

Colombia



Panoramic view of Bogotá, Colombia. In the background the volcano Nevado de Tolima.
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An aerial photograph of Bogotá, Colombia, showing a vast, densely populated urban area. The city is spread across a wide valley, with numerous buildings and structures visible. In the background, a range of mountains is visible under a cloudy sky, with a prominent snow-capped peak (likely Mount El Guineá) standing out. A semi-transparent blue box with white text is overlaid on the lower right portion of the image.

“The problem of water in Colombia is one of quality rather than quantity. Domestic sewage, farming and gold mining are the main factors responsible for its deterioration. The country’s water supply exceeds 2,000 km³ per year, corresponding to an annual average of 57,000 m³ per capita. Agriculture accounts for 55% of water demand and domestic use for 29%. Hydropower and industrial comprise the remaining consumption. The major challenge for Colombia is wastewater treatment, currently amounting to a mere 3%”

Urban Water in Colombia

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Summary

According to the 2013 Census, the population of Colombia that year was 48,321,405, an increase of 616,978 inhabitants versus 2012 when the population was 47,704,427 persons. There are more women than men, with a split of 50.83% (64,562,767 women) /49.16% (23,758,638 men). The population density is moderate with 42 inhabitants/sq. km. and Colombia is the 57th most densely populated country. The country's geographic location, its variable topography and its climate make it one of the countries with the best water supply on the planet, although it is not distributed evenly across its whole territory. Its volume is more than 2,000 cubic km/year averaging 57,000 cubic meters/inhabitant/year. It is estimated that in 2011 potable water reached between 87.3% and 96% of urban areas while reaching only 56.3% of rural areas. It is estimated that the rate of wastewater created by the urban centers and subsequently released into bodies of water is 67 cubic meters/s. The most common water transmitted illnesses are dengue, malaria and diarrhea. Colombia's water problem is not its quantity, but rather its quality, given its improper use. Also, rubbish and garbage dumped directly into the water sources or along their banks or shores is a frequent source of pollution in many areas of the country.

1. Introduction

During the last 50 years, Colombia has managed to successfully establish a decentralized, innovative framework for environmental management that assigns specific tasks to the many players involved. There are still problems, however, that have not been able to be eradicated.

Human activity is a major threat to the well-being of current and future generations. Poor air quality is the result of industrial, commercial, residential and vehicular emissions; the lack of water, drainage systems and hygiene is the result of policies of intervention that have lacked force and responsibility; natural disasters are brought about not only by natural threats, but also by human activity nationwide.

Although Colombia has made significant progress in environmental matters, it still has to face the enormous challenge of reducing the rate of environmental deterioration still affecting the country, the impact of which is clearly seen in urban areas.

2. Water Sources and the Impact of Urbanization

It is estimated that almost 60% of the world's population will live in urban areas by the year 2030 (United Nations, 2004), a population density that has been identified as a possible source for dramatic environmental consequences, due mainly to the increase in impermeable surface areas in densely urbanized zones. These increases directly affect the ability of water to filter into the soil and the subsequent storage and flow of groundwater. Also, the urbanization process has altered the quality of runoff due to the presence of chemicals such as zinc, copper and lead, organic composites such as polycyclic aromatic hydrocarbons, herbicides, pesticides, and fungicides and more recently, the remains of medications consumed by the population.

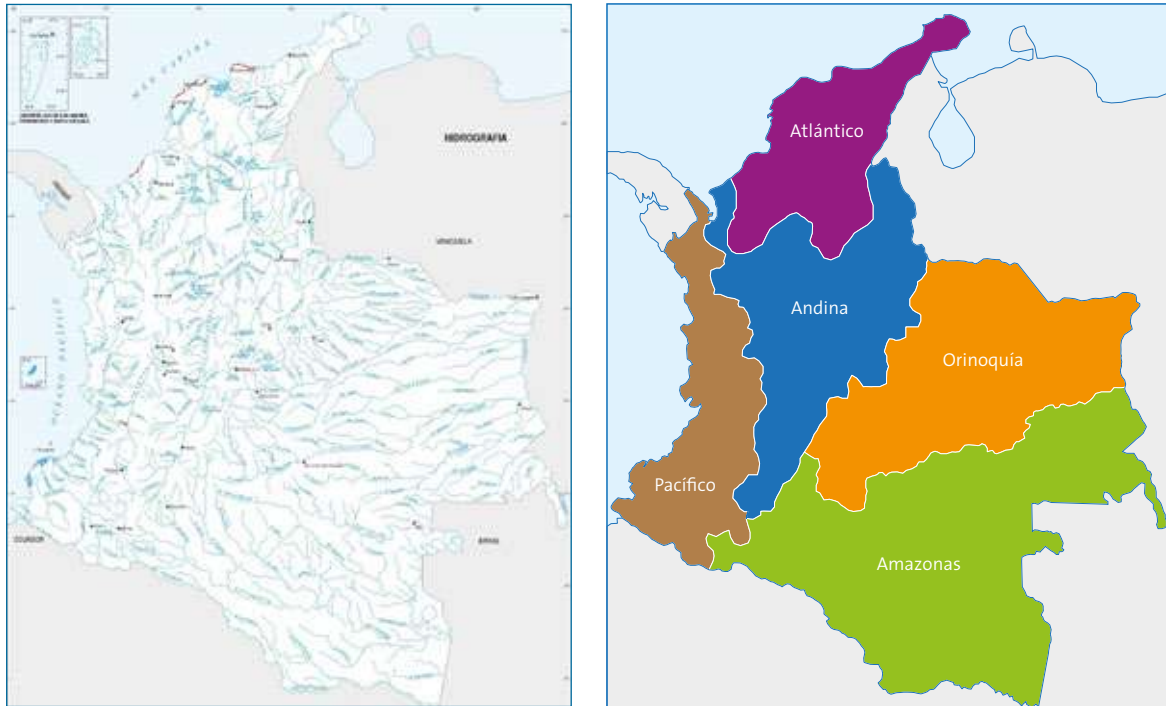
The country's geographic location, its variable topography and its climate make it one of the countries with the best availability of water on the planet. Figure 1. According to the Institute of Hydrology, Meteorology and Environmental Studies (Spanish initials IDEAM) (2008), at the end of the 20th century, Colombia occupied fourth place in

water availability/capita, while the United Nations' report on the development of water resources in the world "Water for Everyone Forever" places Colombia 24th among 203 countries in this respect; this position still shows that Colombia has high hydric potential worldwide, in spite of its current water shortage problems and the degree to which its natural water resources have been affected. In fact, the water supply is not evenly distributed across the entire country and is subject to many variables that determine its availability. In addition, use of the potential water resources is restricted by a series of human factors that affect the hydrological cycle and especially water quality. It is also affected by the form of exploitation characterized by improper or inefficient use of water.

According to IDEAM, estimates made in its National Water Study (2008), the country's water supply is more than 2,000 cubic km/year, the equivalent of an average of 57,000 cubic meters/inhabitant/year. Similarly, it is estimated that if reductions caused by the change in water quality and its natural regulation is taken into account, this figure is reduced to an average of 34,000 cubic meters/inhabitant/year. And if the country experiences a dry year, this figure drops further to 26,700 cubic meters/inhabitant/year. The IDEAM study (2008) allows us to confirm that in spite of the relatively favorable situation regarding water resources and its availability in Colombia, its spatial and temporal distribution is highly variable. Also, the conditions of vegetation cover, land-use, geological and hydrological characteristics of the different watersheds, vary a great deal and for this reason the country's watersheds differ in their ability to be regulated.

This variability in the availability of water is a cause for concern and even alarm in some municipalities and urban areas, given that there is not enough regulation for the use of water resources.

Most of the water in urban water mains that are, generally speaking, supplied by small rivers and streams (more than 80%), is not covered by watershed protection programs or by regulatory systems for its storage, transportation and treatment, and economic provisions are not provided for financing these activities.

Figure 1. Hydrological Map and Regions of Colombia

Colombia has become an urbanized country. The dynamics of urban configuration have remained constant in the last few years, so it is reasonable to expect that the current trends in population concentration in urban settlements will also not change. It is estimated that about 80% of the population of Colombia will be urban by the year 2020 (Ministry of the Environment, Housing and Land Development, 2008) (Spanish initials MAVDT).

Although urban areas are seen to be opportunities for social and economic development, it is also true that Colombia has been urbanized with little or no environmental planning which has had an undeniable cost to the environment, caused by random occupation and the heavy demand for resources entailed (MAVDT, 2008).

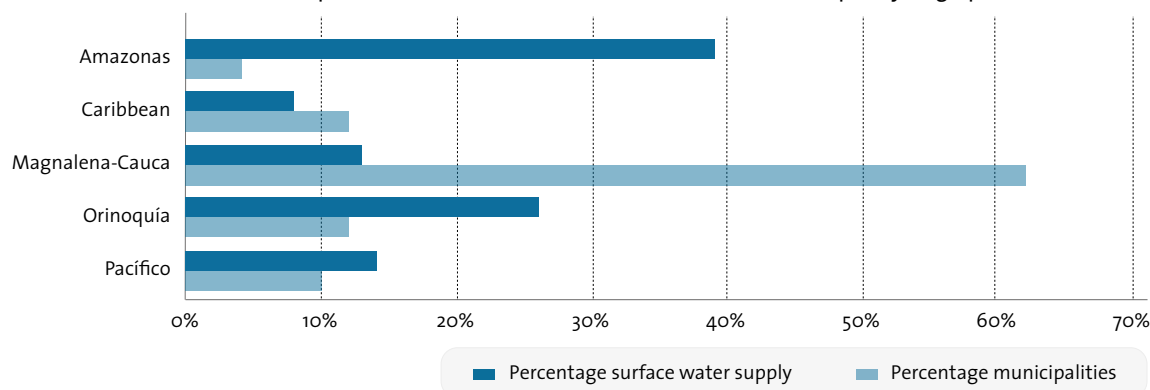
On the other hand, the development of multiple economic activities and services in the urbanized areas tend to cause the accumulation of environmental problems inherent in urban development to the point that they have become the main cause of the deterioration of the quality of life in these areas, to health and well-being of the population, and possibly have other,

indirect consequences on the national and global environment (Ministry of the Environment, Housing and Land Development, 2008) (Spanish initials, MAVDT).

