineral transport.

So in theory, in times of water shortage, domestic water supply has priority over all other water users. In practice, local communities are not the priority beneficiaries considering the lack of water supply network, and they suffer from a lack of a piped water system and water shortages in the dry season and during drought events. According to ASORIOFRIO, the irrigation association leaves at least 20% for the ecological flow of the Río Frío in the river (Visit to ASORIOFRIO, April 2022). ASOSEVILLA is reported to leave 25% for the ecological flow of Río Sevilla, and ideally 30% in the summer period which translates into around 2300 L/s (Santa Marta meeting, April 2022).

CORPAMAG awarded a concession of 3,41 m3/s to ASORIOFRIO (Visit to ASORIOFRIO, April 2022; Interviews) and 4,40 m3/s to ASOSEVILLA (Santa Marta meeting, April 2022; Interviews), based on annual average river flow. People living near the rivers are given a concession of 800 L/s in total.

In the dry season, the average river flow of Rio Frio amounts to 4000 L/s. Once water is getting scarce, the irrigation association reduces equally the water allocation over all the plots (Santa Marta meeting, April 2022; Visit to ASORIOFRIO, April 2022). In practice, producers located in the upstream part of the catchment or near the main water intake of the irrigation channel system tend to capture the most water available, thus depriving downstream users of water resources. Some adaptive measures are implemented locally, including water supply rationing, water storage in reservoirs or improved irrigation systems (Workshop, April 2022).
Overall, the local stakeholders report that CORPAMAG and the municipalities act reactively and not preventively, especially towards the local communities (Parada et al., 2015).

Regarding this subject, local stakeholders report that not all users are supplied water in accordance with the water concession and allocation at all times (Workshop, April 2022). During El Niño much drier conditions affecting the area, many downstream producers no longer receive water for irrigation for instance. On that matter, the fishermen communities and the ecosystem of the Ciénaga Grande are particularly unrepresented in the current stakeholder dialogue and impacted heavily during droughts. The Noticias Caracol TV news item of March 4th 2019 showed the tension between the fishermen communities and the agricultural producers during the 2019 drought[2]. The few small fish farms located in the Río Frío catchment are also unrepresented as they are also not included in the current stakeholder dialogue (Visit to ASORIOFRIO, April 2022). Tensions between water users are also reported in the upper part of the basin, in the Sierra Nevada de Santa Marta National Park, due to historical displacements of indigenous communities from the take-over of land by campesinos communities (Workshop, April 2022).

5.2 Agricultural water demand: overview and current status

5.2.1 Key agricultural production systems and irrigation practices

Whenever possible, data on hectares (ha) of agricultural crops for the hydrological watershed – from Kaune et al. (2020a) – and for the irrigation districts considering the man-made boundaries – from Parada et al. (2015), Findeter (2018), Torres et al. 2019, and directly from ASORIOFRIO and ASOSEVILLA were collected and compared. For Rio Sevilla basin, the production area based on the landcover map of the EO4Cultivar Map (2020) were calculated. The EO4Cultivar Map did not cover the area in service of ASORIOFRIO, but estimates were interpolated based on the size of the service area. Table 5-1 shows that there is no consensus between different sources about the production area per crop type per catchment.

Table 5-1. Comparison of production area per crop type as reported by different sources. The Federación Nacional de Cafeteros has an estimate of the ha in production of the entire Magdalena region, but not specific for Río Frío basin and Río Sevilla basin.

Plantations / Crops	Production area (in ha)	
	Río Frío basin	**Río Sevilla basin**
Banana	4600 *ASORIOFRIO, 2015* 4326 *Findeter, 2018* *4257 + 870 (canal Santa Inez)* *Torres et al. 2019* 5400 *Rough estimate based on EO4Cultivar Map, 2020*	5768 *Findeter, 2018* *6574* *EO4Cultivar Map, 2020*
Palm Oil	310 *ASORIOFRIO, 2015* 577 *Findeter, 2018* 974 *Torres* et *al.* 2019 1400 *Rough estimate based on EO4Cultivar Map, 2020*	11000 *Kaune et al., 2020a* *3482* *Torres* et *al.* 2019 8008 *EO4Cultivar Map, 2020*
Coffee	unknown	unknown
Fruit trees	*761* ASORIOFRIO, 2015 866	1,154 *Findeter, 2018*

[2] https://www.youtube.com/watch?v=2xjwrjB9-fQ

	Findeter, 2018	
Others	115 *Findeter, 2018*	
TOTAL	5770 *Findeter, 2018*	
	5671 ASORIOFRIO, 2015	8476 ASOSEVILLA (pers. Com. 2022)

There is a difference in production area, and area irrigated. ASOSEVILLA holds an inventory of the ha that are irrigated in their service area and reports every 2 months to CORPAMAG. This shows that the irrigated areas is at maximum 4521 ha and in the wet season, it can be as low as 368 ha. For ASORIOFRIO, this is also monitored and the difference between the months for the irrigated area is lower compared to ASOSEVILLA. The irrigated area changes between approximately 3750 to 4300 ha.

Table 5-2: Monthly river discharge in the Sevilla River, available water for irrigation, and theoretical irrigation demand of ASOSEVILLA (Source: GSI, 2015). The months with the lowest river discharge are between December and April. The units are in millions of m³/month. Retrieved from Kaune et al. (2020).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
River discharge	17	11	12	16	32	39	39	42	53	60	49	27
Available water	8	5	6	8	15	19	19	20	26	29	24	13
Demand Asosevilla	7	7	7	7	7	7	7	7	7	7	7	7

There are different types of irrigation practices in use for palm and for banana production. Banana producers use mainly sprinkler irrigation. Palm producers and in general small producers (palm and banana) use irrigation by flooding and do not have reservoirs for water storage. Most large scale producers have private reservoirs. Fertigation (the application of nutrients through irrigation systems is absent or not common).

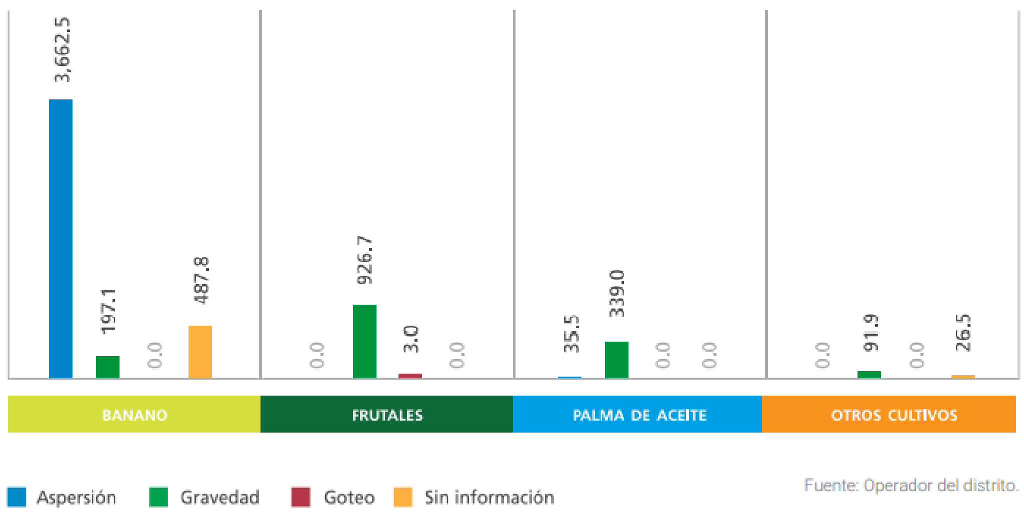


Figure 5-1: Types of irrigation system for each crop in the district of the Río Frío, with values in hectares. Source: Findeter (2018). Legend from left to right: *Sprinkler irrigation, surface irrigation, drip irrigation* and *no information*.

With regards to coffee, all coffee in the SNSM is grown as shade coffee and as a rainfed crop and does not require irrigation. (Hoyos et al. 2019)

Palm oil production

Kaune et al., (2020b) explain that Palm oil smallholders have up to 20 hectares each, medium farmers 20-50 hectares and large farmers may have hundreds of hectares of oil palm plantations. Oil palm farmers are generally organized by palm oil mills for processing, owned by companies in which they tend to be shareholders.

Regarding the way of applying irrigation, in the case of surface methods the most frequently used is surface irrigation (the entire field is flooded) and in some cases partial wetting with the help of furrows or ridges around the palm. This is known as furrow or trench irrigation. (Kaune et al., 2020b). With respect to pressurized irrigation, there is sprinkler irrigation of different types, and at Cenipalma there is also high-flow drip irrigation.

According to Cenipalma, the application of the different irrigation practices amongst smallholders in the region is however: 80% surface irrigation, 20% sprinkler and 0% drip. Banana is much more advanced in terms of irrigation systems because it is much more sensitive (and faster in response) to water stress. Palm trees experience stress as well, resulting in lower yields, but this is visible only on a longer time span.

The visit to Cenipalma showed that there are mulching practices applied to Palm oil fields with surface irrigation. One set of Palm leaves is removed for 1 harvest. With harvest these are cut and left on the ground (laid out in a square around the palm). This way:

- There is less soil moisture evaporation.
- This is natural fertilizer
- This protects the furrows
- This improves soil life.

Since 2010 the palm production in the Río Frío and Río Sevilla basins is threatened by a disease called Pudrición del Cogollo (PC) or bud rot disease by which the fruit bunches decay. The palm tree starts showing black leaves and the palm slowly dies. In Cenipalma they studied crossing the African palm with the original palm (Olivera) from the region so that it would be less vulnerable to the PC disease. The hybrid is highly productive in oil production, it has a slightly higher tolerance to the disease, and it can deal slightly better with a changing climate. This variety needs assisted pollination.

Banana and plantain production.

The banana sector has invested widely in increasing the efficiency in the use of water and currently the majority of farms use sprinkler irrigation (Parada et al. 2015). Banana cultivation requires large amounts of water and is sensitive to water deficits and excesses.

The large banana producers use sprinklers as an irrigation system, and have reservoirs for storage. Some farms, in view of severe droughts, have established more specialized irrigation systems with rainfall and evapotranspiration measurements to establish the amount of irrigation according to the water balance in the soil, applying only what that is needed each day to replace the loss of the previous day (deficit irrigation) (Parada et al., 2015).

Banana trees can be easily affected by root rot, diseases and/or pests in the rainy season, which makes it a highly vulnerable sector. The sector is also very vulnerable because of the scarcity of fresh water for irrigation, the salinization of water and soils

(Deltares, 2021a) and key is the threat by the fungus Fusarium. It can take out large patches of banana trees and stays inactive but present in the soil for many years.

5.2.2 Agricultural water demand and current agricultural water use

Palm oil production

According to Cenipalma the potential yield of oil palm is limited, among other factors, due to the water deficit. Kaune et al., (2020b) explains that (based on Woittiez et al. (2017)), oil palm performance is reduced with rainfall levels lower than 2,000 mm/year, or months with rainfall less than 100 mm. Calliman & Southworth (cited in Corley & Tinker, 2003), concluded in their study that a water deficit of 600 mm experienced in a single year, reduces the yield of palm crops by 8 to 10% for the first year, and between 3 and 4% for the second year after the stress period (Kaune et al., 2020b). Cenipalma explains that after a palm has been stressed it takes at least 18 months to go back to normal production.

Water deficit does occur in the lower basin of the Sevilla River, thus the application of supplementary irrigation is necessary to achieve yields of enough fresh fruit bunches per year. Not applying irrigation implies obtaining yields that do not exceed 12 t of RFF/ha/year and this is a common denominator for the majority of the plantations established in the North Palm zone of Colombia (Kaune et al., 2020).

Cenipalma explains that a single palm tree needs in average 5.5 mm/day, or 380L/plant/day (for a plant older than 5 years). This water demand includes the evapotranspiration (for plants & cover crops). At Cenipalma research station, 3 types of irrigation are investigated. For a drip irrigation the main drip line is installed in the plot. For small palms, 1 or 3 drip lines to the tree are enough. With the current systems, the efficiency of the irrigation systems is: drip 90%, sprinkler 70% and surface 20-15%.(can be lower if electricity fails).

Tabel 1: Information as provided by Cenipalma during the field visit. The Efficiency mentioned in the table is the irrigated water from an irrigation gift, that is actually used by the plant. This information is based on the research plot of Cenipalma. Approximate irrigation for optimal yield in mm/day is based on the water efficiency rates and an assumption of 147 trees/ha.

Irrigation type	Water efficiency	Irrigation moment	Yield (ton/ha)	Trees/ha	Approximate Irrigation for optimal yield
Drip irrigation	90%	380 l/day divided in 3 gifts per day of 120 l/hour.	37	147	6,2 mm/d
Sprinkler (mini wobbler)	70%	600 l/hour capacity Irrigation applied once per 3 to 4 days with 6 hours of irrigation time. 1 day = 2 hours of irrigation time, There is 1 sprinkler per 3 palm trees.	34	Unknown	8,0 mm/d
Surface irrigation	20 – 15 %	Flooded with pressurized piped system. Needs more water to reach the efficiency of the palm. Often furrows present in the field.	12	Unknown	28 mm/d

For drip irrigation, in total 3 drip points are added with the growth of the plant (at an early stage there is only 1d drip nozzle).

The high flow irrigation sprinklers are located around the palm trees and are located 3m away from the palm and there is 1 sprinkler per 3 palm trees. The spatial distribution of the sprinklers (mini wobbler) is very important. They usually irrigate every 3 days. Standard drip irrigation does not work due to the high sediment load of the channel water. At Cenipalma, they work with turbidity, high-flow or high-discharge drips with 40L and 60L drippers, to avoid particulate matter. A field study of Siriat et al., 2020 showed that oil palm seedling (10 months after transplanting), reached a permanent wilting point after 14 days of drought stress with soil moisture content approximately 25%.

Table 5-3. Volumes of water demand necessary for an optimal yield, assuming that 100 % of the estimated production area in ha is either drip/sprinkler or surface irrigation. This shows differences in water demand per irrigation type. Surface area for Rio Frio based upon PCA water balance assessment. Surface area for Rio Sevilla based upon EO4 Cultivar landcover map.

Palm production areas	Total ha	Irrigation type	m3/s	Mm3/month
Rio Frio basin	3482	100% Drip	2,5	6,5
	3482	100% Sprinkler	3,2	8,3
	3482	100 % Surface	11,3	29,2
Rio Sevilla basin	1400	100% Drip	1,0	2,6
	1400	100% Sprinkler	1,3	3,4
	1400	100 % Surface	4,5	11,7

Table 5-3 presents the irrigation water demand to provide the crop with optimal yields. This water can be supplied by rainfall, reservoirs, wells and of course the irrigation water network. The volumes presented here are necessary to provide the Palm trees with the optimal amount of water after losses on for example evapotranspiration and infiltration. It must be noted that some irrigation water that is considered lost, returns to the groundwater system in the basin. Especially for the surface irrigation practices part of the excess water infiltrates into the ground, and it can be debated if this water is wasted or still part of the basin water cycle.

Banana production

The banana plantations need 5 mm/d, but producers consume approximately 7mm/d in summer due to increase evapotranspiration and other use (cover crops, processing etc).

The FAO Crop database (FAO, 2022) explains that the banana plant has a sparse, shallow root system. Most feeding roots are spread laterally near the surface. Rooting depth will generally not exceed 0.75 m.

In general 100 percent of the water is obtained from the first 0. 5 to 0.8 m soil depth, with 60 percent from the first 0.3 m. With maximum evapotranspiration (ETm) of 5 to 6 mm/day, a 35 percent depletion of the total available soil water should not be exceeded (p = 0.35).

Table 5-4. Water demand for the Banana and plantain production areas, calculated with a water demand of 5 mm/day.

