International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 3 Mar 2022, pp: 640-652 www.ijaem.net ISSN: 2395-5252

Total Water Footprint: An Analysis of the Level of Environmental Sustainability in the Taperoá River Sub-basin Located in the State of Paraíba, Brazil

Allan Sarmento Vieira[1]*, Stephano B. L. Cavalcante Moreira[2], Lunara Raquel Paz Silva[3], Isabel Lausanne Fontgalland[4]

[1]*PhD. and professor of University Federal of Campina Grande, Brazil.*
[2]*Graduate of University Federal of Campina Grande, Paraíba, Brazil.*
[3]*Graduate Student of University Federal of Campina Grande, Paraíba, Brazil.*
[4]*PhD. and professor of University Federal of Campina Grande, Brazil.*

Submitted: 10-03-2022 Revised: 21-03-2022 Accepted: 23-03-2022

ABSTRACT: The present research had as main objective to analyze the level of environmental sustainability in the sub-basin of the Taperoá River, located in the semi-arid region of Paraiba. In this perspective, it is necessary to calculate the total water footprint considering the blue, green and gray components of the main water using sectors. The model used to calculate this multidimensional indicator in a given region is described in the Water Footprint Manual. According to the results, it was evident that irrigated agriculture and sanitation are the sectors that exert the greatest pressure on the water resources of the sub-basin studied. Furthermore, the environmental sustainability of the water footprint in the sub-basin for the year 2019 presented favorable levels on an annual scale, but between the months of May and November, the sub-basin presented unsustainable scarcity and pollution indices, due to the decrease in natural flows, caused mainly by the irregularity of rainfall in the region. Therefore, the mapping of the water footprint and its sustainability in the sub-basin of the Taperoá River -PB, may subsidize the public manager in an accurate decision-making and consequently promote the strengthening of the Water Resources Management System that seeks sustainable governance.

KEYWORDS: Water resources, Footprint, Sustainability.

I. INTRODUCTION

Water scarcity is a growing concern, and has been calling for a thorough analyzis, with accurate indicators that draw the map of water scarcity in the world. Hoekstra et al (2012) analysed water consumption in 405 river basins around the world found that water scarcity affects approximately a population of 2.7 billion at least one month each year. This research was the first study in the world to assess water scarcity on a monthly scale at the watershed level.

Thus, in addition to this projection, the constant conflict for this resource is pertinent, making it clear the need to reduce the levels of water scarcity, with the use of efficient technologies, and that consequently promotes the rational use of this strategic resource for society (LIMA, 2014).

According to Hoekstra et. al (2011), the water footprint can be considered a comprehensive indicator that considers the traditional measure of appropriation, as well as the levels of scarcity, i.e., a measure indicator of anthropic pressure on water resources, which considers the water that cannot be seen, called virtual water, which is used in the production of goods and services in a watershed. This concept of virtual water was introduced by Allan (1998) when he wanted to analyze the possibility of importing virtual water to minimize the problems of water scarcity in the middle east.

Cirne and Vieira (2019) analyzed the total water footprint in an ice cream industry located in the hinterland of Paraiba and observed based on the results that the water footprint of the product had a significant variation when there was a change in the type of input in the ice cream recipe. Therefore, an alternative for the analyzed industry would be to adopt inputs that require little water in its production process.

For Palhares et al (2021) the water footprint of a beef production system considering the individual impact of each animal and feed management should consider that the generation of information on the water footprint in beef cattle production can make the product more efficient, when considering water consumption, and can add value since it directly impacts the present and future sustainability.

Albuquerque (2013) defines the three basic components used in the determination of the water footprint in a given entity and by type of uses, they are: the blue footprint that is defined as the consumed volumes of freshwater taken from rivers and lakes; the green footprint that corresponds to the volumes of water resulting from the soil water balance; and the gray footprint that considers the volumes of effluents (domestic and industrial sewage, among others) from human activities.

As can be observed, the water footprint can be calculated for a product, a production process and for a geographic region, which is the case of this research. Thus, the main objective of this work is to analyze the level of environmental sustainability of the Taperoá River sub-basin, located in the semi-arid region of Paraiba, considering the total water footprint.

II. MATERIALS AND METHODS

The present work can be classified as exploratory and descriptive. It involves bibliographical research. In the development of the research, the hypothetical-deductive method was chosen. This option is justified because the chosen method allows the proposition of a hypothesis and deduction to prove or disprove it.

