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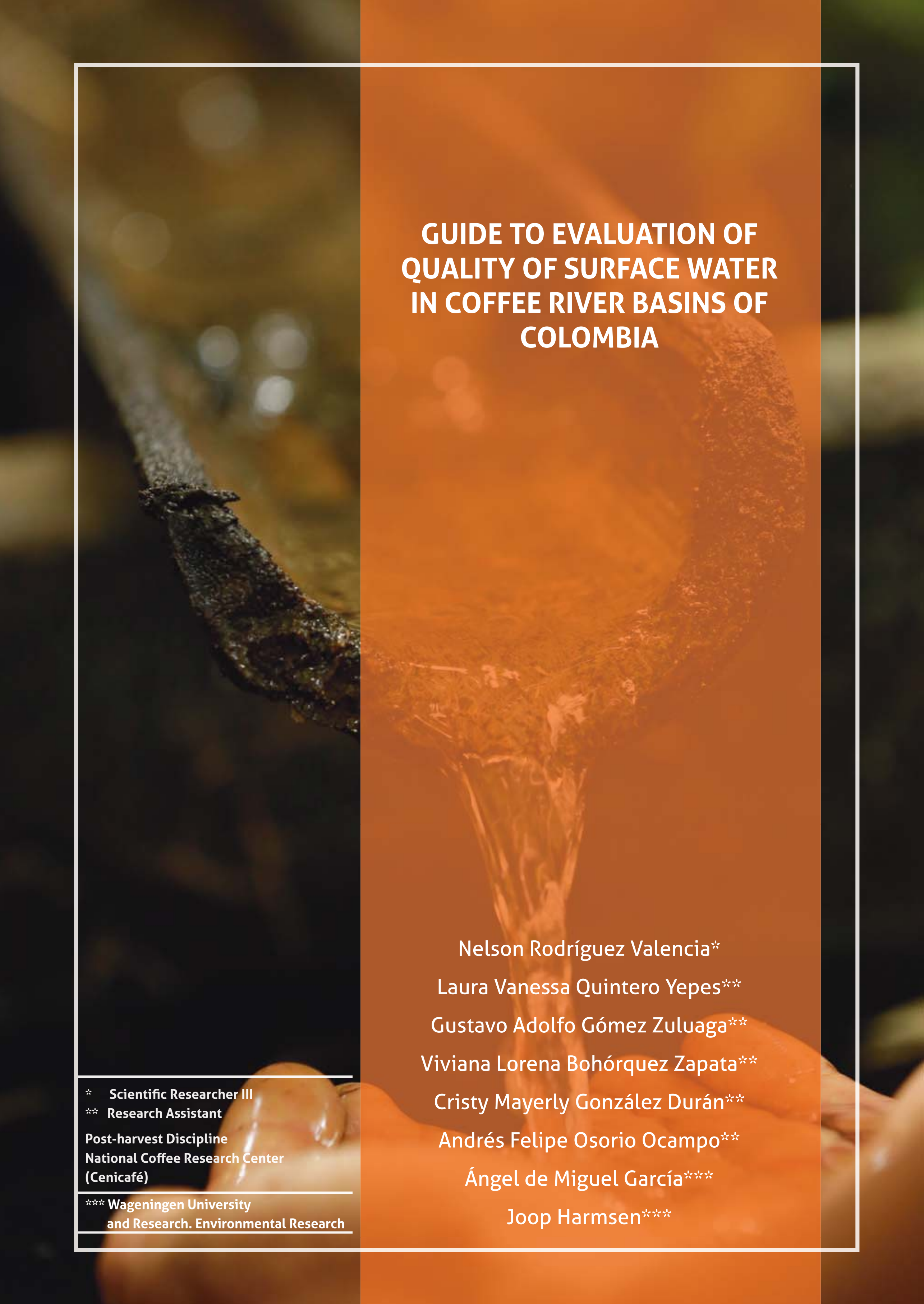
WATER QUALITY IN COFFEE RIVER BASINS



GUIDE TO EVALUATION OF QUALITY OF SURFACE WATER IN COFFEE RIVER BASINS OF COLOMBIA

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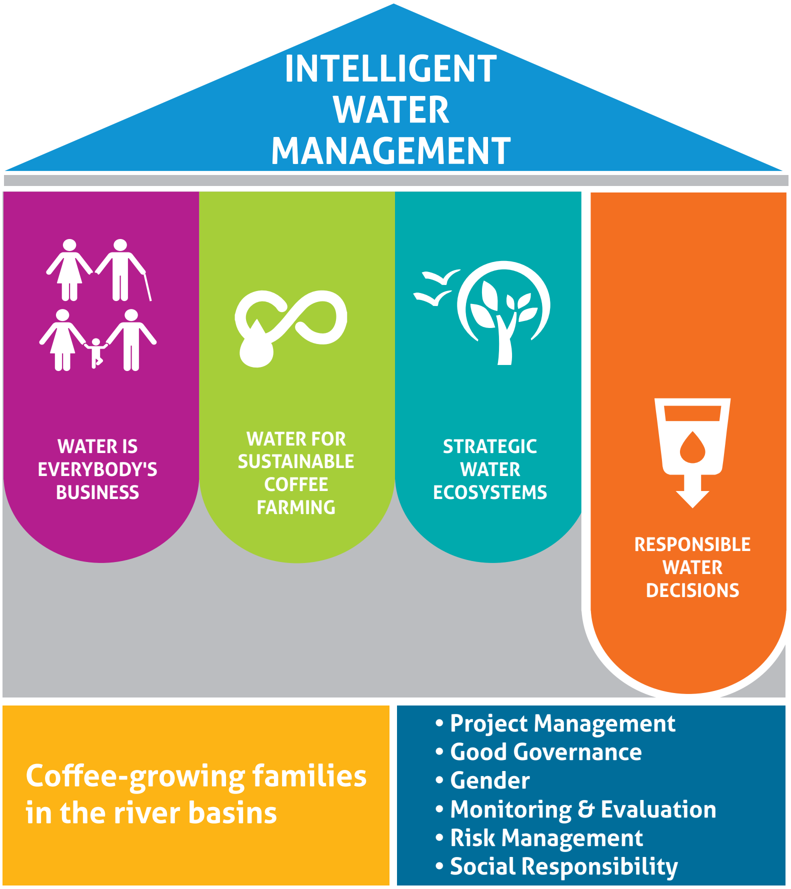

Intelligent Water Management (IWM)-Manos al Agua is a Public-Private Partnership that developed a model to implement and improve systems for intersectoral cooperation, sustainable coffee farming, environmental protection and decision-making that help face water imbalance challenges in the coffee sector and its value chain, creating environmental, social and production conditions for: alleviating poverty, improving rural welfare, contributing to peace, and achieving sustainable development in the Colombian countryside.

Manos al Agua

GUIDE TO EVALUATION OF QUALITY OF SURFACE WATER IN COFFEE RIVER BASINS OF COLOMBIA

RESPONSIBLE WATER DECISIONS

IWM is a 5-year project implemented in the departments of Antioquia, Caldas, Cauca, Nariño and Valle del Cauca, focused on integrated water resources management in 25 river basins, involving over 11,630 coffee-growing families, in an intervention area of 148,754 hectares.

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SUMMARY

Knowing surface water quality is of vital importance when taking measures to guarantee its good state in the long term. Therefore, it is essential to monitor the coffee river basins using techniques that provide information on their water quantity and quality, and to determine quality indices that provide information about the physicochemical, biological and microbiological quality of water and habitat in the river basins.

Water quality monitoring is an essential component of the Intelligent Water Management Project (IWM) within component 4, "Responsible Water Decisions." This component has a double objective: i) to establish a proven methodology for long-term control of quality of water bodies in the coffee regions; ii) To establish a Program for monitoring water quality in the 25 river basins targeted by the IWM Project, with the following objectives:

- To generate reference information on water quality in the water bodies of the 25 IWM river basins.
- To assess impact of coffee wastewater discharges on quality of local water resources.
- To evaluate positive effects on water quality of the measures implemented in the IWM Project.

The methodology developed was based on the criteria established by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM), adapted to the coffee landscape particularities. At each sampling point, 34 variables were analyzed, including physicochemical parameters, presence and abundance of macroinvertebrates in three substrates (leaf litter, sediment, and rock), and habitat characteristics. For analysis and interpretation of results, the different variables were grouped into three quality indices (physicochemical index, NSF WQI; biological index, BMWP/Col, and habitat quality index, SVAP) and an overall quality index (KPI21).

The water quality monitoring program was divided into two types of differentiated sampling, in such a way as to provide a general view on quality of water bodies and discriminate possible impacts derived from other human activities developed in the coffee river basins.

- General monitoring involved: Sampling points in the main river, a Point 1 (P1) located upstream from the Project implementation area, and a Point 2 (P2), located downstream from the Project implementation area. This sampling was implemented in the 25 river basins of the Project. In total, four campaigns were conducted in each of the intervened river basins, coinciding with different coffee production moments (without harvest; mid-harvest or "mitaca", and main harvest).
- Dynamic monitoring consisted of a total of eight to ten points located along the river basin, both in the main water body and in the tributaries. In total, there were three to five campaigns in five river basins selected (one per department). In addition, there was continuous monitoring at farm level for determining water quality evolution in the receiving body as a consequence of direct discharges from coffee wet processing.

From results of the Water Quality Monitoring Program, it's noteworthy that:

Quality of the water body before going through the coffee zone does not necessarily correspond to an unaltered point in the upper part of the river basin: in many cases, there is important anthropogenic pressure. In this sense, variables such as COD show an average concentration of 30 mg/L, and in most of the river basins, fecal pollution was found.

In the case of nutrients, the values both of nitrates and phosphates are relatively low, which may limit biological treatment capacity via the water body's self-purification of coffee pollutants.

It was proven that coffee production has an effect on quality of water bodies in coffee river basins; its impact is directly related to coffee washing wastewater and other byproducts at farm level. This effect is reduced by the high self-purification capacity.

The water quality monitoring program helped confirm that the IWM Project implementations had a positive effect on quality of water bodies. This effect can be clearly observed in the positive evolution over time of most of the evaluated variables and indices when comparing quality of water bodies at all the points located downstream (P2) from the coffee zones: in the river basins intervened, the KPI21 index rose from 16% before the project to 40% at the end. Another clear improvement sign was obtained by comparing water quality between the points located upstream and downstream (P1-P2 stretch). In this case, quality between P1 and P2 was improved throughout the project for most of the river basins, with an average pollution reduction of 86% between P1 and P2 for the KPI21 index.

Better surface water quality was achieved in 23 of the 25 IWM river basins (92%) by comparing initial conditions (before implementation of the IWM Project in the river basins) and average conditions evaluated at the end of the fourth monitoring campaign and at the end of the last one (seventh campaign).

The river basins that didn't show a positive response when comparing average conditions of the seventh monitoring campaign with initial conditions were the Barragán river basin (Caicedonia, Valle del Cauca) and the Quilcacé river basin (Sotará, Cauca). However, in these two river basins, by comparing average conditions of fourth campaign vs. initial conditions and average values of seventh campaign vs. initial conditions, the Barragán river basin went from a 211% quality decline (fourth campaign) to a 74% decline (seventh campaign), thus improving 186.09% (between the fourth and seventh campaign). And the Quilcacé river basin went from a 525% water quality decline (fourth campaign) to a 62% decline (seventh campaign), thus improving 741% (between the fourth and seventh campaign). In both river basins, benefits of the IWM Project implementations on surface water quality in the river basins were evident.

Thanks to dynamic monitoring, with higher frequency and density of sampling points, it was possible to determine that discharges from urban areas, livestock and industrial activities, and coffee households have an important impact on water quality, being very difficult to discriminate the effects of each.

This monitoring has confirmed that pollution peaks during coffee wet processing are attenuated in the bodies of water that receive discharges from coffee farms with on-site IWM Project implementations.

Based on the results obtained, it can be inferred that the water quality monitoring methodology applied in the IWM Project has proven to be effective in assessing coffee production impacts on water bodies. This methodology can be extrapolated to any other coffee river basin; monitoring activities during several consecutive days at the different points of the river basin and more frequently are also recommended.

From the water quality monitoring results, it can be said that the IWM Project strategy of focusing the interventions on farms located up to 200 m from the body of water has had a positive impact on the whole river basin. This strategy, in addition to guaranteeing coffee farmers' adoption of implementations, can be used as a prioritization tool by other institutions.

> ***"Total volume of water saved and unpolluted thanks to the IWM Project actions was estimated at 98 million cubic meters a year; this volume included: total volume of water saved as a result of implementation of water-saving technologies, uncontaminated water as a result of wastewater treatment systems (WTS), and effluent management until achieving acceptable-quality wastewater."***

> ***"Total volume of improved water of "excellent" quality, according to the overall quality index and average flow rates from initial to final monitoring campaigns, was estimated at 116.5 million cubic meters per year. Total volume of improved water of "good" quality available to nature, as a result of the IWM Project actions, was estimated at 167 million cubic meters per year."***

Quality of surface water in coffee river basins of Colombia

PURPOSE OF THE GUIDE

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PURPOSE OF THE GUIDE

Water quality, defined as the set of chemical, physical, biological and radiological characteristics of water (Nancy, 2009), is usually conditioned to requirements of one or more biotic species or any human need or purpose. So, to define water quality it is necessary to indicate its potential uses (Johnson *et al.*, 1997). In that sense, the standards commonly used for referring to water quality are related to health of ecosystems or use and consumption by human beings.

Knowing the quality of water bodies is of vital importance when implementing measures that guarantee its good state in the long term. Therefore, it is essential to monitor coffee river basins, using techniques that provide information on water quantity and quality in the river basins, and to determine quality indices that provide information about physicochemical, biological and microbiological quality of water and habitat in the river basins.

This Guide is divided into two distinct parts. The main objective of the first part is to present a methodology for projects monitoring surface waters to determine the state of water bodies in coffee regions, and the second part describes in greater depth the Monitoring Project performed within the IWM Project, with its main results. This Monitoring Project has in turn three specific objectives:

- To provide reference information on quality of bodies of water in the 25 river basins of the IWM Project.
- To evaluate potential impact of coffee wastewater discharges on quality of local water resources.
- To evaluate the possible positive effects of measures taken in the IWM Project on water quality.

For that purpose, a Monitoring Project has been designed to provide, on the one hand, a general view on water quality in the 25 river basins under the Project; and on the other hand, specific information to discriminate possible impacts of other human activities in the coffee river basins. In this way, the Project has been divided into two monitoring types:

1. Monitoring at river basin level

The objective is to determine the effects of coffee production on the main water bodies of 25 river basins. To do this, two sampling points were located in the main river: a point before (P1) and another after (P2) the coffee zone. This sampling method was implemented in the 25 river basins of the Project. In total, there were four campaigns over two years, which coincided with different coffee harvest moments (without harvest, mid-harvest or "mitaca," and harvest peak). The first campaign can be considered the baseline, as there was no project implementation yet. It is important to highlight that all the IWM Project actions were focused on the zone located between the P1 and P2 defined by the Monitoring Project.

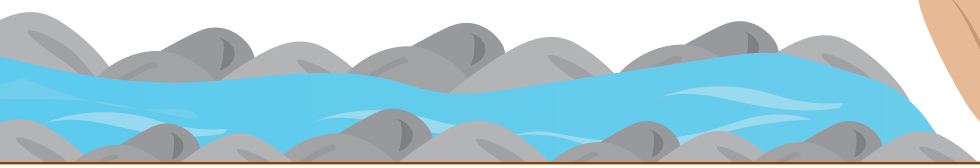
> ***At each sampling point, over 10 physicochemical variables, presence and abundance of macroinvertebrates in three substrates (leaf litter, sediment, and rock), and habitat characteristics were analyzed. For analysis and interpretation of results, the different variables were grouped into three quality indices (NSF WQI, BMWP/Col, and SVAP) and an overall quality index (KPI21).***

2. Dynamic monitoring

In order to prevent possible interferences of other anthropogenic activities in interpretation of results, more intensive monitoring took place as to number and frequency of sampling points. Dynamic monitoring had a total of eight to ten points along the river basin, both in the main river and in tributaries, trying to discriminate effects of coffee production effluents from other urban or industrial ones.

In total, there were three to five campaigns over two years. Due to high costs of going to the river basins and analysis of results, as well as difficult access to many of the selected points, this dynamic monitoring was only implemented in five river basins: La Chaparrala, in the municipality of Andes (Antioquia); La Frisolera, in the Salamina municipality (Caldas); El Marquez, in the municipality of Rosas, and La Esmita, in the municipality of La Sierra (Cauca); San Marcos, in the municipality of Sevilla (Valle del Cauca); and El Molino, in the San Lorenzo municipality (Nariño).

This dynamics also allowed real-time monitoring of different coffee farms to determine water quality evolution in the receiving body, as a result of direct coffee wastewater discharges, and to determine possible degradation capacity of soils in case of receiving discharges.



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Quality of surface water in coffee river basins of Colombia

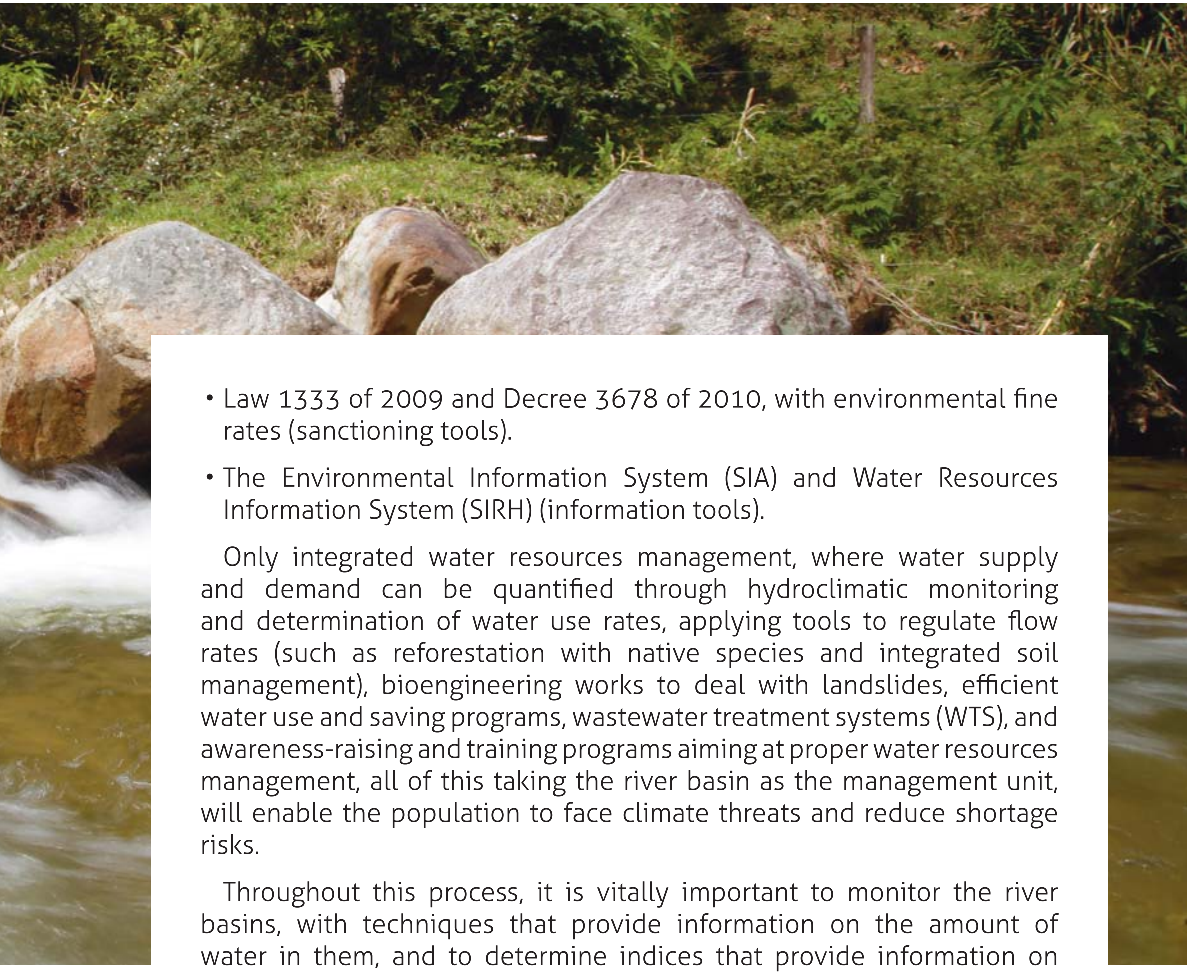
INTRODUCTION

Extreme weather events are occurring in different regions of the world as a result of climate variability, with temperatures that have caused freezing of bodies of water such as Niagara Falls in the United States, and melting of glaciers, such as the Santa Isabel snow-capped mountain and the Nevado del Ruiz volcano, in Colombia. They have also caused droughts, such as those in the Orinoco region and the Colombian Caribbean, and floods, like those in the Bogotá savannah and the Caribbean and Pacific regions. It is in water where climate change effects are most reflected, with changes in the space-time distribution of rainfall, affecting water supply.

In Colombia, around 6 million cubic meters of wastewater are generated, which in most cases are not treated and are disposed of into surface, underground, or marine water bodies or onto the soil, causing great deterioration of natural resources and affecting water supply and quality.

Enactment of the National Policy for Integrated Water Resources Management in Colombia updated planning, management, control, economic, sanctioning and information tools with the aim of recovering and conserving different water sources, including:

- Decree 1640 of 2012, addressing river basin management plans (planning tool).
- Decree 3930 of 2010, with provisions on uses of water resources, their management, and discharges to water, soil and sewers (management and control tool).
- Resolution 631 of 2015, with parameters and maximum permissible values for wastewaters before being discharged to surface water bodies (management and control tool).
- Decree 2667 of 2012, addressing payment of retribution taxes for pollution still present in wastewater (economic tool).



- Law 1333 of 2009 and Decree 3678 of 2010, with environmental fine rates (sanctioning tools).
- The Environmental Information System (SIA) and Water Resources Information System (SIRH) (information tools).

Only integrated water resources management, where water supply and demand can be quantified through hydroclimatic monitoring and determination of water use rates, applying tools to regulate flow rates (such as reforestation with native species and integrated soil management), bioengineering works to deal with landslides, efficient water use and saving programs, wastewater treatment systems (WTS), and awareness-raising and training programs aiming at proper water resources management, all of this taking the river basin as the management unit, will enable the population to face climate threats and reduce shortage risks.

Throughout this process, it is vitally important to monitor the river basins, with techniques that provide information on the amount of water in them, and to determine indices that provide information on physicochemical, biological and microbiological water quality and habitat quality in the river basins.

This Guide addresses water problems at global, national and regional levels and describes the main tools for determining quantity and quality of surface water in coffee river basins.

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Quality of surface water in coffee river basins of Colombia

OVERVIEW

Water problems

Water is an essential element for life; a large number of microorganisms, animals and plants live and reproduce in water. In addition, it is one of the most abundant natural resources on the planet and is fundamental to the welfare of communities.

Despite the amount of water on our planet, a large part is in the seas and is salty, and another part is frozen; that's why we only have a small amount available for our daily activities (Figure 1).

> ***Per each 10,000 L of water in nature, only 1 L is available as fresh water for our use.***

"It is important that we use water properly and in the necessary amounts, avoiding waste."

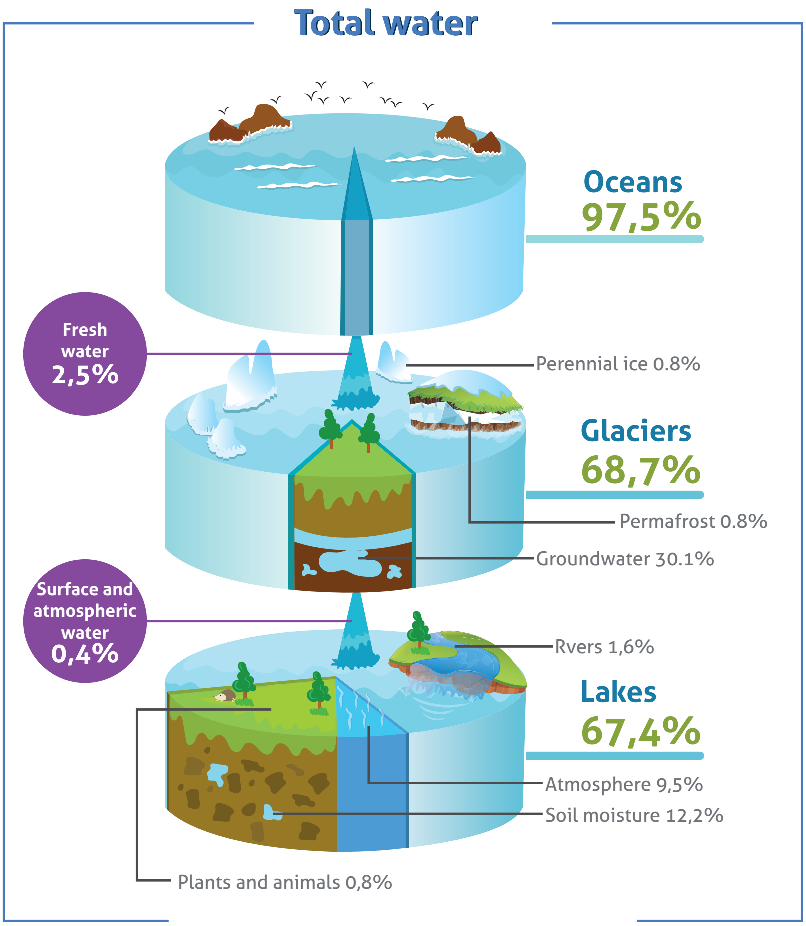


Figure 1. Distribution of water in the world. Source: Data from Shiklomanov and Rodda (2003). United Nations World Water Development Report 2 (2006).

World water balance

Every year, 577,000 km³ of water evaporate (502,800 km³ from seas and 74,200 km³ from mainland) and the same amount returns as precipitation (458,000 km³ to seas and 119,000 km³ to mainland), that is, the continental part receives more water (as precipitation) than it loses (as evapotranspiration), always resulting in a positive balance. The main disadvantage is spatial-temporal distribution of rainfall, since water evaporating from a region in a given period of time does not always return to the same region in equal or greater quantity in the same period (Figure 2).

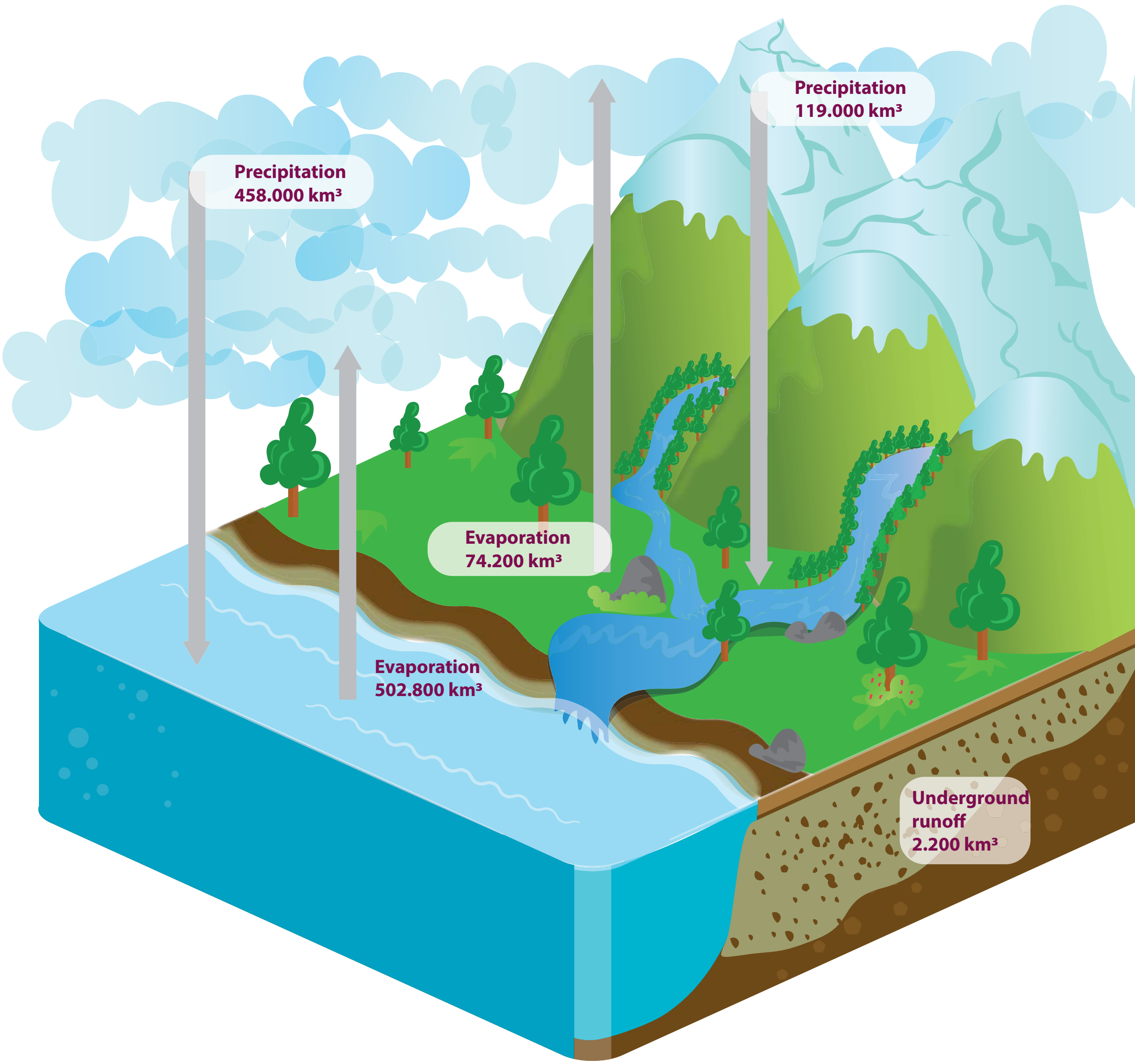


Figure 2. World water balance. Source: Shiklomanov (1998). United Nations World Water Development Report 1 (2003).

Water distribution in Colombia

Colombia is a country rich in water resources, with a surface water supply of 2,084 km^3/year, an underground water supply estimated at 140,879 km^3/year, and a maritime area of 919,376 km^2 (44% of the territory); dynamic groundwater resources reach 10.54 km^3/year. Data shows that 36% of dynamic resources are in the Atrato and San Juan river basins, followed by the Cauca river basin with 25%, and the Cundiboyacense high plateau with 10.5%; so 75% of the country's dynamic groundwater resources are in these three areas (Figure 3). The total area in glaciers is 48.23 km^2.

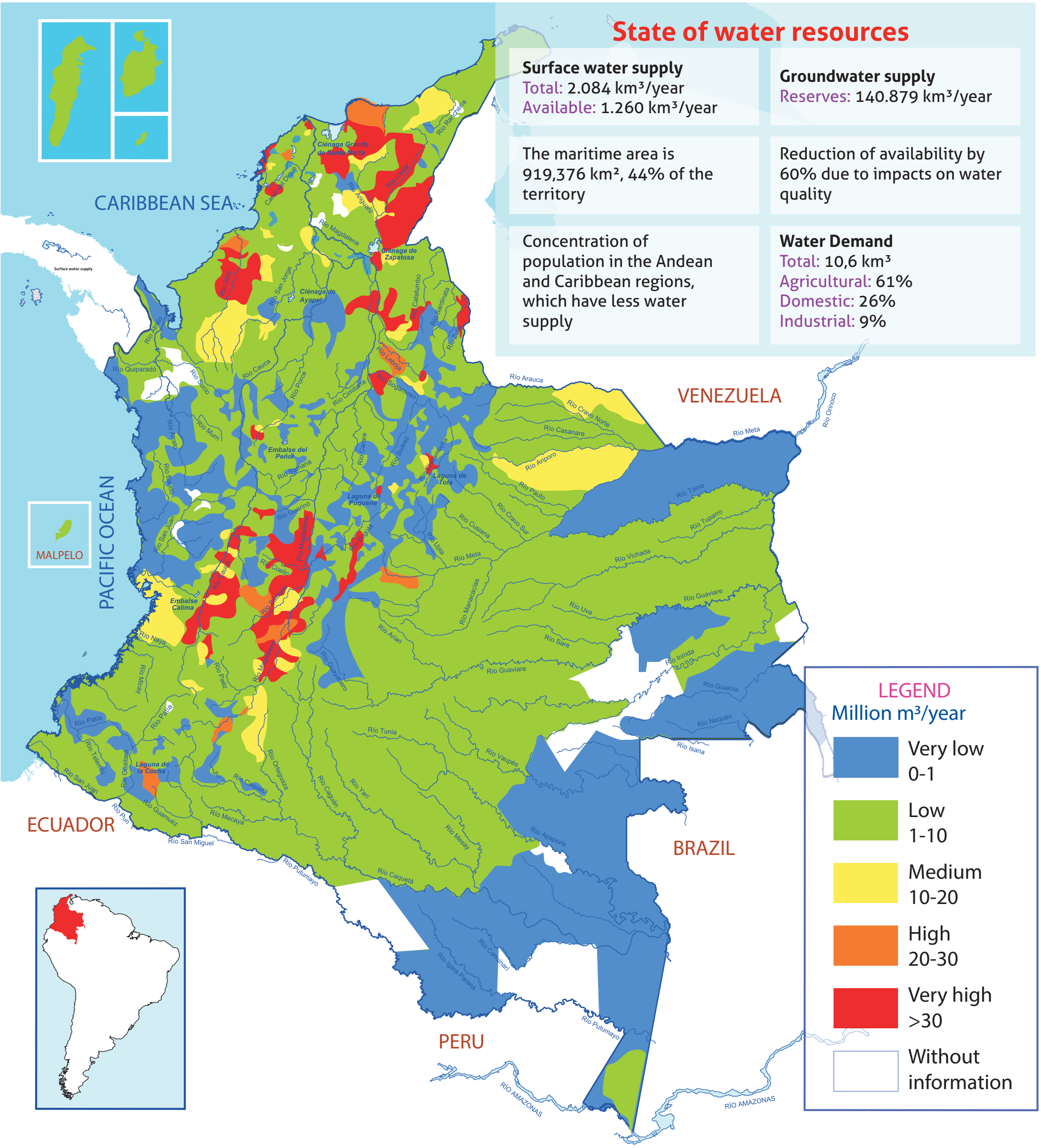


Figure 3. Distribution of water in Colombia. Source: National Policy for IWRM, 2010.

Water balance in Colombia

According to IDEAM (2015), in the four-year period 2010-2014 there was a rainfall decrease in Colombia of 136 mm/year compared to 2006-2010, around 93 km^3 of runoff that did not feed surface water sources (Figure 4). This quantity of unavailable surface water would be enough to meet the needs of the Colombian population for 34 years.

The effect of climate change is most reflected in water. The latest national statistics report less rainwater in the last four years. It is important that at home, on our farms and in our workplaces we implement efficient water use and saving programs to reduce vulnerability to shortage.

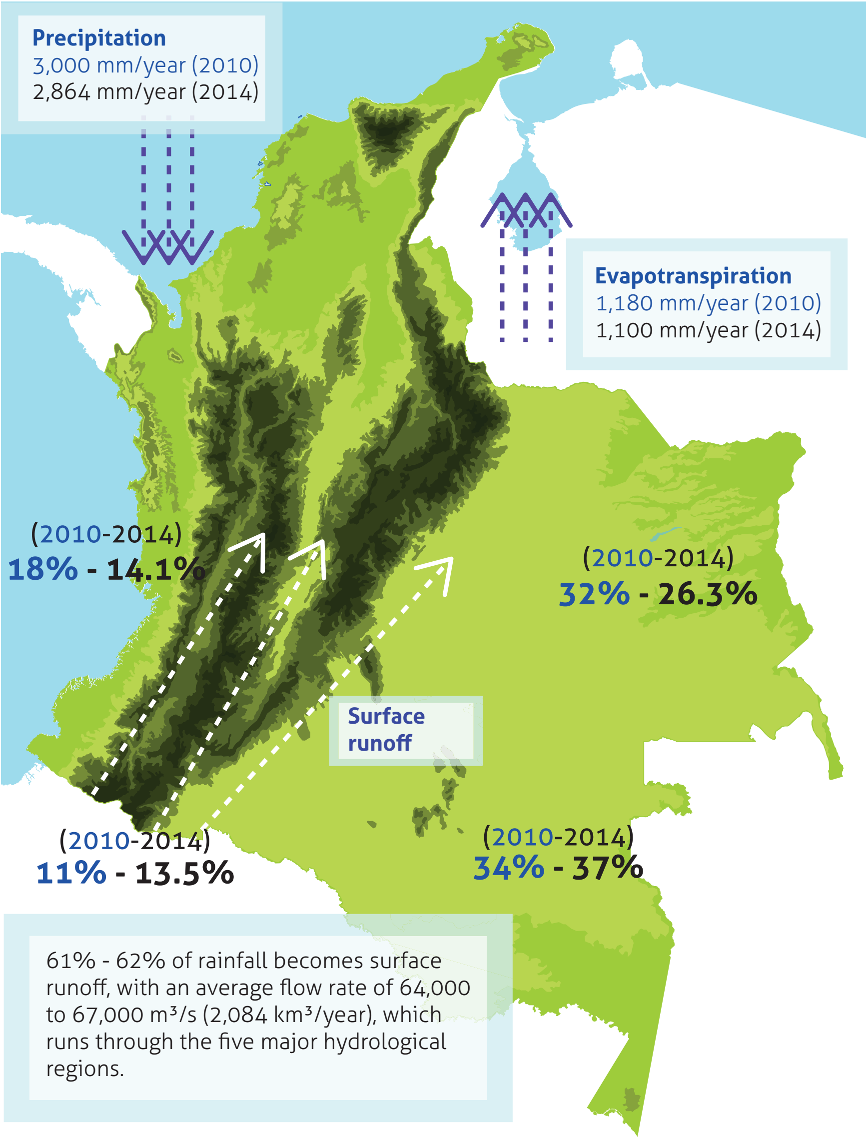


Figure 4. Water balance in Colombia. Source: National Policy for IWRM, 2010; IDEAM, 2015.

Importance of water in coffee farming

Water is fundamental in coffee production. It is estimated that to produce 1 ton of Colombian green coffee around 12,000 m3 of water is required. Our coffee farming is rainfed, i.e. the water needed for coffee production comes directly from the rain.

Faced with a decrease in rainwater supply, it would be necessary to resort to crop irrigation to maintain production, which in the central coffee region is unlikely, being a geographical area with low supply of natural watercourses (between 11% and 13.5% of the total national surface run-off) and having the highest national demand (67%).

The coffee territory has a rich water network supplied by paramo and forest ecosystems, with a great number of supplying river basins. However, water supply and distribution systems are deficient. Currently there is a water deficit for agronomic use in the Magdalena and Cauca basins.

Water balance in coffee plantations

In studies conducted at Cenicafé for different crop arrangements it was estimated that on average 44% of total rainfall reaches the ground, 56% being intercepted by foliage of crops (Figure 5).

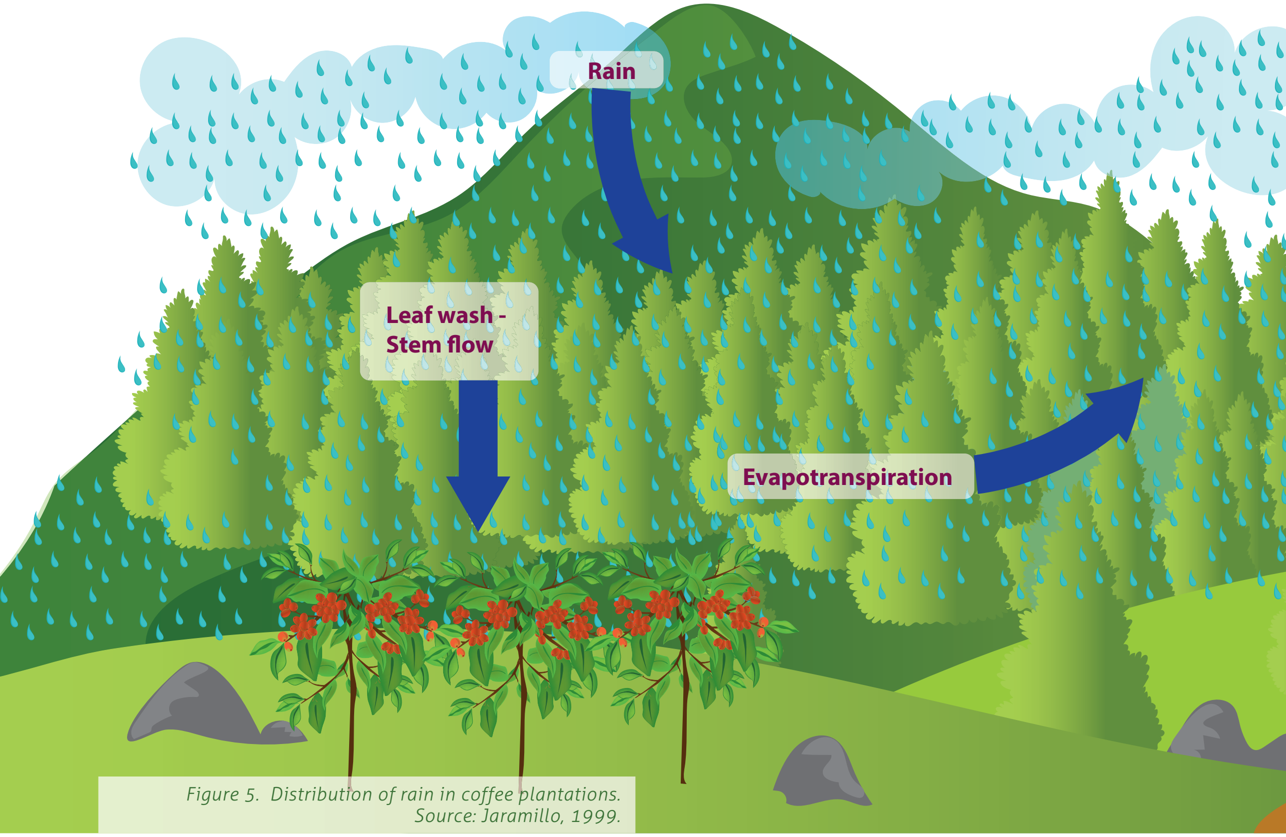
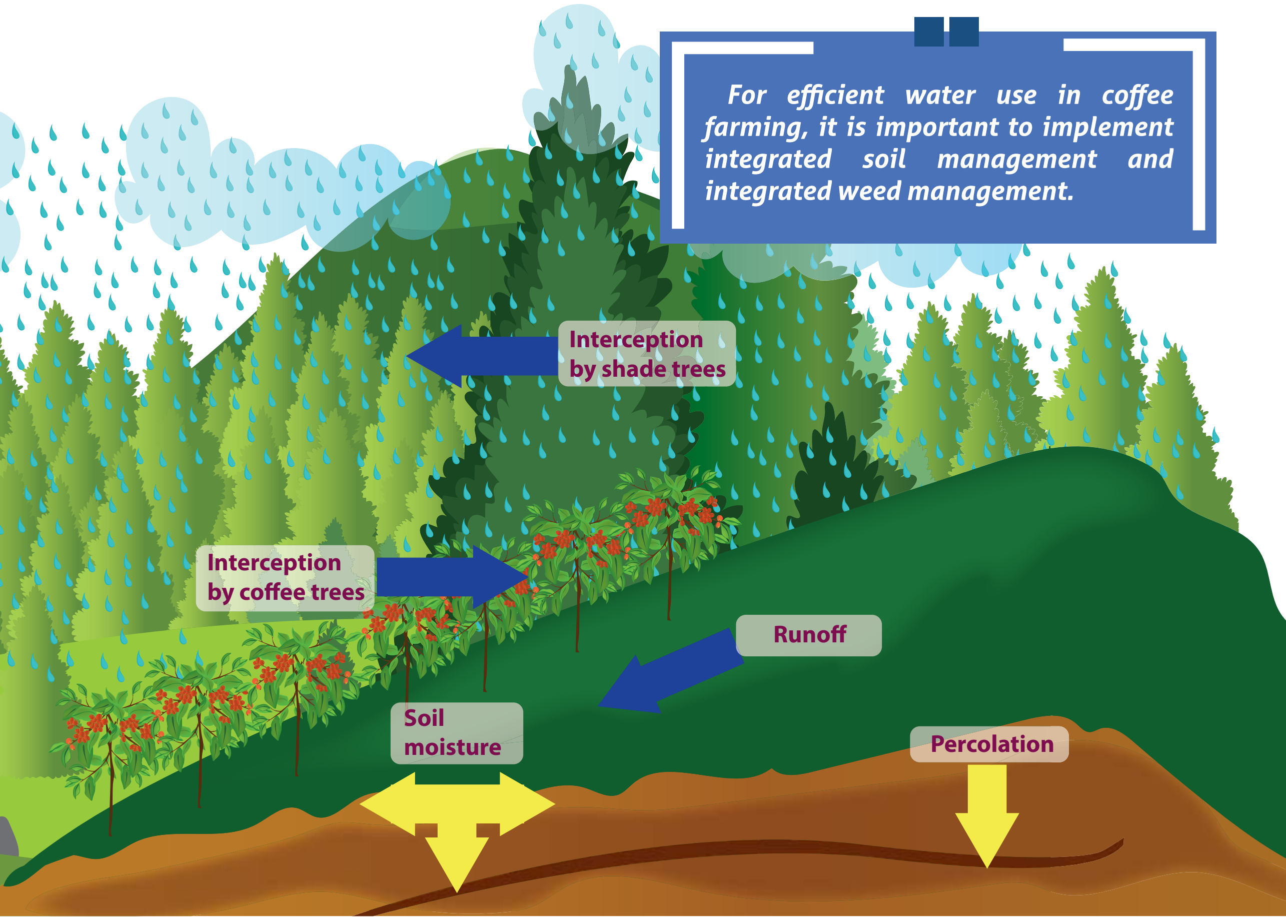


Figure 5. Distribution of rain in coffee plantations.
Source: Jaramillo, 1999.

Soil cover	Rainfall = 100%		
	Evapotranspiration	Runoff	Percolation
Live (creeping indigo)	37	2	61
Dead (guamo leaves)	11	3	86
Without cover	20	10	70

Cover	Interception	Effective rain	Percolation	Runoff
Sun-grown coffee	46	54	48	6
Coffee + guamo	58	42	38	4
Coffee + walnut	61	39	31	8
Coffee + pine	56	44	37	7
Coffee + eu-calyptus	57	43	35	8
Average	56	44	38	6
Standard deviation	6	6	6	2

For efficient water use in coffee farming, it is important to implement integrated soil management and integrated weed management.



Water management indices and indicators

There are different indices and indicators used to assess quality and quantity of water in the river basins, including:

Water quantity indicators

The most commonly used are the Falkenmark and water footprint indicators.

Water availability indicator - Falkenmark indicator

The water availability indicator (Malin Falkenmark) is an indicator of per capita water availability, which enables the identification of those countries with acute water crises in the global context (Falkenmark, 1999).

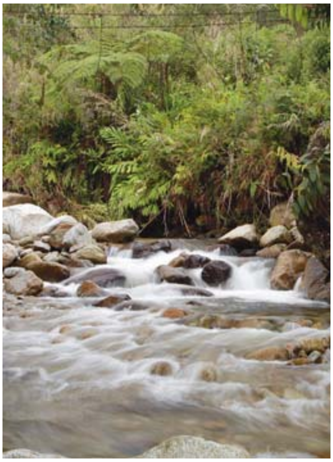


Table 1. Falkenmark indicator (Source: Garrido, 2007).

Annual renewable fresh water (m^3/capita/year)	Water stress level
>5,000	No stress
5,000-1,700	Occasional or localized water stress in an area
1.000-1,700	Moderate water stress
500-1,000	Chronic water scarcity (lack of water for economic and human development of a country)
<500	Absolute water scarcity

The indicator states that, if in a region, the *per capita* availability is less than 500 m^3/year, the region shows absolute water scarcity. If availability is greater than 5000 m^3/year, the region has no stress on its water resources. This indicator is important to manage economic activity based on water demand.

For Colombia, the indicator ranges from 34,000 m^3/year (average year conditions) to 26,700 m^3/year (dry year conditions).

Per capita water availability in Colombia in the last 15 years has decreased 40%, with 60% of this reduction due to pollution impacts on quality of resource (Figure 6).

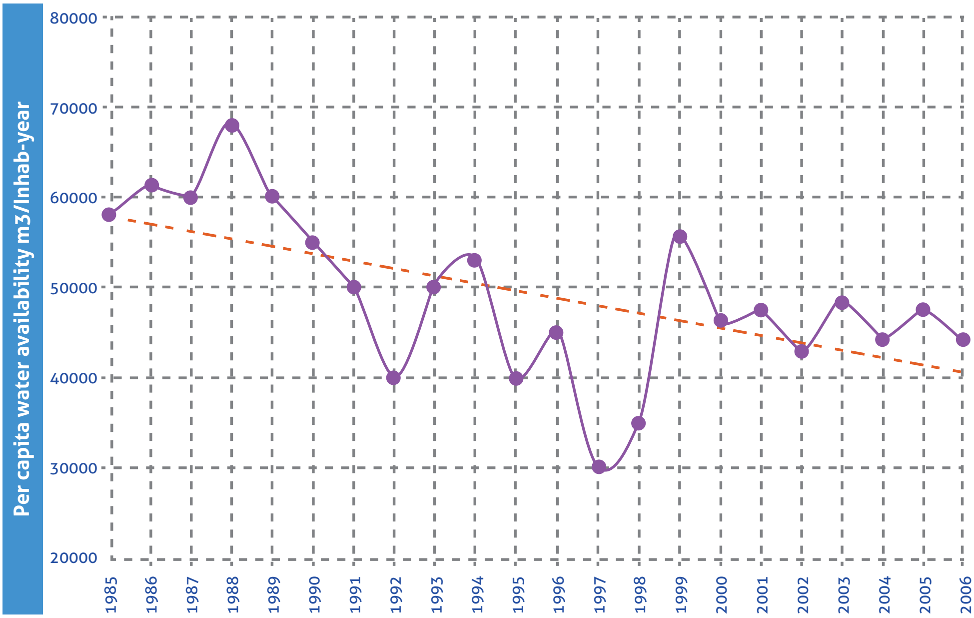


Figure 6. Annual dynamics of per capita water availability in Colombia. Source: Environmental Information System of Colombia (SIAC), 2012.

Virtual water and water footprint

The virtual water and water footprint concepts are relatively new in the scientific language; their meaning has been linked to trade and, especially, to agricultural products, where many already see virtual water trade as an escape route for water stress in countries with water shortages or those wanting to allocate their resources to other more profitable activities (Collado and Saavedra, 2010).

The **virtual water** concept was originally created by Professor John Anthony Allan (Allan, 1993, 1994), of the King's College London and the School of Oriental and African Studies, when studying countries with water deficits. Its innovative nature became evident only a decade later, understanding that **virtual water could represent a more accurate measure of water flows between countries because it took into account all the water that, although not really present, could be added virtually to import and export products, especially agricultural products, and be made "visible" in them based on appropriate estimates** (Parada, 2012).

According to Hoekstra and Chapagain (2006), virtual water is classified according to its origin. Blue virtual water comes from surface and underground water resources and can be destined for irrigation and many other uses; green virtual water is found in soil, coming from the rain and being naturally used by plants, while gray virtual water is wastewater from production processes.

When consumption patterns are related to their effects on water resources, we are talking about "**water footprint,**" a concept introduced in 2002 by Arjen Hoekstra, an expert at the Institute for Water Education of the UNESCOIHE. The concept **arose for calculating the accumulated fresh water volume necessary to produce the goods and services consumed by a certain person, company or country in a year** (Tables 2 and 3). The water footprint is a tool for showing consumers the impact of their consumption patterns on the environment, especially on water resources (Parada, 2012).

Table 2 Water footprint of primary crop categories.

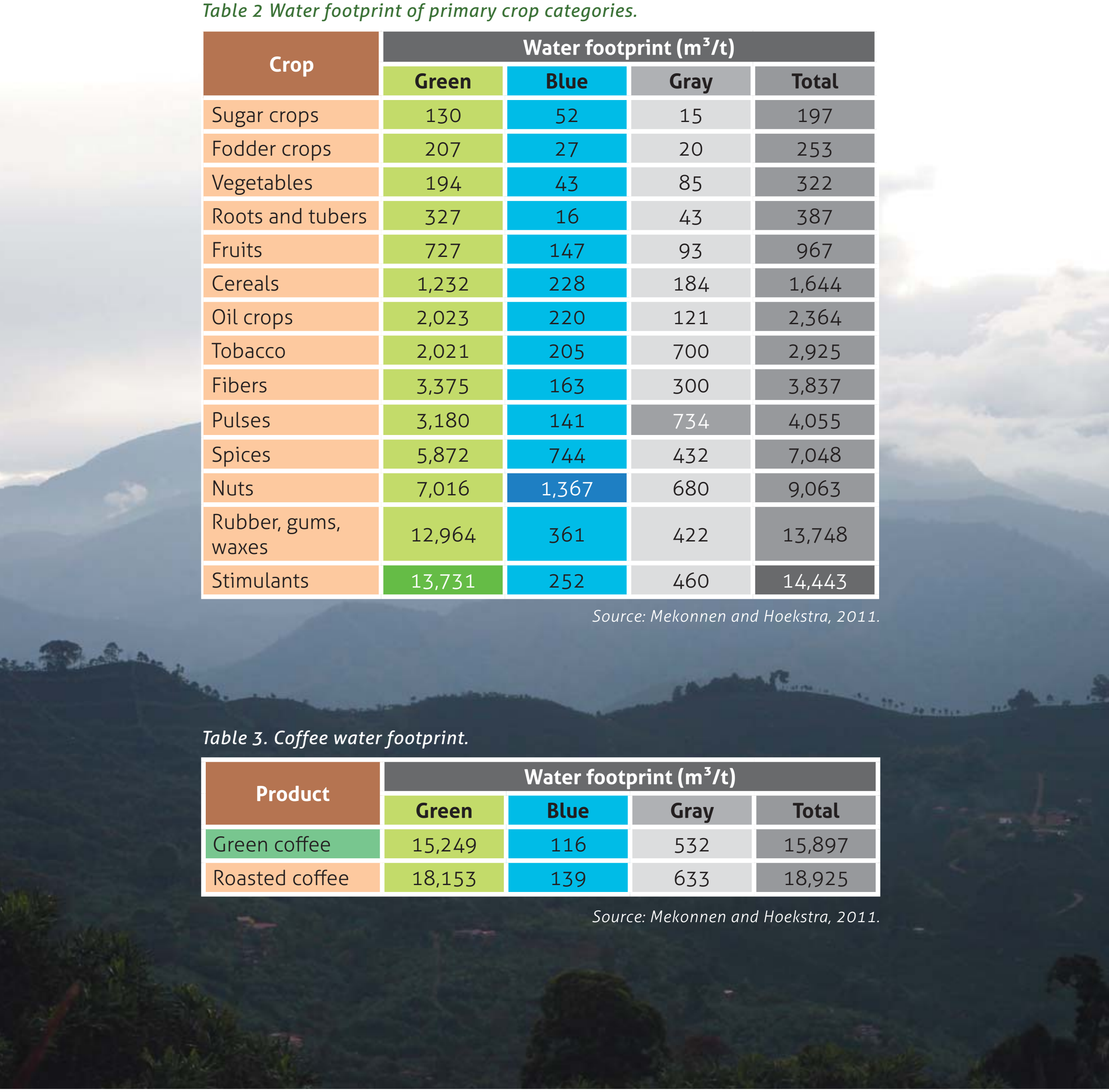
Crop	Water footprint (m^3/t)			
	Green	Blue	Gray	Total
Sugar crops	130	52	15	197
Fodder crops	207	27	20	253
Vegetables	194	43	85	322
Roots and tubers	327	16	43	387
Fruits	727	147	93	967
Cereals	1,232	228	184	1,644
Oil crops	2,023	220	121	2,364
Tobacco	2,021	205	700	2,925
Fibers	3,375	163	300	3,837
Pulses	3,180	141	734	4,055
Spices	5,872	744	432	7,048
Nuts	7,016	1,367	680	9,063
Rubber, gums, waxes	12,964	361	422	13,748
Stimulants	13,731	252	460	14,443

Source: Mekonnen and Hoekstra, 2011.

Table 3. Coffee water footprint.

Product	Water footprint (m^3/t)			
	Green	Blue	Gray	Total
Green coffee	15,249	116	532	15,897
Roasted coffee	18,153	139	633	18,925

Source: Mekonnen and Hoekstra, 2011.



Water Use Index (IUA)

The Water Use Index (IUA, the original acronym in Spanish) is the quantity of water used by different sectors in a determined period of time (annual, monthly) and space analysis unit (area, zone, sub-zone, among others) in relation to surface water supply available for the same time and space units (Figure 7).