Banana and plantain production areas	Total ha	m3/s	Mm3/month

Rio Sevilla basin	6574	3,8	9,9
Rio Frio basin	5400	3,1	8,1

Water Use Index

The Plataforma Custodia del Agua, indicates the state of the basin with a Water Use Index factor (IUA). The water use index compares Water supply (river discharge) and the total (theoretical) water demand. If the IUA is greater than 100% for the driest months, this would indicate that the demand exceeds the available supply. (Parada et al., 2015) calculated the IUA factor for Rio Frio and Rio Sevilla based on a theoretical water demand, and compared with water availability (concessions and average river discharge). According to Parada et al., (2015), for the Río Frío, in the four months of drought (February to April) the IUA index can be estimated of approximately 70%, which reflects a “very high” pressure from the demand over available supply in times of drought. The scarcity of supply vs. demand in this study should be considered as illustrative of the situation of the rivers in a dry year, it should be noted that the scarcity would increase in the event that present the phenomenon of “El Niño”.

In the case of the Sevilla River, Parada et al., (2015) state that there is no complete water balance either. However, the estimates are made based on a theoretical demand based on the water concession granted by CORPAMAG. It is for this reason that the theoretical totals exceed the real values reported for the year 2014 by ASOSEVILLA. Based on this theoretical demand, in the four months of drought the concession of ASOSEVILLA is bigger that the available water.

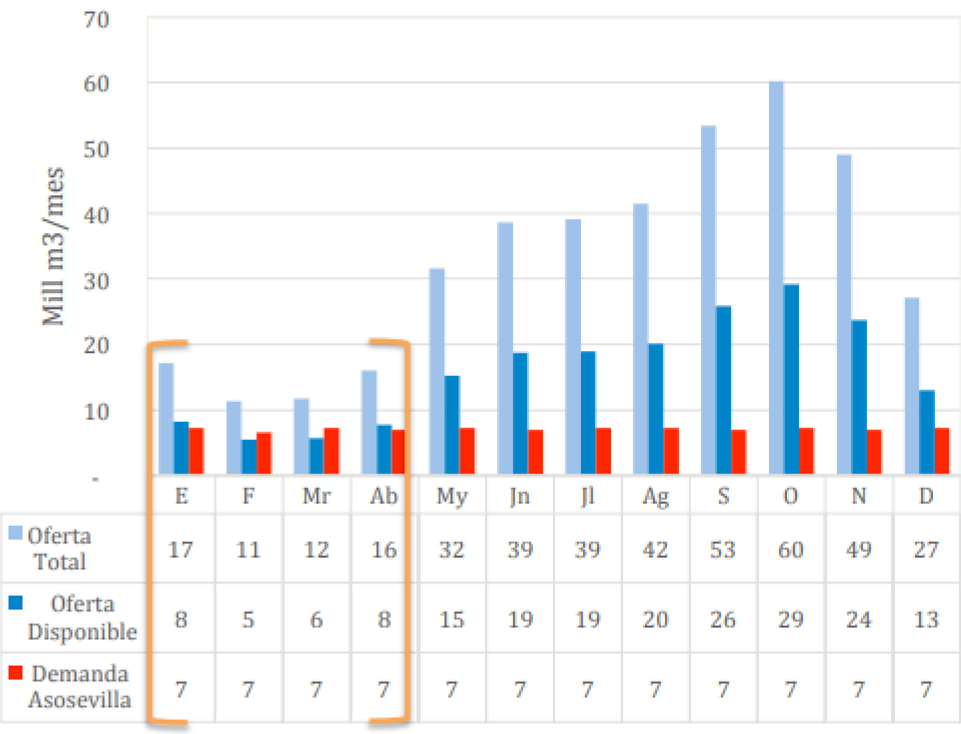


Figure 5-2: Available water of the Rio Sevilla vs the demand of Asosevilla (concession). In Brackets, the four months of droughts. Source: Parada et al. (2015).

5.2.3 Agriculture sector developments

According to several stakeholders, producers tend to switch sometimes between palm and banana production for several reasons (pests and diseases, yields, water deficits, salinization, floods etc). The agricultural sectoral developments will be linked to many different factors. One of them are job opportunities and job security. Banana plantations provide more jobs (1.8 person/ha) compared to palm plantations (1 person per 20 ha).

Kaune et al., (2020b) states that currently, farmers in the Sevilla river basin already apply some water harvesting techniques, such as mulching (recycled leaves as soil cover to reduce evaporation), excavation of planting pits to increase infiltration, and sowing of cover crops to retain runoff.

5.3 Domestic water demand

5.3.1 Estimated domestic water demand

Domestic water use includes indoor and outdoor uses at residences and institutions (e.g. hospitals, schools), and includes uses such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets and watering lawns and gardens. The definition of domestic water use includes potable and non-potable water provided to households by a public water supplier (domestic deliveries) and self-supplied water use.

In the Río Frío and Río Sevilla basins, there are several water sources used for the supply of drinking water, groundwater by wells and boreholes, and river water and canal water with direct take up as there is no piped water system in the Rio Sevilla basin. Domestic water is therefore untreated and not of quality standards for domestic use.

Table 5-5. Retrieved information on the inhabitants of the Río Frío and Río Sevilla basins.

	Rio Frío basin	Rio Sevilla basin	Municipality Ciénaga	Municipality ZonaBananera	Water source for domestic water use	Source information
Inhabitants	11.240	52.412			Groundwater wells	RECARBA project, 2020
Inhabitants		Estimated 80.000			For Sevilla basin: River & canal water	ASOSEVILLA, 2022
Inhabitants			118.435	66.802	Unknown	National Census, 2018

The retrieved information about the population of the Río Frío and Río Sevilla basins is collected for different administrative units, which makes it a challenge to define a clear number of inhabitants that are served from the Río Frío and Río Sevilla rivers. The estimated users of groundwater wells by the RECARBA project is around 63 thousand inhabitants. The total inhabitants of the Municipalities of Ciénaga and Zona Bananera together is approximately 185.000. ASOSEVILLA estimated around 80.000 people making use of surface water from the channel and the Sevilla river. These estimates seem to roughly fit the context.

By law, domestic water use has the highest priority for water allocation and it is therefore important to estimate this water demand. The actual water use by the inhabitants is not known. But for Santa Marta town, a per-capita endowment of 150 L per habitant per day is estimated in the studies of Londoño et al. (2017). This seems on the high end compared to the water supply situation in the Río Frío and Río Sevilla basins. Not everybody is connected to a piped water system, and according to ASOSEVILLA, this water is directly taken up by the river or canal. The effort needed of manual labour suggests that consumption levels for domestic use must be much lower.

Consumption levels of 50 L/inhabitant/day is defined as the essential minimum volume by the government programme "Essential Minimum Potable Water" (*Mínimo Vital de Agua Potable* — MVAP) in Bogota. The volume established within the programme as "essential" translates to 6 m3/month/household for residential water supply and is based on the estimated requirement of a household with four individuals (Vargas, 2018). The 6 m3/month/household was provided free of charge by the local government for the two lowest socioeconomic strata in Bogotá.

WHO (2003) provided estimates for different levels of service according to the type of access to water supply, the quantity of water consumed, and the level of health-related risk. Optimal access to water, meaning that which meets all domestic and hygiene-related needs and lowers health risks, would be an average quantity of at least 100 L/inhabitant/day.

Table 5-6. Different service level as defined by WHO (2003), and translated to the total water demand for all 185.000 inhabitants and estimated total water demand directly from the rivers, for 80.000 people.

	5 l/c/day	50 l/c/day	100 l/c/day
Service level	No access	Intermediate access	Optimal access
Needs met	Consumption – cannot be assured Hygiene – not possible (unless practised at source)	Consumption – assured Hygiene – all basic personal and food met. Hygiene assured; laundry and bathing should also be assured	Consumption – all needs met Hygiene – all needs should be met
Total domestic water demand: 185.000 inhabitants	10,7 L/s 27750 m3/month	107 L/s 277500 m3/month	214,1 L/s 555000 m3/month
Total domestic water demand directly from the Río Frío and Río Sevilla river or channel system: 80.000 inhabitants	4,6 L/s 12000 m3/month	46,3 L/s 120000 m3/month	92,6 L/s 240000 m3/month

The Río Frío and Río Sevilla are used for swimming and bathing, however the water quality is not suited for swimming and bathing purposes, looking at multiple water quality parameters.

5.3.2 Historic and current domestic water supply

The majority of the population lacks a piped water system and basic sanitation and depend on groundwater and irrigation canals to meet its needs. This is one of the factors that contributes to a high rate of unsatisfied basic needs (UBN) among the population of the basins (Parada et al., 2015).

In the 2018 National Census, it is reported that for the municipality of Ciénaga 82% of the households is connected to an aqueduct, and for Zona Bananera this is 49% of the households (DANE, 2018).

Table 5-7. Reported domestic water supplied to inhabitants of the basins.

Region	l/s	m3/month	year	Water source documented	Source
Water demand for drinking water in Zona Bananera	18 l/s	46.656 m3/month	2018	Groundwater	Findenter (2018)
Estimated for ASOSEVILLA service area	0.2 to 2 l/s	5184 to 518 m3/month	2022	River and channel water	ASOSEVILLA
Intake from Río Frío	unknown	Unknown		River water intake for piped water system	CORPAMAG

With 18 l/s, you can supply 15.552 people of 100 L per day. With 0.2 to 2 l/s you can supply 172 to 1728 people of 100 L per day.
For Río Sevilla it is assumed that there is no piped water supply system.

5.4 Industrial water demand

5.4.1 Industrial activities

There are not large industrial activities ongoing in the Río Frío and Río Sevilla basins. There are however some activities that use water for processing. Washing and packaging of bananas needs water. Each farm has its own packing system. There are also palm oil processing stations, but as this is usually a centred activity, the number of processing stations inside Río Frío and Río Sevilla basins are unknown, but estimated that at least one processing station is present in the area. The palm oil processing are oil extraction stations that take the fruits and process them into the oil (pers. Comm. PCA).

Coffee processing

Estimated ha of coffee production in the Magdalena region are between 15.000 and 20.000 ha, and around 6000 ha estimate for upstream Río Frío and Río Sevilla basins. Coffee is a rainfed crop, but water is used in the washing and processing of the coffee beans. On average 19.8 sacks of coffee of 60 kg each are produced per ha in Colombia (Federacion Nacional de Cafeteros de Colombia, 2021). The coffee sector is aware that traditional coffee processing is highly polluting for water quality. In Colombia, standard processing spends 40 liters of water to produce 1kg dry coffee beans. It has been possible to minimize the volume to less than 5 liters of water per kg through ecological processing plants (beneficiaderos ecológicos). The processing beans of coffee takes place from October to December.

5.4.2 Estimated industrial water demand

For the palm oil processing stations it is unknown if and how many are present in the Río Frío and Río Sevilla basins. For banana plantations, it is indicated that the plant water needs are 5 mm/day. According to the water districts, the banana plantations receive on average is 7 mm/day. The assumption is made that the difference in water is used for other, more industrial activities.

Table 5-8. Banana and Plantain industrial water demand, calculated with an industrial water need of 2 mm/day.

Banana and plantain production areas	Total ha	l/s	Mm3/month
Rio Sevilla basin	6574	1500	3,9
Rio Frio basin	5400	1300	3,2

The estimated water demand for 2 types of coffee processing is shown in the table below.

Table 2. Estimated water demand for coffee processing for October, November and December, for different estimates of ha and volume of water used for processing. Assumed that 1 ha produces on average 19,8 sacks of 60 kg of coffee.

	Standard processing of coffee 40 l/kg	Ecological processing plants 5 l/kg
6000 ha	95040 m3/ month 37 l/s	22880 m3/ month 4,6 l/s
15000 ha	237600 m3/ month 92 l/s	29700 m3/ month 12 l/s
20000 ha	316800 m3/ month 122 l/s	39600 m3/ month 15 l/s

5.5 Ecosystem water needs

The ecological flow in a river corresponds to the water necessary to guarantee the ecological values in the channel such as: natural habitats, and environmental functions such as dilution of pollutants, landscape preservation, and, very important in the study area, to guarantee the fresh water that enters the Ciénaga Grande de Santa Marta.

The ecological flow is set by CORPAMAG. Currently, the agreements by CORPAMAG and ASORIOFRIO are that they should consider at minimal 20% ecological flow. The minimal Ecological flow for ASOSEVILLA is 25%. In times of drought, the water districts try to consider a higher ecological flow. Also measurements are carried out by CORPAMAG in dry seasons to check a minimum flow is ensured. ASOSEVILLA reports a minimal ecological flow of 2300 l/sec during the dry season. And ASORIOFRIO reports an intake of 52% over the year 2021, ensuring an ecological flow of 48%.

The basis for the determination of the official environmental flow in the Río Frío and Río Sevilla is the guideline developed for the determination of environmental flow requirements by MADS and IDEAM (2017). The methodology is based on Poff et al. (1997), who identified five key characteristics of river flow that determine ecological aquatic processes, being the magnitude, frequency, duration, rate of change and timing of the flow regime. The ecological condition is assessed by the state of integrity of the aquatic ecosystem, i.e. as the capacity of the system to maintain its ecological processes and functions (Flotemersch et al., 2015).

To assess the environmental flow rates, a morphological classification of river segments in the catchments was made and the variation in precipitation in the catchments was determined (WWF Colombia and CORPAMAG, 2020). In addition, river station data were used as input for characterising the flow regime of river segments in the two catchments. A calibrated HEC-HMS rainfall – runoff model developed by the US Army

Corps of Engineers (Hydrologic Engineering Center) was used to provide simulations representing the natural flow regimes of the river.

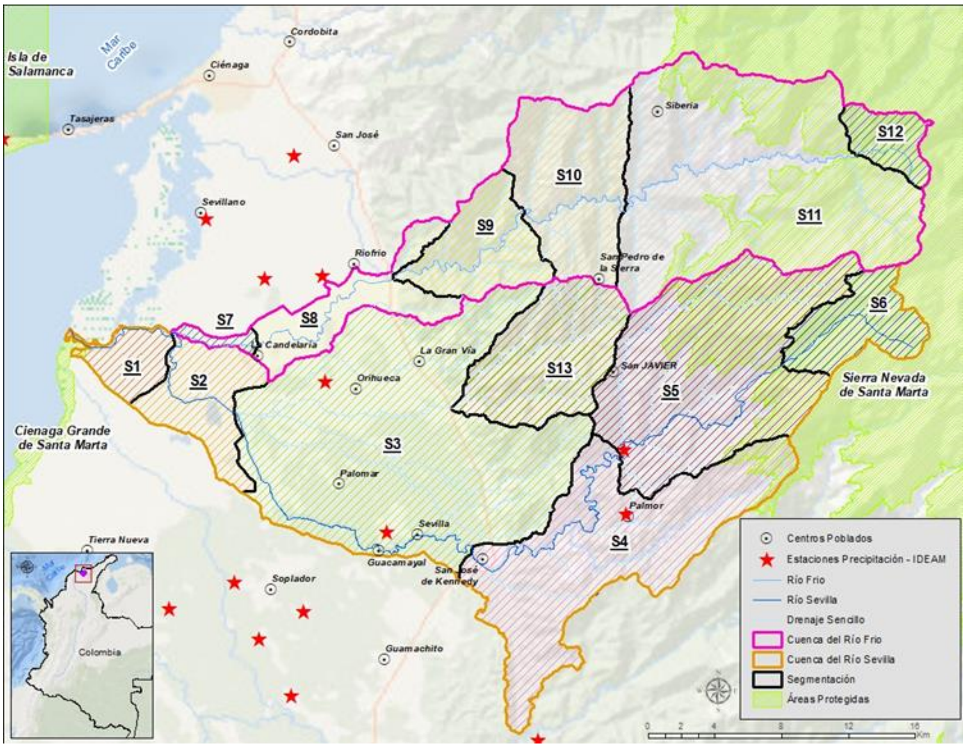


Figure 5-3: Numbered sub-catchments / river segments and precipitation stations in the Río Frío and Río Sevilla catchments in Magdalena Province as used for the Environmental flow assessment. Source WWF Colombia and CORPAMAG (2020).

