WATER FOOTPRINT ASSESSMENT OF COLOMBIA

Results of National Water Study 2014

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ABSTRACT

The Water Footprint Assessment (WFA) at river basin level, is a new technical tool in the National Water Study 2014 (ENA 2014), that increase the knowledge, theoretical and conceptual about the Colombian national water heritage and their management, and offering a different approach in the process of guidelines implementation of National Policy of Integrated Water Resources Management (Environmental Ministry of Colombia, 2010). The WFA incorporate basic concepts of the water footprint (Green water, blue water), the green, blue and gray[1] water footprint and the virtual water. All of those new approaches allow a better approach reality Environmental nationally.

This work is the result of five years of continuous work in Colombia over the water footprint assessment.

- Suizagua Phase I - SDC - (2010-2013). Corporate application[2]. More information in
- Suizagua Phase II - SDC, NCPC - (2012 - Present). Corporate Application
- A view of Colombian Agriculture from the Water Footprint - WWF - (2010-2012)[3].
- Water Footprint Assessment of Porce river basin - CTA, SDC, GSI, et al. - (2012-2014)[4].
- National Water Study 2014 - ENA 2014. Chapter 4 - CTA, SDC, GSI-LAC, Ideam. - (2014-2015)[5]
- Water Footprint Assessment of Colombia– (2015)[6].

Main workstream that was included in WFA of Colombia:

- Methodology for quantification of the water footprint of key economic sectors (Crops, Livestock, Industry, domestic water use, power production (hydro and thermal) and mining (oil extraction), and their geographical results for each of 316 basins.
- Blue and Green water footprint assessment and creation of two new indicators applied to all basins of Colombia, which are complementary of the six indicators that was included from the National Water Study of Colombia 2010.
- Virtual water flow assessment for the main products the trade balance of Colombia.

[1] The Gray Water Footprint is not included in scope of this work. This concept will be included in a independent document of water quality that will be published in 2016 by Ideam.
[2] http://www.suizagua.org/b/colombia/#/empresas
[3] http://www.huellahidrica.org/Reports/Arevalo-2012-HuellaHidricaColombia.pdf
[4] https://docs.google.com/file/d/0B7rWDl8HIMXJRlBjUjIxbl9Vd3c/edit
[5] http://documentacion.ideam.gov.co/openbiblio/bvirtual/023080/023080.html
[6] http://documentacion.ideam.gov.co/openbiblio/bvirtual/023272/023272.html

The project has demonstrated that the application of the basin water footprint allowed to introduce important elements in the national water policy base document that offer the following challenges and opportunities

- Green water concept complement and enrich the analysis done before around only a Blue Water management (river, lakes, ground water).
- Contribution of the water footprint as a tool for Integrated Water Resources Management (IWRM)
- Very clear link between basin management and productive sectors, in order to define a common strategy to face the main threats, challenges and opportunities, based in collective action and collaborative view of key stakeholders.
- Create a new possibility to collaboration between agricultural and environmental sector, around the WFA and the multi sectoral view of basin hydrological sustainability

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1. Multisectoral Blue and Green Water Footprint Assessment for Colombia

Colombia is located in the North of South America. It has a total land surface area of 114 million hectares and a population of 48 million inhabitants. It has 5 million hectares of planted crops and 40 million hectares of pasture (an average of 1,6 heads of livestock per hectare). 16 million hectares of protected areas and 3 million hectares are moorlands, known as “Páramos”: an ecosystem of high importance in tropical altitudes due to its ability to retain rainwater. Hydrologically, Colombia is divided into 5 main areas: Caribbean, Amazonian, Orinoco, Magdalena-Cauca and Pacific. Colombia has one of the leading positions in biodiversity in the world (SibColombia, 2015) and is number six in total internal renewable water resources (FAO, 2015). However, the country faces many water management challenges: 70% of its population is concentrated in a territory that has 13% of Colombia’s water resources, whereas water pollution is the main constrain in water availability. The country is characterized by a high deforestation rate that is estimated in 147.946 hectares per year (IDEAM, 2013). Furthermore, it is estimated that water runoff will be reduced up to 30% in the areas with the highest demand, according to climate change scenarios.

Figure 1. Colombia's location at South America

Colombia periodically analyzes the status of its water resources through the National Water Study (ENA; by its Spanish acronym), published by the National Institute of Hydrology, Meteorology and Environmental Studies (**IDEAM**). It has been published in 1998, 2000, 2004, 2008, 2010 and recently in 2014. In the most recent study, ENA 2014, the blue and green water footprint assessment was incorporated for the first time. ENA 2014 was also the first national water study, worldwide, directed by an official entity, to incorporate the water footprint assessment for each country's river basin. The study was a result of a fruitful partnership among the IDEAM, the Global Programme Water Initiatives of the Swiss Agency for Development and Cooperation (**SDC - GPWI**), the Center of Science and Technology (**CTA**) and Good Stuff International Latin America and the Caribbean (**GSI-LAC**).

This study assessed the green and blue water footprint of five economic sectors: agricultural, domestic, industrial, energy and oil extraction; and for Colombia´s 316 river basins (among them 5 island areas), using the Water Footprint Network methodology (Hoekstra, et al., 2011). Blue and Green Water Scarcities were estimated as part of the WF sustainability assessment. The study was complemented with dynamics and economics scenarios for the main agricultural products in the year 2022, and the analysis of virtual water flows for the main export agricultural products.

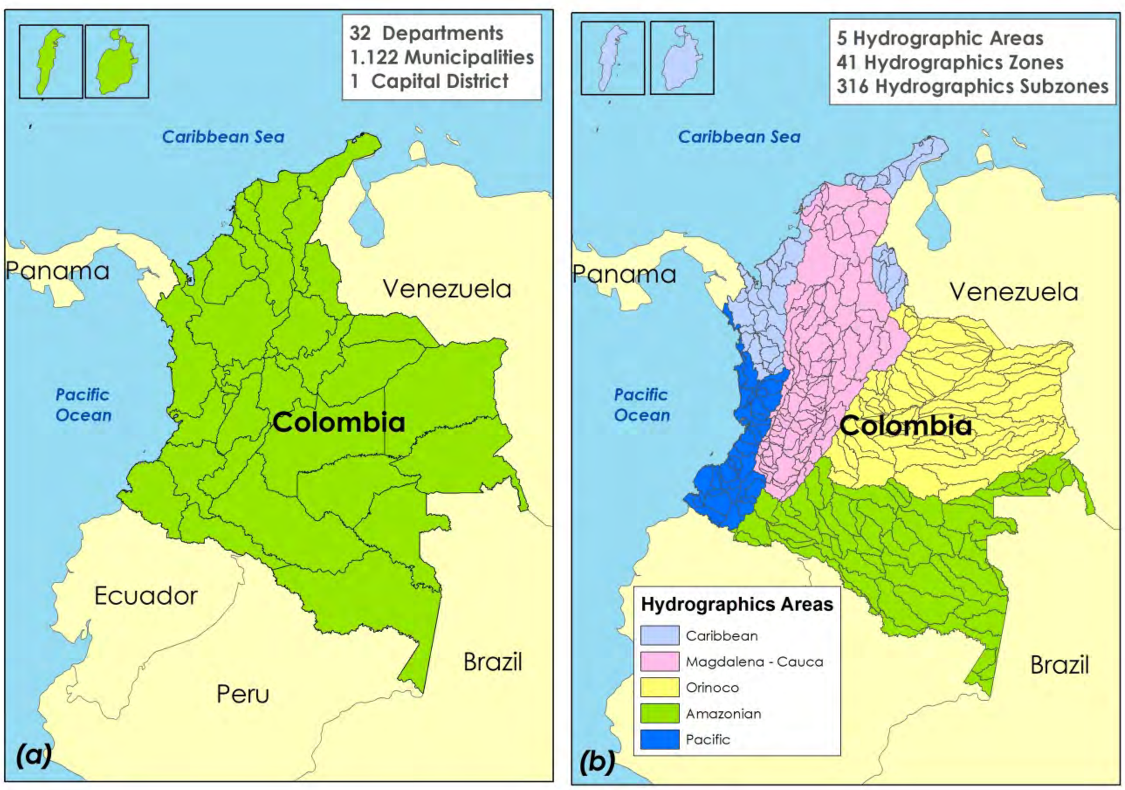


Figure 2. (a) Colombia's Political and Administrative Division; (b) Colombia's Hydrological zonification.

The inclusion of the water footprint assessment at river basin level in ENA 2014 is the result of five years of uninterrupted work applying this concept based on methodologies published by the Water Footprint Network - WFN (Hoesktra, *et. al*. 2011). The WFN has been one of the main promoters of including these assessments in public politics as a tool for Water Resources Management in at the river basin level. The Multisectoral Water Footprint Assessment for the Porce River Basin, conducted by the Center of Science and Technology (**CTA**) *et. al.* (2013a) and (2013b), gave the methodological basis for the application in ENA 2014. The referred study is one of the most important works of water footprint assessment at river basin worldwide level.

The National Water Study 2014 and Water Footprint Assessment of Colombia were published in 2015 and are available for download at www.ideam.gov.co.

2. Methodology

The Green and Blue Water Footprint Assessment methodology was applied for 316 watersheds in Colombia (311 continental and five islands). The scope of WFA in National Water Study of Colombia 2014, only include Green and Blue Water Footprint Assessment. The grey Water Footprint will be including in a new publication about water quality that will be done in 2016.

2.1 Crops and Livestock

The agricultural sector is identified as the main worldwide water consumer. Colombia has a high percentage of its economy in agricultural activities, so these ideas apply for Colombian case as well. The water footprint assessment for this sector include the water requirements of crops, this calculations was done based in local and official information provided by public and private local institutions.

Information	Source
Areas planted by municipality: 2012 base year **Crops:** • 21 perennial crops • 20 annual crops **Livestock:** • Five categories for grassland and pasture systems for livestock.	Municipal Agricultural Assessment (EVA - *Evaluación Municipal Agricola*) Ministry of Agriculture and Rural Development of Colombia, 2013.
Soil: information of physical characteristics that allows a water balance to calculate irrigation needs.	Soil Map of Colombia 1: 500,000 (IGAC, 2003)
Climate: • Three temperature ranges: Warm: Average annual temperature > 24 ° C Temperate: 18 ° C > Average annual temperature < 24 ° C Cold: Average annual temperature < 18 ° C. • Effective rainfall • Potential evapotranspiration - Penman.	Climatic zoning map for Colombia (IGAC, 2008). National Water Study 2014 (IDEAM, 2015)
Land Use: reclassification for agricultural and livestock polygons	Corine Land Cover (IGAC, 2010)

The blue and green water footprint for crops and livestock quantification was done under the limitation of information about two key issues: (1) the form how data is officially reported, include a high uncertain about crops location at basin level, (2) the land use map, only provide information for some singular crops (coffee, sugar cane, others). The cross of information between official municipal database and land use map shows huge differences because a part of individual crops are include in crops aggrupation.