The National Water Studies carried out by the IDEAM (2005, 2008, and 2010) show water consumption by sector (Figure 3); the sector that consumed the most in 2004 was agriculture (this is the same around the world) consuming 59% of the country's water supply. This increased to 61% in 2005 and then decreased in 2010 to 55%. Domestic consumption in 2003 was 29% of the total, increasing to 43.9% in 2005 and then decreasing to 27% in 2010 (including non-consumptive use, as in the case of energy).

The use of groundwater (Figure 4) across most of Colombia is still in its early stages, due, among other reasons, to a lack of knowledge of the potential of this resource regionally and locally.

Large areas of the country are likely to be incorporated into the country's development plans; these areas have groundwater resources that could be used to satisfy different needs, mainly domestic. (IDEAM, ENA, 2010).

Figure 2. Distribution of Municipal Seats and Relation with Surface Water Resources per Hydrographical Area

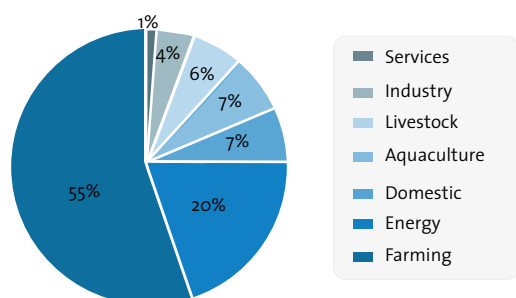
Source: Encuesta Nacional Agropecuaria. IDEAM, ENA 2010

The studies carried out by the IDEAM in 2010 show that 74.5% of the country's surface area is made up of hydrogeological provinces and only 25.5% of igneous or metamorphic rock in areas whose hydrogeological features are as yet unknown, limited or restricted; this suggests the existence of large resources of groundwater that has not been formally evaluated. The total volume of groundwater is in the order of 5,848 cubic km, with 52% of the hydrogeological provinces lying in Amazonia, Orinoquía and Chocó where water is not a priority given these areas' low population and high water yield of these zones; the remaining 48% of the hydrogeological provinces is important nationally, and this resource should be the focus of future sustainability strategies. Figure 4 shows that the agriculture sector has the highest demand for groundwater with 75%, followed by domestic with 9%.

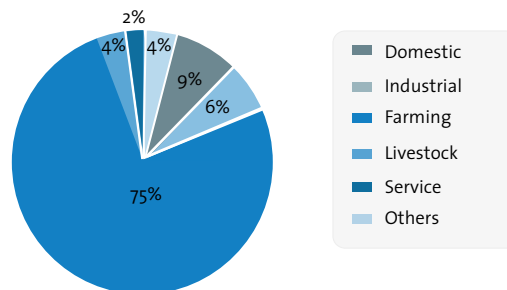
Of the total demand for water in Colombia, 82% of domestic use is by urban areas or municipal seats and 18% by the rest. Moreover, the five main cities account for 30.7% of domestic demand (Bogota, 13.6%, Cali 6.4%, Medellin 5.9%, Barranquilla 2.8% and Cartagena 2.0%)

Regarding the quality of the country's water, the main sources of pollution are: domestic, industrial, agricultural and livestock wastewater, rainwater, and water in transportation over land, rivers and maritime carrying dangerous substances and petroleum products and its derivatives; infrastructure works, water used in mining extraction activities, solid waste of sanitation deposits or released directly into receiving waterbodies. Additionally, the domestic sector is the main source of river pollution (IDEAM, ENA, 2010).

Population density and industry has traditionally been located in the areas surrounding

Figure 3. Potential demand by sector in Colombia

Source: IDEAM, ENA, 2010

Figura 4. Use of Groundwater by sector in Colombia

Source: IDEAM, ENA, 2010.

Colombia's main cities in the Andean region (Figure 1) and therefore affects the water resources in the basins of the Magdalena and Cauca Rivers. The tributaries of these rivers receive most of the pollutants affecting water quality.

These conditions, added to human activities such as occupation of the land and the indiscriminate felling of the vegetation are the main causes affecting the country's water regulation.

Approximately 80% of the water supply is provided by surface waters. However the water supply to some rural as well as to some urban areas is threatened by quality problems in those areas; the water's progressive deterioration is caused mainly by developing urbanization combined with poor or non-existent water resource planning and management activities, improper use of the land, the lack of protection of the watersheds, uncontrolled discharges of domestic, industrial and mining wastewater, deforestation, as well as deficient management of domestic and urban solid waste (Guerrero et al., 2013).

In addition, the main cities are also the destination of the large number of families that have been ousted from their original homes by violence. In 2005, according to the Human Rights and Displacement Consultancy (Spanish initials CODHES), more than 260,000 persons were registered as displaced, the equivalent of 3.8% of the total population of Bogotá (CODHES, 2006). Studies show that the displacement phenomenon is growing in the city confronting the reduction in care services; Bogotá has become the main destination for displaced persons, as pointed out by the High Commissioner of the United Nations for Refugees (Spanish initials, ACNUR), (2003). Also, the 2007 Quality of Life in Bogotá Survey showed that in areas of poverty and misery, the indicator for homes with inadequate public services (this indicator is used with four other simple indicators to calculate the composite indicator of Basic Needs not Supplied (Spanish initials NBI, (Feres, et al., 2001)) is higher than in other towns/cities (Office of the Mayor of Bogotá, Secretariat of Planning, 2007).

Although the potable water and sanitation sector in Colombia has improved significantly since the passing of Law 142 in 1994, potable water and sanitation services are provided by public or

private firms that all have different management styles (Bernal and Rivas, 2011); however, in peri-urban areas and in informal settlements, these basic services are provided by small local operators (Colombia Ministry of Social Protection and the Ministry of the Environment, Housing and Land Development, 2007). It has been confirmed that there are deficiencies in providing of public services in some peri-urban areas of Bogotá, an example of which is in Usme (Cárdenas Quiroga and Solano Peña, 2007). These supply conditions generate a big threat to the health of the population that coincides with the area's incidence of disease, corresponding profiles of morbidity in these zones, mainly to respiratory infections, diarrhea and intestinal intestinal parasite ailments (Cárdenas Quiroga and Solano Peña, 2007). Similarly, the supply of potable water and sanitation services in the city of Medellín does not reach the population living in settlements considered to be illegal; the city's poorest population is concentrated in those areas (Balcázar, 2008).

According to a study carried out by the Colombia People's Advocacy office that evaluated the degree of compliance with potability laws in 959 municipalities (approximately 86% of all municipalities in Colombia) only 18% were found to comply with the norms for potable water. The evaluation was carried out considering physical-chemical and biological parameters. The total population covered in this of research was 22,464,114 inhabitants of the municipal seats. As already mentioned, a large percentage of this population -55%- consumes water that does not fulfill the requirements of the norm (Colombia. People's Advocacy office, 2005).

As a result, the Colombian Government has recognized that since 2008 the illegal use of water is one of the problems related to renewable water resources. Also, it recognizes that regarding the settlements and the living conditions in those areas, it is well known that the homes do not have an adequate supply of potable water and that their occupants use alternative or illegal systems (Colombia Ministry of the Environment, Housing and Land Development, 2008). The cost of potable water in some cities is very high, making it unaffordable to economically vulnerable populations (see the example of Barranquilla as reported by the United

Nations Development Program, 2006). These particularities force the city's poorest inhabitants to obtain water from the only available source, even if it is contaminated or presents serious risks to their health. Many Colombian communities collect rainwater for different domestic uses, such as flushing toilets, washing the floor and the walls, garden watering systems, and for animal as well as human consumption (Torres et al., 2013). This practice is common in rural areas and in indigenous shelters. However, demonstrations have shown that rainwater is not suitable for these domestic uses due to its high degree of turbidity and high concentrations of suspended solids, biochemical oxygen demand and some heavy metals (Torres et al., 2013).

The management of solid waste is also an important source of water pollution in urban areas and in public spaces when it causes rainwater gutters and drains to block; this, in turn, is one of the main causes of flooding in vulnerable areas. The lack of land appropriation impedes the preservation of public spaces being a priority in a community. In Urban and peri-urban areas, illegal settlers from distant cities or towns do not regard the land they settle on as their own, and therefore dispose of their waste in streets, parks, canals and in streams. Within the scope of waste management, the practices and behavior of those who create the waste bears considerable weight. The attitudes and interests of the inhabitants are the key to creating public spaces and sources of water that are free of trash. Proof of this can be seen in activities aimed at introducing waste recycling in cities.

It is of vital importance that the environmental authorities and the providers of services strengthen their technical strategies and public policies that will reduce the numbers of people in the marginalized areas acquiring diseases through the consumption of contaminated water, be it because the water was accessed illegally or because it became polluted by poor waste management. But in either case, educational programs on the environment and citizen responsibility play an important role. Similarly, creating programs and using technologies that involve the community increase the probability of success not only to appropriate these measures but also this allows people to identify with the land and therefore treat it with more respect.