The environmental flow rates for each river segment in the numbered sub-catchments (Figure 5-3) were subsequently derived using the HeCCA tool for environmental flow estimation (Cortés-Torres et al., 2019). This tool uses time series of daily discharge values to calculate minimum and maximum flows and adjusts these to return periods for normal and bank full values (2.0 and 2.33 years return periods, respectively) and to 10 and 15 year return periods for extreme minimum and maximum flows, respectively. Comparison of observed and natural flow regime data provides information on the monthly utilization potential of water.

The calculation procedure results in minimum environmental flow values that need to be maintained on daily/monthly basis. For each of the stream segments of the Río Frío and Río Sevilla the environmental flows have been presented, as well as the percentage flow that can be used for other purposes, which varies from 5-30% of the average monthly flow (WWF Colombia and CORPAMAG, 2020). Which indicates a recommendation of an environmental flow of 95-70%.

The report concludes that the environmental flows calculated for each segment show that the management of water resources in these basins should not be static, but on the contrary, they must be dynamic, to fit the behaviour of the flows during the different months of the year.

As an example from the study of WWF Colombia and CORPAMAG (2020), the monthly flow patterns for segment S4 in the Río Sevilla catchment are shown in Figure 5-4. This shows that the environmental flow requirement is much higher than the utilisable flow component of the discharge. The latter amounts to 10% (June), 15% (March) and 20% (all other months) of the average monthly flow for this segment.

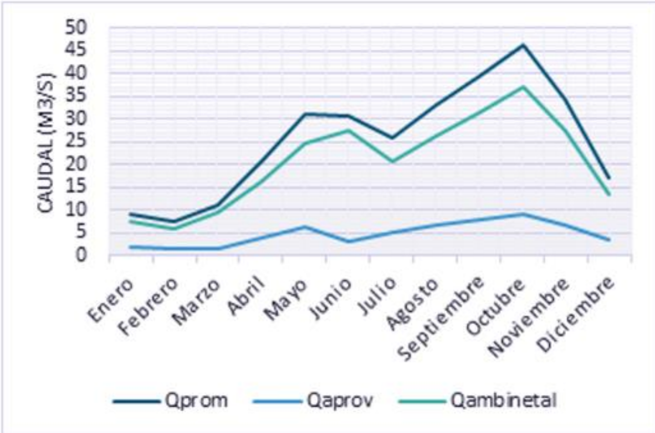


Figure 5-4 Average monthly (Qprom), utilisable (Qaprov) and environmental (Qambiental) flows for subcatchment/segment 4 in the Río Sevilla catchments (WWF Colombia and CORPAMAG, 2020)

There are different methodologies to determine the environmental flow. In the study of WWF and CORPAMAG, the river dynamics approach was applied, with the main input of river flow regime. This methodology is more focussed on the river dynamics and the environmental flow necessary for the river habitat. This approach is less focused on the downstream habitat requirement of the Ciénaga Grande wetland system after the river outlet.

Another approach for determining environmental flow limitations is based on establishing favourable conditions to maintain the habitat for different aquatic species. This approach has been applied using models to determine environmental flow (Kim and Choi, 2019; Maddock, 2017). Such modelling was also done to establish impacts of climate change on river ecology (House et al., 2017) and of groundwater abstraction (Olsen et al., 2009). Models are often complex and need detailed input data on river hydraulics, morphodynamics and aquatic biota life stages.

Related to this approach is the use of the wetted perimeter requirement to maintain habitat conditions in rivers (Berthot et al., 2021; Gippel and Stewardson, 1998; Prakasam et al., 2021; Reinfelds et al., 2004). This approach is based on maintaining a minimum water level in the river to allow aquatic life to sustain and has the advantage that it can be derived from GIS analysis of rivers (Prakasam et al., 2021). These approaches have not yet been applied to the Río Frío and Río Sevilla basins.

To conclude, the current concession of CORPAMAG for ecological flow fits the national guidelines. But, the river dynamics environmental flow study (WWF Colombia and CORPAMAG (2020) shows that the current concession for irrigation water use is too high looking at the desired ecological flow for this specific area and that the ecosystem of Río Frío and Río Sevilla catchments need more fresh water than it currently receives. As a result of the WWF Colombia and CORPAMAG (2020) study, possible changes in the ecological flow concession are assessed with a participatory process with different stakeholders.

6 Overview of the current water availability

6.1 Overview of the current water availability

River water availability

The water availability in the Río Frío and Río Sevilla basins is strongly dependent on the rainfall in the upstream part of the catchment. There is a strong interannual variability between the different years, e.g. there are wet and dry years looking at the precipitation. The graph below from (Kaune et al., 2020a) is an indication of the water availability by comparing precipitation and evapotranspiration. The historical data shows a clear pattern of water deficit between December and March and water surplus between August and November. The year 2015 was the year with the lowest water yield in the basin with water deficit in most of the months.

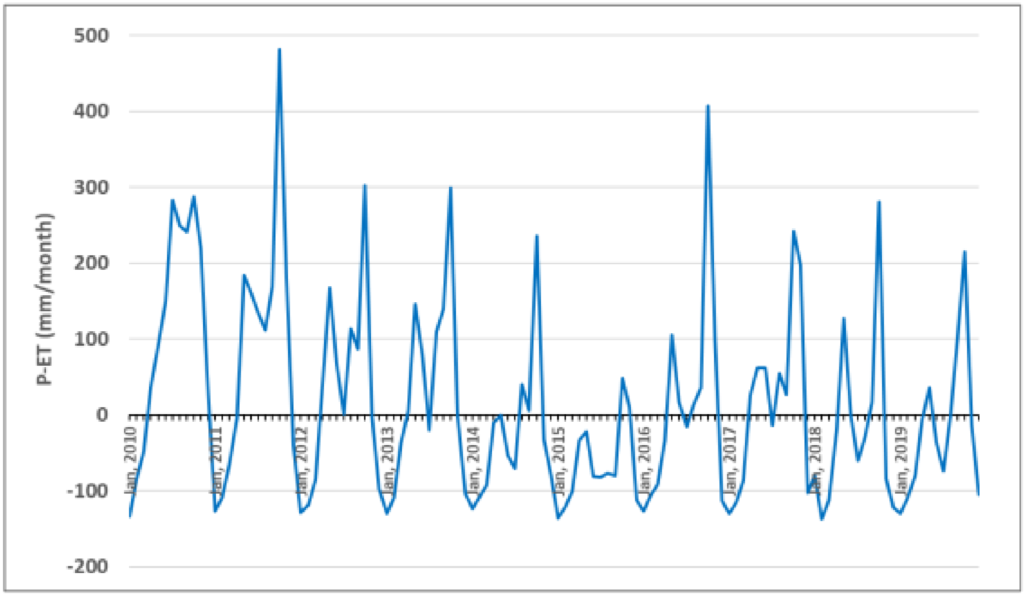


Figure 6-1: Historical monthly water yield, P-ET in the Sevilla basin, Colombia, period 2000-2019 (Source: CHIRPS and MODIS). Drought event in 2015. Source: Kaune et al. (2020a).

Irrigation water availability Rio Frio

The irrigation water availability and environmental flow volumes as presented in this chapter are assessed for the main intake at ASORIOFRIO. The environmental flow for ASORIOFRIO was determined as 20% of the average flow in this assessment and is the reported official concession environmental flow. In reality, for the year 2021, an environmental flow of 48% was applied of the actual flow, not the average flow (Figure 6-2).

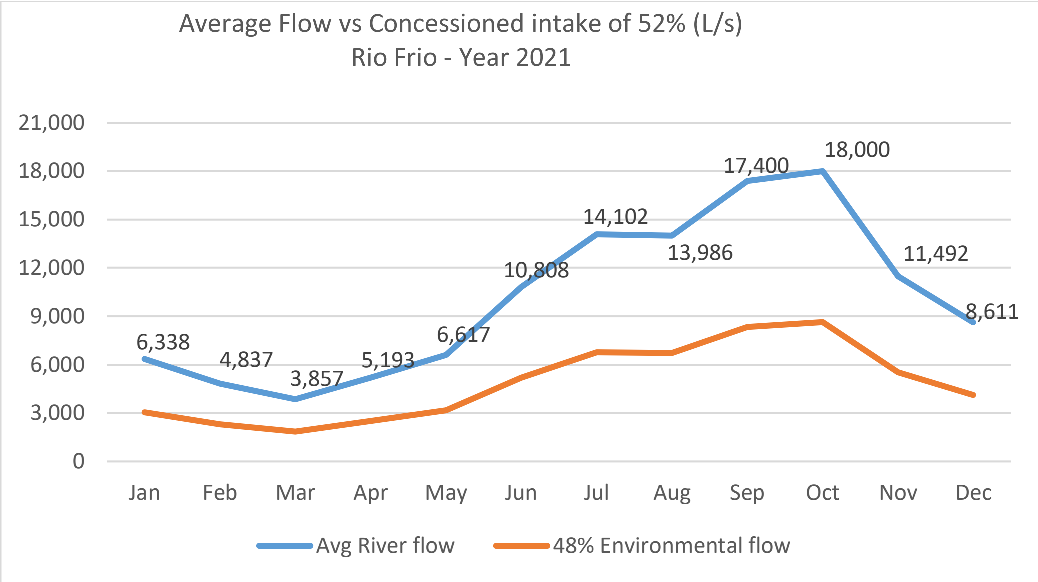
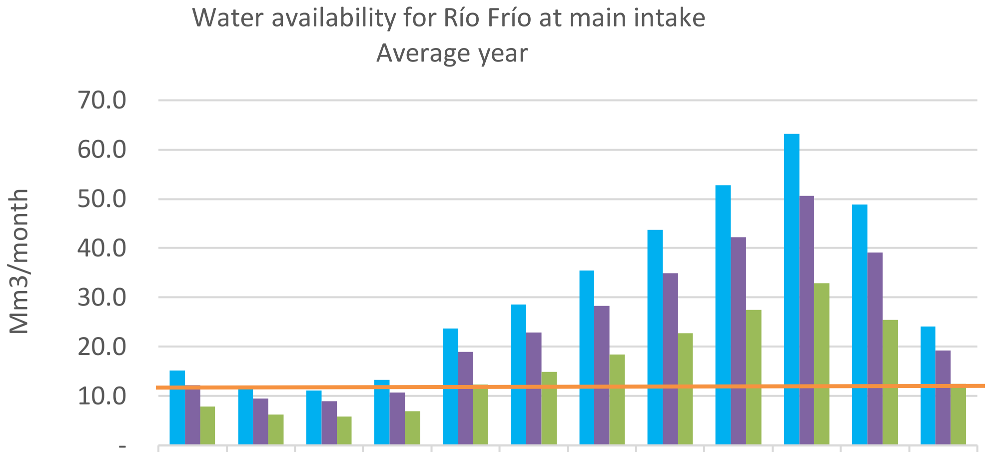


Figure 6-2: Monitored intake data of ASORIOFRIO confirms that for 2021 a dynamic environmental flow of 48% (Intake of 52%) was considered, instead of 20% environmental flow or a fixed environmental flow.

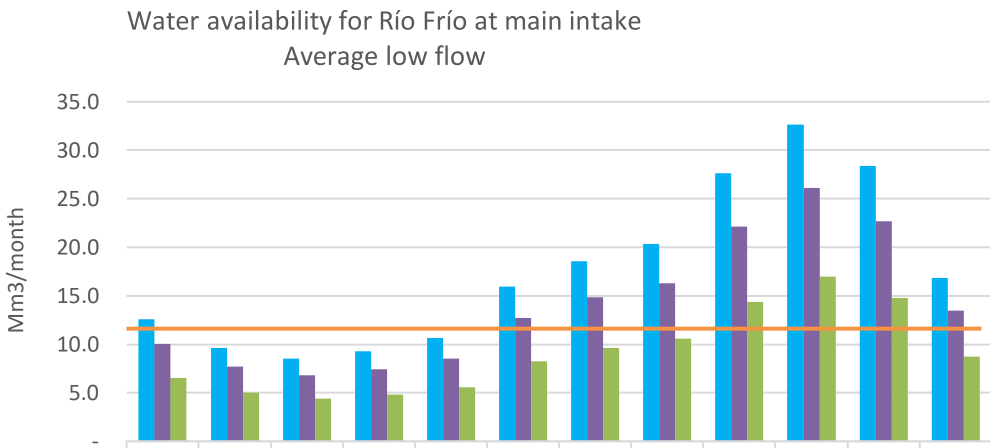
The PCA developed a water balance and analyzed the river discharge for 1965 – 2015, and determined minimal, average and maximum stream flow. This dataset was used in this study for a comparison of the available water in an average (median, Q50) and average low flow water discharge scenario vs the reported environmental flows. Both values of 20% and 48% environmental flow have been mentioned by literature and stakeholders.

On paper, the water demand for at the intake of ASORIOFRIO is at maximum 12.71 Mm3/ month based on the concessions for ASORIOFRIO and the private concessions combined, assuming that the producers with private concessions are also using water from the channel network.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Average River flow	15.24	11.92	11.15	13.32	23.69	28.62	35.43	43.70	52.75	63.24	48.83	24.11
80% concession	12.19	9.54	8.92	10.66	18.95	22.89	28.35	34.96	42.20	50.60	39.07	19.28
52% concession	7.93	6.20	5.80	6.93	12.32	14.88	18.42	22.72	27.43	32.89	25.39	12.53

Figure 6-3: The figure shows the average (Q50, median) river flow over the years 1965 – 2015 for Rio Frío, with the corresponding dynamic concessions of 80% intake or 52% intake for ASORIOFRIO. Orange line indicating the maximum intake of ASORIOFRIO of 12.71 Mm3/ month based on the concessions for ASORIOFRIO and the private concessions combined.

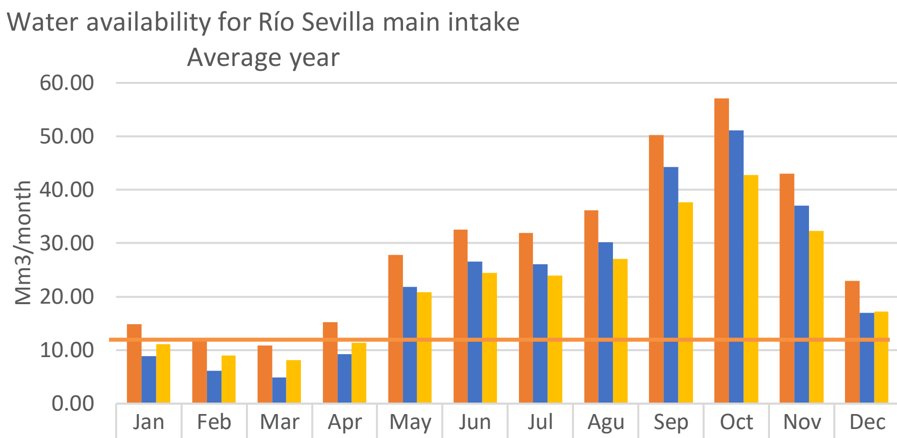


	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Average River Low Flow	12.6	9.6	8.5	9.3	10.7	15.9	18.5	20.3	27.6	32.7	28.4	16.8
80% concession	10.06	7.67	6.80	7.40	8.52	12.73	14.83	16.26	22.10	26.13	22.71	13.48
52% concession	6.54	4.99	4.42	4.81	5.54	8.28	9.64	10.57	14.37	16.98	14.76	8.76

Figure 6-4: The figure shows the lowest average (median) monthly river flow over the years 1965 – 2015 for Rio Frío with the corresponding dynamic concessions of 80% intake or 52% intake for ASORIOFRIO. Orange line indicating the maximum intake of ASORIOFRIO of 12.71 Mm3/ month based on the concessions for ASORIOFRIO and the private concessions combined.