The calculation has a first approach that identifying the zones where agricultural or livestock activities could exist and the exclusion of land where the agricultural activity is not allowed (natural forest, moorland, national parks, wetlands) or where activity is not possible (cities, lakes and rivers, snow peaks). After that, only with potential agricultural land, proceeded with next step by identification and characterization of approximately 14.000 agro-climatic homogeneous polygons for all country (6.587 polygons for crops and 6.995 polygons for grassland and pastures), in order to calculate of crop water requirements through its monthly evapotranspiration, identifying the water that is used can be from rain or irrigation (FAO, 2006).

In the calculation, each irregular polygon has a non-representative monthly variation about climate, rainfall and soil, this information was obtained from an algebra maps. In the other side, inside this polygon could be "n" crops or type of pasture and grassland, this information was extracted from the municipal database.

The final results of this calculation estimated the monthly evapotranspiration for each one of 41 crops. It was assumed that: (1) the areas of perennial crops do not have monthly variation, (2) the areas of annual crops have a monthly variation defined by the crop harvesting calendar, provided for Agricultural Ministry of Colombia, (3) for grassland and pasture, only two of the five categories considered generate water footprint Blue, pasture and fodder, so those were taken as a part of the agricultural sector, (4) for grassland (natural, managed and agroforestry) livestock generates only water footprint Green.

2.2 Other sectors

For water footprint assessment at basin level, was included quantification of blue water footprint for production of industrial goods, domestic water use, power production (hydro and thermal) and mining (oil extraction). The methodology applied was focused on the official information available for each sector, and the interpretation of information in order to achieve an real complementarity about water demand in terms of water abstraction, water allocation and real water consumption. The blue water footprint is a complementary concept to show the geographical impact of water use.

3. Multisectoral Quantification of Colombia’s WATER Footprint

3.1 Water footprint of the agricultural and livestock sector

Colombia’s economy depends in a high percentage on agricultural activities. The water footprint assessment for the agricultural sector requires understanding the crop’s water demand. The official and local information, published by both public and private entities, was used for this purpose, in accordance with methodology that previously mentioned.

3.1.1 Blue and green water footprint of the agricultural sector

The perennial crops' water footprint adds up to 3.918,4 million m³/year. The highest value resulted for palm oil, followed by plantain and sugar cane. Coffee did not report blue water footprint (BWF) because this crop is not irrigated in Colombia. The BWF of Annual crops was estimated in 847,1 million m³/year. The highest value corresponds to irrigated rice, followed by potato and corn.

Coffee holds the highest green water footprint (GWF) for perennial crops (11.822 million m³/year), followed by sugar cane, oil palm and plantain. Regarding Annual crops, corn has the highest GWF, followed by rainfed mechanically sown rice. The lowest values come from carrot, tomato and wheat. The annual GWF from pastures used in the agriculture sector is 10.826 million m³, mainly located in the hydrological areas of Magdalena-Cauca, the Caribbean and the Pacific.

The estimated GWF and BWF of agriculture distributed in Colombia's main hydrological areas are shown in **Figure 3** and **Figure 4.** These account for the main GWF and BWF's results for each Hydrological Subzones (SZH) nationwide. The annual geographical distribution of the GWF and BWF can be found in **Figure 5** and **Figure 6** and the monthly distribution in **Figure 7** and **Figure 8**.

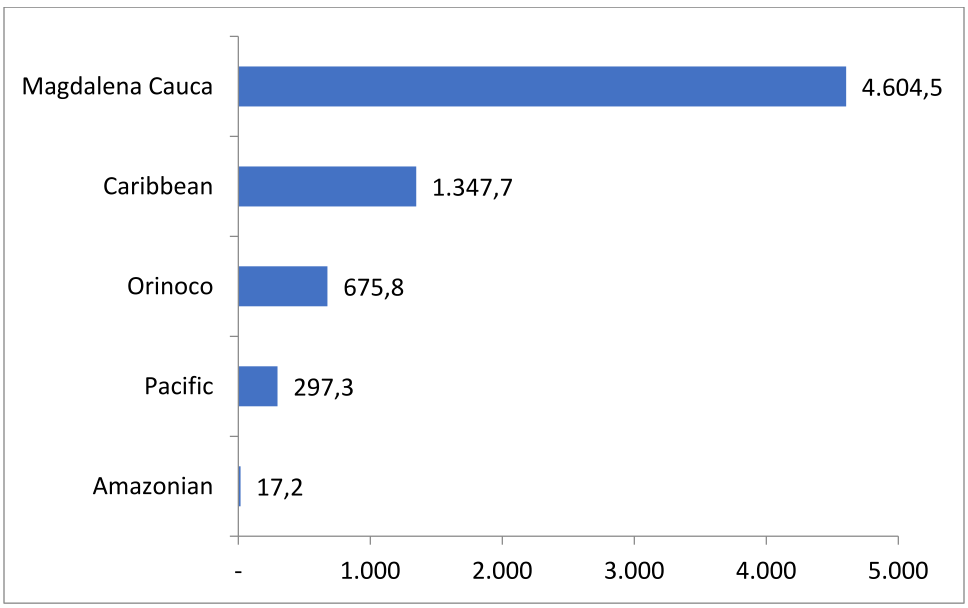


Figure 3. Blue water footprint of agriculture in Colombia's main hydrological areas (million m³/year)

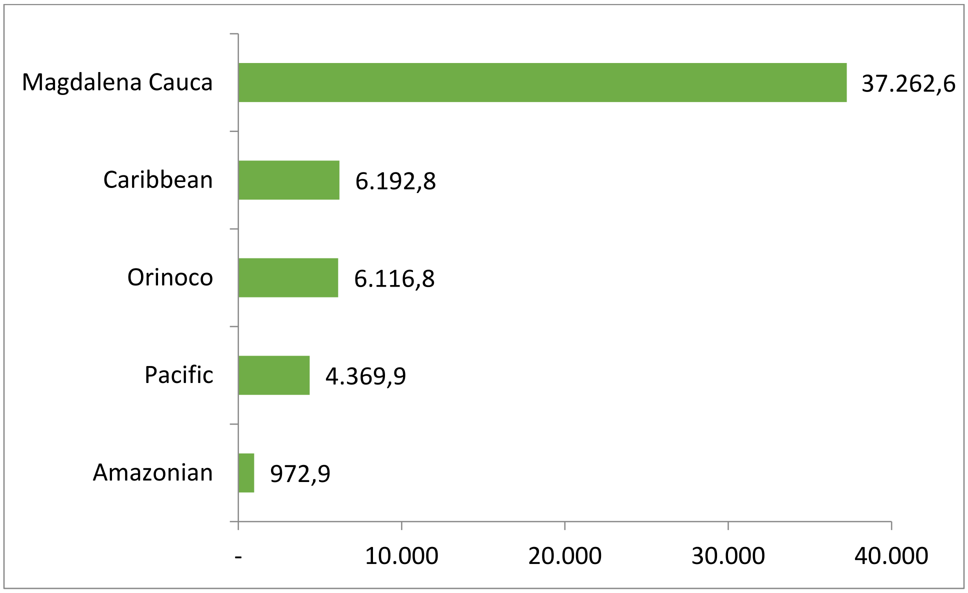


Figure 4. Green water footprint of agriculture in Colombia's main hydrological areas (million m^3/year)

The 5 SZH with the most contribution to the blue water footprint are Bogotá River, Santa Marta's Grand Swamp, the Direct Streams to the Caribbean, the Right Margin of the Dike's Canal, and the Ranchería River basins. The main crops are grass feeds and forage, except in Santa Marta's Grand Swamp SZH, near Cartagena City, where the perennial crops are more important. Perennial crops are also of importance in the Bogota River's SZH. The months with the highest BWF are January, July and August in the Bogota River SZH and in Santa Marta's Grand Swamp SZH, and from January to Mars in the other areas. The SZH with the highest BWF (Bogota River) represents 5% of the national BWF.

The 5 SZH with the highest contribution to the green water footprint are Lebrija River and other tributaries to the Magdalena River such as: Suárez River, La Vieja River, San Jorge La Mojana River and Negro River. Perennial crops are the most important. The highest GWF seasons vary considerably depending on the SZH. The SZH with the highest GWF represents 3% of national water footprint.

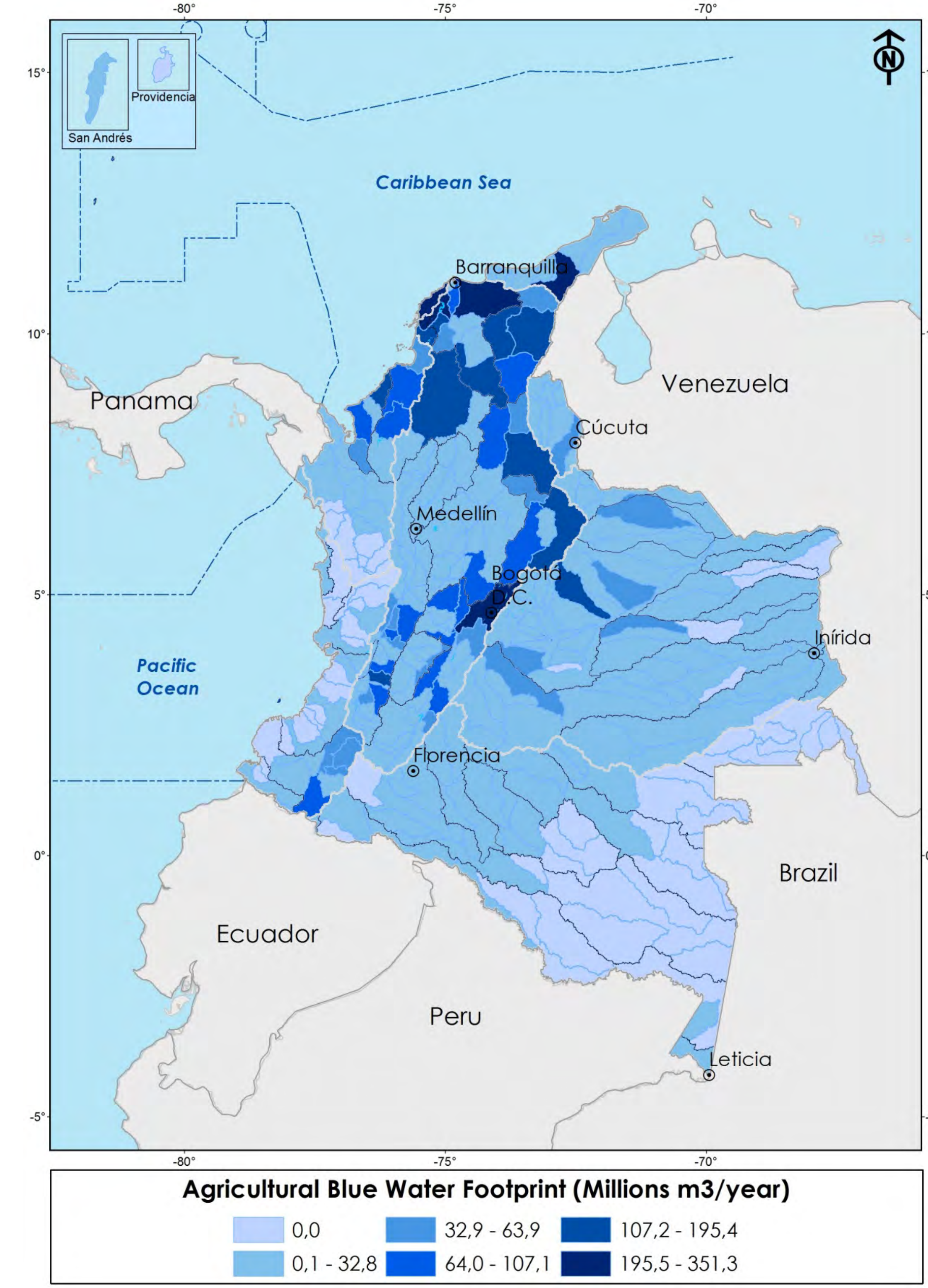


Figure 5. Annual spatial distribution of the Blue Water Footprint for Colombia's agricultural sector.