3. Potable Water Service

In Colombia, it is the responsibility of the State to provide public services, including potable water under which it guarantees the quality of the service, extension of coverage and a supply which is efficient, continuous and uninterrupted. Public services companies, both private or public or in some cases a mixture of both- are allowed to offer the service of potable water. The state encourages competition and promotes for economies of scale. The water tariff regime is governed by economic efficiency, equality, solidarity and redistribution, and creates a system whereby commercial, industrial, and high income consumers help those in low income areas to pay for their water, thus helping them cover their basic needs. Also, there are several entities involved in water management; it is primarily regulated by two agencies: The Potable Water and Basic Sanitation Regulation Commission (Spanish initials CRA) whose main functions include: regulating the competition between the companies offering the service; establishing norms for tariffs and defining the criteria for the efficient supply of the service. There is also the Domestic Public Services Superintendency (Spanish initials SSPD) that, as a regulatory entity, is responsible for the sector's systems of communication and information; it also resolves consumer conflicts and supervises the suppliers, sanctioning them when they do not comply with the sector's rules and regulations. In order to properly protect natural resources in the provision of potable water, all companies or entities that offer services related to water supply, sanitation, irrigation and drainage, and hydro-electric production must carry out a series of actions to ensure efficiency and economy in the use of the resource. Their five-year action plans must be presented to the autonomous regional corporations that are responsible for monitoring and controlling the country's natural resources.

It was estimated that potable water services reached 96% coverage in urban areas in 2011 (National Department of Statistics, Spanish initials DANE, 2012) and 97% (WHO/UNICEF, 2013); the water supply reached 87.3% of the country, though only 56.3% of rural areas (DANE, 2012). Previous census information for the whole country in 2005 showed that water was provided to 47.1% of rural areas and

94.3% of townships (Figure 5) (DANE, 2005). Water supply distribution was observed in the different urban centers with 98% of the inhabitants of 475 urban centers having access to mains water supply, and between 90 and 98% of the inhabitants in 425 urban centers had similar access.

This coverage is concentrated in the Andean region of the country where the main cities are located. In the north, water supply coverage to the Caribbean region is a little less, though greater in the urban areas with coverages are between 80 and 90%. Potable water services in the Orinoco and Amazon regions (the eastern part of the country) and Pacifica in the west, however, have the lowest coverage (less than 60% in some cases). According to the 1993 Census and estimates provided by the Colombia Department of National Planning, water supply to the big cities by 2015 will be extensive; it will not, however, reach the entire population of those cities. More efforts are required in medium- and small-sized cities to provide potable water to their populations. This is particularly true in regions that are socio-economically underdeveloped. In some department capital cities, the water supply reaches less than 60% of the city populations, the city of Quibdó being a good example.

Table 1 shows some water supply indicators in some important Colombian cities. Universal water supply has not been achieved in Colombia's cities, including those that reported having superior water supply services. The indicator for the efficient use of water refers to the amount of potable water sold over the total raw water extracted.

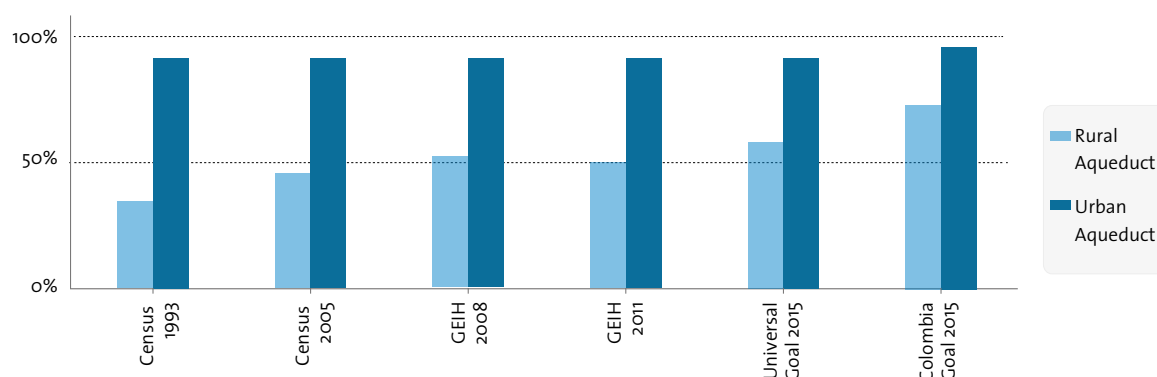
Some cities reported poor efficiency. The daily per inhabitant consumption varied between 98.82 L/inhab/day and 143.57 L/inhab/day; this difference may be due to climactic factors and to a higher rate of wastage in some of the cities. Losses in the network are the percentage difference between the amount of water in the network and amount that reaches its destination; some studies estimate that a 20% loss of this type is acceptable; the high values reported by the cities studied are a cause for concern.

According to these figures, basic water consumption in Colombia is in the order of 20 cubic meters/subscriber-month (CRA, 1994), the equivalent of 110L/inhab-day (SSPD, 2007). However, several studies consider this to be a high level of consumption. The Pan-American Health Organization (Spanish initials OPS) has determined basic water consumption to be between 80 L/inhab-day and a maximum of 100L/inhab-day.

Table 2 shows the trend in the number of subscribers to the water service in the most important companies in the potable water and sanitation sector. Classification by level refers to the financial position of the population, with 1 being those with the lowest income and 6 with the highest.

In the case of small urban centers, using the information reported in the Public Services Registry System of the Potable Water and Basic Sanitation Regulatory Commission (CRA) for 2013, only 64% of small urban centers have a master plan for connecting to the mains water supply and drainage networks, with 46% of these reporting that their plans are actually being implemented.

Figure 5. Trend in access to potable water in Colombia according to different sources of information



Source: Census 1993 y 2005, GEIH 2008 and 2011, DANE.

Table 1. Water supply indicators in some Colombian cities, 2011

City	Population	Population connected to the main potable water supply	Efficiency in water usage	Daily consumption/ inhabitant (L/inhabitant/day)	Water loss in networks % water supplied
Bogotá	7,467,804	98%	55.87%	98.82	43.99%
Medellín	2,368,282	97%	56.81%	143.57	40.87%
Cali	2,269,653	97.54%	60.85%	126.15	47.79%
Barranquilla	1,193,667	91.21%	38.17%	123.1	61.23%
Cartagena	955,709	89.70%	49.93%	137.71	41.99%
Cúcuta	624,661	94.45%	35.39%	132.18	55.34%
Ibagué	532,020	96.22%	48.93%	129.18	51.83%
Pereira	459,667	97.57%	55.49%	102.76	34.09%

Source: GRTB-ADERASA Annual Report- 2012.

Table 2. Subscription to water services trend by level, 2006-2011

Levels	2006	2007	2008	2009	2010*	2011
Level 1	797,885	856,013	891,574	935,560	1,025,481	1,125,441
Level 2	1,803,405	1,874,624	1,891,114	1,941,870	1,904,253	1,954,729
Level 3	1,723,888	1,762,615	1,750,679	1,779,813	1,598,642	1,662,325
Level 4	528,810	552,514	575,780	605,809	471,907	504,124
Level 5	238,936	248,682	256,685	266,174	219,274	226,594
Level 6	137,547	146,124	152,504	159,143	120,928	124,921
Industrial	20,656	22,500	21,350	21,254	16,106	17,327
Commercial	351,994	372,512	379,573	393,023	359,797	379,306
Official	24,257	22,617	21,744	21,520	23,264	23,377
Other	58,634	68,474	71,708	19,286	42,519	47,183
Total	5,686,012	5,926,675	6,012,711	6,143,452	5,782,171	6,065,327

SUI, Consolidado Comercial. *Different companies did not report their information in 2010.

Such plans are an articulation mechanism between urban management and the development of their sanitation systems; they contain strategies, programs and projects that guarantee current and future supply of potable water and sewage systems in the cities. Of these municipalities, only 86% report that the water consumed there is potable; only 91% of the townships who reported having a water treatment plant have them in operation. Of the townships that reported water quality information, 86% report the water is potable, but when analyzing the risk levels in the water supply, only 11% reported that there was no risk. A large proportion of the rest reported that they did not monitor water quality. The above indicates that although coverage of water supply has grown in urban areas, greater efforts must be made in managing water supply systems,

in improving water treatment processes and in monitoring water quality, especially in more remote, low-income urban areas.

It is important to mention the vulnerable condition of the municipal water mains. In 2007, “close to 200,000 inhabitants were affected by flooding (or the collapse of the sewage system), and about 500,000 inhabitants suffered a suspension in the water supply as a result of avalanches, of the increase in the turbidity of the water in rivers, of blockages or the collapse of water withdrawal systems, and more than 20,000 inhabitants had their water supply cut off as a result of landslides that threatened the stability of the water supply service infrastructure”. To date, the country still has no plan for reducing this vulnerability, and no research or inventories is being carried out on this subject.

4. Water Treatment in Cities

Population density and industry has traditionally been found in the areas surrounding Colombia's main cities located in the Andean region and therefore affect the water resources in the basins of the Magdalena and Cauca Rivers. The tributaries of these rivers receive most of the pollutants affecting water quality.

According to the study "Requirements for the formulation of a National Wastewater Plan" (Andes University-Ministry of the Environment, 2002) an estimate of the volume of wastewater produced in urban centers suggests that in Colombia close to 67 cubic meters of wastewater are being dumped into bodies of water per second, with Bogotá accounting for more than 15.3%, Antioquia 13%, Valle del Cauca 9.87% and the other departments under 5%. Coastal areas are polluted mainly by domestic and industrial waste. Most domestic waste is deposited untreated into the coastal waters or into rivers, mainly those in the Magdalena River basin, with the Cauca and Bogotá Rivers being the main destinations of all kinds of pollutants.