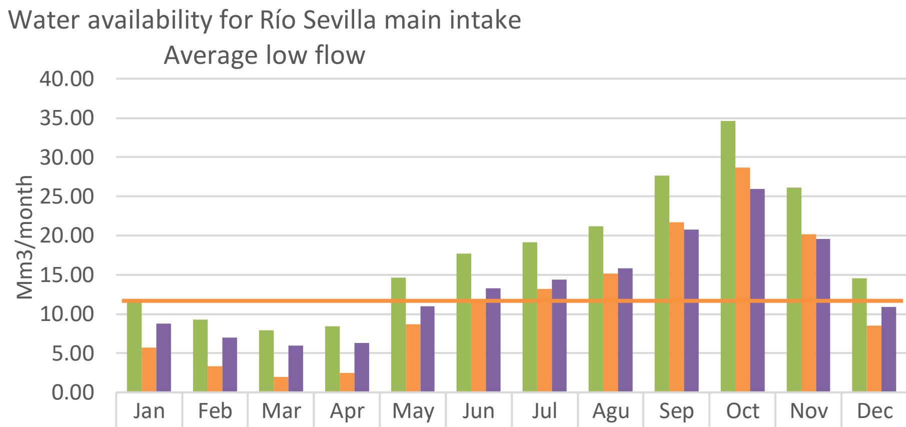
Irrigation water availability Rio Sevilla

For ASOSEVILLA, a percentage of 25% environmental flow was reported, also a minimal environmental flow of 2300 l/s (~6 Mm3/month) has been reported. On paper, the water demand for at the intake of ASOSEVILLA is at maximum 11.42 Mm3/ month based on the concessions from Corpamag.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Average River flow	14.9	12.1	10.9	15.2	27.8	32.6	32.0	36.1	50.2	57.1	43.1	22.9
Average water availability considering 2300 l/s env. Flow	8.9	6.1	4.9	9.3	21.9	26.6	26.0	30.1	44.3	51.1	37.1	17.0
75% concession	11.2	9.0	8.2	11.4	20.9	24.4	24.0	27.1	37.7	42.8	32.3	17.2

Figure 6-5: The figure shows the average (Q50, median) river flow over the years 1965 – 2015 for Rio Sevilla with the corresponding dynamic concessions of 75% intake fixed environmental flow of 2300 l/s for ASOSEVILLA. Orange line indicating the maximum intake of ASOSEVILLA of 11.42 Mm3/ month.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Agu	Sep	Oct	Nov	Dec
Average River Low Flow	11.7	9.3	7.9	8.4	14.6	17.7	19.1	21.2	27.6	34.6	26.1	14.5
Average water availability considering 2300 l/s env. Flow	5.7	3.3	1.9	2.5	8.7	11.7	13.2	15.2	21.7	28.6	20.1	8.6
75% concession	8.8	7.0	5.9	6.3	11.0	13.3	14.4	15.9	20.7	25.9	19.6	10.9

Figure 6-6: The figure shows the lowest average (median) monthly river flow over the years 1965 – 2015 for Rio Sevilla with the corresponding dynamic concessions of 75% intake fixed environmental flow of 2300 l/s for ASOSEVILLA. Orange line indicating the maximum intake of ASOSEVILLA of 11.42 Mm3/ month.

6.2 Summary of the water demand

6.2.1 Upstream water demand, before the water district intakes

Domestic water supply should be located upstream of the intakes of ASORIOFRIO and ASOSEVILLA. For ASORIOFRIO this is the case, and the intake is connected to a piped water system. For ASOSEVILLA there is not piped water system at the moment, but this should be developed in the near future looking at the priorities for water allocation. Therefore an estimated water demand for all inhabitants of the basins is taken into account with a service level of 50 l/c/day.

Table 6-1 Overview of upstream water demand, before the water district intakes, combined for Río Frío and Río Sevilla.

	L/s	Mm3/month
Total domestic water demand for 185000 inhabitants with a service level of 50 l/c/day.	107,1	0,28
Standard processing of coffee with water use of 40 l/kg, for 6000 ha of coffee production	37	0,1 (only in harvest season).

6.2.2 Irrigation water demand

To estimate channel losses, the combined losses of evaporation, non-concessioned uptakes and leakages were estimated at 50%. ASOSEVILLA indicated also an estimated channel water loss of approximately 50%.

Table 6-2. Overview of estimated irrigation water demand and water losses for the irrigation system of ASORIOFRIO. Water use by oil extraction mills is not taken into account.

Rio Frio	L/s	Mm3/month
Total water demand Banana and plantain for irrigation purposes 6574 ha	3100	8,1
Total water demand industrial processing water Banana and plantain 5400 ha	1300	3,2
Palm oil production with 80% traditional irrigation and 20% sprinkler irrigation. 3482 ha	9680	25,0
Channel losses, estimated at 50%	7140	18,5

Table 6-3 Overview of estimated irrigation water demand and water losses for the irrigation system of ASOSEVILLA. Water use by oil extraction mills is not taken into account.

Rio Sevilla	L/s	Mm3/month
Total water demand Banana and plantain for irrigation purposes 5400 ha	3800	9,9
Total water demand industrial processing water Banana and plantain 6574 ha	1500	3,9
Palm oil production with 80% traditional irrigation and 20% sprinkler irrigation. 1400 ha	3860	10,0

Channel losses, estimated at 50%	4580	11,9

These values are an indication of the water demand based on multiple assumptions and do not present the real situation precisely.

6.2.3 Environmental flow

The environmental flow requirement and different ways of application of the environmental flow are presented in subchapter 5.5. Below an overview is provided for the different options to calculate the environmental flow in Mm3/month for a dry situation (March) and a wet situation (October). At this moment, the agreements by CORPAMAG and ASORIOFRIO are such, that they should consider at minimal 20% ecological flow. The minimal Ecological flow for ASOSEVILLA is 25%. In practice, ASOSEVILLA reports a minimal ecological flow of 2300 l/sec during the dry season, and ASORIOFRIO reports an intake of 52% over the year 2021, ensuring an ecological flow of 48%.

Table 6-4 Overview of environmental flow for a dry situation (March) and a wet situation (October) for ASORIOFRIO, for an average year and a low flow situation.

Rio Frio	Mm3/month
48% environmental flow average year	
March	5,4
October	30,4
48% environmental flow Average low flow	
March	4,1
October	15,7
20% environmental flow average year	
March	2,3
October	26,1
20% environmental flow Average low flow	
March	1,7
October	6,5

Table 6-5 Overview of environmental flow for a dry situation (March) and a wet situation (October) for ASOSEVILLA, for an average year and a low flow situation.

Rio Sevilla	Mm3/month
Fixed environmental flow of 2300 l/s	
March	6,0
Fixed environmental flow of 2300 l/s	
October	6,0
25% environmental flow average year	
March	2,7
October	14,3
25% environmental flow	

Average low flow	
March	2,0
October	8,6

6.3 Water balance: Theory vs actual

There are different ways to calculate and visualize the water balance. For the Rio Frio and Rio Sevilla case, assumptions have to be made on the total water demand as there are different uncertainties in component of the water balance. . In Figures 38 and 39, the theoretical water balance for the Río Frío and the Río Sevilla is presented. For the water availability, the water intake amounts are used, taking into account the ecological flow which is considered in practice. For the demand, the theoretical volumes needed for production, processing, and channel losses are calculated. The water balance is shown for the month of March in an average (i.e. not dry) year.

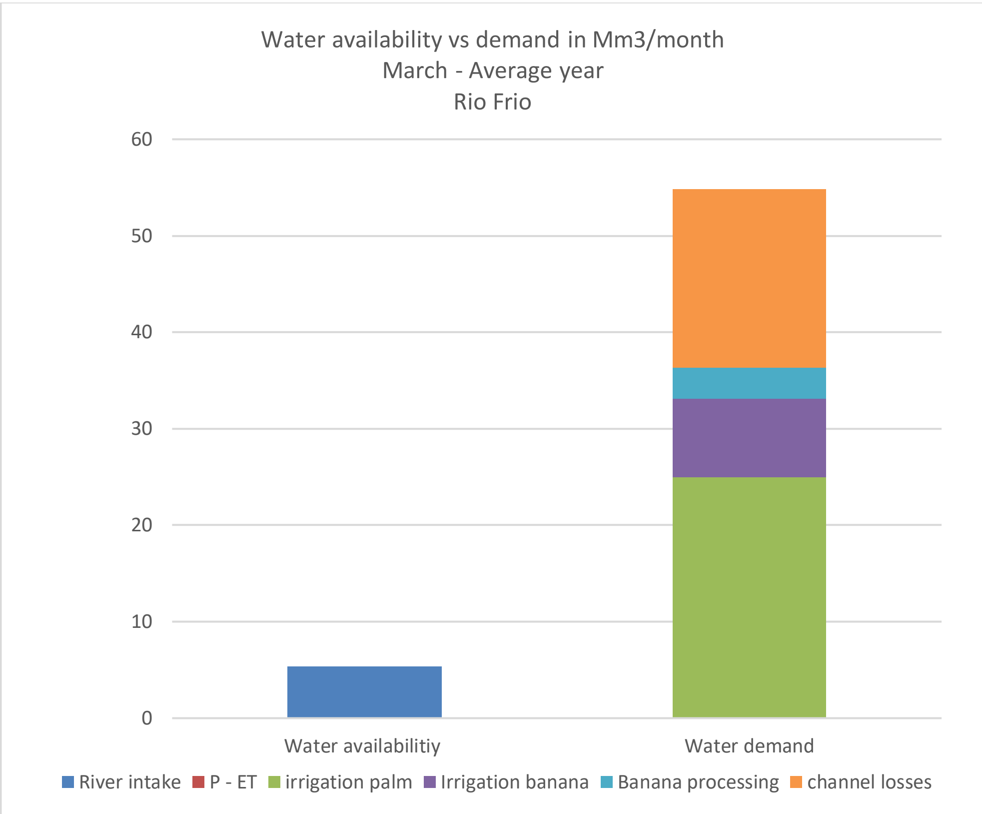


Figure 6-7 Theoretical water balance for the Río Frío for the month of March for an average year. 48% environmental flow is considered to calculate the water availability. The water demand was calculated to provide all crops with an optimal yield.

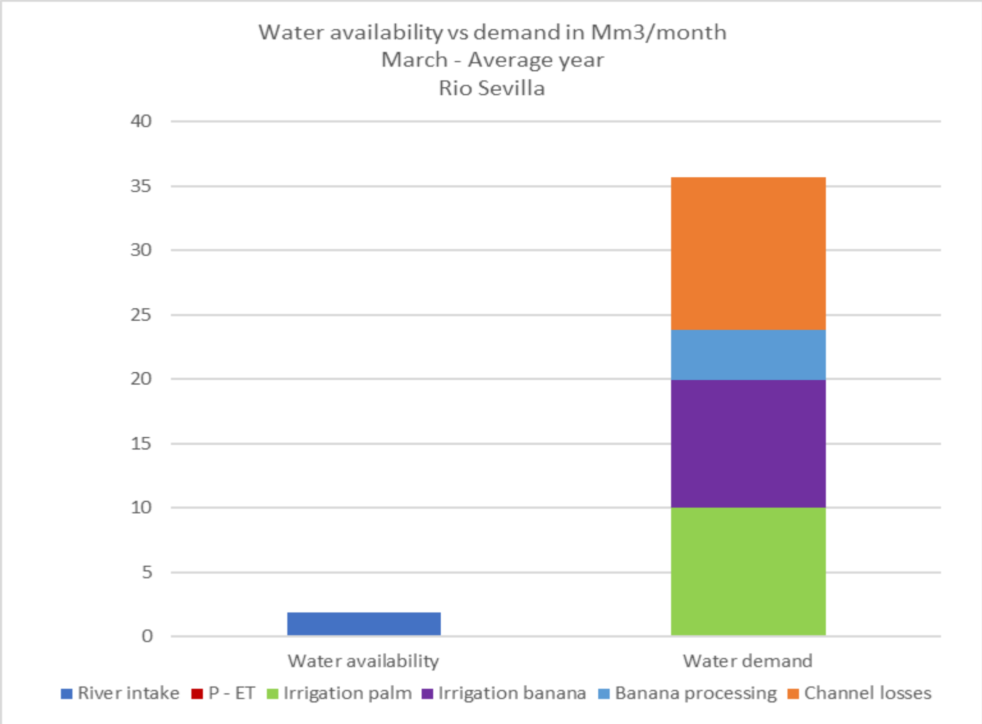


Figure 6-8 Theoretical water balance for the Rio Sevilla for the month of March for an average year. The water availability considers the ecological flow of 25%. The water demand was calculated to provide all crops with an optimal yield.

These figures clearly indicate the theoretical lack of water to cater for all the demand in both catchments. This could mean that river intakes in dry months are higher than indicated, but even if the entire flow is captured, this is not sufficient for all the demand (see also Figures 36 and 37). This would mean that during dry months, many of the producers do not get enough water, which was also indicated during the stakeholder feedback sessions. Alternatively, ground water use could be much further developed than the extent that is currently known.

The RECAR-BA project (Deltares, 2021d) indicates that during times of drought there is a shortage of irrigation water available from the channels. The majority of the producers use groundwater to fill this water gap for irrigation. Also reservoirs are used to fill the water gap in dry times.

6.4 Main challenges and needs of the water sector

6.4.1 Key issues

The Río Frío and Río Sevilla basins are under high anthropic pressures due to population growth and the palm oil and banana productive sectors, besides being impacted by climate change (Parada et al., 2015; Kaune et al., 2020a). Key issues that are experienced in the focus area and that affect the local communities, the productive sector and the SNSM and CGSM ecosystems, are:

- Declining availability of water for irrigation of plantations combined with low irrigation efficiencies, which leads to a decline in productivity;
- Declining availability and quality of water for human consumption;

- Increasing salinization of groundwater and soils, which threaten drinking water availability and decrease soil quality; also the fish population within the CGSM will be strongly threatened by salinization and reduced river flow.
- Increasing sedimentation
- Increasing incidence of floods, which cause damage to crops, infrastructure and homes.
- Water use conflicts between irrigation associations and water users, especially in times of drought when there are claims for rationing. For instance, some downstream users eliminate trenches located upstream, so the water can be re-directed to their irrigations systems
- Lack of institutional presence in the territories that leads to a lack of governance; and disjointed actions in the territory.
- Competition between different and non-aligned governmental organizations.

6.4.2 Conflict resolutions

In general, CORPAMAG has the overall responsibility for conflict resolution over water availability and water scarcity issues; however, active on the ground conflict resolution is lacking in the region. The environmental authority accounts for this deficiency by the fact that they have a lack of resources and a wide range of responsibilities.
Several initiatives towards conflict resolution are taking place in the Río Frío and Río Sevilla basins:

- The PCA is seen as an effective Water Stakeholder Platform to articulate interests of different stakeholders; however, participants of the PCA state that the PCA is still in the diagnosing phase, and implementation could be faster.
- CORPAMAG and ASBAMA are working together on an environmental agenda – *Agenda Ambiental* – to take preventive measures among the banana producers.
- A new space for dialogue between communities, authorities, and agro-industrial actors opened in early May, organized by a student who made a documentary about the water security struggle of downstream communities. The agroindustry did not turn up to this event, but the participating actors agreed on repeating the event to make steps towards water security in the river basin.