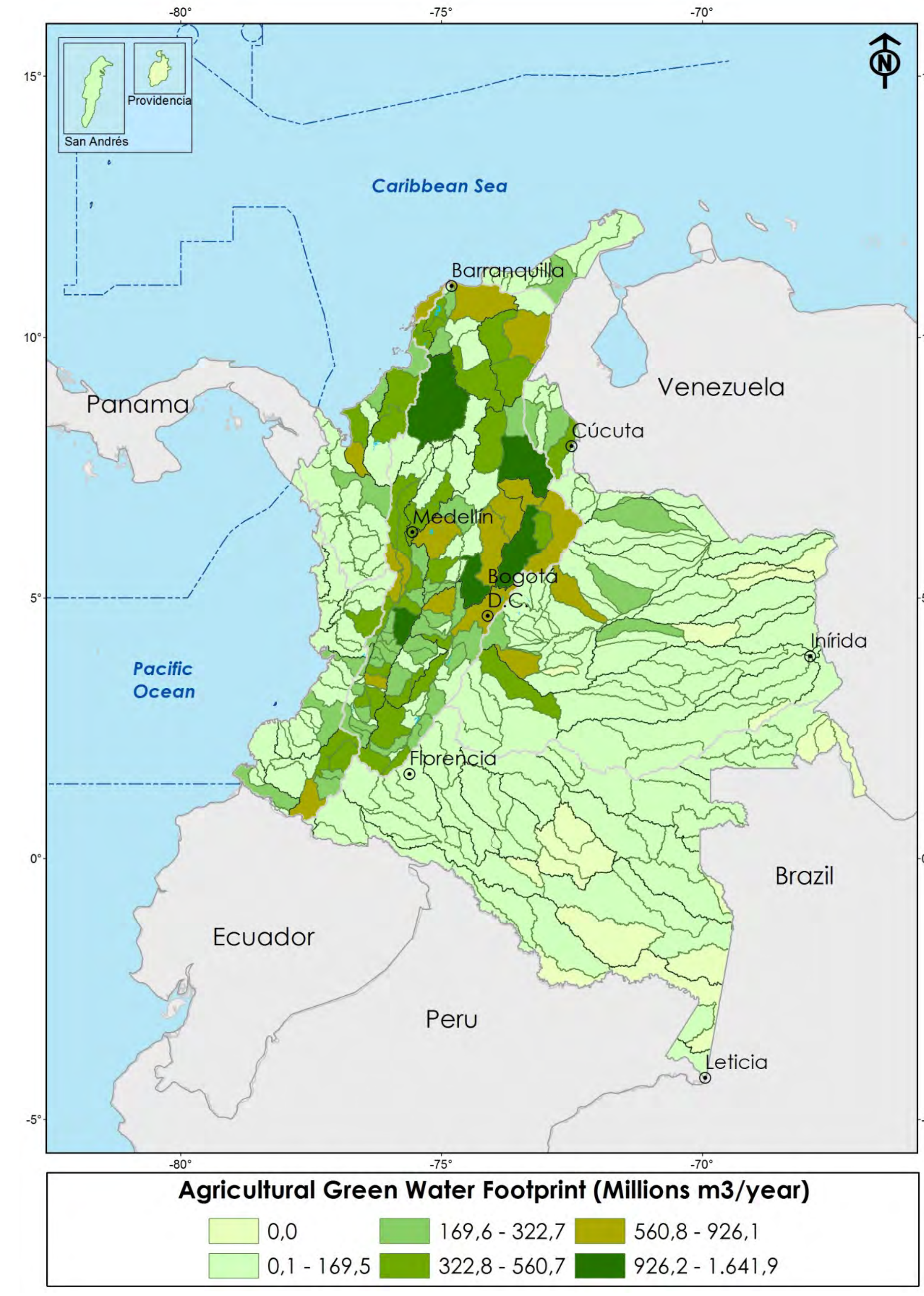


Figure 6. Annual spatial distribution of the Green Water Footprint for Colombia's agricultural sector.

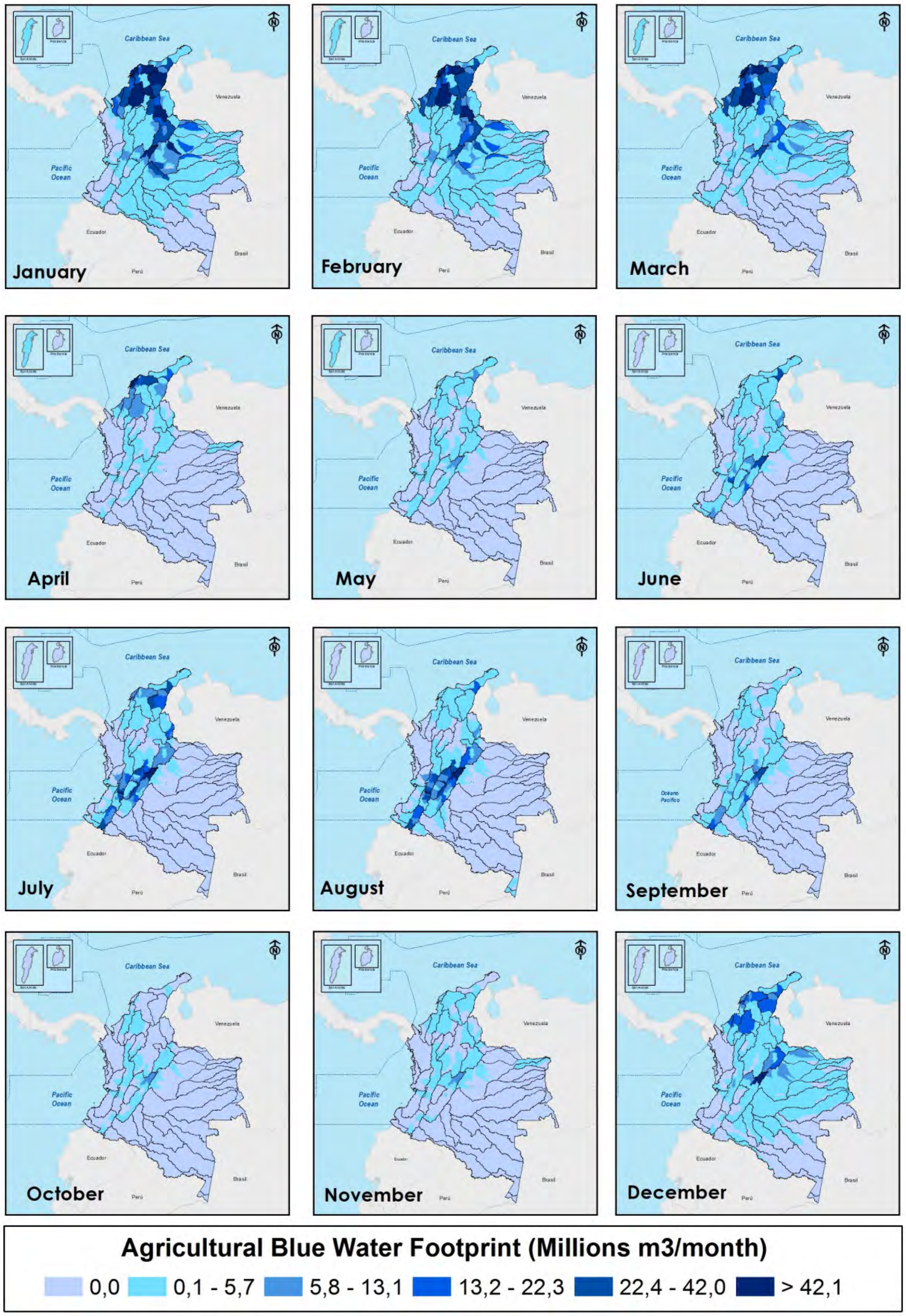


Figure 7. Monthly spatial distribution of the Blue Water Footprint for Colombia's agricultural sector.

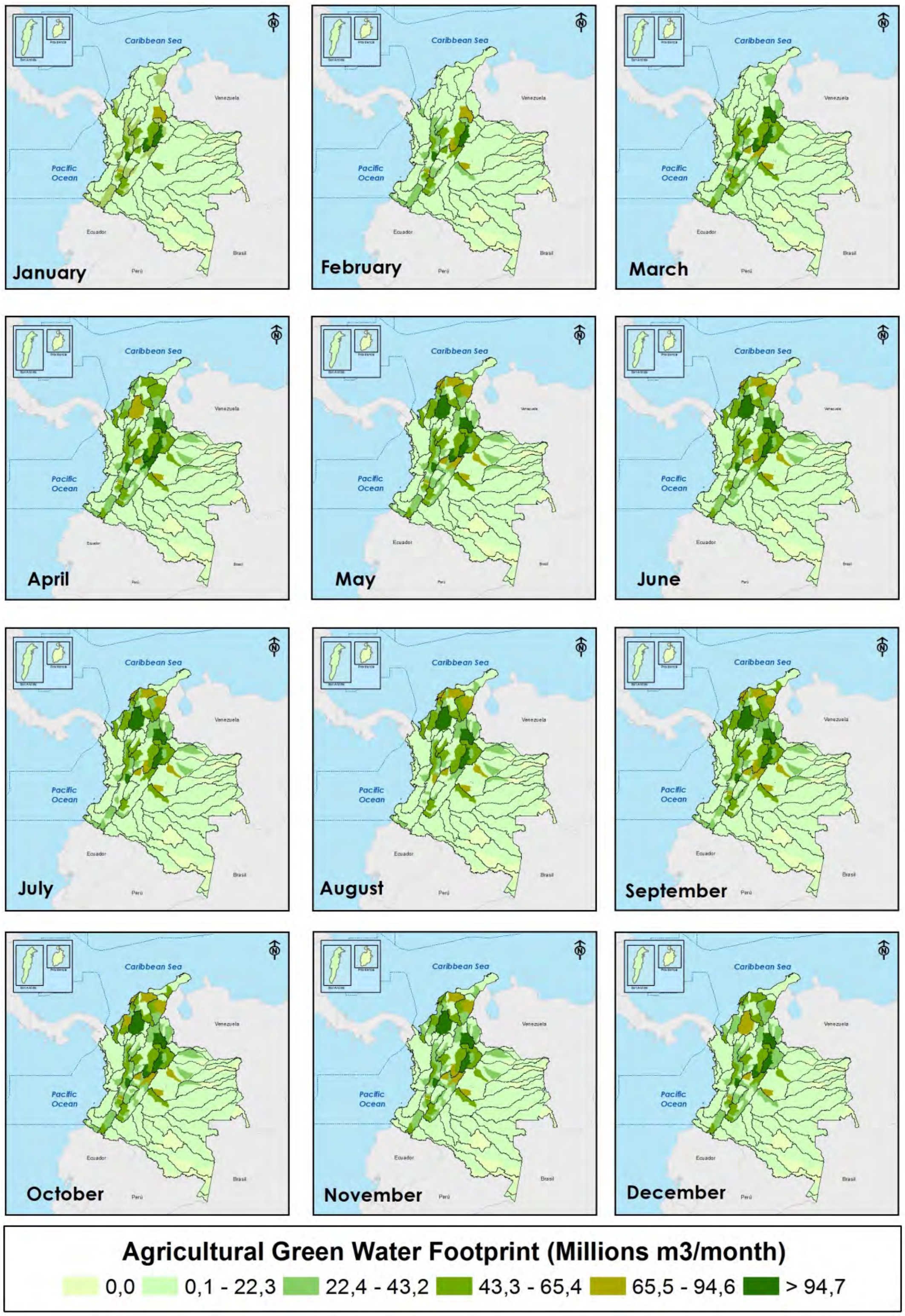


Figure 8. Monthly spatial distribution of the Green Water Footprint for Colombia's agricultural sector.