IUA Range* (Dh/Oh) x100	IUA Category	Meaning
>50	Very high	Pressure of demand is very high with respect to available supply
20.01 - 50	High	Pressure of demand is high with respect to available supply
10.01 - 20	Moderate	Pressure of demand is moderate with respect to available supply
1 - 10	Low	Pressure of demand is low with respect to available supply
≤ 1	Very low	Pressure of demand is not significant with respect to available supply

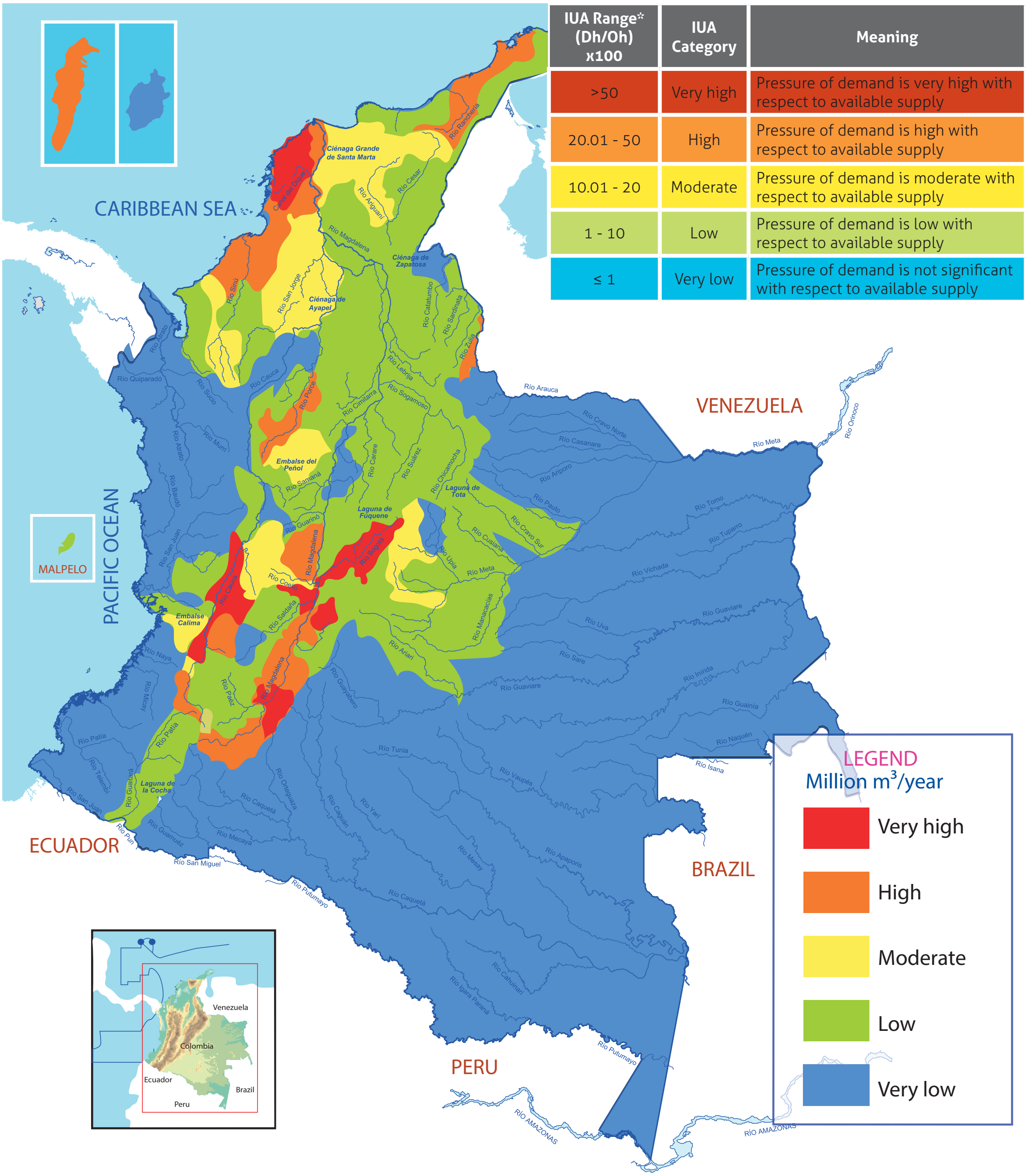


Figure 7. Index of water use in Colombia. (Source: IDEAM, 2015).

Water Use Index calculation

The index is calculated through Equation (1):

(1)

$$IUA = (Dh/Oh)*100$$

Where: ***Dh:*** *Sectoral water demand*
Oh: *Surface water supply*

Surface water supply (Equation (2)) is obtained by subtracting environmental flow rate from total water supply, the former defined as water volume per time unit required in terms of quality, quantity, duration and seasonality to ensure sustainability of water ecosystems and development of socio-economic activities (current and potential) of users downstream from a given water source (MADS, 2010).

(2)

$$Oh = Oh_{Total} - O_{Qamb}$$

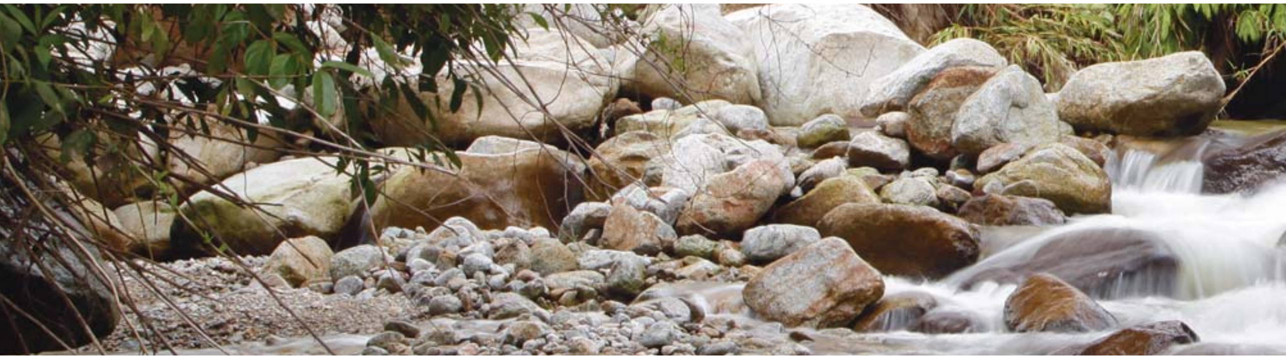
Where: Oh_{total}: *Total water supply*
O_{Qamb}: *Environmental flow rate*

Water demand is determined by Equation (3)
Dh=∑*(Volume of water abstracted for sectoral uses in a given period)* ***Dh = Ch +***

(3)

$$Csp + Csm + Css + Cea + Ce + Ca + Aenc$$

Where: *Dh: Water demand*
Ch: Human or domestic consumption
Csp: Consumption by livestock sector
Csm: Consumption by manufacturing sector
Css: Consumption by services sector
Cea: Consumption by agricultural sector
Ce: Consumption by energy sector
Ca: Consumption by agricultural species sector
Aenc: Abstracted water not consumed



Water quality indicators

Water quality depends on hydrological, physicochemical and biological characteristics of the water body under study, and is determined by monitoring physicochemical parameters and bioindicators in the field and conducting bio tests in the laboratory.

Water quality indicators determine general physicochemical conditions of quality of a body of water and, to some extent, enable recognition of pollution problems at a given point for a specific time period. In addition, they show general water conditions and possibilities or limitations for certain uses depending on physical, chemical and biological variables to be weighted and aggregated.

Physicochemical water quality indices (WQI)

These indices are intended to summarize the information provided by the large number of parameters involved in water quality diagnosis. Indices enable quality comparisons in different places and times and facilitate assessment of wastewater and self-purification processes.

There are several models worldwide, the most used being:

NSF Water Quality Index: It is one of the most known and used, developed in 1970 by the US National Sanitation Foundation. It has been used in 12 of the 50 states of the United States. It is a multiparameter index that uses nine parameters (Biochemical oxygen demand (BOD5), total solids (TS), temperature, oxygen saturation percentage, fecal coliforms, content of nitrates and phosphates, pH, and turbidity). This index is used in the IWM Project for building the Overall Quality Index KPI21.

For determination of the quality index, the values of these variables are transformed to obtain numerical values known as quality values (using mathematical models), which are multiplied by a weighing value (according to importance of the parameter evaluated); the resulting water quality value ranges between 0 and 100 (Tables 4 and 5). For example, poor quality water has a water quality index below 25, and if value is greater than 90, it is of excellent quality. For water to be used for human consumption its value must be greater than 90; above 70, it can be used for recreation and aquaculture.

Table 4. Weighting of physicochemical and microbiological quality index - NSF WQI.

Variable	Units	Factor
Dissolved oxygen	Saturation percentage	0.17
Fecal coliforms	Colony/100 mL	0.16
pH	Units	0.11
BOD_5	ppm	0.11
Temperature change	°C	0.10
Phosphates	ppm	0.10
Nitrates	ppm	0.10
Turbidity	(Nephelometric Turbidity Units) NTU	0.08
Total solids	ppm	0.07

Table 5. NSF WQI ranking.

Quality rating	Range
Blue - Excellent	91 - 100
Green - Good	71 - 90
Yellow - Medium	51 - 70
Orange - Bad	26 - 50
Red - Very bad	0 - 25

Source: Adapted from Fernández et al., 2005.

Oregon Water Quality Index (OWQI): It uses nine parameters (temperature, dissolved oxygen, BOD5, pH, total solids, ammoniacal nitrogen, nitrates, total phosphorus, and fecal coliforms).

Idaho Water Quality Index (WQI): It uses five parameters (dissolved oxygen, turbidity, total phosphorus, fecal coliforms, and electrical conductivity).

Universal Water Quality Index (UWQI) based on European Community Standard: It uses 12 parameters (dissolved oxygen, BOD5, pH, total phosphorus, nitrates, total coliforms, fluoride, cyanide, mercury, cadmium, selenium and arsenic).

The Netherlands Water Quality Index (AMOEBA): It uses physicochemical parameters (temperature, BOD5, COD, dissolved oxygen, pH, total phosphorus, orthophosphates, nitrates, nitrites, ammonium, total nitrogen, electrical conductivity, turbidity, organochlorine pesticides, organophosphorus pesticides, heavy metals, oils, phenols) and biological parameters (chlorophyll, thermotolerant bacteria, and benthic macrofauna).

In Colombia, the indices have been addressed by Ramírez *et al.* (1997) and have been called pollution indices (ICO, the acronym in Spanish). The most used are:

- ICOMI (for mineralization; it integrates conductivity, hardness, and alkalinity); ICOMO (for organic matter; it integrates biological oxygen demand, total coliforms, and oxygen saturation percentage); ICOSUS (for suspended solids); ICOTRO (for trophic, with phosphorus base); ICOTEMP (for temperature), and ICOpH (for pH).

Biological water quality indices

Over physicochemical indices, their advantage is that their responses are not instantaneous; they are efficient to subtle perturbations, their methodology is simple and inexpensive, and have taxonomic accuracy.

BMWP Index. The Biological Monitoring Working Party (BMWP), modified from Roldán by Álvarez (2005), is a simple and quick method to evaluate water quality using macroinvertebrates as bioindicators. This index is based on presence or absence of organisms, identified up to family level. This index is used in the IWM Project to build the overall quality index KPI21.

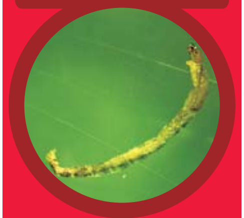
Macroinvertebrates are organisms responsible for removal of leaf litter and other organic pollutants that enter water, enabling the resource to continue enjoying "good health." They are also predators and control proliferation of organisms such as zooplankton or phytoplankton, which can cause great damage to water quality when they proliferate in excess.

Among aquatic macroinvertebrates, there are species very tolerant to water pollution and other highly susceptible or intolerant. With this method, the organisms found in water are given a score from 1 to 10; the higher or lower score of an organism depends on its higher or lower sensitivity to organic pollution; and with the sum of scores and the help of a reference table, water quality can be determined in different zones of the river basin.

Below are images of some species that inhabit bodies of water, their taxonomic classification, ecological aspects, and the BMWP value. In addition, it is specified if they are indicators of pollution or of clean water to determine potential uses of the water body where they are.

Species living in water bodies

Miniature midge
Their presence is indicator of strongly contaminated water



Order: Diptera
Family: Chironomidae
Ecological aspects: They live in rivers, streams and lakes, stuck to rocks, logs, and in the sand. They are also found around decaying organic matter.

BMWP Value: 2

Dobsonfly
Their presence is indicator of moderately polluted water

Order: Megaloptera
Family: Corydalidae
Ecological aspects: They live in running waters, under logs, rocks and submerged vegetation; they are predators. They usually eat small animals and larvae.

BMWP Value: 7

Caddisfly
Their presence is indicator of slightly polluted water

Order: Trichoptera
Family: Hydropsychidae
Ecological aspects:
They build shelters to live therein; they are on water surface, fast-running water, and rocks.

BMWP Value: 7

Bladder snail
Their presence is indicator of very polluted water

Order: Basommatophora
Family: Physidae
Ecological aspects:
They live preferably in polluted waters, also in vegetation in the water; herbivores.

BMWP Value: 3

Dragonfly
Their presence is an indicator of clean water

Order: Odonata
Family: Gomphidae
Ecological aspects:
They are found in still, shallow waters of sand and rock beds; they feed on little animals and fish.

BMWP value: 9

Beetle
Their presence is indicator of slightly contaminated water

Order: Coleoptera
Family: Elmidae
Ecological aspects:
They live in rivers and streams, on logs and decaying leaves, gravel, rock, sand and aquatic vegetation. They feed on plants and animal and vegetable remains.
BMWP value: 7

Water-penny beetle larva (Psephenidae)
Their presence is indicator of clean water

Order: Coleoptera
Family: Psephenidae
Ecological aspects:
They live under rocks, in rivers and streams, and feed on algae.

BMWP value: 10

Freshwater crab
Their presence is indicator of slightly contaminated water

Order: Decapoda
Family: Pseudothelphusidae
Ecological aspects:
They live on the banks of water bodies, they are scavengers, carnivores, herbivores, and when it rains, they seek refuge on the ground.
BMWP value: 8

Flatworm
Their presence is an indicator of moderately polluted waters

Order: Tricladida
Family: Dugesiidae
Ecological aspects: They inhabit shallow waters, of permanent and stagnant current, under rocks, logs, branches, leaves; some species may resist some degree of pollution.

BMWP value: 6

Mayfly
Their presence is indicator of slightly contaminated waters

Order: Ephemeroptera
Family: Baetidae
Ecological aspects: They live on rocky substrates, although in lower number in moss, but always in fast current. They are scrapers and tolerate some degree of pollution.

Value BMWP 7

Stonefly
Their presence is indicator of clean waters

Order: Plecoptera
Family: Perlidae
Ecological aspects: They are predators living in cold, clean and fast-flowing rivers and streams; they are sensitive to habitat and water quality changes.

BMWP value: 10

Mosquito larva
Their presence is an indicator of very polluted waters

Order: Diptera
Family: Tipulidae
Ecological aspects: They live in still or rapid waters, in decomposing organic matter, in algae growing on rocks, mud, puddles, and marshes.

BMWP value: 3

Long-horned caddisfly
Their presence is indicator of slightly contaminated waters

Order: Trichoptera
Family: Leptoceridae
Ecological aspects: They build shelters. They live in clean waters, rocks with high current, and backwaters with vegetation. They eat animal and vegetable remains.

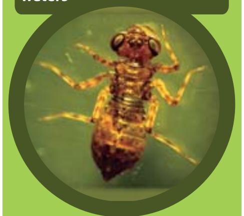
BMWP value: 8

Common fly
Their presence is indicator of very polluted waters

Order: Diptera
Family: Muscidae
Ecological aspects: Most are scavengers; they inhabit the banks of bodies of water, where there is decaying material. They are predators.

BMWP value: 4

Dragonfly (Libellulidae)
Their presence is indicator of moderately contaminated waters



Order: Odonata
Family: Libellulidae
Ecological aspects:
They inhabit puddles and backwaters of rivers and streams, attached to logs, branches and rocks; some species prefer sandy soils. They are predators.

BMWP value: 5

Tables 6 and 7 show classification of water quality and biotic index values according to scores of the macroinvertebrates found.

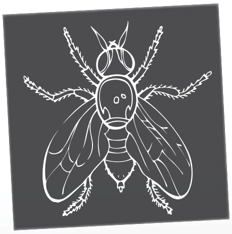
Table 6. BMWP score according to the families of macroinvertebrates present in the river basins of the IWM study.

Families	Score
Anomalopsychidae, Atriplectididae, Blephariceridae, Ptilodactylidae, Chordodidae, Gripopterygidae, Lampyridae, Odontoceridae, Perlidae, Polymitarcyidae, Polythoridae, Psephenidae	10
Coryphoridae, Ephemeridae, Euthyplociidae, Gomphidae, Hydrobiosidae, Leptophlebiidae, Limnephilidae, Oligoneuriidae, Philopotamidae, Platystictidae, Polycentropodidae, Xiphocentronidae	9
Atyidae, Calamoceratidae, Hebridae, Helicopsychidae, Hydraenidae, Hydroptilidae, Leptoceridae, Limnephilidae, Lymnaeidae, Naucoridae, Palaemonidae, Planorbidae (when Biomphalaria dominates), Pseudothelphusidae, Saldidae, Sialidae, Sphaeriidae	8
Ancylidae, Baetidae, Calopterygidae, Coenagrionidae, Collembola, Dicteriadidae, Dixidae, Glossosomatidae, Hyalellidae, Hydrobiidae, Hydropsychidae, Leptohyphidae, Lestidae, Pyralidae.	7
Aeshnidae, Ampullariidae, Caenidae, Corydalidae, Dryopidae, Dugesiidae, Elmidae, Hydrochidae, Hyriidae, Limnichidae, Lutrochidae, Megapodagrionidae, Mycetopodidae, Pleidae, Staphylinidae, Simuliidae	6
Ceratopogonidae,Corixidae, Gelastocoridae, Glossiphoniidae, Gyrinidae, Libellulidae, Mesoveliidae, Nepidae, Notonectidae, Tabanidae, Thiaridae	5
Belostomatidae, Chrysomelidae, Curculionidae, Ephydridae, Haliplidae, Hydridae, Muscidae Scirtidae, Empididae, Dolichopodidae, Hydrometridae, Noteridae, Sciomyzidae	4
Chaoboridae, Cyclobdellidae, Hydrophilidae (larvas), Physidae, Stratiomyidae, Tipulidae	3
Culicidae (cuando la familia no es dominante, si domina es 1), Culicidae, Psychodidae, Syrphidae	2
Tubificidae (Haplotaxida)	1

Table 7. Classification of water and ecological meaning according to BMWP index.

Class	Quality	BMWP value	Meaning	Color
1	Good	>150 123-149	Very clean waters Unpolluted waters	Blue
2	Acceptable	71-122	Slightly polluted waters	Green
3	Doubtful	46-70	Moderately polluted waters	Yellow
4	Critical	21-45	Very polluted waters	Orange
5	Very critical	<20	Heavily polluted waters	Red

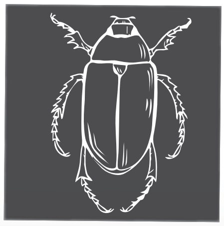
Example of water quality bioindicator insects



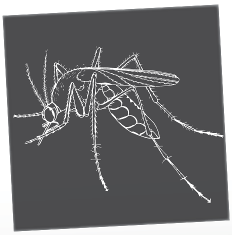
Fly

The order **Diptera** is one of the most numerous and diversified in the whole world, occupying in their different development states an immense variety of ecological niches (Lopretto & Tell, 1995). This group of insects, which are supremely complex, abundant and widely distributed throughout the world, have a very varied habitat, and can be found in rivers, streams, and lakes at all depths, in the bracts of many plants, and in holes of decaying logs. There are representatives of very clean waters, such as the Simuliidae family, or of contaminated ones, such as Tipulidae and Chironomidae (Roldán, 1996).

The **Coleoptera** order is one of the main groups of freshwater arthropods, including the largest order of insects as to diversity, with around 300,000 species, about 5,000 of these being aquatic; they also occupy a wide spectrum of aquatic and semi-aquatic habitats (Merritt & Cummins, 1996).



Beetle



Flies of the lakes

The **Chironomidae** family is found in natural and artificial environments, pools, ponds and plant receptacles; larvae of many species feature great habitat selectivity (ecological indicators), others are herbivores, detritivores, but some may be predators. Usually they inhabit hot or cold waters, though some are semi-aquatic; their distribution is cosmopolitan (Bedoya and Roldán, 1984). This family is found in three regions (lands of tropical mountains, high Andean mountains, and tropical-temperate transition areas). In the Cauca-Magdalena basin, they are found up to 3,533 masl and in adjacent sub-basins. The use of these organisms as indicators derives from the fact that their formation and development occur in historical periods that go from weeks to months, thus reflecting an accumulated effect, and with precise analysis, they provide excellent information on bodies of water.

EPT index

It is calculated using three groups of macroinvertebrates: Ephemeroptera (E), Plecoptera (P) and Trichoptera (T), water quality indicators as they are more sensitive to pollution.

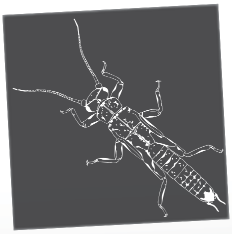
The analysis consists of taking abundance of the three orders to be evaluated and dividing it by total abundance of taxa in general, the quotient being multiplied by 100 to obtain the result, which is compared with preset values to obtain the water quality category, according to Equation 4 (Carrera and Fierro 2001; Leiva, 2004).

$$EPT = \frac{EPT\ Total\ X\ 100}{total\ abundance} \quad (4)$$

EPT water quality categories	
75-100%	Very good
50-74%	Good
25-49%	Regular
0-24%	Bad

The **Ephemeroptera** order usually has high abundance values in its natural history, and from the altitudinal point of view it is found from sea level until about 3,500 masl (Roldán, 1988). In addition, this group occupies most of available meso-habitats, being abundant and diverse, and accounting for 27% of orders reported. These organisms are good water quality indicators.

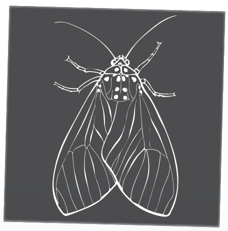
Mayfly



Stoneflies

The **Plecoptera** order, also known as stoneflies, is a relatively small group of insects. It is a cosmopolitan taxon that usually lives in fast, turbulent, cold and highly oxygenated waters, a profile consistent with the physicochemical quality results obtained from water quality monitoring in the coffee river basins, where these rivers mostly have high oxygen values (Roldán, 1996; Fernández & Domínguez, 2001).

The **Trichoptera** order is one of the most important aquatic orders of the Insect class, and its species are key bioecological components for their abundance, diversity, distribution, and role in trophic chains of Colombian and Neotropical freshwater ecosystems (Muñoz-Quesada, 2000). This group of insects is characterized by building houses or shelters during their larval state. Shelters attached to substrate serve as protection and movement in search of oxygen and food. Most of them live in running, clean and oxygenated waters, under rocks, logs and plant material; some species live in quiet waters or backwaters of rivers and streams. In general they are indicators of oligotrophic (low nutrient content) waters (Roldán, 1992).



Long-horned caddisflies

Habitat assessment index (SVAP)

A river or stream shows special ecological conditions, which can be visually assessed to verify their current state. The results of these characteristics assessed as a whole indicate the habitat health or quality.

The habitat assessment index or Stream Visual Assessment Protocol (SVAP) provides a significant diagnosis to know riparian habitat status and water quality, in addition to monitoring these variables in the long term when implementing management actions aimed at improving these conditions. This index is used in the IWM Project to build the overall water quality index KPI21.

This protocol uses a scoring system that assesses 15 variables, detailed in Table 8, "Criteria for visual habitat assessment with the SVAP index."

Table 8. Criteria for visual habitat assessment with the SVAP index.

Variables	Values: 10	7	5	3	1
1 Water appearance	Very clear	Somewhat cloudy	Moderately cloudy	Turbid	Very turbid or muddy all the time
2 Sediments (remove the bottom in rapids)	Water remains clear	2 seconds for water to clear	5 seconds for water to clear	8 seconds for water to clear	Water does not clear
3 Riparian zone (width and quality). Assess one side, then the other, add and divide by 2	Primary forest on the whole side	Patches of some kind of trees	Strips of few trees	Plantations on the sides	Paddocks on the sides
4 Canopy cover. Assess one side, then the other, add and divide by 2	100% of canopy cover over the channel	75% of canopy cover over the channel	Strips of few trees	25% of canopy cover over the channel	No canopy cover over the channel
5 Pools	Deep and shallow pools abundant, 1 m deep on average	Few pools (3-4), less variety in depth	N/A	Presence of shallow pools (2-4)	Pools absent, the old ones are full of sediments
6 Channel condition	Natural channel, no degradation or sedimentation	Shows past alteration, but it is recovering	N/A	Altered channel	Channel completely altered
7 Hydrologic alteration (flooding)	Flooding occurs one or several times a year	Flooding every 1 to 2 years	N/A	It occurs every 3 to 5 years	No flooding

Variables	Values				
	10	7	5	3	1
8 Instream fish cover	+ 7 cover types available	6 to 7 cover types available	4 or 5 cover types available	2 or 3 cover types available	One or no type of cover available
9 Macro invertebrate habitat	At least 5 types of habitat available	3 to 4 types of habitat	N/A	1 to 2 types of habitat	One or no type of habitat
10 Bank stability. Assess one side, then the other, add and divide by 2	Stable. Protected by tree roots	Moderately stable. Banks erode in bends	N/A	Unstable. Some roots exposed and trees falling	Unstable. Many trees falling
11 Barriers to fish movement (throughout the river or stream)	No barriers	Man-made barriers	N/A	Culverts or bridges	Dams or water diversions
12 Fishing pressure	Nobody fishing there	Fishing infrequent, no use of nets	N/A	Fishing with hook or cast net, rarely with poison	Indiscriminate fishing with poison and trammel
13 Solid waste presence	No evidence of solid waste	Presence of solid waste	Presence of solid waste (one or 2 types)	Presence of solid waste (+2 types)	Abundance of waste of all kinds
14 Manure presence	No evidence near the river	Livestock on banks without access to river	N/A	Manure or livestock in the river	A lot of manure or blackwater discharge pipes
15 Organic nutrient enrichment	No filamentous algae	Moderate algal growth	N/A	Abundance of filamentous algae, greenish water	Excess of algae; pea green, gray or brown water

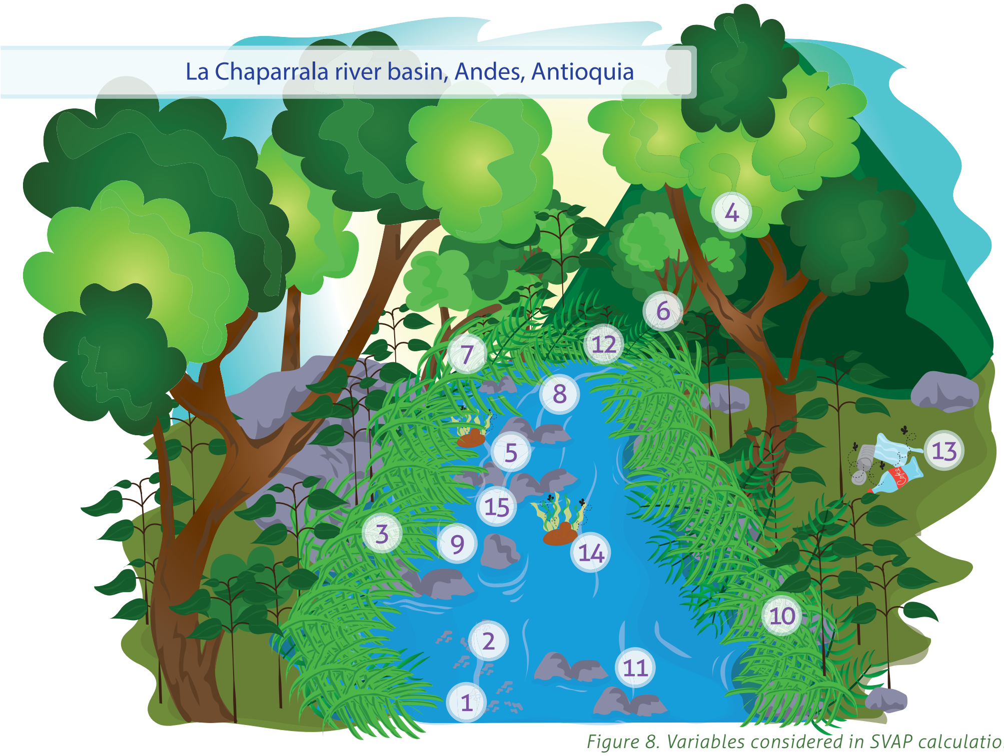


Figure 8. Variables considered in SVAP calculation.

Upon recording visual assessments at each sampling point, their respective indices are calculated according to the formula **Total score/number of criteria assessed**. Finally, for each river basin, the average value of the two sampling points is determined, according to which the final index value is given a quality rating. The assessment categories considered by the SVAP index are shown below:

Table 9. SVAP habitat assessment index.

Criteria for determining water quality with the SVAP index CRITERION/VARIABLE	
1 Water appearance	9 Aquatic macroinvertebrate habitat
2 Sediments	10 Bank stability
3 Riparian zone	11 Barriers to fish movement
4 Canopy cover	12 Fishing pressure
5 Pools	13 Solid waste presence
6 Channel condition	14 Manure presence
7 Hydrologic alteration (flooding)	15 Organic nutrient enrichment (filamentous algae presence)
8 Instream fish cover	
Total score/# of criteria assessed	

SVAP Value	Quality
9,0-10	Excellent
7,0-8,9	Good
5,0-6,9	Regular
3,0-4,9	Bad
1,0-2,9	Very bad

A high score of the SVAP index indicates better water quality or good "health" of the stream.

Source: SVAP version 2 USDA (2012).

Overall Water Quality Index (KPI21)

Although there are many water quality indices, this Guide has focused on three that are widely used: physicochemical index, NSF-WQI; biological index, BMWP/Col; and hydro-morphological index, SVAP. In addition, with the objective of grouping the three indices into a single performance index, the use of the "Overall Water Quality Index" KPI21 is proposed, which was created expressly in the IWM Project and integrates equally the above-mentioned indices.

To obtain the Overall Water Quality Index on a 0-to-1 scale, the following procedure is used for calculation:

- The value obtained for the physicochemical quality index is divided by 100 and multiplied by 1/3 (weighting factor).
- The value obtained for the biological quality index is divided by 123 and multiplied by 1/3 (weighting factor).
- The value obtained for the habitat quality index is divided by 10 and multiplied by 1/3 (weighting factor).
- Finally, the resulting weighted values of the three indices are added.

Equation 5 shows calculation of the Overall Water Quality Index.

$$WQI_{Overall} = \left(\frac{NSF}{100} * 0{,}333\right) + \left(\frac{BMWP/Col}{123} * 0{,}333\right) + \left(\frac{SVAP}{10} * 0{,}333\right) \quad (5)$$

From the values obtained, the Overall Water Quality Index categories are shown in Table 10.

Table 10. Overall Water Quality Index categories.

OVERALL WQI	RATING
0.90-1.0	Excellent
0.70-0.89	Good
0.50-0.69	Medium
0.30-0.49	Bad
0-0.29	Very bad

Water Quality Risk Index (IRCA)

IRCA, the original acronym in Spanish, refers to the risk index of quality of water for human consumption, a basic tool to ensure drinking water quality. It is defined in Resolution 2115 of 2007, issued by the former Ministry of the Environment, Housing and Territorial Development (MAVDT).

For calculation of this index, risk scores are assigned to those water characteristics or parameters that do not comply with limit values set in the resolution. The characteristics considered are: color, turbidity, pH, residual chlorine, alkalinity, calcium, phosphates, manganese, molybdenum, magnesium, zinc, hardness, sulphates, iron, chlorides, nitrates, nitrites, aluminum, fluorides, total organic carbon, total coliforms, and fecal coliforms.

IRCA calculation

For calculation of the IRCA, Equation 6 is used:

$$IRCA\ (\%) = \frac{\sum \text{ of risk scores of unacceptable characteristics}}{\sum \text{ of risk scores of all characteristics analyzed}} \times 100 \quad (6)$$

The IRCA value is zero when all of the characteristics included in the resolution meet acceptable values and 100 when none of them meets acceptable values.

According to the **IRCA** scores, risk level of water supplied for human consumption is classified (Table 11).

Table 11. IRCA classification and risk level.

IRCA classification (%)	Risk level
80.1-100	Sanitarily unviable
35.1-80.0	High
14.1-35.0	Medium
5.1-14.0	Low
0-5.0	Without risk

Source: MAVDT, 2007

Criteria for selection of water bodies that were monitored

One of the most important reasons to study surface water quality is to help to determine supply, in both quantity and quality, so it is necessary to prioritize those water bodies featuring lower natural flow rate and greater demand by different socio-economic activities in the river basin, identifying and quantifying alteration of flow rates by water abstraction for consumption uses, and recognizing and measuring water quality deterioration in the river basin because of discharges from domestic, industrial and farming activities.

Criteria for selection of monitoring sampling points

The criteria for selection of sampling points are those established by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) in the Guide to surface water sampling (2002). The factors established in this Guide are described below:

Fundamental factors: They determine why and for what the site is located, and involve aspects such as: reference conditions, major wastewater discharges, confluence with main rivers, water policies, existing and potential industrial and urban development areas, aqueduct inlets, and irrigation districts, among others.

Conditioning factors: They make reference to limitations of each location and are related to difficult access, equipment and staff safety, existing infrastructure, section and stretch hydraulic characteristics, proximity to hydrological stations, and ease for hydrometric activities and sampling, among others.

Limiting factors: They refer to budget and measurement equipment (capacity, accuracy and installation, operation and maintenance requirements, among others).

For preliminary selection of the sampling points, cartographic information can be used and literature can be reviewed, and for their georeferencing, information from the website of the Agustín Codazzi Geographic Institute (IGAC) can be used as a tool; however, a field visit is necessary for recognition of the site and to corroborate its location, as there may be limitations in the area preventing access to the points pre-selected.

4

Quality of surface water in coffee river basins of Colombia

MAIN RESULTS OF SURFACE WATER QUALITY MONITORING CAMPAIGNS

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Analysis of flow rates in IWM river basins

Flow rate analysis is important in any water quality study because water self-purification capacity impacts concentration of pollutants. It also provides valuable information for characterizing the sampling point.

As shown in Figure 9, most water bodies in the IWM river basins are low-volume bodies, with average flow rates ranging from 0.004 to 3.561 m^3/s at Point 1 (before entering the coffee zone) and from 0.067 to 7.107 m^3/s at Point 2 (downstream from the coffee zone). In all cases there is a notable flow rate increase between P1 and P2, thus increasing capacity of dilution of pollutants of the receiving body downstream, which in turn can mask interpretation of possible variations in pollution concentration before and after flowing through the coffee zone.

It is also important to note that for the different types of water bodies, in the middle-upper parts of rivers the flow rate in general is strongly influenced by rainfall, with significant flow variations in the different monitoring sessions. This fact must be considered when comparing surface water quality results between the different monitoring sessions.

Additionally, powerful increases of flow caused by intense precipitation events typical of the coffee river basins may facilitate transport of macroinvertebrates, masking results of biological indicators, mainly for those located in the most exposed substrates.

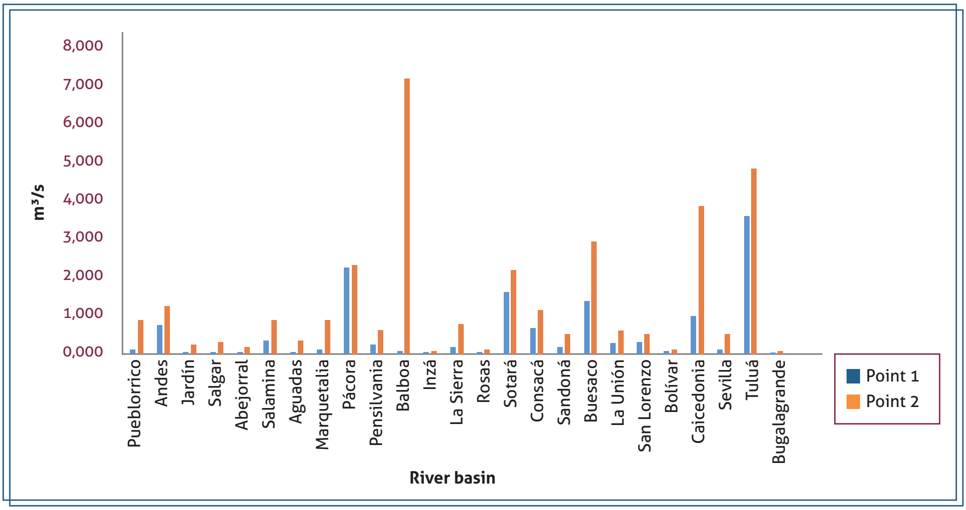


Figure 9. Average flow rate of the four monitoring campaigns in the 25 river basins evaluated.

Characterization of quality of water bodies before entering the coffee zone

Determining the initial concentration of pollutants in the bodies of water before entering the coffee zone helps understand their evolution as they move through. Table 12 shows values of surface water variables evaluated at P1, and for most of the physicochemical variables it is observed that average concentration before entering the coffee zone shows low values.

In this sense, variables such as COD have an average concentration of 31 mg/L, and in most river basins there is some fecal pollution. On the other hand, in the case of nutrients, both nitrate and phosphate values are relatively low.

Before the coffee zone, the water quality indices (NSF WQI, BMWP/Col, SVAP, and KPI) show good-to-excellent values for most of the river basins. It is worth noting that in the river basins of El Marquez (in Rosas, Cauca) and Azufral (Consacá, Nariño), the biological index on average shows bad quality, due mainly to presence of phosphates.

It is important to stress that P1 is not a pristine point in the upper part of the river basin, as there is, in many cases, important anthropogenic pressure upstream from the coffee zone. This can limit capacity of the body of water to assimilate coffee pollutants.

Table 12. Average concentration, standard deviation, and coefficient of variation of parameters evaluated in surface waters before entering the coffee zone (P1).

Parameter	Average value	Standard deviation	Coefficient of variation (%)
pH (Units)	7.39	0.37	4.97
Temperature (°C)	19.60	1.91	9.72
Turbidity (NTU)	7.89	7.56	95.86
Dissolved O_2 (ppm)	7.42	0.39	5.26
Oxygen saturation (%)	101.14	5.06	5.01
Electrical conductivity (μs/cm)	164.47	301.79	183.50
Total Solids (ppm)	166.23	329.46	198.20
Fecal coliforms (UFC/100 mL)	1,027.00	2,700.02	262.83
Phosphates (ppm)	0.29	0.14	46.69
Nitrates (ppm)	1.30	0.42	32.53
COD (ppm)	30.81	10.01	32.50
NSF WQI	75.34	3.47	4.61
BMWP/Col	86.12	23.50	27.29
SVAP	7.15	0.47	6.52
KPI	0.72	0.07	10.11

Effects of coffee production on surface water quality

Thanks to statistical analysis of the information gathered during monitoring at river basin level, with a point before and another after the coffee zone, it is possible to analyze if coffee wastewater discharges have a significant effect on water quality in the coffee river basins. For this purpose, results of the four monitoring campaigns have been analyzed, comparing quality variations for different surface water variables and indices before and after the coffee zone in harvest time and without harvest (Table 13).

For those variables showing normal distribution and homogenous variance, the difference among variables was assessed through a One-way Analysis of Variance (one-way ANOVA). In those variables not meeting these requirements, the nonparametric Kruskal-Wallis test was applied. The significance level was set below 5%. The analysis was done through the IBM SPSS statistical package (Version 17). This analysis makes reference to the set of the 25 river basins, for a total of 200 samples. By means of the Kolmogorov-Smirnov test and the Levene's test, normality and homoscedasticity of variables have been respectively confirmed.

Chapter 5 shows a detailed analysis at the level of each river basin.

Table 13. Average concentration of the parameters evaluated in surface water before and after the coffee zone.

Parameter	P1	P2 - Without harvest	P2 - Harvest
pH (Units)	7.39	7.50	7.70
Temperature (°C)	19.60	22.1	22.10
Turbidity (NTU)	7.89	13.66	18.15
Dissolved O_2 (ppm)	7.42	7.66	7.52
Oxygen saturation (%)	101.14	104.44	102.91
Electrical conductivity (µs/cm)	164.47	97.30	190.00
Total solids (ppm)	166.23	160.00	207.00
Fecal coliforms (UFC/100 ml)	1027	1722	1889
Phosphates (ppm)	0.29	0.39	0.38
Nitrates (ppm)	1.30	2.30	1.70
COD (ppm)	30.81	35.0	51.00
NSF WQI	75.34	71.00	70.00
BMWP/Col	86.12	67.88	77.37
SVAP	7.15	6.10	6.00
KPI	0.72	0.63	0.64

Figure 10 is a box-and-whisker plot for the variables COD and fecal coliforms and the four water quality indices used, showing values of median and dispersion, as well as data symmetry. In results of Table 13 and Figure 10 it can be observed that surface water quality decreased between points P1 and P2; this quality decrease is higher during coffee harvest.

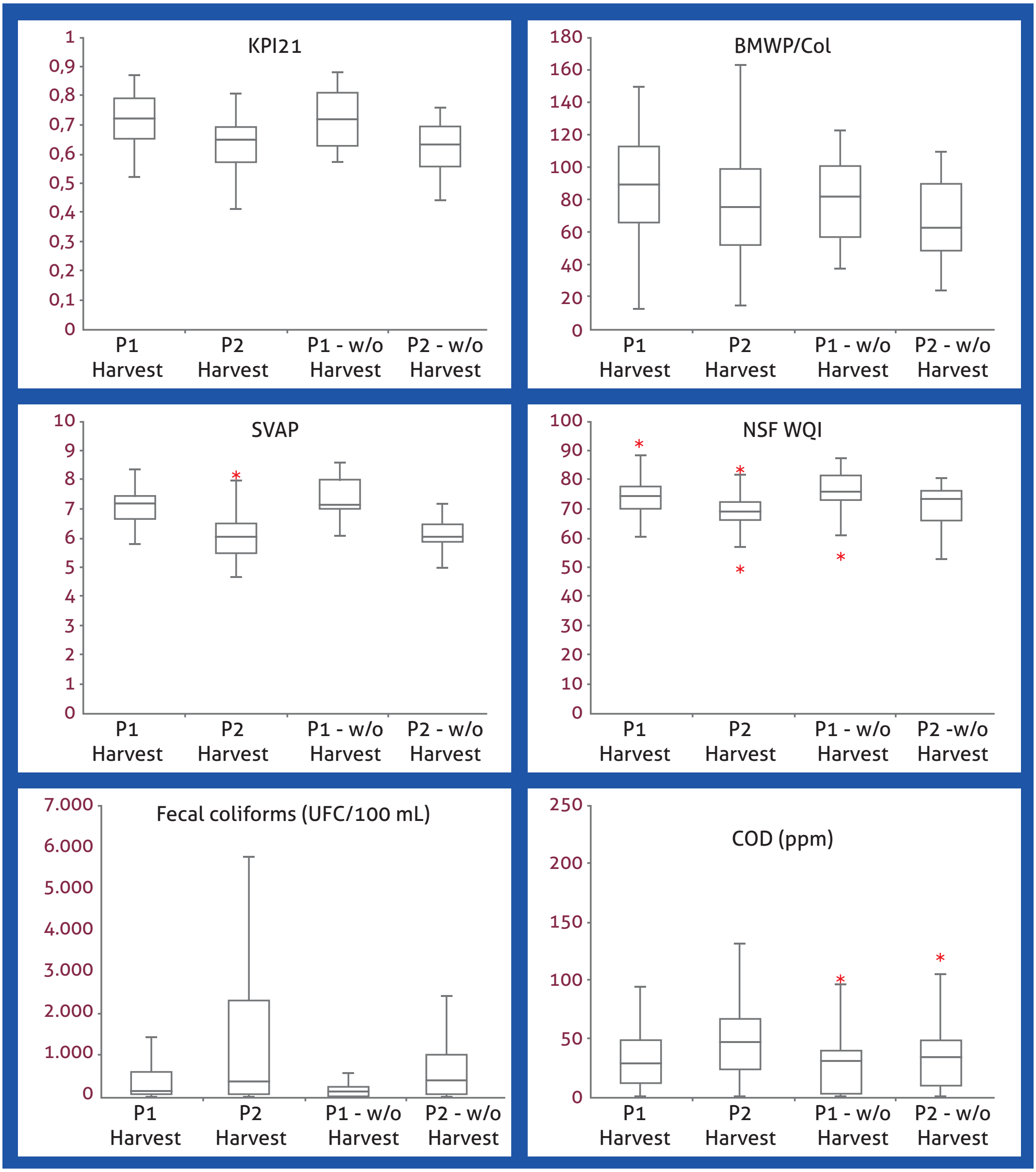


Figure 10. Box-and-whisker plot for variables COD and fecal coliforms and the four water quality indices, both during coffee harvest and without harvest at Point 1 (P1) and Point 2 (P2).

At a general level, the main results of statistical analysis of data generated can be summarized as follows:

- Without coffee harvest, no statistical differences were found at a 5% significance level between P1 (before the water body enters the coffee zone) and P2 (after the coffee zone) in most of the variables analyzed. Differences lower than 5% were found by comparing average values of the parameters pH, oxygen dissolved, oxygen saturation percentage and total solids between P1 and P2. There were differences of 5% to 15% in the average values of temperature, COD, and the NSF WQI, SVAP and KPI indices; and differences greater than 15% in values of turbidity (73.13%), fecal coliforms (67.67%), phosphates (34.48%), nitrates (76.92%), and the BMWP/Col index (21.18%).
- During coffee harvest, statistical differences at a 5% significance level were found between P1 and P2 for many variables analyzed. There were differences lower than 5% when comparing average values of pH, dissolved oxygen, and oxygen saturation percentage between P1 (before of coffee zone) and P2 (after of coffee zone); differences of 5% to 15% in values of temperature and the NSF WQI, BMWP/Col and KPI indices, and differences greater than 15% in the values of turbidity (130.04%), electrical conductivity (15.52%), total solids (24.53%), fecal coliforms (83.93%), phosphates (31.03%), nitrates (30.77%), COD (65.53%), and the SVAP index (16.08%).
- Wastewater discharges when there was no coffee harvest are responsible for an average increase of over 20% in values of the following surface water parameters, which cause a decline in the BMWP/Col index (21.18): phosphates (34.48%), fecal coliforms (67.67%), turbidity (73.13%), and nitrates (76.92%). These wastewaters come basically from domestic and agroindustry activities.
- Discharges during coffee harvest are responsible for an additional deterioration (to that already caused by other wastewater types in the coffee river basins) in values of the following parameters: turbidity (32.87%), electrical conductivity (95.27%), total solids (29.38%), fecal coliforms (9.70%), and COD (45.71%).
- When the parameters are compared in terms of mass load, calculated as the product of concentration by flow rate, the differences between P1 and P2 are greater for almost all the physicochemical variables over the values compared in concentration terms.
- There is no evidence of a relationship between pollution concentration and flow rate, so it cannot be affirmed that results obtained for the different parameters are due to a dilution effect.
- There is important pollution by fecal coliforms before the coffee zone and this pollution increases after it. As this type of pollution is exclusively of urban origin, it can be said that domestic wastewaters are an important source of pollution in the coffee river basins, and in some cases they may mask interpretation of results. Therefore the river basin monitoring, with two points before and after the coffee zone, can be masked by other type of wastewater of domestic, livestock or industrial origin.
- It should be noted that, although the biological index BMWP/Col decreases significantly between P1 and P2, it does not seem to be directly affected by coffee production. This can be due to several factors, including that pollution by coffee effluents is eminently organic. This type of pollution can affect abundance of macroinvertebrates less than urban wastewater. On the other hand, aquatic organisms' longer reaction time to pollution events can dilute effects of wastewater over time, not being

directly comparable the periods of harvest and without harvest, like in the case of physicochemical variables.

For all these reasons, it can be concluded that incorrect disposal of coffee byproducts (wastewater and pulp) does have a negative effect on quality of water bodies in the coffee river basins, but considering the results obtained, this effect is minimized by their high self-purification capacity. Likewise, pollution sources in the river basins other than coffee production, such as urban areas and livestock or industrial activities, have an important impact on water quality, not being possible to discriminate the effects of each.

Evolution of water quality during the IWM Project: Impacts of implementations

Many types of actions were performed as part of the IWM Project, which, in one way or another, can have an effect on quality of water bodies: from actions with direct effects—such as those aimed at reducing pollution by implementing ecological wet mills and domestic or coffee wastewater treatment systems (WTS)—to actions with indirect effects—such as reforestation, bioengineering, community work promotion, or education and environmental awareness-raising campaigns.

One objective of water body monitoring is to assess whether the different IWM Project implementations have a demonstrable positive effect on water quality of the targeted river basins. To this end, evolution of quality of water bodies has been compared throughout the four monitoring campaigns, paying special attention to comparison between monitoring 1 (without IWM actions yet) and monitoring 4 (with over 80% of actions implemented).

Figure 11 shows evolution of water quality indices along the four monitoring campaigns for the 25 river basins evaluated.

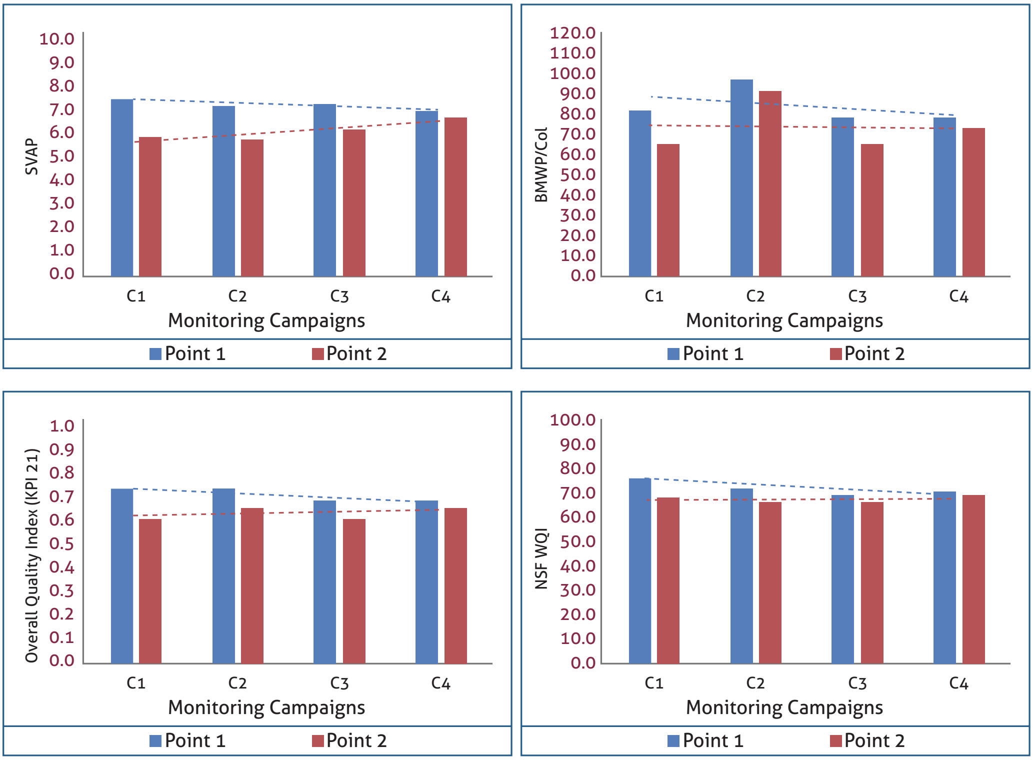


Figure 11. Evolution of water quality indices during the four monitoring campaigns for the 25 river basins evaluated in the IWM Project.

The main results can be summarized as follows:

- In general, for the four indices evaluated, there is a clear worsening water quality trend at Point 1 (before the coffee zone). This point is not affected by the IWM actions, which are exclusively focused on the coffee zone.
- On the contrary, a clear water quality improvement is observed at Point 2 (after the coffee zone). This point is directly affected by the IWM Project actions.
- This means that quality decline was clearly attenuated between P1 and P2 over time, which means a remarkable water quality improvement at P2 as a result of the IWM actions.
- In the case of the KPI21 index, 80% of the river basins intervened (20 of 25) show attenuated quality deterioration by comparing initial conditions to those of the fourth monitoring campaign. This occurs in the following river basins: La Leona in Pueblorrico, La Chaparrala in Andes, La Gulunga in Salgar, and La Liborina in Abejorral, in the department of Antioquia; La Frisolera in Salamina, El Edén-Bareño in Aguadas, Los Saínos in Marquetalia, and La Linda in Pensilvania, in the department of Caldas; Capitanes in Balboa; La Chorrera in Inzá and Quilcacé in Sotará, in the department of Cauca; Azufral in Consacá, El Ingenio in Sandoná, Buesaquito in Buesaco, La Fragua in La Unión, and El Molino in San Lorenzo, in the department of Nariño; Platanares in Bolívar, San Marcos in Sevilla, Bugalagrande in Tuluá, and La Paila in Bugalagrande, in the department of Valle del Cauca.

• Measured through the KPI21 index (Figure 12), the overall water quality decline between Points 1 and 2 in initial conditions (first sampling campaign) was 16.70%, while it was only 3.69% in the fourth monitoring campaign. This means water quality improved on average 86.11% between P1 and P2 over initial conditions.

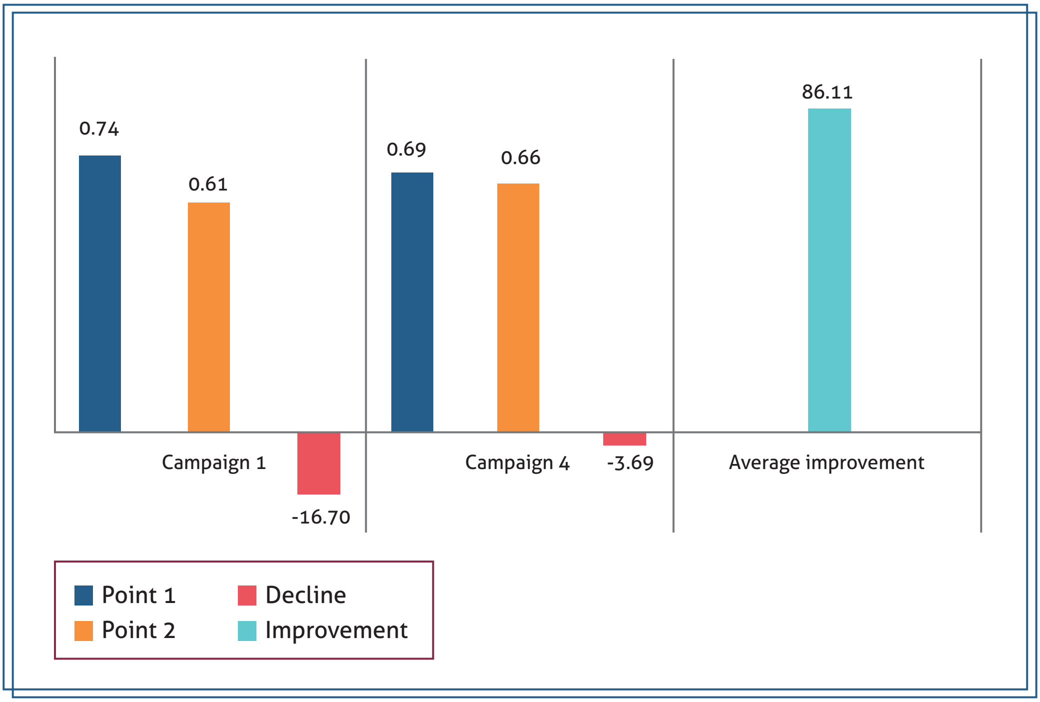


Figure 12. Changes in water quality (based on overall quality index KPI) from Point 1 to Point 2 in initial conditions and fourth monitoring campaign.

• Regarding evolution of each point separately, when comparing average results found in the river basins (initial conditions vs. conditions of fourth campaign), overall quality at points 1 (before the coffee zone) decreased 4.84%, while at points 2 (after the coffee zone) overall quality improved 11.19% (Figure 13).