According to an analysis carried out by the Domestic Public Services Superintendency (2006) the treatment systems used by the companies providing sewage services in the big cities (Bogotá, Medellín, Cali), treat only 32% of the wastewater dumped into bodies of water.

Even more alarming is the fact that only 17%, 26% and 11% of wastewater is treated in such cities as Barranquilla, Bucaramanga and Ibagué respectively. Also cities such as Cartagena, Cúcuta, Pereira, Manizales, Neiva, Pasto, Valledupar, Popayán, Palmira, Florencia, Sincelejo, Buenaventura, Piedecuesta, Tuluá, Armenia, Tunja, Rionegro, Cartago, Sogamoso and Girardot do not treat any of their wastewater.

The country's underdevelopment in terms of wastewater treatment is due to both the lack of treatment infrastructure systems and the low coverage of the existing treatment plants. Only 354 (33%) of municipalities nationwide have waste treatment systems and it is known that 29% of those are not in operation. It is estimated that of the 159 cubic meters collected per second nationally, the volume of water that is treated is close to 5 cubic meters/second, the equivalent of 3.1% of this volume.

Given the deterioration in the quality of water and of the watersheds, the low coverage, capacity and the poor maintenance of water treatment plants, as well as the lack of control, follow-up and monitoring of water quality, it can be said that a high percentage of Colombians receive water that is not fit for human consumption.

Between 2002 and 2006, advances were made in the number of municipalities that have wastewater treatment plants, rising from 218 in 2002 to 355 in 2006; this figure, however, represents only 32.33% of the country's municipalities (including the Capital District) which can be considered a low coverage.

It is also worth mentioning the departments with more than 100 municipalities, such as Antioquia, Boyacá and Cundinamarca, whose percentage of municipalities with wastewater treatment systems in 2006 was 31.2%, 20.83% and 38.79% respectively, figures that are well below the national average of 41.39%. This is less than in other regions in the country and is undoubtedly due to the enormity of the task required to provide this service to a higher portion of the population.

Table 3 shows the trend in the number of persons connected to sewage system services in Colombia.

5. Water Reuse

The increase in the consumption of potable water due to the increase in urban populations around the world (United Nations Population Division, 2008) and especially in Latin America and in Colombia, (DANE, 2005), and the deterioration of the water eco-systems due to hydrological impacts and in the quality of the water produced by urbanization, has generated increasing interest in alternative water sources such as the reuse of wastewaters, the use of "gray water", water from urban runoff, and the utilization of rainwater (IDEAM, 2008).

These alternative sources of water are becoming an attractive option for communities with insufficient potable water or for those that foresee having a supply problem, given that, in theory, they can: (i) use this water when good quality

Table 3. Trends in connectivity to the drainage system by level 2006-2011

Levels	2006	2007	2008	2009	2010*	2011
Level 1	584,209	635,338	672,295	704,706	698,831	804,758
Level 2	1,620,039	1,728,577	1,759,061	1,807,590	1,729,719	1,792,205
Level 3	1,619,037	1,713,498	1,726,782	1,750,545	1,529,554	1,623,322
Level 4	503,009	544,323	571,922	599,248	444,039	492,719
Level 5	228,126	241,435	524,505	260,123	210,809	221,566
Level 6	130,234	141,256	146,418	253,636	113,688	119,464
Industrial	18,661	20,451	19,872	19,647	13,733	14,647
Commercial	331,328	360,628	372,612	383,211	337,290	362,632
Official	21,273	19,840	19,286	19,131	19,461	20,280
Other	54,401	66,778	70,151	73,287	40,509	43,827
Total	5,110,317	5,472,124	5,882,904	5,870,851	5,137,633	5,495,420

Source: SUI, Consolidado Comercial. *Different companies did not report their information in 2010.

potable water is not required, such as: toilet flushes, irrigation, washing of hard surfaces, etc.; (ii) increase the number of water supply sources and provide alternative sources to satisfy present and future water needs; (iii) protect the water eco-systems by reducing the amount of freshwater extracted so that the dilution capacity of bodies of water is not reduced (a response to the quantities of nutrients and other toxic contaminants found in water); (iv) reduce the need for water control structures, such as dams and reservoirs; (v) comply with environmental legislation by means of improved management of water and of wastewater.

5.1 Water Recycling

In Colombia, recycled wastewater with little or no treatment has been used mainly for crop irrigation (Silva, 2008; Silva et al., 2008). Technical feasibility studies have been developed and proposals for wastewater recycling have been made since 1998 (Vanegas Gálvez et al., 2001; Osorio, 2006) thus demonstrating that the recycling option (Valencia, 1998; Madera et al., 2003) is viable in terms of availability and of reducing the environmental harm to the receptor waterbodies in which wastewater is deposited.

For the recycling of wastewater to be promoted, an integrated water management system should be adopted; therefore legislation and regulations must be given an integrating focus that takes into account

the characteristics of wastewater, its treatment, the quality needed of the recycled water and the area's natural conditions (Manga et al., 2001). Also, the concept of recycling has been difficult to understand in certain regions of Colombia (Madariaga et al., 2005).

Valencia et al. (2010) proposed a methodology for recycling domestic wastewater, which serves as a navigation map for the implementation of recycling projects, and in 2012 they carried out a study to determine the potential of recycling the outflow of the Wastewater Treatment Plant (WTP) at Nátaga in the Huila department. The authors concluded that the area in question (that suffers from an insufficient water during most of the year) could use recycled water to irrigate the local cacao crops, but not before the effects of the treated water on the soil, the cacao plant and on public health had been evaluated.

Jaramillo (2010) evaluated the potential of recycling domestic wastewater as a way to control the contamination caused by wastewater in the Cauca River valley. This study formed part of the SWITCH¹ project, a joint research project financed by the European Commission (SWITCH, 2013). The study concluded that 2 out of 26 municipalities in the area made direct use of recycled wastewater (planned usage) (treated wastewater used for a specific purpose) and the others made indirect or unplanned, use of recycled wastewater (untreated wastewater

1. <http://www.switchurbanwater.eu/>

outflow used without having any specific purpose). The study's principal conclusion was that the use of recycled water depends on multiple factors that have to be evaluated on the local level.

The Pontificia Javeriana University (Spanish initials PUJB) developed a proposal to recycle the outflow of the El Salitre Wastewater Treatment Plant in Bogotá. The main thrust of the proposal was that the treated outflow be used for crop irrigation, given that the La Ramada Irrigation District (with a surface area of more than 23,000 ha) is located near to the El Salitre Wastewater Treatment Plant. A situation analysis was carried out on the irrigation area at that time and it was found that the treated outflow could be used as a complement to the surface water used to irrigate the existing and also the extended areas. Parallel to this analysis, other possible uses were evaluated—industrial, landscape and recharge for aquifers—bearing in mind the quality of the Wastewater Treatment Plant outflow in the secondary system, treatment of the water with disinfectant, the potential market in the city of Bogotá and the cost of implementation. It was concluded that of the above uses, the most viable is industrial use of treated wastewater. This conclusion was reached based on a survey carried out among the industries located near to the WTP, though the main barrier to implementation were the costs of wastewater distribution; regarding the other uses analyzed, it was found that additional treatment was required to improve the treated wastewater's quality. The principal conclusion, however, was that the treated wastewater use with the greatest potential was agricultural irrigation, given that greater volumes could be used and that the cost was acceptable to farmers when compared with the amount they paid for water of a lower quality (Campos et al., 2011).

Lasso and Ramírez (2011) studied the recycling of wastewater from the regulatory, hydro-climatological and environmental point of view for irrigating sugar cane and palm oil crops for the production of biofuels. The authors concluded that recycling wastewater was in the economic interests of the producers, given that the practice of using

fertilizer and the cost of water would be reduced. It was also established that if recycling wastewater was to be implemented, integrated management policies and mechanisms had to be developed that take into account the characteristics of wastewater as well as its treatment and the required quality.

Echeverri et al. (2012) evaluated the quality of the treated water produced by the Cali WTP and used for irrigation purposes, and they compared it with the quality of the groundwater in a well. This study was the first step towards launching a plan to recycle domestic wastewater to irrigate sugar cane crops in the Cauca River basin.

Regarding the policies and regulations related to wastewater recycling in Colombia, Law 373, passed in 1997, encourages the use of treated wastewater as a low-cost alternative that should be valued. (MAVDT and the National Planning Department Spanish initials DNP, 2004). Decree 3930, passed in 2010 by the Ministry of the Environment, Housing and Land Development, that substituted Decree 1594 (1984) of the Ministry of Health, (excepting Articles 20 and 21) contemplates, among others, a review of current water uses with a view to the MAVDT updating the water quality criteria for its different uses and the dumping regulations to guarantee these criteria. Its transitory Article 76 states that while the MAVDT is responsible for regulating water usage and providing the quality criteria for each of its uses, Articles 37 to 48 of Decree 1594 (1984) are still in effect. These articles define the quality criteria for human and domestic consumption, for agricultural, livestock, and recreational uses through primary and secondary contact, and for aesthetic and industrial uses.

Based on Decree 3100 of 2003 (regulation of compensatory rates), Decree 3440 of 2004 (an amendment to Decree 3100) and Resolution 1433 (2004) (regulations for Article 12 of Decree 3100 (2003), and on the Plan for Sanitation and Waste Deposit, the autonomous regional corporations of Colombia have developed other definitions of the water quality in watersheds that should be linked to the quality objectives and goals for different water uses.