3.1.2 Blue and Green water footprint from the livestock sector

The livestock sector's GWF was obtained for grassland and pastures associated with rainfed extensive livestock farming, managed grassland, natural pastures and silvo-pastoral systems (**Figure 9**). The final GWF is 245.537 million m^3/year, approximately five times the GWF of the agricultural sector. This result for Colombia was expected, considering the fact that there are five million hectares dedicated to agriculture against almost forty million hectares of grassland and pastures.

Associating these results with the national cattle inventory, it is estimated that approximately 19,18 million hectares of pasture is enough to feed the total livestock heads reported in the year of 2012 in Colombia. The result is that 18 million hectares of grassland that could be susceptible to transform its use to agriculture.

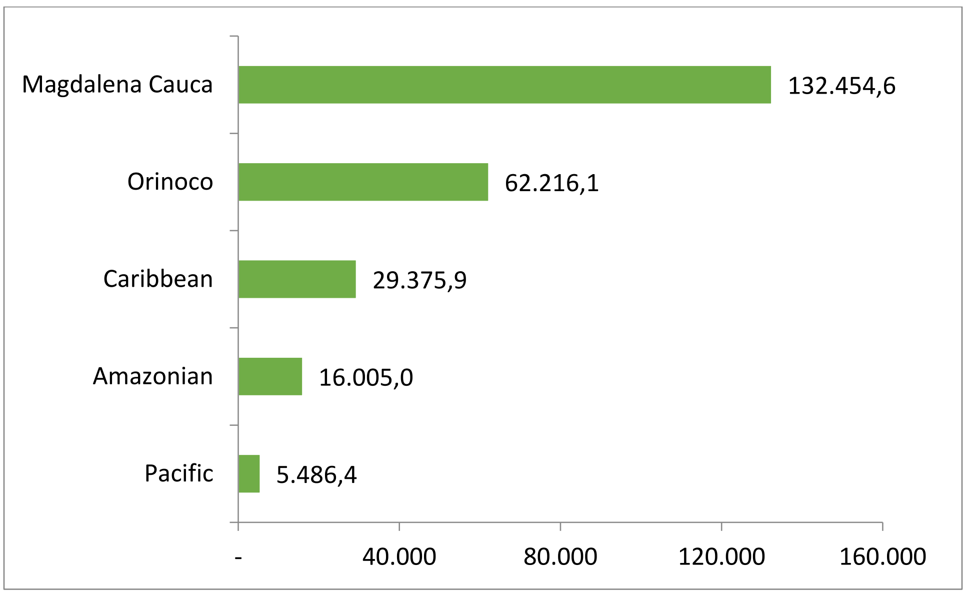


Figure 9. Green water footprint per hydrographic area for Colombia`s livestock sector (million m^3/year).

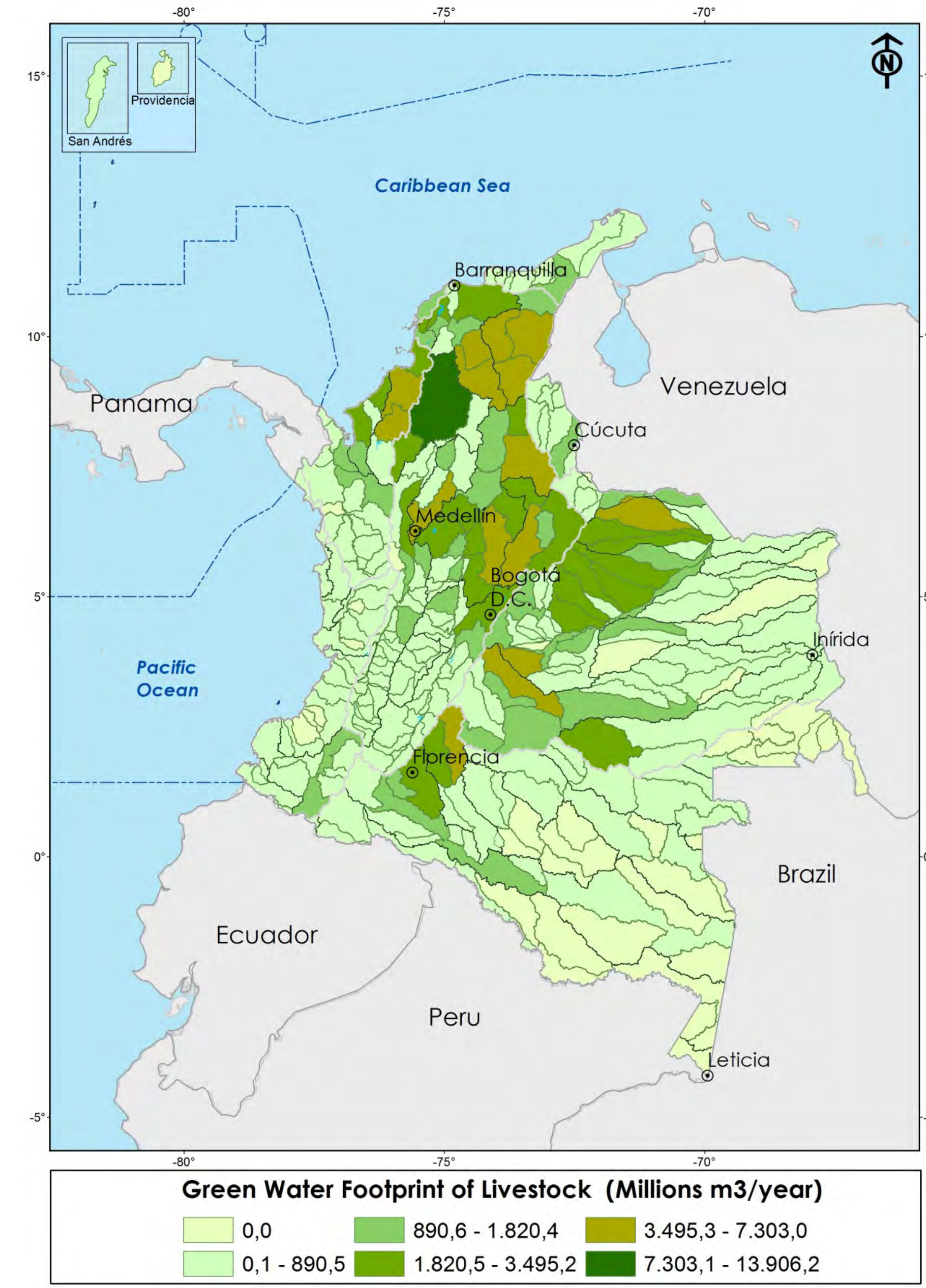


Figure 10. Annual spatial distribution of the Green Water Footprint for Colombia's livestock sector.

3.2 Blue Water Footprint results for the domestic component

For Colombia, a BWF of 385,8 million m³/year is reported. The SZH that report the highest BWF are Bogotá River and Porce River (**Table 1**). The most representative hydrographic areas are Magdalena-Cauca (72,4%) and the Caribbean (12,2%). The most important SZH in terms of hydrographic area reach between 17-22% of their respective area's BWF, except for Guatiquia River, which adds up to 30,6% of Orinoco's domestic BWF.

Table 1. Domestic blue water footprint for the 5 main hydrographic subzones.

SZH Code/ SZH Name	**Blue Water Footprint (**million m³/year**)**	**Percentage (%)**
2120 / Bogotá River	61,3	15,9
2701 / Porce River	28,6	7,4
2630 / Lili, Meléndez y Cañaveralejo Rivers	17,2	4,5
2319 / Lebrija River and others direct to the Magdalena	11,9	3,1
2502 / Bajo San Jorge La Mojana River	10,1	2,6

3.3 Blue Water Footprint results for the industrial sector

The industrial sector's BWF is 65,4 million m³/year. The SZH with the highest BWF are Arroyohondo River-Yumbo River (Code 2631) and Bogotá River (Code 2120). The two subzones together mount up to 15,9 million m³/year, which represents 24,4% of the estimated BWF for this sector. **Table 2** presents the BWF of the most representative economic activities nationwide. Almost all of these activities are located in the Magdalena-Cauca area (94,3% of the industrial sector's BWF) and a smaller amount in the Caribbean area (4,3%).

Table 2. Economic activities with higher industrial blue water footprint at national scale.

CIIU Code rev 4.0	**Activity description**	**Blue Water Footprint (**million m³/year**)**
1071	Sugar processing and refinement	22,7
1701	Pulp fabrication, celluloses; paper and carton	5,8
1089	Fabrication of other dietary products	4,4
1104	Non-alcoholic beverages development, mineral water production and other bottled beverages	4,4
1103	Malt production, beer production and other malted beverages	3,6

It is important to point out that the results underestimate the industrial sector's BWF. This situation occurs because the number of official records by which the calculation is made, it's of only 1.674 establishments, while DANE (National Administrative Department of Statistics) reports around 150.000 enterprises in Colombia. It is unknown if the enterprises taken into consideration for the calculation are the most representative of water consumption.

3.4 Blue Water Footprint results for the energy sector

40 dams have been identified in Colombia, 22 of which reportedly generate energy. The BWF of those 22 energy generating dams is 286,7 million m^3/year. The thermoelectric plant inventory indicates that in 2012 there were 35 stations which used mainly gas and coal as supply sources. These represented 97,5% of the thermoelectric plant's generation for the year of 2012. The BWF of the gas and coal thermoelectric plants is 10,7 million m^3/year.