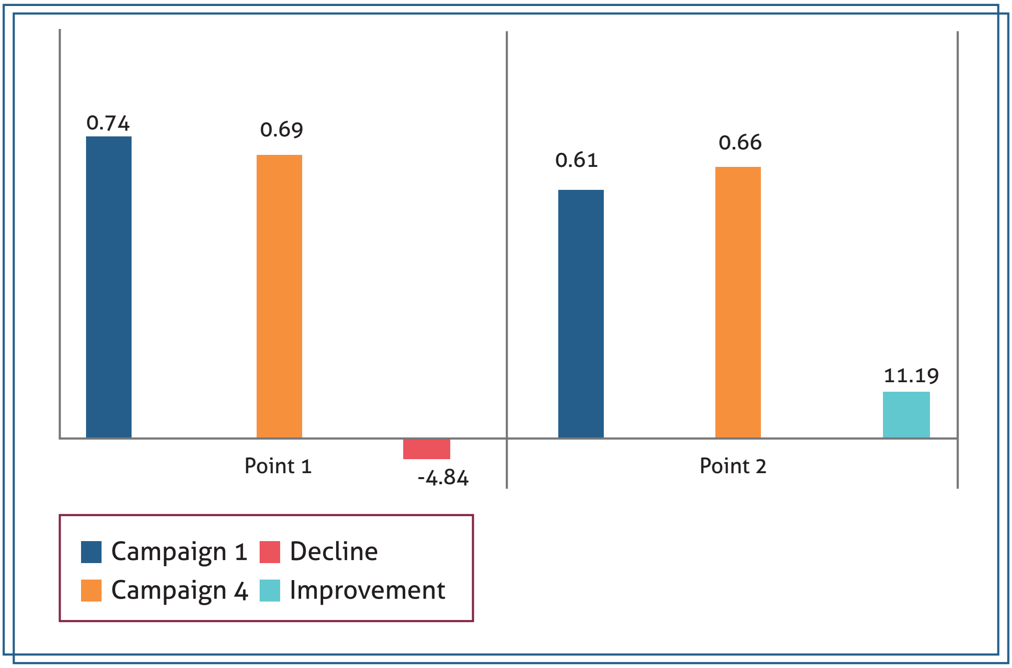


Figure 13. Average behavior of the overall quality index KPI21. Initial conditions (II Quarter 2015) vs. fourth campaign conditions (I Quarter 2017).

• For the rest of the quality indices, a very similar trend can be observed, showing lower quality deterioration for the NSF WQI, BMWP/Col and SVAP indices in 88%, 76% and 88% of the river basins, respectively.

• There has been a significant water quality decrease at Point 1 from initial conditions to the fourth monitoring campaign, reflected in the number of river basins with good or excellent quality according to the overall quality index (Table 14), falling from 56% of the river basins (at the beginning of the Project) to 40% in the fourth monitoring campaign.

• On the contrary, the number of river basins with good or excellent quality at Point 2 (after the coffee zone), according to the overall quality index, increased from 16% at the beginning of the Project to 28% in the fourth campaign.

• Despite improvement in the fourth monitoring campaign, only 28% of the river basins show good or excellent quality in the KPI21 index after the coffee zone (Table 14). This value reaches 48% in the cases of the NSF WQI and the BMWP/Col indices, and 20% in the SVAP index.

Table 14. Percentage of the 25 river basins with good or excellent quality values for the indices evaluated.

	NSF WQI	BMWP/Col	SVAP	KPI21
P1 - Initial conditions	92%	64%	80%	56%
P1 - 4th monitor. campaign	68%	72%	48%	40%
P1 - 4th monitor. campaign	56%	44%	0%	16%
P2 - 4th monitor. campaign	48%	48%	20%	28%

Abundance of macroinvertebrates

Results of the first four water quality monitoring campaigns, which included the 25 river basins, showed abundance of aquatic macroinvertebrates: 32,373 individuals in the 50 sampling points, which are taxonomically grouped into 6 phyla, 27 orders, and 79 families respectively (Figures 14 and 15).

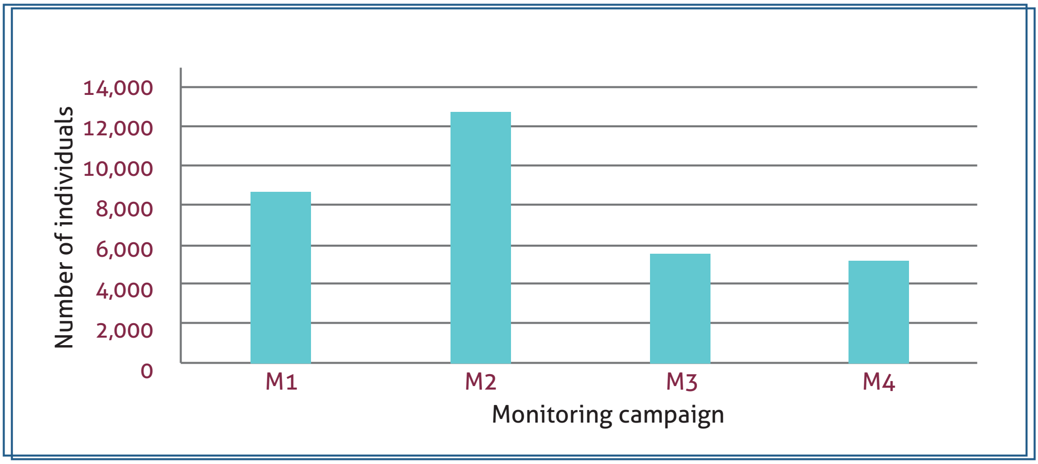


Figure 14. Total abundance of aquatic macroinvertebrates in the four monitoring campaigns that included the 25 river basins.

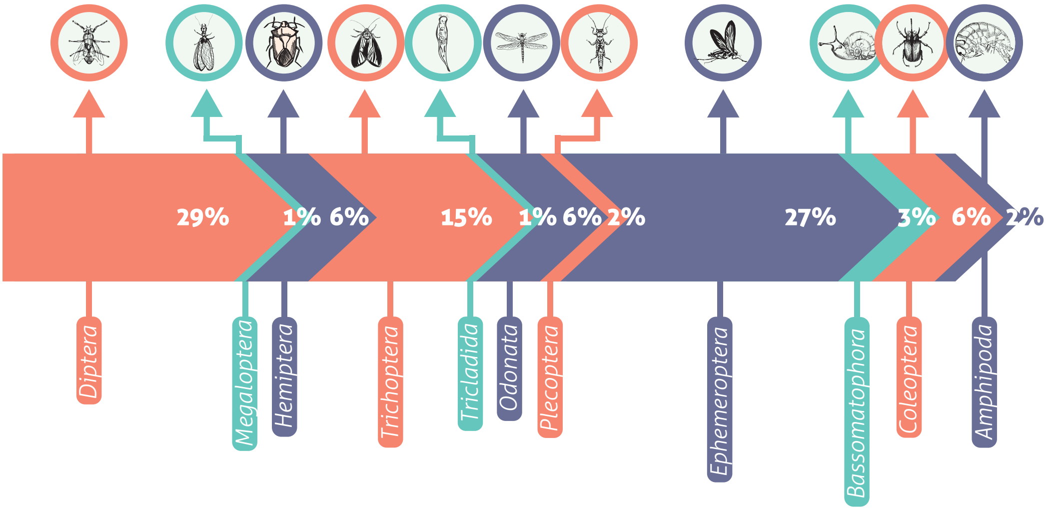


Figure 15. Relative abundance of the most representative orders of aquatic macroinvertebrates in the four monitoring campaigns that included the 25 river basins.

The abundance information recorded agrees with previous studies by different authors for coffee departments; therefore, the microhabitats evaluated in the monitored water bodies respond to natural dynamics, based on natural geological and biogeographic processes of their area of distribution.

Figure 16 shows relative abundance of the most representative families of aquatic macroinvertebrates collected in the four monitoring campaigns of the IWM Project.

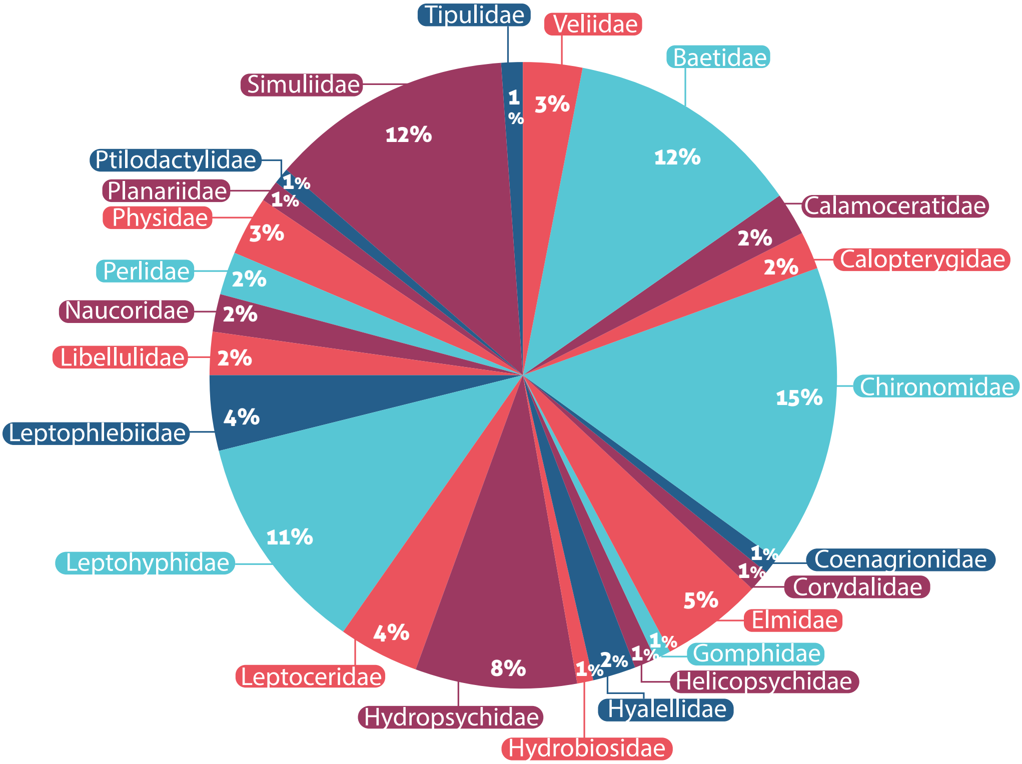


Figure 16. Relative abundance of the most representative families of aquatic macroinvertebrates.

Results show dominance of families of the orders Chironomidae (15%), Baetidae (12%), Simuliidae (12%), Leptohyphidae (11%) and Hydropsychidae (8%). These families are indicator groups that serve as parameters of analysis, from structural and functional points of view, of aquatic biota, with processes of ecological interactions in the body of water in much of their development. These families are highly sensitive, because they do not tolerate high pollution, and their reporting indicates that many of the river basins studied are well conserved; therefore, they are considered bioindicators and, consequently, the BMWP index used in this study shows how these water quality indicators have fluctuated during the monitoring campaigns at the 50 sampling points, distributed in the five departments of the IWM Project.

Families of these orders are recognized for their sensitivity to changes caused by different human activities, since they do not tolerate the stress caused by them, decreasing or disappearing in impacted areas. Therefore, they are considered bioindicators and the BMWP index is used for this study. This feature enables them to be indicators of variations that may arise in the aquatic ecosystems that they inhabit (Zuñiga & Rojas, 1995). For this reason, they are a valuable complement when evaluating a hydrobiological community, since they refine diagnosis of the areas evaluated (Bonada *et al.*, 2006).

The ecosystems evaluated provide conditions for establishment of these communities of macroinvertebrates, which are so demanding in ecological terms.

Figure 17 shows results of abundance of individuals and families in the four monitoring campaigns.

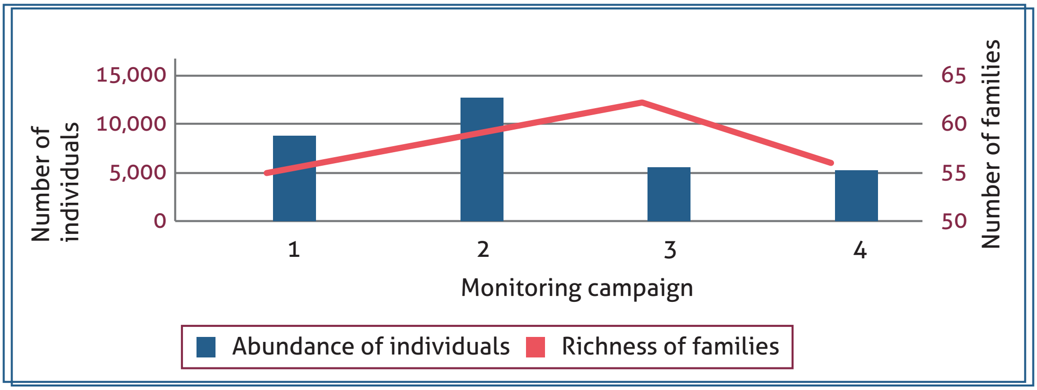


Figure 17. Total abundances of aquatic macroinvertebrates in the four water quality monitoring sessions.

Aquatic insect families reported in each sampling showed the following behavior: Monitoring 1 (55 families), monitoring 2 (59 families), monitoring 3 (62 families), and monitoring 4 (56 families). These results fall within normal ranges of reports of groups of organisms: in the Neotropic, especially in the Andes, there is representativeness of families of 45 to 70 taxonomic groups, the coffee river basins of the IWM Project serving as a reference, not only in bioindication terms, but as a contribution to the state of the art on these groups of organisms in the Colombian Andes.

As to distribution of aquatic macroinvertebrates in the sampled substrates, the dominant substrate regarding abundance of organisms was leaf litter with 41%, followed by rock with 36%, and finally fine sediment with 23%.

It is noteworthy that the coffee production area in the Andes of Colombia features great vegetal and entomological diversity per square meter compared to other altitudinal zones, taking into account that the tropical cloud forests host their greatest diversity between 1,200 and 2,500 masl. These forests are unique and strategic ecosystems not only for terrestrial organisms but also for aquatic ones, given that supply of leaf litter to bodies of water is one of the main inputs of nutrients to channels, and are a key point in their cycling, including physical, chemical and biological mechanisms that transform matter into more stable forms (Doumenge *et al.*, 1995; Stadtmüller, 1987).

Transport of dissolved particles and organic matter (produced from headwaters to mouths of water ecosystems) creates a narrow relationship between river and land ecosystems. It is worth noting that leaf litter plays a key role in the trophic chain of freshwater environments, enabling the establishment of communities of insects and, along with rock and sediment, making it easier for these organisms to reproduce, feed, and move around water sources.

Fish diversity and abundance

In nine of the 25 river basins studied: La Chaparrala (Andes, Antioquia), San Bartolo (Jardín, Antioquia), La Leona (Pueblorrico, Antioquia), Los Saínos (Marquetalia, Caldas), La Frisolera (Salamina, Caldas), La Linda (Pensilvania, Caldas), San Marcos (Sevilla, Valle del Cauca), Platanares (Bolívar, Valle del Cauca) y Capitanes (Balboa, Cauca), 25 fish specimens were identified, grouped into 16 species, 7 genera, 6 families, and 4 orders.

The most representative and abundant orders for this study in the coffee river basins (Figure 18) were: Siluriformes (64%) and Cyprinodontiformes (20%), results that agree with percentages reported in other studies in the middle Cauca river basin (Villa-Navarro *et al.*, 2003, 2005) and in most river systems of Colombia and the Neotropic (Villa-Navarro *et al.*, 2007). Reports also agree with diversity in fresh water bodies, where, together with Characiformes (which in this study accounted for 12%), they account for 80% of fish worldwide (Nelson, 2006).

Most representative and abundant orders

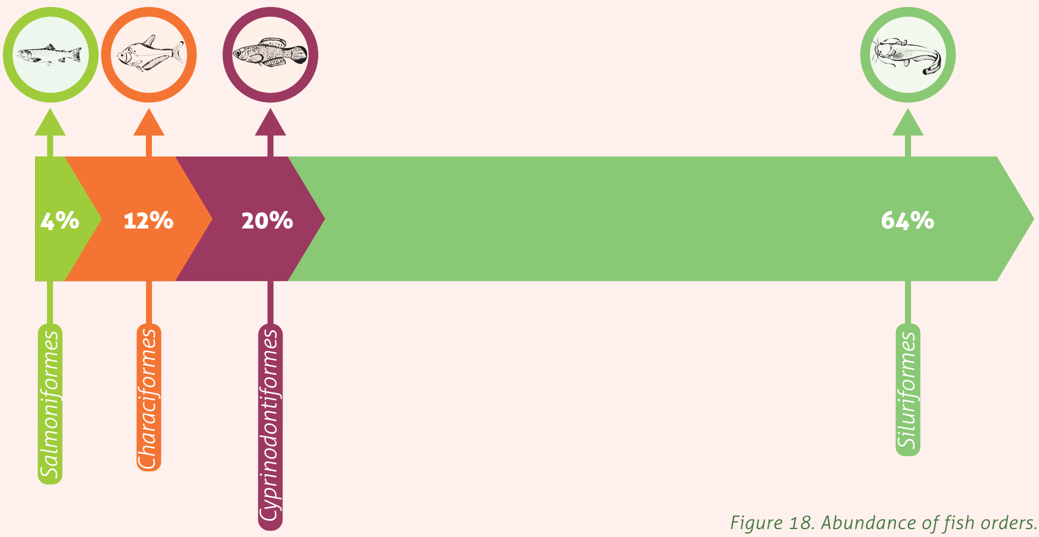


Figure 18. Abundance of fish orders.

The order Cyprinodontiformes accounted for 20% of species, due to abundance of *Poecilia reticulata* in the river basins of San Bartolo, in the municipality of Jardín (Antioquia), and Platanares, in the Bolívar municipality (Valle del Cauca). These bodies of water have backwater portions (lentic areas), suitable for feeding and reproduction of this species, which tolerates low dissolved oxygen concentrations, pH ranging from 5.5 to 8.5, and temperatures of 20 to 30 °C (Meffe and Snelson, 1989).

As to abundance of families (Figure 19), the family Astroblepidae ("bagrecitos de montaña") accounted for 36%, followed by the families Trichomycteridae ("barbudo") and Poeciliidae (guppies) with 20% each. Diversity of these families is widely known and coincides with reports for the middle and upper Cauca river basin (Ortega-Lara, 2004).

Most representative and abundant families

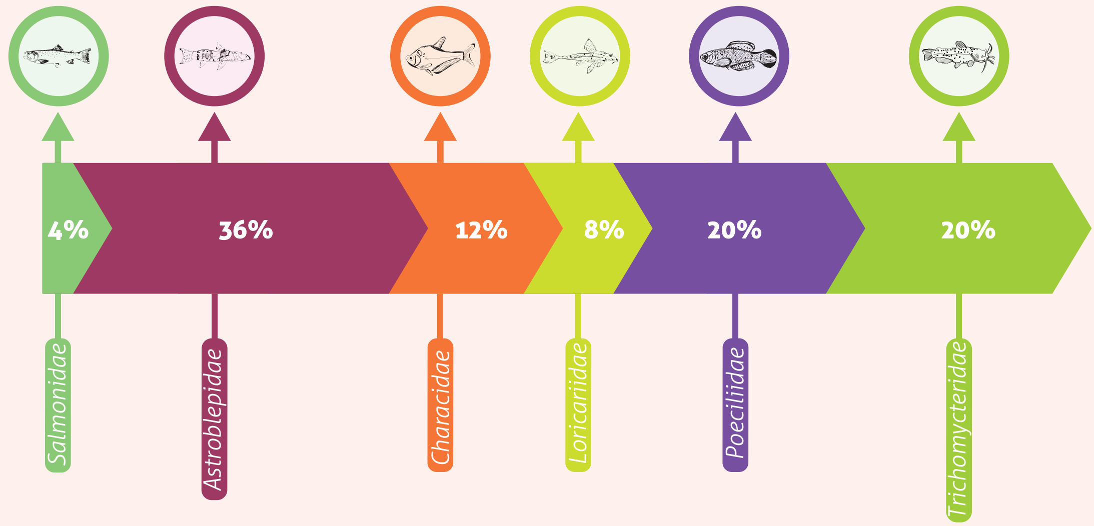


Figure 18. Abundance of fish families.

Figure 20 shows abundance of species for the fish caught.

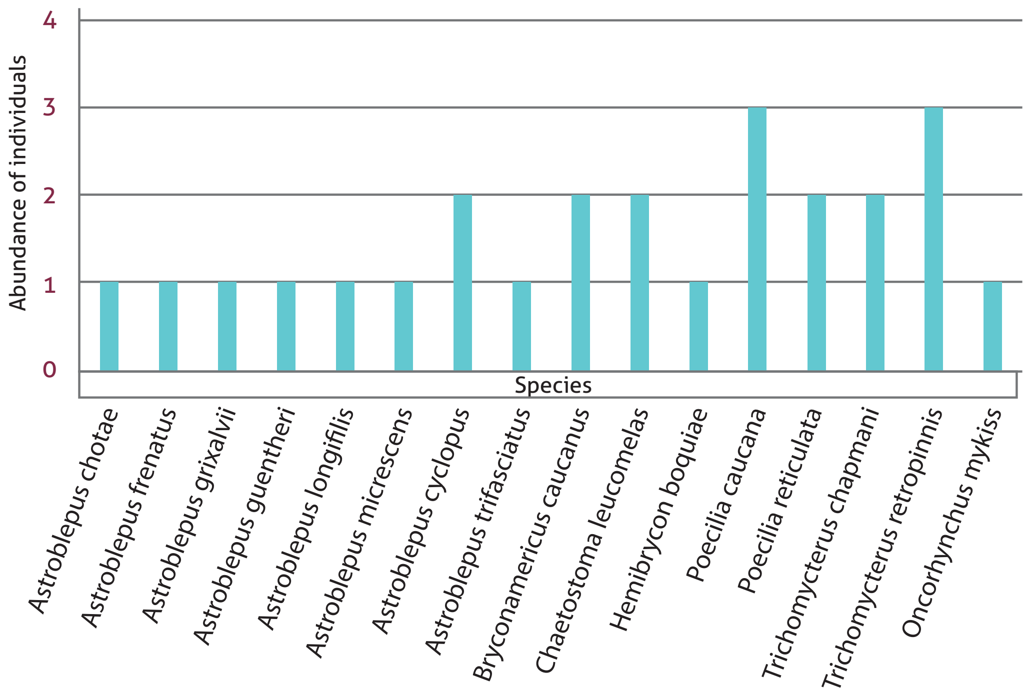
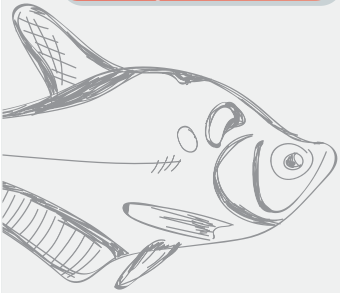
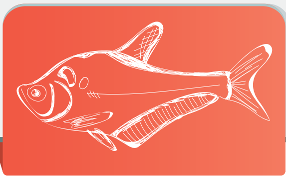


Figure 20. Abundance of fish species.

Sardine
Family Characidae



12%



The species of the family Characidae (sardines) accounted for 12%. The individuals of this family are distributed from the southern border of the United States until Buenos Aires, Argentina (Lima, 2003), and inhabit all kinds of environments, from marshes and large lakes to small streams.

Suckermouth catfish
Family Loricariidae

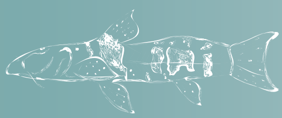
8%

The Loricariidae family ("cuchas" or suckermouth catfish) is distributed in Central and South America, and is the most diverse of all Siluriformes (Nelson, 2006). Their high diversity derives from the fact that they can occupy different microhabitats: they may be found in rapid-current streams and rivers with rocky and sandy beds, or in lentic environments of muddy beds.

According to Maldonado Ocampo *et al.* (2005), fish in the mountain ranges above 500 masl inhabit isolated pools and current zones, with special adaptations such as opercular odontodes (Trichomycteridae) and mouth suckers (Loricariidae and Astroblepidae) that enable them to adhere to rocks and go against the flow. Astroblepids have specialized in high Andean environments where they are one of the most important and adapted fish groups; this explains the presence of these communities in habitats at 2,000 masl. In general, distribution of families agrees with that reported for other river basins of the Colombian coffee systems.

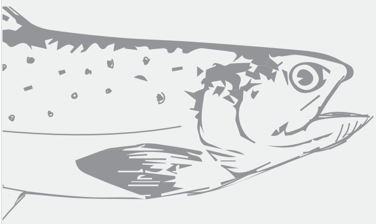
Catfish
Family Astroblepidae

36%

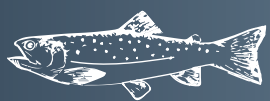


The Astroblepidae family is distributed in small rushing rivers from north of Bolivia to Panama and Venezuela (Román-Valencia, 2001), with an altitudinal distribution from 600 to 3,500 masl (Schaefer, 2003). *Astroblepus micrescens* showed the largest distribution in the coffee river basins studied. This species has been reported in different sub-basins of the country and feeds mainly on Blephariceridae, Chironomidae (Diptera), and Ephemeroptera (Baetidae) families (Briñez-Vásquez, 2004). By relating the sites where this species was found with abundance of macroinvertebrates, it was observed that these families account for about 50% of insects collected in these sites, so food availability and suitable habitats determine their distribution and abundance.

Rainbow trout
Family Salmonidae

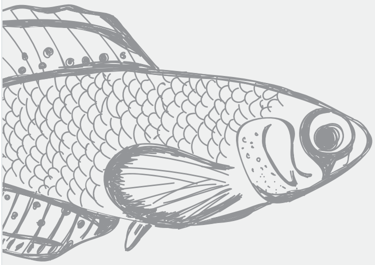


4%

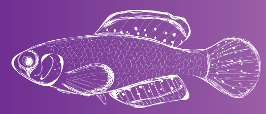


The family Salmonidae, with a representative, *Oncorhynchus mykiss* (rainbow trout), introduced for farming production in the mid-20th century, is a predatory fish, competitor of native species, causing their displacement (Sarpa, 1995). Trout is a high-mountain organism; their distribution ranges from 1,500 to 4,500 masl and it develops in clean, well oxygenated waters, with average temperatures of 10 °C, and tolerance ranging from 12 to 24 °C. It is among the 100 most harmful exotic species in the world, being the second cause of extinction of organisms, second only to habitat destruction. So in 1992 the Convention on Biological Diversity, held in Rio de Janeiro, established that it must be eradicated and treated in a special way (Gómez-Zuluaga *et al.*, 2014).

Guppy
Family Poeciliidae



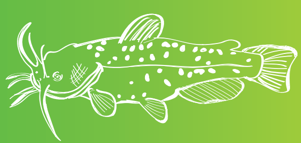
20%



Guppies are a group of small species (2-10 cm) of ovoviviparous toothed carps, that is, the eggs are fertilized and develop, and thereof the fry are born inside the mother, which gives birth to them alive. These fish have colors ranging from grayish to iridescent, well known as ornamental fish. They are distributed from the United States to Argentina, generally in freshwater, although it has been mentioned that they tolerate some degrees of salinity. There are specific reports in Africa and Asia, the result of introduction by man to counteract mosquitoes carrying malaria, as they feed on larvae of these insects. Poecilids are usually omnivores, as their morphology and history show colonization of great diversity of habitats and ecological niches (Garman, 1895).

Mountain catfish
Family Trichomycteridae

20%



The mountain catfish ("bagrecitos de montaña") are one of the most successful fish groups in colonization of underground habitats (DoNascimiento, 2005, Castellanos-Morales, 2007). Until now, the family comprises 241 species described; they are one of the most diverse Siluriformes groups, widely distributed in inland waters of the Neotropic. Due to their elongated morphology, little or no presence of scales, and nasal beards, they feature excellent adaptations for coffee water ecosystems, because living in small-to-medium-sized bodies of water with abrupt slopes and fast currents typical of high Andean systems makes their movement, reproduction and feeding easier.

Figure 21 shows some of the specimens identified in the ichthyological studies.

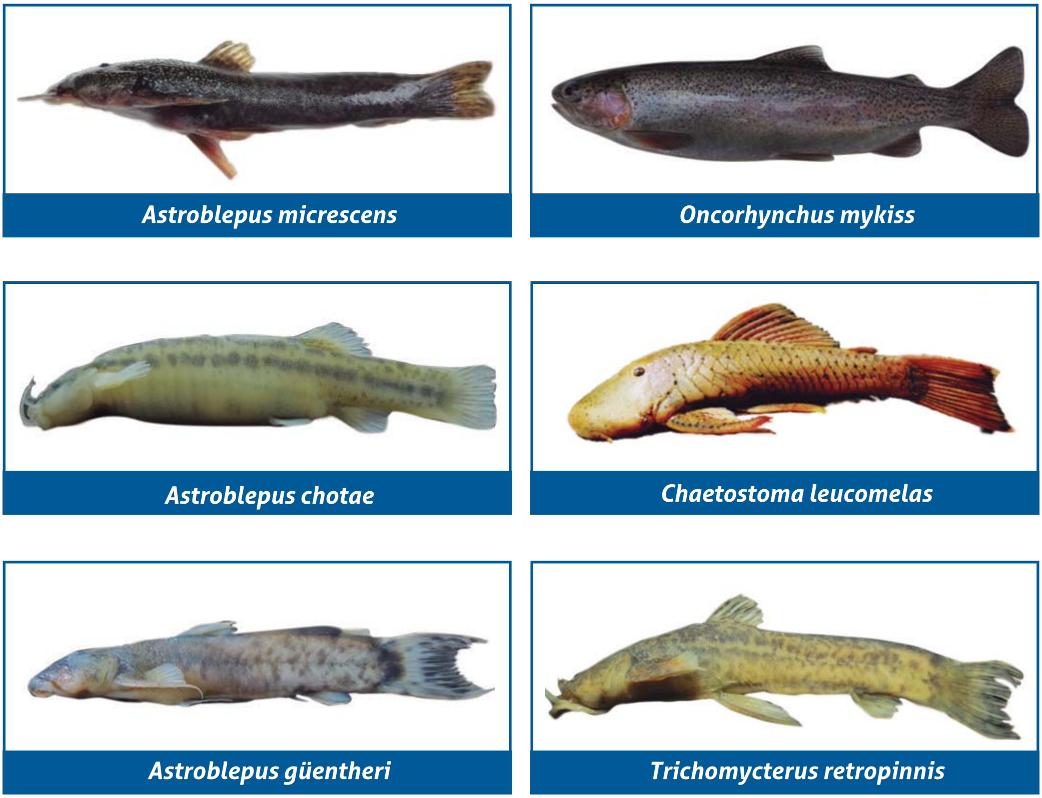


Figure 21 Some fish specimens identified in the coffee river basins.

Dynamic monitoring

Coffee production is not the only economic activity in the coffee river basins, which share territory with other agricultural, livestock and industrial activities. It is therefore important to try to identify and differentiate the impacts of these activities so as not to mistakenly attribute all impacts on water resources to coffee production.

Identification of urban impacts

As observed in different coffee river basins, urban wastewater discharges have a great impact on surface water quality. In some cases these discharges can be isolated and distributed throughout the territory. An example is urban discharges from coffee farms themselves. But in other cases these discharges can be concentrated in a single stream and their impact on the body of water can be significant. It is essential to identify these types of discharges that may mask interpretation of coffee production effects.

In the IWM Project, an example is the river basin La Frisolera, in Salamina, Caldas. In this river basin, wastewater from the Salamina municipality, with about 20,000 inhabitants, is discharged into La Palma stream (Figure 22), an affluent of La Frisolera that discharges upstream from the Point 2 defined in the monitoring project and located at the end of the coffee zone (Figure 22).

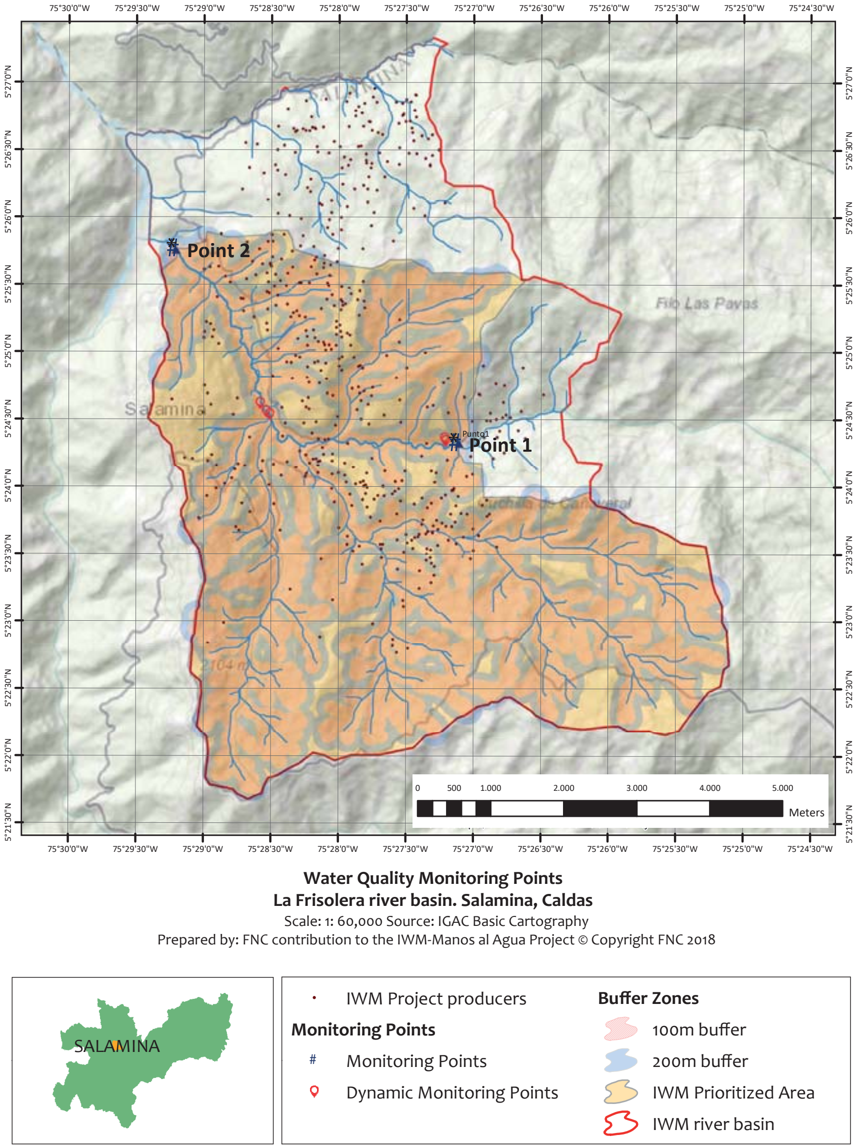


Figure 22. Location of dynamic monitoring sampling points for La Frisolera river basin, in Salamina, Caldas.

In Figure 23, Point 4, located in La Palma stream (body receiving discharges from the Salamina municipality), has a quality value much lower than the rest of the points for the four quality indices analyzed. Once La Palma flows into the main body (Q. La Frisolera), and despite important dilution effects, quality declines significantly (see quality difference between P3 and P5). This effect is much more noticeable in the biological index (BMWP/Col) due to capacity of macroinvertebrates to show long-term effects.

Thanks to the high self-purification capacity of the body of water, and as most of the evaluated indices show, quality values are restored when reaching P2 (downstream from P5 and the coffee zone), the P2 values being very similar to those at P3 (before urban discharge).

Figure 23. Average value of water quality indices at the different sampling points in La Frisolera river basin, in Salamina, Caldas.

Assessment of direct discharges of coffee farm wastewater into surface waters

With the objective of assessing evolution of surface water quality during discharges of wet coffee processing effluents (coffee wastewater), different coffee farms were monitored, choosing those with different wet coffee processing systems, and with or without wastewater treatment systems (WTS).

Figures 24 and 25 show that COD concentration in the receiving body increases considerably during discharges, to then return to its initial concentration after discharges end.

In the case of coffee farms with traditional wet processing (water consumption greater than 40 L/kg of dry parchment coffee) and without treatment systems (Figure 24), although effluents show concentrations not very high (800-600 ppm of COD), discharges have a considerable effect due to high volumes of water used. This means a significant change in COD concentration in the receiving body, reaching values of almost twice the initial concentration (140 ppm).

On the contrary, on farms with ecological wet mills (water consumption below 5 L/kg of dry parchment coffee) and treatment systems (Figure 25), and although effluent concentrations before treatment are much higher (15,000-20,000 ppm of COD), thanks to lower water volumes, and especially to capacity of treatment systems to remove around 80% of organic load, the discharge effects are attenuated, with a slight increase in COD concentration in the receiving body. Due to detention capacity of treatment systems, the discharge effects are extended over time, but with lower peaks.

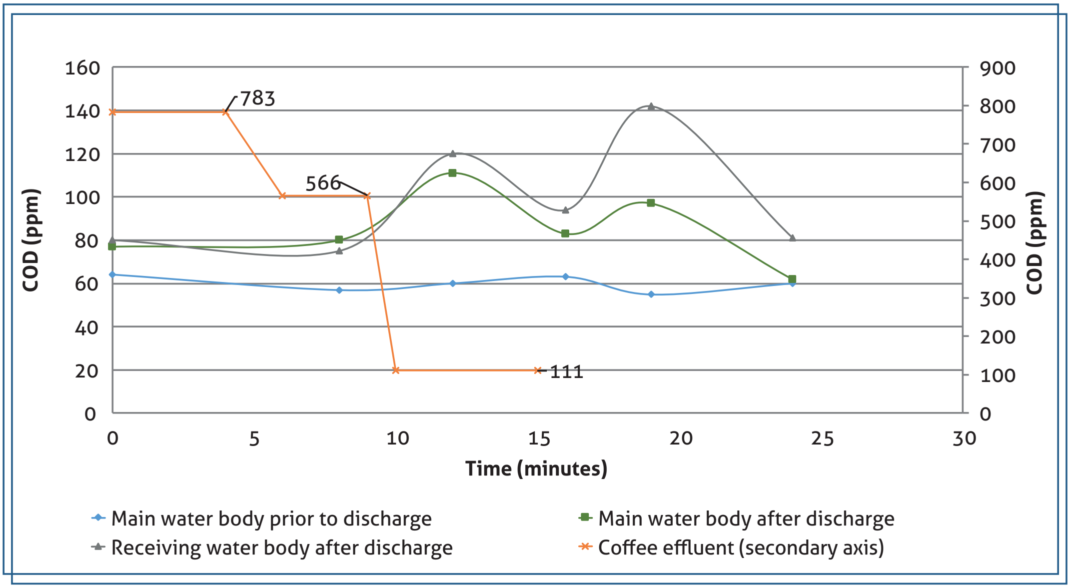


Figure 24. COD evolution in receiving body and main water body before and after coffee effluent discharge by a farm with traditional wet processing and without water treatment.

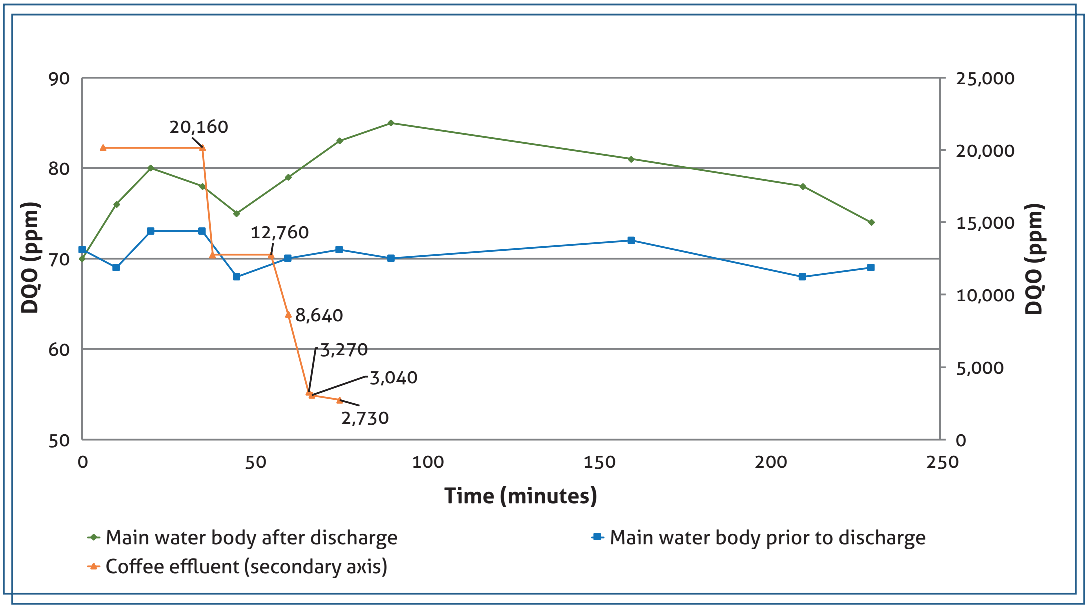


Figure 25. Evolution of COD in the main water body before and after coffee effluent discharge by a farm with ecological wet milling and wastewater treatment system (Modular Anaerobic Treatment System, SMTA).


Manos al Agua
B

5

Quality of surface water in coffee river basins of Colombia

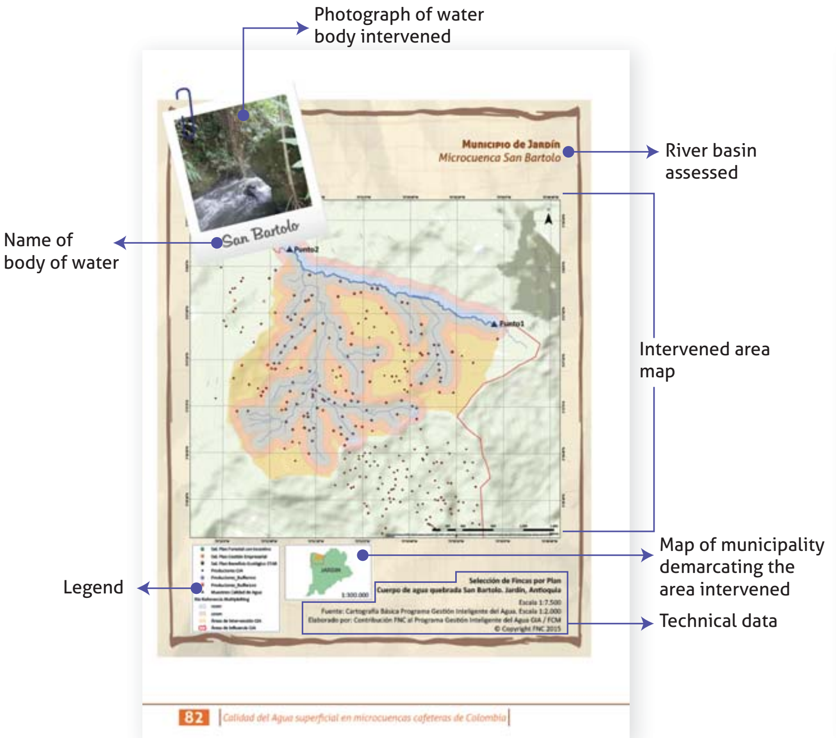
EVOLUTION OF MONITORING OF WATER QUALITY IN COFFEE RIVER BASINS

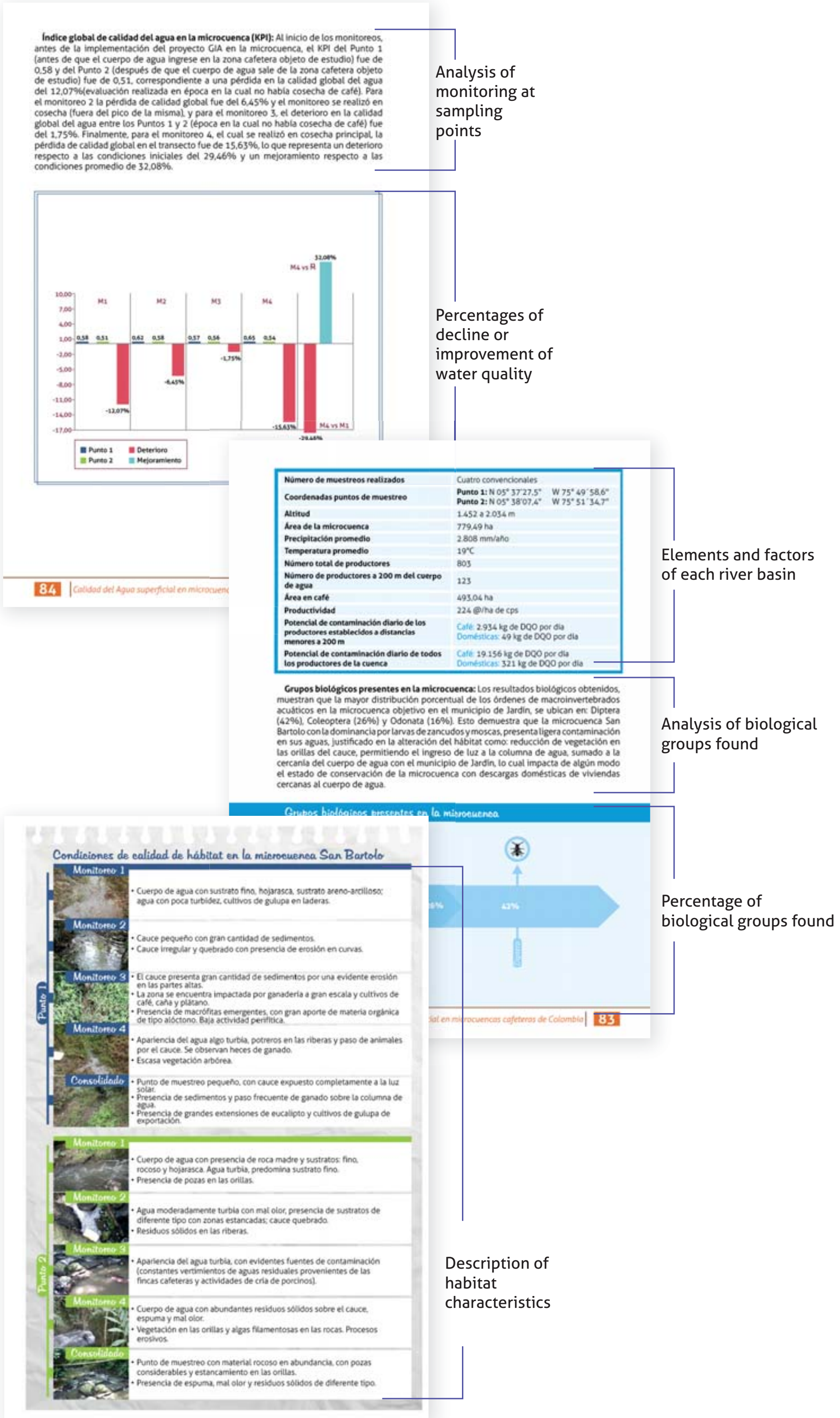
EVOLUTION OF MONITORING OF WATER QUALITY IN COFFEE RIVER BASINS

This section is comprised of a series of fact sheets with results of the Water Quality Monitoring Project for each of the 25 river basins assessed. Each fact sheet contains the river basin map, its total area, average rainfall and temperature conditions, its altitude, coffee area, total number of coffee growers and those located within 200 m from the bodies of water, coffee crop productivity, polluting potential of all producers and of those located within 200 m from the water bodies (for both domestic and coffee wastewater), and coordinates of the monitoring points in the body of water.

This section also reports on biological groups found in the river basins in the monitoring campaigns, overall water quality index (KPI21) values for each monitoring campaign at P1 and P2, and water quality decline or improvement percentages at the P1-P2 stretch based on KPI21. Finally, it summarizes water quality declines or improvements between initial conditions and average conditions of the monitoring campaigns, and between initial conditions and those of the last monitoring campaign (the fourth in 14 river basins and the seventh in 11 river basins).

The fact sheets also contain a summary of the habitat quality conditions for the different monitoring campaigns.





Índice global de calidad del agua en la microcuenca (KPI): Al inicio de los monitoreos, antes de la implementación del proyecto GIA en la microcuenca, el KPI del Punto 1 (antes de que el cuerpo de agua ingrese en la zona cafetera objeto de estudio) fue de 0,58 y del Punto 2 (después de que el cuerpo de agua sale de la zona cafetera objeto de estudio) fue de 0,51, correspondiente a una pérdida en la calidad global del agua del 12,07%(evaluación realizada en época en la cual no había cosecha de café). Para el monitoreo 2 la pérdida de calidad global fue del 6,45% y el monitoreo se realizó en cosecha (fuera del pico de la misma), y para el monitoreo 3, el deterioro en la calidad global del agua entre los Puntos 1 y 2 (época en la cual no había cosecha de café) fue del 1,75%. Finalmente, para el monitoreo 4, el cual se realizó en cosecha principal, la pérdida de calidad global en el transecto fue de 15,63%, lo que representa un deterioro respecto a las condiciones iniciales del 29,46% y un mejoramiento respecto a las condiciones promedio de 32,08%.

84 | Calidad del Agua superficial en microcuen

Número de muestreos realizados	Cuatro convencionales
Coordenadas puntos de muestreo	**Punto 1:** N 05° 37'27,5" W 75° 49'58,6" **Punto 2:** N 05° 38'07,4" W 75° 51'34,7"
Altitud	1.452 a 2.034 m
Área de la microcuenca	779,49 ha
Precipitación promedio	2.808 mm/año
Temperatura promedio	19°C
Número total de productores	803
Número de productores a 200 m del cuerpo de agua	123
Área en café	493,04 ha
Productividad	224 @/ha de cps
Potencial de contaminación diario de los productores establecidos a distancias menores a 200 m	Café: 2.934 kg de DQO por día Domésticas: 49 kg de DQO por día
Potencial de contaminación diario de todos los productores de la cuenca	Café: 19.156 kg de DQO por día Domésticas: 321 kg de DQO por día

Grupos biológicos presentes en la microcuenca: Los resultados biológicos obtenidos, muestran que la mayor distribución porcentual de los órdenes de macroinvertebrados acuáticos en la microcuenca objetivo en el municipio de Jardín, se ubican en: Diptera (42%), Coleoptera (26%) y Odonata (16%). Esto demuestra que la microcuenca San Bartolo con la dominancia por larvas de zancudos y moscas, presenta ligera contaminación en sus aguas, justificado en la alteración del hábitat como: reducción de vegetación en las orillas del cauce, permitiendo el ingreso de luz a la columna de agua, sumado a la cercanía del cuerpo de agua con el municipio de Jardín, lo cual impacta de algún modo el estado de conservación de la microcuenca con descargas domésticas de viviendas cercanas al cuerpo de agua.

Grupos biológicos presentes en la microcuenca

...ial en microcuencas cafeteras de Colombia | 83

Condiciones de calidad de hábitat en la microcuenca San Bartolo

Punto 1

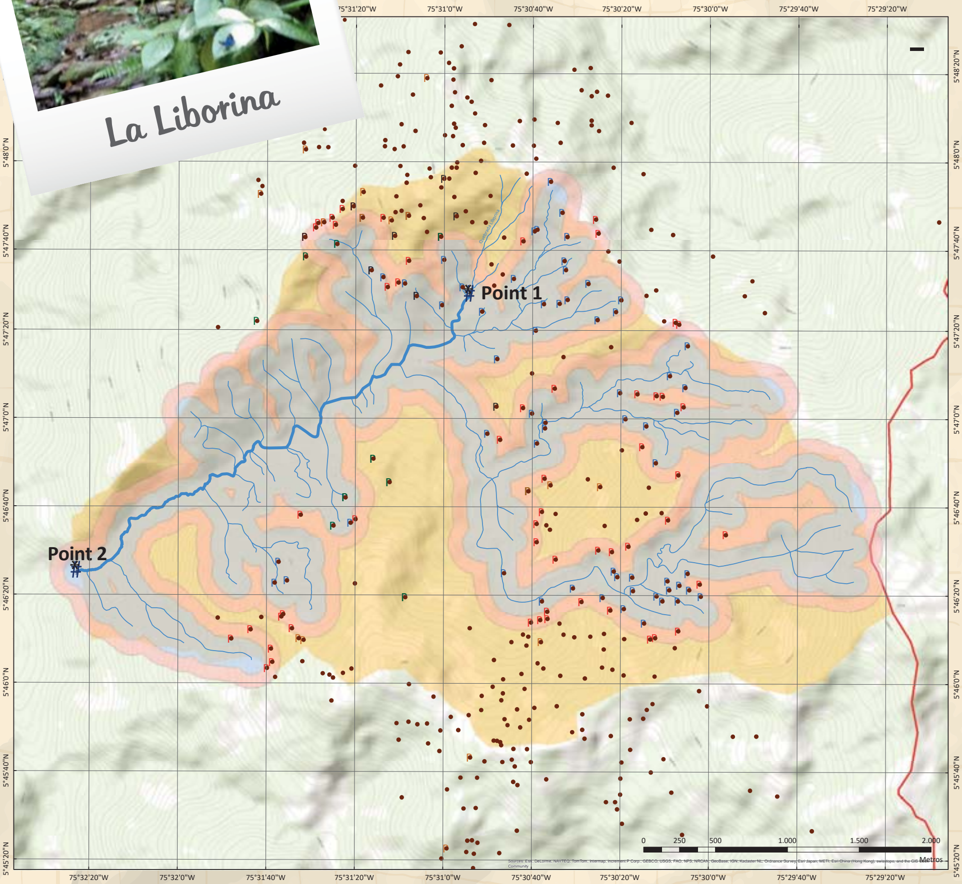
Monitoreo 1	• Cuerpo de agua con sustrato fino, hojarasca, sustrato areno-arcilloso; agua con poca turbidez, cultivos de gulupa en laderas.
Monitoreo 2	• Cauce pequeño con gran cantidad de sedimentos. • Cauce irregular y quebrado con presencia de erosión en curvas.
Monitoreo 3	• El cauce presenta gran cantidad de sedimentos por una evidente erosión en las partes altas. • La zona se encuentra impactada por ganadería a gran escala y cultivos de café, caña y plátano. • Presencia de macrófitas emergentes, con gran aporte de materia orgánica de tipo alóctono. Baja actividad perifítica.
Monitoreo 4	• Apariencia del agua algo turbia, potreros en las riberas y paso de animales por el cauce. Se observan heces de ganado. • Escasa vegetación arbórea.
Consolidado	• Punto de muestreo pequeño, con cauce expuesto completamente a la luz solar. • Presencia de sedimentos y paso frecuente de ganado sobre la columna de agua. • Presencia de grandes extensiones de eucalipto y cultivos de gulupa de exportación.

Punto 2

Monitoreo 1	• Cuerpo de agua con presencia de roca madre y sustratos: fino, rocoso y hojarasca. Agua turbia, predomina sustrato fino. • Presencia de pozas en las orillas.
Monitoreo 2	• Agua moderadamente turbia con mal olor, presencia de sustratos de diferente tipo con zonas estancadas; cauce quebrado. • Residuos sólidos en las riberas.
Monitoreo 3	• Apariencia del agua turbia, con evidentes fuentes de contaminación (constantes vertimientos de aguas residuales provenientes de las fincas cafeteras y actividades de cría de porcinos).
Monitoreo 4	• Cuerpo de agua con abundantes residuos sólidos sobre el cauce, espuma y mal olor. • Vegetación en las orillas y algas filamentosas en las rocas. Procesos erosivos.
Consolidado	• Punto de muestreo con material rocoso en abundancia, con pozas considerables y estancamiento en las orillas. • Presencia de espuma, mal olor y residuos sólidos de diferente tipo.