The approach of this research is qualitative-quantitative, in which when developing his study, the researcher can use both, enjoying, on one hand, the advantage of being able to explain all the steps of the research and, on the other hand, the opportunity to prevent the interference of his subjectivity in the conclusions obtained. The instruments used to understand and evaluate the water footprint and its sustainability are: articles, books, websites, documents such as the Paraíba State Plan on Water Resources (PERH-PB, 2007), among others.

To put into action the objective of this research, a bibliographic and exploratory research was initially made to understand the concepts of the water footprint and raise the main available methods that allow knowing the level of sustainability of the Taperoá River Sub-basin in the State of Paraíba.

Thus, we started from the premise of the following hypothesis: "Can the water footprint determine the degree of water scarcity and consequently know the level of sustainability of the Taperoá River Sub-basin/ PB?

Characterization of the studied area

The Paraíba Basin is the second largest in the State of Paraíba, covering 38% of its territory, and is therefore one of the most important in the Northeastern, semi-arid region. From this perspective, according to the PERH-PB (2007), in view of the large scale of its coverage and for the purposes of analysis and administration, the basin was divided into a sub-basin of the Taperoá River and three hydrographic regions (upper, middle and lower Paraíba).

Thus, the universe of this study refers to the sub-basin of the Taperoá River, which has an area of 5,666.38 km2, between latitudes 6°51'47" - 7°34'33" South and longitudes 36°00'10" - 37°14'00" West of Greenwich. In which, according to AESA (2019) and Lima, Silva and Duarte (2017) 26 municipalities are included, with total or partial coverage. Furthermore, in accordance with Lima, Silva and Duarte (2017) in the premise of Koeppen's climate classification it has a hot semi-arid climate, with average annual rainfall ranging from 400 to 600 mm and with a dry season of 8 to 10 months.

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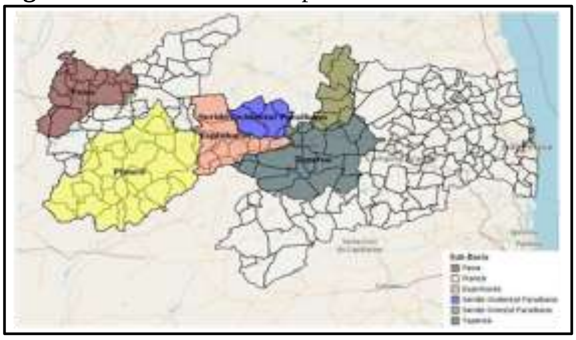
Volume 4, Issue 3 Mar 2022, pp: 640-652 www.ijaem.net ISSN: 2395-5252

Figure 1: Location of the Taperoá Riversub-basin/PB.



Source: SIG WEB / AESA (2019).

The evaporation obtained from the Class A tank, whose variation in the year 2019 was 119.4 mm/month to 250.53 mm/month (BRITO, 2019). In addition, corroborating the data, Lopes (2008) describes an average of 1,787.83 mm year-1, therefore, it shows a very high value, responsible for significant water losses in the dams.Moreover, the population of the sub-basin, with possession of the water resource, uses it for human and animal supply; agriculture of leakage, which manifests itself on the banks of the reservoirs, when there is a lowering of the water level; fruit farming and irrigation, located in the alluvial soil formed on the banks of streams.

Total Water Footprint Model

The total water footprint of the Taperoá River sub-basin in the year 2019 was calculated based on the main water uses, considering the main sectors: urban and rural supply, sanitation, agriculture and livestock. The total water footprint of the analyzed sub-basin is calculated by adding the water footprints (blue, green and gray) of each sector, according to Equation 1 below:

$$PHtotal = PHa + PHi + PHp + PHs \qquad (1)$$

where:PHtotal – Total water footprint (m³/year); PHa – Urban and rural supply water footprint (m³/year); PHi – Irrigated agriculture water footprint (m³/year); PHp – livestock water footprint (m³/year); and PHs – Sanitation water footprint (m³/year);

In order to estimate the individual water footprint of the sectors, which is fundamental for the total calculation, it was necessary at first to collect specific data for each sector. In the supply sector, only the blue component was considered, referring to the stages of water collection, treatment, reservation and distribution, carried out to supply the direct consumption needs of the inhabitants of the municipalities located in the sub-basin. For this, the volume of blue water for this sector was obtained according to PAB (2014), which is equated by the relationship between the total population supplied (POP), the average per capita water consumption (q), and the distribution loss index (IP), according to Equation 2:

$$PHa_{blue} = q*POP*(1+IP) \qquad (2)$$

where:PHa_{blue} – Blue supply water footprint (m³/year);

The data regarding the population supplied in 2019 in the 26 municipalities with headquarters in the sub-basin were collected through the IBGE-WEBSITE (2020). The average water consumption in the sub-basin and the average index of losses by distribution were obtained through the Sanitation Information System (SNIS-WEBSITE,2019).