Vision and Integrated Water Management

Proposal for an Integrated Water Management Model

The main problem faced in supplying water in Colombia is quality rather than quantity. The institutional and administrative system, in other words, water governance, is also a significant factor in this problem. The Integral Water Management model consists of four steps:

First step: Recovering and protecting the affected basins

The majority of the basins supplying the municipal aqueducts have been affected for several decades by various man-related activities. Principal man-related activities affecting water quality:

- Contamination by domestic wastewater.
- Contamination by industrial wastewater.
- Contamination by fertilizers and pesticides.
- Inadequate waste disposal.
- Alluvial and artisanal mining activities.
- Animals decomposing in the open.
- Crops on hillsides and close to water sources and courses.
- Livestock grazing close to water sources and courses.
- Sediment dragging caused by road building, quarry mining and other engineering works that involve modifying the landscape.
- Modification of the courses (meander cut-offs, obstruction of connection to lagoons, among others).
- Construction of engineering works that modify the dynamics and course of current (bridges, dams, water diversions, among others).
- Burning and cutting down of forests.

Second step: Educating the community on efficient water use and saving

Recommended actions for efficient water use:

- Repair defective faucets.
- Check pipes for breakdowns.
- Check bathroom tank for leaks.
- Reduce the volume of toilet tank.
- Take short showers.
- Wait until washing machine is full before using it.
- Turn off the tap while brushing teeth.
- Water fields and gardens using only the necessary water.
- Do not use the hose to wash the front of the house or the street.
- Raise awareness among all family members regarding water saving.
- Immediately report leaks in pipes on public roads.
- Promote wastewater treatment in factories; this can result in savings of up to 70%.
- Do not think that you can use all the water that you wish, just because you can pay for it. Others need this water.
- Water fields and gardens in the morning.

Box 1

Third step: Recovering and managing wastewater

Most commonly used wastewater treatment systems.

- Activated sludge.
- Physiochemical treatments.
- Oxidation ponds.
- Channels planted with aquatic plants.
- Wetlands.
- Microfiltration using modern nanotechnology.

Fourth step: Recovering and managing riverbanks. Linear ecological parks

Once the wastewater has been recovered, the currents flowing through each municipality will regain their physiochemical and bacteriological properties. In these circumstances, the population will have the opportunity to use them for fishing and leisure, and nearby land will become parks for the community's recreation activities.

- Walking and relaxing.
- Children's play
- Family relaxation.
- Artistic activities.
- Enjoying Nature and the landscape.
- Communing with Nature.
- Engaging in cultural traditions.
- Integrating urban with environmental development.
- In short, this means **Quality of Life**.

5.2 Recycling urban run-off water and the use of rainwater

Around the world, the use of rainwater is seen as an efficient use of water and as a basic pre-requisite for ensuring more sustainable cities. Use of rainwater in cities is considered to be a multi-purpose strategy for controlling flooding; at the same time, it helps to reduce potable water consumption, to lessen the demands heavy rainfall makes on the drainage system (European Environment Agency –EEA–, 2012), and to reduce and, in some cases, to resolve water shortage problems and those related to the contamination of surface and groundwater; such usage is especially helpful to local populations when the price of potable water rises. Using rainwater could also play a key role in increasing evapotranspiration as an additional way of addressing the problem of global warming, together with policies aimed at preventing carbon dioxide emissions.

Use of rainwater in Colombia is part of the Program for the Conservation and the Efficient Use of Water established by Law 373 in 1997, that states that the public agencies responsible for granting water concessions must offer consumers, as per the previous studies, the use of rainwater and put in place the necessary technology so that its use is a viable option at the right price.

Collecting rainwater that falls on the tiled roofs of houses is currently carried out using traditional means such as bottles, pots and hand-dug wells; this water is given non-potable use in shopping malls, service centers, office buildings and apartment blocks (Ramírez-Fonseca, 2009; Castañeda, 2010). For example, as per the direct observations made by the authors in the outskirts of Bogotá since 2002, several families are currently making use of untreated

Succesful project for Water Recovery in Colombia

Domestic and industrial wastewater management has always been a challenging problem. The costs and significant investments involved in treatment plants for purifying water before pouring it into ravines or rivers have been one of the principal obstacles to satisfactorily solving this problem.

The aquatic plant biotechnology has been developed as an alternative system for treating wastewater which, in small communities and industries, has efficiently removed a wide range of substances, including organic matter and nutrients.

This biological water purification system is a recent innovation in the fight against pollution and an ecological and economic option for treating wastewater in tropical and subtropical regions worldwide.



Panoramic view of canals planted with water hyacinths (*Eichhornia crassipes*)

- 1.2 hectares are required to treat 680 m³/day of wastewater for a population of 5,000 inhabitants.
- Length of canals: 500 m
- Layout of canals: 50 m long x 6.0 m wide x 0.20 - 0.80 m deep
- Approximate discharge rate: 8 to 10 liters/sec.
- Water retention time: 14 to 21 days
- Only one workman is required to maintain them (plant and sludge removal).
- Removal of saturated (yellowing) plants: every 4 to 5 weeks.
- One hectare of hyacinths produces: 16 to 32 tons/day of biomass; 90 to 180 m³ of methane gas and 0.5 tons/day of fertilizer.

For more information about this experience, please visit:

<http://www.ianas.org/index.php/books>

http://www.ianas.org/books/books_2015/water_lines.pdf

surface rainwater collected from roofs (including human consumption). This practice is therefore linked to substantial health risks, especially in terms of its collection, storage and distribution methods. In spite of this risk, there is little scientific study on or analysis of the quality of rainwater in Colombia (Lara et al., 2007; Castañeda, 2010; Buitrago y Camacho, 2012; Torres et al., 2013), or complementary themes such as its volume, collection or storage (Torres et al., 2012). Research on this subject is therefore required, as is an evaluation of the volume of contaminants to receptor waterbodies, and new rainwater treatment systems must be designed.

6. Water and Health in Colombia

According to information provided by the office of the Attorney-General, the Government has allocated a total of \$117 billion pesos (approximately \$53 billion dollars) over the last ten years, of which \$7.2 billion pesos (approximately \$3 billion dollars) were assigned for the potable water sector; however, the morbidity and mortality rates caused by water transmitted bacteria. Chronic diarrhea is the most common disease, in spite of the investment by the General Subsidy Scheme (Spanish initials SGP), donations and other sources.

According to information provided by Sánchez-Triana et al. (2006), 7.2% of infant deaths are attributable to diarrhea-related illnesses; prevalence of two-week diarrhea in children under the age of 5 is 2.9%, with 90% of the cases and subsequent hospitalizations being attributed to poor water quality, poor sanitation services and hygiene.

The National Political and Economic Council (Spanish initials CONPES) 3343 has established that the average cost of public health due to “inadequate, unhygienic water supply and sanitation services reaches \$1.96 billion pesos (approximately \$890 million dollars)”.

The Ministry of Health and Social Protection informed that Colombia was one of the 20 nations that convened in Bogotá to evaluate, analyze and be updated on the situation regarding yellow fever, cases of which have not been reported in Colombia since 2010. This meeting was an important event in terms of public health monitoring. Table 4 shows diseases most frequently caused by poor water quality.

7. Climate Variability and its Impact on the Water Supply

The reduction in surface waters at times of lowest water levels related to long-term climate trends or extreme climate conditions is one of the greatest threats to integrated water management of watersheds that supply the demand from large urban centers. This situation is especially alarming in mountain basins that supply water to the aqueduct

systems in several cities in the Andean region. Large cities located in Colombia’s mountainous regions such as Bogotá, Medellín, Manizales and Bucaramanga, whose populations make up a large proportion of the country’s urban dwellers, could face significant water supply challenges to their domestic, commercial and industrial needs in the medium and long term. The net decrease in surface waters combined with a disproportionate increase in demand and poor water quality makes it urgent that planning organizations and decision-makers to design appropriate strategies and actions that ensure the continual supply of high quality potable water. Capacity expansion projects, together with water conservation and efficient usage programs are the usual strategies adopted by the public service companies and planning authorities when faced with the problem of an increase in water consumption in urban areas. These initiatives have materialized in parallel with water business proposals and policy guidelines that consider this resource to be a structural axis. Proposals for citizen training and sensitization regarding water as well as for the restructuring of the organization responsible for managing the water resources have also accompanied these proposals and have allowed that these improvements affect the daily lives of the urban population more rapidly.

Apart from the concerns about the increase in demand, certain conflicts of interest are currently arising in Colombia regarding the presentation of projects at the sources of water basins that have been at times interpreted as being a threat to optimal water quality and volume. Such projects, which many of the members of urban communities have

Table 4. Most frequent diseases in Colombia

Type of illness	Cases reported	Mortality cases
Acute Diarrhea illness (Spanish initials EDA)	605,497	26
Malaria	15,000	1
Hepatitis A	1,237	220
Dengue	1,010	29
Leptospirosis	718	12
Typhoid fever	104	0
Cholera	57	0
Poliomyelitis	1	0
Yellow fever	0	0

Several sources INS, SIVIGILA, DANE

demonstrated to be in conflict with their proposals for the integrated watershed management of the basins that supply their potable water, emphasize the need for the environmental authorities and environmental licensing agencies to work more closely and prioritize the different proposals.

8. Rainwater and Flooding Problems

The problem of managing rainwater is linked to the disproportionate growth of the urban population. This growth requires that more impermeable areas be constructed and constant renovation be made to the drainage systems that are such important features in modern life. In addition to the above, and due to the way climate change affects the hydrological cycle, changes in rainfall patterns, including in some cases an increase in the frequency of extremely intensive rainfall have been observed. Such rapid change in land use together with urbanization bring about a change in the flow of matter and energy in the hydrological cycle—changes

in micro-climates— (Araujo and González, 2010), causing the infiltration rate to decrease drastically; this modifies the concentration times, causing an increase in the amount of surface runoff. This increase in the volume of and flow of surface waters causes more sediment transport, which could be an environmental threat to the receptor waterbody.