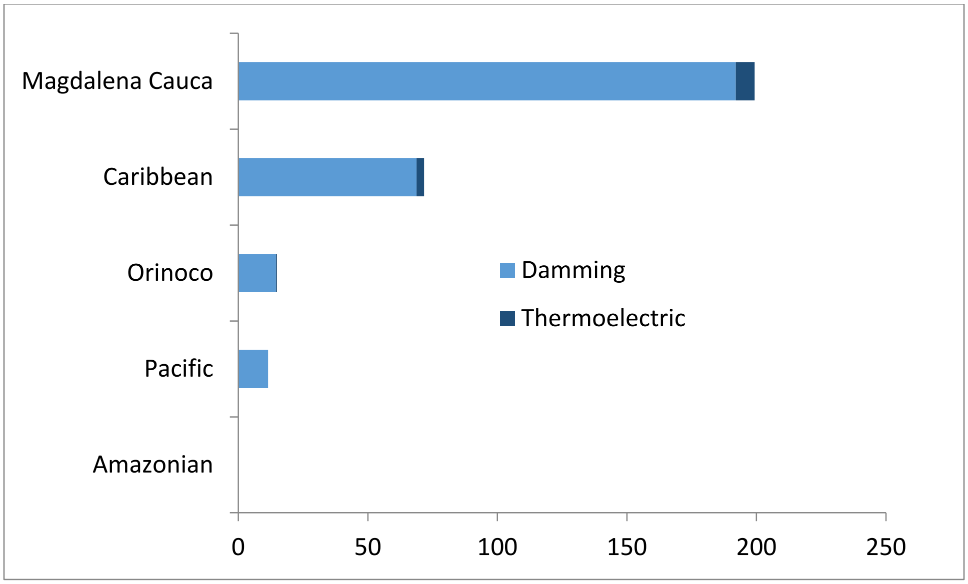


Figure 11. Blue water footprint of the energy sector.

3.5 Blue Water Footprint for the mining sector

The national BWF generated by oil extraction is 6,6 million m^3/year. Meta and Casanare, located in the Orinoco's hydrographic area, mount up to 4,4 million m^3/year and represent 66,6% of the national total. The BWF has been spatially distributed between 156 oil fields that make 64,7% of this sector's BWF (4,3 million m^3/year). **Table 3** presents the 5 SZH with the highest BWF.

Table 3. Blue water footprint of oil extraction in the main hydrographic subzones.

SZH	**Blue Water Footprint** (million m^3/year**)**
3301 / Alto Vichada	1.245.556,6
3501 / Metica River	446.777,7
3521 / Cravo Sur River	349.838,2
3519 / Cusiana River	230.820,6
3603 / Cravo Norte River	204.183,4

The total blue water footprint in a river basin is equal to the aggregate of all blue process water footprints within the river basin. In this case, the multisectoral blue water footprints correspond to the aggregate of the blue water footprint of: agriculture and livestock, domestic component and the industrial, energetic and mining sector. The spatial distribution of the multisectoral BWF is shown in Figure 12.

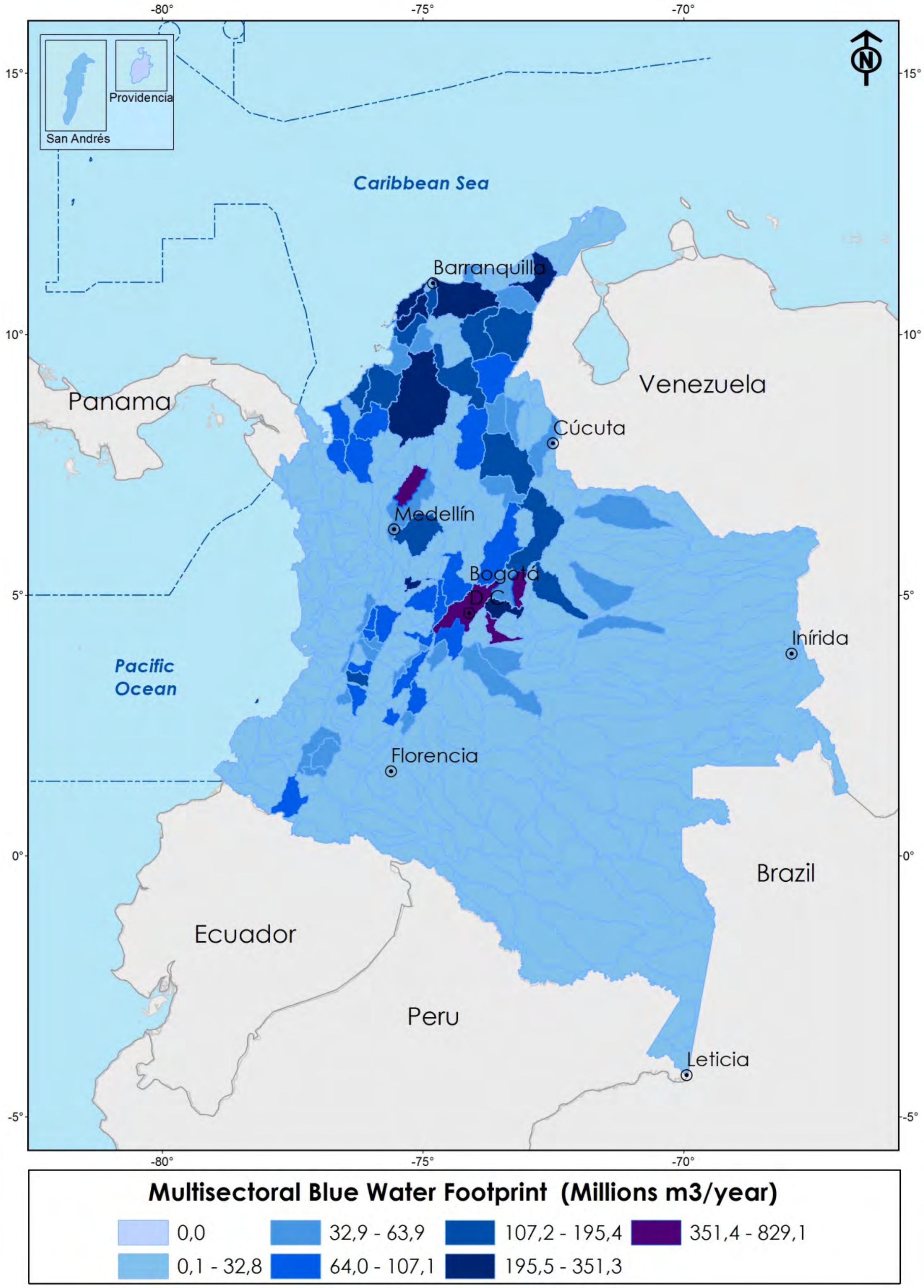


Figure 12. Spatial distribution of the multisectoral Blue Water Footprint in Colombia.

4. MULTISECTORAL WATER FOOTPRINT SUSTAINABILITY ASSESSMENT

4.1 Blue Water Footprint sustainability assessment in Colombia

The environmental BWF assessment of a river basin is based on the comparison between the multisectoral BWF and superficial water availability at basin level. For those SZH where the multisectoral BWF is higher than the superficial water availability (supply), a case of BWF unsustainability is identified. This means that superficial water supply does not satisfy the consumption of all sectors for those SZH analyzed.

4.1.1 Methodology

For the BWF sustainability assessment, annual values for the blue water availability and BWF have been determined.

Blue water availability	**Blue Water Footprint**	**Water not returned to basin Index (IARC) by hydrographic subzone**
The blue water availability is given by the Available Water Offer (OHD; by its Spanish acronym) in a typical Year, as defined in ENA 2014. The Available Water Offer is considers the environmental flow requirements and is estimated 1.126.905 million m^3/year.	The BWF has a multisectoral perspective. It includes the agriculture and livestock sectors, the domestic component, and the industrial, energetic and oil extraction sectors, and it also consider the water transfers between the SZH. The national total multisectoral BWF is 9.956.8 million m^3/year.	Equation 1 $IARC = \frac{\sum BWF}{OHD}$ IARC: Water not returned to basin Index (SZH) $\sum BWF$: Multisectoral BWF inside the SZH in a period of time "t", in volume/time. OHD: The blue water availability in the SZH in a period of time "t", in volume/time.

The categories' ranges vary from *Critical* state for values higher than 1. *Very high* for values within 0,5 and 1; *High* for values within 0,1 and 0,5; *Moderate* for values within 0,1 and 0,2; *Low* and *Very Low* for values inferior to 0,1. In such cases, it is considered a favorable situation in terms of blue water supply/demand.

4.1.2 Results

The IARC results (Table 4 and Figure 13) show 4 SZH that present values superior to 1, which means that in those territories there is limited blue water availability and the multisectoral BWF yields a result superior to the water offer.

Table 4. Hydrographic subzones with IARC in a Critical state.

SZH	SZH Name	Hydrographic Areas	Water not returned to basin Index (IARC)
1206	Streams Direct to the Caribbean	Caribbean	1,05
2903	Right margin of the Dike’s canal	Magdalena - Cauca	1,38
2904	Direct streams to Bajo Magdalena between Calamar river’s mouth to the Caribbean sea	Magdalena – Cauca	1,31
2909	Mallorquín Swamp	Magdalena - Cauca	1,54