River basins in the department of Antioquia

Municipality of Abejorral
La Liborina river basin



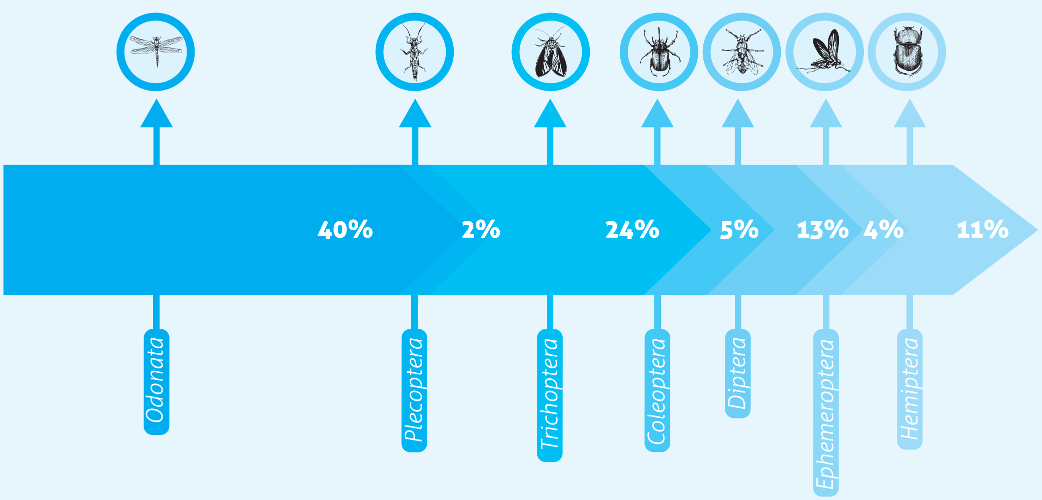
Selection of Farms by Plan
Body of water: Q. La Liborina. Abejorral, Antioquia
Scale 1:10,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program / FCM

Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 05° 47′ 27.8″ W 75° 30′ 54.4″ **Point 2:** N 05° 46′ 25,079″ W 75° 32′ 22,344″
Altitude	1,043 to 2,312 masl
Area of the river basin	2,611,12 ha
Average rainfall	2,235 mm/year
Average temperature	16.4°C
Total number of producers	756
Number of producers within 200 m from the body of water	128
Coffee area	786.86 ha
Productivity	206 @/ha of dry parchment coffee (dpc)
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 2,779 kg of COD per day Domestic: 51 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 16,411 kg of COD per day Domestic: 302 kg of COD per day

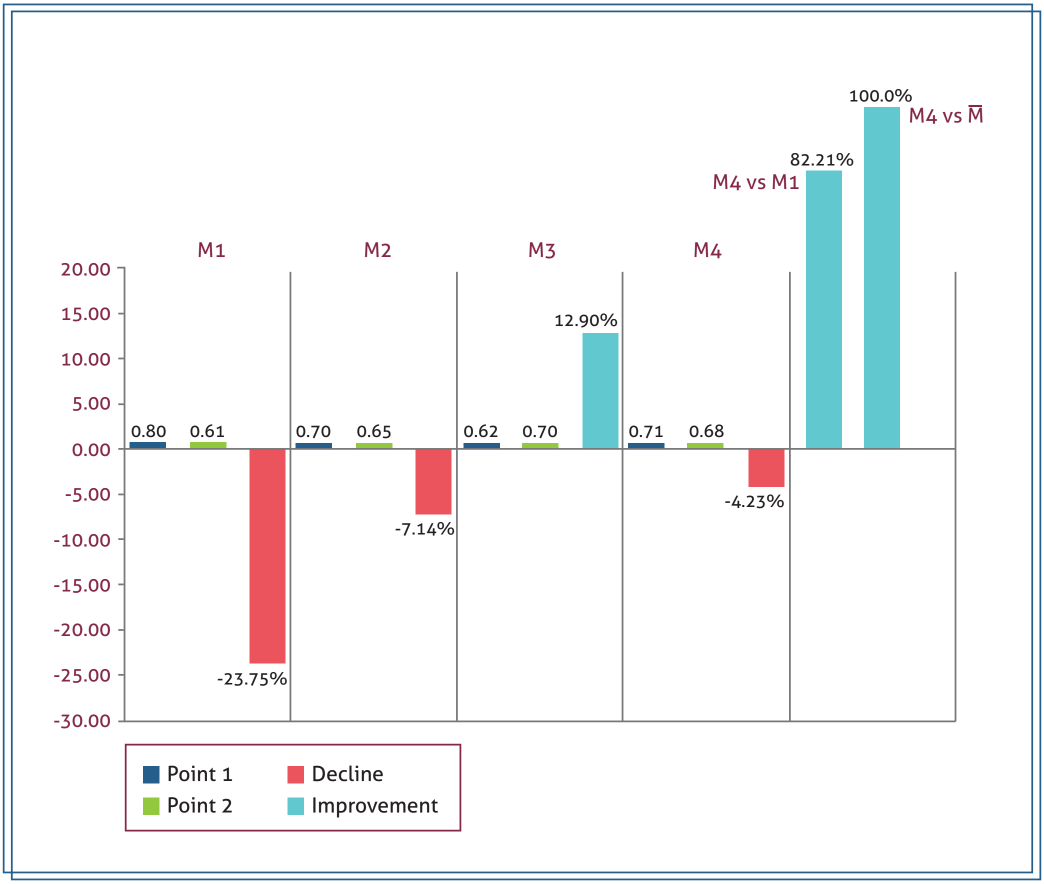
Biological groups in the river basin: Among biological groups found in the four samplings, the most dominant were: Odonata (40%), Trichoptera (24%), and Diptera (13%), which mostly are medium-to-excellent water quality indicators. They are also predatory insects, that is, they belong to groups that feed on others directly, which in some way explains health of the ecosystem. These organisms are typical of habitats with good input of leaf litter, as they use this substrate as refuge; they also require oxygen in great measure for their development and usually are in low-turbidity waters.

The orders Hemiptera, Coleoptera, Ephemeroptera, Plecoptera and Basommatophora were less represented in the total of organisms reported; they are also biological indicators of excellent-quality water and food for the dominant group (Odonata).

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, KPI at Point 1 (before the water body enters the coffee zone under study) was 0.80 and at Point 2 (after the coffee zone) was 0.61, a 23.75% decrease of overall water quality (measured when there was no coffee harvest). In sampling 2, overall quality declined 7.14% and samples were drawn in harvest time (but not in the peak); in sampling 3, overall water quality improved 12.90% from Point 1 to Point 2 (without coffee harvest). Finally, in sampling 4, in main harvest, overall quality declined 4.23% in the stretch, an improvement over initial conditions of 82.21% and over average conditions of 100%.



Habitat quality conditions in La Liborina river basin

Point 1

Monitoring 1

- Body of water of small channel and slow flow, presence of leaf litter and fine substrate, do not show rocky substrate. Clear water, undulated topography with rocks in the path.

Monitoring 2

- Small course with much sediment, coffee crops, rough waterfall-type channel, with shallow pools and good shade.

Monitoring 3

- Channel protected by large amount of vegetation around it, clear water.
- Presence of bryophytes on rocks, low periphytic activity; abundance of leaf litter.

Monitoring 4

- Small water body, shrub vegetation on both sides.
- Somewhat cloudy water, little sun exposure.

Consolidated

- Small water body with abundant leaf litter and much sediment. Cultivation of coffee on the banks.
- Low entry of sunlight into the column of water and bryophytes associated with rocks.

Point 2

Monitoring 1

- Clear water, bedrock, vegetation on the banks.
- Undulations and rocks in the channel; fine, rocky and leaf litter substrate.

Monitoring 2

- Rough channel, with falls, entrenched; rock, sediment and leaf litter substrates.
- Good shade. Clear water.

Monitoring 3

- Water appearance is somewhat cloudy; it features sandy bed, and leaf litter and sediment substrates.
- Rough portion, with 50% of canopy cover in some stretches.

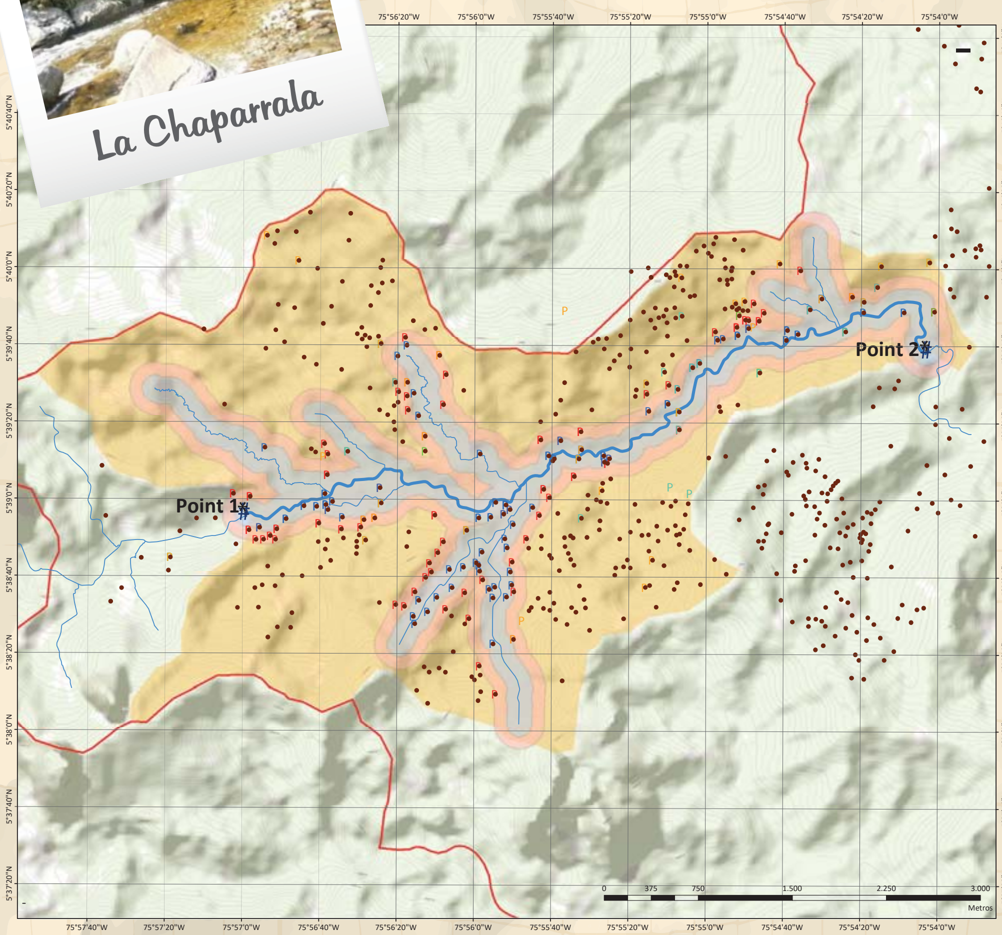
Monitoring 4

- Body of water with moderately cloudy appearance, more vegetation on the banks, with abundant climbers.

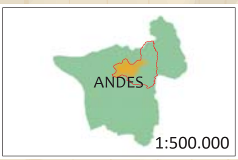
Consolidated

- Sampling point of low turbidity and abundant associated vegetation.
- Uneven, rough topography, influencing erosion processes, 50% of sunlight, bad smell and constant livestock crossing in times of agricultural production.

Municipality of Andes
La Chaparrala river basin



P Producers_Buffer100
P Producers_Buffer200
IWM Producers
P Sel. Business Management Plan
P Sel. Ecological Wet Milling Plan-WTS
P Sel. Forest Plan with Incentive
Water Quality Sampling
Reference River MultipleRing
100m
200m
IWM Intervention Areas
IWM Influence Areas



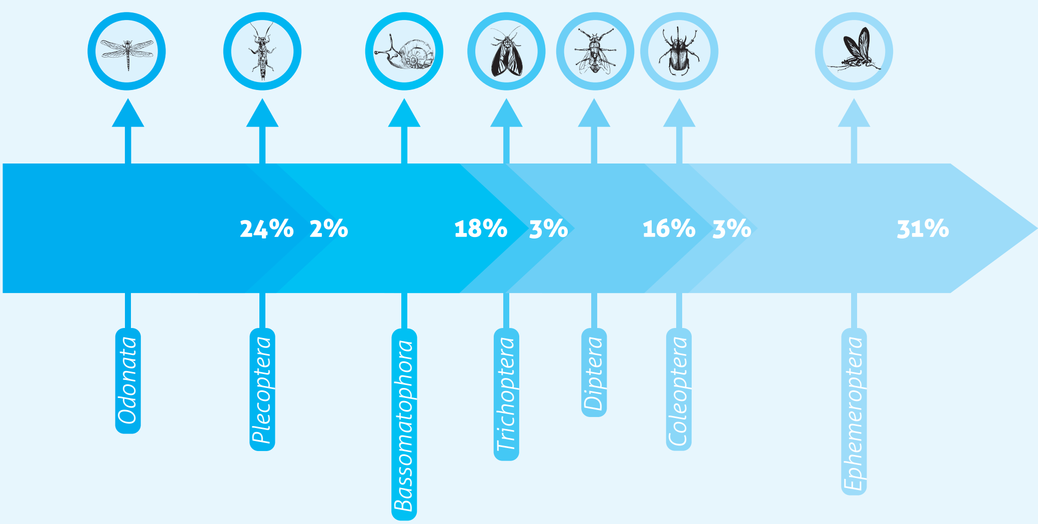
Selection of Farms by Plan
Body of water: Q. La Chaparrala. Andes, Antioquia

Scale 1:12,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program / FCM

Number of samplings	Seven conventional (including three dynamic)
Coordinates of sampling points **Point 1:** N 5° 38′ 45.7″ W75° 57′ 33.6″ **Point 2:** N 5° 39′ 38.6″ W 75° 54′ 01.8″ **Point 3:** N 5° 39′ 01.3″ W 75° 56′ 21.5″ **Point 4:** N 5° 39′ 10.7″ W 75° 56′ 00.2″ **Point 5:** N 5° 38′ 59.6″ W 75° 55′ 46.3″	**Point 6:** N 5° 39′ 07.3″ W 75° 55′ 41.7″ **Point 7:** N 5° 38′ 54″ W 75° 55′ 22.6″ **Point 8:** N 5° 38′ 54.3″ W 75° 55′ 23.1″ **Point 9:** N 5° 39′ 24.1″ W 75° 55′ 05″ **Point 10:** N 5° 39′ 41.7″ W 75° 54′ 38.6″ **Point 11:** N 5° 38′ 44.5″ W 75° 55′ 18.6″
Altitude	1,264 to 2,192 masl
Area of the river basin	2,354.90 ha
Average rainfall	1,800 mm/year
Average temperature	22°C
Total number of producers	1,261
Number of producers within 200 m from the body of water	142
Coffee area	1,401.35 ha
Productivity	227 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 5,210 kg of COD per day Domestic: 57 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 46,265 kg of COD per day Domestic: 504 kg of COD per day

Biological groups in the river basin: The most representative aquatic macroinvertebrate orders reported during the four monitoring campaigns in this river basin are: Ephemeroptera (31%), Odonata (24%), and Basommatophora (18%). These insect groups as a whole indicate medium water quality, with a trend to good; however, presence of snails indicates some degree of organic pollution in the body of water. This agrees with description of habitat conditions, with sun exposure in some stretches of La Chaparrala because of deforestation of its banks, a primary productivity increase factor in the body of water, with disproportionate growth of algae.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the beginning of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee area under study) was 0.78 and at Point 2 (after the coffee zone) was 0.63, a 19.23% decline in overall water quality (measured when there was no coffee harvest). In sampling 2, overall quality fell 31.43%, measured in harvest time (out of the peak); in sampling 3, quality declined 29.33% (without coffee harvest); in sampling 4, in main harvest, overall quality in the stretch fell 11.29%; in sampling 5, in harvest time, water quality improved 19.27%, and in sampling 6, without harvest, quality improved 2.35%. Lastly, in sampling 7, in harvest time, quality declined 12.92%, an improvement over initial conditions of 32.80% and over average conditions of 39.53%.

Habitat quality conditions in La Chaparrala river basin

Point 1

Monitoring 1

- Body of water with large rocks, rough topography, clear water, coarse-grained rocks, transport of material because of increase in flow.

Monitoring 2

- Rough channel with substrates favorable for establishment of fish; submerged vegetation; presence of rapids, substrates for macroinvertebrates, sandy bed, large rocks, moderate algal growth and stagnant water (pools).

Monitoring 3

- Body of water with low periphytic activity, substrates for macroinvertebrates, rocky bed, sediment, and a little leaf litter; pools for fish development.
- Livestock on the banks.

Monitoring 4

- Water somewhat cloudy, rocky substrate, with abundant algae.
- There are rapids and large rocks along the path.
- Paddocks on the banks are evident, and livestock have access to water body.

Consolidated

- Sampling point with 70% of sun exposure, which influences periphytic activity in the column of water.
- Substrate is mostly rocky. Livestock access to banks.

Point 2

Monitoring 1

- Water somewhat cloudy due to sediments. Good vegetation presence, and coffee and banana plantations.
- Bedrock, homogeneous topography, and substrates for macroinvertebrates.

Monitoring 2

- Great flow, moderately turbid water, much sediment, native vegetation, moderate growth of filamentous algae.
- Large amount of solid waste around the river basin and bad smell.

Monitoring 3

- Somewhat cloudy water, substrates are evident as rocky bed, submerged vegetation, sediment, and roots. Cultivation of coffee and banana on the banks, near town.
- Solid waste of different types in the water body. Eroded banks.

Monitoring 4

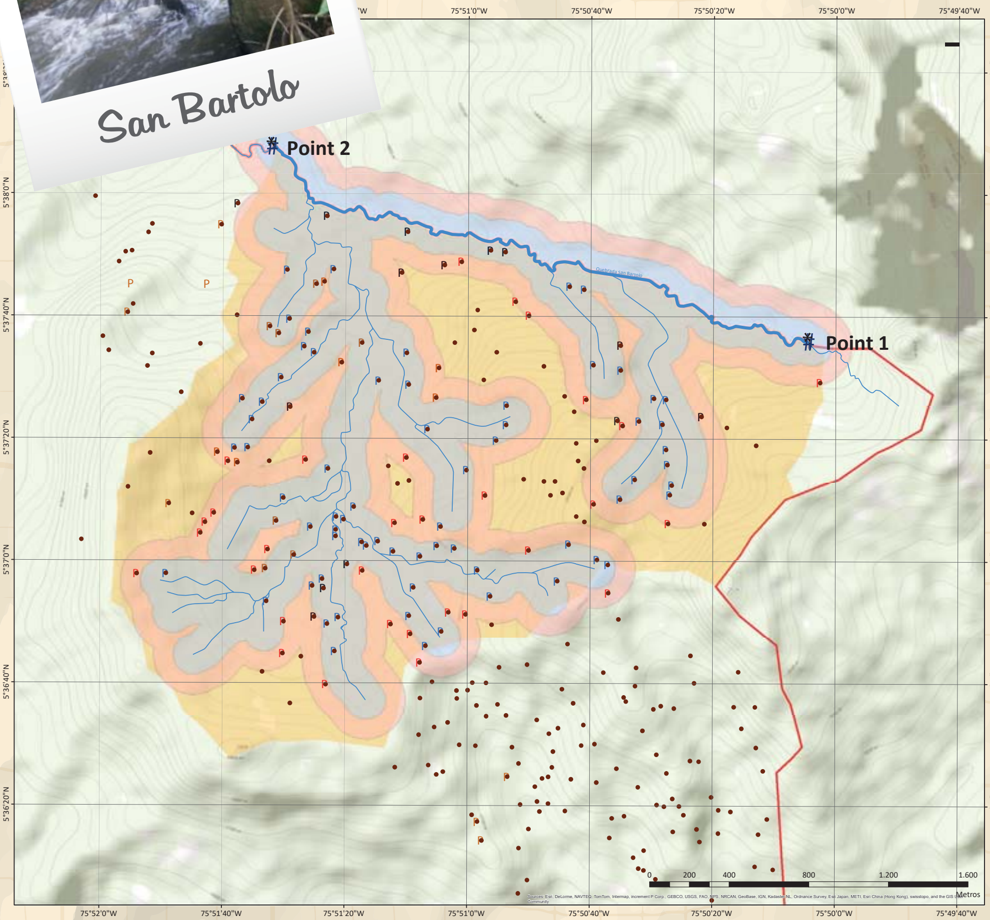
- Large rocks and coffee wastewater smell, white foam and erosion upstream from the monitoring point.

Consolidated

- Sampling point with abundant flow, moderate turbidity because of primary activity in the channel mediated by algae.
- Vegetation on both banks and large rocks, intermittent presence of solid waste. Extensive areas cultivated with coffee a few meters away from the river.

Municipality of Jardín

San Bartolo river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Body of water: Q. San Bartolo. Jardín, Antioquia

Scale 1:7,500

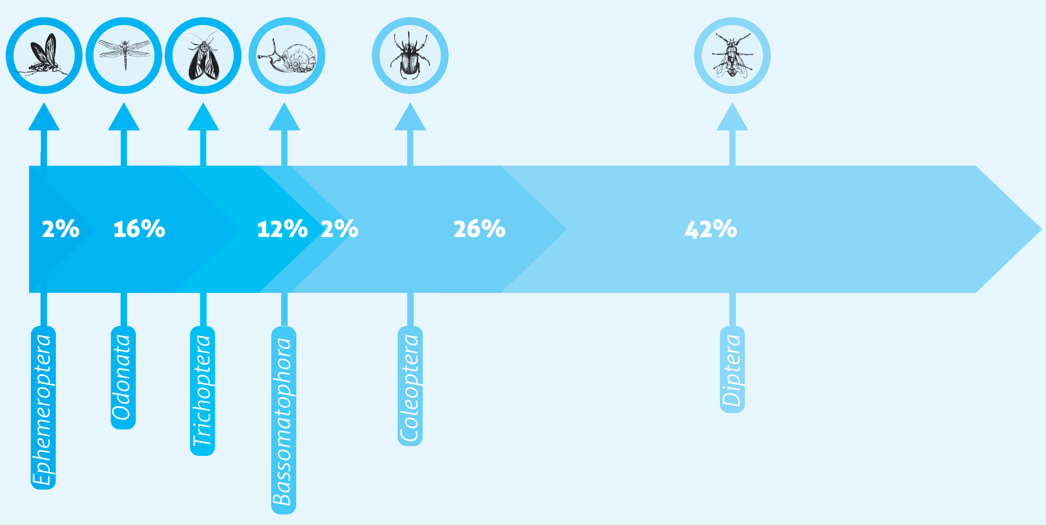
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program / FCM

Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 05° 37' 27.5" W 75° 49' 58.6" **Point 2:** N 05° 38' 07.4" W 75° 51' 34.7"
Altitude	1,452 to 2,034 masl
Area of river basin	779.49 ha
Average rainfall	2,808 mm/year
Average temperature	19°C
Total number of producers	803
Number of producers within 200 m from the body of water	123
Coffee area	493.04 ha
Productivity	224 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 2,934 kg of COD per day Domestic: 49 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 19,156 kg of COD per day Domestic: 321 kg of COD per day

Biological groups in the river basin: Biological results show that the largest percentage distributions of aquatic macroinvertebrate orders in the target river basin in the municipality of Jardín are Diptera (42%), Coleoptera (26%), and Odonata (16%). This shows that the San Bartolo river basin, with dominance of larvae of mosquitoes and flies, shows slight pollution in its waters, with habitat alteration: reduction of vegetation on the banks, allowing entry of sunlight into the column of water, in addition to proximity of the body of water to the Jardín municipality, which impacts its conservation with domestic discharges from nearby households.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.58 and at Point 2 (after the coffee zone) was 0.51, a 12.07% decline in overall water quality (measured without coffee harvest). In sampling 2, overall quality declined 6.45%, assessed during harvest (out of its peak), and in sampling 3, overall water quality between points 1 and 2 (without coffee harvest) declined 1.75%. Finally, in sampling 4, during main harvest, overall quality in the stretch fell 15.63%, a decline over initial conditions of 29.46% and an improvement over average conditions of 32.08%.

Habitat quality conditions in the San Bartolo river basin

Point 1

Monitoring 1

- Body of water with fine, leaf litter, and sandy-clayey substrate; low turbidity, gulupa crops on hillsides.

Monitoring 2

- Small channel with much sediment.
- Irregular and rough channel with banks eroded in bends.

Monitoring 3

- The channel features much sediment because of evident erosion in upper parts.
- Impacts by large-scale livestock and coffee, sugarcane and banana plantations.
- Emergent macrophytes, with great contribution of allochthonous organic matter; low periphytic activity.

Monitoring 4

- Somewhat cloudy water, paddocks on the banks and animal access to channel. Livestock manure.
- Scarce tree vegetation.

Consolidated

- Small sampling point, channel fully exposed to sunlight.
- Sediment and frequent access of livestock to course.
- Large extensions of eucalyptus and export gulupa crops.

Point 2

Monitoring 1

- Body of water with bedrock, and fine, rocky and leaf litter substrates. Turbid water; fine substrate predominates.
- Pools on the banks.

Monitoring 2

- Moderately turbid water with bad smell, substrates of different types with stagnant zones; rough channel.
- Solid waste on the banks.

Monitoring 3

- Turbid water, with notorious sources of pollution (constant discharges of wastewater from coffee farms and pig farming).

Monitoring 4

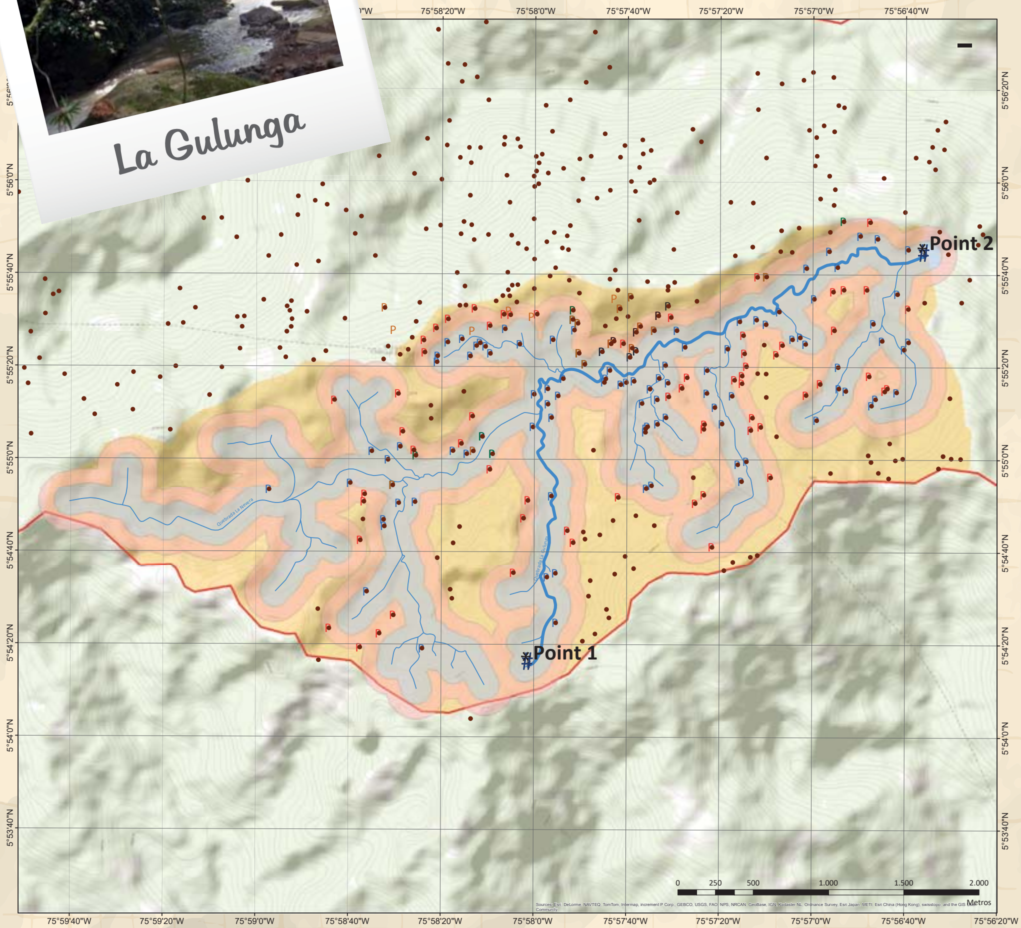
- Body of water with much solid waste on the channel, foam and bad smell.
- Vegetation on the banks and filamentous algae on the rocks. Erosion processes.

Consolidated

- Sampling point with rocky material in abundance, with a number of pools and stagnant waters on the banks.
- Presence of foam, bad smell, and waste of different types.

Municipality of Salgar

La Gulunga river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Body of water: Q. La Gulunga. Salgar, Antioquia

Scale 1:10,000

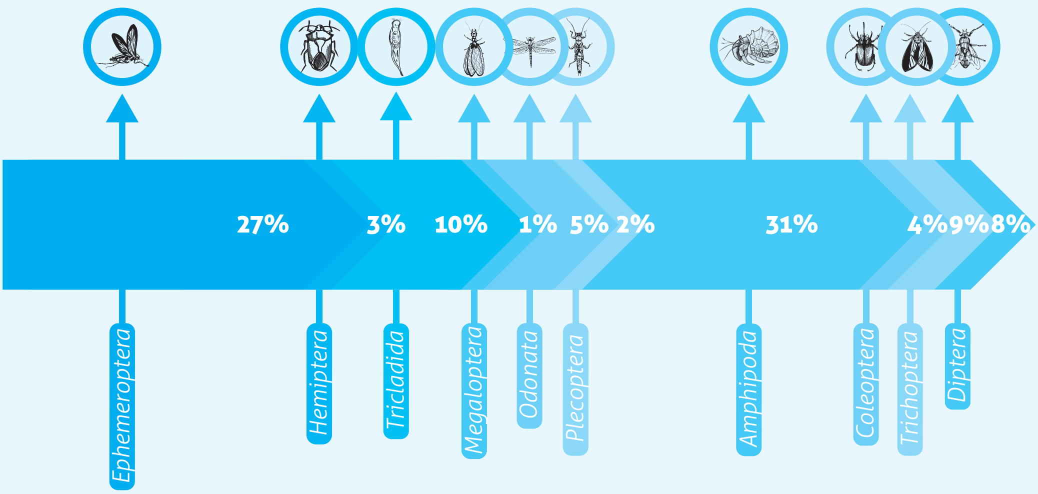
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program / FCM

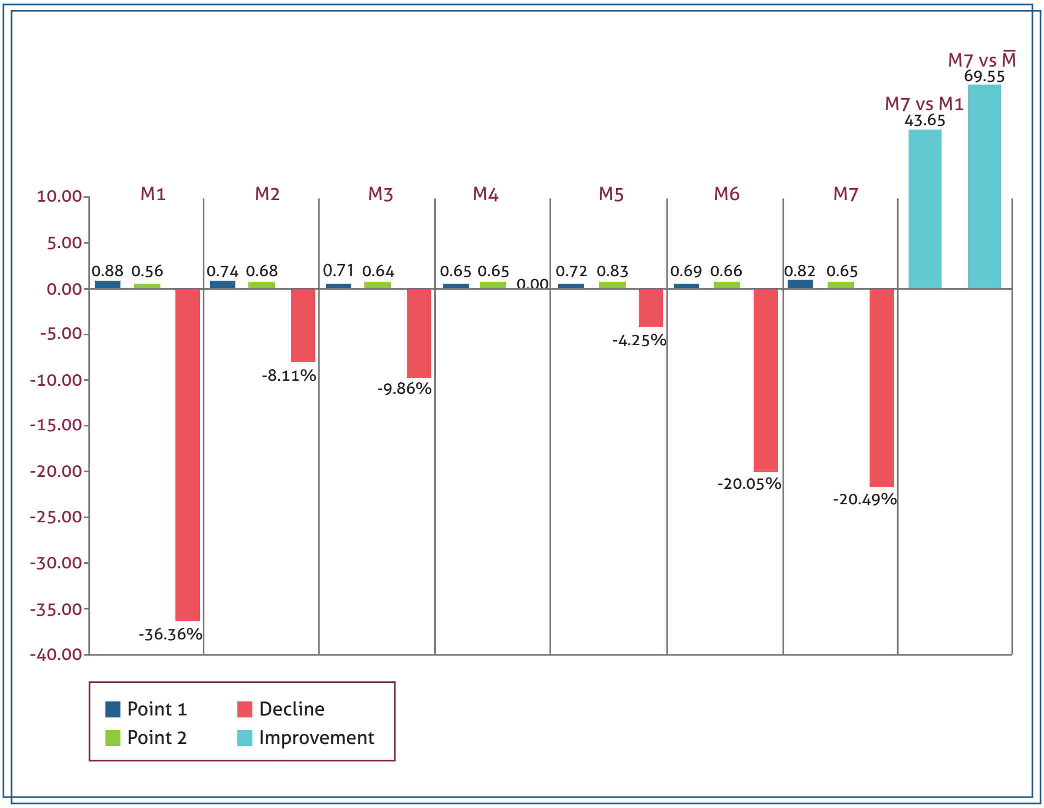
Number of samplings	Seven conventional
Coordinates of sampling points	**Point 1:** N 5° 54' 19.6" W 75° 58' 17.5" **Point 2:** N 5° 55' 44.9" W 75° 56' 34.5"
Altitude	1,182 to 2,140 masl
Area of the river basin	2,879.16 ha
Average rainfall	2,000 to 4,000 mm/year
Average temperature	23 °C
Total number of producers	714
Number of producers within 200 m from the body of water	197
Coffee area	1,397.96 ha
Productivity	229 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 6,885 kg of COD per day Domestic: 79 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 24,955 kg of COD per day Domestic: 286 kg of COD per day

Biological groups in the river basin: The groups of aquatic insects found, Amphipoda (31%), Ephemeroptera (27%) and Tricladida (10%), suggest that water quality is good; however, the third group, Tricladida (flatworms), indicates some pollution by domestic wastewater, especially after the intervention zone (Point 2). Low presence of orders Trichoptera, Diptera and Odonata indicates low-pollution quality and a river basin habitat that is mostly well conserved.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone intervened) was 0.88 and at Point 2 (after the coffee area) was 0.56, a 36.36% decline in overall water quality (measured without coffee harvest). In sampling 2, overall quality fell 8.11%, assessed in harvest time (out of its peak); in the third monitoring campaign, overall water quality between Points 1 and 2 (without coffee harvest) fell 9.86%; in sampling 4, in main harvest, there was no quality decline in the stretch; in sampling 5, during harvest time, water quality fell 4.25%, and in sampling 6, without harvest, quality declined 20.05%. Finally, in sampling 7, in harvest time, quality declined 20.49%, a 43.65% improvement over initial conditions and a 69.55% improvement over average conditions.



Habitat quality conditions in the La Gulunga river basin

Point 1

Monitoring 1

- Clear water, thick riparian vegetation, homogeneous rocky bed, low flow, small channel; fine, rocky, and leaf litter substrate.

Monitoring 2

- Very small channel, with large canopy cover. Rocky bed, with good vegetation around.

Monitoring 3

- Located in the upper part of the river basin, clear water, good vegetation around. Large coffee and banana plantations in the upper part.

Monitoring 4

- Body of water of small channel, solid waste on banks. Eroded bends. Access of animals to the channel.

Consolidated

- Small water body with clear water, slight transport of rocky material, abundant vegetation. Rough topography, little sunlight coming into the column of water.

Point 2

Monitoring 1

- Clear water, thick riparian vegetation, homogeneous rocky bed, low flow; fine, rocky substrate, and abundant leaf litter.

Monitoring 2

- Cloudy water, with much sediment, abundance of filamentous algae on rocks, fragmented channel, good canopy cover along the stretch, rocky bed.

Monitoring 3

- Somewhat cloudy water, much sediment, good presence of leaf litter, and sandy bed. Canopy cover over the channel.
- Coffee crops in much of the area. Moderate growth of filamentous algae. Wastewater smell.
- Fallen trees by anthropogenic activity.

Monitoring 4

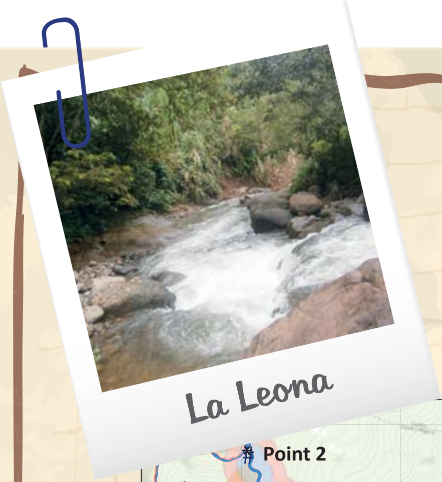
- Body of water with evident sources of pollution (bad smell and moderately turbid water). Solid waste along the stretch, eroded bends, full canopy cover, and low periphytic activity.

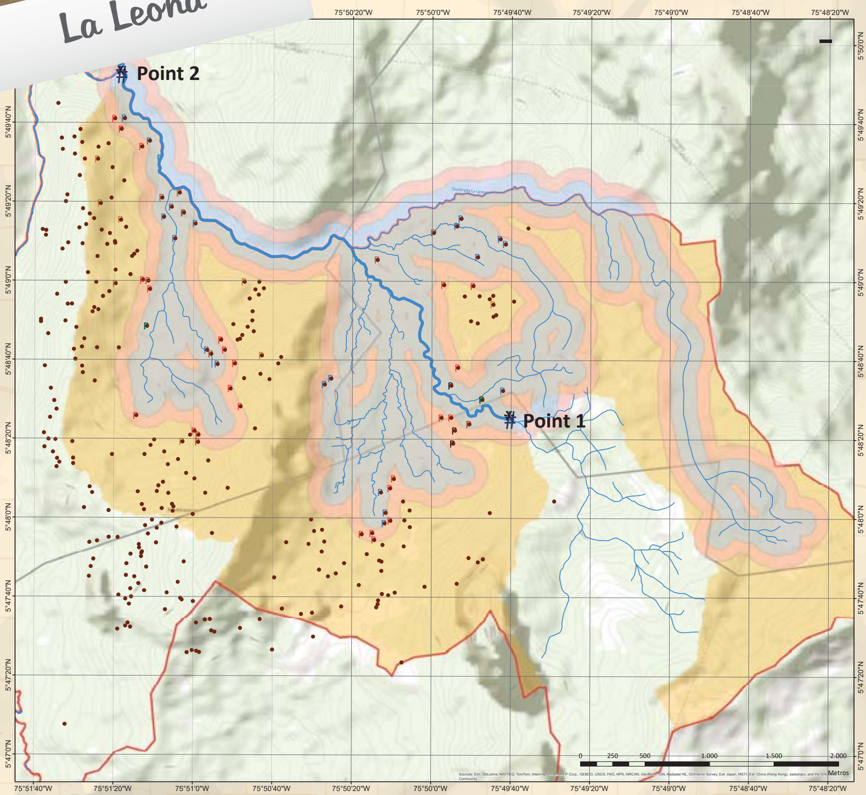
Consolidated

- Sampling point with some turbidity, rocky bed, slight slope of watercourse.
- Significant supply of plant material; in some areas, with sunlight, there is periphytic activity.
- Strong wastewater smells.

Municipality of Pueblorrico

La Leona river basin





- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Body of water: Q. La Leona. Pueblorrico, Antioquia

Scale 1:10,000

Source: IWM Program Basic Cartography. Scale 1:2,000

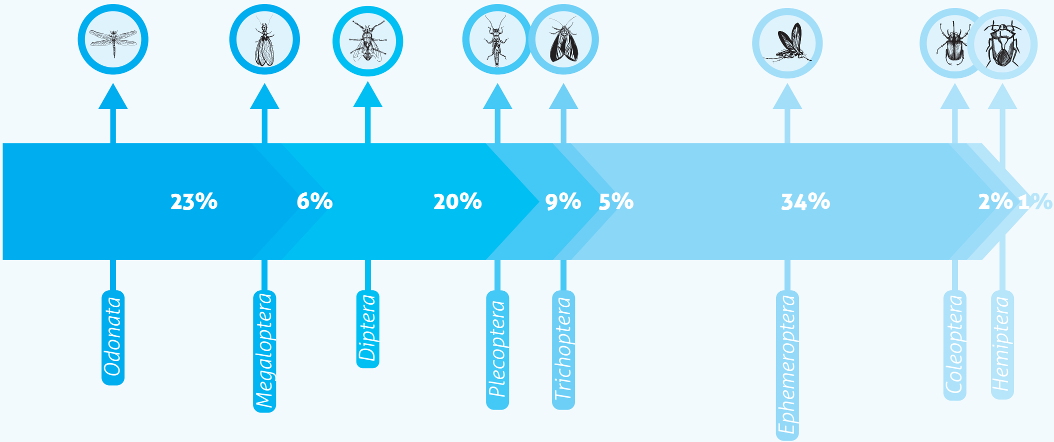
Prepared by: FNC contribution to IWM Program / FCM

Number of samplings	Four conventional
Coordinates of sampling points	Point 1: N 05° 48' 27.8" W 75° 49' 43.4" **Point 2:** N 05° 49' 27.1" W 75° 51' 08.1"
Altitude	1,239 to 2,032 masl
Area of the river basin	822.44 ha
Average rainfall	2,993 mm/year
Average temperature	19 °C
Total number of producers	392
Number of producers within 200 m from the body of water	64
Coffee area	399.34 ha
Productivity	240 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 1,688 kg of COD per day Domestic: 26 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 10,337 kg of COD per day Domestic: 157 kg of COD per day

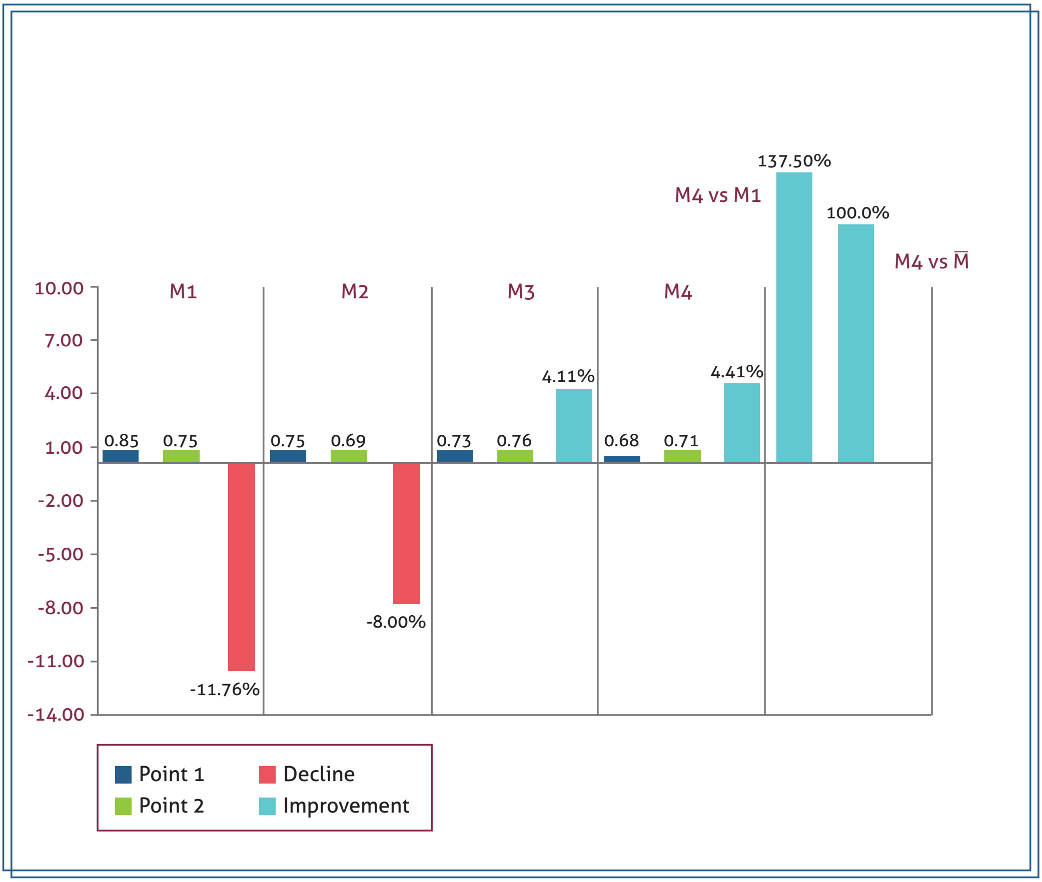
Biological groups in the river basin: To estimate water quality through aquatic macroinvertebrates (bioindication), in this body of water the orders with greatest presence were Ephemeroptera (34%), Odonata (23%), and Diptera (20%), indicating that water quality in general is good; however, presence of larvae of mosquitoes and flies as third percentage (Diptera) indicates some pollution degree in the freshwater habitat; and as shown in the habitat assessment protocol, there are some risks in Q. La Leona such as livestock access, riparian deforestation, and domestic wastewater.

On the other hand, the less abundant groups keep the trend of good conditions, with some degree of pollution associated with the above-mentioned risks, allowing establishment of communities of organisms typical of moderately polluted waters.

Biological groups in the river basin



Overall index of water quality i¬n the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the body of water enters the coffee zone under study) was 0.85 and at Point 2 (after the coffee area) was 0.75, a 11.76% decline in overall water quality (measured when there was no coffee harvest). In sampling 2, during harvest (out of its peak), overall quality fell 8%, and in sampling 3, overall water quality between Points 1 and 2 (without coffee harvest) improved 4.11%. Lastly, in sampling 4, during main harvest, overall quality improved 4.41% in the stretch, an improvement over initial conditions of 137.5% and over average conditions of 100%.



Quality habitat conditions in La Leona river basin

Point 1

Monitoring 1

- Body of water with bedrock; fine, rocky substrate. Clear water, sediment in pools. Vegetation on the banks.

Monitoring 2

- Channel with abundant rocky material, clear water, and sediment. Upper part of the river basin with moderate algal growth, and paddocks downstream from sampling point. Pink cedar plantations.

Monitoring 3

- Paddocks on the banks (frequent access of livestock to river basin) and coffee plantations, with diverse vegetation on the banks as substrate for fish and macroinvertebrates.

Monitoring 4

- Body of water with clear water, rocks completely covered by moss.
- More vegetation on the banks over the other samplings and continuous evidence of livestock on the banks.

Consolidated

- Clear water in all the monitoring campaigns, abundant rocky material, moderate algal growth.
- Frequent access of livestock on both sides, coffee crops downstream from the point, and eroded banks.

Point 2

Monitoring 1

- Body of water with bedrock, undulations and roughness along the channel, abundant red and green algae, smooth rocks; fine, rocky and leaf litter substrate. Paddocks on the banks.

Monitoring 2

- Turbid water, patches of mixed vegetation, and large rocks.

Monitoring 3

- Diverse vegetation on the banks, rocky bed, and pools of different sizes, allowing fish development.
- Impact on the zone by large-scale sugarcane crops and coffee in the upper part.

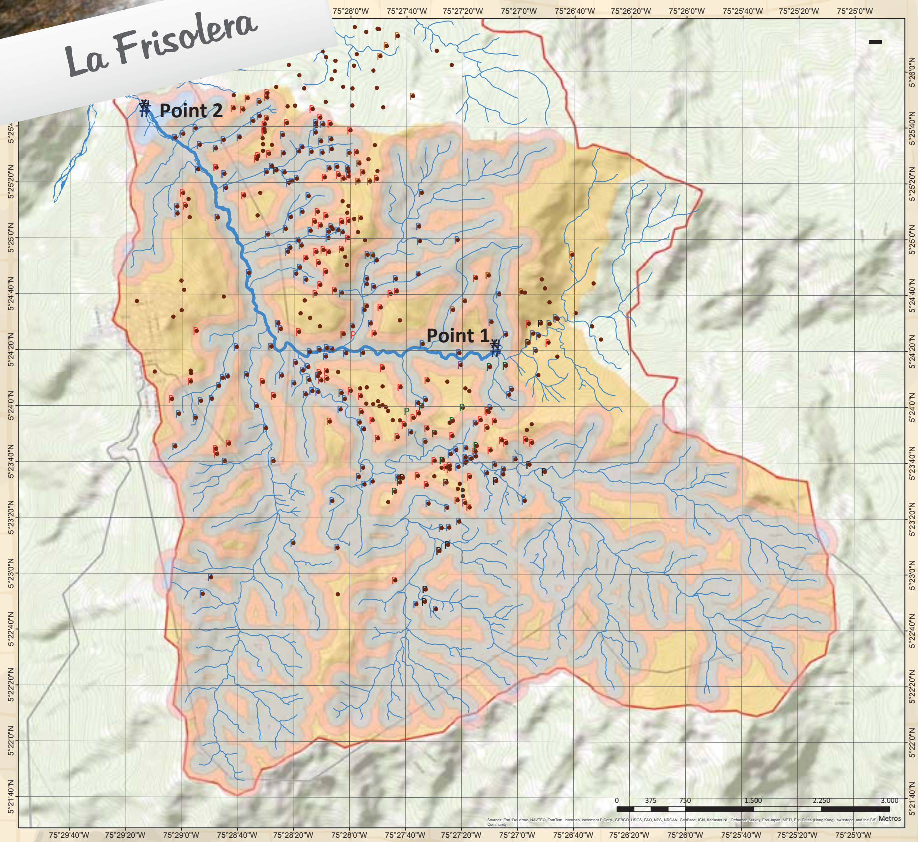
Monitoring 4

- Body of water with large rocks.
- Paddocks on one of the banks.

Consolidated

- Turbid water, undulating channel. Evidence of primary productivity by presence of photosynthetic algae, being the substrate of different aquatic organisms.
- Continued access of livestock to the river.

Municipality of Salamina
La Frisolera river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

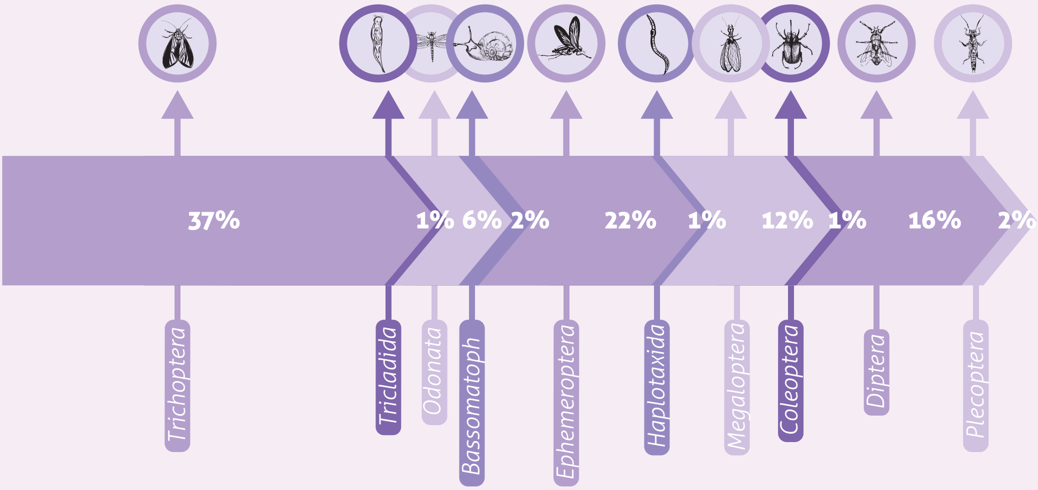
- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan
Body of water: Q. La Frisolera. Salamina, Caldas
Scale 1:15,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program / FCM

Number of samplings	Seven conventional (including five dynamic)
Coordinates of sampling points **Point 1:** N 5° 24' 19.92" W 75° 27' 7.64" **Point 2:** N 5° 25' 46.55" W 75° 29' 12.14" **Point 3:** N 5° 24' 33.38" W75° 28' 32.38"	Point 4: N 5° 24' 31.98" W 75° 28' 30.72" **Point 5:** N 5° 24' 36.97" W 75° 28' 35.01" **Point 6:** N 5° 24' 21.47" W 75° 27' 13.07" **Point 7:** N 5° 24' 20.30" W 75° 27' 12.71"
Altitude	1,160 to 2,016 masl
Area of the river basin	1,600.91 ha
Average rainfall	1,800 to 2,000 mm/year
Average temperature	19 °C
Total number of producers	432
Number of producers within 200 m from the body of water	290
Coffee area	731.93 ha
Productivity	211 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 5,438 kg of COD per day Domestic: 116 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 8,101 kg of COD per day Domestic: 173 kg of COD per day

Biological groups in the river basin: After the four water quality monitoring campaigns in this coffee river basin, the most representative aquatic insect orders were Trichoptera (37%), Ephemeroptera (22%) and Diptera (16%). The first two organism groups indicate a water body in process of recovery, in transition of medium to good quality, with colonization of new groups, establishment of communities indicating good quality, and more microhabitats available for development and reproduction of these taxa. However, the third-largest order, Diptera, is a group of organisms that one way or another generates alert for some habitat parameters, as they indicate processes of pollution of a different nature, tending to moderately polluted waters.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project, the KPI at Point 1 (before the coffee zone) was 0.87 and at Point 2 (after the coffee zone) was 0.56, a 35.63% decline in overall water quality, assessed in mid-harvest or "mitaca". In sampling 2, overall quality declined only 6.33%, despite being assessed in main harvest; in sampling 3 overall water quality between points 1 and 2 (in mid-harvest or mitaca) improved 4.76%. In sampling 4, in main harvest, water quality declined 17.72%; in sampling 5, in harvest time, water quality declined 18.65%, and in sampling 6, without harvest, quality declined 11.62%. Finally, in monitoring campaign 7, in harvest time, quality declined 22.08%, an improvement over initial conditions of 38.03% and over average conditions of 64.79%.

Habitat quality conditions in La Frisolera river basin

Point 1

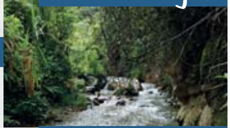
Monitoring 1

- Bedrock, undulations along the body of water; predominance of herbs, shrubs, bamboo, and coffee on both sides, with bridle path. Fine, rocky, and leaf litter substrate.

Monitoring 2

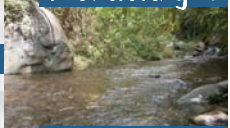
- Body of water with bedrock; sediment, rocky, and leaf litter substrate. Water is clear and there is abundant dry vegetation.

Monitoring 3



- Slope on both sides with large rocks, low periphytic activity with sun exposure and much sediment.

Monitoring 4



- Laminar flow, rough channel. Small and medium-sized rocks, clear water, vegetation on the banks, substrates of different types.

Consolidated

- Body of water with large rocks, predominance of shrubs on both sides, and coffee crops.

Point 2

Monitoring 1

- Undulations through the channel, cloudy water, with herbaceous and shrubby vegetation.
- Landslides and unstable areas, rough channel.

Monitoring 2

- Body of water with bedrock; sediment, rocky, and leaf litter substrates.

Monitoring 3

- Channel with sun exposure, tree and shrub vegetation on both sides; meandering course, and large oxbow lakes.
- Small pool areas and slight slope.

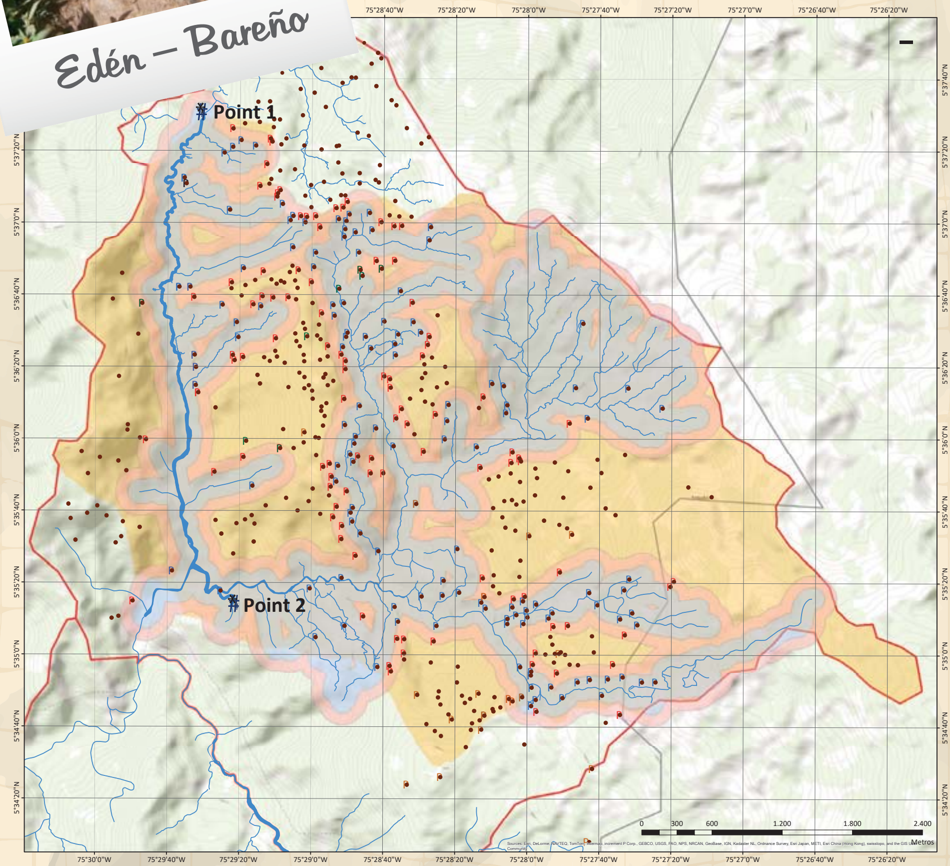
Monitoring 4

- Body of water with laminar flow in some portions, medium-sized rocks. Fine and rocky substrate, with roots submerged in the body of water.

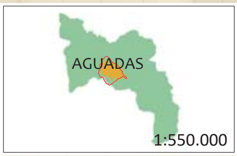
Consolidated

- Undulating and heterogeneous topography; herbaceous and shrub vegetation; landslides and unstable areas around the channel.
- Availability of different substrates for establishment of aquatic communities.