8.1 Flooding in cities

Flooding in cities is one of the problems caused by urbanization that has a high impact on the population and its lifestyle, given that floods affect densely populated areas that, generally speaking, are the locations of vital important infrastructure. Between 2001 and 2010, this was the most common type of natural disaster around the world and floods were responsible for at least half of the victims of such natural disasters and for related financial losses estimated to be \$185 billion dollars (International Disaster Database, 2011. <http://www.emdat.be/>).

In 2010 and 2011, Colombia experienced an unprecedented historical rainy season. During that period of 14 months, 1,734 floods were reported, the equivalent of 45% of those occurring between

Figure 6. The effects of flooding in the Sabana de Bogotá (October, 2011)



1998 and 2008. This number of floods in such a short period of time had unheard of consequences: hundreds of deaths and more than three million affected inhabitants (National Unit for Disaster Risk Management, Spanish initials, UNGRD, 1998-2011; Hoyos et al., 2013)

Regarding the research on this subject carried out in Colombia, it is important to point out the work on urban hydrology done by the del Norte University (Colombian Caribbean) in the basins of the streams in the city of Barranquilla (Ávila et al., 2012; Ávila and Díaz, 2012; Ávila and Sisa, 2012; Sisa and Ávila, 2012). Of similar importance is the analysis of the relationship between rainwater and runoff in basins in the urban area of Lorica carried out by the Pontificia Bolivariana University, Córdoba campus (Salgado and Dickson, 2012). In the valley of Cauca, the Water Supply, Environmental Sanitation and Water Conservation Institute of Research and Development (Spanish initials, CINARA) of the University del Valle has done some outstanding work in the application of simplified models in urban hydrology, hydrodynamic modeling of the urban drainage systems of the city of Cali, and in the analysis of the challenges presented by climate change in urban centers (Galvis et al., 1987; Galvis et al., 2007; and Carvajal, 2007). In Bogotá, recent work on an urban watershed by Hernández and Cubillos (2012) also stands out; they proposed and successfully implemented a methodology to evaluate the public risk from flooding caused by rain in the basin of the Salitre River. There is, however, very little research on the effects of flooding caused by rain on sewage systems (Sandoval et al., 2012) and its interaction with other parts of the system such as water treatment plants or rivers.

For predicting flash floods, early warning systems are applied which have been recognized as the most advanced system in the world (Quintero et al., 2012). Colombia has made little progress in this sense (Rogelis and Ardila, 2012). The PUJB (university) has carried out work on basins in the city of Bogotá related to the subject of technology, particularly on the importance of installing meteorological radar system (Copete et al., 2012); there is also a study on the distribution of rain over Bogotá (Vargas et al., 2010; Santos, 2011; Vargas et al., 2011; Rada Ariza and Torres, 2011). In addition to the work mentioned above, the National University (Manizales campus)

has analyzed the spatial-temporal variability in rainfall in the city of Manizales (Botero, 2009; Botero and Cortés, 2010; Cortés, 2010), the rainwater-runoff conversion process in the urban basin of the San Luis ravine (Suárez, 2008), and they have made an estimate of the variability in times of concentration in this urban micro-basin (Vélez and Botero, 2011), using an installed urban meteorological network for these purposes. Another project, developed by the National University, Medellín Campus with the assistance of professors from the National University, Bogotá Campus (Vélez et al., 2010) and carried out by the Public Companies of Medellín (Spanish initials EPM), aimed at launching urban hydrology research in EPM is the pilot hydro-meteorological information network for the Valley of Aburrá (Jiménez et al., 2008), in the SIATA (the early warning system of Medellín, which is actually the first in the country)² and also the analysis of the urban watershed of the La Picacha stream. The research projects to date underline the fact that studying rainfall in Colombian cities is a more complex process than in other countries. This is due to the cities' extension, the landscape, and the limitations of the instruments installed, making it difficult to understand local rainfall patterns and forecasts. It is therefore necessary that meteorologists and climatologists work together in Colombia and continue to develop in-depth research projects on urban hydro-meteorology.

8.2 New solutions

The understanding of the environmental impact of urbanization has brought about a new focus aimed at improving the management of the urban water resources. This focus contemplates the concept of sustainable drainage that includes long term environmental and social factors in drainage projects; they seek to maintain the ecological, environmental and hydrological integrity of a location related to the natural condition prior to urbanization by means of controlling floods and by collecting, storing and improving the water quality of runoff and minimizing the impact of infrastructure and human activity on water quality.

2. <http://www.siata.gov.co/newpage/index.php>

However, given that the urban drainage system is complex and interacts in many ways with social, economic and ecological aspects, the challenge lies not only in the question of technology or in the uncertainty of climate change, but also in a consideration of the whole mega-urban water system and how its different parts inter-relate with each other and with sub-systems. It is therefore necessary to evaluate the traditional urban drainage system that is becoming increasingly out of line with society's environmental values and makes progressing in the search of more sustainable urban environments difficult. To the two traditional objectives of urban drainage, which are (i) to protect and maintain the security and health of the community, ensuring that floods do not interfere with the city's activities and eliminating human waste in order to ensure a healthy environment; and (ii) to protect the natural surroundings, maintaining environmental standards and complying with the pollution limits of waterbodies and of the environment, a third that seeks the sustainability of the system should be added. This implies taking into account the long term consequences of drainage practices in general.

8.3 Structural and non-structural solutions

Sustainable urban drainage systems (SUDS) are classified into two large groups: structural and non-structural. Non-structural types consist of a variety of institutional and educational practices commonly known as << control at source or the prevention of contamination >> that seek to reduce or stop contaminants from coming into contact with rainwater. These practices do not eliminate contaminants entirely, but they can make the structural controls more effective by reducing the amounts of contaminants these controls can manage.

Non-structural SUDS are the following: (i) reduction of consumption; (ii) good practices at home and in industry; (iii) preventative maintenance of the drainage systems; (iv) prevention of point source discharges; (v) education of the community.

SUDS of the structural kind are systems that increase infiltration, minimize the volume of surface runoff, temporarily hold back urban runoff or treatment before it reaches the receptor bodies

of water. Examples of these systems are retention ponds, permeable paved surfaces, canals with vegetation and constructed wetlands, among others (Durrans, 2003).

Compared to conventional drainage systems, which are created to collect, channel and discharge surface runoff as quickly and efficiently as possible, but that do not take into account large volumes of urban runoff and their impacts on surface water bodies, SUDS seek to preserve the hydrological conditions of the location in place before urbanization and minimizing the impact. The inclusion of the SUDS in urban design seeks to produce low impact on the location which conserves and improves locations with high environmental value in order to adapt them to the new urban conditions; this implies the use of permeable materials in hard zones and a reduction in these impermeable areas, thus making the most of green areas (gardens, public parks, traffic circles and street separators) designed from the point of view of hydrology (Fernández, 2011).

In order to replicate the natural processes of urban watersheds, the use of a "management train" is being proposed. This concept consists of considering the following techniques, in hierarchical order. (i) Prevention. Use good designs and apply maintenance measures in the locations in order to prevent run-off and contamination, and design and implement measures for the use or of recycling of rainwater; (ii) Control at the source. Control runoff water that lies closest to the impermeable areas that create them (by means of infiltration and retention); (iii) Control at the locations. Manage the water in local areas (direct the water from rooftops, from car parks into large retention tanks or infiltration systems; (iv) Regional control. Manage the water from different local areas.

The implementation of SUDS in Colombia is relatively recent and has great potential for improving water management in urban centers. SUDS are not used nationwide, and even less so as means of reducing contamination.

In Bogotá in 2008, the City Council agreed to create the Unique Sustainable Construction Standard in Bogotá's building Code (Agreement 323, 2008) in order to be able to evaluate the reduction in the environmental impact of a construction. In 2011, the Ministry of the Environment passed Resolution No.

5926 designed to create and regulate the Recognition of ECO-efficient Buildings Program (Spanish initials PRECO). This program seeks to promote eco-efficient, environmentally friendly construction projects that encourage the use of new technologies in favor of environmental sustainability.

In Medellín an environmental management manual was developed for construction that seeks to reduce the environmental impact of construction, and the Colegio Mayor de Antioquia (Upper College of Antioquia) and the National University currently offer post-graduate courses in sustainable construction.

The experience nationwide are considering studies on the technical feasibility of SUDS (Galarza and Garzón, 2005) and on the benefits of reducing peak volumes of urban runoff (Ávila and Díaz, 2012). Modeling has been developed for the location of SUDS (Díaz-Granados et al., 2009), as have simulations and experiments in scale models in a laboratory setting (Gómez et al., 2010; Torres et al., 2011; León and Avellaneda, 2012; Álvarez and Celedón, 2012; Devia et al., 2012; Torres et al., 2012).

In practice are the construction of productive greenroofs built in low-income areas of Bogotá (Forero et al., 2011) and constructed wetlands have been created alongside natural wetlands with a view in controlling the contamination of urban runoff (Lara-Borero, 2010). However these systems have not been monitored on a continuous basis so the degree to which they provide hydric attenuation and amounts of contaminants, among others, has not been determined. Also, in 2013, the PUJB (university) built a constructed wetland/regulating tank in order to treat runoff water coming from a car park building for its subsequent re-use. This system will be monitored in order to understand how the system works from the hydraulic point of view and to see whether it improves water quality (Galarza-Molina et al., 2013).

