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REVIEW ARTICLE

Dilemmas in water use: How is the water resource distributed in the Colombian Amazon basin?

Camilo Torres Sanabria[1*], Mauro Alejandro Reyes Bonilla[2], Jorge Armando Cuartas Ricaurte[3], Edwin Agudelo Córdoba[2]

[1] *Facultad de Ciencias Económicas-Administrativas, Universidad Jorge Tadeo Lozano, Bogotá, Colombia. Email: camilo.torres@utadeo.edu.co*

[2] *Instituto Amazónico de Investigaciones Científicas—SINCH, Bogotá, Colombia.*

[3] *Research Institute of Industrial Science, Hanyang University, Seoul 133-791, Republic of Korea. E-mail: hari83@hanyang.ac.kr*

ABSTRACT

This paper contextualizes the economic environment of the productive sectors that depend on the intensive use of water resources in the Colombian Amazon basin (it is composed of the departments of Amazonas, Caquetá, Guainía, Guaviare, Putumayo, Vaupes, La Bota Caucana and southern Nariño) through the collection and organization of information from official entities and consultations in the region carried out by the Amazon Scientific Research Institute (ASRI). Macroeconomic indicators of the Amazonian departments in each of the different sectors were analyzed considering the added value exposed in the annual average of the Gross Domestic Product (2000–2012 in constant values) and contrasted with the sectoral demand for water and the growth projection, both of the human population and the growth trends of the economic activities. As a relevant result, it was found that the departments with a mining-energy tradition base their economic growth on the intensive use of water (greater pressure on the resource in m3/year). An average annual value of $374.42 million dollars is reported in water use (economic cost for the department of Putumayo alone) for oil extraction, which will increase in the future. This value has not been offset by the department, let alone taken into account in the economic growth indicators. It is concluded that the policy guidelines for water resource management in Colombia should be differentiated by sectors and by departments, considering the economic dynamics in the demand for water use and the heterogeneity of the populations.

Keywords: Water Resources; Economic Sectors; Colombian Amazon Basin; Water Use

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1. Introduction

The water resources of the Colombian Amazon basin (comprising the departments of Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupes) are indispensable for the development of the different economic sectors, as well as for any productive activity and territory in the country. The levels of productive organization are differentiated into sub-sectors that contribute to the country's economic growth through the levels of added value presented by the National Administrative Department of Statistics[1] and expressed through the Gross Domestic Product (GDP) growth index. This quantification generates an approximation that expresses the monetary value of the production of goods and services of final demand during a given period of time, based on the direct or indirect use of available resources. This paper analyzes the particular case of the water resources of the Colombian Amazon basin.

There are great differences in the use of production factors in different sectors of the Amazon basin in Colombia. However, water is part of the backbone of the production systems, whether from the perspective of sectoral demand or from the large supply of this macro region. The productive sectors analyzed that directly and indirectly use water resources are:

- Crude oil and natural gas extraction.
- Cultivation of agricultural products.
- Livestock production, including veterinary activities.
- Fishing, fish production in hatcheries and fish farms.
- Forestry, logging and related activities.
- Service activities related to fishing.
- Extraction of non-metallic minerals.
- Water transportation.
- Water collection, treatment and distribution.
- Extraction of metalliferous minerals.
- Waste and sewage disposal, sanitation and similar activities.
- Tourist activities.
- Coffee cultivation.

The main objective of the analysis of these overlapping sectors in a heterogeneous region is to expose to decision makers in the field of water resource management the differences in the territories and uses of the resource, which highlight the need to propose policy guidelines based on the real economic cost in the use of the resource and the differentiation of sectors and regions, particularly in the case of water, which has a differentiable economic cost in the use, regional and sectoral growth trends. The document is developed according to the following structure: first, the economic contribution of each sector in the Amazonian departments is presented based on the analysis of GDP in a time series of 12 years at constant values (allowing the comparison of variables); the second part analyzes the demand for water resources in each sector for each department; the third section projects the dynamics of demand in the use of water resources up to 2020 based on water supply and sectoral growth rates, showing the trend in the water balance; finally, a series of arguments are postulated to discuss the final considerations in the analysis of this scientific review and synthesis.