Interviews with stakeholders in the basin lead to the conclusions that there are many governance initiatives, that should be better aligned and focused. Stakeholder indicate that there are many ongoing initiatives, but that they are poorly aligned and that they would like to see more integral project objectives to avoid working in separate initiatives. For example, there are multiple projects related to sustainable landscapes & biodiversity that could be better aligned:

- the Protected areas project in the Magdalena river basin of WFF and PNN,
- the Territorial governance project in sustainable landscapes, financed by the European Union and executed by FAO and INVEMAR,
- the GEF Project 7 Conservation and sustainable use of the Ciénaga Grande de Santa Marta of INVEMAR and IDB,
- In Río Frío, work is being done on the identification of amphibians in the Sierra Nevada de Santa Marta by PNN and Cebolleta creek, this project is led by the Atelopus foundation.
- Water Security: An adaptation to climate change with a hydro-social approach in the Colombian Caribbean. Project in formulation, led by AGROSAVIA, articulated with the University del Magdalena, Javeriano Institute of Water and UCCA.

7 Water governance analysis in the Río Frío and Sevilla basins

7.1 Water governance system

This chapter takes a closer look at the water governance in the Río Frío and Río Sevilla basins in the Magdalena region. The analysis results in an overview of the water governance and provides recommendations for the focus area by compiling information from various sources, notably:

- the available literature;
- a round of interviews and a workshop session with the key stakeholders;
- field visits with Cenipalma, ASORIOFRIO and ASOSEVILLA;
- and interpersonal communications.

7.1.1 Definition

Water governance, as defined by Rogers and Hall (2003), is a "range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society" (UNDP, 2013). In other words, water governance encompasses the system by which is determined who has the right to water, and when and how water resources are made available to water users along with their related services and benefits. Though they are interdependent concepts, water governance is not to be confused with water management and integrated water resources management that are pragmatic processes for managing water resources, promoting the co-ordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital eco-systems (GWP, 2000)

The 'User's guide on assessing water governance' developed by the United Nations Development Programme (UNDP, 2013) describes the four fundamental dimensions of water governance, as shown in the figure below. These dimensions are important to review when analyzing dynamics within the water governance.

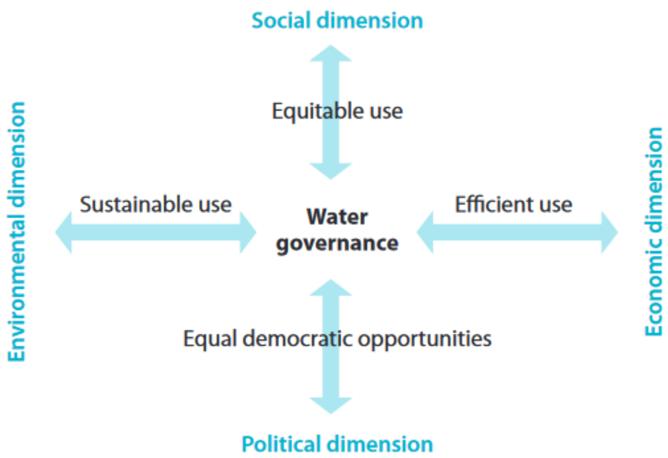


Figure 7-1 The four dimensions of water governance, as defined by Tropp, H., 'Water Governance Challenges', in World Water Assessment Programme, 2006, The United Nations World Water Development Report 2: Water, a shared responsibility, UNESCO, Paris. Retrieved from UNDP (2013).

UNDP further recommends to review three key components when carrying out a water governance assessment:

- Actors and institutions. This component provides a framework that helps build a first understanding of the governance system in place. The main stakeholders of the focus area have been previously introduced in Chapter 3 of this study.
- Performance assessment. The following Section 6.2 provides the relevant clarifications.
- Governance principles. This component helps analyzing how stakeholders behave and relate to each other. In this matter, details are provided in Section 7.3 of this report.

7.2 Indication of water governance system performance

This assessment aims at establishing the performance of the water governance system status in the Río Frío and Río Sevilla basins. Increasing the insight in the performance of the water governance allows to identify possible lacks in the system, and thus brings the attention on key aspects that could improve towards actions on the ground. For this, the OECD Water Governance Indicator Framework inspired the assessment of the state of play of water governance policy frameworks (what), institutions (who) and instruments (how), and their needed improvements over time.

A five-scale traffic light baseline was used to establish the performance index of the water governance over key components of the water system. Index I (green) represents the optimal scenario in which the water governance is in place and fully operating with no major concerns. On the contrary, Index V (red) points out that the governance dimension under investigation does not exist and there are no plans or actions taken for developing it.

Traffic light baseline					
In place, functioning	In place, partly implemented	In place, not implemented	Framework under development	Not in place	Not applicable
I	II	III	IV	V	0

This performance assessment builds on the stakeholder map for which two levels of stakeholders have been distinguished: responsible entity with direct mandated responsibilities (1st level) and secondary stakeholders with supporting role or beneficiaries (2nd level). Table 15 presents the overview of the performance assessment which is described in more details in the following sub-sections for key components of the water system.

Table 7-1: Performance assessment as carried out by Acacia Water. Secondary entity, either supporting role or beneficiaries. Legend performance index presented below table.

No.	Key components of the water system	Responsible entity	Supporting entity	Performance index
SURFACE WATER				
1	Upstream & midstream water quality	- unknown	- PNR/PNN - Indigenous comm. - Campesinos and rural comm.	V
1'	Sierra Nevada de Santa Marta – Water quality	- PNR/PNN - Indigenous com.	- Campesinos and rural comm.	II
2	Surface water resource	- MADS - CORPAMAG - ASORÍOFRIO - ASOSEVILLA - INVEMAR - IDEAM	- PCA - Farmers associations	II
3	River water quality	- CORPAMAG - INVEMAR - IDEAM	- Indigenous comm. - Campesinos and rural comm.	II
4	Surface water monitoring	- CORPAMAG - IDEAM - INVEMAR	- CORMAGDALENA	II
5	Ciénaga Grande de Santa Marta	- CORPAMAG - PNN	- CORMAGDALENA - INVEMAR	II
GROUNDWATER				
6	Groundwater resource	- MADS - CORPAMAG	- INVEMAR - PCA	IV
7	Groundwater abstraction	- CORPAMAG		II
8	Deep groundwater quality	- CORPAMAG		V
9	Groundwater monitoring and regulation	- CORPAMAG - SGC	- INVEMAR	IV
IRRIGATION				
10	Irrigation water concession	- CORPAMAG	- PCA	II
11	Irrigation water allocation and supply	- CORPAMAG - ASORÍOFRIO - ASOSEVILLA	- Farmers ass. - UPRA - ADR - Alcaldia ZB - SDE & Alcaldía Ciénaga - MADR	II
12	Irrigation network	- ASORÍOFRIO - ADR - ASOSEVILLA		II
13	Irrigation monitoring	- CORPAMAG - ASORÍOFRIO - ASOSEVILLA	- IDEAM	II.

14	Agricultural wastewater	- MADS - CORPAMAG	- PCA	IV
AGRICULTURE				
15	Agricultural practices	- Farmers associations - CORPAMAG	- AGROSAVIA - Cenipalma - PCA - AUNAP	II
16	Agricultural and rural planning	- ADR - UPRA - Alcaldía ZB – SDE & Alcaldía Ciénaga		II
DOMESTIC WATER USE				
17	Domestic water supply	- MADS - Alcaldía ZB & Alcaldía Ciénaga - Gobernación del Magdalena - Aguas del Magdalena - CORPAMAG	- MADR - PCA - ASORÍOFRIO - ASOSEVILLA	III
18	Sewage water effluent	- Alcaldía ZB – SDE & Alcaldía Ciénaga - Aguas del Magdalena	- Gobernación del Magdalena - PCA	V
EXTREME EVENTS				
19	Drought mitigation / Flood control	- UNGRD - Farmers associations - Alcaldía ZB & Alcaldía Ciénaga - CORPAMAG	- MADS - CORMAGDALENA - PCA	IV

Surface water

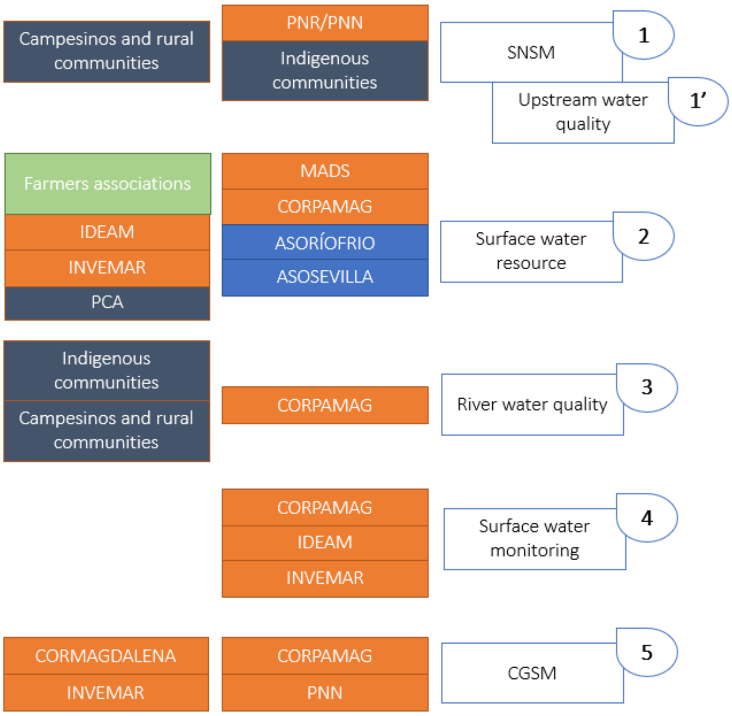


Figure 7-2: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to surface water.

1. No authority seems to be accountable for the **upstream water quality**. There has been no mention of any regulatory or monitoring activities at this moment. There are supporting organizations that are involved in initiatives to improve the upstream water quality: PNR/PNN, indigenous communities, campesinos and rural communities.
2. The National Park of **Sierra Nevada de Santa Marta** is protected through the *Sistema de Parques Nacionales Naturales* (System of National Natural Parks). The government recognizes the importance of community participation and regulates it through prior consultation processes. However, the participation of the indigenous communities is not systematic, often unrepresented on the basis of their absence from the PCA. The specifics of the dialogue and the interactions between the indigenous communities, the campesinos communities and the PNR are not yet clear.
3. **Surface water resource**. CORPAMAG is in charge of managing the natural resources and promoting sustainable development of Magdalena. The MADS is the public entity in charge of defining the National Environmental Policy and promoting the recovery, conservation, protection, ordering, management, use and exploitation of renewable natural resources. IDEAM is a public institution that provides technical and scientific support to the National Environmental System. ASORIOFRIO and ASOSEVIILA allocate the river water resources in the irrigation network.
4. **River water quality**. CORPAMAG is responsible for the quality of water; however, CORPAMAG does not conduct quality analyses. INVEMAR conducts sediment & water quality sampling at Rio Sevilla outlet into the Ciénaga Grande, and INVEMAR assesses water quality near the intake of the water districts.
5. **Surface water monitoring**. Monitoring of surface water is managed by the Environmental Management Sub-directorate of CORPAMAG. They manage IDEAM

stations that are focusing on surface water; However, there is no permanent monitoring of water quality. ASORIOFRIO takes samples periodically for international certifications. CORMAGDALENA might have a play as they are setting up an observatory (Workshop, April 2022).

6. **Ciénaga Grande de Santa Marta**. CORPAMAG manages this Ramsar wetland, prioritized to develop the Watershed Management Plan (Plan de Ordenamiento y Manejo de Cuenca). Parques Nacionales Naturales (National Natural Parks) is the entity in charge of managing the Santuario de Flora y Fauna de Ciénaga Grande de Santa Marta (SFFCGSM). CORMAGDALENA might have a play as they are setting up an observatory (Workshop, April 2022).

Groundwater

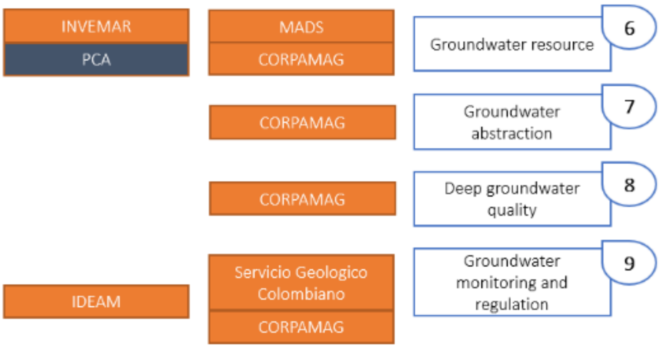


Figure 7-3: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to groundwater.

7. **Groundwater resource**. CORPAMAG is in charge of managing the natural resources and promoting sustainable development of Magdalena. It promotes community participation and programs for environmental protection, sustainable development and proper management of renewable natural resources. The water system of Sierra Nevada – Ciénaga Grande de Santa Marta offers the opportunity to contribute to a planning process prioritized by the authority local environment through the *Plan de Ordenamiento y Manejo de Cuenca*. The MADS is the public entity in charge of defining the National Environmental Policy and promoting the recovery, conservation, protection, ordering, management, use and exploitation of renewable natural resources. INVEMAR carries out basic and applied research on renewable natural resources and the environment in coastlines and marine and ocean ecosystems in order to provide the necessary scientific knowledge for policy formulation and decision making. PCA is concerned about the sustainability of the groundwater resources (due to salinization) and includes this in the stakeholder discussion.
8. **Groundwater abstraction and concession**. CORPAMAG is responsible for providing groundwater concessions. They also keep a database with all groundwater concessions made. However, this database is not complete as not all groundwater wells have a concession. There are no plans at the moment to make a complete inventory of all groundwater wells and abstractions.
9. **Deep groundwater quality**. CORPAMAG is responsible for providing groundwater concessions and as part of the concessions, monitoring audits are carried out as follow up. Information from the field on water quality changes reported during the audit can be stored in the database of CORPAMAG.
10. **Groundwater monitoring**. The Servicio Geológico Colombiano (SGC) is a scientific agency of the Colombian government in charge of monitoring groundwater. CORPAMAG should also be responsible for monitoring the groundwater in the region; in practice, There is no aquifer management or

monitoring plan in place for the Ciénaga-Fundación Aquifer. . IDEAM has carried out studies on the topic of groundwater in the region.

Irrigation water use

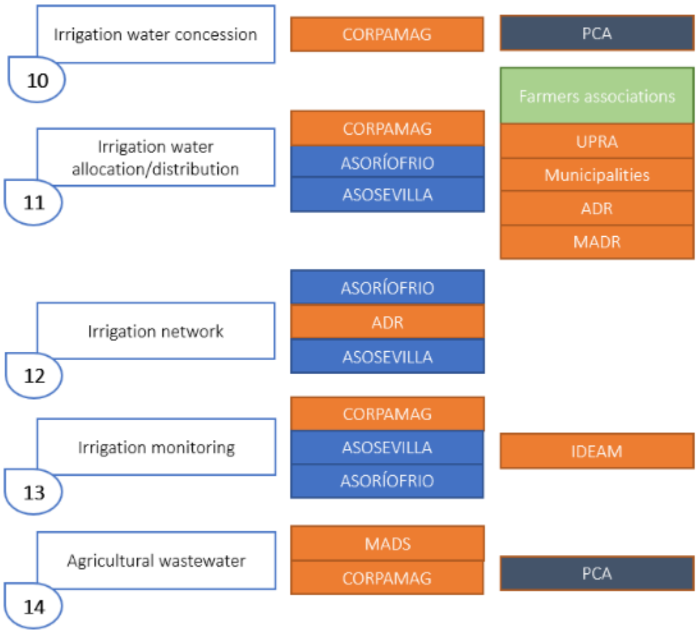


Figure 42: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to irrigation water use.