In addition, the volume of blue water referring to rainwater harvesting by cisterns was also considered in this sector, as recommended by the Water Footprint Assessment Manual. For this, the calculation involved the quantity of cisterns in the sub-basin in 2019 and the respective average storage capacities provided by the Articulação do SemiáridoBrasileiro (ASA, 2019) database.

In the sanitation sector, to calculate the volume of untreated sewage that is discharged into rivers, the value of per capita water consumption of the municipality and the percentage of the population that is not served by the sanitary sewage network were used. The total gray water footprint (PHs_{gray}) of sanitation was given by the untreated pollutant load (Lntrat) divided by the difference between the maximum allowable concentration (Cmax) and the average natural concentration of the selected pollutant (Cnat) (HOEKSTRA et al., 2011), according to Equation 3:

$$PHs_{gray} = \frac{Lntrat}{Cmax - Cnat} \qquad (3)$$

where:PHs_{gray} – Gray sanitation water footprint (m³/year);

In irrigated agriculture, the green and blue components were evaluated so that they correspond to the total water that undergoes evapotranspiration (from fields and crops). The gray water footprint was not considered in irrigated agriculture, since no reports were found on the use of fertilizers or pesticides on crop development. For the calculation, the temporary and permanent crops grown in the municipalities of the sub-basin in 2019 were considered, as well as their respective planted areas collected through the Municipal Agricultural Production made available by the IBGE System of Automatic Recovery (SIDRA-WEBSITE, 2019). As such, the green water evapotranspiration (ETgreen), that is, the rainwater evapotranspiration, is defined, by the Food and Agriculture Organization (FAO) model, as the minimum value between the total crop evapotranspiration (ETc) and the effective precipitation (Pefet) (HOEKSTRA et al., 2011), demonstrated in Equation 4.

$$ET_{green} = \min(ET_c, P_{efet}) \qquad (4)$$

In another twist, the blue water evapotranspiration (ETblue), or the evapotranspiration from irrigated water in the field, is equal to the total crop evapotranspiration (ETc) minus the effective precipitation (Pefet), and will equal zero when it exceeds the crop evapotranspiration, according to Equation 5:

$$ET_{blue} = \max(ET_c, P_{efet}) \qquad (5)$$

The ETc according to Hoekstra et al. (2011) can be calculated using the method proposed by the United States Department of Agriculture Soil Conservation Service (USDA SCS), as laid out in Equation 6:

$$ET_c = K_c * ET_o \qquad (6)$$

where:K_c – Crop coefficient; ET_o – Reference evapotranspiration.
For the Pefet Hoekstra et. al (2011) apud FAO (1998) recommends that it is estimated by the relationship between the precipitation in month t in perimeter k, in the region to be irrigated, according to Equations 7 and 8.

$$P_{efet.kt} = (0{,}8 \text{ x } P_{kt}) - 25, \text{ se } P_{kt} \geq 75\text{mm} \qquad (7)$$
or
$$P_{efet.kt} = (0{,}6 \text{ x } P_{kt}) - 10, \text{ se } P_{kt} < 75\text{mm} \qquad (8)$$

In the livestock sector, we considered the blue component referring to the direct consumption of water for animal watering and the green component related to feeding by grazing and specific feed. The grey water footprintwas not considered in livestock farming because no reports were found on the use of fertilizers or pesticides in the development of corn and sorghum, the basis of silage consumed by animals. To this end, PHp_{blue} in livestock was estimated based on information on the number of heads per animal category (nº) of the municipalities based in the sub-basin in 2019 and the average water consumption per animal (CA) in Equation 9:

$$PHp_{blue} = n^o * CA \qquad (9)$$

where:PHp_{blue} – Blue livestock water footprint (m³/year);

Furthermore, the sustainability of the water footprint within a river basin can be analyzed from three perspectives: environmental, social and economic. To understand the meaning of the magnitude of the water footprint it is necessary to compare it with the available water resources, so the assessment of the sustainability of the water footprint in this research is made according to water demand, water availability and the natural water flows of the region. Environmental sustainability, adopted for this study, requires that water quality remains within pre-defined standards and that quantity respects minimum environmental flow.