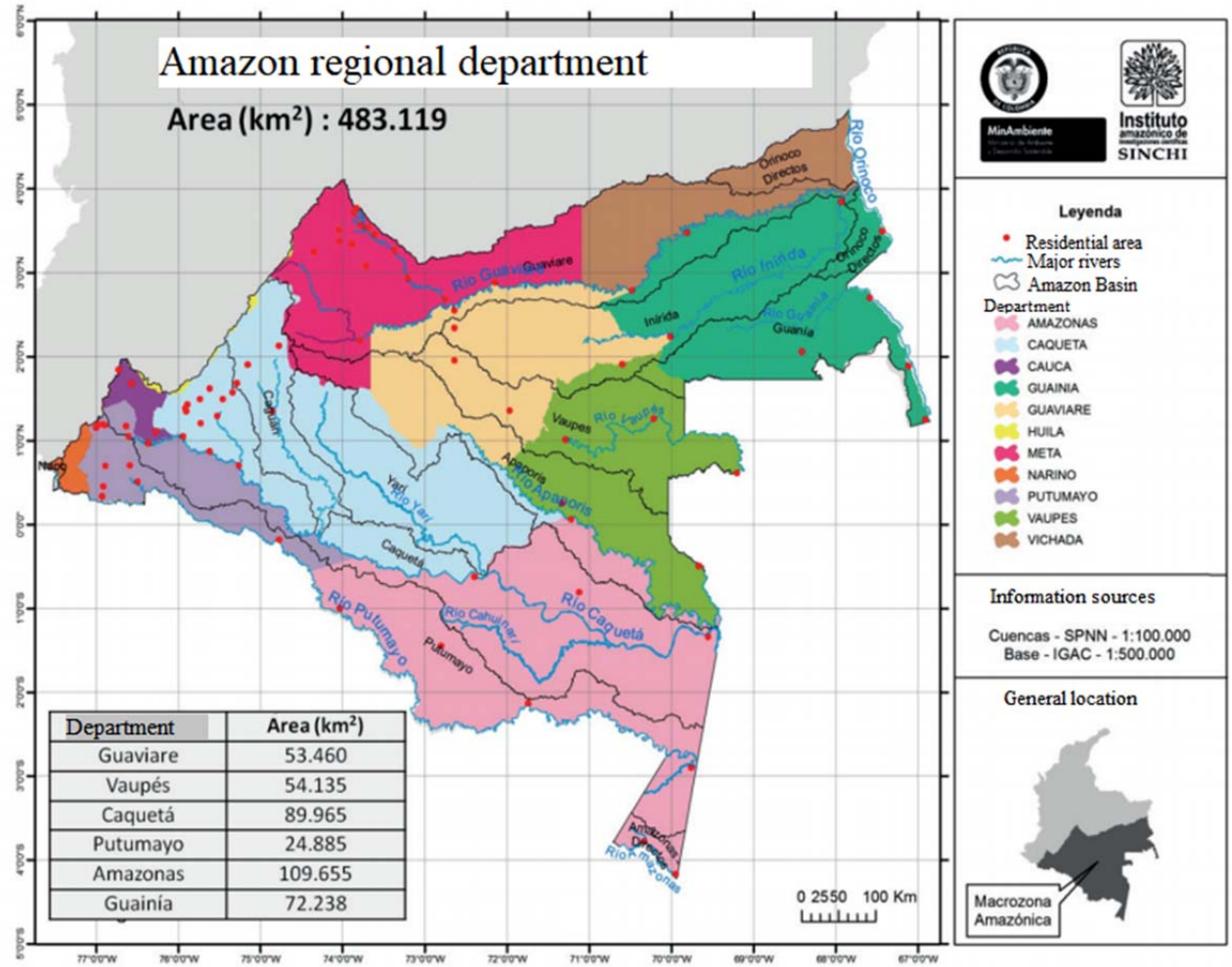
2. Methodology

According to the zoning of the Colombian Amazonian macro-basin, the Amazon Scientific Research Institute (ASRI) developed the delimitation of the southeastern territory of the country, which is affected by the Andes Amazon River, Piedmont river and plain, covering an area of about 483,000 km^2[2,3]. This biogeographic vision covers the departments of Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupés, as well as areas in the southeast of Meta, south of Vichada, La Bota Caucana and the hills of Narino (see **Figure 1**).

The other data included in this work arise from the process of analysis of secondary information from surveys and national studies conducted by state entities such as DANE, the Institute of Hydrology, Meteorology and Environmental Studies of Colombia (IHMESC) and the Office of the Auditor General of the Republic (AGR), which were complemented with primary data recorded by ASRI in 2013 from six regional perception workshops on aquatic ecosystems conducted in the Amazonian departments (one in each capital city). In addition, it is necessary to point out that the following results are underestimated due to the uncomputed demand, which is very important for a comprehensive analysis. It is said to be underestimated since the calculations do not include the demand for water resource used in activities such as illegal mining, illicit crops, among others. For this reason, it can be stated that this calculation of water demand of these activities is almost impossible to perform.