Municipality of Aguadas
El Edén-Bareño river basin



P Sel. Forest Plan with Incentive
P Sel. Business Management Plan
P Sel. Ecological Wet Milling Plan-WTS
• IWM Producers
P Producers_Buffer100
P Producers_Buffer200
Water Quality Sampling
Reference River MultipleRing
100m
200m
IWM Intervention Areas
IWM Influence Areas

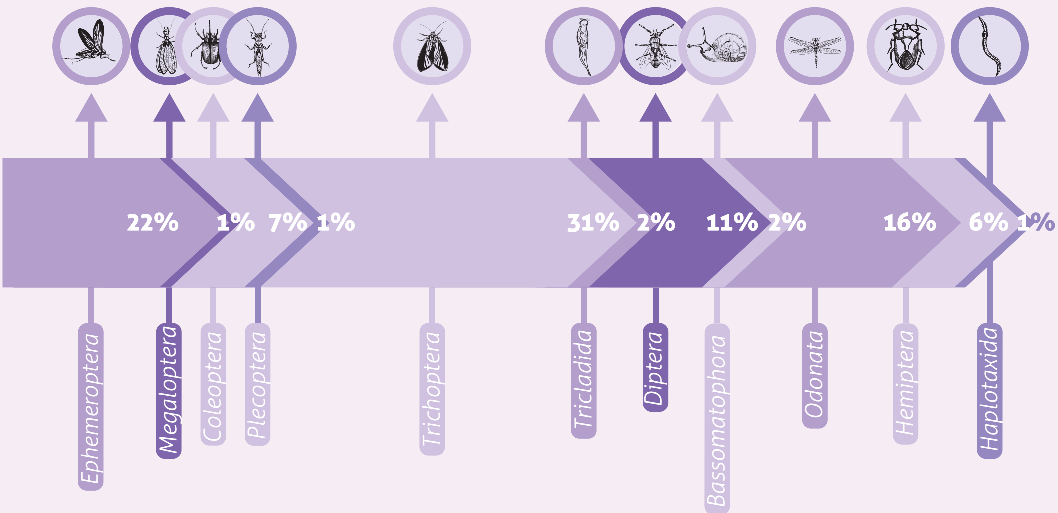


Selection of Farms by Plan
Body of water: Q. El Edén-Bareño. Aguadas, Caldas
Scale 1:12,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program / FCM

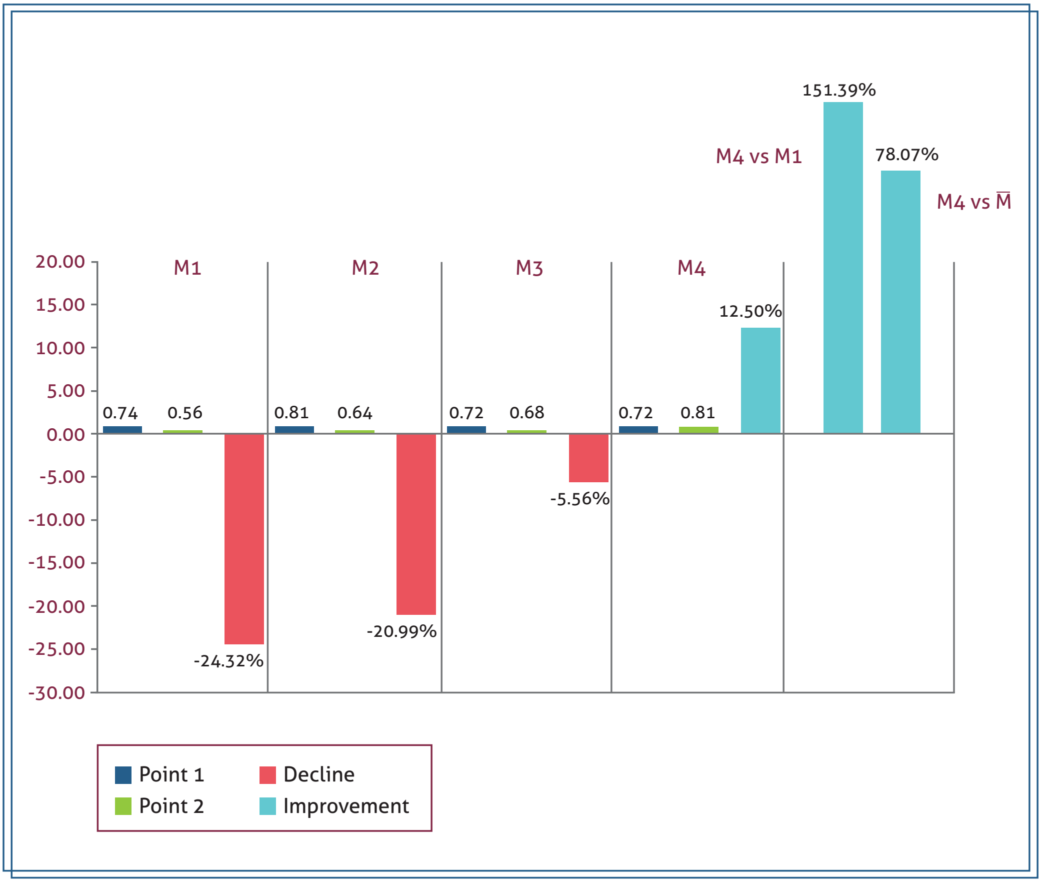
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 05° 37.498' **Point 2:** W 75° 29.503'
Altitude	1,126 a 2,113 masl
Area of the river basin	1,605 ha
Average rainfall	1,500 a 2,500 mm/year
Average temperature	17 °C
Total number of producers	601
Number of producers within 200 m from the body of water	245
Coffee area	831.22 ha
Productivity	218 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 4,446 kg of COD per day Domestic: 98 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 10,907 kg of COD per day Domestic: 240 kg of COD per day

Biological groups in the river basin: A recovery process is evident in the monitored areas; the most represented taxa were Trichoptera (31%), Ephemeroptera (22%) and Odonata (16%), whose trophic chains enable these insectivorous and omnivorous groups to increase their populations and dominate over the rest of the orders. They bioindicated quality improvement along the monitoring, according to the variables of habitat assessment protocol and physicochemical conditions.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone intervened) was 0.74 and at Point 2 (after the coffee zone) was 0.56, a 24.32% decline in overall water quality (evaluated in mid-harvest or mitaca). In sampling 2, in main harvest, overall quality fell 20.99%, while in sampling 3 water quality between points 1 and 2 (in mid-harvest or mitaca) declined 5.56%. Finally, in sampling 4, in main harvest, overall quality improved 12.50% in the stretch, an improvement of 151.39% over initial conditions and of 78.07% over average conditions.



Habitat quality conditions in El Edén-Bareño river basin

Point 1

Monitoring 1

- Confined body of water, not featuring rocky substrate. Small and slow-flow channel. Fine and leaf litter substrate.

Monitoring 2

- Predominance of sediment substrate, presence of leaf litter and rock, crops around, solid waste on one side, access of pack animals.

Monitoring 3

- Sampling point with vegetation on both sides, low sun exposure because of canopy cover, rocky-sandy substrate, with periphytic activity.

Monitoring 4

- Small channel, more vegetation over the other samplings.

Consolidated

- Monitoring point with rocky substrate mainly, due to topographic conditions.
- Incoming sunlight into the column of water, causing photosynthetic algal proliferation, more vegetation as monitoring progresses.

Point 2

Monitoring 1

- Body of water with large rocks, vegetation on the banks. Fine, rocky, and leaf litter substrate.

Monitoring 2

- Foam, slight turbidity; sediment, rocky substrate, and submerged vegetation.
- Paddocks, tree strips, some primary forest in the upper part.

Monitoring 3

- Body of water with large rock substrate (island type), slight slope with abundant deposition of leaf litter, small percentage of vegetation cover.

Monitoring 4

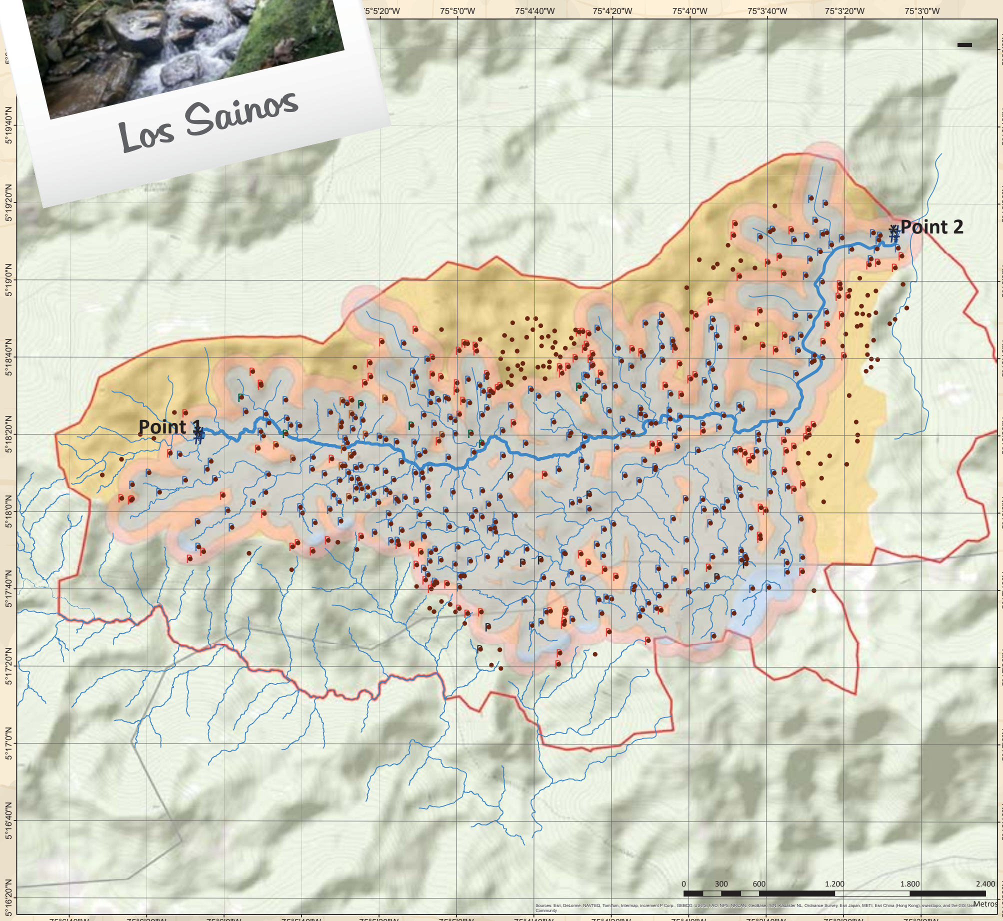
- Body of water with rocks of different sizes, white foam, and vegetation. Fine, rocky, and leaf litter substrate.

Consolidated

- Body of water with large rocks, vegetation on both sides, somewhat cloudy water.
- Body of water with slight slope, evident sources of pollution.

Municipality of Marquetalia

Los Saínos river basin



P Sel. Forest Plan with Incentive
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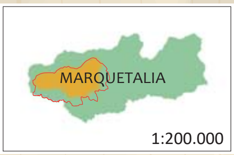
Water Quality Sampling

Reference River MultipleRing

100m
200m
IWM Intervention Areas
IWM Influence Areas



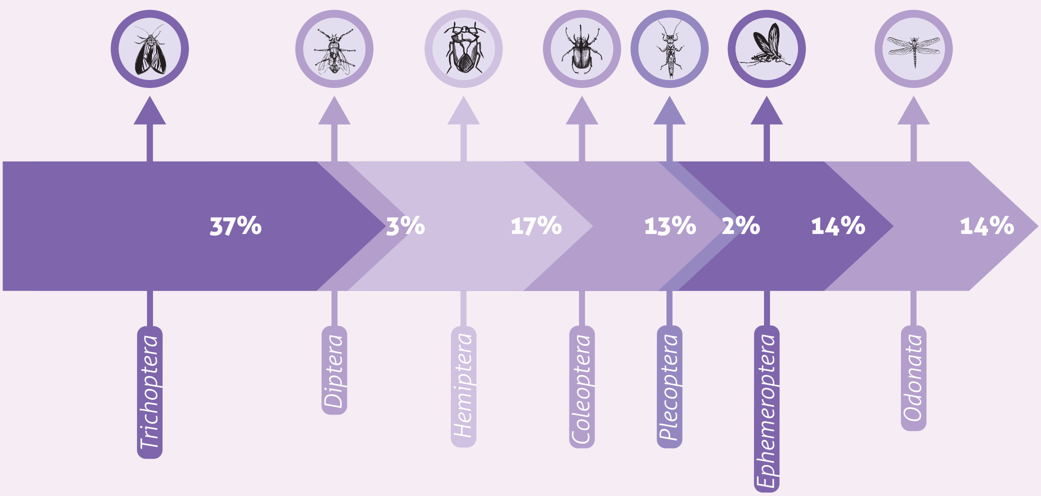
Selection of Farms by Plan
Body of water: Q. Los Saínos. Marquetalia, Caldas

Scale 1:12,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program / FCM

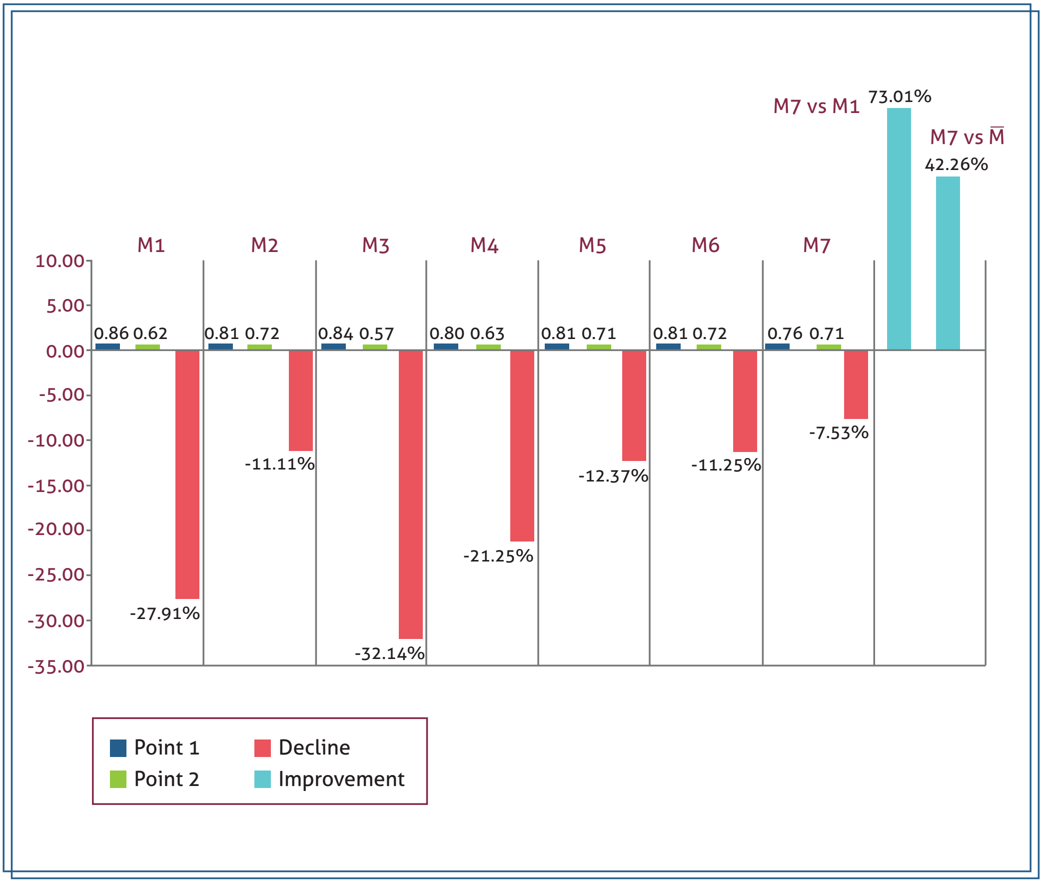
Number of samplings	Seven conventional
Coordinates of sampling points	**Point 1:** N 05° 18.326' W 75° 06.099' **Point 2:** N 05° 19.181' W 75° 03.105'
Altitude	1148 to 1874 masl
Area of the river basin	1413.08 ha
Average rainfall	500 to 1000 mm/year
Average temperature	21°C
Total number of producers	851
Number of producers within 200 m from the body of water	504
Coffee area	742.39 ha
Productivity	177 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 6189 kg of COD per day Domestic: 202 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 10450 kg of COD per day Domestic: 340 kg of COD per day

Biological groups in the river basin: Among biological representatives in the target body of water, the orders Trichoptera (37%), Hemiptera (17%) and Odonata (14%) were recorded, with caddisflies dominating again (Trichoptera); they derive their name from the structure they form with plant and rocky remains, as a bag, to protect themselves in their larval phase in water; then, by a metamorphosis process, they go out to land to fly and reproduce. They are considered indicators of good and excellent water quality, being colonizers of freshwater systems in process of ecological restoration.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.86 and at Point 2 (after the coffee zone) was 0.62, a 27.91% decline in overall water quality (assessed in mid-harvest or mitaca). In sampling 2, overall quality declined 11.11%, during main coffee harvest; in sampling 3, water quality between Points 1 and 2 (in mid-harvest or mitaca) fell 32.14%; in sampling 4, in main harvest, water quality fell 21.25%; in sampling 5, in harvest time, water quality declined 12.37%, and in sampling 6, when there was no harvest, quality declined 11.25%. Lastly, in sampling 7, in harvest time, quality declined 7.53%, an improvement over initial conditions of 73.01% and over average conditions of 42.26%.



Habitat quality conditions in Los Saínos river basin

Point 1

Monitoring 1

- Filamentous algae on the rocks; channel with undulations and roughness along the stretch; bedrock, and substrates of different types.

Monitoring 2

- Rocks along the channel. Abundant leaf litter, sediments and rocks.

Monitoring 3

- Sampling point with abundant vegetation, good organoleptic properties, rocky material of different sizes, and significant supply of leaf litter.

Monitoring 4

- Vegetation fallen on the channel; clear water, and large rocks on the stretch.

Consolidated

- Monitoring point with photosynthetic algae and abundant leaf litter deposited by allochthonous vegetation or introduced. Acceptable organoleptic properties and good trophic supply for aquatic biological groups.

Point 2

Monitoring 1

- Beach and undulations in some portions of the channel, somewhat cloudy and shallow; broad channel with substrates of sediment, rock and leaf litter.

Monitoring 2

- Substrates of leaf litter, sediment and rocks, with various crops around. Patches of different trees, clear water, and little canopy cover.

Monitoring 3

- Rocky material, acceptable organoleptic properties, full solar exposure, and low periphytic activity.

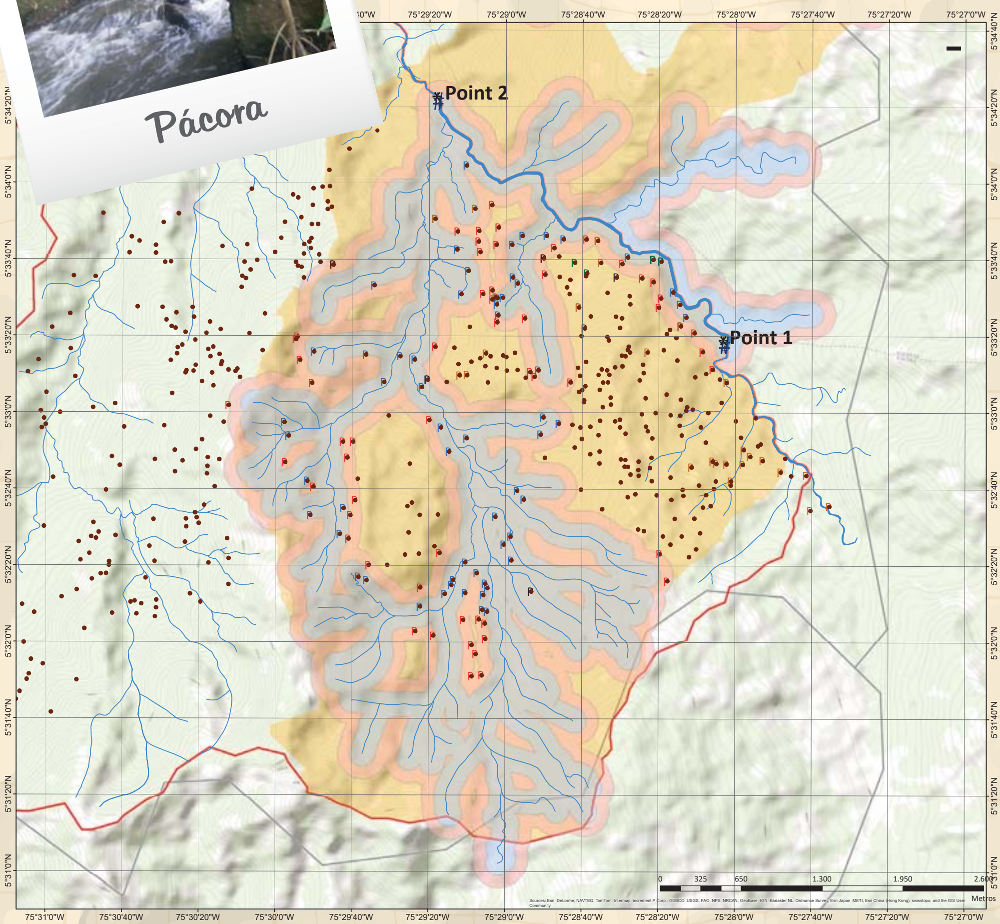
Monitoring 4

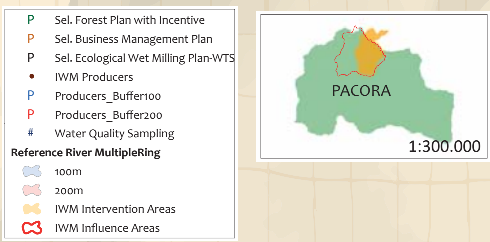
- High turbidity, road built nearby recently (sediment input).
- Coffee and banana plantations up to the edge of the sampling point.

Consolidated

- Sampling point with good organoleptic properties, low turbidity, and different types of substrates.
- Tree and shrub vegetation on both banks, allowing entry of sunlight into the column of water.

Municipality of Pácora
Pácora river basin





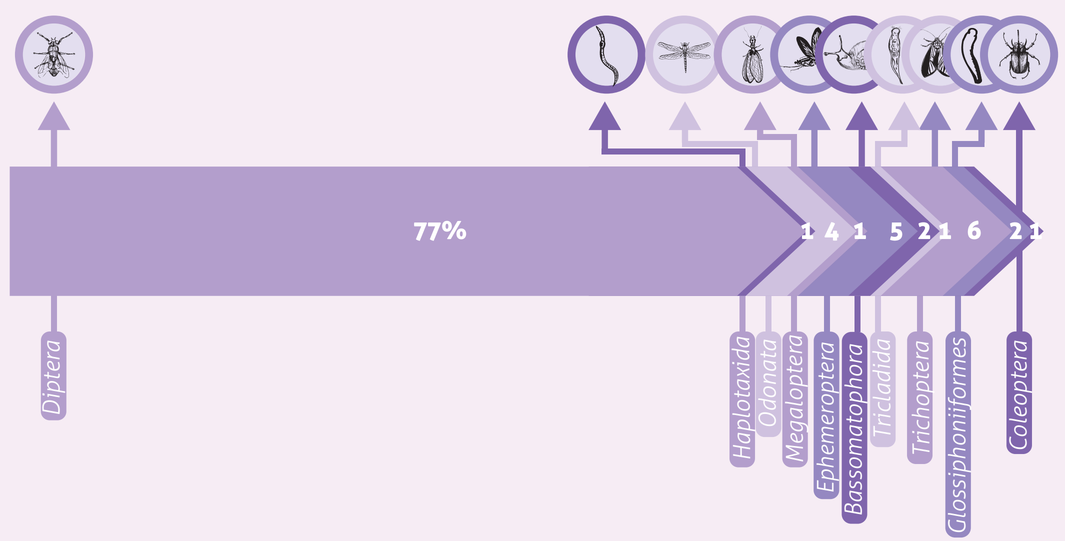
Selection of Farms by Plan
Body of water: Pácora river. Pácora, Caldas

Scale 1:12,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program/FCM

Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 05° 33.274' W 75° 28.037' **Point 2:** N 05° 34.337' W 75° 29.279'
Altitude	1151 to 2099 masl
Area of the river basin	2000.20 ha
Average rainfall	1000 to 3000 mm/year
Average temperature	21°C
Total number of producers	448
Number of producers within 200 m from the body of water	127
Coffee area	1250.50 ha
Productivity	251 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 5582 kg of COD per day Domestic: 51 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 19,692 kg of COD per day Domestic: 179 kg of COD per day

Biological groups in the river basin: In the Pácora river basin, the order Diptera dominated with 77% of representation, followed by Trichoptera with 6% and Ephemeroptera with 5%, indicating pollution of the river in a large part of its path; however, low presence of caddisflies and mayflies shows that decline of physicochemical and habitat conditions over time has been attenuated.

Biological groups in the river basin

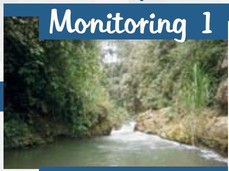


Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the body of water enters the coffee zone under study) was 0.69 and at Point 2 (after the coffee zone) was 0.66, a 4.35% decline in overall water quality (assessed in mid-harvest or mitaca). In sampling 2 (in main harvest), overall quality improved 5.80%, while in sampling 3 water quality between Points 1 and 2 (assessed in mid-harvest or mitaca) fell 5.17%. Finally, in sampling 4, in main harvest, overall quality in the stretch declined 8.70%, a decline with respect to initial conditions of 100% and an improvement over average conditions of 41.33%.

Habitat quality conditions in the Pácora river basin

Point 1

Monitoring 1



- Riffles and pools, cloudy water, bedrock, and many undulations along the channel. Fine and rocky substrates mostly.

Monitoring 2

- Turbid water, evenness in some portions with undulations, abundant foam, variety of solid waste, bedrock.

Monitoring 3

- Channel with steep slope, rocky-sandy bed, with vegetation on both banks. Evident sources of pollution by wastewater.

Monitoring 4

- Sampling point with strong odor, some turbidity, and white foam. Solid waste, crops on the banks and paddocks around the channel. Bedrock and vegetation in the body of water.

Consolidated

- Evident sources of pollution: strong odor, probably from domestic wastewater, high turbidity, foam, solid depositions, paddocks on both banks, and submerged vegetation in the channel.

Point 2

Monitoring 1

- Channel with undulations and roughness. Flooding on both sides of the riverbank. Cloudy water. The banks feature vegetation. Fine, rocky, and leaf litter substrates.

Monitoring 2

- Turbid water, foam, large rocks in the path. Substrate: sediment, rock and little leaf litter.
- Submerged vegetation on the banks, little shade, solid waste.

Monitoring 3

- Sampling point with solar exposure, arboreal vegetation on both banks, scarce weeds, rocky-sandy substrate, and many island-like rocks.

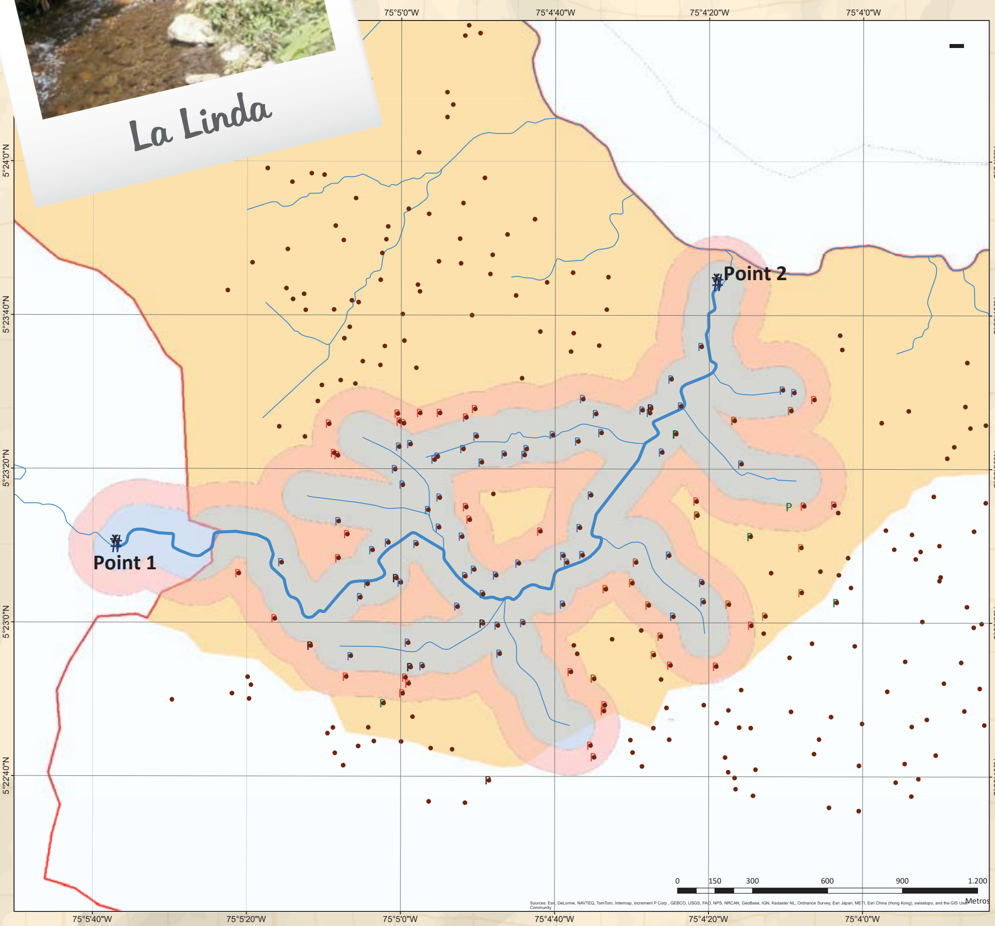
Monitoring 4

- Turbid water, many rocks in rough channel, substrate, sediment, and rock. Vegetation on both banks.

Consolidated

- Monitoring point with undulating topography and flooding in different portions, submerged vegetation on both banks because of their instability.

Municipality of Pensilvania
La Linda river basin



P Sel. Forest Plan with Incentive
P Sel. Business Management Plan
P Sel. Ecological Wet Milling Plan-WTS
• IWM Producers
P Producers_Buffer100
P Producers_Buffer200
Water Quality Sampling

Reference River MultipleRing

100m
200m
IWM Intervention Areas
IWM Influence Areas

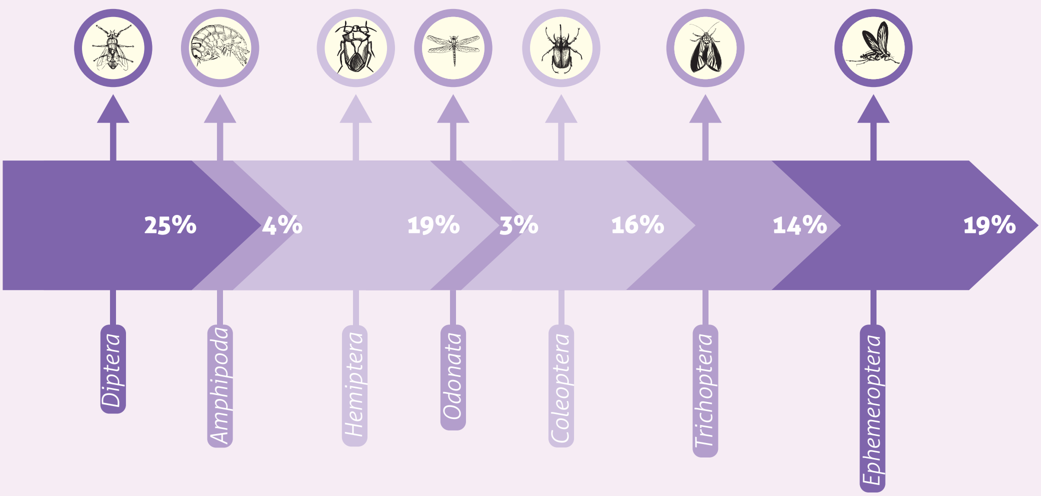
Selection of Farms by Plan
Body of water: Q. La Linda. Pensilvania, Caldas

Scale 1:6,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program/FCM

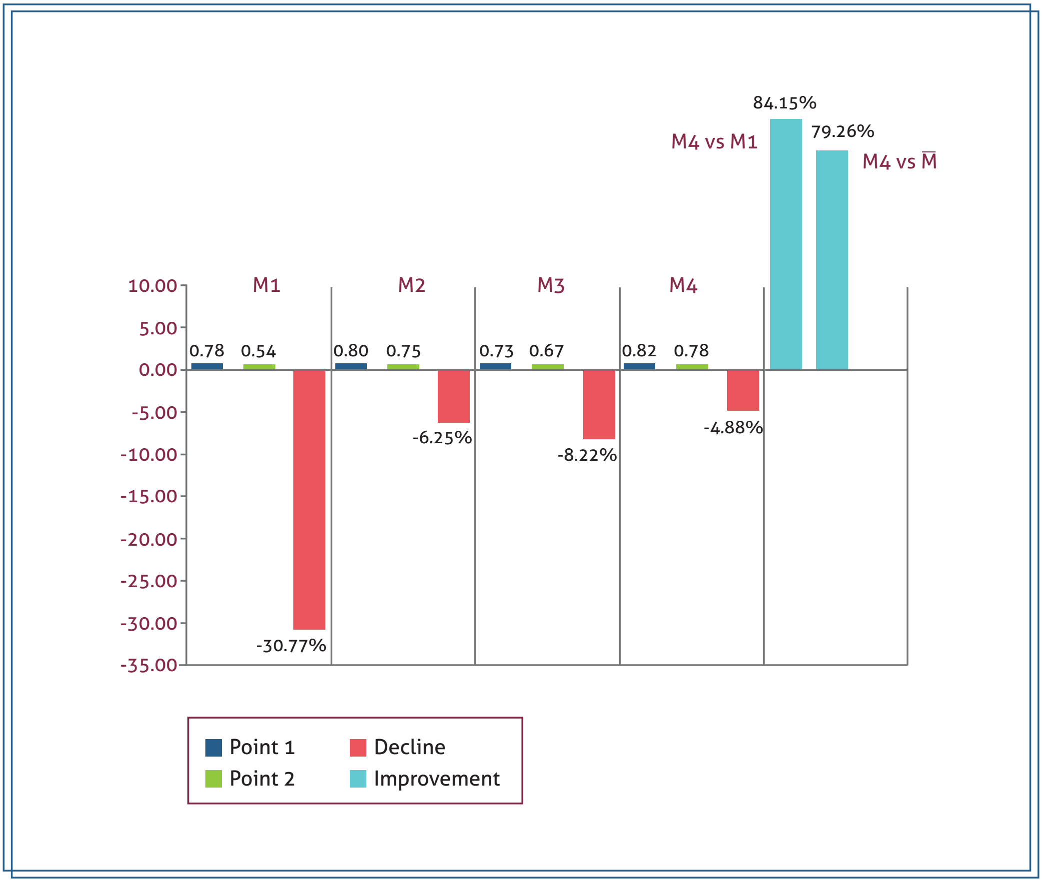
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 05° 23.160' W 75° 05.612' **Point 2:** N 05° 23.730' W 75° 04.289'
Altitude	1011 to 1948 masl
Area of the river basin	1155.44 ha
Average rainfall	3000 mm/year
Average temperature	17°C
Total number of producers	684
Number of producers within 200 m from the body of water	110
Coffee area	588.87 ha
Productivity	164 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 1035 kg of COD per day Domestic: 44 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 6436 kg of COD per day Domestic: 274 kg of COD per day

Biological groups in the river basin: The proportions of organisms in the river basin are: Diptera (25%), Ephemeroptera (19%), and Hemiptera (19%), insects indicating bodies of water with some degree of pollution of different types, especially larvae of mosquitoes and flies (Diptera), as their feeding and development niches are stagnant and eutrophic waters; nevertheless, mayflies and water bugs give an idea of good conditions, mediated by wide availability of habitats that La Linda river basin offers in its topography such as: slopes, diverse vegetation, and stretches with some degree of conservation.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.78 and at Point 2 (after the coffee zone) was 0.54, a 30.77% decline in overall water quality (assessed in mid-harvest or mitaca). In sampling 2, in main harvest, overall quality in the stretch declined 6.25%. In sampling 3, water quality between Points 1 and 2 (in mid-harvest or mitaca) fell 8.22%. Finally, in sampling 4, in main harvest, overall quality in the stretch declined 4.88%, an improvement over initial conditions of 84.15% and over average conditions of 79.26%.



Habitat quality conditions in La Linda river basin

Point 1

Monitoring 1

- Bedrock with smooth rocks and abundance of brown algae. The channel is rough with vegetation in the water.

Monitoring 2

- Bedrock on the banks, clear water. Rocks with brown algae.
- Livestock in the upper part.

Monitoring 3

- Slight slope, significant periphytic community biofilm, especially in backwater areas, rocky material of different sizes.

Monitoring 4

- Laminar flow, rough channel, large rocks on the stretch, clear water, rocks with moss, vegetation on the banks, little canopy cover.
- Paddocks upstream from monitoring point.

Consolidated

- Sampling point with large rocks, with filamentous algae adhered to them. Undulating topography with slope changes, low turbidity.

Point 2

Monitoring 1

- Rough channel, with some undulations, somewhat cloudy water, and fine, rocky and leaf litter substrates. Bedrock.

Monitoring 2

- Water body with large rocks in its path, clear water, and smooth rocks covered with algae. Substrates for macroinvertebrates.

Monitoring 3

- Channel with vegetation of diverse heights, rocky material of different sizes in the bed, and high supply of leaf litter.

Monitoring 4

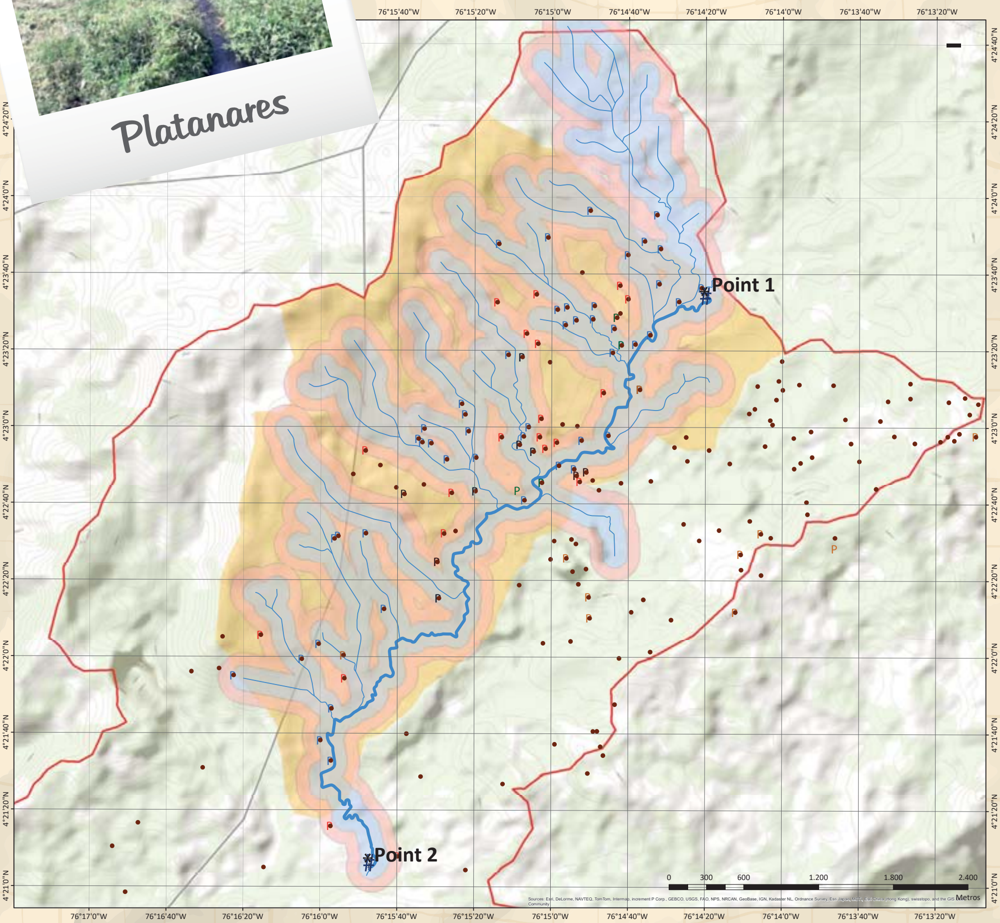
- Clear water, laminar flow with some roughness, rocks in its path. Good amount of vegetation on both sides, paddocks on one of the banks.

Consolidated

- Monitoring point with rough channel, low turbidity, and large rocks. Substrates of different types, which allow establishment of aquatic communities; high supply of leaf litter.

Municipality of Bolívar

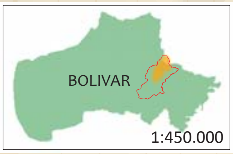
Platanares river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas



Selection of Farms by Plan

Body of water: Platanares river. Bolívar, Valle del Cauca

Scale 1:12,000

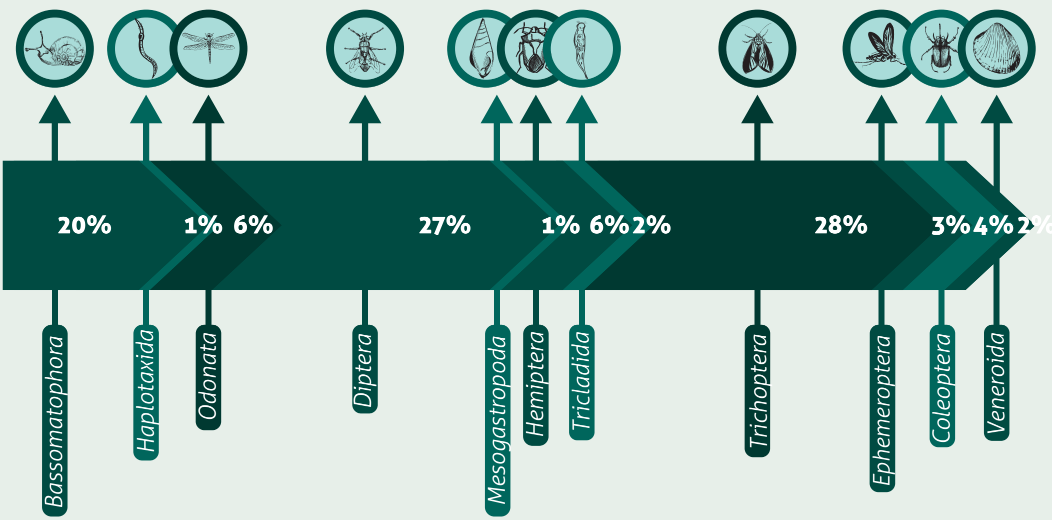
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program/FCM

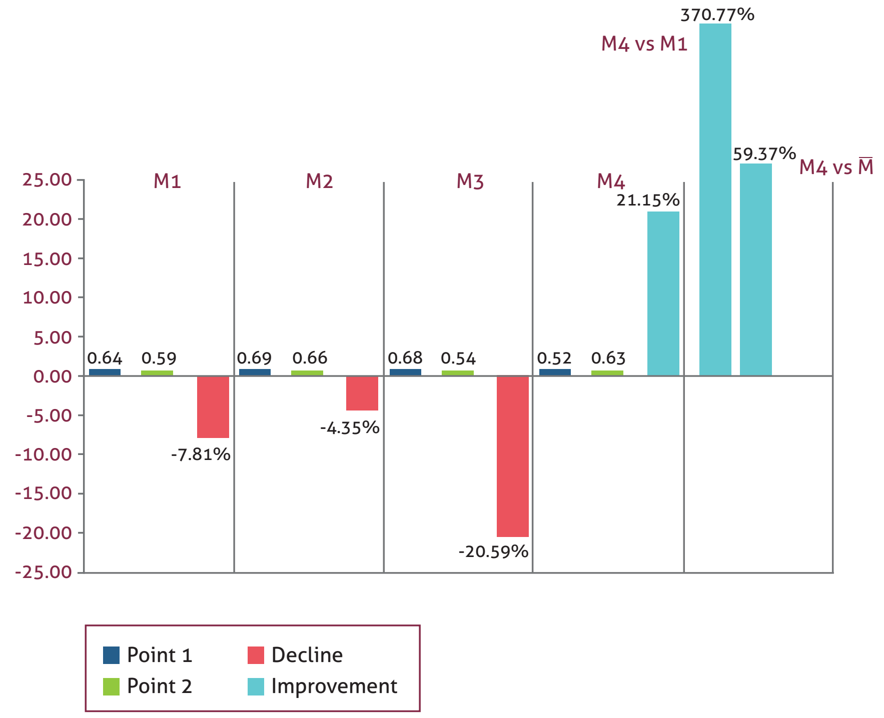
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 04° 23' 33.9" W 76° 14' 19.6"
	Point 2: N 04° 21' 04.9" W 76° 15' 46.4"
Altitude	1,495 to 1,931 masl
Area of the river basin	1,382.57 ha
Average rainfall	1,429 mm/year
Average temperature	23°C
Total number of producers	218
Number of producers within 200 m from the body of water	86
Coffee area	559.20 ha
Productivity	187 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 3,510 kg of COD per day Domestic: 34 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 8,897 kg of COD per day Domestic: 87 kg of COD per day

Biological groups in the river basin: Among the aquatic insects identified, the highest relative abundances were for Trichoptera (28%), Diptera (27%), and Basommatophora (20%). This indicates that in some sections there are acceptable conditions for caddisflies, while larvae of flies and mosquitoes, along with snails, are not good indicators, as these normally inhabit slightly contaminated waters, with problems of eutrophication of water sources. It must be taken into account that this body of water is strongly impacted by pig and livestock farming, with excreta and erosion on the banks, where these animals have access. Nevertheless, as monitoring progressed, the impact proportions decreased, allowing progressive improvement of water quality.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.64 and at Point 2 (after the coffee zone) was 0.59, a 7.81% decline in overall water quality (when there was no coffee harvest). In sampling 2, in main harvest, overall quality declined 4.35%, while in sampling 3 overall water quality between Points 1 and 2 (in coffee harvest time) fell 20.59%. Lastly, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch improved 21.15%, an improvement over initial conditions of 370.77% and over average conditions of 59.37%.



Habitat quality conditions in the Platanares river basin

Point 1

Monitoring 1

- Clear water, canopy cover on both sides, rocky and leaf litter substrate. Instream cover for fish.
- Structures in the body of water made by people in the area for creating habitat for fish (deep pools).

Monitoring 2

- Rough channel with pools and riffles, sandy bed with sediments, clear water, banks eroded in bends, native vegetation, and discharges of domestic and garage-washing wastewater.

Monitoring 3

- Settlement with pig breeder within 10 m from the body of water. The farms located on the bank do not have any system for treating their wastewater, being discharged directly into the river.

Monitoring 4

- Water body moderately intervened, with vegetation on the banks by natural succession. Dominance of "matandrea" (white garland-lily) and elephant grass.

Consolidated

- Domestic sewage and feces of animals such as pigs and livestock reach this sampling point; erosion process, shallow pools, nearby households, vegetation on the banks, coffee and banana plantations.

Point 2

Monitoring 1

- Small channel, brown algae; fine, rocky and leaf litter substrate. Bad smell from domestic wastewater; channel altered by man, deforestation, causing flooding in bends.

Monitoring 2

- Clear water, small channel with vegetation on both sides, deep pools in some sections, evidence of fish, rocky bed.
- Bridge over the river and livestock on the banks.

Monitoring 3

- Paddocks on the banks, farms without wastewater treatment, solid waste on the banks, and high growth of brown algae.

Monitoring 4

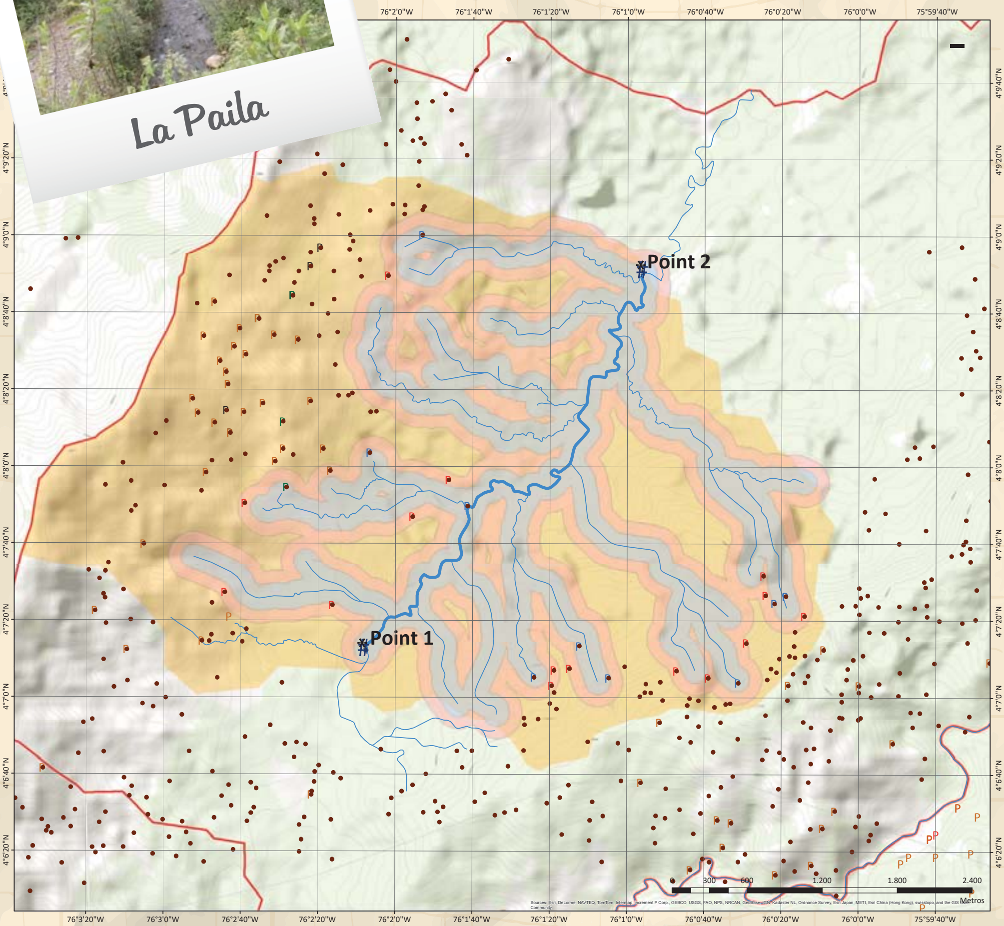
- Evident sources of pollution by domestic and industrial wastewater.
- Erosion is evident on both banks.

Consolidated

- Wastewaters of different types arrive in this point. Substrates for establishment of aquatic macro-invertebrates, shallow pools, a bridge next to the sampling point, animals and bovines on the banks, erosive processes.

Municipality of Bugalagrande

La Paila river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Water body: La Paila river. Bugalagrande, Valle del Cauca

Scale 1:12,000

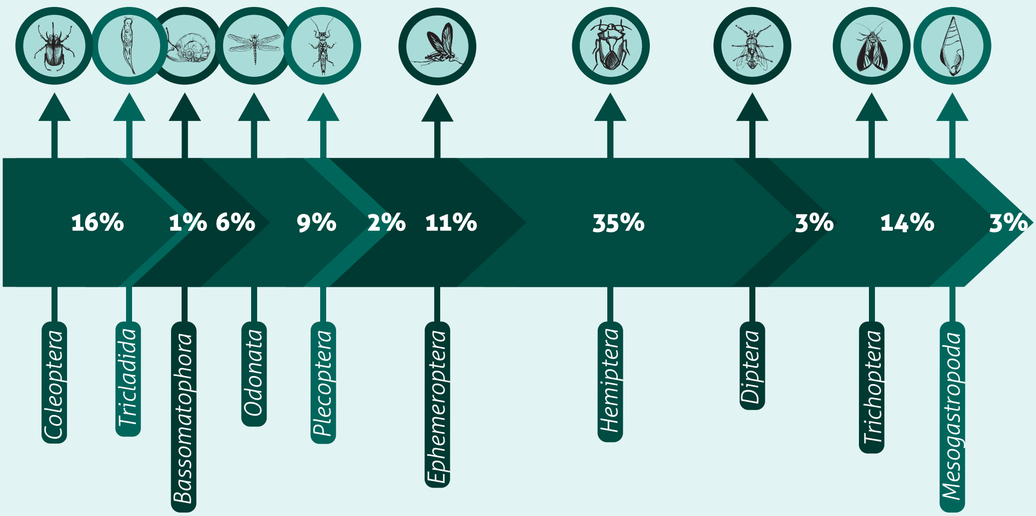
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program/FCM

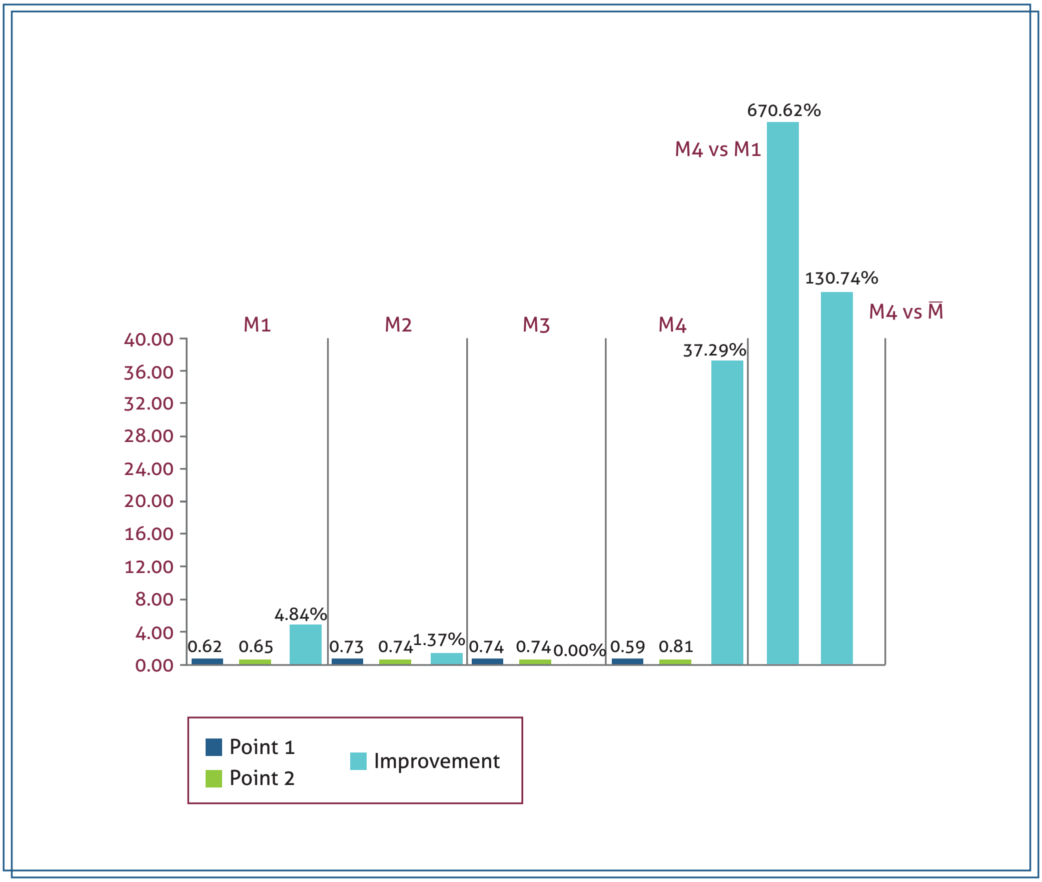
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 04° 07' 12.1" W 76° 02' 07.4" **Point 2:** N 04° 08' 50.1"W 76° 00' 55.6"
Altitude	1201 to 1917 masl
Area of the river basin	3,261.97 ha
Average rainfall	1,200 to 1,500 mm/year
Average temperature	20.5 °C
Total number of producers	540
Number of producers within 200 m from the body of water	32
Coffee area	1,374.96 ha
Productivity	215 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 970 kg of COD per day Domestic: 13 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 16,370 kg of COD per day Domestic: 216 kg of COD per day

Biological groups in the river basin: The most representative orders of aquatic insects were Ephemeroptera (52%), Trichoptera (20%), and Diptera (12%), conforming to average habitat conditions, mostly dominated by good vegetation and different substrates, which allow establishment of groups such as mayflies and caddisflies; however, in some specific points of the body of water there are domestic wastewater discharges.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee area under study) was 0.62 and at Point 2 (after the coffee zone) was 0.65, a 4.84% increase in overall water quality (without coffee harvest). In sampling 2, in mid-harvest or mitaca, overall quality improved 1.37%, while in sampling 3 there was no change in water quality between points 1 and 2 (in main coffee harvest). Finally, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch improved 37.29%, an improvement over initial conditions of 670.62% and over average conditions of 130.74%.



Habitat quality conditions in La Paila river basin

Point 1

Monitoring 1

- Clear water; rocky, fine (gravel, silt, sand) substrate, and large amount of leaf litter.
- Few pools, some are deep; moderate algal growth.
- Discharges of domestic wastewater from nearby settlements.