The assessment of the sustainability of the Blue Water Footprint was carried out through the indicators of water scarcity (Blue Water Footprint). In which according to Hoekstra et al. (2011) in a basin x is defined by the ratio between the sum of the total blue water footprints in the basin (∑ PHblue) and the blue water availability (DAblue), in Equation 10:

$$EA_{blue}[x\,,t] = \frac{\sum PH_{blue}[x\,,t]}{DA_{blue}[x\,,t]} \qquad (10)$$

To this end, the blue water availability (DA_{blue}) in a basin x at a given period t is defined as the natural runoff in the basin (Qnat) minus the environmental flow demand (ESD). The blue water footprint will exceed the blue water availability in a given period and in a given basin when the environmental flow demand is violated. According to Hoekstra et al. (2011) blue scarcity is time dependent, so monthly measurement is usually sufficient and more technically interesting to know the variation over the year.

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The analysis of the sustainability of PHgreen was defined through the green water scarcity indicator (EAgreen). According to Hoekstra et al. (2011) the green EA in a basin x in a period t is defined as the ratio between the total green water footprint in the basin (∑ PHgreen) and the green water availability (DAgreen), according to Equation 11:

$$EA_{green}[x\ ,\ t] = \frac{\sum PH_{green}[x\ ,\ t]}{DA_{green}[x\ ,\ t]} \qquad (11)$$

Regarding green water availability (DAgreen), this is defined by Hoekstra et al. (2011) as the total rainwater evapotranspiration (ETgreen) minus the sum of evapotranspiration reserved for natural vegetation (ETa) and evapotranspiration from non-productive areas (ETid), according to Equation 12:

$$DA_{green}[x,t]=ET_{green}[x,t] - ET_{a}[x,t] - ET_{id}[x,t] \quad (12)$$

In calculating the availability of DAgreen the average monthly evapotranspiration's were adopted, as well as the unproductive and preserved areas defined by the PDRH-PB (2001), through the mapping of land use and occupation.
To evaluate the sustainability of the Grey Water Footprint, the indicator used was the level of water pollution (NPA). For this purpose, NPA is defined as the consumed fraction of the effluent assimilation capacity and calculated by the ratio of the total gray water footprint (∑ PHgray) to the actual runoff from a basin (Qreal) (HOEKSTRA et al., 2011), as per Equation 13:

$$NPA[x\ ,\ t] = \frac{\sum PH_{gray}[x\ ,\ t]}{Q_{real}[x\ ,\ t]} \qquad (13)$$

This level of pollution in a watershed, in a given period, can be defined as the ratio between the natural flow (Qn), minus its environmental flow demand, which in this case was considered the Q90%, which is flow with 90% guarantee.

III. RESULTS AND DISCUSSION

It is important to emphasize that all the data collected and sourced in the methodology have been used in the above-mentioned equations, which culminated in the following results.

Estimation of the water footprint in human supply

The Water Footprint of human supply was taken into account in the urban and rural set, using only the blue component. Therefore, in the aegis of the data, made available on official websites, mentioned above, it was possible to estimate the blue water footprint consumed by the supply sector, as can be seen in Table 1.

Table 1: Blue water footprint in supply.

Population Served	**Average per capita water consumption (liter/inhabitant.day)**
630,401	115.3
Distribution loss index (%)	**Blue water footprint (m^3/year)**
7%	36,346,252

Source: Adapted from IBGE-WEBSITE and SNIS-WEBSITE; Data obtained for 2019.

Correspondingly, it is current to mention that the average per capita consumption is the average daily per individual of the volumes of water used to satisfy domestic, commercial, public and industrial consumption.

Thus, as the distribution loss rate has been mitigated with the aim of incorporating the water that is lost along the destruction network before reaching the establishments. Therefore, the blue water footprint of the supply in the sub-basin of the Taperoá river, which corresponds to the sum of the 27 municipalities integrating the basin, is 36,346,252 m^3/year.