3. Results

The different productive sectors analyzed base their economies on the direct and indirect use of water resources, which makes this resource an essential element for economic growth. This contribution to the real growth of national accounts in the different sectors was based on the survey of household and production sectors developed in 2005 by DANE, which was updated in 2012 for the departments of Amazonas, Caquetá, Guaviare, Guainía, Putumayo, Vaupés and Vichada. Similarly, the DANE has provided the database of macroeconom-



Department	Area (km²)
Guaviare	53.460
Vaupés	54.135
Caquetá	89.965
Putumayo	24.885
Amazonas	109.655
Guainía	72.238

Figure 1. Coverage and departments of the Colombian Amazon.
Source: it is based on Gutiérrez *et al.*[2] and Murcia *et al.*[3].

Table 1. Economic participation in sectoral water use activities

	Gross domestic product (GDP)—Millions of dollars—The average annual price remained unchanged from 2000 to 2012						
Production sectors	**Amazon**	**Caquetá**	**Guainía**	**Guaviare**	**Putumayo**	**Vaupés**	**Vichada**
Crude oil and natural gas extraction					$317.65		$3.52
Agricultural product cultivation	$1.11	$44.66	$1.71	$10.38	$30.75	$1.67	$3.29
Livestock production, including veterinary activities	$0.46	$104.71	$0.42		$13.01		
Fishing, fish production in hatcheries and fish farms	$15.39	$3.45	$1.48	$3.71	$1.39		$2.83
Forestry, timber harvesting and related activities	$3.80	$9.95	$0.60	$1.07	$8.34	$0.37	$2.22
Fishing-related services							$0.32
Extraction of non-metallic minerals		$2.00	$0.04	$1.21	$0.83	$0.18	$0.32
Water transportation	$0.23	$2.67	$0.04	$0.18	$1.39		$0.09
Water collection, treatment and distribution	$0.56	$3.50		$0.04	$0.72		$0.04
Extraction of metalliferous minerals			$0.37		$0.33		
Waste and sewage disposal, sanitation and similar activities	$0.51	$2.95		$0.04			$0.04
Tourist activities	$0.04						
Coffee cultivation		$4.73					
GDP water use	$22.11	$178.84	$4.68	$16.59	$374.42	$2.22	$12.69
Total departmental GDP	$152.74	$918.13	$71.09	$195.01	$814.63	$56.26	$145.27

Source: DANE[1] and Banco de la Republica[6-8].

ic indicators from 2000 to 2012, which measures the growth and contribution of the different sectors and sub-sectors of the economy, considering the average contribution of each of the activities in the use of

water resources in the Colombian Amazon basin.

Below is a summary for each department, taking into account the GDP contribution[1] to each activity based on the use of environmental goods and services offered by water resources (see **Table 1**). The GDP contribution of the Colombian Amazon region ilent to 1.1% of the national total amount (GDP for Colombia: USD 211,279.3 million or $37 USD 2,353 million considering the average from 2000 to 2012 (in the past ten years, the average time series is USD 42.3147 billion pesos), which is equiva 9,928.8 billion constant pesos in the base year of 2012).

From the above it can be seen that the department with the largest contribution to the national economy is Putumayo, and in turn this contribution is largely based on the use of available water resources (parallel to the development of the electric energy sector and specialized work in the mining sector), playing a major leverage role in the crude oil and natural gas extraction sectors (USD $317.65 million) and the agricultural crop development sector (USD $30.75 million).

4. Sectoral demand for water in Amazonia

The Amazon region is one of the areas of the country with the highest water supply per year. According to the *National Water Resources Study*[4], the surface water supply of the Amazon region is 893,389 mm^3 and 576,442 mm^3 in average annual and dry years respectively, while other regions such as the Pacific or the Caribbean, the modal year data does not exceed 297,088 mm^3 (in dry years they do not reach 187,804 mm^3, according to the same IHMESC study). On the other hand, the potential demand for water resources in the country is close to 35,877 mm^3 per year, and the Colombian Amazon region covers approximately 336.3 mm^3, which is close to 1% of the total demand.

Although the livestock and agricultural sectors are among those that add the least significant value in water use in terms of their contribution to economic growth, these two sectors are among the activities with the highest demand, as shown in **Figure 2**.