Monitoring 2

- Clear water with large amount of sediment, shallow pools, without currents; abundant leaf litter and large rocks.

Monitoring 3

- Rough channel with abundant sediment and rocks of different sizes, algae in areas without shade, thick vegetation with soil covered by tree leaf litter, fine and rocky substrate.
- Influence of crossing of livestock from side to side, discharges from farms less than 100 m away, pig farming.

Monitoring 4

- Livestock feces. Erosion on the banks, changes in slopes, fallen trees, some vegetation in some portions. Farms around the channel with coffee, banana and other crops.

Consolidated

- Livestock feces. Erosion on the banks, changes in slopes, fallen trees, some vegetation in some portions. Farms around the channel with coffee, banana and other crops.

Point 2

Monitoring 1

- Substrates: leaf litter, rocks, sand, gravel, and silt. Strips of few trees, clear water, moderate algal growth, stability of banks, some roots exposed and fallen trees.
- Livestock movement along the banks, solid waste.

Monitoring 2

- Clear water with large amount of green and brown algae, low flow rate, 50-cm pools, bended path with roots in water, fallen trees and sediments. Low water level due to drought.

Monitoring 3

- Laminar flow, slight slope, predominance of rocky substrate.
- Vegetation up to the banks, meanders and areas with pools.
- Discharges of domestic and pig farming wastewater from rural districts in the upper part.

Monitoring 4

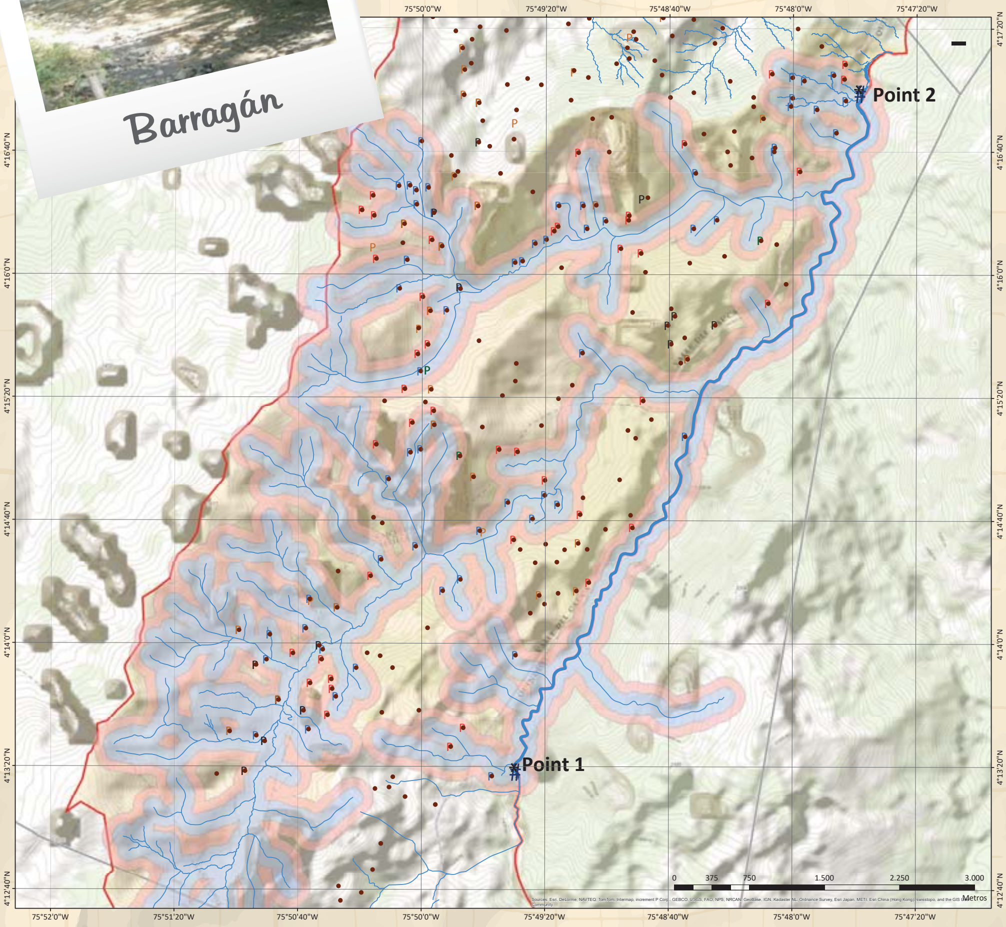
- Sources of pollution are evident by bad smell.
- Riparian vegetation, high periphytic activity, the result of reduced canopy cover and light intensity.
- Laminar flow and substrates for development of macroinvertebrates.

Consolidated

- This body of water features reduced flow rate and vegetation on the banks. Livestock has access to the river, no fishing, shallow pools, rocky substrate is predominant, little canopy cover, and trees and shrubs fallen into the water body.

Municipality of Caicedonia

Barragán river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Water body: Barragán river. Caicedonia, Valle del Cauca

Scale 1:15,000

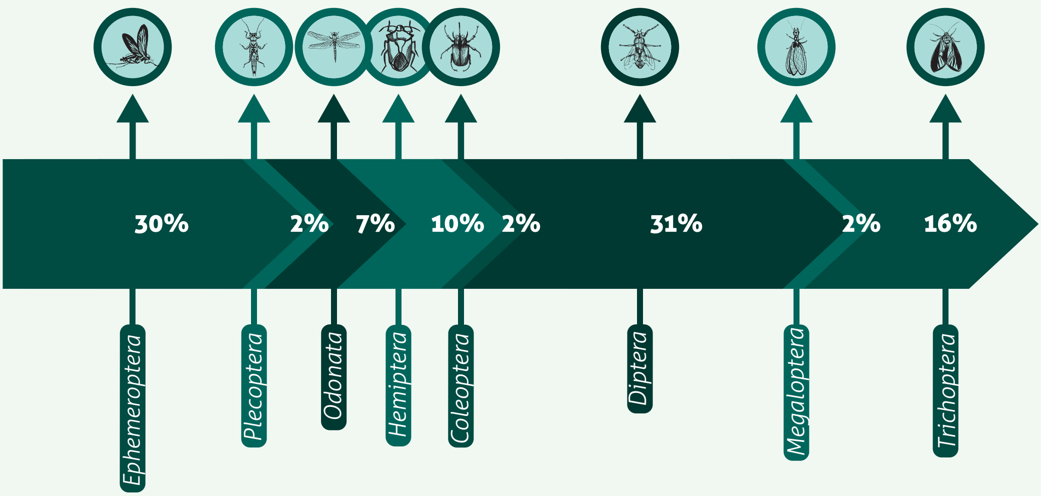
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program/FCM

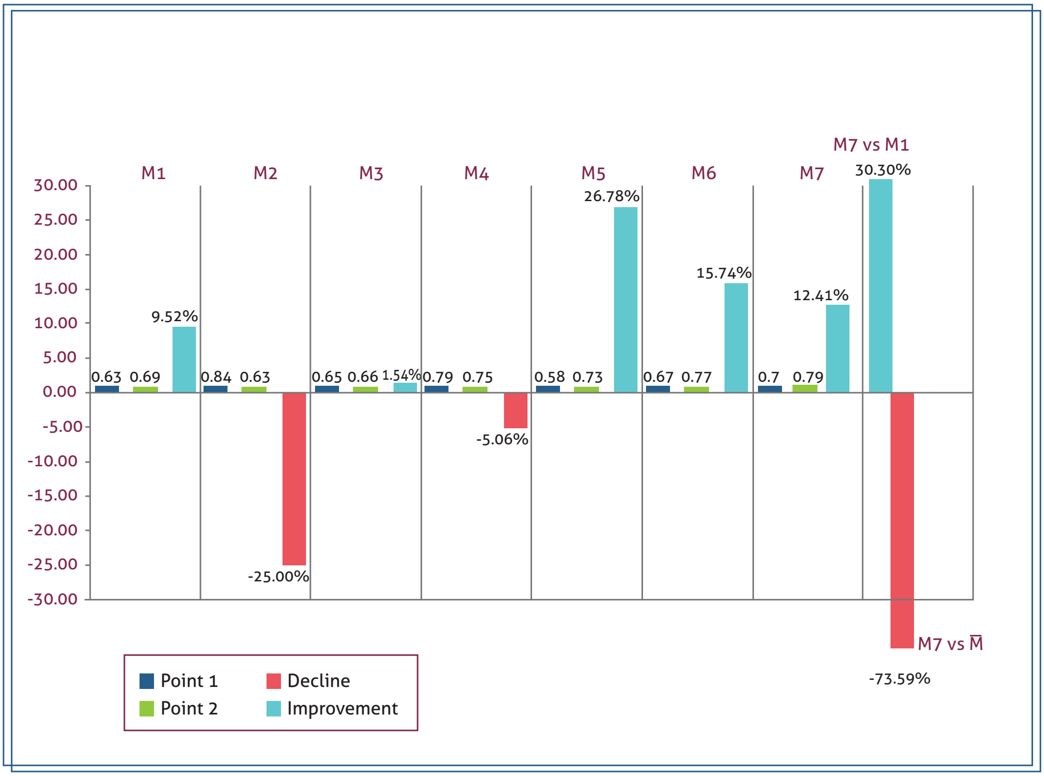
Number of samplings	Seven conventional
Coordinates of sampling points	**Point 1:** N 4° 13' 16.5" W 75° 49' 28.3"
	Point 2: N 4° 16' 57.2" W 75° 47' 36.1"
Altitude	1,177 to 1,897 masl
Area of the river basin	3,589.75 ha
Average rainfall	2,800 mm/year
Average temperature	22 °C
Total number of producers	417
Number of producers within 200 m from the body of water	115
Coffee area	1,472.85 ha
Productivity	193 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 6,251 kg of COD per day Domestic: 46 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 22,665 kg of COD per day Domestic: 167 kg of COD per day

Biological groups in the river basin: As to biological information gathered in the river basin in the four water quality samplings, the most abundant orders were Diptera (31%), Ephemeroptera (30%), and Trichoptera (16%). The similar values of two contrasting quality indicator groups are explained by the fact that the Barragán river supplies most of the settlements in the municipalities of Caicedonia (Valle) and Génova (Quindío). It also shows primary production problems, with algal proliferation due to solar exposure derived from channel alterations and high bed load extraction; on the other hand, for its abrupt topography (steep slope and difficult access), it has a quite thick conservation stripe. That's why contrasting situations occur, with a good-quality indicator group (mayflies) and the other of contaminated waters (flies and mosquitoes).

Biological groups in the river basin



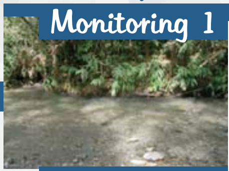
Overall indicator of water quality in the river basin (KPI): At the beginning of monitoring, before implementation of the IWM Project in the river basin, KPI at Point 1 (before the coffee area under study) was 0.63 and at Point 2 (after the coffee zone) was 0.69, a 9.52% increase in overall water quality (assessed when there was no coffee harvest). In sampling 2, overall quality declined 25%, in mid-harvest or mitaca, and in sampling 3 overall water quality between Points 1 and 2 (in main coffee harvest) improved 1.54%; in sampling 4, in mid-harvest of mitaca, water quality fell 5.06%; in sampling 5, in harvest time, water quality increased 26.78%, and in sampling 6, when there was no coffee harvest, quality improved 15.74%. Finally, in sampling 7, in harvest time, quality improved 12.41%, accounting for a 30.30% improvement over initial conditions and a 73.59% decline over average conditions.



Habitat quality conditions in the Barragán river basin

Point 1

Monitoring 1



- Bedrock, fallen trees, few pools; fine (silt, sand, gravel), rocky and leaf litter substrate.
- Solid waste on the banks and moderate growth of algae.

Monitoring 2

- Moderate turbidity, gray sand, rock bed, surrounded by thick vegetation, mostly guadua and native forest, some shallow pools, fishing with hook.

Monitoring 3

- Submerged vegetation and roots, riffles and pools of different sizes. Banks are stable, with thick vegetation protecting them.
- Presence of macrophytes and coffee production waste.

Monitoring 4

- Laminar flow, rocks of different sizes allowing instream cover for fish and macroinvertebrates, clear water.
- Erosion in some bends.

Consolidated

- Monitoring point with some turbidity and abundant fine sediment; large rocks related to volcanic activity in the area.
- On both banks, tall vegetation, with large supply of plant material.

Point 2

Monitoring 1

- Cloudy water, with much sediment. Riparian zone with patches of trees and little canopy cover.
- Substrate is mostly rocky, with some fine sediment (silt, gravel, sand) and leaf litter. Solid waste of different types and shallow pools.

Monitoring 2

- Moderate turbidity and gray sand with rocky bed.
- Channel mostly surrounded by abundant vegetation, native forest; some shallow pools.

Monitoring 3

- Turbid water and diverse vegetation on both banks.
- Fishing with hook; upstream from the monitoring point, abstraction for irrigation; nearby settlement.

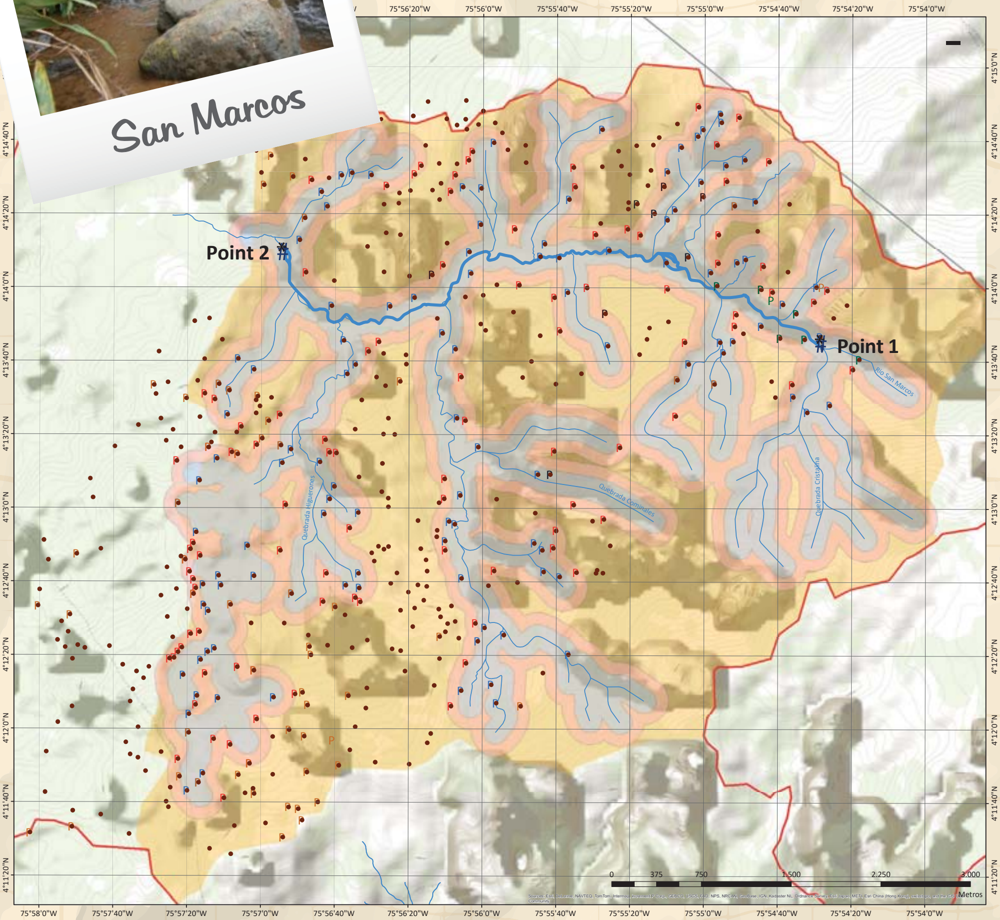
Monitoring 4

- Clear water, small rocks in its path, laminar flow, fallen guadua on the body of water, and substrates for macroinvertebrates.
- Steep slopes, poor vegetation, coffee crops on one side.

Consolidated

- Monitoring point with artisanal mining; domestic and coffee wastewater.
- Laminar flow and acceptable organoleptic properties, full sun exposure of column of water.
- Arboreal and shrubby vegetation on both banks, with livestock and crops on the sides.

Municipality of Sevilla
San Marcos river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

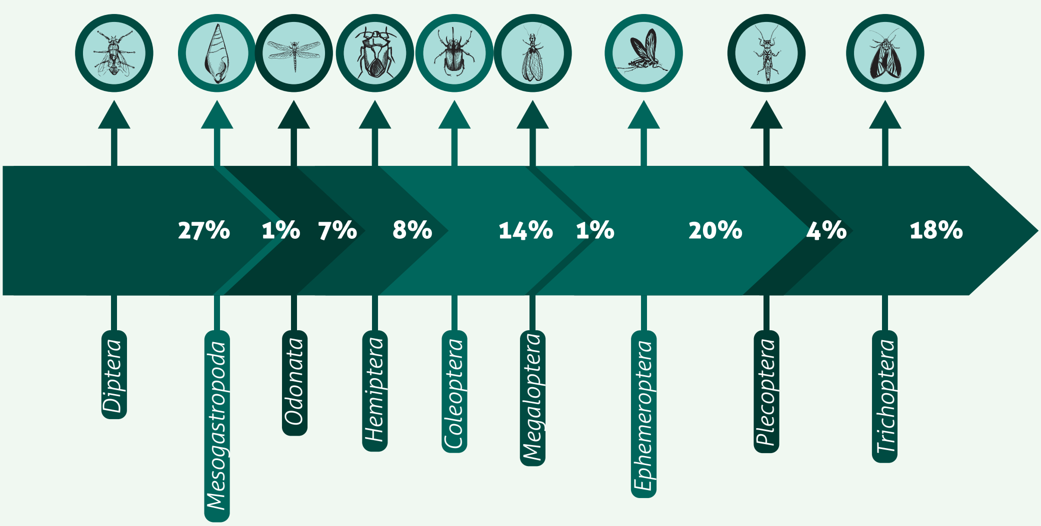
- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan
Body of water: San Marcos river. Sevilla, Valle del Cauca
Scale 1:12,500
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program/FCM

Number of samplings	Seven conventional (including three dynamic)
Coordinates of sampling points **Point 1:** N 04° 13' 45.3" W 75° 54' 27.6" **Point 2:** N 4° 14' 12,9" W 75° 56' 55.9" **Point 3:** N 4° 13' 55.3" W 75° 56' 10.2" **Point 4:** N 4° 13' 54.7" W 75° 56' 09.8" **Point 5:** N 4° 13' 07.5" W 75° 56' 05.3" **Point 6:** N 4° 13' 50,1" W 75° 56' 31.6"	Point 7: N 4° 13' 47.2" W 75° 56' 38.5" **Point 8:** N 4° 14' 13.1" W 75° 55' 02.8" **Point 9:** N 4° 14' 15.8" W 75° 55' 01.6" **Point 10:** N 4° 11' 52.4"W 75° 57' 04.6" **Point 11:** N 4° 12' 24" W 75° 56' 42.1" **Point 12:** N 4° 13' 45.9" W 75° 55' 18.1" **Point 13:** N 4° 13' 47" W 75° 55' 18.4"
Altitude	1277 to 2071 masl
Area of the river basin	2,935.70 ha
Average rainfall	2,000 mm/year
Average temperature	20 °C
Total number of producers	697
Number of producers within 200 m from the body of water	241
Coffee area	1,607.10 ha
Productivity	207 @/ha of dpc
Daily potential pollution of producers located within 200 m from the body of water	Coffee: 7,352 kg of COD per day Domestic: 96 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 21,263 kg of COD per day Domestic: 279 kg of COD per day

Biological groups in the river basin: The aquatic biota identified is dominated by Diptera (27%), followed by Ephemeroptera (20%) and Coleoptera (20%). Like in the Barragán River, there are two contrasting groups dominating the biological freshwater community within a matrix of impacts such as: farming activities on the banks, deforestation, abstraction for supply, power generation, transit over the channel and households. The river is surrounded by an intensive production zone with different activities; however, it features high self-purification capacity, with an overall improvement of the body of water.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.85 and at Point 2 (after the coffee zone) was 0.75, a 11.76% decline in overall water quality (assessed when there was no coffee harvest). In sampling 2, overall quality declined 8.54%, in mid-harvest or mitaca; in sampling 3, water quality between Points 1 and 2 (during main coffee harvest) fell 20%; in sampling 4, in mitaca or mid-harvest, water quality increased 13.43%; in sampling 5, in harvest time, water quality declined 4.42%, and in sampling 6, when there was no harvest, quality declined 4.86%. Lastly, in sampling 7, in harvest time, quality declined 9.42%, an improvement over initial conditions of 19.93% and over average conditions of 51.20%.

Habitat quality conditions in the San Marcos river basin

Point 1

Monitoring 1

- Primary forest along the bank, few pools, stable banks, fish and filamentous algae on the rocks, rough path, and large rocks.

Monitoring 2

- Turbid water, with sediment transport and native vegetation near the river.
- Moderate growth of filamentous algae, along with lulo cultivation on one of the banks.

Monitoring 3

- Coffee and banana plantations on one of the banks.
- Channel with good habitat conditions. Fish in deep pools, clear water, rocky bed, submerged roots and vegetation.

Monitoring 4

- Clear water, pools of different sizes.
- Substrate with fine sediments, rock and leaf litter.

Consolidated

- Channel with high supply of leaf litter, as it is located in a primary forest matrix.
- Large rocks, erosive processes on both banks.
- Upstream from the sampling point, lulo crop with coffee and banana plantations near the channel.

Point 2

Monitoring 1

- Primary forest on the banks, without canopy cover on both sides, shallow pools.
- Rocky substrate, unstable banks.

Monitoring 2

- Primary forest on the banks, without canopy cover on both sides, shallow pools.
- Rocky substrate, unstable banks.

Monitoring 3

- Rough channel, high growth of green algae.
- New, more abundant vegetation on the banks, which provides cover for aquatic organisms.

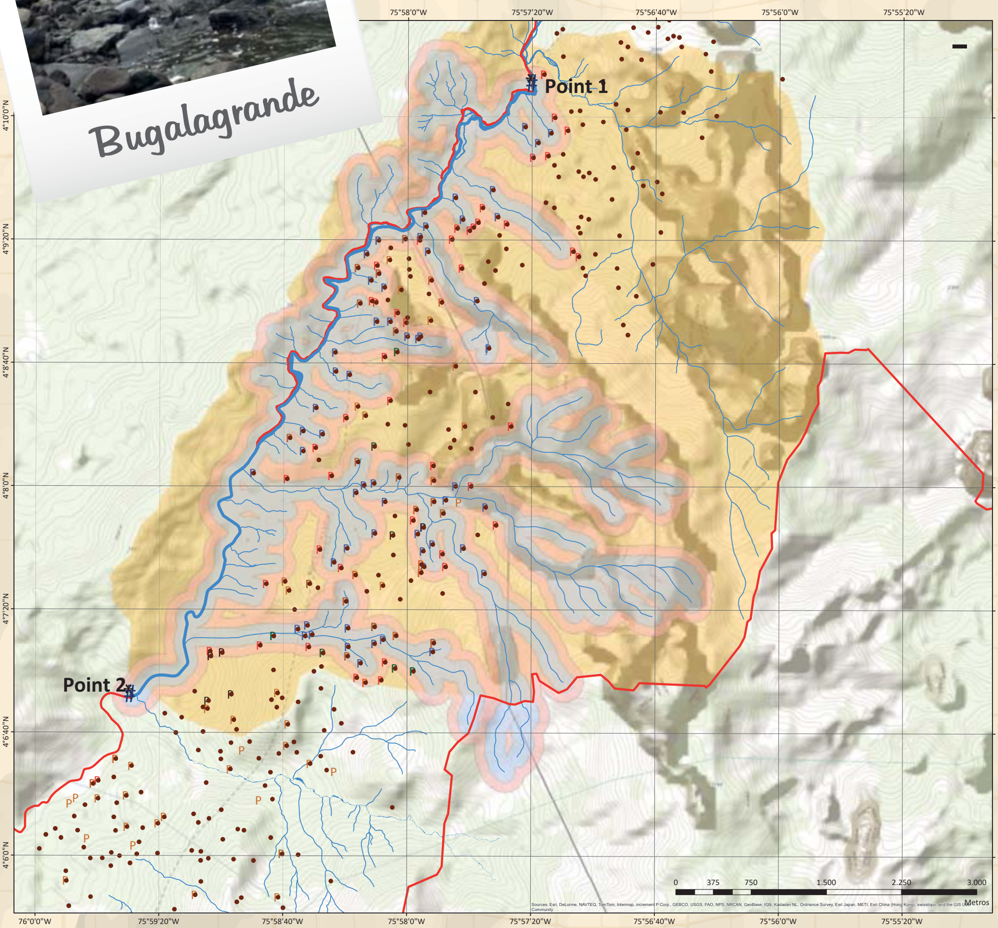
Monitoring 4

- Laminar flow, large rocks, vegetation on the banks, filamentous algae, clear water, substrate for macroinvertebrates.

Consolidated

- Monitoring point with some turbidity; in some samples, reports of filamentous algae, forest on both banks.

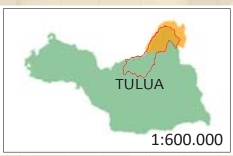
Municipality of Tuluá
Bugalagrande river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas



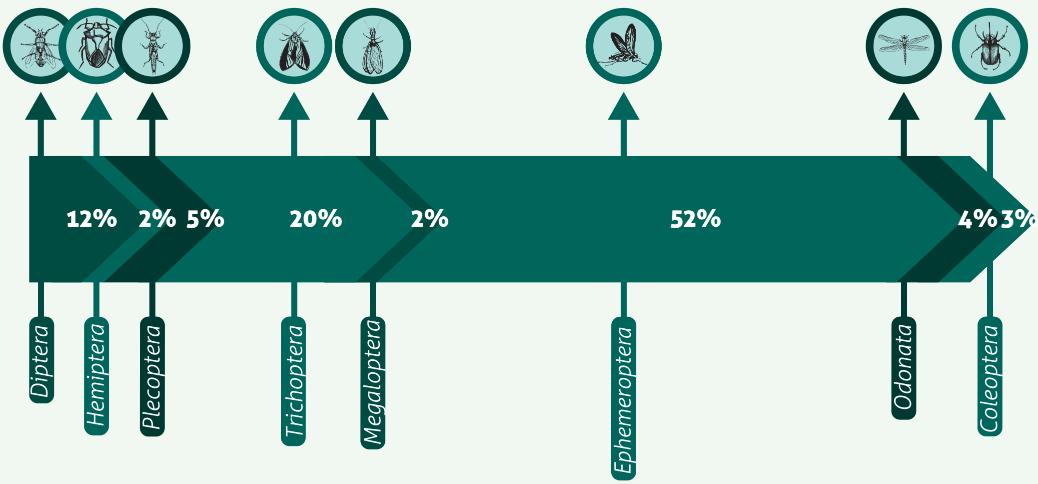
Selection of Farms by Plan
Water body: Bugalagrande river. Tuluá, Valle del Cauca

Scale 1:15,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program/FCM

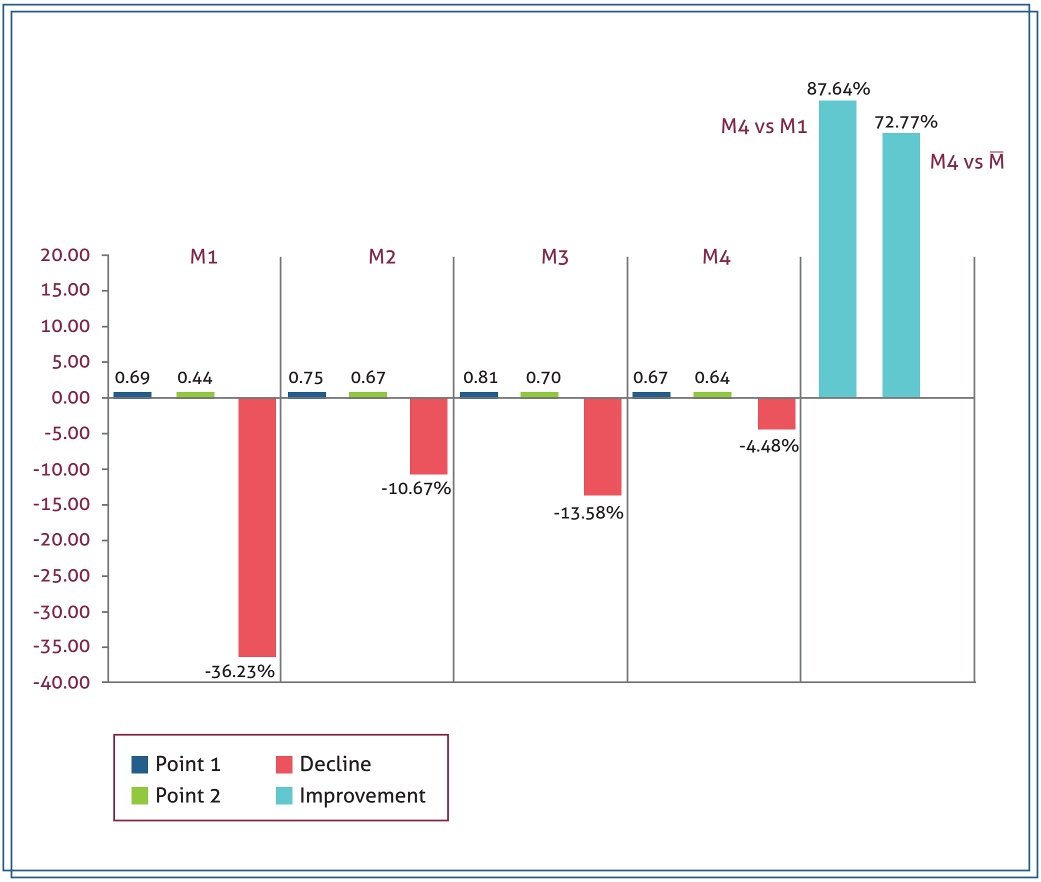
Number of samplings	**Four conventional**
Coordinates of sampling points	Point 1: N 04° 10' 09.8" W 75° 57' 19" **Point 2:** N 04° 06' 51.9" W 75° 59' 28.5"
Altitude	1,295 to 2,021 masl
Area of the river basin	2,071.89 ha
Average rainfall	1,000 to 2,000 mm/year
Average temperature	21 °C
Total number of producers	876
Number of producers within 200 m from the body of water	150
Coffee area	933.80 ha
Productivity	205 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 3,909 kg of COD per day Domestic: 60 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 22,829 kg of COD per day Domestic: 350 kg of COD per day

Biological groups in the river basin: The most representative aquatic insect orders in the samples were Ephemeroptera (52%), Trichoptera (20%) and Diptera (12%), the most diverse groups in the Neotropic, especially in the north of South America, a determining factor in their distribution, along with potential habitat conditions provided by natural impacts and habitats to hydrobiological communities, allowing mayflies to still show a high value (taking into account the size of this river basin), followed by caddisflies, a group that uses available resources such as leaf litter and sediment to establish their communities and colonize spaces in the channel that would be impossible for other groups, such as current zones, as they can secrete a mucilage that adheres their anchor-shaped bodies to substrate.

Biological groups in the river basin



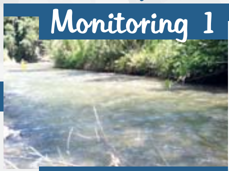
Overall index of water in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project, the KPI at Point 1 (before the coffee zone under study) was 0.69 and at Point 2 (after the coffee zone) was 0.44, a 36.23% decline in overall water quality (assessed when there was no coffee harvest). In sampling 2, in mitaca or mid-harvest, overall quality declined 10.67%; and in sampling 3, water quality between points 1 and 2 (during main harvest) fell 13.58%. Finally, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch fell 4.48%, an improvement over initial conditions of 87.64% and over average conditions of 72.77%.



Habitat quality conditions in Bugalagrande river basin

Point 1

Monitoring 1



- Moderately turbid water, high flow rate, rocky and fine substrate (sand, gravel), great variety of vegetation and few pools.

Monitoring 2

- Moderately turbid water, high flow rate, rocky and fine substrate (sand, gravel), great variety of vegetation and few pools.

Monitoring 3

- Somewhat turbid water, laminar flow with slight slopes, thick vegetation over the bed. Abundant periphytic communities.

Monitoring 4

- Laminar flow, good general conditions, periphytic activity, reduced vegetation on both banks, and homogeneous substrate.

Consolidated

- Sampling point with moderately turbid water, considerable flow rate, submerged vegetation, eroded banks; different instream covers for groups of aquatic organisms.

Point 2

Monitoring 1

- Cloudy water, shallow pools, and strong currents. Most of the vegetation is dry, with two substrates available: rock and fine sediment.
- Instream covers for fish (pools, rapids, sandy bed, and submerged vegetation), solid waste, and moderate growth of filamentous algae.

Monitoring 2

- Water somewhat cloudy, sandy bed, bad smell, rough channel, many rocks and swirls, good aeration, surrounding vegetation and leaf litter.

Monitoring 3

- The banks are protected with thick shrub-like vegetation, riffles and pools as instream cover for fish. Nearby settlement. Fishing in the area. Abundant solid waste.

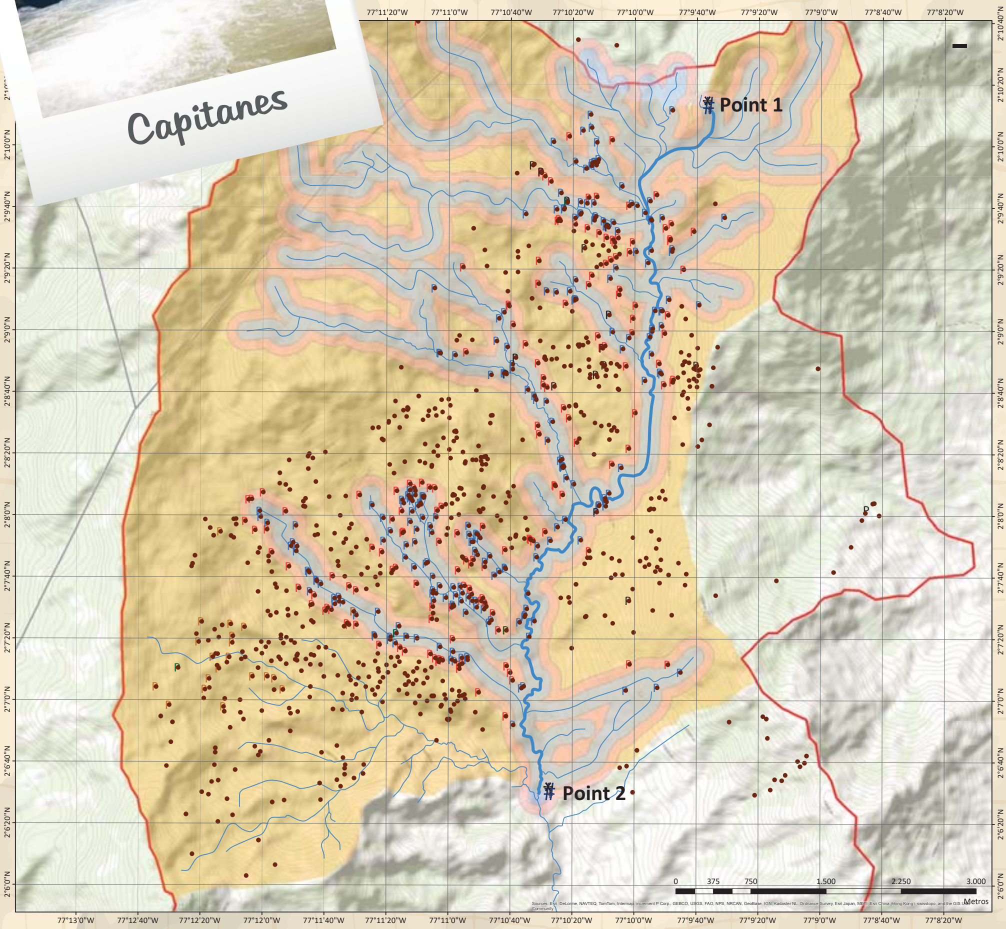
Monitoring 4

- Turbid water, rocky-sandy substrate, with moderate erosion in bends, laminar flow with rapid-type height changes.
- Low periphytic activity because of high current.

Consolidated

- Large body of water, with different-height vegetation on both banks; diverse substrates available, favoring different organism groups.

Municipality of Balboa
Capitanes river basin



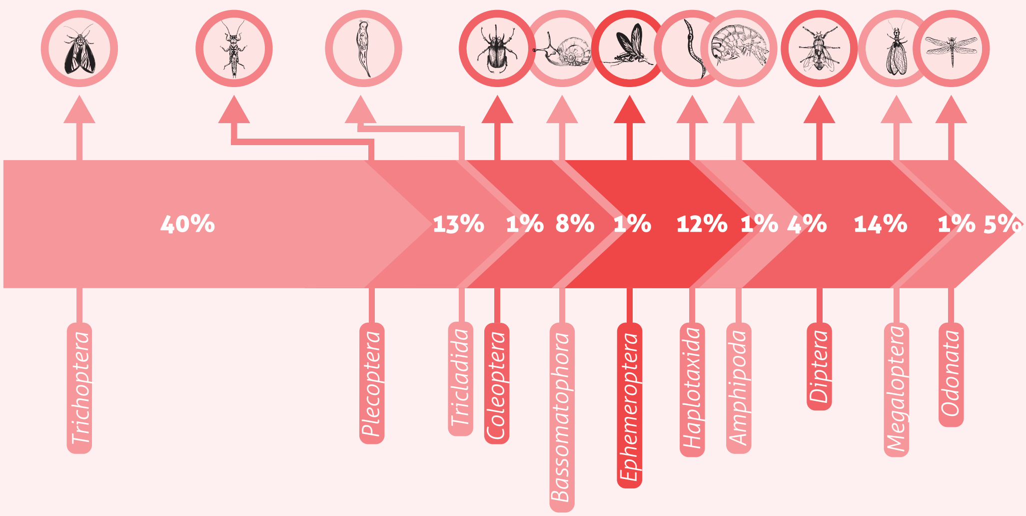
Selection of Farms by Plan
Body of water: Capitanes river. Balboa, Cauca

Scale 1:15,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program/FCM

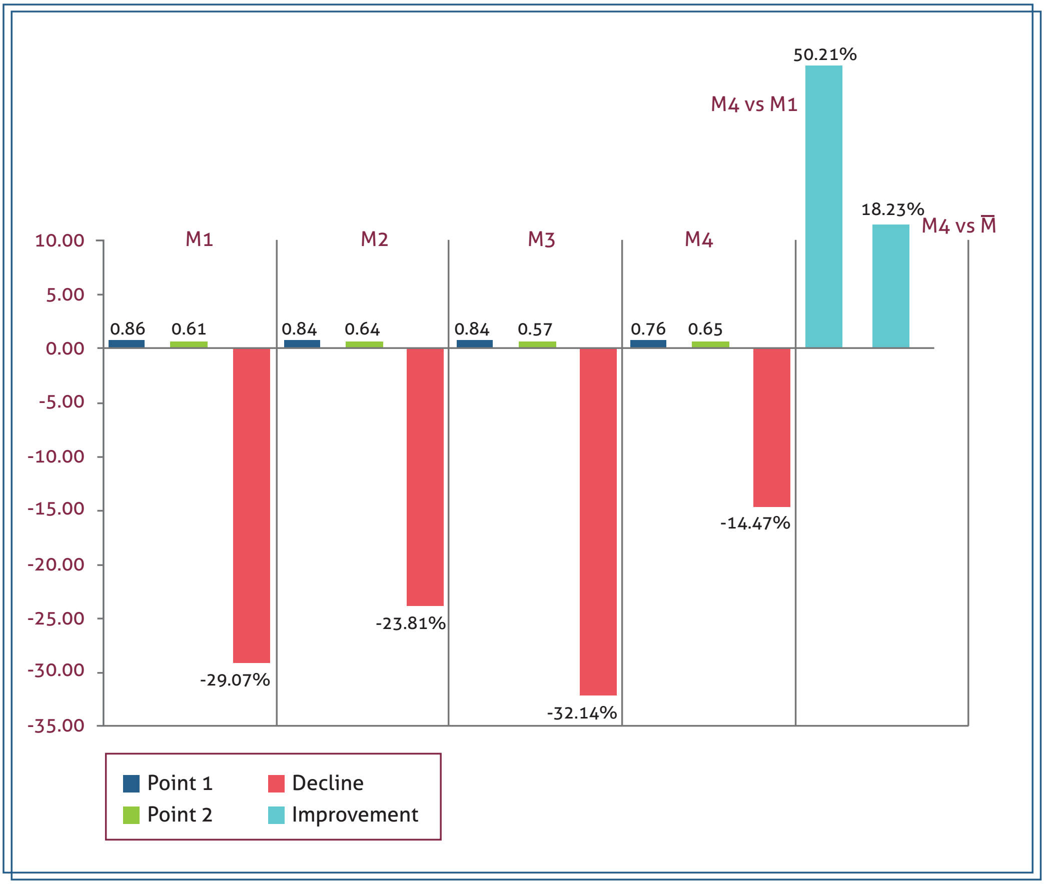
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 02° 10'13.5¨ W 77° 09' 34.9¨ **Point 2:** N 02° 06'29.3¨ W 77° 10' 26.1¨
Altitude	1236 to 2640 masl
Area of the river basin	2098 mm/year
1,762.28 ha	19°C
Average rainfall	2098 mm/year
Average temperature	19 °C
Total number of producers	1314
Number of producers within 200 m from the body of water	399
Coffee area	823.73 ha
Productivity	200 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 3,322 kg of COD per day Domestic: 160 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 10,939 kg of COD per day Domestic: 526 kg of COD per day

Biological groups in the river basin: Results in the river basin show the following distribution of richness of aquatic macroinvertebrates: Trichoptera (40%), Diptera (14%), and Ephemeroptera (12%), these groups together being indicators of medium-to-good quality, explained by substantial habitat changes: less waste, protection of banks, and availability of habitats for associated biological communities. However, in this stretch monitored, there are problems of domestic wastewater discharges, which negatively impact it and favor the reporting of poor-quality organisms such as Diptera. Thus water quality, according to the insects found, is acceptable.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone) was 0.86 and at Point 2 (after the coffee zone) was 0.61, a 29.07% decline in overall water quality (in main coffee harvest). In sampling 2, when there was no harvest, overall quality declined 23.81%; in sampling 3, overall water quality between Points 1 and 2 (in harvest time) fell 32.14%. Finally, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch fell 14.47%, an improvement over initial conditions of 50.21% and over average conditions of 18.23%.



Habitat quality conditions in the Capitanes river basin

Punto 1

Monitoreo 1

- Small channel, clear water; fine, rocky, and leaf litter substrate, located by a road, shallow pools, banks are stable, no fishing, and no solid waste.

Monitoreo 2

- Large amount of leaf litter, rocky bed, excellent canopy cover over the channel.
- Small rocks, no fine substrate, water is clear.

Monitoreo 3

- Shallow channel, clear water, without coffee intervention. Thick vegetation and rocky bed.
- Large number of macroinvertebrates indicating excellent quality.

Monitoreo 4

- Body of water crossed by road; rocky, leaf litter, and sediment substrate for macroinvertebrates. The channel is protected by abundant vegetation on the banks.

Consolidado

- The monitoring point features slow flow, with good organoleptic conditions. It has abundant vegetation on its banks and water is clear; instream covers for aquatic macroinvertebrates and fish.

Punto 2

Monitoreo 1

- Rocky, fine substrate, high flow rate and roughness in the path, with smooth and large rocks.
- Water is clear; there are instream covers for fish and macroinvertebrates.

Monitoreo 2

- Clear water, rough channel with large rocks, rocky bed, riffles and pools, no livestock.

Monitoreo 3

- Cloudy water.
- Little leaf litter, no nearby settlements, but the river is affected by extensive agricultural crops in the area.
- Erosion of soils is evident. Continuous discharges from economic and domestic activities.

Monitoreo 4

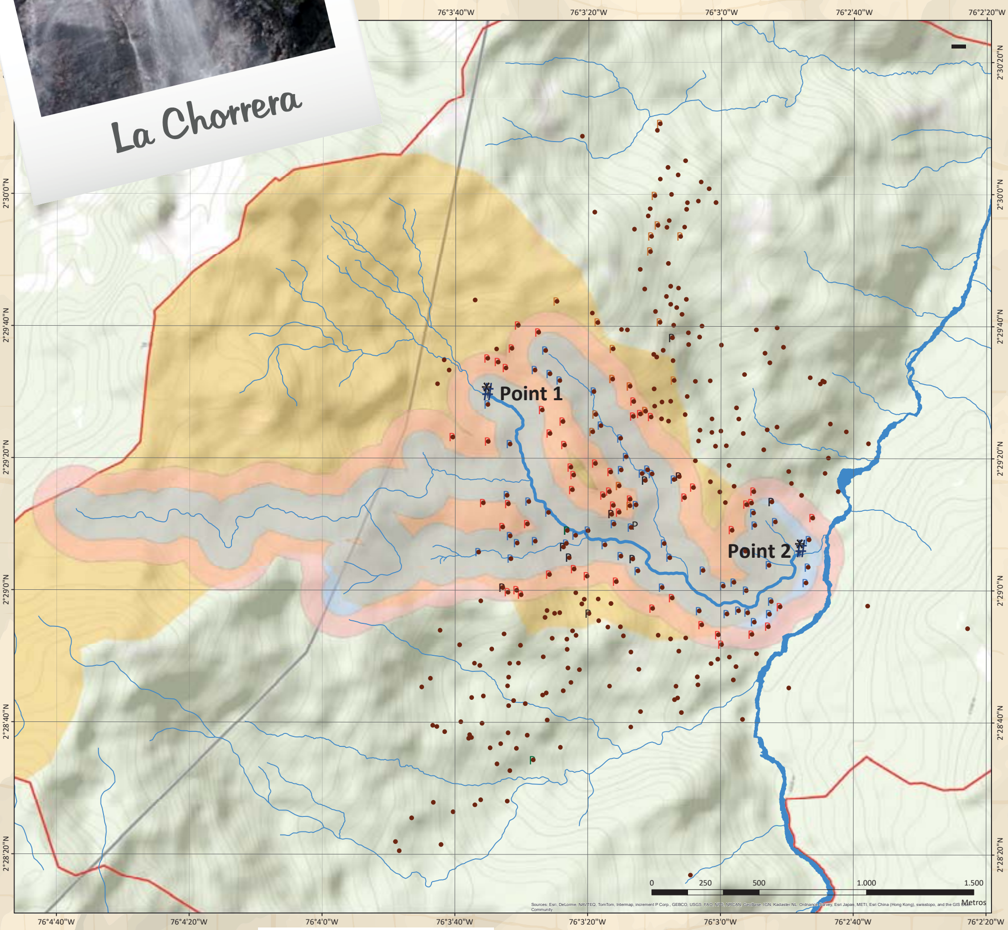
- Large bedrock in the path.
- Solid waste around and abundant forest cover; water is somewhat cloudy.

Consolidado

- Large flow rate; this point receives wastewater from several rural districts, from the San Alfonso jurisdiction treatment plant, and agrochemical pollution.
- Inorganic solid waste, large rocks, moderate algal growth, rocky substrate, and little leaf litter for macroinvertebrates.

Municipality of Inzá

La Chorrera river basin



P	Sel. Forest Plan with Incentive
P	Sel. Business Management Plan
P	Sel. Ecological Wet Milling Plan-WTS
•	IWM Producers
P	Producers_Buffer100
P	Producers_Buffer200
#	Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

Selection of Farms by Plan

Body of water: Q. La Chorrera. Inzá, Cauca

Scale 1:7,000

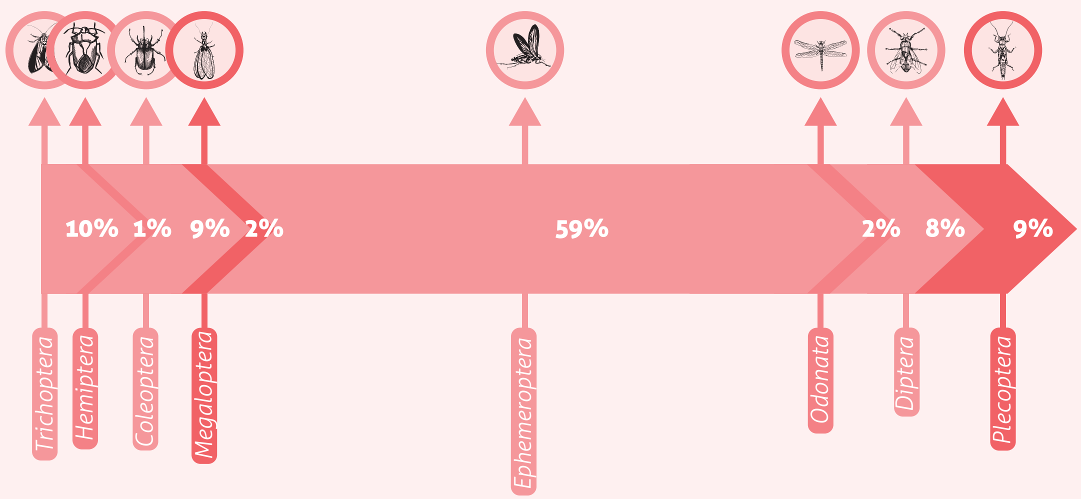
Source: IWM Program Basic Cartography. Scale 1:2,000

Prepared by: FNC contribution to IWM Program/FCM

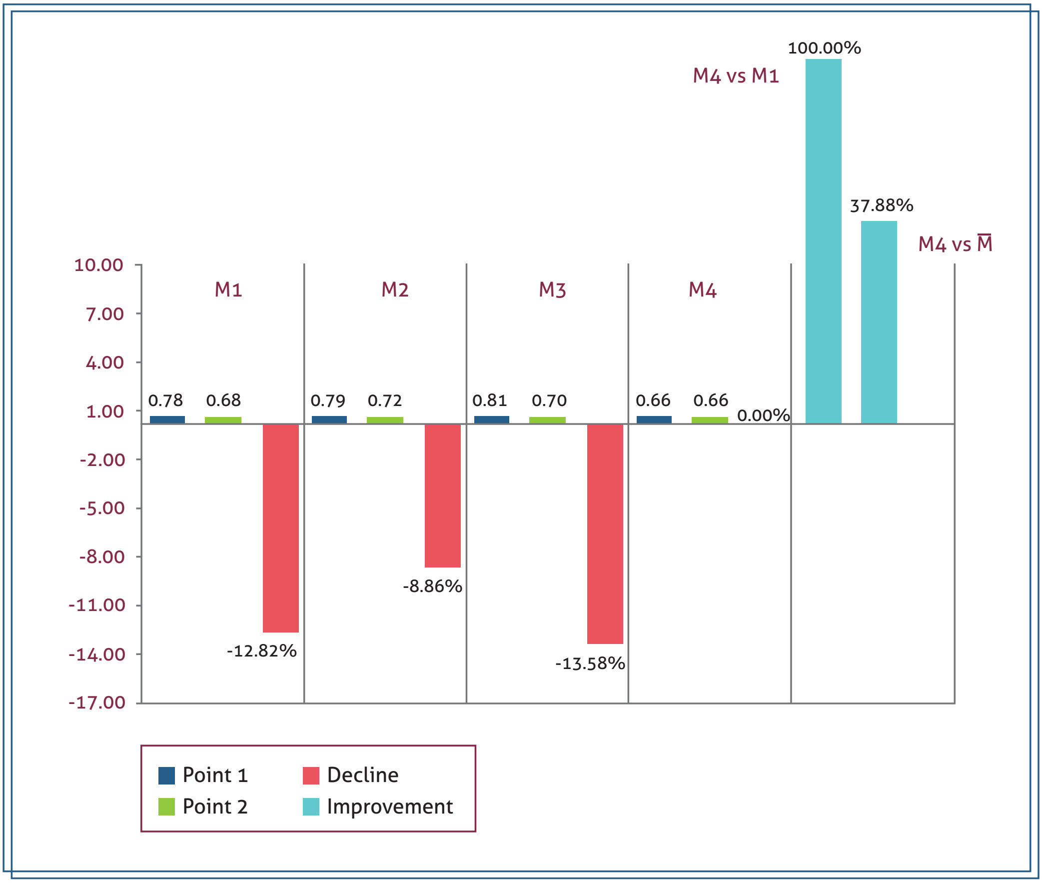
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 02° 29' 29.5¨ W 76° 03' 34.9" **Point 2:** N 02° 29' 05.1¨ W 76° 02' 48"
Altitude	1,438 to 2,151 masl
Area of the river basin	509.61 ha
Average rainfall	1,858 mm/year
Average temperature	19 °C
Total number of producers	882
Number of producers within 200 m from the body of water	122
Coffee area	228.54 ha
Productivity	215 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 915 kg of COD per day Domestic: 49 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 6,613 kg of COD per day Domestic: 353 kg of COD per day

Biological groups in the river basin: Biological conditions in this stream show the following relative abundances: Ephemeroptera (59%), Trichoptera (10%), and Plecoptera (9%). After intervention processes, conditions are suitable for establishment of aquatic biota: better available microhabitats and food supply for the different groups of organisms (evidence of reproduction), as results show higher abundance and specific diversity. There are still lower-percentage groups such as Diptera and Coleoptera, which indicate some degree of ecological impact on the body of water.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project, the KPI at Point 1 (before the body of water enters the coffee zone under study) was 0.78 and at Point 2 (after the coffee zone) was 0.68, a 12.82% decline in overall water quality (assessed in mid-harvest or mitaca). In sampling 2, in main harvest, overall quality declined 8.86%, and in sampling 3, water quality between points 1 and 2 (in mitaca or mid-harvest) fell 13.58%. Lastly, in sampling 4, in main harvest, overall quality in the stretch remained the same, meaning an improvement over initial conditions of 100.00% and over average conditions of 37.88%.



Habitat quality conditions in La Chorrera river basin

Point 1

Monitoring 1

- Many rocks around, steep slope, large waterfall upstream from the monitoring point, clear water, rough channel. Fine, rocky and leaf litter substrate.

Monitoring 2

- Waterfall, bedrock, many rocks fallen on the banks and in the body of water. Fine, rocky and leaf litter substrate, moss, smooth rocks, clear water.

Monitoring 3

- Clear water, waterfall that allows good water aeration, thick vegetation, rocky bed, and vegetation submerged in the channel.

Monitoring 4

- Thick vegetation, dissolved oxygen supply by high waterfall upstream from the monitoring point.
- Clear water.

Consolidated

- Waterfall, few households and livestock in the upper part, vegetation on the banks, clear water, and multichannel in some portions; fine and rocky substrate predominates.

Point 2

Monitoring 1

- Many rocks in the path, bedrock, cloudy water. Roots exposed in the watercourse; fine, rocky and leaf litter substrate.
- Solid waste and unstable land around.

Monitoring 2

- Anthropic alteration by construction of new road, clear water; fine, rocky and leaf litter substrate, moss, smooth rocks, trees fallen in the channel, vegetation in the body of water.

Monitoring 3

- Alterations due to livestock and solid waste on the banks.
- Discharges of domestic, coffee and carwash wastewater.
- Settlement close to the channel.

Monitoring 4

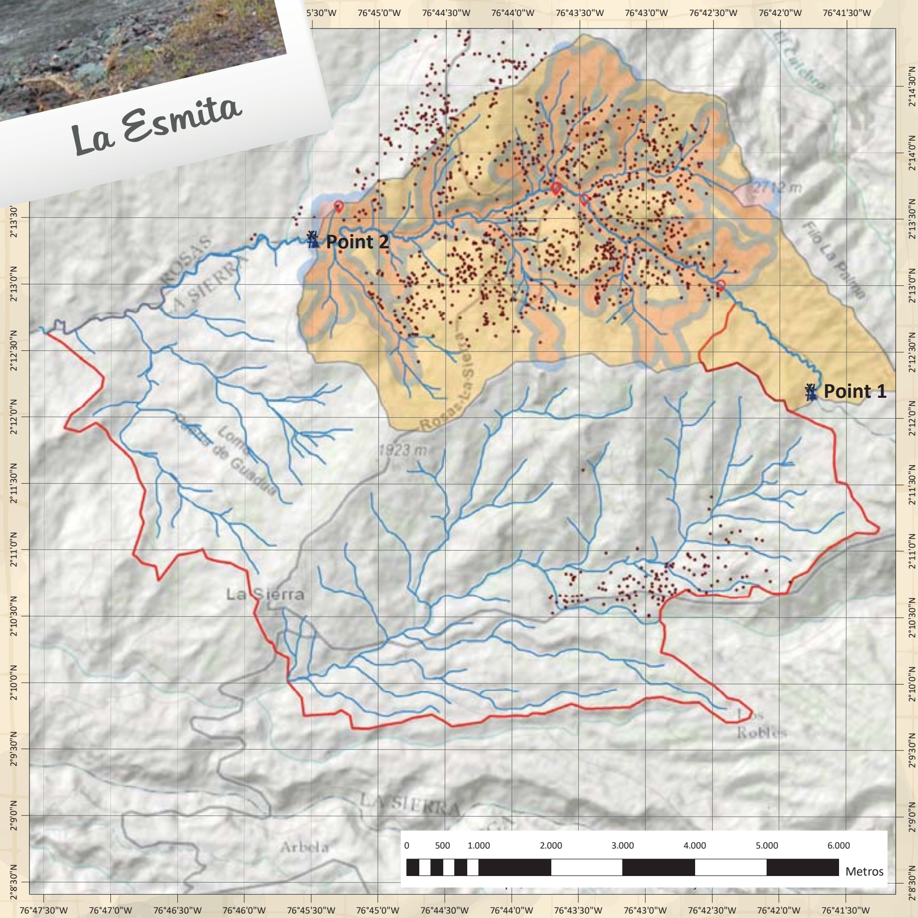
- Vegetation on both banks, cloudy water; predominant fine (sediment) and rocky substrate.
- Trees fallen in the body of water.