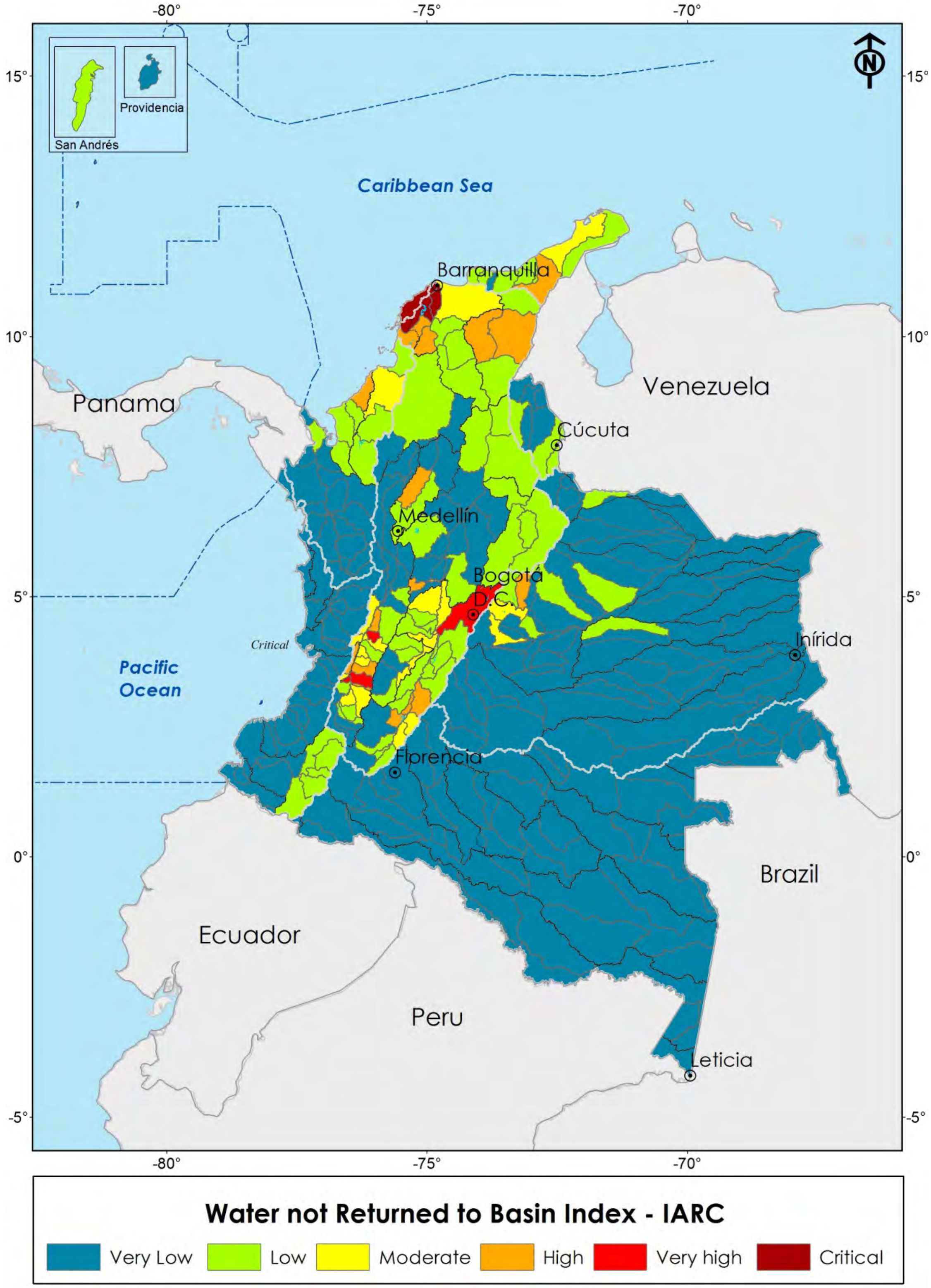


Figure 13. Water not returned to basin Index (IARC) for Colombia's hydrographic subzones.

4.2 The Green Water Footprint sustainability assessment in Colombia

The GWF sustainability assessment of a river basin is based on the comparison between the multisectoral GWF and the Green Water Availability (DAV; by its Spanish acronym) at river basin level. If the consumption is higher than what it has been determined as available for human use or for the same SZH, it is declared that this water footprint is not sustainable. The basic premise states that not all the existing green water in a determined area is available for productive uses since a portion of it should be saved for the environment and another portion cannot be productive because of physical reasons such as topography or urban settlements.

4.2.1 Methodology

To establish the GWF sustainability assessment, annual values of DAV and GWF are determined for 311 continental SZH in Colombia through the Water Pressure to the Ecosystems Index.

Green Water Availability (DAV)	**Green Water Footprint (multisectoral GWF)**	**Water Pressure to the Ecosystems Index (IPHE)**
Equation 14 Monthly DAV = Total ET – Natural ET – Non-productive ET Where: DAV: Green water availability per SZH Total ET: Total green evapotranspiration inside the SZH Natural ET: Reserved evapotranspiration for the environment – equivalent to the protected area's annual ET. Non-productive ET: Soil's evapotranspiration that cannot be made productive for reasons such as topography, human settlements and other intervened areas.	The GWF has a multisectoral perspective that includes the sectors that consume green water such as the agricultural and livestock sectors. Colombia's total multisectoral GWF is 300.451.51 million m^3/year	Equation 15 $IPHE = \frac{\sum GWF}{DAV}$ $IPHE$: Water Pressure to the Ecosystems Index $\sum GWF$: Multisectoral GWF inside the SZH in a period of time "t", in volume/time. DAV: Green water availability in a SZH in a period of time "t", in volume/time.

The 1:100.000 land cover map was used, adapted for Colombia following the Corine Land Cover methodology (IDEAM, 2010). The map was reclassified in accordance to three categories of interest: productive, natural and intervened areas. Colombia's protected areas were identified through the Cartographic Boundaries Map for Colombia's Moorland Complex (Research Institute of biological resources Alexander von Humboldt and the Department of Environment and

Sustainable Development, 2012),and through the areas in the National Natural Parks System, among them, Colombia's National Natural Parks (Colombia's National Natural Parks 2013) and the Civil Society's Natural Reserves (Colombia's National Natural Parks, 2014).

17.167.378 hectares in total are protected, 15,1% of Colombian territory. It is assumed, for this analysis, that in a SZH the areas that should be protected are determined in advance in order to maintain the SZH's environmental sustainability. The evapotranspiration has been obtained through the Annual Real Evapotranspiration Map, estimated with the Budyko method and distributed geographically nationwide (IDEAM, 2014).

The categories ranges vary from *Critical* state for values higher than 1,0 which shows that there is a clear competition for green water between the land use linked to the agriculture and livestock sectors and the protected areas associated with strategic ecosystems at the basins; *Very high* for values between 0,08 and 1,0; *High* for values between 0,5 and 0,8; *Moderate* for values between 0,3 and 0,5; *Low* for IPHE between 0,1 and 0,3 and *Very Low* for values inferior to 0,1.

4.2.2 Results

The total green water available in the country is 1.221.345,9 million m³/year, which corresponds to 38,7% of precipitation. It can be observed that, at SZH level, the DAV varies from 0 to 28.764,3 million m³/year. The IPHE's calculation (**Table 5** and **Figure 14**) evince that 22 SZH are in *Critical* state. This means that the SZH does not have available water because it is located in a protected zone and, nevertheless, it presents GWF greater than cero or, because although the DAV is higher than 0, it is very limited and is surpassed by the GWF. Additionally, there are 22 SZH that present *Very High* IPHE, 61 SZH with *High* value and 47 SZH with *Moderate* value. 38 SZH are on the *Low* value and 119 *Very Low*.

Table 5. Hydrographic subzones with *Critical* IPHE

SZH	Hydrographic Subzone	Hydrographic Area	IPHE
3501	Metica River (Guamal-Humadea)	Orinoco	1,77
4505	Luisa River	Amazonian	1,47
2634	Cali River	Magdalena Cauca	1,44
2405	Sogamoso River	Magdalena Cauca	1,34
2314	Opón River	Magdalena Cauca	1,26
2903	Right margin of the Dike's canal	Magdalena Cauca	1,22
1204	Canalete River and other Streams direct to the Caribbean	Caribbean	1,21
2613	Otún River and other Streams direct to the Cauca	Magdalena Cauca	1,21
2303	Streams direct to the Magdalena between Ríos Seco and Negro	Magdalena Cauca	1,20
1303	Bajo Sinú River	Caribbean	1,19
1206	Streams direct to the Caribbean	Caribbean	1,18
2637	Las Cañas, Los Micos and Obando Rivers	Magdalena Cauca	1,16

2120	Bogotá River	Magdalena Cauca	1,14
2607	Guachal River (Bolo-Fraile and Párraga)	Magdalena Cauca	1,13
2904	Streams direct to the Magdalena between Calamar and the river's mouth to the Caribbean sea	Magdalena Cauca	1,10
2609	Amaime and Cerrito Rivers	Magdalena Cauca	1,09
2615	Chinchiná Rivers	Magdalena Cauca	1,07
1116	Tolo Rivers and other streams direct to the Caribbean	Caribbean	1,07
2601	Alto Cauca River	Magdalena Cauca	1,04
2632	Guabas, Sabaletas and Sonso Rivers	Magdalena Cauca	1,04
2612	La Vieja River	Magdalena Cauca	1,02
5310	Anchicayá River	Pacific	1,00

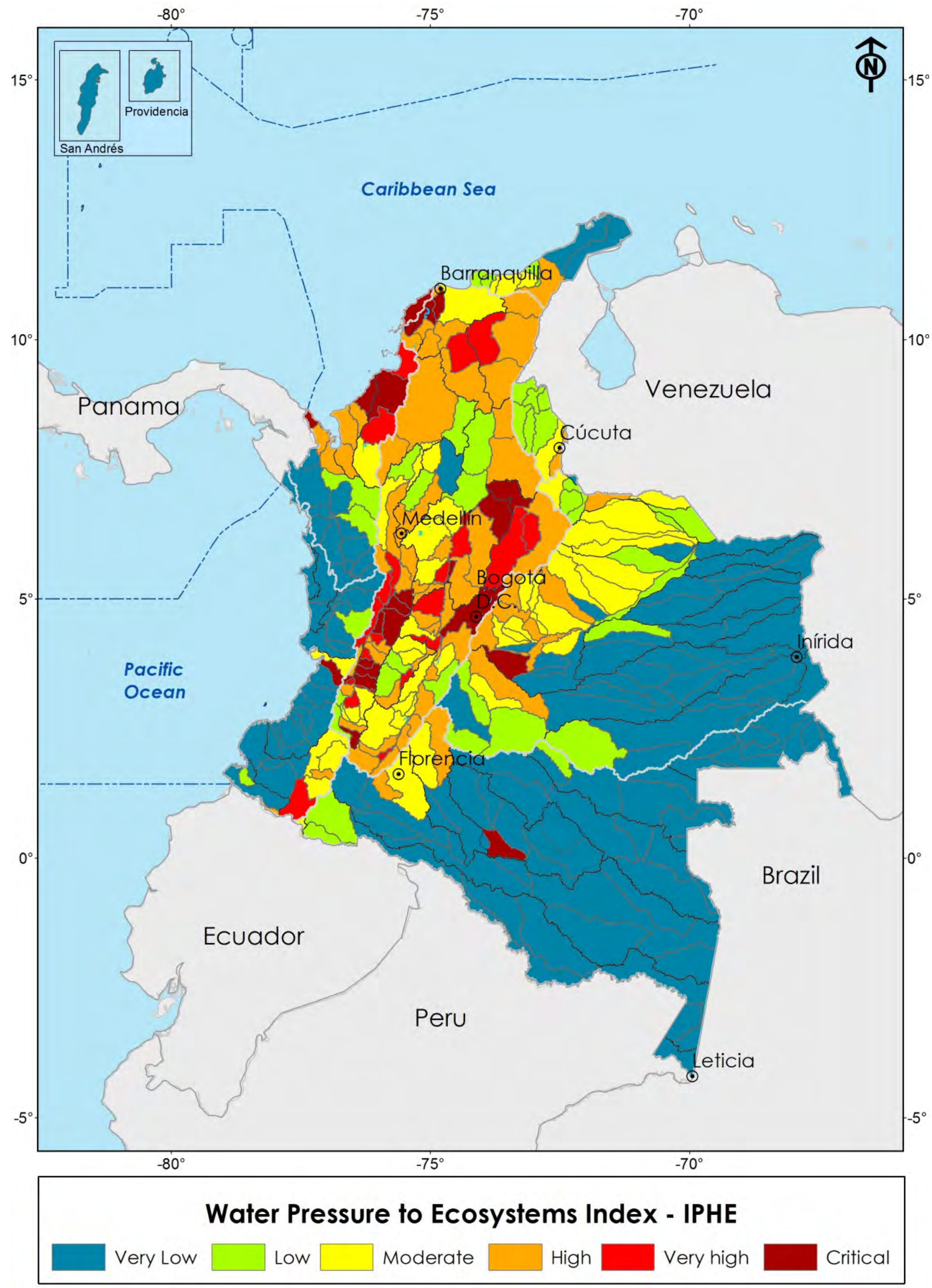


Figure 14. Water Pressure to Ecosystems Index (IPHE) for 311 hydrographic subzones in Colombia.