11. **Irrigation water concession**. CORPAMAG is in charge of managing water availability and grants permits, concessions and licenses. About 80% is concessioned to the agricultural sector and in practice they are the priority users in case of drought; as the water needs of the local communities are covered though they tend to be disregarded. The water resource governance strategy was consolidated between Fedepalma, Cenipalma and CORPAMAG in December 2021. However, ASOSEVILLA and ASORIOFRIO are not part of the of the board of directors of CORPAMAG, though they are the main water consumers. PCA initiative intends to fill this gap, with a special focus on 'Water management' which includes topics such as water demand reduction and water supply conservation goals.
12. **Irrigation water allocation/distribution**. ASOSEVILLA and ASORIOFRIO allocate the water from the Río Frío and Río Sevilla to the different agricultural uses and oversee that the concession (legal allocation), as determined by the regional government CORPAMAG, is respected. CORPAMAG allocates and manages few concessions directly, but overall the environmental authority has a smaller role in short-term allocation/distribution decisions. CORPAMAG has the key role of determining the long term water allocation (5 to 15 year time window) by granting concessions. Water allocation issues and related conflicts are reported to occur, especially during drought events. Water availability is compromised for the downstream users due to excessive water intake though the resource is limited. Some users in the lower middle part of the districts also take water illegally as they do not have concessions from CORPAMAG. In case of water availability issues, users contact the irrigation districts, and these in turn report to the environmental authority. However, CORPAMAG is unlikely to resolve on the ground conflicts since water is scarce and of poor quality. In practice, the Agricultural Rural Planning Unit (UPRA) the MADR and the municipalities are

contacted by ASORIOFRIO and ASOSEVILLA when experiencing water availability issues. UPRA has the mandate at the local level, though UPRA's role is passive. MADR has an influence on the irrigation water concessions as they develop the national water tariff guidelines.

13. **Irrigation network**. ASOSEVILLA has the objective to operate, conserve and maintain the works that make up the district. ADR is the owner of the irrigation district of ASORIOFRIO and their infrastructure, intake, irrigation channels and drainage canals. The ADR owns Río Frío channel network system, and controls and provides technical supervision to ASORIOFRIO who operates and maintains the system. The ADR cannot exercise an administrative supervision to ASOSEVILLA, as it is not part of the entity. ADR can provide financial tools for irrigation districts. Districts can reach out to ADR to generate irrigation channel projects, machinery, maintenance.
14. **Irrigation monitoring**. Although CORPAMAG grants licenses to collect water for crops, they do not monitor concessions or irrigation continuously, but they carry out audits of the water use approximately every six months. CORPAMAG has only historical distribution and allocation data. IDEAM has both historic and real time data. IDEAM has 2 points to measure water supply. However, there is limited interaction with irrigation districts. ASORIOFRIO and ASOSEVILLA carry out measurements of water level/flow from the channels of their supervision. . IDEAM has a water monitoring location inside of the ASORIOFRIO channel system, and IDEAM continuously monitors the river discharge just before the intake of the water districts, therefore contributing to the monitoring of the water intake for irrigation of the water districts.
15. **Agricultural wastewater**. For CORPAMAG, the return flow of agricultural lands to the river is of interest looking at environmental flow. Drainage water quality and quantity is not monitored by most producers at the moment. Among the three focus topics of PCA can be mentioned 'Solid waste and disposal'. The MADS has established a dumping permit format that must be filled out by any natural or legal person who carries out agricultural activities that generate the discharge of polluting substances into water bodies. It was reported that coffee production is highly polluting during the process phase, causing problems to the downstream users.

Agriculture

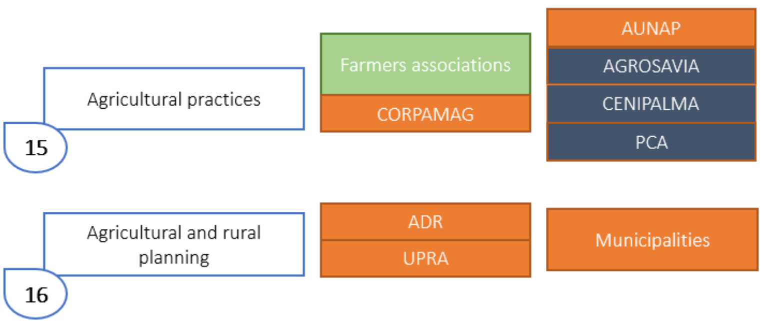


Figure 14: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to agriculture.

16. **Agricultural practices**. CORPAMAG promotes programs for environmental protection, sustainable development and proper management of renewable natural resources. The purpose of AGROSAVIA is to work on the generation of scientific knowledge and agricultural technological development to improve the

competitiveness of production, equity in the distribution of the benefits of technology and sustainability in the use of natural resources (therefore also water resources). The same can be said about Cenipalma and other research institutes and NGO's. The farmer association AUGURA is working on a €7,000,000 project led by the MADR, funded by the Green Climate Fund, to reduce their carbon footprint and work at the agronomic level to find varieties or cultivars that are more resistant to climate variability. PCA initiative encourages discussions across stakeholders and intends to fill the gap in the governance system, with a special focus on 'Water management' which includes topics such as water demand reduction and water supply conservation goal.

17. **Agricultural and rural planning**. ADR is the entity attached to the Ministry of Agriculture in charge of structuring, co-financing and executing comprehensive agricultural and rural development plans and projects with a territorial approach to contribute to the transformation of the countryside. UPRA is attached to the Ministry of Agriculture, and is in charge of planning the efficient use of land, define the criteria and create the instruments required for this purpose. Municipalities support and guide strategic agricultural and rural planning.

Domestic water use

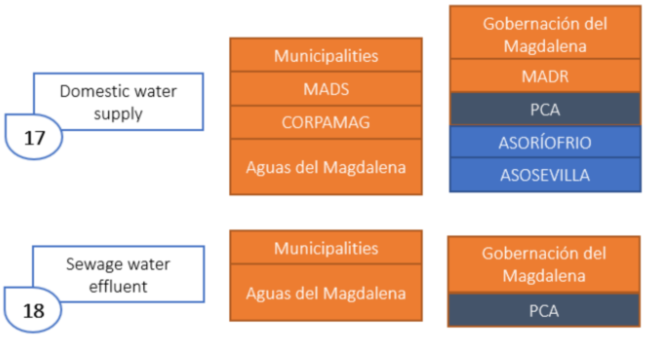


Figure 42: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to domestic water use.

18. **Domestic water supply**. The SDE department of the municipality of Zona Bananera (*Alcaldía de Zona Bananera*) is responsible for ensuring the provision of water services to the local population. CORPAMAG awards a concession to the municipality; however, it appears to have a lower priority in regards to water allocation, especially in the event of a drought. PCA initiative intends to fill the gap in the governance system, with a special focus on 'Water management' which includes topics such as water demand reduction and water supply conservation goal. Aguas del Magdalena is committed to the realization and implementation of infrastructure works in sustainable water supply and sewage systems for urban and rural communities, but the implementation and maintenance is the responsibility of the municipalities.
19. **Sewage water effluent**. The municipality of Zona Bananera (*Alcaldía de Zona Bananera*) is responsible for the development of a sewage system, through special units or office secretariats; in this case it is the Secretary of Economic Development (*Secretaría de Desarrollo Económico* - SDE). In practice, however, the Río Sevilla basin is not equipped with a sewage system. PCA initiative encourages discussions across stakeholders and intends to fill the gap in the

governance system, with a special focus on 'Solid waste and disposal', so the topic is in discussion. Aguas del Magdalena is the manager (gestor) of the PDA (Departmental Water Plan), they are an entity that works jointly with the government in each of the projects that are carried out. They are not in charge of the operation of the services, they are in charge of the construction of the aqueduct and sewage systems in the department of Magdalena in the populated centers, in the rural area and in the urban area.

Extreme events

Figure 7-446: Map of stakeholders responsibilities (level 1) and supporting or beneficiary roles (level 2) for key aspects of water governance related to extreme events.

20. **Drought mitigation and flood control**. The UNGRD (National Unit for Disaster Risk Management) directs the implementation of disaster risk management, At this moment, there is not yet a functional warning system in place. ASBAMA (*Asociación de Bananeros del Magdalena*) led the creation of a water table to discuss and seek solutions to the water regulation problems in the area (floods in the rainy season, scarcity in drought). All the guilds were summoned, except the indigenous ones. Several studies were made to present solutions but the initiative was not continued due to lack of interest of the actors to invest. Based on information gathered during the workshop session, municipalities make risk plans at the municipal and district levels. PCA also discusses flood and drought risk in the round tables of the stakeholder platform.

7.3 Assessment on water governance and IWRM

The water governance system can be assessed according to the OECD Principles on Water Governance, an analytical framework aiming at identifying possible action points to further enhance and improve water governance and integrated water management in the river basins. The Principles were developed through a bottom-up and multi-stakeholder approach within the OECD Water Governance Initiative (WGI). The Principles are clustered around three main governance dimensions: 1) effectiveness, 2) efficiency, and 3) trust and engagement. Each of these dimensions contains four principles, as shown in the figure below.

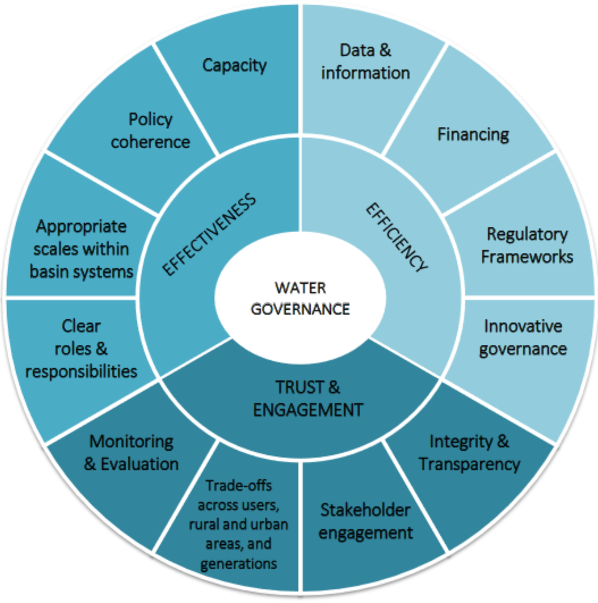


Figure 47. The OECD principles on Water Governance (source: OECD, 2015). The OECD water governance principles are clustered around three main governance dimensions. Each of these dimensions contains four principles.

The OECD Principles on Water Governance are developed on the premise that there is no one-size-fits-all solution to water challenges worldwide, but a menu of options building on the diversity of legal, administrative and organizational systems within and across countries. OECD recognizes that governance is highly contextual, that water policies need to be tailored to different water resources and places, and that governance responses have to adapt to changing circumstances.

Integrated Water Resources Management (IWRM), is an umbrella concept encompassing multiple principles that ensures all three governance pillars of OECD are touched upon. IWRM approaches involve applying knowledge from various disciplines as well as the insights from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to water and development problems. As such, IWRM is a comprehensive, participatory planning and implementation tool for managing and developing water resources in a way that balances social and economic needs, and that ensures the protection of ecosystems for future generations. Water's many different uses — for agriculture, for healthy ecosystems, for people and livelihoods — demands coordinated action. An IWRM approach is consequently cross-sectoral, aiming to be an open, flexible process, and bringing all stakeholders to the table to set policy and make sound, balanced decisions in response to specific water challenges faced.

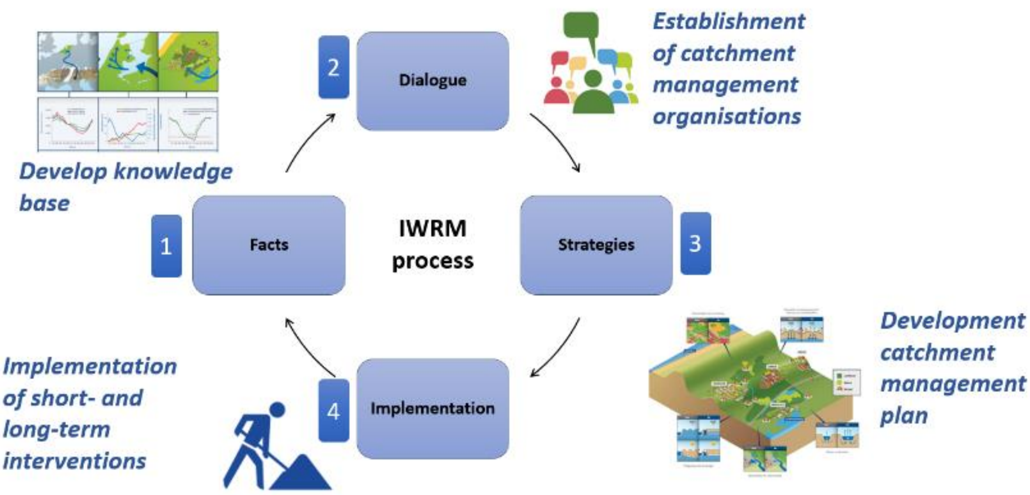


Figure 7-5. The hands- on IWRM process as recommended by Acacia Water. The loop of activities in Río Frío and Rio Sevilla is ongoing through different initiatives. The dialogue in this case is not through Catchment Management Organizations, but through the round table meetings of the PCA. Implementation of interventions is done by many different stakeholders in the basins.

As this report describes, the water governance of the Río Frío and Río Sevilla basins has been developed over the years separately and resulted in different water governance systems. Also for Colombia, there is no one-size-fits-all solution to water challenges, and a tailor-made water governance systems has been developed over the years and will keep developing in the future. For Río Frío and Río Sevilla basins, there are actions already in place, or planned for the short, medium and long run related to each of the OECD Water governance principles: Effectiveness, Efficiency, and Trust & Engagement. There are several on the ground initiatives already carried out or in place, such as the desilting, rehabilitation and reforestation project of 13 km riverbed near the outlet towards the Ciénaga Grande. Fundeban, Asoriofrío, Ecopetrol, Corpamag, among others, participate in this project (Parada et al. 2015). Prosierra works together with the indigenous communities and coffee producers in the middle catchment on issues of reforestation, environmental education and risk mitigation. Also INVEMAR, for example, presents an annual monitoring overview of the Ciénaga Grande. (Parada et al, 2015)

And also national initiatives, such as the development of the Geoambiental monitoring tool of CORPAMAG. There are still possible action points on water governance and IWRM that can be implemented for the Río Frío and Río Sevilla basins. The recommendations here can be incorporated in a future Water Resources Management Plan for the Río Frío and Río Sevilla basins in collaboration with CORPAMAG and the PCA.

Effectiveness

Clear roles & responsibilities, Capacity

For good water governance, it is recommended to promote inclusiveness across stakeholders and identify the role that each can play to water governance. This is applicable to all levels of government: policy making, policy implementation, operational management and regulation and enforcement.

The dialogue of the round tables of the PCA contribute to clarity on the roles and responsibilities of the stakeholders involved in water management of the basins. The stakeholders in the workshop indicated that a joint vision of the region is also needed. Currently, initiatives from many sectors are seen but a joint and long-term vision is

needed. This relates to common goals, but also to intertwine with plans of the municipalities for better integration of actions on the ground.
IWRM and Fact-based decision making underlines the need for continued and elaborated monitoring and research to elaborate the knowledge base of Río Frío and Río Sevilla, in order to ensure sustainable vision for a future horizon. Currently PCA is developing a tool that will communicate the state of the basins, this will support in the priority setting and strategic planning for the Río Frío and Río Sevilla basins.

The stakeholders indicate that, while there are national laws and regulations to follow, these often not suit to the specific situation of the Río Frío and Río Sevilla basins. This provides challenges in priority setting, and strategic planning. It would be to the interest of all stakeholders that flexible, and tailor-made plans can be developed for the region. It would be good to identify the possibilities to adapt ruling laws and regulations to fit the local context.