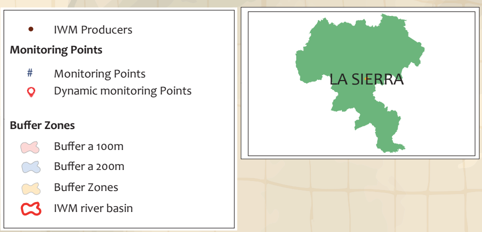
Consolidated

- Vegetation on the banks, this point receives domestic and coffee wastewater, livestock on the banks, which are eroded in the bends, habitats for fish and aquatic macroinvertebrates.

Municipality of La Sierra

Esmita river basin





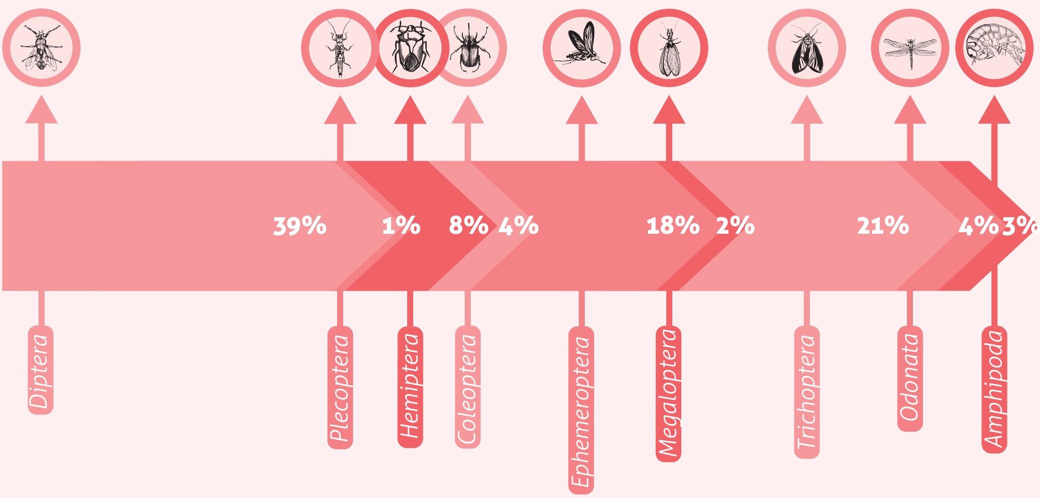
Selection of Farms by Plan
Water body: Esmita river
La Sierra, Cauca

Scale 1:65,000
Source: IGAC Basic Cartography
Prepared by: FNC contribution to IWM Program/FCM

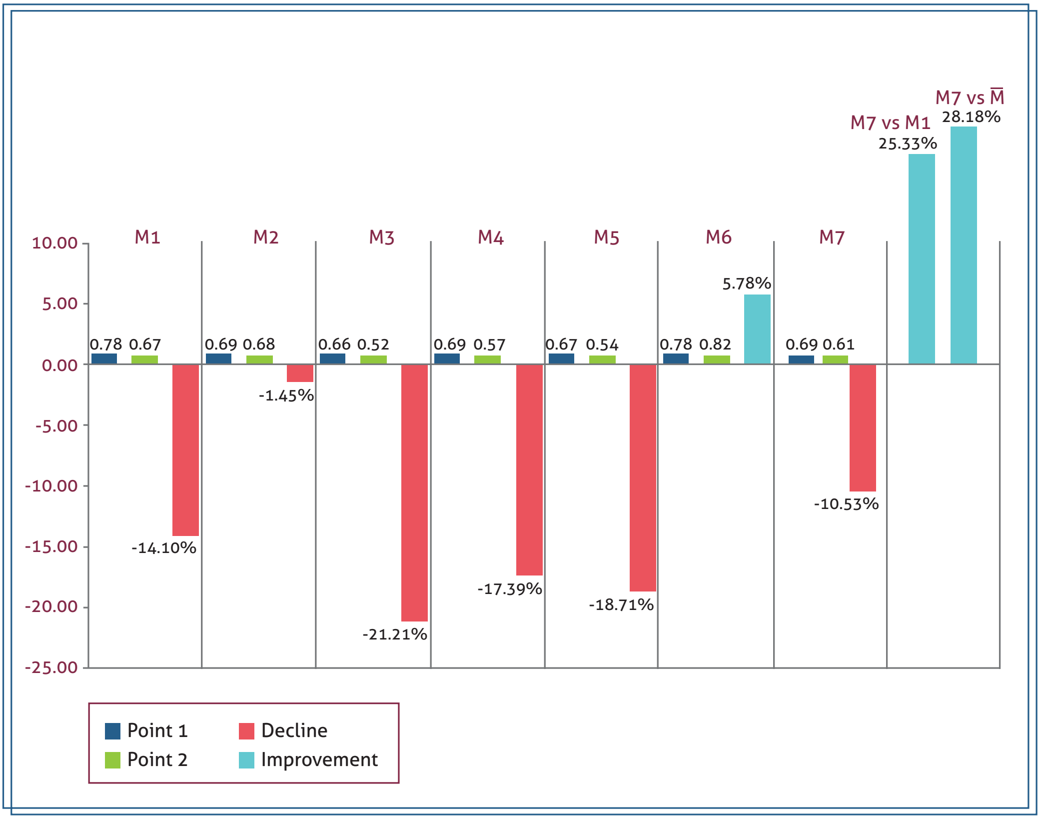
Number of samplings	Seven conventional (including three dynamic)
Coordinates of sampling points **Point 1:** N 2° 12′ 59.219″ W 76° 42′ 26.758″ **Point 2:** N 2° 13′ 38.2″ W 76° 45′ 27.9″ **Point 3:** N 2° 13′ 37.83″ W 76° 43′ 27.76″	**Point 4:** N 2° 13′ 43.9″ W 76° 43′ 40.5″ **Point 5:** N 2° 13′ 43.0″ W 76° 43′ 40.0″ **Point 6:** N 2° 13′ 42.9″ W 76° 43′ 40.6″
Altitude	1,121 to 2,118 masl
Area of the river basin	744.97 ha
Average rainfall	2,440 mm/year
Average temperature	18 °C
Total number of producers	1,804
Number of producers within 200 m from the body of water	235
Coffee area	345.22 ha
Productivity	204 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,133 kg of COD per day Domestic: 94 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 8,694 kg of COD per day Domestic: 722 kg of COD per day

Biological groups in the river basin: The aquatic insects found indicate a slightly contaminated body of water, given the relative abundance of Diptera (39%), followed by Trichoptera (21%) and Ephemeroptera (18%). This conforms to general habitat conditions: access of animals, discharges of domestic wastewater from households on the banks and poor vegetation, making colonization by some groups indicating good water quality difficult; that's why percentages of caddisflies and mayflies are low, being confined to some channel areas and, therefore, their reproduction and establishment values tend to be low.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project, the KPI at Point 1 (before the coffee zone under study) was 0.78 and at Point 2 (after the coffee zone) was 0.67, a 14.10% decline in overall water quality (assessed in main coffee harvest). In sampling 2, overall quality declined 1.45%, in mitaca or mid-harvest; in sampling 3 water quality between Points 1 and 2 (in coffee harvest) fell 21.21%; in sampling 4, during mid-harvest or mitaca, water quality declined 17.39%; in sampling 5, in harvest time, water quality declined 18.71%, and in sampling 6, when there was no harvest, quality improved 5.78%. Finally, in sampling 7, in harvest time, water quality declined 10.53%, an improvement over initial conditions of 25.33% and over average conditions of 28.18%.



Habitat quality conditions in the Esmita river basin

Point 1

Monitoring 1

- Roughness in the path, bedrock, abundant sandy mud; fine, rocky and leaf litter substrate, moss-covered and smooth rocks.

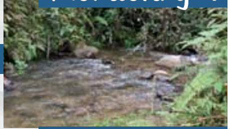
Monitoring 2

- Clear water, increased sediment in the body of water, large rocks on the path, brown algae; fine (mud), rocky and leaf litter substrate, fallen bushes and leaves in the channel, rocks with moss.

Monitoring 3

- Clear water, deep pools in most of the path, track with transit of animals and people. Trees fallen on the channel and exposed roots.

Monitoring 4



- Rocks in the path, vegetation in the body of water, roots and trunks fallen in the water, rocks with moss, leaf litter, fine and rocky substrate. Clear water.

Consolidated

- Transit of people and animals, and paddocks in surroundings. Laminar and discontinuous flow, habitats for fish and macroinvertebrates. Water is clear, submerged vegetation, fallen trees and bushes.

Point 2

Monitoring 1

- Bedrock, roughness in the path, deep pools; fine, rocky and leaf litter substrate.
- The river shows undermining and extraction of bed load.

Monitoring 2

- Bedrock on the banks, clear water; fine, rocky substrate, little leaf litter, brown filamentous algae. Livestock with access to the river.

Monitoring 3

- The body of water is completely exposed to sunlight, with clear appearance, exposed roots, erosion in the bends, and unprotected soils. Pools of different sizes and leaf litter, rocky and sediment substrates for macroinvertebrates.

Monitoring 4

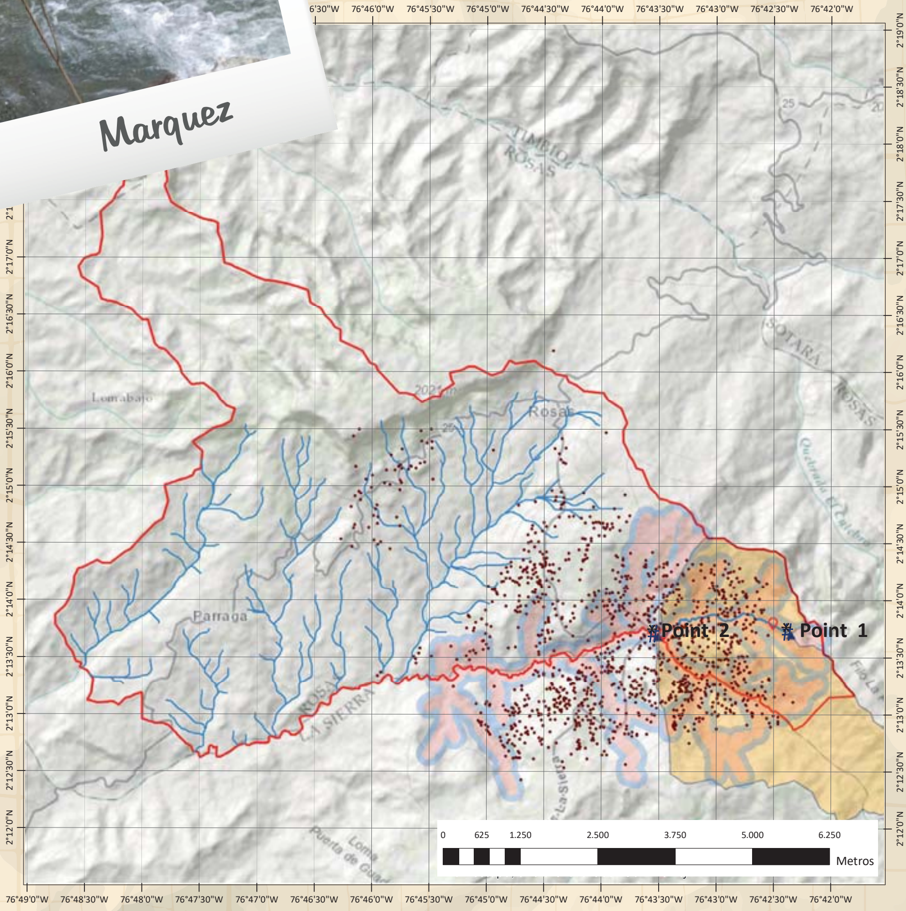
- Large rocks in the path, clear water; fine, rocky substrate predominates, little leaf litter, low diversity of macroinvertebrates, and little canopy cover.
- Paddocks around and livestock with access to the river.

Consolidated

- The water body receives discharges from households located in the upper part of the river basin, influenced by several tributaries, including El Marquez stream.
- Predominant rocky and fine substrates for aquatic macroinvertebrates.
- Into this stretch of the river, the Sapongo rural district discharges wastewater. Livestock have access to the river and canopy cover is poor.

Municipality of Rosas

El Marquez river basin



- IWM Producers

Monitoring Points

- Monitoring Points
- Dynamic monitoring Points

Buffer Zones

- Buffer a 100m
- Buffer a 200m
- Buffer Zones
- IWM river basin

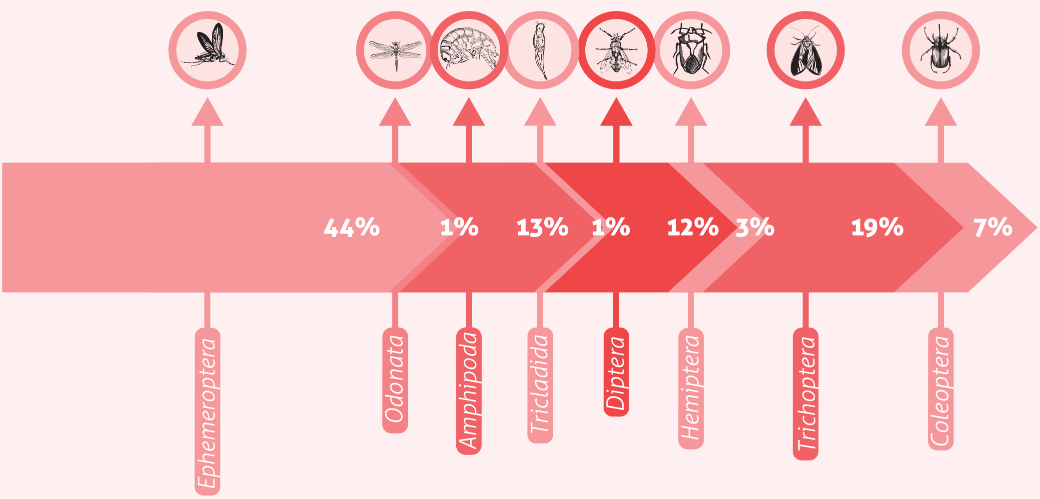
Water Quality Monitoring Points
Q. El Marquez
Rosas, Cauca

Scale 1:75,000
Source: IGAC Basic Cartography
Prepared by: FNC contribution to IWM Program/FCM

Number of samplings	Seven conventional
Coordinates of sampling points	**Point 1:** N 2° 13' 47.538" W 76° 42' 30.389" **Point 2:** N 2° 13' 42.202" W 76° 43' 27.603"
Altitude	1105 to 2013 masl
Area of the river basin	905.97 ha
Average rainfall	2,700 mm/year
Average temperature	19 °C
Total number of producers	1034
Number of producers within 200 m from the body of water	322
Coffee area	402.63 ha
Productivity	210 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,876 kg of COD per day Domestic: 129 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 6.026 kg of COD per day Domestic: 414 kg of COD per day

Biological groups in the river basin: Regarding biological characterization, throughout monitoring the report of organisms indicating good water quality was significant, as the aquatic insect order with highest relative abundance was Ephemeroptera (44%), followed by Trichoptera (19%) and Diptera (12%). This shows a trend toward oligotrophy, taking into account that the first two dominant groups are indicators of good water quality, while the third one (flies and mosquitoes) shows a trend of declining conditions, these organisms being indicators of water sources with some degree of pollution.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.66 and at Point 2 (after the coffee zone) was 0.78, an 18.18% improvement in overall water quality (assessed in coffee harvest). In sampling 2, overall quality improved 21.15%, assessed in mitaca or mid-harvest; in sampling 3, water quality between points 1 and 2 (in coffee harvest) rose 28.85%; in sampling 4, in mitaca or mid-harvest, water quality improved 3.39%; in sampling 5, in harvest time, water quality improved 36.83%, and in sampling 6, when there was no harvest, quality improved 37.68%. Finally, in sampling 7, in harvest time, quality improved 25.14%, an improvement over initial conditions of 38.29% and over average conditions of 39.02%.

Habitat quality conditions in El Marquez river basin

Point 1

Monitoring 1

- Heterogeneous topography, rocks fallen in the path, small channel (less than 1 m) and of slow flow; fine, leaf litter substrate, clear water.

Monitoring 2

- Fine, rocky and leaf litter substrate, abundant rock fallen in the path, unstable and unprotected soils, trees with exposed roots in water and small channel.

Monitoring 3

- Soils are eroded, large amount of sediment in water, and abundant leaf litter.

Monitoring 4

- Rocks fallen in the path, as well as roots and trees.
- Abundant leaf litter, fine and rocky substrate, clear water, rocks with abundant moss and smooth.

Consolidated

- The point is characterized by its heterogeneous topography and small flow, unprotected soil, shrubs and rocks fallen in the body of water, abundant leaf litter, some tree roots exposed, low diversity of aquatic macroinvertebrates.
- Domestic wastewater is discharged in the upper part, with handmade septic tanks and poor solid waste management.

Point 2

Monitoring 1

- Fine, rocky and leaf litter substrate. Bedrock, clear water, smooth rocks and shallow pools.
- Concrete bridge over sampling point.

Monitoring 2

- Clear water, rocks in the path, filamentous algae, smooth and rough rocks; fine, rocky substrate and little leaf litter, bedrock and instream fish covers.

Monitoring 3

- Clear water, nearby settlement, shallow pools.
- Solid waste, evident alterations due to domestic and coffee farm wastewater discharges.

Monitoring 4

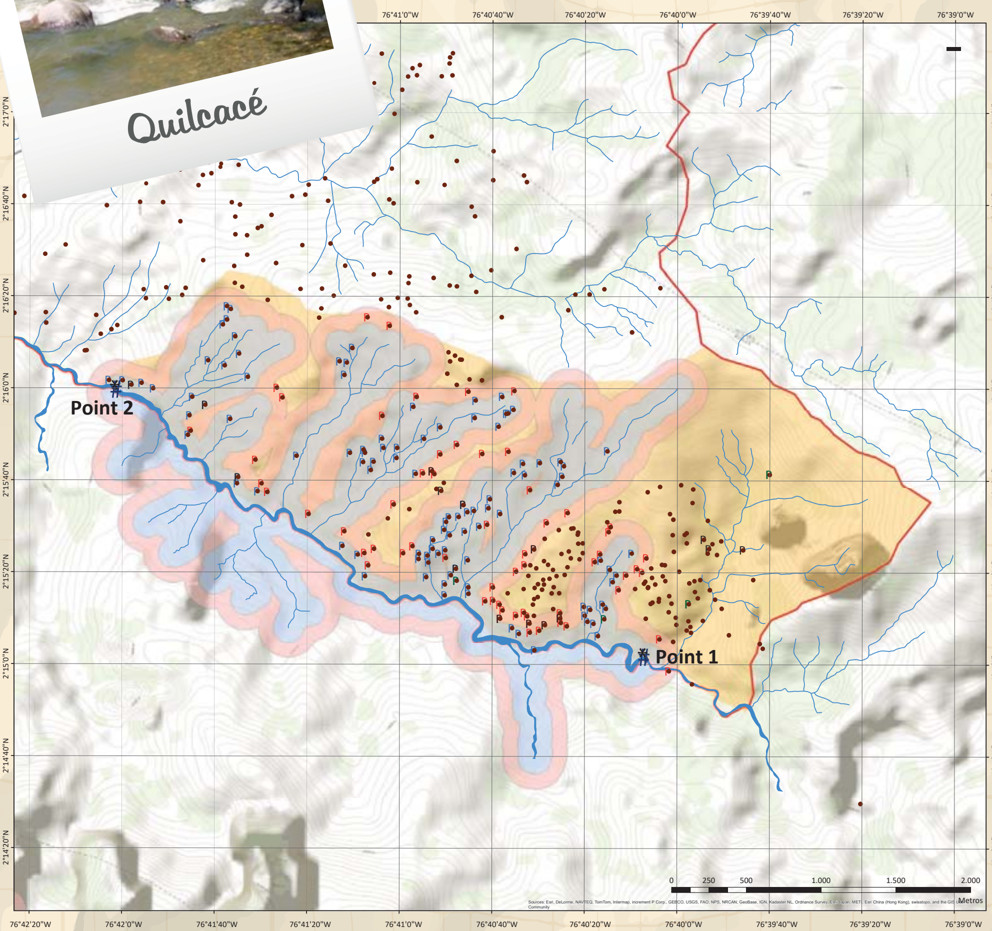
- Increased flow over previous samples. Clear water, bedrock, little diversity of macroinvertebrates, fine and rocky substrate, and little leaf litter.

Consolidated

- Clear water, vegetation on both banks, fine and rocky substrate predominates, little leaf litter, bedrock, structure over the body of water (concrete bridge), which allows communication between rural districts. Some meters downstream from the point, El Marquez joins the Esmita river.

Municipality of Sotará

Quilcacé river basin



P Sel. Forest Plan with Incentive
P Sel. Business Management Plan
P Sel. Ecological Wet Milling Plan-WTS
• IWM Producers
P Producers_Buffer100
P Producers_Buffer200
Water Quality Sampling

Reference River MultipleRing

100m
200m
IWM Intervention Areas
IWM Influence Areas

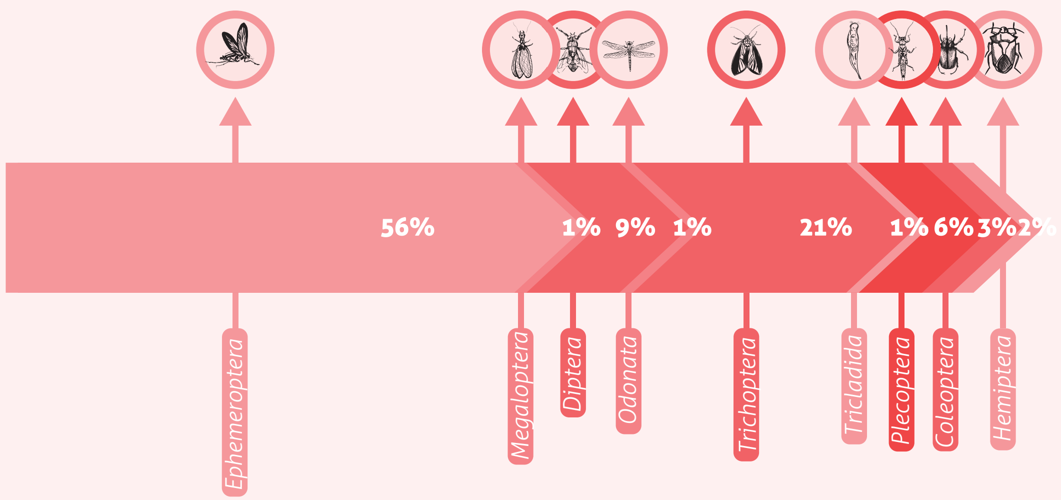
Selection of Farms by Plan
Body of water: Quilcacé river. Sotará, Cauca

Scale 1:10,000
Source: IWM Program Basic Cartography. Scale 1:2,000
Prepared by: FNC contribution to IWM Program/FCM

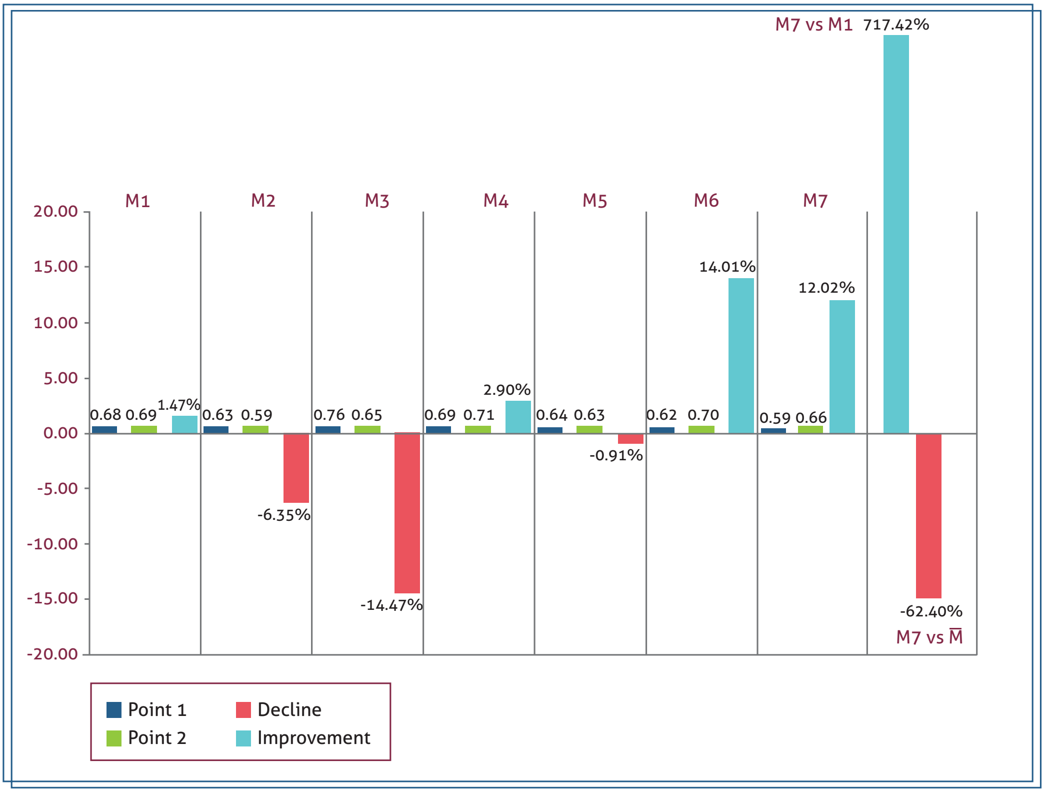
Number of samplings	**Seven conventional**
Coordinates of sampling points	**Point 1:** N 2° 15' 00.9¨ W 76° 40' 06,2¨ **Point 2:** N 2° 15' 59.4¨ W 76° 42' 00.8¨
Altitude	1,440 to 2,057 masl
Area of the river basin	934.56 ha
Average rainfall	1,200 to 2,500 mm/year
Average temperature	18 °C
Total number of producers	546
Number of producers within 200 m from the body of water	170
Coffee area	388.68 ha
Productivity	204 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,392 kg of COD per day Domestic: 68 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 4,469 kg of COD per day Domestic: 218 kg of COD per day

Biological groups in the river basin: Relative abundance of aquatic macroinvertebrates identified in this body of water is the following: Ephemeroptera (56%), Trichoptera (21%), and Diptera (9%). This river basin shows conditions similar to those of El Marquez, with strong evidence of recovery and an improving trend of aquatic habitat, which is propitious for progressive colonization of clean water organisms.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee area under study) was 0.68 and at Point 2 (after the coffee zone) was 0.69, a 1.47% improvement in overall water quality (assessed in coffee harvest). In sampling 2, overall quality declined 6.35%, in mitaca or mid-harvest; in sampling 3 water quality between Points 1 and 2 (in harvest time) fell 14.47%; in sampling 4, in mitaca or mid-harvest, water quality improved 2.90%; in sampling 5, in harvest time, water quality declined 0.91%; and in sampling 6, when there was no harvest, quality improved 14,01%. Lastly, in sampling 7, in harvest time, quality improved 12.02%, a 717.42% improvement over initial conditions and a 62.40% decline over average conditions.



Habitat quality conditions in the Quilcacé river basin

Point 1

Monitoring 1

- Bedrock, rocks with moss, rapid flow; fine, rocky and leaf litter substrate. Cloudy water. Banks are stable and no evidence of solid waste.

Monitoring 2

- Bedrock, turbid water, fine and rocky substrate, little leaf litter. Dry vegetation, tall grass.

Monitoring 3

- Somewhat cloudy water, caused by eventual rain. Upstream from the monitoring point, there is a coffee zone; fishing with hook, some solid waste on the banks; rocky bed, sediment and leaf litter. Some pools serve as instream cover for fish.

Monitoring 4

- Rocks in the path, roots and trunks fallen in the water, rocks with moss, leaf litter, fine and rocky substrate, clear water, and rocky bed.

Consolidated

- This point of the Quilcacé River is located in the middle part of the basin, in La Paz rural district. Wide channel, high water flow, vegetation on the banks; near the point, a suspension bridge facilitates passage of people and animals.
- Habitat for macroinvertebrates and fish, big rocks in the path, little canopy cover.

Point 2

Monitoring 1

- Gravel; fine, rocky and leaf litter substrate, bedrock, somewhat turbid water, pools, smooth and rough rocks. Trees and shrubs fallen in the body of water.

Monitoring 2

- Somewhat turbid water, bedrock and high slope; fine, rocky substrate and little leaf litter; wide, shallow channel, filamentous gray and green algae.

Monitoring 3

- The channel is rough, with cloudy water due to heavy rains.
- Erosion in the bends, large amount of sediments, bad smell, different types of solid waste in the channel, nearby settlement, and large number of coffee farms.

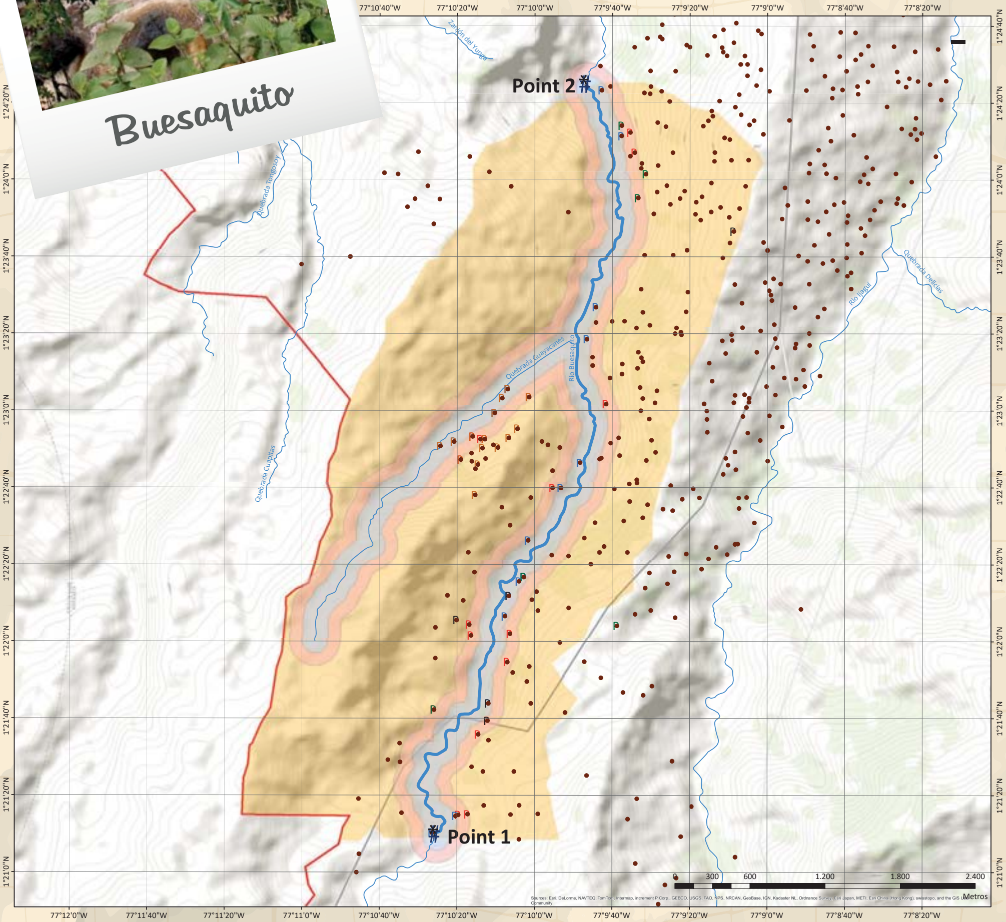
Monitoring 4

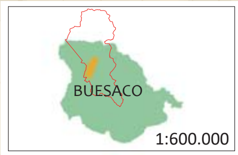
- Bedrock, vegetation on both banks, large rocks in the path, somewhat turbid water; fine, rocky substrate, and little leaf litter.
- Fallen trees and roots exposed in the channel.

Consolidated

- This sampling point features vegetation on both banks, large rocks in the path, and domestic wastewater is discharged in the upper part. Habitat for fish and aquatic macroinvertebrates, a number of different pools, submerged vegetation; trees and shrubs fallen into the channel.

Municipality of Buesaco
Buesaquito river basin





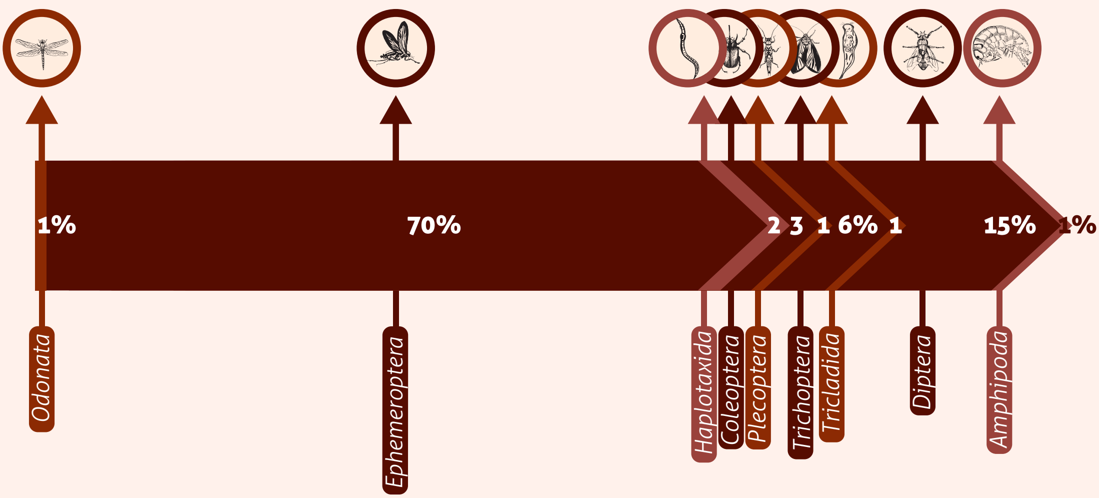
Selection of Farms by Plan
Body of water: Buesaquito river. Buesaco, Nariño

Scale 1:12,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program/FCM

Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 01° 21′ 09.0″ W 77° 10′ 25.5" **Point 2:** N 01° 24′ 24.0″ W 77° 09′ 45.9"
Altitude	1,182 to 2,254 masl
Area of the river basin	1,628.56 ha
Average rainfall	1370 mm/year
Average temperature	17 °C
Total number of producers	3172
Number of producers within 200 m from the body of water	68
Coffee area	854.03 ha
Productivity	248 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,240 kg of COD per day Domestic: 27 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 57,819 kg of COD per day Domestic: 1,269 kg of COD per day

Biological groups in the river basin: Biological characterization in this body of water shows relative abundance of aquatic macroinvertebrates dominated by Ephemeroptera (79%), followed by Diptera (15%) and Trichoptera (15%). This is explained by gradual improvement of effective habitat for these organisms, because after a disturbance event the colonization of good-quality indicator groups is massive, that is, after ecological recovery of sites favorable for movement, nesting and feeding of mayflies, they invade again those niches that previously had pollution problems. However, larvae of mosquitoes and flies are still reported, showing there is point source pollution in some sectors, which favors these medium-to-bad water quality indicator communities.

Biological groups in the river basin

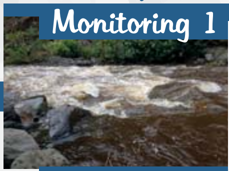


Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.61 and at Point 2 (after the coffee zone) was 0.44, a 27.87% decline in overall water quality (during coffee harvest). In sampling 2, in mitaca or mid-harvest, overall quality declined 28.57%, and in sampling 3, water quality between points 1 and 2 (in coffee harvest) decreased 7.94%. Finally, in sampling 4, in mitaca or mid-harvest, overall quality in the stretch declined 12.48%, an improvement over initial conditions of 55.21% and over average conditions of 39.03%.

Habitat quality conditions in the Buesaquito river basin

Point 1

Monitoring 1



- High flow rate, cloudy water, and bedrock along the channel. Patches of some type of vegetation, few pools, instream covers for macroinvertebrates and fish, riffles and pools, and sandy bed.

Monitoring 2

- Channel modified for a recreational center, structures for water storage, deep pools. Upstream from the monitoring point, water abstraction.

Monitoring 3

- Channel with somewhat turbid water, little vegetation on one of the banks due to topography. On one side, river damming is still there, possibly for recreational use, as there are stone structures in the channel.

Monitoring 4

- Turbid water, rapid current, bedrock, erosion on the banks, large rocks in the path; fine, rocky, and leaf litter substrate, multichannel in some portions.
- White foam and natural pool in the river basin.

Consolidated

- This sampling point features wide channel, large rocks, variety of pools, solid waste.
- On one side, recreational center with "natural" pool built in the river.

Point 2

Monitoring 1

- Channel with great flow and deep, turbidity, dark brown water, banks are stable, increase of organic nutrients.

Monitoring 2

- Reduced flow rate compared to previous sampling, clear water, large rocks, surrounding vegetation, rocky bed, coffee and corn crops on hillside, channel located in a canyon.

Monitoring 3

- Channel with abundant rocky and fine substrate, laminar flow in portions, heterogeneity in the path, and little leaf litter.
- Somewhat cloudy water, vegetation on the banks, providing food to organisms inhabiting the channel, few pools, banks are unstable in the bends, and solid waste.

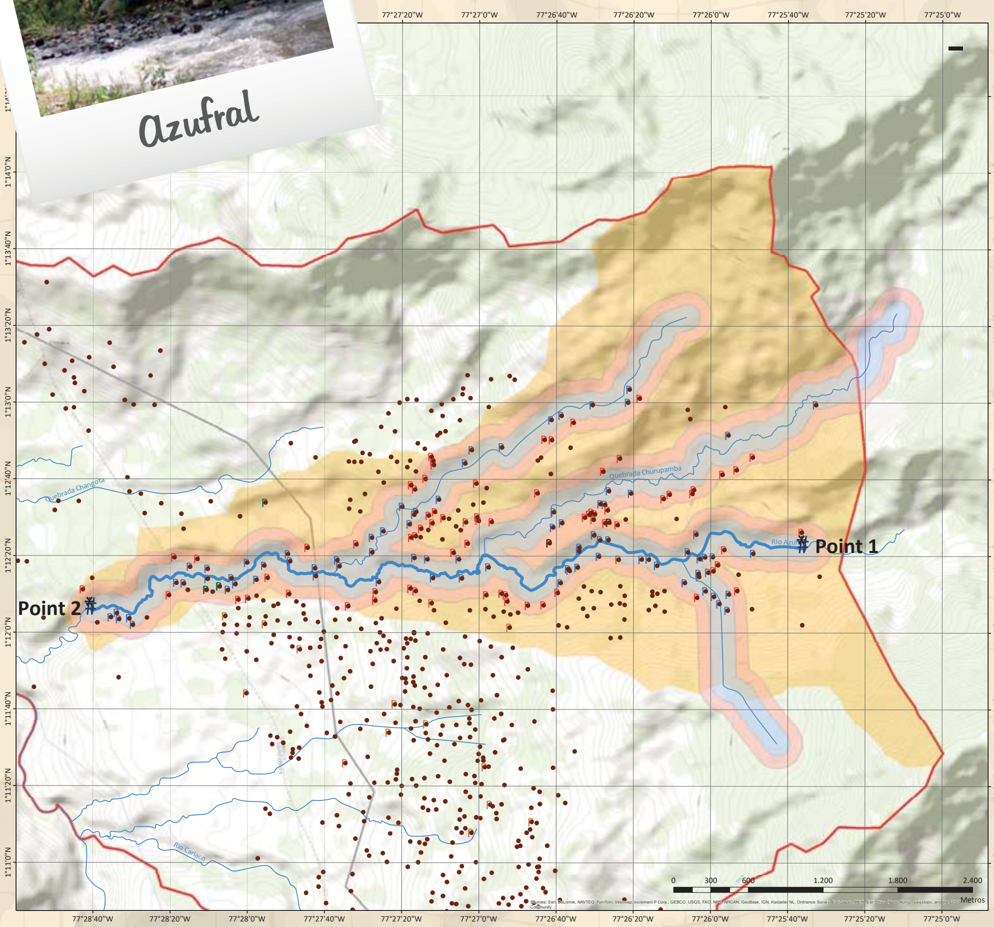
Monitoring 4

- Increased flow compared to previous sampling, turbid water, bedrock of different sizes, fine and rocky substrate.
- Domestic wastewater from farms located upstream arrives at this point.

Consolidated

- This sampling point features bedrock, vegetation on the banks, rough topography, coffee plantations on hillsides, domestic wastewater discharges from urban area of the Buesaco municipality.
- Rocky substrate for macroinvertebrates is the most abundant; instream fish covers and fishing with hook.

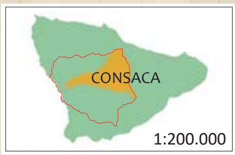
Municipality of Consacá
Azufral river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas



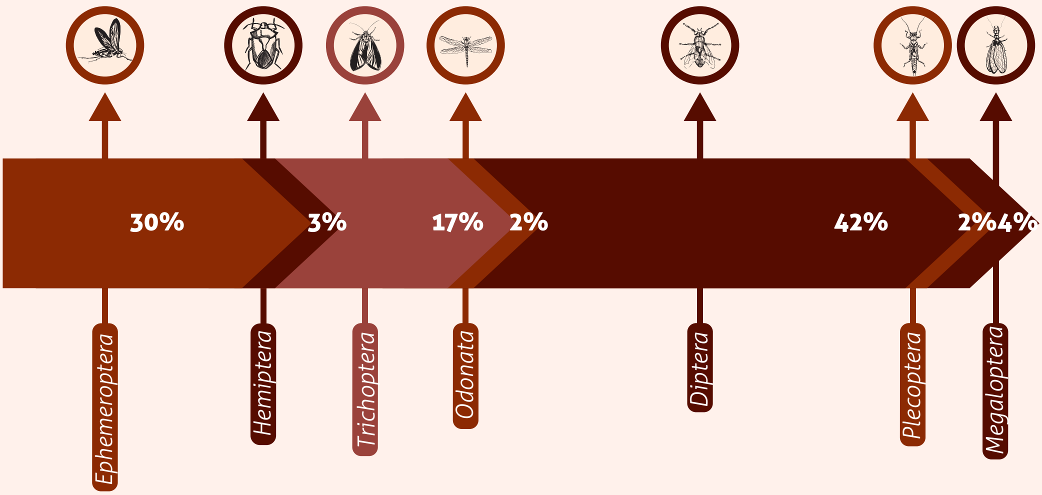
Selection of Farms by Plan
Body of water: Azufral river. Consacá, Nariño

Scale 1:12,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program/FCM

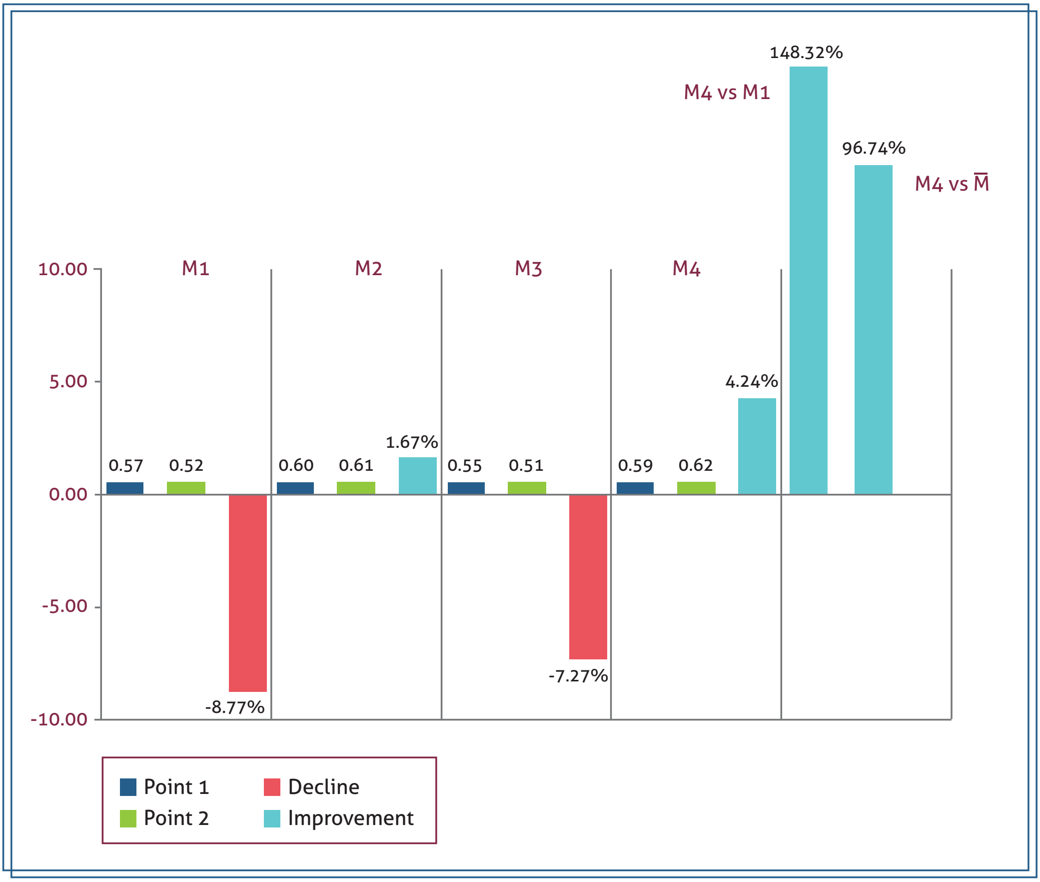
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 01° 12' 22.0" W 77° 25' 35.0" **Point 2:** N 01° 12' 06.1" W 77° 28' 39.5"
Altitude	1,333 to 2,215 masl
Area of the river basin	1,129.63 ha
Average rainfall	1,161 mm/year
Average temperature	21 °C
Total number of producers	1197
Number of producers within 200 m from the body of water	149
Coffee area	593.32 ha
Productivity	221 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 2,643 kg of COD per day Domestic: 60 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 21,229 kg of COD per day Domestic: 479 kg of COD per day

Biological groups in the river basin: Biological indicators in this river basin show dominance of order Diptera, with 42%, followed by 30% of Ephemeroptera and 17% of Trichoptera, a distribution similar to the other river basins in the department of Nariño; larvae of flies and mosquitoes are the most abundant, intimately associated with channel conditions (permanent waste in the stretch because of human activity, unacceptable organoleptic properties and strong erosion problems); hence the aquatic macroinvertebrates found in the stretch indicate medium water quality. There is moderate pollution with recovery processes, so with effective interventions, good quality could be reached, depending on monitoring progress.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the body of water flows into the coffee zone under study) was 0.57 and at Point 2 (after the coffee zone) was 0.52, a 8.77% decline in overall water quality (measured in coffee harvest). In sampling 2, in mid-harvest or mitaca, overall quality improved 1.67%, and in sampling 3, water quality between Points 1 and 2 (in harvest time) fell 7.27%. Lastly, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch improved 4.24%, an improvement over initial conditions of 148.32% and over average conditions of 96.74%.



Habitat quality conditions in the Azufral river basin

Punto 1

Monitoreo 1

- The body of water has zones with large rocks, few pools, somewhat cloudy water, and instream covers for macroinvertebrates.

Monitoreo 2

- Channel with rocky bed, fine substrate and little leaf litter, large rocks, and flooding in rainy season due to steep slopes on both sides.

Monitoreo 3

- Turbid water, gray-greenish color (as a result of possible sulfur supply from the Galeras volcano) and conductivity above 1500 µS/cm.
- Laminar and discontinuous flow; fine and rocky substrate.

Monitoreo 4

- Fine and rocky substrate, no leaf litter, little variety of macroinvertebrates.
- Over previous sampling, greater flow, rocky hillsides on both banks.

Consolidado

- This body of water features gray-greenish waters, probably coming from a volcano, and high conductivity values.
- The banks are unstable, confined channel, few aquatic macroinvertebrates; rocky and fine substrates are the most available for them.

Punto 2

Monitoreo 1

- Bedrock, rapids, rough channel along the river basin, moderately turbid water, with sediments, and two substrate types: rocky and fine (gravel, silt and sand).

Monitoreo 2

- Slightly cloudy water, bluish color, rocky bed, rough channel, large rock, shallow and scarce pools, submerged vegetation.

Monitoreo 3

- Grayish to green water, possibly due to sulfur from the upper part of the river basin, abundant undulations, steep slopes with erosion in bends, and unprotected soil due to topography.
- Leaf litter, rocky bed and sediments.

Monitoreo 4

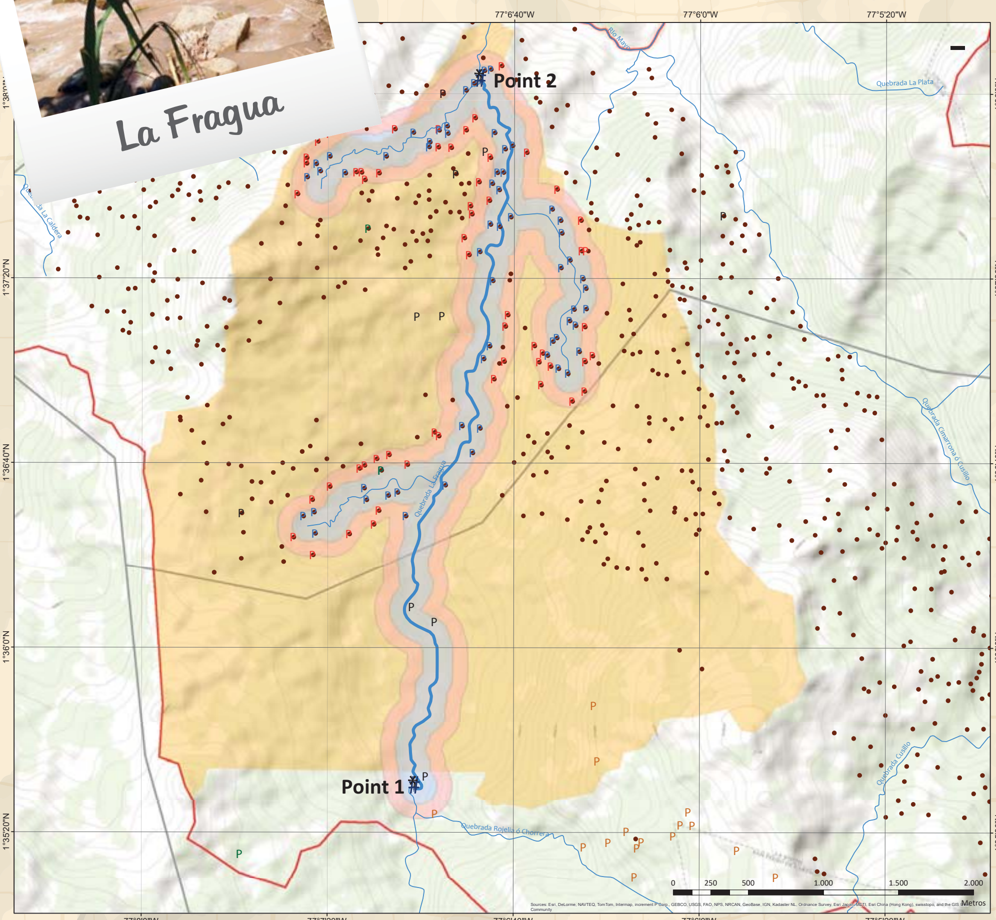
- Increased flow, turbid water, fine and rocky substrate, shrubs fallen in the channel, big rocks on hillsides, no leaf litter, abundant solid waste.

Consolidado

- This sampling point is entrenched, receiving domestic wastewater from the municipality of Consacá, gray to green color, and the most available substrates are: rocky and fine, little leaf litter.
- The banks are unstable and rocks fall constantly, little canopy cover, inorganic waste.

Municipality of La Unión

La Fragua river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas

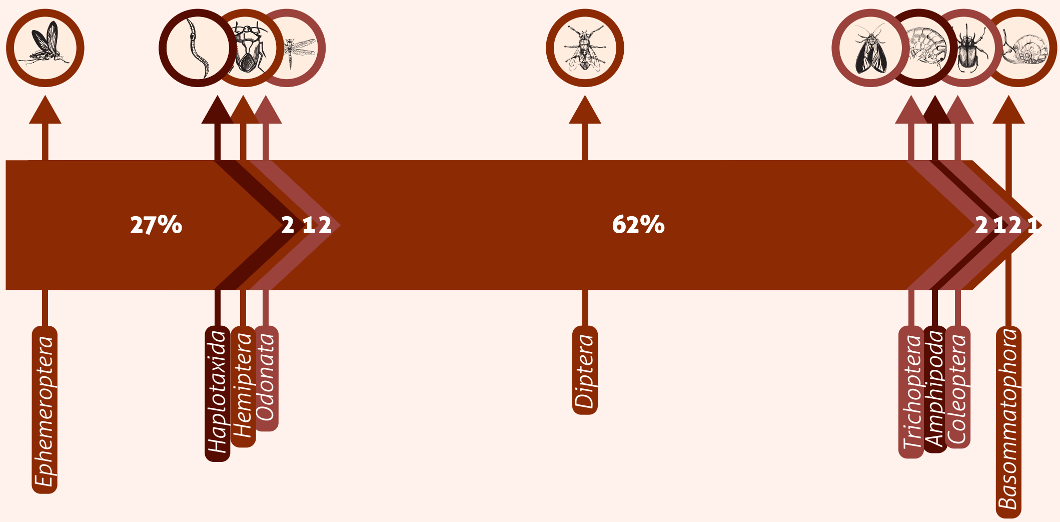
Selection of Farms by Plan
Body of water: Q. La Fragua. La Unión, Nariño

Scale 1:10,000
Source: IGAC Basic Cartography. Scale 1:100,000
Prepared by: FNC contribution to IWM Program/FCM

Number of samplings	Seven conventional
Coordinates of sampling points	**Point 1:** N 1° 35.487' W 77° 7.005' **Point 2:** N 1° 38' 03.6" W
Altitude	1238 to 2061 masl
Area of the river basin	1326 ha
Average rainfall	1200 mm/year
Average temperature	18 °C
Total number of producers	2784
Number of producers within 200 m from the body of water	152
Coffee area	1006.09 ha
Productivity	237 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 2,067 kg of COD per day Domestic: 61 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 37,856 kg of COD per day Domestic: 1114 kg of COD per day

Biological groups in the river basin: This river basin shows dominance of order Diptera, with 62% of relative abundance, followed by Ephemeroptera with 23% and Haplotaxida with 2%. This indicates the great pollution inconveniences of the body of water: due to its proximity to the municipality of La Unión (Nariño), the different samplings have found inorganic waste, farms without any kind of domestic wastewater treatment, and erosion and deforestation problems, together with hydrological dynamics of the river basin, which increases its flow suddenly, flooding the banks and carrying biota of all groups. Because of these effects, it is difficult for groups such as mayflies and caddisflies to dominate over flies and mosquitoes, as their morphology does not tolerate abrupt increases and they rather suffer ecological drift that favors Diptera.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.56 and at Point 2 (after the coffee zone) was 0.41, a 26.79% decline in overall water quality (assessed in coffee harvest). In sampling 2, overall quality declined 35% during mitaca or mid-harvest; in sampling 3, water quality between Points 1 and 2 (in coffee harvest time) fell 25.42%; in sampling 4, during mitaca or mid-harvest season, quality declined 18.81%; in sampling 5, in harvest season, water quality declined 4.85%, and in sampling 6, when there was no harvest, quality declined 5.52%. Finally, in sampling 7, when there was no coffee harvest, quality declined 3.06%, an improvement over initial conditions of 88.58% and over average conditions of 36.97%.