Regarding the green roofs, monitoring and modeling studies of these systems have to be developed, as follows: the effects of the vegetation on thermal flows; the rate of evotranspiration through the soil and the vegetation; the transference of heat; the balances of energy for the vegetation and the substratum as well as the economic benefits obtained from these green roofs as applicable to the country's main cities.

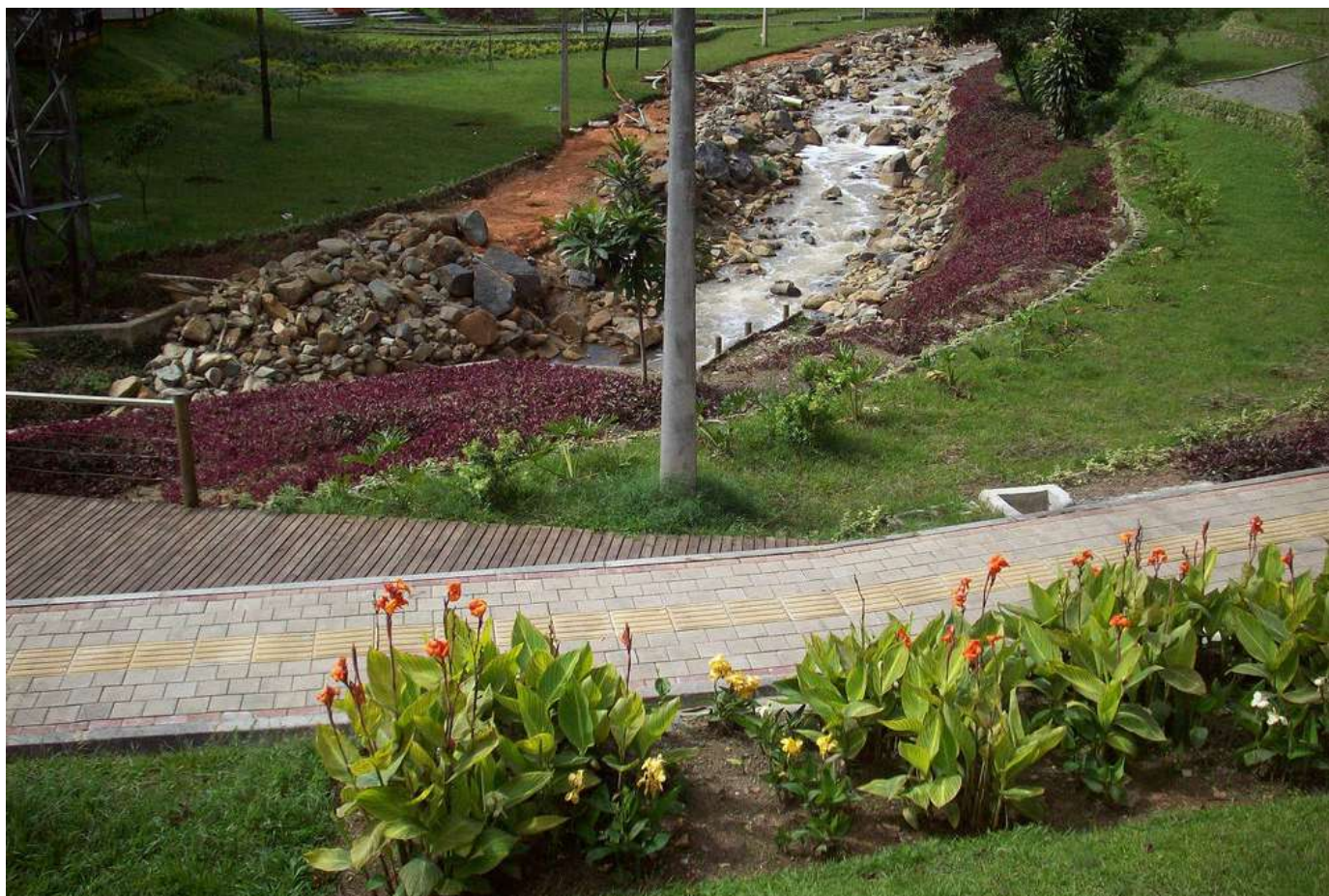
Progress has been made in Colombia in the area of environmental architecture since the '90's, but it has been during the last decade that projects at institutions, universities, family compensation funds (caja de compensación familiar), schools, hotels and industry have joined in the global environmental movement and the paradigm of sustainable development in cities such as Bogotá, Medellín and the medium-sized cities of Pereira and Palmira.

Similarly, environmental solutions such as linear parks (Figure 7) have been implemented in Colombia that contain measures that reduce the risk of flooding and erosion. These provide natural flooding control along rivers or streams and bring about savings in investment in more complex structures. They conserve the land, natural resources and the landscape. They conserve and improve urban living conditions. They make up a migratory corridor for plants, birds and fish found in the immediate surroundings. They allow for the proliferation of the wildlife. They conserve and protect water quality. They improve and protect the quality of air given that they serve as a contaminant filter. They serve as an integrating factor that allows for a balance between environmental conservation, economic improvement and community participation. And although they have different names in different countries, they are an alternative that improve individual mobility and the quality of life in our cities and towns, and they represent a valuable contribution to the achieving sustainability in our communities.

Six of these linear parks have been developed in Medellín: Bermejala Linear Park, La Presidenta Linear Park, Los Sentidos, Linear Park, La Hueso Linear Park, La India Linear Park, La Herrera Linear Park, and a competition to design and create the Medellín River Linear Park has just been announced.

Although there is in some cases a high number of green areas in urban centers in Colombia, many parks or recreational areas are considered of low value; urbanization has intruded into the spaces taken by streams and has adopted a type of vegetation that is more aesthetic than ecological and is thus limited in its potential to carry out all the functions of urban vegetation.

Figure 7. La Presidenta Linear Park in Medellín



If there is to be an integrated approach to environmental management based around the development of water resources, conflicts in the use of rural areas must be reduced and agricultural, ranching and agroforestry activities must be carried out in their appropriate areas. With these sorts of activities as the development of linear parks, habitats for flora and fauna can be protected in strategic ecosystems, thus restoring the natural landscape surroundings, preserving the soil and diversifying the forest environments for all inhabitants of the watersheds in general.

Also, with the purpose of functionally linking existing public green areas in urban centers to the fragments of natural vegetation in nearby rural areas, it is important to have an ecological network that includes ecological restoration activities in

protected areas. This provides a tool for urban green area planning and for the recovery, restoration and conservation of natural resources. This also prompts the establishment of a closer relationship between the city and nature, and better enjoyment and appreciation of natural areas resulting in the community taking better care for these spaces.

The country is becoming aware of the need to implement an urban planning process that analyzes the problems and potential of watersheds in all their components. Scenario planning and interaction with the community and the municipal agencies have determined that a likely and desirable scenario is the one whose short-term goal is to create conditions that are favorable for finding integrated solutions to the socio-economic as well as the environmental problems in the river basins.

9. Conclusions

- Colombia is one of the countries with the largest availability of water resources in the world, but they are not uniformly distributed across the country.
- The area with the heaviest rainfall is the Pacific coast that receives up to 12,000 mm per year.
- Close to 90% of the population is located in the Andean range of mountains with a high population density that affects the quantity and quality of the water resources. Also contamination originated in homes, agriculture, industry and deforestation greatly limits the use of water.
- The greatest problem is that most of the wastewater is not treated, making recycling impossible. It is estimated that only 3% of wastewater is properly treated.
- Colombia's water problem is not the quantity, but rather its improper use. Also rubbish and garbage that is deposited directly into the water sources or along their banks or shores is a frequent source of pollution in many areas of the country.
- To summarize, quality and quantity problems of water resources are more a question of educating the public in its use and management,

and improving the deficiencies of governance and non-application of the existing laws.

10. Recommendations

- The first priority to plan the use of the watersheds and micro-basins in order to guarantee a sufficient quantity of good quality water.
- For this to happen, deforestation and the use of pesticides and fertilizers has to be controlled, and promote sustainable agriculture.
- Wastewater treatment plants must be built in all cities and towns in order to prevent the water sources from becoming contaminated and thus allow for the reutilization of treated water.
- Organize technical management and recovery of garbage that allows for a high percentage of recycling.
- Adopt a vision of integrated use and management of water that takes into consideration the basin as the source of water; that educates the public in the rational use and conservation of water, and makes the municipal authorities responsible for the treatment of wastewater.

Linear Ecological Parks

Colombia has seen the development of numerous linear park projects, designed principally to meet the leisure, educational, environmental, health, sport and transport requirements of the communities living in an urban environment undergoing significant changes.

The municipal government of Medellín in the state of Antioquia has designed a concrete and decisive program to recover the withdrawals of urban water flows, and this mainly by implementing green corridors and linear parks. These linear parks are a strategy that complies with the investment guidelines established by the municipal government. These spaces have also responded to the environmental, social and economic needs of the basins developed. Consequently, they have been created together with plans for the organization and management of these basins, coordination initiatives with the communities living in the basin, and the application of the relevant Colombian norms.

The linear park of the La Presidenta ravine is a good illustration of the environmental, social and economic services that this space provides for citizens. The project is described below.

The Linear Park project was designed to link the public space of the center of the El Poblado neighborhood to the pedestrian areas network and the withdrawal and protection borders of the La Presidenta ravine. It thus became one of the pilot actions of the Integral Organization and Management Plan for this microbasin, and a model for other initiatives in the region.

Furthermore, the project aimed to recover a natural corridor that contributed to maintaining the area's fauna and flora, making it an element of urban quality of life. It also envisaged linking it with other nearby natural spaces, configuring an environmental network across the entire zone, and contributing to designing a peripheral pedestrian ring around the center of the El Poblado neighborhood. In later years this would be complemented by recovering the edges of the La Poblada ravine, the principal affluent of the La Presidenta ravine and the development of public spaces.