5. Agriculture Water Footprint Projections for the Period 2012-2022

Projections of water demand for the different economic sectors were made within the framework of 2010 National Water Study. The objective was to measure the impacts that in the future could occur in terms of water availability. This chapter contains the Water Footprint projection calculations for the agricultural sector, taking 2012 as the base year and the year 2022 as a horizon. The projections were specifically for 12 types of crops that concentrate approximately 85 % of Colombia's cultivated area.

The water footprint projections were done based on the formulation and calculation of a systems dynamics model, produced with the *VENSIM* software. The results show a fast growth of oil palm cultivation, reaching around 3 million hectares in 2022, while coffee barely duplicates its area for that same year. In addition to this, a significant growth of sugar cane is observed, triplicating its area in that period. Sugar cane and palm crops increase because demand and production of biofuels continue to growing up and also due to favorable public policies to this kind of crops.

In 2022, the participation of each of these crops changes in relation to what was found in 2012. According to the projection, oil palm will be the dominant crop with 33,3% of the projected area. Coffee follows with 21,2%, then sugar cane with 16,3%, cocoa 8,2%. It is worth highlighting the fact that the most representative crops in 2022 correspond with the crops for which the highest amount of incentive policies was found. This dynamic is in line with the revision of current policies that hold oil palm as the most benefited crop, followed by coffee, sugar cane, rice and cacao. **Figure 15** shows the projected hectares for each crop from 2013 to 2022.

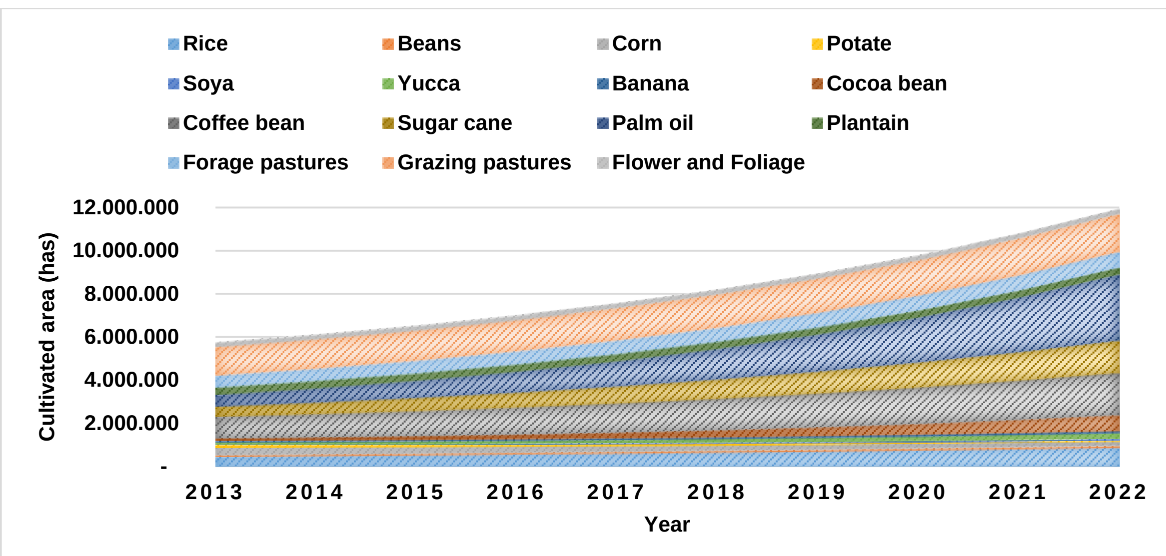


Figure 15. Projected areas (hectares) from 2013 to 2022 for 12 crops.

Taking the agricultural sector's water footprint methodology and results as a base line, an estimation of the water footprint corresponding to each of the 12 crops for the period 2012-2022 was made, in terms of the sown areas for each year. **Figures 16** and **17** show the blue and green water footprints for each crop from 2013 to 2022.

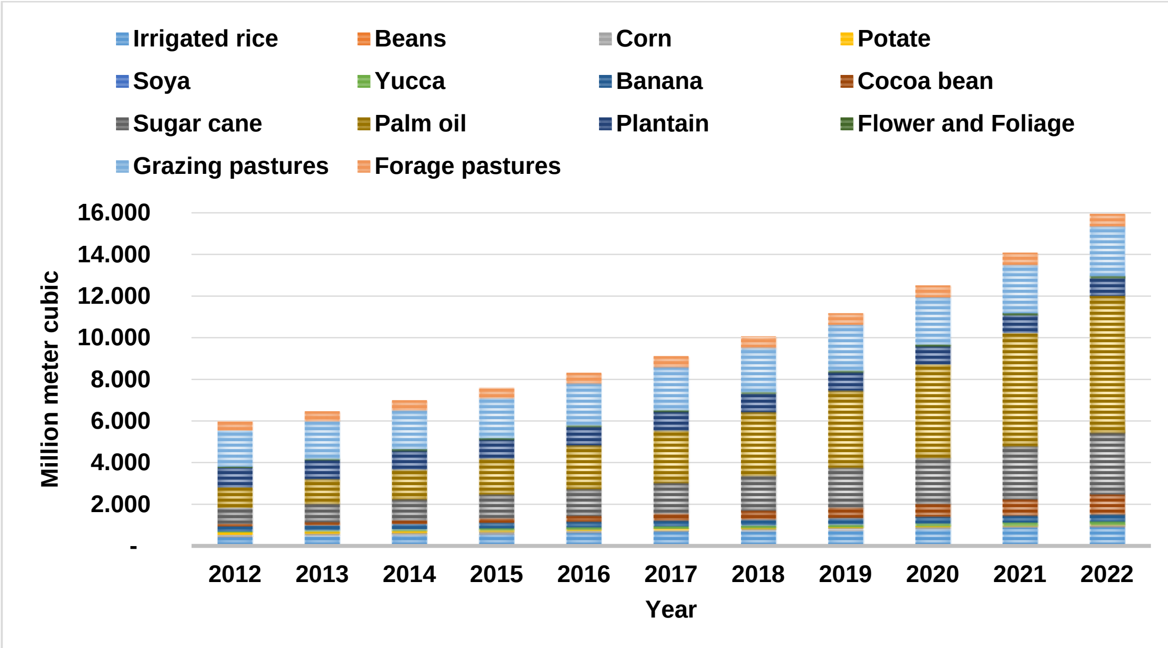


Figure 16. Projected blue water footprint from 2013 to 2022 for 12 crops.

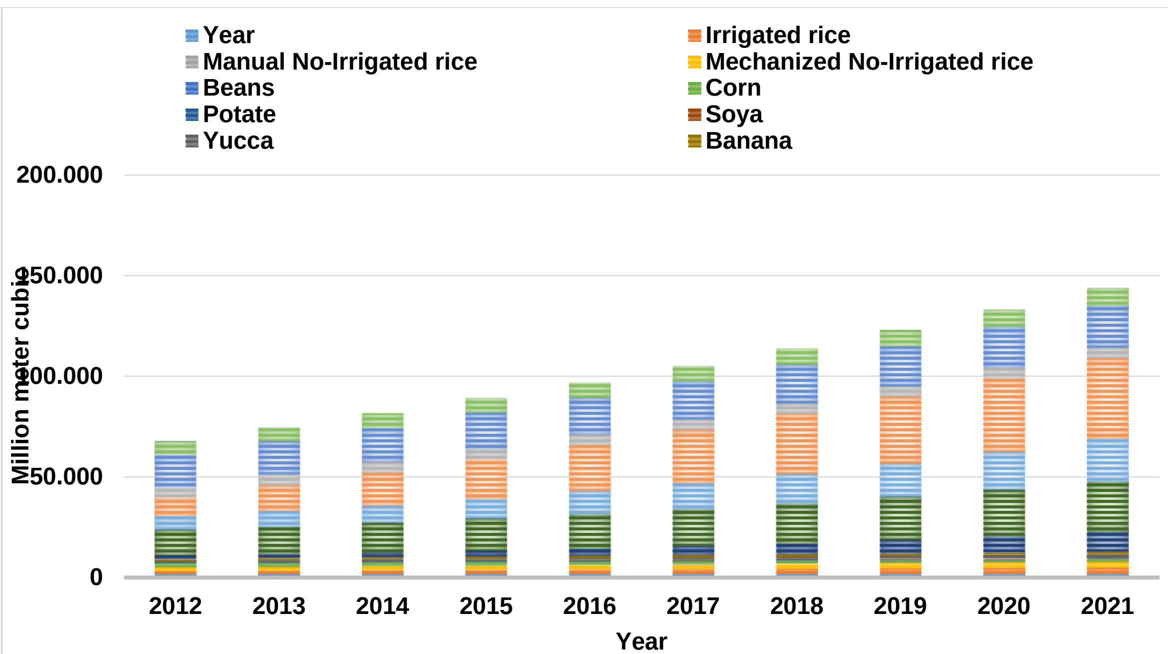


Figure 17. Projected green water footprint from 2013 to 2022 for 12 crops.

Regarding Annual crops, a water footprint decrease can be seen in crops such as corn and potato, while irrigated rice doubles its value and the highest increase comes from soy and yucca. These results are directly influenced by how the cultivated areas behave each year.

As far as the water footprint's projection for perennial crops, a general increase is observed, except for plantain; however, oil palm and sugar cane stand out from the rest in part because their expected growth is much higher, partly because of favorable conditions from the political and economic domains.

In respect to agricultural pastures, there is neither evidence of potential growth of sown areas nor of a water footprint that differs from the growth tendency reported by the Department of Agriculture and Rural Development.

6. Analysis of Virtual Water Flows for the Agricultural Sector, Period 2012-2022

Virtual water flows represent the green and blue water footprints contained in export products. In order to calculate them it is necessary to establish the water footprint value per unit of product, its production volume and the respective export level.

6.1 Virtual water flow analysis for 2012

Colombia's opportunity costs of water use for agricultural purposes is lower than in other regions of the planet, where a larger volume of blue water is required to produce the same goods (Asia, for example). This represents a comparative advantage for Colombia in the production of agricultural goods in terms of the efficient use of the water resources and of the costs associated with the construction of irrigational infrastructure destined to the production of these same goods.

The calculations of virtual water flows for 2012 show that Colombia, with its exports of palm oil, sugar, banana, coffee, cocoa, flowers and plantain, follows the South American tendency to export mainly green water (Suweis *et. Al.*, 2011), which, by 2012 represented for Colombia 92% of the virtual water flows exported (see **Figure 18**). This shows that the product with the most volume of green water is palm oil with about 735 million m^3/year, followed by sugar cane with 214 million m^3/year and banana with 144 million m^3/year.