Habitat quality conditions in La Fragua river basin

Point 1

Monitoring 1

- Channel with many rocks, slightly turbid water, tree patches on the banks; rocky, fine (gravel, silt, and sand) and leaf litter substrate.
- Few pools, moderate growth of algae, some solid waste, fishing is infrequent, the banks are stable, as there is abundant vegetation around.

Monitoring 2

- Channel with great quantity of sediment, clear water, large amount of large rocks; rocky, fine and leaf litter substrate, moderate growth of algae on rocks; water abstraction upstream from the sampling point.

Monitoring 3

- Somewhat turbid water, solid waste on the riverbanks, bad smell, pools of different sizes, and moderate growth of filamentous algae.
- Coffee crops and vegetation on the banks; fine, rocky and leaf litter substrate.

Monitoring 4

- Increased flow compared to previous sampling.
- Turbid water; fine, rocky and leaf litter substrate, vegetation and crops on both banks, large rocks on the channel.

Consolidated

- This sampling point is located in the middle part of the river basin, it shows inorganic waste, crops on the banks, agricultural and domestic wastewater discharges from farms located around.
- Fine, rocky and leaf litter substrate, several instream covers for fish, large rocks in the channel.

Point 2

Monitoring 1

- Heterogeneous channel, slightly turbid water, pools +0.5 m deep, foam in some points, coffee mucilage waste; large amount of fine, rocky and leaf litter substrate.

Monitoring 2

- Rough channel, water somewhat turbid, brown color, bed with large rocks, wet mill less than 100 m away.
- Pools, thick vegetation around the body of water, large amount of sediment, and bad smell.

Monitoring 3

- Water is cloudy; coffee, corn and guava crops on the banks; rocky, leaf litter and some fine substrate, much foam.
- Solid waste on the banks.

Monitoring 4

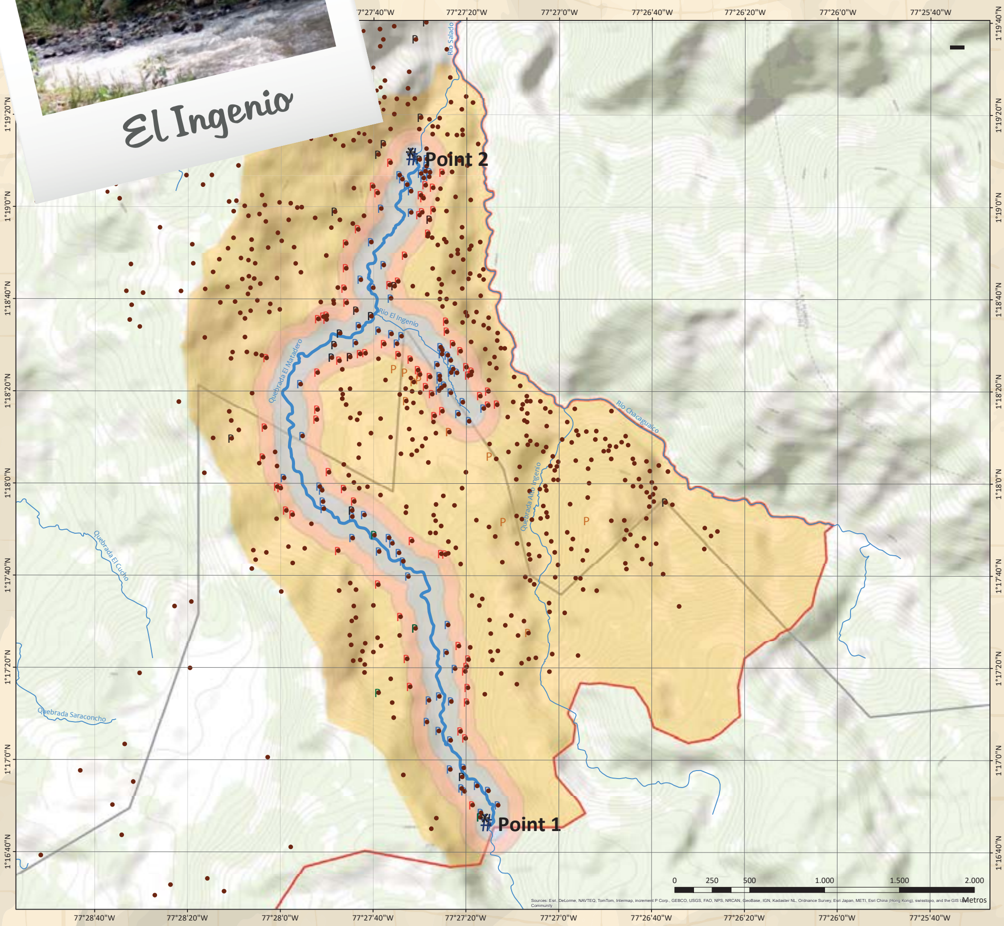
- Cloudy water, increased flow compared to previous monitoring, solid waste, rocks of different sizes, coffee crops on both sides of the river.

Consolidated

- This point suffers a large number of users mostly discharging wastewater directly into the water body.
- Large rocks along the channel, fallen trees and shrubs, crops on the banks, inorganic waste, substrates for macroinvertebrates and instream covers for fish.

Municipality of Sandoná

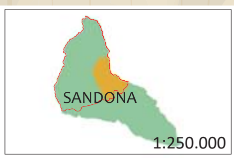
El Ingenio river basin



- P Sel. Forest Plan with Incentive
- P Sel. Business Management Plan
- P Sel. Ecological Wet Milling Plan-WTS
- • IWM Producers
- P Producers_Buffer100
- P Producers_Buffer200
- # Water Quality Sampling

Reference River MultipleRing

- 100m
- 200m
- IWM Intervention Areas
- IWM Influence Areas



Selection of Farms by Plan

Body of water: Q. El Ingenio. Sandoná, Nariño

Scale 1:10,000

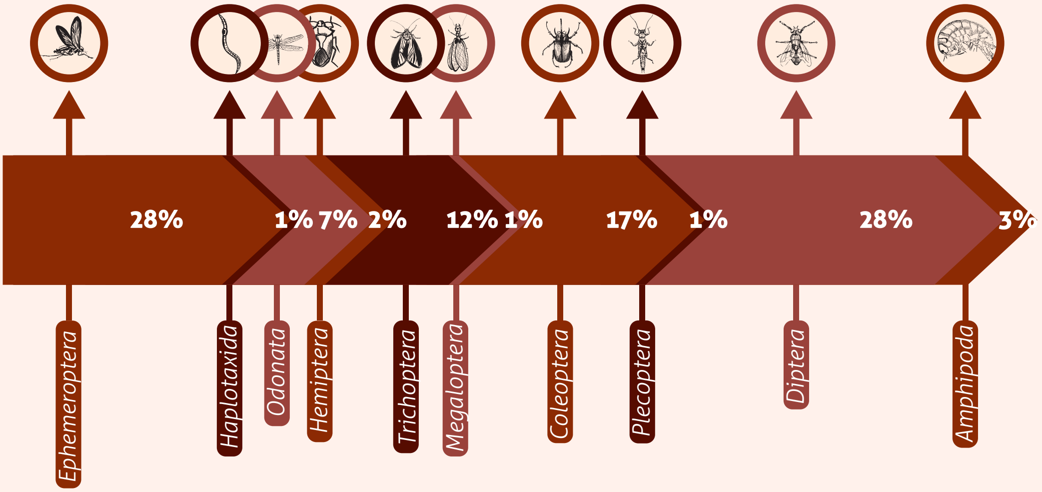
Source: IGAC Basic Cartography. Scale 1:100,000

Prepared by: FNC contribution to IWM Program/FCM

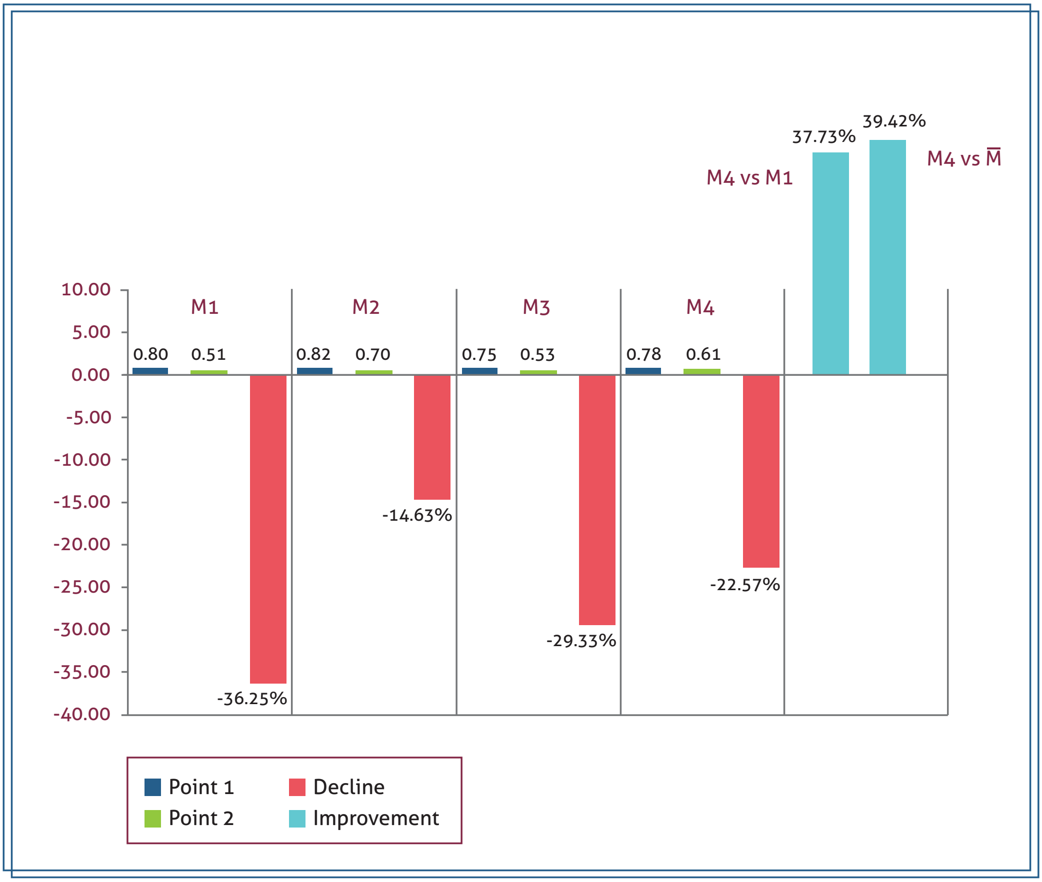
Number of samplings	Four conventional
Coordinates of sampling points	**Point 1:** N 01° 16'45.7" W 77° 27' 13.7" **Point 2:** N 01° 19'10.4" W 77° 27' 30.9"
Altitude	1,333 to 2,129 masl
Area of the river basin	902.39 ha
Average rainfall	1,133 mm/year
Average temperature	19 °C
Total number of producers	1061
Number of producers within 200 m from the body of water	204
Coffee area	686.38 ha
Productivity	200 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,454 kg of COD per day Domestic: 82 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 16370 kg of COD per day Domestic: 424 kg of COD per day

Biological groups in the river basin: Relative abundances found in biological characterization are grouped into Ephemeroptera (28%), Diptera (28%) and Coleoptera (17%), which together indicate a quality that ranges from medium to good. Among negative effects that prevent excellent quality are: extensive paddocks on the banks, access of livestock to channel, abstraction, discharges from agricultural production without some type of treatment. All these specific factors generate ecological pressure on populations of organisms and don't allow groups such as mayflies, caddisflies, stoneflies and other good indicators to proliferate in the body of water due to their high habitat requirements.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the start of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the coffee zone under study) was 0.80 and at Point 2 (after the coffee zone) was 0.51, a 36.25% decrease in overall water quality (during coffee harvest). In sampling 2, in mitaca or mid-harvest, overall quality declined 14.63%; in sampling 3 water quality between points 1 and 2 (in harvest time) fell 29.33%. Finally, in sampling 4, in mid-harvest or mitaca, overall quality in the stretch fell 22.57%, an improvement over initial conditions of 37.73% and over average conditions of 39.42%.



Habitat quality conditions in El Ingenio river basin

Point 1

Monitoring 1

- Reduced channel, with large rocks; rocky (gravel), fine (silt and sand) and leaf litter substrate.
- Some patches of vegetation and canopy cover around the channel, shallow pools, submerged vegetation and sandy bed.

Monitoring 2

- Clear water, large amount of brown algae and livestock on the banks.
- Abstraction for the municipality's hydroelectric facility, rough channel, rocky and leaf litter substrate, vegetation around the river basin.

Monitoring 3

- Large rocks in the path, abundance of periphytic communities attached to rocks, laminar flow and roughness; fine, rocky and leaf litter substrate, paddocks on the banks.

Monitoring 4

- Big rocks in the channel, clear water; fine, rocky and leaf litter substrate, surrounded by paddocks, instream covers for macroinvertebrates and fish, no fishing.

Consolidated

- Body of water surrounded by paddocks, clear water, substrate for aquatic macroinvertebrates, and instream cover for fish, no fishing and no evidence of inorganic waste.
- Livestock arrives until the banks; algae adhered to rocks, paddocks and tree patches around.
- Abstraction of water for the municipality’s hydroelectric facility.

Point 2

Monitoring 1

- Channel with rocky bed, shallow, with foam, clear water, some pools of different depths, moderate algal growth, little canopy cover on both sides, instream cover for macroinvertebrates and fish such as: gravel, silt, sand, submerged vegetation, riffles and some pools.

Monitoring 2

- Rough channel, divided by vegetation, brown foam, thick vegetation, clear water, and large rock.

Monitoring 3

- Heterogeneous rocky bed, slightly turbid water, little canopy cover, foam, periphyton-covered rocks, and livestock on the banks.

Monitoring 4

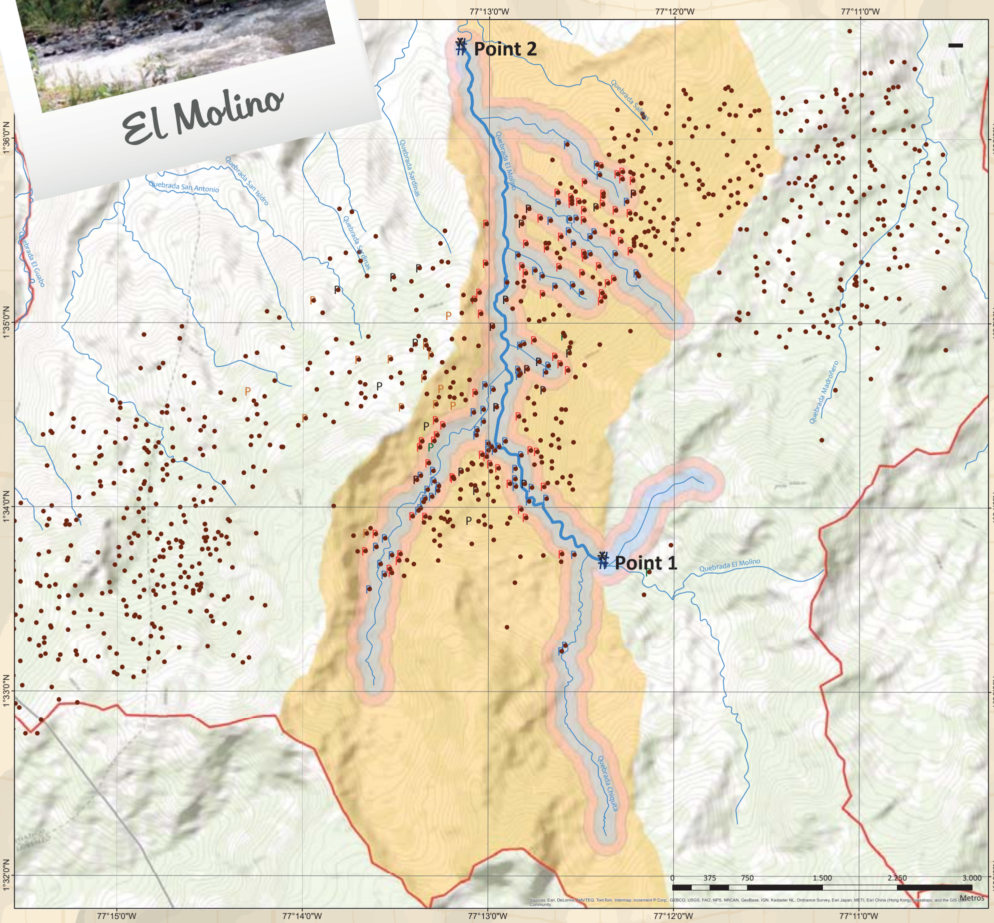
- Somewhat turbid water, increased flow, vegetation on the banks, predominant rocky substrate, laminar and vertical flow, bridle paths with frequent passage of animals, bad smell, discharges of wastewater from farms upstream from the point.

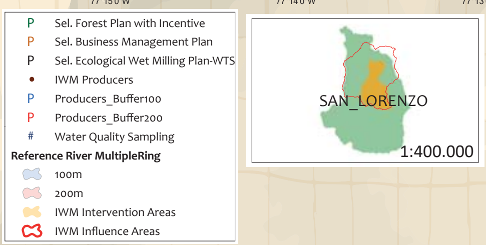
Consolidated

- This point features vegetation on the banks and crops around; it receives wastewater from sugar mill, pig farming and rural districts. In general, foam in the water, no fishing, little canopy cover, substrate for macroinvertebrates, and inorganic waste.

Municipality of San Lorenzo

El Molino river basin





Selection of Farms by Plan

Body of water: Q. El Molino. San Lorenzo, Nariño

Scale 1:15,000

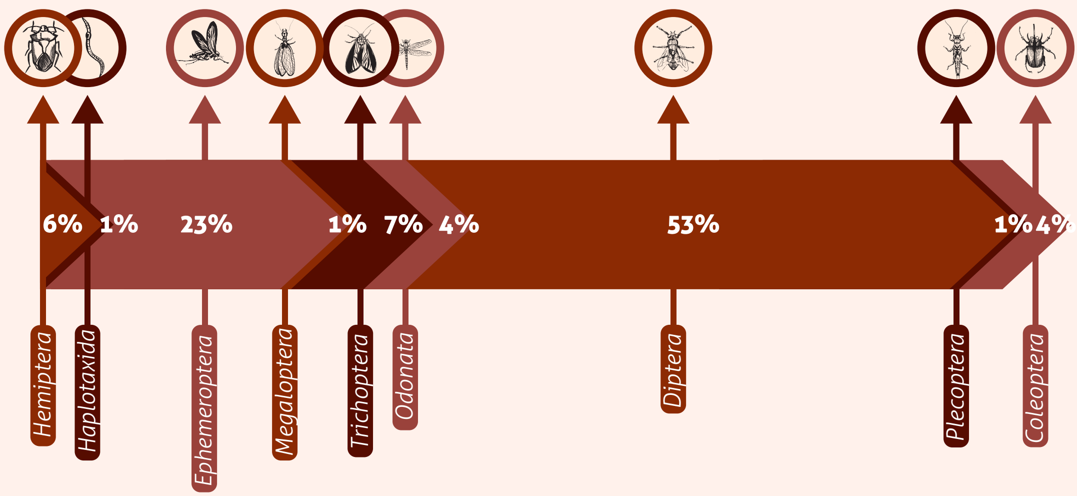
Source: IGAC Basic Cartography. Scale 1:100,000

Prepared by: FNC contribution to IWM Program/FCM

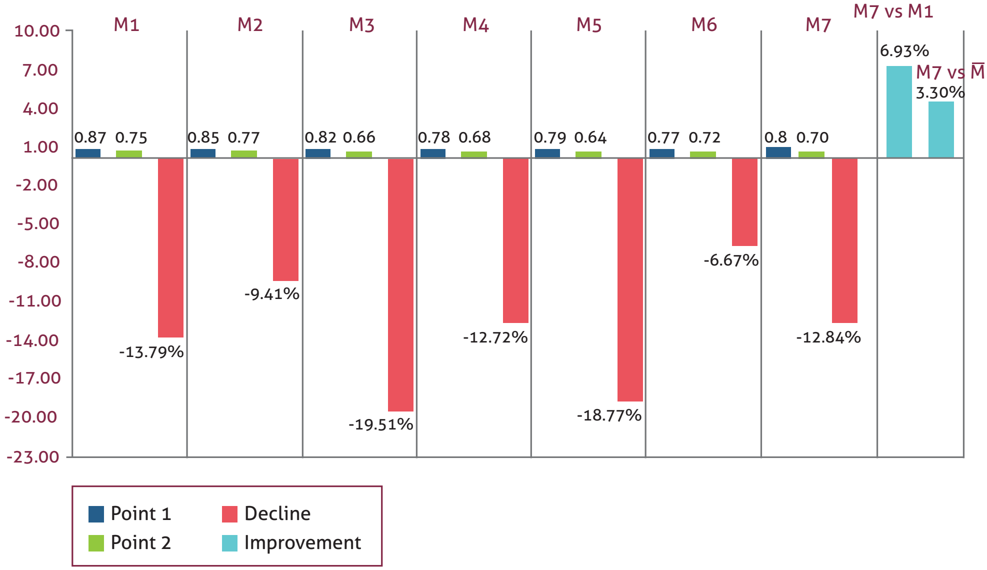
Number of samplings	Seven conventional (including three dynamic)
Coordinates of sampling points **Point 1:** N 1° 33′ 40.4″ W 77° 12′ 21.8″ **Point 2:** N 1° 36′ 29.1″ W 77° 13′ 07.6″ **Point 3:** N 1° 34′ 41.4″ W 77° 12′ 39.6″ **Point 4:** N 1° 34′ 45.0″ W 77° 12′ 43.2″ **Point 5:** N 1° 34′ 13.5″ W 77° 12′ 50.0″	**Point 6:** N 1° 35′ 05.4″ W 77° 12′ 29.3″ **Point 7:** N 1° 34′ 13.7″ W 77° 12′ 50.1″ **Point 8:** N 1° 33′ 32. 8″ W 77° 12.30.0″ **Point 9:** N 1° 32′ 58.8″ W 77° 13′ 38.0″ **Point 10:** N 1° 33′ 00.0″ W 77° 13′ 33.4″
Altitude	1,219 to 2,246 masl
Area of the river basin	855.49 ha
Average rainfall	1,740 mm/year
Average temperature	17 °C
Total number of producers	2,290
Number from producers within 200 m from the body of water	150
Coffee area	583.14 ha
Productivity	210 @/ha of dpc
Daily potential pollution of producers located within 200 m from the water body	Coffee: 1,205 kg of COD per day Domestic: 60 kg of COD per day
Daily potential pollution of all producers in the river basin	Coffee: 18,394 kg of COD per day Domestic: 916 kg of COD per day

Biological groups in the river basin: Distribution of abundance of bioindicator organisms at the monitoring points shows a high value for Diptera (53%), followed by Ephemeroptera (23%) and Trichoptera (7%), results that indicate high pollution, in contrast with some ecological spaces that host good-quality indicator insects such as mayflies. This contrast is explained by discharges and their effects, which are point-source in some specific sites in the river basin, where bioindicators of contaminated water (Diptera) increase.

Biological groups in the river basin



Overall index of water quality in the river basin (KPI): At the beginning of monitoring, before implementation of the IWM Project in the river basin, the KPI at Point 1 (before the body of water enters the coffee area under study) was 0.87 and at Point 2 (after the coffee zone) was 0.75, a 13.79% decline in overall water quality (assessed in coffee harvest). In sampling 2, overall quality declined 9.41%, in mitaca or mid-harvest; in sampling 3, water quality between Points 1 and 2 (in harvest time) fell 19.51%; in sampling 4, in mid-harvest or mitaca, water quality fell 12.72%; in sampling 5, in harvest time, water quality declined 18.77%, and in sampling 6, when there was no harvest, quality declined 6.67%. Lastly, in sampling 7, when there was no harvest, quality declined 12.84%, a 6.93% improvement over initial conditions and a 3.30% decline over average conditions.



Habitat quality conditions in El Molino river basin

Point 1

Monitoring 1

- Water is clear, with rocky, fine substrates (gravel, silt and sand) and a large amount of leaf litter, favoring development of macroinvertebrates.
- Instream covers for fish such as pools, riffles, vegetation, sandy bed and roots.

Monitoring 2

- Channel with small rocks, altered with structure for water abstraction for the municipality of Taminango; in this part, bed is of cement.
- Sandy bed upstream, substrate for macroinvertebrates such as leaf litter, rocks and fine; thick vegetation.

Monitoring 3

- Significant changes in the channel, such as much foam, its origin unknown.
- Channel protected by great quantity of vegetation of various species.

Monitoring 4

- Fine, rocky substrate and little leaf litter, bedrock and rocks of different sizes.
- Clear water, inlet pipe, increased flow compared with previous sampling.

Consolidated

- Channel with rocks of different sizes, altered with structure for water abstraction for the municipality of Taminango.
- It receives discharges from households in the upper part, vegetation on both banks, located a few meters from the road, instream cover for fish and macroinvertebrates.

Point 2

Monitoring 1

- Channel with homogeneous portions, clear water and fish in several portions.
- Small and abundant rocks throughout the path.
- Patches of some type of vegetation, little canopy cover, fishing is rare, solid waste. Riffles, pools and submerged vegetation.

Monitoring 2

- Rough channel, clear water, large rocks, instream cover for fish, pools about 40 cm deep, rocky bed; fine, rocky and leaf litter substrate, canopy cover by sectors. The channel is fragmented.

Monitoring 3

- Abundant rocky substrate, pools of different depths, fish therein.
- Channel fully exposed to sunlight, moderate periphytic activity, fishing with hook, passage of pack animals.
- Nearby settlement, wastewater discharged from farms, large amount of sediment.

Monitoring 4

- Rocks of different sizes; fine, rocky and leaf litter substrate, submerged vegetation, laminar and discontinuous flow, vegetation on both banks; wooden suspension bridge over the sampling point, passage of pack animals, solid waste.

Consolidated

- Wide channel, rocks of different sizes, vegetation on both banks, suspension bridge for passage of people and animals over the sampling point, little canopy cover, variety of pools, instream cover for fish and macroinvertebrates.
- This point receives wastewater discharges from farms.

6

Quality of surface water in coffee river basins of Colombia

ESTIMATED QUANTITY OF SAVED, UNPOLLUTED AND IMPROVED WATER UNDER THE IWM PROJECT

Estimated quantity of saved, unpolluted and improved water under the IWM Project

Capacity building for the effective accounting of water use and corporate impacts is essential to help institutions promote better water management, protect natural resources and align with external stakeholders' expectations. Currently there are some methods employed by companies to quantify water, including (UNEP, 2010):

Water footprint: A method to measure the volume of water used by any group of consumers (including a business or its products), aimed to help these consumers understand their relationship with watersheds, plan resource management and spread awareness of water challenges.

Life cycle assessment: An analysis tool designed to measure environmental sustainability of products and services (including water use, generation of wastewater and emissions, among others), throughout all components of the value chain.

Global Water Tool (WBCSD): An online tool that couples corporate water use and discharges with watershed- and country-level data as a means to assess water-related risks.

Water Sustainability Planner (GEMI): A tool aimed at helping companies better understand their water-related needs and circumstances. The sustainability tool assesses a company's relationship with water and identifies associated risks.

The IWM Project has based its interventions on actions that have both a direct impact on available water volume, either in quantity and quality, and an indirect effect, which are more difficult to quantify. Therefore, to evaluate the impact of these actions on available water volume, two complementary approaches have been used:

A **first approach** based on quantification of direct water saving as a result of implementations at farm level, with water-saving and wastewater treatment systems, and awareness-raising actions with coffee growers.

And a **second approach** based on quantification of the Project's general impact at the level of each river basin, seeking to integrate the aforementioned actions with others whose effect on water bodies is difficult to quantify, such as bioengineering works, reforestation, waste collection, renewal of coffee plantations, and community awareness-raising. This second approach makes it possible to calculate the water made available to other users, including the environment, and has been possible thanks to monitoring of quality of bodies of water throughout the Project.

Saved and unpolluted water quantity as a result of IWM Project implementations

Calculation of saved and unpolluted water volume took into account the number of implementations at farm level and pollution prevented in the river basins as a result of interventions.

Total saved water volume

To calculate the volume of water saved in wet coffee processing, the 1,004 implementations of ecological wet coffee processing systems (tub-tank, Becolsub and Ecomill®) were taken into account, which reduce volume of water used in coffee processing by over 87.5%, from 40 L/kg of dry parchment coffee (dpc) to less than 5 L/kg of dpc.

Water volume was calculated by considering an average coffee farm, with 2.64 ha, a production of 212 @/ha of dpc, and saving of 35 L/kg of dpc. Based on this, the reduced volume of water used in wet coffee processing as a result of implementation of saving technologies is an estimated **198,720 m^3/year**.

Water saving at household level as a result of implementation of saving technologies was calculated considering the 900 water savers installed on the farms, a 10% saving of water by an average coffee-farming family of four members and a consumption of 200 L/day per person. So household-level water saving as a result of the saving technologies implemented is an estimated **26,280 m^3/year**.

Water saving as a result of awareness-raising campaigns and technical assistance, targeting mainly coffee-growing families and their communities, was estimated considering a 10% saving of water used at home by 11,000 beneficiaries (the focus of awareness-raising and advice campaigns) and a consumption of 200 L/day per person, which results in an estimated water saving of about **80,300 m^3/year**.

Total volume of water saved as a result of implementation of water-saving technologies is an estimated 305,300 m^3/year.

Total volume of unpolluted surface water

Volume of unpolluted freshwater was estimated using the gray water footprint approach (Hoekstra *et al.*, 2011), that is, the difference of volumes potentially polluted before and after the implementations; it is calculated as the water volume required to dilute Chemical Oxygen Demand (COD) concentration of wastewater to an acceptable level according to environmental quality standards, set by the IDEAM at 25 ppm of COD for acceptable quality.

The calculation took into account pollution prevented as a result of the Project interventions (tons/year of organic load that were not discharged into the river basin), considering a 85% organic load removal (COD) in the coffee wastewater treatment systems installed and 80% in domestic wastewater treatment systems (Equation 7).

$$\text{Unpolluted water } (m^3/year) = \frac{\text{Pollution prevented (in t/year)}}{0{,}000025\ t/m^3} \quad (7)$$

Volume of freshwater unpolluted as a result of discharges prevented in wet coffee processing (by implementation of pulp and coffee wastewater management and treatment technologies) was an estimated **93.4 million m^3/year** (20,898 m3/year of wastewater treated by 740 implementations).

Volume of freshwater unpolluted as a result of discharges prevented by domestic wastewater treatment was an estimated **4.3 million m^3/year** (191,756 m3/year of wastewater treated by 1,022 implementations).

On-farm interventions for treatment and management of (both domestic and coffee) effluents to achieve acceptable quality wastewater prevented 2,443 t/year of pollution, equivalent to an estimated unpolluted water volume of **97.7 million m^3/year**.

Total volume of unpolluted water as a result of IWM Project actions is an estimated 97.7 million cubic meters a year.

In addition to water saving solutions, **drinking water supplied** by domestic water purifiers was an estimated **5,454 m^3/year**, considering 909 family filters with a treatment capacity of 18,000 L/filter during three years of average lifetime.

Total volume of saved and unpolluted water as a result of IWM Project actions is an estimated 98 million cubic meters a year.

Quantity of "excellent" quality water improved as a result of the IWM Program implementations

The amount of water improved in the IWM Project was calculated through the Overall Water Quality Index (KPI21) and flow rate at the sampling point located after the IWM Project implementation zone (Equation 8). With this method, improved water quantity was determined as the difference between "initial pure water," the product of initial flow rate by the initial overall quality index value, and "final pure water," the product of final flow rate by final overall quality index value.

$$\text{Improved water quantity}\left(\frac{m^3}{year}\right) = \left(Q_{CF} * KPI_{CF}\right) - \left(Q_{CI} * KPI_{CI}\right) \quad (8)$$

Where

Q = Flow rate at sampling Point 2 (m^3/year)

KPI = Overall Water Quality Index at sampling Point 2

CI: Initial conditions

CF: Final conditions

The calculation was made for each of the 25 river basins, the initial conditions being those related to the first monitoring campaign and the final conditions those of the fourth monitoring campaign. For calculation of total water improved only those river basins where the product of flow rate by overall quality index was greater in final conditions than in initial conditions were considered.

Total volume of improved water of "excellent" quality, considering overall quality index and average flow rate between initial and final monitoring campaigns, is an estimated 116.5 million cubic meters per year.

Total volume of "good" quality water made available to nature (WA)

General impact of all activities of the IWM Project on quality of surface water bodies can be expressed in volumetric terms using the "*Water Sustainability Benefit Accounting Method (WSBAM).*" Still under development, it enables estimation of the volume of water made available to nature (WA), depending on quality increase observed in the bodies of water located downstream from the coffee zone after the Project implementations.

Estimation of volume of water made available to nature took into account the flow rate at Point 2 in the last monitoring campaign (fourth), net water quality progress (measured as the difference between KPIs at Point 1 and Point 2 at the beginning and end of the Project), and the quality difference between the KPI21 overall quality index value at Point 2 (affected by the Program interventions) and the index value equivalent to "Good" water quality, estimated at a KPI21 of 0.70 at the beginning of the Project (Equation 9).

$$\text{Net Progress} = \left(KPI_{p1} - KPI_{p2}\right)_{\text{project start}} - \left(KPI_{p1} - KPI_{p2}\right)_{\text{project end}} \quad (9)$$

$$\text{Quality difference}_{\text{project start}} = 0{,}70 - KPI_{p2}$$

If net progress is higher than quality difference at the start of the Project, volume of water made available (WA) is equal to final water volume at Point 2 (Equation 10).

$$WA_{\text{net progress} > \text{Initial quality difference}} = \left(Q_{final}\right) \quad (10)$$

If net progress is lower than quality difference at the start of the Project, volume of water made available (WA) is given by Equation 11.

$$WA_{\text{net progress} < \text{Initial quality difference}} = \left(Q_{final}\right) * \frac{\text{Net progress}}{\text{Quality difference}_{\text{project start}}} \quad (11)$$

To prevent overestimations, only those river basins that showed significant water quality improvement at the evaluated point, were taken into account, that is, where net progress between the first and fourth sampling was greater than 0.1, and calculations were made exclusively for those river basins that did not show "good" quality at the start of the Project, i.e. an initial KPI lower than 0.70; Figure 26 shows graphical interpretation of the WSBAM method.

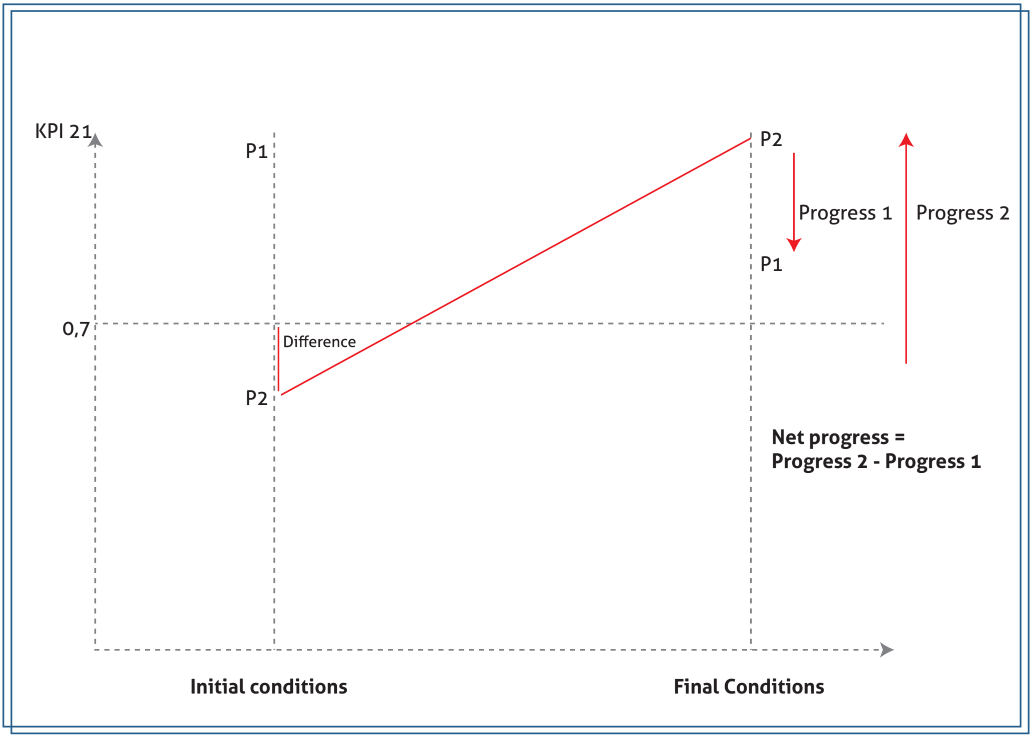


Figure 26. Calculation of volume of water made available to nature (WA) with the WSBAM methodology.

Total volume of "good" quality improved water made available to nature as a result of the IWM actions is estimated at 167 million cubic meters per year.


Manos al Agua

7

Quality of surface water in coffee river basins of Colombia

CONCLUSIONS AND RECOMMENDATIONS

Effects of coffee production on quality of surface water in coffee river basins of Colombia

- The IWM Project, thanks to the water quality monitoring program, has generated relevant information to determine the impact of Colombian coffee production on surface water quality.
- The IWM Project has provided a better understanding of the influence of Colombian coffee production on surface water quality.
- Coffee production in Colombia has an impact on water quality in coffee river basins.
- The impact caused by coffee production is higher in harvest time, but it is lower than the expectations we had before implementation of the IWM Project in the river basins, thanks to the high self-purification capacity of bodies of water in the coffee region.
- Impact of coffee production on water resources is directly related to the water management practices used in wet processing and how coffee byproducts are disposed of at farm level.
- The coffee sector is not solely responsible for pollution of water bodies in the coffee river basins. There are other pollution sources, such as household, livestock, slaughterhouse and industrial activities. Sometimes these sources are located upstream from the coffee area, reducing the water body's capacity to assimilate coffee wastewater discharges.
- Given the diverse sources of pollution in the river basins, it is not always easy to monitor impact of coffee production on a polluted body of water.
- Discharges by coffee households have an important impact, mainly in harvest time, when wastewater increases significantly as a consequence of temporary workers.

Effects of IWM Project implementations on surface water quality

Based on results of the IWM Project water quality monitoring, it can be concluded that there is a positive effect of the Project interventions on surface water quality. These positive impacts are described below:

- In 92% of the river basins, water quality improved between the two monitoring points P1 and P2, the former being located upstream from the coffee area and P2 downstream. This improvement is reflected in reduction of water quality deterioration between Point 1 and Point 2.
- Water quality at P1 (upstream from the intervened coffee area) is generally better than quality at P2 (downstream from the intervened coffee zone). Along the Project, it was observed that water quality at P1 has deteriorated, while quality at P2 has improved, so quality deterioration between Point 1 and Point 2 was attenuated, an evidence of improved water in the stretch evaluated.

- The overall water quality index (KPI 21) shows that quality decline was attenuated 86% between Point 1 and Point 2 when comparing initial conditions (before implementation of the IWM Project) and those at the end of the fourth monitoring campaign (for the 25 river basins evaluated). Similarly, at P2, downstream from the coffee zone, this index has shown an estimated 11% average quality increase.
- The overall water quality index (KPI 21) shows that quality deterioration between Point 1 and Point 2 was attenuated 101% by comparing initial conditions (before the IWM Project) vs. those at the end of the Project (seventh monitoring campaign) for the 11 river basins still under evaluation. And at P2, downstream from the coffee zone, this index has shown an average quality increase estimated at 6.5%.
- Based on the overall water quality index, the number of river basins reaching a "good" quality level downstream from the coffee zone (Point 2) increased from 16% at the beginning of the Project to 40% at the end (seventh monitoring campaign). At Point 1, water quality declined from 56% to 52%.
- Dynamic monitoring, which involved a greater number of monitoring points and greater evaluation frequency, allowed identifying and evaluating sources of pollution different from coffee production in the river basins studied and enabled to determine that pollution peaks, in harvest time, are lower in bodies of water that receive discharges from farms with IWM Project implementations.
- Implementations on the coffee farms located within 200 m from the body of water resulted in better water quality in the whole river basin.
- Total volume of saved and unpolluted water thanks to the IWM Project actions is estimated at 98 million cubic meters per year, including: total volume of water saved as a result of water-saving technologies implemented and unpolluted water because of treatment and management of effluents until achieving acceptable quality.
- Total volume of water improved of "excellent" quality, considering overall quality index and average flow rates between initial and final monitoring campaigns, is estimated at 116.5 million cubic meters a year. Total volume of improved water of "good" quality made available to nature as a result of the IWM actions is estimated at 167 million cubic meters year.

The strategy of the IWM Project to focus interventions on farms located within 200 m from the body of water resulted in better quality of surface water in the whole river basin.

Recommendations

Water quality is one of the key aspects and one of the objectives of the National Policy for Integrated Water Resources Management formulated by the Ministry of the Environment of Colombia, with the support of IDEAM and Regional Autonomous Corporations (regional environmental authorities). The following recommendations may be useful for relevant environmental authorities:

- The methodology to assess surface water quality applied by the IWM Project has proved to be useful to evaluate the impact of coffee production on bodies of water. This methodology is recommended for other coffee areas lacking information about surface water quality. More frequent monitoring is recommended, with a time horizon not shorter than 5 years.
- The use of the KPI21 index, which is a combination of 34 physical, chemical, biological and habitat parameters, provided a comprehensive water quality assessment. It is recommended to review and adjust the weighting of the different parameters, especially in areas with different sources of pollution, as biological indices may not be representative enough to evaluate water quality.
- Water quality monitoring campaigns are to be conducted in similar conditions, both climatic and harvest-related, so that results are comparable within the same campaign and among campaigns. It is recommended that sampling duration for the same point be increased from the four hours in this methodology to several days.
- The IWM Project implementation strategies, based on criteria regarding location, producer's interest in adoption and specific clean technologies, can be very useful for local environmental authorities' decision-making in terms of investment and pollution control.

8

Quality of surface water in coffee river basins of Colombia

METHODOLOGIES USED

Methodologies for determining quantity and quality of surface water in coffee river basins

Sample type and sampling frequency

Bodies of water in the coffee zones are sampled both during coffee harvest (main and mid-harvest (mitaca), depending on the area), during the peak harvest months, and when there is no harvest. The objective of sampling in harvest times is to determine water quality based on the factor "wet coffee processing and by-product management." Assessment when there is no harvest serves to compare water quality in harvest and non-harvest times.

For evaluation of bodies of water, these must be sampled each hour over four hours, and an integrated sample must be taken, i.e. made up of the mix of point samples taken from nine different points simultaneously. This type of integrated sampling shows how the river composition varies according to width and depth. For the sampling, a tape measure must be used to measure the width from side to side of the channel; width is divided into four equal sections to obtain three verticals for the sampling, i.e. at ¼, ½ and ¾ of the cross section of the river. In each vertical, point samples are taken at three depths (20%, 60% and 80%). Additionally, samples are taken at three points at the channel bottom (in the same verticals) to characterize sediments. Figure 27 shows the diagram for taking samples.

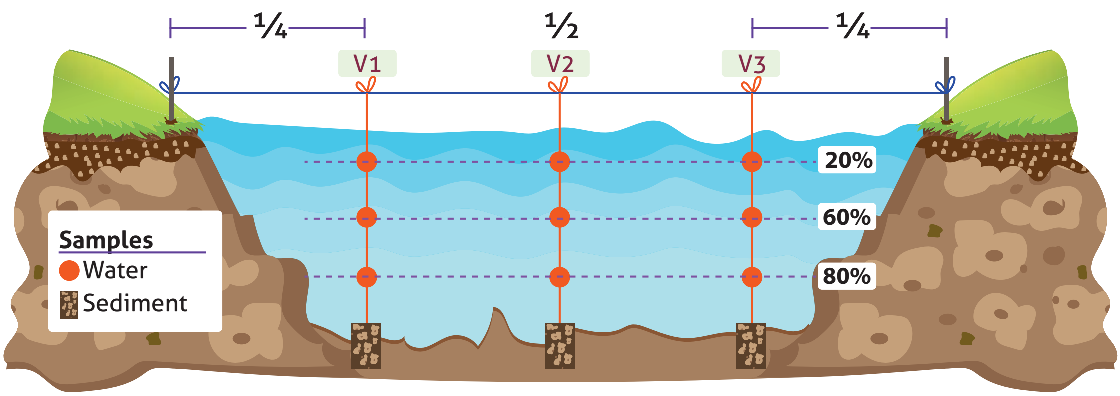


Figure 27. Points for taking samples.

Determination of flow rate

The first step to determine water quality in the river basins is to measure flow rate, as it is a parameter required to know the weight of pollutants in the body of water. Before measuring flow rate, the following must be verified: that the section to be assessed is located in a straight portion of the stream, the portion length is at least five times the section width, and the riverbed is free of obstacles (tree trunks, large rocks and vegetation, among others).

To measure the flow rate, a number of verticals across the channel must be defined to determine how the riverbed varies, as well as vertical and horizontal speeds. Partial sections where up to 10% of total flow goes through must be established by taking 12 to 15 verticals, depending on channel bottom uniformity (Figure 28).

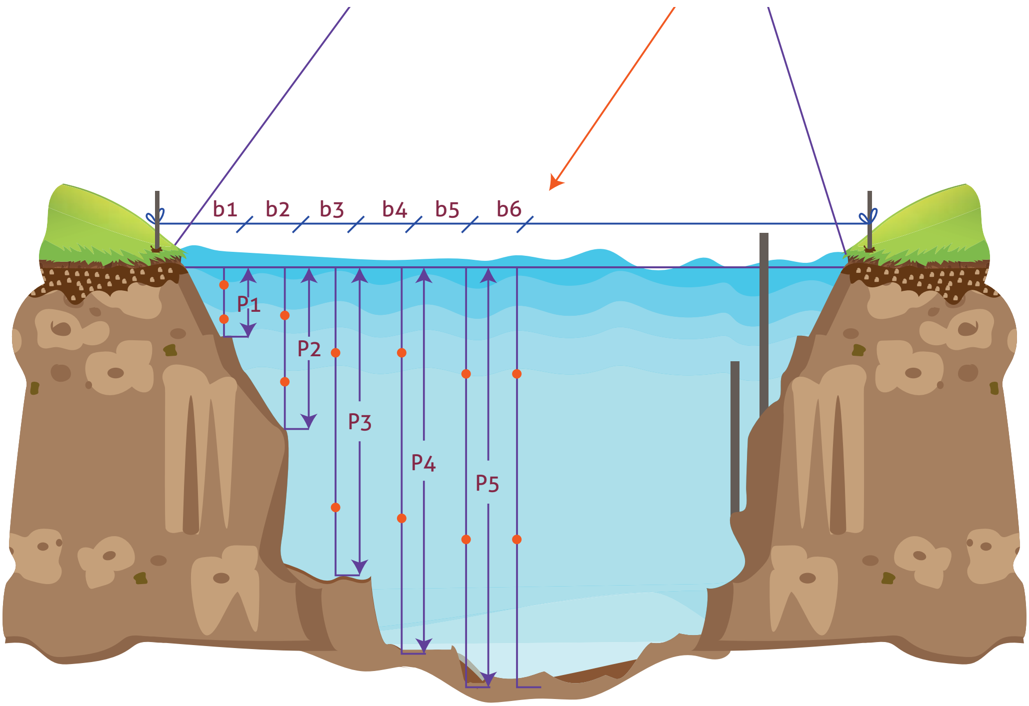


Figure 28. Divisions across the channel.

If depth of the body of water to be evaluated is up to 1 m, the width of each section can be determined by extending a tape measure across the river. If the body of water features greater depths, this measurement must be made with a suspension cable and from a fixed point on the bank. Each section will be delimited by two verticals of different depths (P1 and P2); average depth of each partial section will be calculated as the average of the two successive depths. This depth will be measured with a wading rod as long as depth is up to 1 m; for greater depths, a weight suspended from a winch must be used.

For measuring current speed, as it is the first time the flow rate is determined in this body of water and speed behavior must be determined accurately, the five-point method is to be followed, by locating a flow meter slightly below the surface, at 20%, 60% and 80% of depth, and slightly above the bottom of each vertical, giving different weights to each percentage as shown in Equation 12.

$$V_{average} = 0{,}1\left(V_{surface} + 3V_{0.2} + 2V_{0.6} + 3V_{0.8} + V_{bottom}\right) \quad (12)$$

To calculate partial flow rate, the area of each section is multiplied by average velocity of the section (Equation 13), which is the flow that goes through each section of the channel.

$$Q_p = A_p * V_{mp} \quad (13)$$

Where :

Qp = Partial flow rate

Ap = Partial area

Vmp = Average partial section velocity.

Partial flow rates are added to obtain total flow rate, and with the ratio of total flow rate (**QT**) to total area (**AT**) the average velocity (**Vm**) of the gauging station is obtained.

Figure 20 shows some aspects of determination of flow rate.

Figure 20 shows some aspects of determination of flow rate.

River basin habitat quality assessment

Before assessing habitat quality at different points, available information must be gathered to have a clear view of characteristics of the sites to be studied. From the information obtained, reference sites close to those to be evaluated are identified, featuring "unaltered" or nearly "unaltered" conditions to help assign values when evaluating each criterion in the body of water under study.

The stretch to be assessed is determined: length must be, as far as possible, 12 times the average channel width, and width will be the floodplain width (to where riparian vegetation extends or 10 m beyond the riverbank), going upstream and downstream over each bank, depending on accessibility (Figure 30).

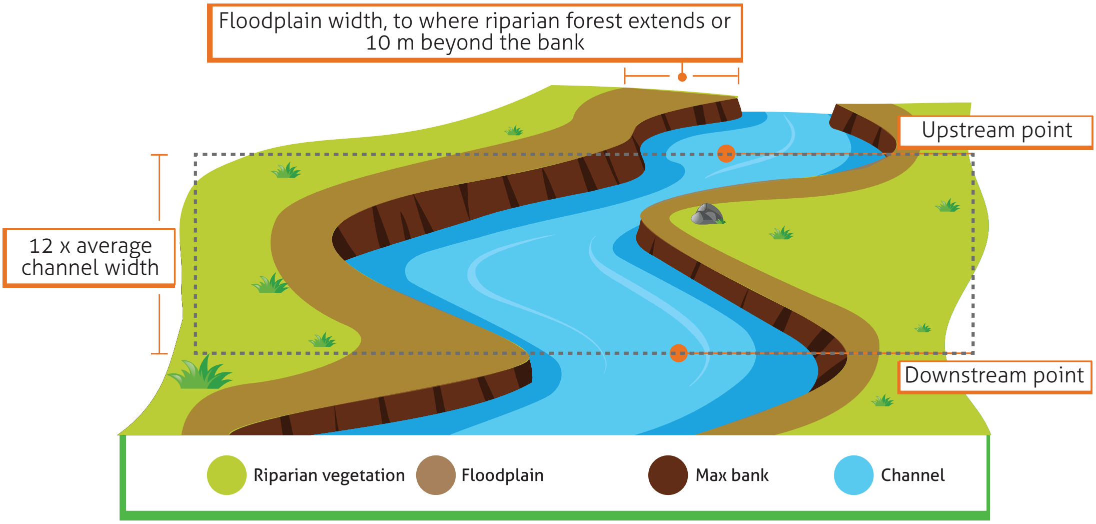


Figure 30. Stretch considered for evaluation of sampling points with habitat assessment methodology (SVAP).

According to the Stream Visual Assessment Protocol (SVAP) (USDA, 2012), the criteria and values for each parameter evaluated are recorded.

Ichthyological abundance assessment

For collection of fish, the methodology reported by the Ministry of the Environment, Housing and Territorial Development (MAVDT, 2010) is used, which consists in selection of a 100m stretch of the body of water, using as capture means a trawl 3m long, 1m wide and 1cm mesh-sized, making successive countercurrent passes. After that, the captured specimens are extracted, counted and put into hermetic-seal plastic bags, refilled with water every 5 min. From 5% to 10% of captured specimens are collected according to Villa-Navarro *et al.* (2006). Then the specimens are identified, measured and weighed, and their sex is determined (Figure 31).

The specimens are identified based on taxonomic keys and descriptions available in Eigenmann, 1918; Dahl, 1971; Harold & Vari, 1994; Ambruster, 2004; Briñez-Vásquez, 2004; García *et al.*, 2008; Maldonado-Ocampo *et al.*, 2005; Covain & Fisch-Muller, 2007; Bertaco, 2008, Roman-Valencia *et al.* 2008 and Provenzano, 2011.

Figure 31. Ichthyological sampling in coffee river basins.

Physicochemical and microbiological water quality assessment

Parameters in the field (pH, dissolved oxygen, conductivity, turbidity and temperature) must be measured with portable equipment, such as multiparameter probes, pH meters and EC meters. The *in situ* parameters must be taken from the point samples, since their representativeness is lost if they are taken from composite or integrated samples (Figure 32).

For measuring these parameters, the equipment (multiparameter probes, pH meters and EC meters) must be immersed directly in the middle of the cross section to be evaluated, from 20 to 30 cm deep, in a zone of low turbulence and proceed to reading. If this is not possible, by either turbulence or cable length, the sampler must be purged and a sample must be taken to be transferred to a plastic bucket (preventing agitation) and immediately be measured.

All samples from the same sampling point must be stored in the same cooler to prevent possible confusion with samples from other points; the containers must be placed in upright position, with enough ice bags interspersed to reach a temperature close to 4° C. Finally a label with information about the person, date and hour of sampling is placed. Table 15 shows parameters for storage and preservation of samples for later analysis.

Table 15. Parameters for preservation of water samples.

Analysis	Container material	Volume (mL)	Preservation	Maximum storage
COD	Plastic or glass	100	Add H_2SO_4 up to pH ≤ 2	Up to 28 days
Total solids	Plastic or glass	200	Refrigerate	Up to 7 days
Phosphorus	Glass	100	Add H_2SO_4 up to pH ≤ 2	Up to 28 days
Nitrates	Plastic or glass	200	Add H_2SO_4 up to pH ≤ 2	Up to 28 days
Turbidity	Plastic or glass	100	Refrigerate and keep in darkness	Up to 48 hours
Microbiological	Sterile glass	200	Refrigerate	Up to 30 hours

Regarding physicochemical and microbiological characterizations to determine the water quality index, the *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WPCF, 1992) must be used as a reference. The characterizations in the laboratory to evaluate water quality are the following:

- Turbidity: Absorptiometric method.
- Chemical Oxygen Demand (COD): Closed reflux method.
- Phosphates: Ascorbic acid method.
- Nitrates: Method of reduction with cadmium.
- Total Solids (TS): Gravimetric method.
- Total and Fecal Coliforms: Membrane filtration method.

Figure 32. Determination of in situ parameters and sampling.

Biological water quality assessment

In order to assess biological quality, aspects such as climate, topography, land use, and organic and inorganic substrate type must be taken into account, as well as evaluation of some parameters such as substrate available for colonization, speed and depth combination, frequency of turbulence zones, banks stability and riparian protection.

For collection of macroinvertebrates, these must be sampled within a stretch about 30 m long of the watercourse, using Surber-type nets (for high current stretches) or D-nets (for low-flow bodies of water), according to physical and depth conditions, in order to obtain quantitative information. Three replications by substrate type must be done (microhabitats: rocky substrate, fine sediment, leaf litter, and vegetated bank); where possible, manual collection with metal clamps is recommended.

In the field, the gravel, stones and organic remains caught in the net must be removed, and samples must be taken to a white tray with some water; later, coarse leaves and remains must be removed by hand (Figure 24), but if the sample has a lot of sand or is very dirty, successive washes, by filtering in the net what is left, are necessary, repeating the action several times until the sample is clean.

Samples to be conserved may be of organisms previously separated in the field or come from material collected with the hand net; in both cases, samples must be placed in glass jars, kept in 70° GL ethyl alcohol, and labeled with the name of the project, municipality, river basin, station number, and date.

Samples that are not identified in the field must be taken to the laboratory and be stored and labeled for later identification up to the most detailed taxonomic level, using the taxonomic keys by Domínguez *et al.*, 2006; Fernández and Domínguez, 2009, and Prat *et al.*, 2009.

Figure 33. Collection of aquatic macroinvertebrates.

CALCULATION OF WATER QUALITY INDICES

Calculation of physicochemical quality index NSF WQI:
Methodology of the Institutes of Health of the United States is followed.

Calculation of the Biological Quality Index BMWP/Col:
The methodology implemented by Alba-Tercedor *et al*., 2005; Prat *et al*., 2009; Sermeño *et al*., 2010, and Zúñiga, 2009 is applied.

Calculation of the habitat assessment index SVAP:
The Stream Visual Assessment Protocol (USDA, 2012) is used.

Calculation of Overall Water Quality Index:
It is the sum of products of physicochemical quality index*1/3 (weighting factor) + biological quality index*1/3 + habitat quality index*1/3.

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