The roles and responsibilities of the different stakeholders are directly linked to their capacity as a limiting factor. Capacity could be financial resources, or knowledge (f.e. related to monitoring methodology). It would be good to identify and address the capacity gaps for the different roles and responsibilities, for example in the enforcement of regulations on the ground.

Appropriate scales within basin systems
The IWRM process starts with a strong knowledge base. In practice, however, the development of a good knowledge base is not simple. Challenges arise in collecting, processing, and mapping results. With groundwater resources, a 3D situation is translated to 2D maps. Socio-economic data often stored based on administrative boundaries and need corrections for hydrological source-area delineation. It is therefore recommended to for example collect gridded datasets of population density, as they are of great value in water demand assessments on a larger scale. Also looking at groundwater resources, the entire aquifer extent needs to be taken into account with sustainable water management, this extent is wider than the hydrological catchments, see also the aquifer extent in Figure 2-3.

Regarding water allocation, the areas that receive service from ASOSEVILLA and ASORIOFRIO (the man-made channel catchments) are crossing the hydrological catchment boundaries. In communication and assessments it is therefore important to clearly refer to the area of interest.

Looking at local water availability, rainfall and surface water flows are becoming more variable and less reliable. Therefore, an assessment of the rainfall regime and corresponding behavior and land use changes is key. Also for water infrastructure and water demand assessments, it is recommended to keep detailed records of yields and usage instead of averaged values. Recording seasonal changes and variations as well as highlighting extreme situations is elemental to identify the impacts of climate change on (agricultural) activities in the basin. These records help to formulate and implement appropriate mitigation and adaption measures.

Furthermore, it is important to realize that the Río Frío and Río Sevilla basins do not stop at their discharge point into the Ciénaga Grande as there are downstream users and system depending on the fresh water flow from these river. It is therefore most important that the Ciénaga Grande and the downstream communities are represented in the dialogue, assessments and water allocation.

Policy coherence
According to local stakeholders that attended the workshop session in April 2022, priorities for water allocation are by law: 1) Domestic supply, 2) Ecosystem, i.e. environmental flow, irrigation and forestry and 3) other uses. In practice, local communities are not the priority beneficiaries considering the lack of water supply network. There is a mismatch here in policy vs. practice. It would be good to start filling the knowledge gap for the domestic water demand and supply in order to strive towards a water supply network meeting the demands of the inhabitants.

Also, it is a clear challenge that environmental flow, irrigation and forestry are broad concepts looking at terminology, as this still leaves room for discussion on water allocation amongst stakeholders. A clearly defined and transparent strategy on water allocation will contribute to effective water management in the basins.

Efficiency

Data & information
The IWRM process and water governance starts with a strong knowledge base. Therefore it is key to produce, update, and share timely, consistent, comparable and policy-relevant water and water-related data and information, and use it to guide, assess and improve water policies (OECD, 2015). Information is collected with different methods and registered in different units. To ensure data sharing of reliable information, clarity on the data collection methods is important. For example, is only a water meter an accepted method of collecting actual water use information? Or are pump statistics also accepted and trusted by all stakeholders?
Providing guidance on the formats and ways to collect and share data that can be used for multiple purposes is recommended. Also a joined (open access) database for monitoring data is recommended to ensure fact based decision making. Sharing of ongoing (implementation) initiatives to a central platform (such as PCA) or other community communication platform is also recommended.

Financing
There is currently an agricultural water tariffing system from the water districts to the producers, covering the cost of the actual water and the service provided. CORPAMAG has its water tariffing system with the producers (with direct concessions) and water districts. This is a standard tariffing system. The national guidelines for agricultural water tariffing are set by MADR. Other financing mechanisms that can be explored are building on alternative principles such as the polluter-pays and user-pays principles, as well as payment for environmental services (OECD, 2015).

The PCA organizes monthly round tables with stakeholders. For these activities financial support is necessary for facilitation. Therefore, the facilitation of dialogue between the stakeholders is in itself an activity that requires support for its realization, so it is required to propose financial mechanisms for its sustainable implementation.

There is also an opportunity with municipality or regional government budget to purchase and manage land midstream and upstream in the catchments (outside of PNN governance) that play a key role in ensuring water supply. These lands could also be of special environmental interest or play a role in conservation strategies and be assisted in natural regeneration. The acquisition of land could also be done with a trust fund. Prosierra pointed out during an interview that improvements of the water governance will only be sustainable if there is long-term financing available. If a water governance system is able to capture and quantify socioecological and socioeconomic impact due to good water governance, and performance of good partnerships, then contingent payers can be found adding to a trust fund of some sort. That trust fund can be used to upkeep and optimize the adaptive governance process.

Regulatory Frameworks
This entails that sound water management regulatory frameworks are effectively implemented and enforced in pursuit of the public interests. For example, CORPAMAG has many responsibilities and tasks but cannot always achieve everything, among others, due to lack of resources and capacity. It is important that all those who use water participate in controlling and monitoring water resources. One of the main challenges is that land ownership administration and land use changes are not always updated continuously. Therefore is not always clear who is producing what and where. The type of production (traditional vs modern irrigation), and production sizes are not entirely registered. A landcover map with registration of irrigation types, could be the key to develop a sound basis that ensures effective implementation and develop water governance that fits the situation.

Innovative governance
Ongoing initiatives of encouraging experimentation and pilot-testing on water governance and water efficiency, supports drawing lessons learned from success and failures, and scaling up replicable practices. To implement these lessons learned in governance, requires adaptive and inclusive governance. Governance is the management defined by formal rules (constitution and laws) and informal ones (traditions, habits and customs) (Saras Institute[3]). The informal rules are easier to adapt than the formal rules. But including strategic planers of national level in local dialogues supports future changes in national government.

Citizen science projects can be implemented to ensure wide spread data collection by the producers on for example groundwater quality and salinization issues. An example of such a project is the *Farmers Measure Water*[4] project in the Netherlands. where each farmer collect water quality information on his/her own agricultural field, which is published at an online dashboard to support water management by the local water board.

Promoting social learning to facilitate dialogue and consensus-building, for example through networking platforms, social media, Information and Communication Technologies (ICTs) and user-friendly interface (e.g. digital maps, big data, smart data and open data) and other means (OECD, 2015). This can be facilitated by national initiative such as the open source website providing maps of Colombia[5].

Trust & Engagement

Integrity & transparency & Stakeholder engagement
The PCA is using a multi-stakeholder approach for their round tables and dialogue process, and this contributes strongly to the stakeholder engagement, transparency of action plans and tools to be developed.

Improvements can be made on transparency and trust. Establishing clear accountability and control mechanisms for transparent water policy making and implementation. Enforcement of laws and regulation (f.e. to prevent illegal water uptake from channels and rivers) would support trust and engagement of stakeholders. Spreading the word

[3] https://saras-institute.org/adaptive-governance/
[4] https://boerenmetenwater.nl/
[5] https://www.colombiaenmapas.gov.co/

about positive actions already undertaken will also help with trust and engagement. For example, some producers have already made large investments in shifts towards more efficient irrigation systems. Trust between different groups of stakeholders would increase if the efforts and the beneficial impacts of implemented activities are shared to the entire group of stakeholders. The roundtables of the PCA can facilitate a trusted envireonment and play a role in this. Sharing of data and information, efforts in what the partners do, issues and needs of water availability with the whole stakeholder group will improve stakeholder engagement.

The downstream communities that are dependent on the Ciénaga Grande, the largest lagoon-delta ecosystem in the Colombian Caribbean, are possibly hit hardest during times of droughts and in the near future looking at sea level rise. These communities are to be recognized and be sufficiently represented in the stakeholder process and decision making process in a transparent way. There are several organizations that can speak up for their interests, such as PNR, INVEMAR, CORPAMAG and of course community representatives or municipalities.

To ensure a strong water buffering function of the Santa Marta de Sierra Nevada mountains, the importance of these mountains and natural vegetation needs to be known to the stakeholders. Awareness on the importance of the stakeholders will improve the conservation of the natural vegetation and will influence strategic planning and decision making in the basins. An awareness campaign can be started to stress the importance of the Sierra Nevada de Santa Marta in providing economic and ecological services.

Trade-offs across users, rural and urban areas, and generations
Choices will have to be made in water allocations, and these choices will be tailor-made to the context and the wishes of the stakeholders of the Río Frío and Río Sevilla basins. It is important that these decisions are well-founded knowledge-based decisions, and that the impact of these decisions for different users is well understood and accepted.

Promoting public debate on the distribution of risks and costs associated with too much, too little or too polluted water to raise awareness in one particular region, builds consensus on who pays for what, and contribute to better affordability and sustainability now and in the future (OECD, 2015). For the Ciénaga Grande and the freshwater dependent ecosystems, the public debate about the tipping point (or point of no-return) should be well researched and communicated in order to allocate the amount of water to avoid irreversible damage to the Ciénaga Grande.

Promoting non-discriminatory participation in decision-making across people, especially vulnerable groups and people living in remote areas (OECD, 2015). Including these stakeholders in dialogue will also increase awareness on specific issues that would otherwise not receive the same attention.

Monitoring & Evaluation
In the Río Frío and Río Sevilla basins, there are several dedicated institutions for monitoring and evaluation. In the stakeholder workshop it was stated by the participants that there is a strong need for extra monitoring stations in especially the upper part of the catchment. Extra funds should be made available to allow for purchasing these monitoring stations, including the technical support for the installation and operation of for example telemetric monitoring stations. Additionally, the responsible entities for these extra monitoring points should be determined.

At the moment, many different types of private organizations and producers are collecting monitoring data on meteorology, water availability and water use. Most data records are private and not published. Data sharing and transparency on water availability and use would improve the trust and engagement of all stakeholder to contribute to sustainable water management for all. The Decision Support Tool that will be developed by this consortium will contribute to the first steps in data sharing and transparency in water availability and use.

During the workshop, it was stated by the participants that the monitoring of the river flow and the water demand is important for decision making. Also non-concessioned uptake needs to be monitored and controlled. The interaction between groundwater and surface water is also of importance to understand risk for salinization and to quantify the sustainable water resources available.

In these times, also satellite information can contribute to estimates of water availability and demand.

7.3.1 Outlook for the Río Frío and Río Sevilla basins

The water governance should also consider future changes. A reduction in precipitation is expected for the Department of Magdalena of 24.6% between 2011 and 2040. The Department of Magdalena will go from having mainly a semi-arid climate to an arid climate between 2071 and 2100 (Parada et al., 2015). The outlook for the basins indicate that climate change will have its effect on the catchments, with a 30% decrease in runoff during El Niño and a severe surplus of water up to 40% during La Niña, both projections for the year 2100 (Parada et al., 2015). This results in drought during El Niño years, and floods during La Niña years. Future reduction in precipitation and El Niño years will likely result in a strong water scarcity experienced by all stakeholders.

Additionally, Ciénaga Grande and agricultural lands adjacent to the Ciénaga Grande (f.e. Zona Bananera) will be affected by the rise in sea level. IDEAM presents two scenarios, an increase of 0.3 m by 2030, and a rise of 1m by 2100. If there is a sea level rise of 1m, the villages surrounding the Ciénaga will be strongly affected and partly flooded. The ecosystem of the Ciénaga will change, likely strongly affecting the fish population and therefore also the livelihoods of the fishing communities. The birds residing in the Ramsar site, will be also strongly affected by the resulting changes in fish and (freshwater depended) vegetation. The decrease in precipitation and the rise in sea level will have repercussions on the salinization on the groundwater resources, the swamps, the Mangroves and other water bodies.

Figure 7-6. A fishermen of the Ciénaga Grande using the wind to return home after a long night of fishing. He is completely dependent on a thriving fish population for his livelihood. Picture of Acacia Water.

This outlook highlights the importance of securing the water buffering function of the Sierra Nevada de Santa Marta mountains. By keeping the natural vegetation in an optimal condition, the landcover and topsoil will act as a water buffer to store rainfall. During rainfall events, this will reduce flooding downstream, and after rainfall events, the baseflow of the rivers will be higher due to the delayed release of infiltrated rainfall from the soils to the rivers. The water buffering functions and anti-erosion can be strengthened by 3R interventions, that ensure Recharge, Retention and Reuse of water in rivers and landscape (Mekdaschi Studer, R. and Liniger, H. 2013.). Examples are reservoirs, or gabion dams to reduce the velocity and lower the sediment transport by the river, or river bank protection zones, to stabilize river banks and support vegetation growth for natural protection from erosion.

The groundwater resources can be enhanced by Managed Aquifer Recharge (MAR) systems or Aquifer Storage and Recovery (ASR) systems. The RECARBA project supported the feasibility of future pilot for an ASR system. The project consisted of 4 phases, and the activities of these four phases resulted in a set of calculations, maps, guidelines and tools to be used when the installation of ASR pilots for medium-sized banana producers is considered in the Río Frío and Río Sevilla basins. The results also provided the basis for future assessments on the impact of ASR systems in the basins.

Also improved water (and fertilizer and herbicides) use efficiency in irrigation practices will contribute to reduced pressure on the available water resources in the river basins. Already many producers (especially in the banana sector) have made the switch to sprinkler and drip irrigation. The transfer of the other producers that still irrigate in a more traditional, less efficient, way needs a good enabling environment. At the same time it is of importance to ensure that the area in use for irrigation is not extended anymore, as then the water demand will increase again. The transfer to more modern irrigation techniques is supported by research and pilot projects. Several projects and research institutions are contributing to the knowledge base and the possibilities for improved water use efficiency. A consortium of FutureWater, Solidaridad, Cenipalma and Delphy worked together on a feasibility study on efficient irrigation for oil palm areas in Río Sevilla basin, identifying several techniques to improve water efficiency.

Also extension officers of, for example, Cenipalma contribute to the distribution of knowledge and provide support to the producers. The research organizations in Río Frío and Río Sevilla basins are actively approaching the farmers, and the uptake of improved irrigation methods in the region is increasing. But also the financing mechanisms should be improved. Currently the bank loan to producers is 5 years, while the return of investment time is 7 years. This provides a big obstacle for many producers that want to implement a more water use efficient irrigation system.

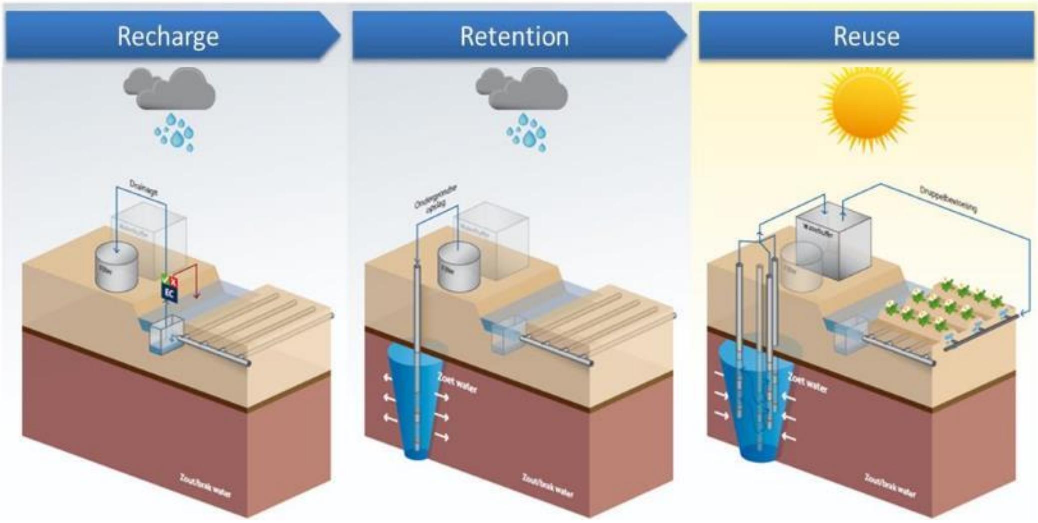


Figure 50. An example of an Aquifer Storage and Recovery(ASR) system. Image of Acacia Water.