The design of the Park maintained the existing vegetation as far as possible, in order for green to predominate over gray. It aimed to provide the community with a fresh, friendly, tranquil environment with attractive, pleasant-smelling trees, bushes and gardens, and home to a great diversity of wild animals, which could find food and nesting places in this area. The embellishment of the landscape had an ecological purpose, as in addition to its pleasing appearance for pedestrians it also strengthened the environmental conditions of this area as a biological corridor for fauna and flora, and as a space to mitigate the region's flood risk.

Proposal of areas to be developed as part of the linear park of the La President basin:



Box 3

The architectural design of the stretch to be developed is displayed below



Current view of the linear park of the microbasin of the La Presidenta ravine in Medellín (Antioquia - Colombia)



Box 4

Water Footprint

The water footprint indicator was developed by two researchers, A. Hoekstra and A. Chapagain, in 2003. It is based on two previously proposed ideas, the first being the concept of virtual water put forth by J.A. Allan in 1993, the second being M. Falkenmark's idea of green water proposed 1995. These two concepts are the primary components of the conceptual and methodological basis of the water footprint. The Water Footprint Network (WFN) led the standardization of the concept, its quantification methodology and the guidelines for undertaking an evaluation at the international level.

The water footprint makes it possible to consider the use of water hidden in the production chain of consumer goods and services, providing information on the effects on water of the habits or people or populations, guilds and firms. This multidimensional indicator shows water consumption according to its origin and the volume required to absorb the pollution generated. The components of the water footprint geographically and time specific.

There are a number of applications for the water footprint, including the perspective of consumption and production, for a single person or a group of people, a farmer or a group of farmers, a product or group of products and a geographically limited area such as a water basin.

The water footprint is made up of three components:

The green water footprint

refers to the consumption of groundwater stored from rainfall that maintains vegetation without irrigation. It meets a need without requiring human intervention.

The blue water footprint

refers to the consumption of water extracted from surface or underground to meet the needs of a process. It measures the loss of available water (evaporation, change of watershed, product incorporation) due to specific consumption. It requires human intervention.

The grey water footprint

is defined as the amount of fresh water required to absorb the amount of pollution in a body of water, taking into account the environmental quality norms and limits established for quality for both the environment and people.



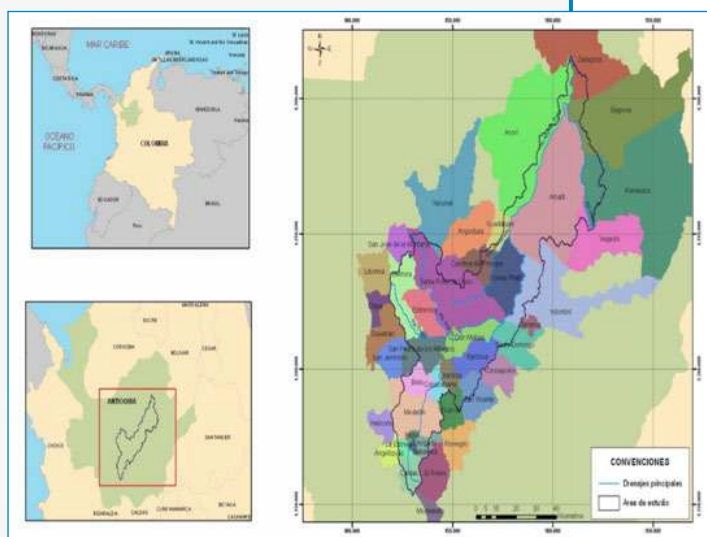
A number of countries, economic sectors and businesses have begun to incorporate a water footprint evaluation into their environmental sustainability plans. In the Americas, Colombia has made the greatest progress in this respect. The water footprint for Colombia's agricultural sector was established in 2010 and since then, more than ten large corporations have assessed their water footprint, and scrupulously followed the methodology established by the Water Footprint Network to evaluate the Porce river basin. To date, this evaluation is unique, not only in the Americas, but also across the globe. Knowledge of the water footprint in Colombia has advanced to such an extent that this year it was decided that the National Water Study, the most widely consulted document on water and the basis for the country's water-related decision-making, should include the concept of water footprint. Some results from the water footprint assessment of the Porce River basin are included.

Geographical Characteristics:

The Porce River basin covers 5,248 km² and is located in the area of Antioquia along the Colombian Central Mountain range. Its main channel is off the Aburra River, which rises in the Alto de San Miguel in the municipality of Caldas. It runs for 252 km before joining the Nechi River in the municipality of Zaragoza. The basin's topography is irregular and on an incline, with elevations of between 80 and 3340 masl. The political-administrative division of the basin includes 29 municipalities that are either totally or partially included within the basin area.

The study of the basin covered six economic sectors: the agricultural sector, including 48 large products within the basin; the livestock sector, including cattle, horses, pigs and poultry; the energy sector, with an analysis of the five reservoirs within the basin responsible for 16% of the country's power; the industrial sector, with the 56 most important subsectors and Colombia's three most heavily industrialized municipalities; the domestic sector, including the population of the country's second largest city; and the mining sector, since the lower regions of this basin is the site of extensive mining activity, both formal and informal. The analyses yielded the following results:

During the final stage, a gradual, collective process of construction of the actions necessary to solve the problems identified in the Porce River basin through the water footprint



Sectors with presence throughout the basin

Agricultural sector: 48 crops, eleven high priority crops.

Green HH (mm³/year) = 230 Blue HH (mm³/year) = 14 Grey HH (mm³/year) = 5 (N)*

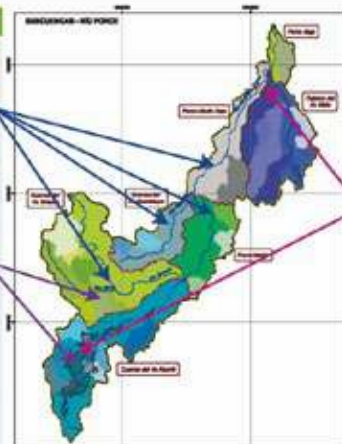
Livestock sector: cows (meat and milk), pigs (meat), fowl (meat and eggs) & horses.

Green HH (mm³/year) = 470 Blue HH (mm³/year) = 12 Grey HH (mm³/year) = (220)

Local sector

Hydroelectric sector:
Including 5 dams
Blue HH (mm³/year) = 24

Industrial Sector:
Includes 63 subsectors
four digits (CIIU rev.
3.0 A.C.)
Blue HH (mm³/year) = 8
Grey HH (mm³/year) =
4.000 (DBO)*



Local sector

Mining sector:
Gold and other materials
for construction
Blue HH (mm³/year) = 4
Grey HH (mm³/year) =
2.800 (SST)*

Note: The diversity of practices for mining gold and the difficulty accessing reliable information about these practices within the basin made it impossible to estimate the grey footprint for both mercury and cyanide; nevertheless the grey footprint was calculated for the municipality for various probable scenarios.

Sectors with presence throughout the basin

Domestic sector:

19 municipalities were given priority because 100% of their municipal seat is within the basin area.

Blue HH (mm³/year) = 29 Grey HH (mm³/year) = 12.000 (DBO)*

Box 4

The three water footprints obtained during the quantification process (sectoral and multi-sectoral analyses) were compared to the characteristics of the land associated with the significance of each footprint in different current, possible and ideal scenarios. According to the Water Basin Development and Management Plans and the environmental conservation and protection goals established for rivers and streams by the Environmental Authorities for the basin. Through these means, more than 100 important geographical and temporal points were identified and can now be used to inform an effective, concrete decision with regards to space and time.



Workshop for formulated response strategies and policy guidelines



evaluation. Various public, academic, economic, communal and non-governmental organizations contributed their knowledge and experience to the process, producing policy guidelines and defining top-priority projects to be implemented in the basin and reduce its water footprint.

One of the project's main achievements grew was the multi-disciplinary and inter-institutional approach that involved the participation of public and private entities and the leading social stakeholders within the area of the river basin. These stakeholders included environmental and land authorities with jurisdiction over the basin, businesses and cooperatives that provide public services, universities, non-government organizations, private citizens and communities who voluntarily joined forces and collectively worked to construct and develop a project to obtain a shared result and a multi-sectoral perspective on water use (alteration of availability in terms of quantity and quality).

The water footprint evaluation project for the Porce River basin is presented as a tool for informing the decision-making process for integrated water management. According to the authors of this study, it also contributes to the state of the art of water footprint evaluation. It was developed through a participatory work approach involving those who make decisions on the basin, both as regards operational development and the design and formulation of strategies to reduce the water footprint.

The water footprint has proved to be a robust tool for conveying comprehensible results to all the sectors and stakeholders present in the basin. The results and conclusions of the study (at the basin level) show that they are complementary to the results obtained through other applications of the water footprint evaluation (corporate, national and global applications). They are on the verge of becoming a tool to support other indicators designed for integral water resource management in both the local and national context.

One recommendation made during the development of the project and the ensuing

discussions was to maintain the focus on the basin as a basic unit of analysis for the water footprint. It should be regarded as a basic study that complements and is complemented by other water footprint applications at the micro (business and production) and the macro (national and large-scale geographic) levels. Specifically with regard to corporate applications, emphasis was placed on the fact that businesses should reflect on and contextualize their water footprints and guide their responses, as proactive actors within the basin. They must maintain awareness of the space that creates an impact due to its water use, transferring the benefits of water use to communities and the land where they engage in their economic activity and including the stakeholders present in them, with whom they share resources, risks and the challenges of sustainability.



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