On the other hand, the relevance of the the domestic sector's demand for water resources can be seen, which reaches 71.9 mm^3 per year, benefiting about 1.1 million people with a consumption of about 180 liters per inhabitant per day (see **Table 2**). Family demand (rural and urban) ranks second, but from a social and human perspective, family demand is the most important sector.

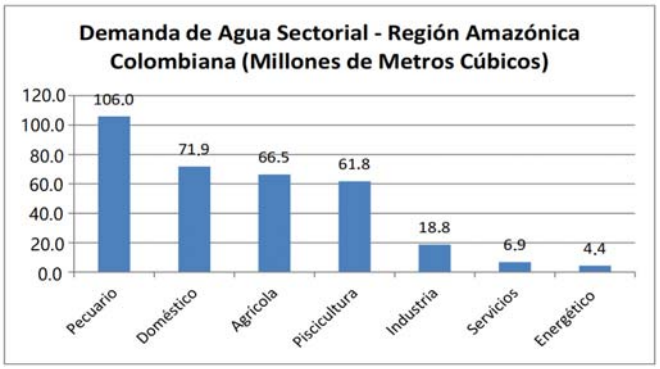


Figure 2. Sectoral demand in the Amazon region in millions of cubic meters.
Source: the National Water Resources Study[4].

Table 2. Departmental population in the Colombian Amazon Basin

Department	Total population—Number of inhabitants		
	2005	2010	2012
Amazon	39.266	47.241	48.150
Caquetá	337.932	447.767	459.515
Guainía	15.676	18,906	192,82
Guaviare	56.758	103.307	106.386
Putumayo	237.197	326.093	333.247
Vaupés	18.636	34.347	34.968
Vichada	44.592	63.670	66.917
Total	750.057	1,041.331	1,068.465

Source: prepared based on DANE[9].

5. Forecast of water demand growth in Amazon region

It is clear that population growth generates an increase in household water demand, but this is closely related to increased use of other sectors. For example, if there is a greater consumption of foodstuffs such as meat (caused by a larger population), water demand in the productive sectors increases. According to the records of water consumption demand presented by Turner *et al.*[5], it can be said that the average domestic consumption requires a maximum of 300 liters of water per day for a family in contrast to the daily demand of water use for food production, which implies an approximate of

[1] Thousands notation (.) and decimal notation (,). The base year is 2012.

3,000 liters per person. This is only a contextualization of the difference in water use for different activities. In Colombia, domestic consumption is considered high when it reaches 122 liters per person per day[4]. The report also points out that the calculation is based on 2012 and expressed in constant values, so as to make consistent comparisons between sectors and between departments.

According to DANE, the population growth rate between 2005 and 2010 in Caquetá was 1.26; in Putumayo it was 1.00; and in the rest of Amazon (Amazonas, Guainía, Guaviare, Vaupés and Vichada), it was 1.65 (see **Table 3**). On the other hand, the national growth rate for the same period was 1.19, which shows that only Putumayo was below the national average.

Regarding the forecast for 2010−2015 and 2015−2020, Caquetá and the other Amazonian departments are expected to reduce their population growth rates, although they will continue to be higher than the national average. In the case of Putumayo, which between 2005 and 2010 was the only department in the region with a lower average, accelerated growth is expected, surpassing the Colombian average between 2015 and 2020. This indicates that there will be a significant increase in the demand for water by households, which must be considered in order to guarantee the supply and efficient use of the resource.

Apart from the demand for water by households, it is clear that certain sectors of the economy have an impact on the resource, either in terms of quantity (water balance) or quality (negative externalities in the production process). The growth of these sectors may be generated by an increase in demand or for other reasons linked to economic growth. Particularly, in the case of sectors such as mining or oil extraction, their expansion is largely due to the incentives provided by the government because they are considered an engine of growth. The following data shows the performance of some productive sectors in the departments of Amazonas, Caquetá, Guainía, Guaviare, Putumayo and Vaupés.

Table 4 summarizes the growth of some sectors related to water resources in the department of Amazonas. It can be seen that the activities that have shown the greatest growth from 2000 to 2011 are livestock production and hunting. On the other hand, fishing and agriculture have lost added value as a measure of macroeconomic approximation that constitutes the GDP. Despite the above, the inhabitants of the department of Amazonas consider that one of the threats related to the hydrobiological resource is indiscriminate fishing.