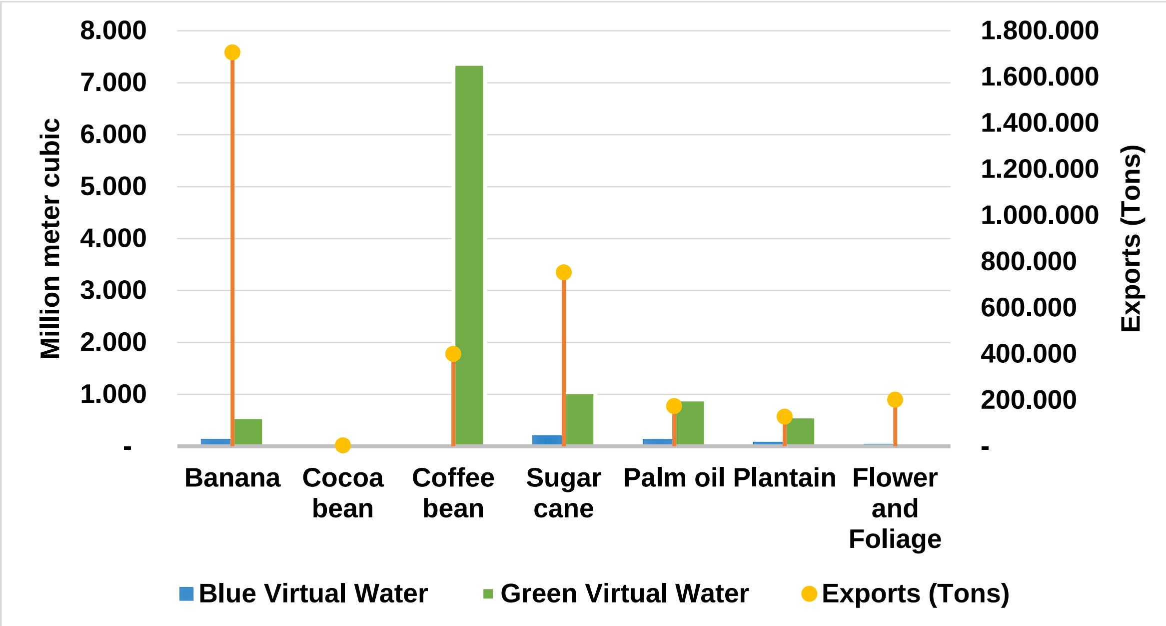
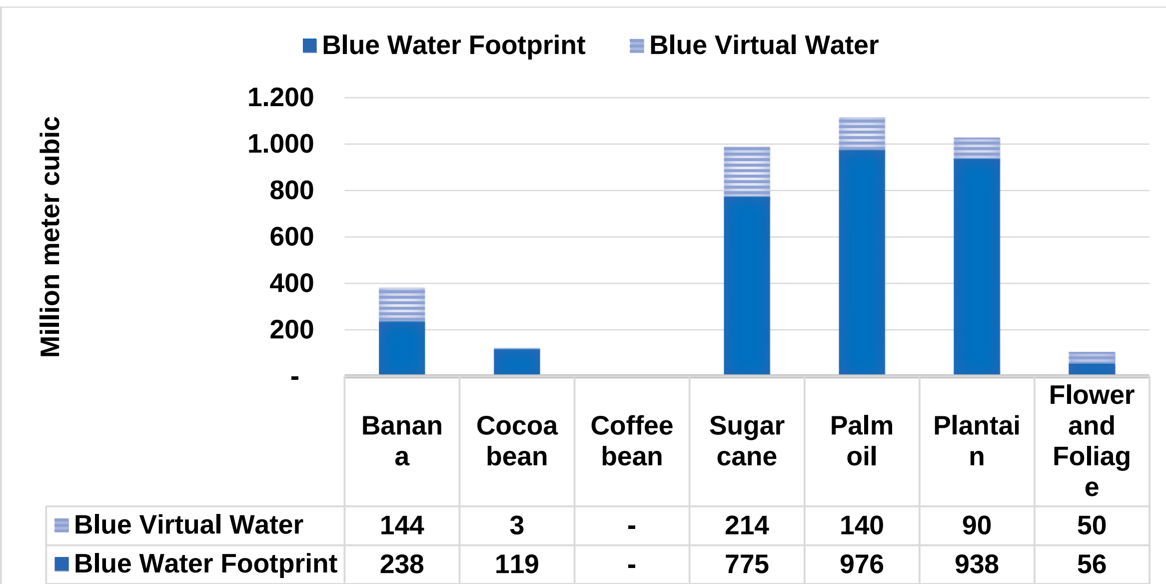


Figure 18. Green and blue virtual water and export volumes for banana, cocoa, coffee, sugar, palm oil, flowers and plantain for 2012.



	Banana	Cocoa bean	Coffee bean	Sugar cane	Palm oil	Plantain	Flower and Foliage
Blue Virtual Water	144	3	-	214	140	90	50
Blue Water Footprint	238	119	-	775	976	938	56

Figure 19. Blue water footprint and blue virtual water for banana, cocoa, coffee, sugar, palm oil, flowers and plantain for 2012.

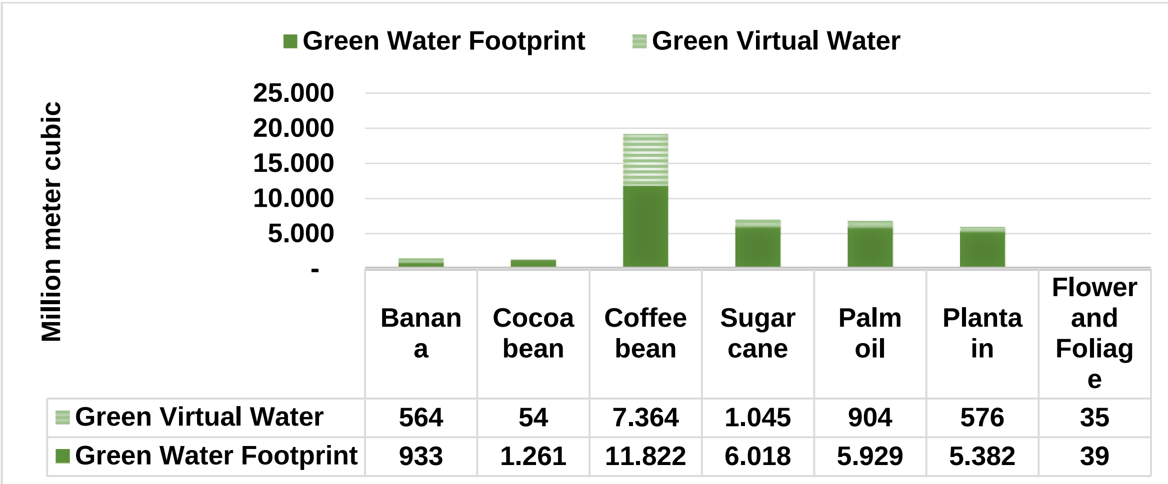


Figure 20. Green water footprint and green virtual water for banana, cocoa, coffee, sugar, palm oil, flowers and plantain for 2012.

6.1.1 Blue and green virtual water analysis by hydrographic area and by product

Table 6 shows the green and blue virtual water associated with each crop, distributed by hydrographic area. Note that 62% of the total blue virtual water, as well as 68% of the total green virtual water, consumed for the production and export of banana, , coffee, cocoa, sugar, palm oil, plantain and flowers, is extracted from the Magdalena-Cauca hydrographic area.

Table 6. Blue virtual water by hydrographic area and by crop[7]

Hydrographic Area/Crop	Caribbean	Magdalena-Cauca	Orinoco	Pacific	Total Blue Water Footprint (Million meter cubic)
Banana	73,7	70,4	-	-	144,1
Cocoa bean	0,1	0,6	1,9	-	2,7
Sugar cane	-	213,9	-	0,5	214,3
Palm oil	1,0	425,2	309,1	-	735,2
Plantain	90,0	0,1	-	-	90,1
Flower and Foliage	0,1	49,9	0,4	0,1	50,4

Tabla 7. Green virtual water by hydrographic area and by crop

Hydrographic Area/Crop	Amazonian	Caribbean	Magdalena-Cauca	Orinoco	Pacific	Total Green Water Footprint (Million

[7] There is no data reported regarding Amazonias's hydrographic area. There is also no data regarding blue virtual water for coffee since its blue water footprint is zero.

						meter cubic)
Banana	-	475,3	89	-	-	564,3
Cocoa bean	-	5,3	26,9	10,5	11	53,6
Coffee bean	22,3	242,1	6480,5	22	596,9	7.363,8
Sugar cane	-	-	1042,4	-	2,4	1.044,8
Palm oil	-	259,1	2047,7	2337,4	111,3	4.755,6
Plantain	-	517,6	58,3	-	-	575,8
Flower and Foliage	-	0,2	34,5	0,6	0,2	35,3

7. Key Results

- Colombia's National Development Plan (2014 - 2018) marks deforestation as one of the main threats to the country's environmental sustainability and green growth. The analysis of green water scarcities (IPHE in ENA 2014) incorporates a new argument for defining strategic conservation areas for water risks mitigation.

- Green water is included for the first time in the national water accounting. 97% of the total water footprint corresponds to the agricultural sector (including livestock) in the form of green water footprint.

- The analysis of the green water footprint and its sustainability points to conflicts between land use for the agricultural sector and land use for ecosystem conservation, and the analysis is useful to evaluate the local situation and to identify potential risks related with provision of ecosystem services essential for life and development.

- Blue and green virtual water flows of main export crops show the comparative advantages of Colombia's agriculture, since it is based 90% on green water. Sustainable agriculture in the country is a way of contributing to cover the world's growing food demand.

- The free trade agreements and the internal demand of biofuels, driven by the current local economic policy, promote the agroindustry of sugar cane, palm oil and cocoa, among others. These drivers, based on growth projections for the year 2022, will translate into impacts on local water resources as well as conflicting land use.

- Water quality is a challenge for the country; the situation demands improved monitoring and control, free access to information and investment decisions for treatment and pollution reduction.

8. Recommendations

- Promote mechanisms to increase green water productivity (produce more in less area) and optimize the use of blue water (produce more with less water), both have to be addressed within the context of the existing National Policy for Integrated Water Resources Management.

- Review policies of economic incentives for bioefuel crops (palm and sugar cane) and define a limit of growth for these sectors based on the requirements for other uses (balance: water for people, water for development and water for the ecosystems).

- Many river basins in Colombia do not have any protected areas or ecosystem services protection schemes, in order to ensure water supply. It is urgent to define these areas and effective conservation schemes.

- The analysis of virtual water in export products allows to visualize the regional and local impacts of the corresponding water consumption. Guidelines and control mechanisms for efficient water use and conservation are needed.

- Based on the results obtained in this study, new possibilities on how the Water Footprint Assessment can be used emerge:
    - Support agricultural planning processes that incorporate water resources. For example, the agricultural land division in the context of post-conflict agricultural programs.
    - Design of economic tools for conservation (Water Funds, Payment for Environmental Services);
    - Contribution to land planning and river basin management by providing uses and availability.

- The water footprint of the environmental sector and the agriculture and livestock sectors has been included in the National Water Study as a possibility of improving its joint vision of sustainability in the country's territory. Also, as an opportunity to enhance multisectoral cooperation in terms of planning and managing river basins.

- By including water footprint, public institutions in charge of generating guidelines for the regulation and management of river basins receive additional tools to undertake the analysis of territorial issues as well as indicators that complement their work.

Further information:

- www.goodstuffinternational.com
- www.ideam.gov.co
- www.suizaguacolombia.net
- www.cta.org.co

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