8 Conclusions

This water resources baseline assessment and water governance analysis was developed for the Río Frío and Río Sevilla basins in the Magdalena region of Colombia. The basins increasingly face challenges between different water users in terms of both water quantity and quality. Within these basins, the largest share of the available water is predominantly used for irrigation purposes in oil palm and banana plantations. The sustainability of these production systems is threatened by water shortages and inefficient irrigation practices, alternating availability of water (shortage during dry seasons vs frequent flooding in the wet seasons) due to climate change, and other environmental problems such as salt intrusion and soil erosion. Lower river discharges in the dry season also mean that access to water (which is provided by the irrigation associations (ASOSEVILLA and ASORIOFRIO)) is restricted. The unpredictability in water supply poses difficulties. Not only agricultural producers suffer from these issues, but also the rural population and natural ecosystems, since the rationing of water during the dry season does not only affect water utilized for irrigation purposes, but also water destined for domestic use and the environment.

This baseline assessment is the first output of this project. In the next step, a decision-support system (DSS) will be developed, to improve water allocation amongst all users. Several stakeholders have started initiatives to support sustainable use of water resources in the Magdalena region, and most notably is the Water Stewardship Platform (Plataforma Custodia del Agua, PCA), which brings together a large group of stakeholders to support sustainable use of the water resources. To support the development of the DSS, this report presents a stakeholder assessment of the Río Frío and Río Sevilla basins, combined with a baseline assessment to assess the status of identified water sources. This report also identifies knowledge gaps on these subjects.

Both the Río Frío and Río Sevilla, originating in the Sierra Nevada de Santa Marta (SNSM) Mountain, discharge into the Ciénaga Grande de Santa Marta (CGSM) wetland. Both SNSM and CGSM are two very rich ecosystems, highly sensitive to change and with great biodiversity. Droughts have significantly impacted the productive sector, the ecosystems and (fishing) communities. This study showed that there is no consensus between different sources about the production area per crop type per basin or irrigation district.

The water supply from the rivers to the agricultural producers is arranged by ASORIOFRIO and ASOSEVILLA. They divide the water over the channels based on the hectares served by the channel. In times of drought, all producers receive less water. Irrigation efficiency is low, especially on most (~80%) of the oil palm plantations still irrigation with surface flooding. Both basins have major issues with sediment load due to upstream erosion and poor water quality, largely because a lack of a sewage system.

When looking at the water balance for both catchments, it is evident that during the dry season water demand far exceeds the available intake water. Also when not taking into account environmental flow (which can be calculated in different ways in the study area), water availability is not sufficient for all the producers. This water gap can be partly, but not fully, covered with water from reservoirs and groundwater wells. In times of drought, all producers thus receive less water (proportionally), but it was also indicated that some tail-end farmers are worse off than farmers located more upstream (or those with larger land holdings). Alternative coping mechanisms are the use of groundwater or small-scale reservoirs, which are both largely unmonitored.

Conclusions made in report are based on stakeholder inputs, but have not been presented or endorsed by stakeholders.

8.1 Data gaps in the water resources baseline assessment

Unclear catchment boundaries

The existence of channel networks in the Río Frío and Río Sevilla basins implies that surface water is diverted beyond the hydrological boundaries of the watersheds. The man-made irrigation network boundaries have been roughly identified, but a complete mapping exercise is necessary. This information is crucial for determining the production areas in the irrigation district, and hence the exact irrigation water demand and the potential surface runoff that leaves the system.

Land cover and irrigation production systems

The actual land use is not clearly known. Information found in previous studies on landcover and irrigated areas do not match, or do not correspond with information gathered from stakeholders. Production areas are the most documented for banana and oil palm plantations; for the other landcover types and crops, the production areas are not well documented in records. The irrigation methods used in each field are also often not specified or documented between surface, sprinkler or drip irrigation. Altogether, this implies that the actual water demand for irrigation cannot be determined with great accuracy.

Surface runoff and discharges

There is little information available on the upstream parts of the catchments, whether it is regarding water quantity, water quality, water demand or water use. There is also little information available about the return flow from agricultural fields and the channel network towards the Ciénaga Grande wetland. It was identified that the districts do not have a sanitary sewage infrastructure and wastewater treatment system, and (domestic) wastewater is unmonitored.

Centralized monitoring network

There are several dedicated institutions active in the basins for monitoring and evaluation, each for its own areas of interest. Also, most producers are collecting monitoring data on meteorology, water availability and water use. Most data records are private and not published. An open, centralized monitoring network would improve data sharing and transparency on water availability and use would improve the trust and engagement of all stakeholders to contribute to sustainable water management for all. The Decision Support Tool that will be developed by this consortium will contribute to the first steps in data sharing and transparency in water availability and use.

Non-concessioned and unmonitored water intakes from rivers and channels for irrigation purposes and domestic use

Not all water users are granted a water concession in the Río Frío and Río Sevilla basins, such as smallholder farmers, or the water demand of users exceeds their granted water concession. Besides, in practice local communities/domestic are not prioritized in the water allocation schemes. In the Rio Sevilla basin, there is no domestic service water supply system present. To meet their domestic water demand, water is taken from the channel system. This leads to unregulated water intakes from river and channels, either for irrigation purposes or for domestic use adding unaccounted pressure on the available water resources.

Little monitoring of reservoirs and groundwater

Water users in the Río Frío and Río Sevilla basins resort on groundwater use or privately owned reservoirs for their water supply, especially when they face water shortages and water use restrictions that can occur in periods of drought. However, there is very little monitoring over groundwater use which introduces a bias in the water balance. The number of wells, the number of users and the abstraction volumes are not known. CORPAMAG is responsible for providing groundwater concessions, therefore also abstraction volumes and the number of wells of officially registered wells, but the database is far from complete as there are many non-registered wells.

Environmental flow

There are different hydrological-based methods to determine the environmental flow. For Río Frío and Río Sevilla basins, the river dynamics approach was applied, with the main input of river flow regime. This methodology is more focused on the river dynamics and the environmental flow necessary for the river habitat.
It is essential that also the environmental flow necessary for maintaining the habitat for different aquatic species and wetland vegetation is determined.
Also clarity should be provided by the stakeholders on the official and on the applied environmental flow for the water districts, as different descriptions of the actual environmental flow are in use by different stakeholders. The environmental flow could be a fixed volume or percentage, but could also be dynamic volumes or percentages mimicking the river's intra-annual variability to meet the specific ecological function at different river trophic levels and in different periods over a year covering biotas life stages..

8.2 Recommendations on water governance

Interviews with stakeholders in the basin lead to the conclusions that there are many governance initiatives, that should be better aligned and focused. Possible actions were discussed in Chapter 7 . Some can be highlighted:

- The stakeholders in the workshop indicated that <u>a joint vision for the region</u> is needed. Currently, initiatives from many sectors are seen but a joint and long-term vision is needed to provide clarity on the way forward, make strategic decisions for all stakeholders. This relates to common goals, but also to intertwine implementation initiatives with plans of the municipalities for better integration of actions on the ground.

- <u>Policy coherence</u>: According to local stakeholders that attended the workshop session in April 2022, priorities for water allocation are by law: 1) Domestic supply, 2) Ecosystem, i.e. environmental flow, Irrigation and forestry and 3) other uses. Resulting in a mismatch in policy vs. practice. In practice, local communities are not the priority beneficiaries considering the lack of water supply network. Also the shared position of environmental flow, Irrigation and forestry on the same level of priority, provides challenges in water allocation. A more detailed policy on priorities for allocation will contribute to effective water management in the basins. The policy should have clear rules for the dry season.

- Stakeholder engagement and partnerships formation is key and requires financial support. The PCA organizes monthly round tables with stakeholders. For these activities financial support is necessary for facilitation. Therefore, the facilitation of dialogue between the stakeholders is in itself an activity that requires support for its realization, so it is required to propose financial mechanisms for its sustainable implementation.

- The climate change outlook highlights the importance of securing the water buffering function of the upstream parts of the catchment and stop man-made erosion. There is an opportunity with budget of municipality or regional government to purchase and manage land midstream and upstream in the catchments (outside PNN governance) that play a key role in ensuring a water buffer function, are of special environmental interest or play a role in conservation strategies. The acquisition of land could also be done with a trust fund where long term financing is available ensuring sustainability.

- The improved water (and fertilizer and herbicides) use efficiency in irrigation practices will contribute to reduced pressure on the available water resources in the river basins. To speed up the transition from more traditional irrigation methods to more water efficient irrigation methods, the financing mechanisms for producers should be improved. Currently the bank loan for producers is shorter (5 years) then the return of investments time (7 years for sprinkler irrigation.

- Furthermore, it is important to realize that the Río Frío and Río Sevilla basins do not stop at their discharge point into the Ciénaga Grande as there are downstream users and system depending on the fresh water flow from these river. It is therefore most important that the Ciénaga Grande and the downstream communities are represented in the dialogue, assessments and water allocation.

Most recommendation cost time and money for their realization, not only meetings/ gatherings with stakeholders. A new sustainable development framework could generate these finances.

8.3 Main lessons learned for the Magdalena region

There are several lessons learned and recommendations from this study that are applicable to the wider Magdalena region, some mentioned already in the section above. Listed below are additional highlighted recommendations:

- Looking at groundwater resources and groundwater management a regional approach is necessary. The entire aquifer extent needs to be taken into account for monitoring and sustainable water management. This extent is wider than the hydrological catchments or man-made irrigation network catchments. Groundwater resources management has to deal with balancing the exploitation (in terms of quantity, quality and surface water interactions) with the increasing pressure on resources.

- The Watershed Planning and Management Plan (POMCA) is updated only once in approximately 10 years. This means that the water permit concessions - that are based on the POMCA - are not fitting to the current context and dynamics. Some stakeholders in the basin see more frequent updates of the POMCA, and therefore the water permit concessions, as the most important step in water governance in the region. Updating the POMCA regularly with lessons learned and actual state of the basins, must be paired with concrete actions to monitor the actions and rules that were adopted in the POMCA. Without monitoring and enforcement, the POMCA will have little meaning.

- The climate change outlook highlights the importance of securing the water buffering function of the Sierra Nevada de Santa Marta mountains. By keeping the natural vegetation in an optimal condition, the landcover and topsoil will not erode and act as a water buffer to store rainfall. The water buffering functions and anti-erosion can be strengthened by 3R interventions, that ensure Recharge, Retention and Reuse of water in rivers and landscape. Also protection zones of river banks and natural vegetation, will stabilize soil, and support the water buffering function and biodiversity. The groundwater resources can be enhanced by Managed Aquifer Recharge (MAR) systems or Aquifer Storage and Recovery (ASR) systems.

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Annexes

Annex 1 – Data sources

Table 8-1. Weblinks and initiatives

Organisation	Description	Weblink
ADR	webviewer of ADR	https://adrcolombia.maps.arcgis.com/apps/webappviewer/index.html?id=b32c7e70c40b4a379d6b15848a117d31
CORPAMAG	map and GIS info download	https://www.corpamag.gov.co/informacion-ambiental/catalogo-de-mapas
DANE	National Census	https://geoportal.dane.gov.co/
EO4 Cultivar Colombia	Supporting nature based solutions - project site	https://jncc.gov.uk/our-work/eo4c-colombia-mapper/
Fundacion Natura Colombia	Several publications for download	https://natura.org.co/
Good Stuff International	GIS information	http://data.goodstuffinternational.com/santamarta/
Government of Colombia	Map downloads	https://www.colombiaenmapas.gov.co/
IDEAM	Rio Sevilla precipitation and discharge graphs and csv download	http://fews.ideam.gov.co/colombia/MapaEstacionesColombiaEstado.html
IDEAM	Water quality station locations (sediment) and discharge	http://www.ideam.gov.co/mapas3-portlet/view.jsp
IDEAM	Weather forecast	http://bart.ideam.gov.co/wrfideam/precipitacion.html
IDEAM	Weather forecast	http://www.pronosticosyalertas.gov.co/datos-abiertos-ideam
IDEAM	Data download of all stations	http://dhime.ideam.gov.co/atencionciudadano/
IDEAM	Unknown – unable to load page. Should be IDEAM raw data	http://visormapas.ideam.gov.co/datainmotion-geox/productos/generales/estaciones/automaticas/crudos/instantaneos/
INVEMAR	water quality station locations (sediment) and discharge	https://siam.invemar.org.co/redcam-geovisor/
INVEMAR	Some station data. Boca la Barra (outlet CGSM to sea)	https://experience.arcgis.com/experience/dbbec24c96054e199a25b8709dc7099a/page/P%C3%A1gina-1/?views=Escala-estaci%C3%B3n
PCA	WaterData4Action database	http://plataformadecustodiadelagua.org/
Servicio geologico Colombia	map downloads	http://srvags.sgc.gov.co/Flexviewer/Estado_Cartografia_Geologica/
SIAC, Sistema de informacion Ambiental de Colombia	Map downloads	http://www.siac.gov.co/catalogo-de-mapas

Organisation	Topic	What information	Measurement types	collection points	Database	Frequency	Unit
IDEAM	Precipitation	Rainfall	Automatic telemetric weather station	several	IDEAM database	10 minutes, hourly, daily	mm
IDEAM	Precipitation	Rainfall	Conventional/Manual	several	IDEAM database	not fixed	mm
ASORIOFRIO	Precipitation	Rainfall	Automatic station – not published	main office	Private weather station	precipitation	mm
Cenipalma	Precipitation	Rainfall	Automatic station – not published	research office	Private weather station	precipitation	mm
Several producers, privately owned stations	Precipitation	Rainfall	Not published		Private weather station	precipitation	mm
IDEAM	Discharge	River Water level	Automated water level	Intake at water districts	IDEAM database	Flow max daily, Flow avg daily, Flow min daily. Also monthly and annual data.	Cm or m water level, and interpreted flow
INVEMAR	Discharge	Flow	Manual	Outlet into Cienage Grande	pdf publications	once a month	m3/s
CORPAMAG	Discharge	River Water Level	(bi)weekly measurements during field visits		Not published, maybe not stored digitally.	unknown	Cm or m water level, and interpreted flow
ASORIOFRIO	Discharge	River water level	manual. Portable flow meter	Upstream of main intake.		Once per 2 weeks	cm or m3/s
ASOSEVILLA	Discharge	River water levels	manual			daily	cm or m3/s
ASORIOFRIO	Discharge	Channel water levels	automatic	Main channel		daily	cm or m3/s

ASOSEVILLA	Discharge	Channel water levels	manual			daily	cm or m3/s
Producers	Water use	water supplied to producers	Private water meters or pump statistics	Not published		Continuously (water meter) or with likely monthly intervals.	m3/s or hours of active pump & pump capacity
Several producers and farmers associations	Wells on private land	Groundwater level (wells)	Groundwater level and water quality	Not published		unknown	Meter below surface level.
INVEMAR	Water quality	Water quality	Sediment & water quality parameters at Rio Sevilla outlet into the Cienaga Grande	Only pdf publications			
IDEAM	Water quality	Water quality	Variables: Temperatura, Oxígeno Disuelto, pH, Conductividad Eléctrica, Demanda Química de Oxígeno, Sólidos Suspendidos Totales, Nitrógeno Total, Fosforo Total, Sulfato, Carbono Orgánico Total, Turbidez, Pesticidas (organoclorados y organofosforados), Nitrato, Nitrógeno Amoniacal, Metales Biodisponible Sedimento, Mercurio Total(en sedimentos)	Near main intake of Water districts	pdf publications	between 2 or 3 times a year.	Depending on variable

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