Table 3. Projected rate of exponential population growth

Department	2005–2010	2010–2015	2015–2020
National	1.19	1.15	1.09
Caquetá	1.26	1.29	1.25
Putumayo	1.00	1.14	1.35
Amazon group*	1.65	1.54	1.52

Note: * Refers to the departments of Amazonas, Guainía, Guaviare, Vaupés and Vichada.

Source: revised calculations from DANE[9].

Table 4. Amazonas—Average growth rates of added value of some economic activities (2000–2011)

Sector	Growth rate (%)
Agricultural	-66.7
Livestock production and hunting	100.0
Fishing and fish farming	-26.9

Source: revised calculations from DANE[1].

With respect to the department of Caquetá, **Table 5** shows the generality of the sectors related to water resources, which have shown significant growth rates in recent years; this is related to the dynamics of the region, whose growth between 2000 and 2011 was close to 40%. The sector that has seen the greatest expansion is water transportation, which generates problems related to the emission of waste through the dumping of oils and lubricants, as well as the use of fuels. On the other hand, the extraction of non-metallic minerals produces a series of negative externalities that affect water resources and ecosystems in this same department.

Table 5. Caquetá—Average growth rates of added value of some economic activities (2000–2011)

Sector	Growth rate (%)*
Agricultural	87.3
Livestock production and hunting	38.0
Fishing and Fish Farming	28.3
Mining	248.3
Water collection, treatment and distribution	14.3
Transport by water	1,323.1
Waste and sewage disposal, sanitation and similar activities	95.0

*Values at constant prices in 2012.

Source: revised calculations from DANE[1].

The agricultural and livestock sectors (the latter is the subsector that contributes the most to the regional GDP) also grew significantly, which

should be considered with special care due to the expansion of the agricultural and livestock frontier and the associated problem of deforestation. Livestock production should receive special attention, for that according to FAO[10], it is the main producer of water pollutants worldwide; despite this, due to its great economic power and the enormous demand for meat in households, this sector seems to have an ever-increasing trend.

Table 6 summarizes the DANE data for the department of Guainía. It is striking to note how the extraction of non-metallic minerals (limestone, minerals, salts, among others) has decreased nearly 150% in recent years; on the other hand, activities such as agriculture and fishing have had significantly increased. Fishing has grown by more than 180%, which is a cause for concern due to overexploitation, poor control and non-compliance with minimum size regulations. These problems could jeopardize ecosystems and the sustainability of the resource.

Table 6. Guainía—Average growth rates of added value of some economic activities (2000–2011)

Sector	Growth rate (%)
Agricultural	50.0
Fishing and Fish Farming	183.3
Mining	-150.0
Transport by water	-100.0

Source: revised calculations from DANE[1].

As can be seen in **Table 7**, the value added by the extraction of non-metallic minerals in Guaviare has grown by more than 260%, a very high figure that obliges policy makers to impose restrictions to minimize the negative impacts of this activity on water resources.

Table 7. Guaviare—Average growth rates of value added of some economic activities (2000–2011)

Sector	Growth rate (%)
Agricultural	-256.0
Livestock production and hunting	40.2
Mining	263.3

Source: revised calculations from DANE[1].

In the department of Putumayo, where oil extraction contributes in relative terms the largest amount to the regional GDP, it can be observed that this sector is the one that continues to grow at a higher rate. Similarly, the extraction of non-metallic minerals had a considerable increase of 3.4% for the year 2012, as did the disposal of solid waste and wastewater[11]. Finally, in the department of Vaupés, the agricultural sector has grown by nearly 213% in the last decade, which has generated a deforestation problem associated with the expansion of the agricultural frontier (see **Table 8**).

In addition to population and productive sector growth, water resources are particularly threatened by illegal activities, especially illegal mining, a practice that has experienced unprecedented growth in recent years due to the interest of illegal groups, as this activity is an alternative to coca cultivation.

Table 8. Putumayo—Average growth rates of added value of some economic activities (2000–2011)

Sector	Growth rate (%)
Agricultural	-26.4
Livestock production and hunting	-10.8
Fishing and fish farming	33.3
Crude oil and natural gas extraction	180.0
Mining	50
Water transportation	116.7
Waste and sewage disposal, sanitation and similar activities	100.0

Source: revised calculations from DANE[1].

6. Discussion

Water resources itself is a kind of public goods[12-14].

In very heterogeneous contexts of use, it would behave more like a common-pool resource, where it faces a high degree of competition without excluding access[15]. Similarly, the relationship of water resources in public policy depends on the availability of quantity, not the amount used[16]. As a consequence, the use of water resources is inefficient in economic terms and in several cases affects the quality and inequity of access and availability, as shown in the studies[17,18], which is not different from the context of the Colombian Amazon basin. These differentiated demands have generated rivalry in their consumption and intersectoral competition[19]. Furthermore, these inequalities result in inefficient allocations, increased poverty and social inequity[20], which does not differ from the results previously presented (oil extraction versus human consumption). In addition, it is shown that the people who use water the most are those who enjoy this right at the lowest economic cost.

The characterization of the sectoral demand presented shows the social function of water for the

satisfaction of basic consumption and food produc-production needs. However, this differentiated demand proves the inequity in the allocation of the resource. Due to the dynamic use of water by indigenous communities according to their traditional lifestyles, livelihood patterns and local traditional co-management organizations[21], their economic use costs are very low. This can be contrasted with users in the mining-energy sector, who use large quantities of water, which entails a very high economic cost in a scenario of non-existent compensation.

In the case of livestock activities in the Amazon, it can be stated that the sector does not generate high added value (in relative terms of innovation and inclusiveness), but it does promote local development and market positioning from the source; however, there are minimal employment opportunities created[22]. Furthermore, this activity is highly demanding of surface water and its main impact is deforestation, which affects the regulation and supply role of forests on surface water supply, which is the key to maintaining the hydrological and climatic cycle in most parts of the country.

In the case of mining, although it is one of the sectors with the lowest demand for surface water (industry), it is an activity that affects the region's water resources, an aspect that is not considered in the analysis of surface water concessions of the *National Water Resources Study*. If the production of beef consumes 15.4 liters of water per gram, the production of one gram of gold consumes 450 – 1,060 liters[11]. In terms of mining activities, illegal situations can be identified, which overlap with artisanal mining, whose negative effects are of a social, environmental, economic and cultural nature. This is proved in the results of the department of Caquetá and validated by the study of Verschoor and Torres[23].

In addition, the allocation of gold mining rights should also be considered, which is the right most directly granted to international concessionaires and operators. This causes a high risk to public health, for the inputs used in the operation will cause water pollution[11]. These and other factors of extractive activities affect water quality and make water availability a scarce ecosystem service, which undermines its social function, which should take precedence over its use as a production input.

Torras[24] considers that in order to calculate the true GDP of an economy, the depreciation of natural capital should be considered, i.e., it would be necessary to focus not only on how much an economic sector produces, but also on how production associated with the use of a natural resource affects nature. Under this perspective and because of the growing global concern about environmental destruction (and water scarcity), it is essential to find alternatives to approximate the total economic value of the water resource (in terms of function), considering this resource as a high-value input.

Considering the above situation, it is important to focus on the different uses of water in the Colombian Amazon basin, where the vulnerability and limitation of water resources is evident. More importantly, over time, the incremental dynamics used are predicted, which increases the difficulty of formulating and implementing appropriate management policies. Policy guidelines should consider not only the water balance (the quantity of water), but also the associated ecosystems and other water-related ecosystem services, which have not been valued economically in a holistic context in interactions. Policy guidelines should consider the following items:

- Heterogeneity of the territory.
- Identification of sectors, users and forms of use.
- Co-management, governance and local strengthening strategies.
- Environmental stressors.
- Water balance.
- Demand growth trends.

In this order of ideas, the water resource in the Amazon region can be considered abundant, but the dynamism of high impact productive activities directly affects it, both in quantity and quality. Likewise, population growth generates a conflict of use, which reveals the need to balance the effects of economic growth versus human wellbeing, guaranteeing the environmental quality of the resource[25]. On the one hand, we found that the

population growth in an area is accelerating, and new demand tends to increase; on the other hand, there are consequences of economic growth that affect the productive base itself by affecting the quantity and quality of water resources: deforesta-deforestation, pollution, extractive activities and degradation of tropical rainforests.

Finally, the dilemma facing the use of water resources in the Amazon region has the following characteristics: (1) it takes 47% of Colombia's territory; (2) it contributes only 1% to the national GDP; (3) various sectors and ethnic populations interact; (4) it is a region of high population growth; (5) it has a low institutional framework and state coverage; (6) it presents a high environmental vulnerability. According to the above situation, it can be said that in this highly complex context, public policies on water resource use are inefficient. It is here where the debate can be opened: to focus regional development policies on sectoral activities that contribute significantly to GDP, or (on the contrary) to centralize public policy on the development of long-term social benefits, under a scenario of sustainability of natural resources.

Conflict of interest

The authors declared no conflict of interest.

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