In compliance with the Manual of Water Footprint Assessment, the volume of rainwater captured by the cisterns, which is used primarily for human consumption, were considered as elementary blue water for the sector under discussion. For this, data provided by the ASA technologies map (2019) was used, as noted in the diction of Table 2.

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Table 2: Blue water footprint of cistern supply.

Plate Cistern		Slab Cistern		Slurry Cistern		Trench Cistern		Blue Water Footprint (m3/year)
Q* unit	**C** liter**	**Q* unit**	**C** liter**	**Q* unit**	**C** liter**	**Q* unit**	**C** liter**	
12636	16,000	1197	52,000	817	52,000	173	50,000	301,644

Source:*Quantity; **Capacity; Database of Articulation Semiarid Brazil (2019)

Thus, the blue water footprint for cisterns accounted for 301,644 m^3 for the year 2019 in the sub-basin. Likewise, the total blue water volume in the supply sector totaled 36,647,896 m^3 in the year 2019.

Water footprint estimation in sanitation

In the sanitation sector the water footprint study involves only the gray component, since it is understood as the collection and treatment of domestic sewage from the municipalities that discharge tributaries into the sub-basin under discussion, as shown in Table 3 below. In this way, in compliance with Equation 3, it was possible to obtain Table 3, the natural concentration of biochemical oxygen demand (Kg/m³) was considered equal to zero.

Table 1: Blue water footprint in supply.

Untreated effluent (Kg/ano)	Lntrar(Kg/ano)
630,401	115.3
C_{max} DBO (Kg/m^3)	**Gray water footprint (m³/year)**
7%	36,346,252

Source: Adapted from Hoekstra et al. (2011) and CONAMA 357/05; Data obtained for 2019.

Thus, the Gray Water Footprint, which corresponds to the volume of water needed to dilute the pollution generated by the municipalities of the Taperoá River sub-basin, totaled 912,576,387 m^3 in the year 2019. In analysis, it should be noted that this value corresponds to the annual volume in m3 necessary to dilute all the organic matter produced and discharged in the sub-basin during the year under study, so that the water remains within the pre-established standards for human consumption.

Estimation of the Water Footprint in irrigated agriculture

In the agricultural sector, the green and blue components were considered, since agricultural crops intercept rainwater and absorb it through their roots, besides demanding water for irrigation. Therefore, the estimates of PHigreen and PHiblue in agricultural activity were obtained by calculating the water demand of temporary and permanent crops grown in the municipalities of the region studied, which related the green evapotranspiration and blue evapotranspiration.

Total crop evapotranspiration and effective precipitation were calculated by the methodology proposed by FAO and recommended by the Water Footprint Assessment Manual. For this, the calculation also involved the monthly crop coefficients (Kc) (Table 4), the monthly average evaporation (Table 5) and the monthly average precipitation (Table 6).

Table 4: Crop coefficient

Crops	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mango	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Guava	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Banana	1	1	1	1	1	1	1	1	1	1	1	1
Rice (s – es)	0	1.05	1.2	1.2	0	0	0	1.05	1.2	1.2	0	0
Potato (s – es)	0	0.5	0.8	1.2	0.75	0	0	0.5	0.8	1.2	0.75	0
Cassava (s – es)	0	0.4	0.98	0.69	0	0	0	0.4	0.98	0.69	0	0

Maize (s – es)	0	0.7	1.1	0.95	0.95	0	0	0.7	1.1	0.95	0.95	0
Sugarcane (s – es)	0	0.4	1.25	1.25	0.75	0	0	0.4	1.25	1.25	0.75	0
Beans	0.7	1.1	0.9	0	0	0	0	0.7	1.1	0.9	0	0
Fava Beans	0.7	1.1	0.9	0	0	0	0	0.7	1.1	0.9	0	0
Watermelon (s – es)	0	0	0	0.67	0.91	0.98	0.82	0	0.67	0.91	0.98	0.82
Sisal	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Avocado	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Tomato (s – es)	0	0.5	0.6	1.15	0.8	0	0	0.5	0.6	1.15	0.8	0

Source: Adapted from Municipal agricultural production (IBGE-WEBSITE), where s - harvest; es - off-season and Aspersion and drip, GOMES (1999).

The Table 5 presents the monthly average evaporation values for the São João do Cariri station, which includes the Taperoá II, Mucutu, Serra Branca II, Soledade and Boqueirão reservoirs. In another twist, it should be noted that the monthly volume of water evaporated in the reservoirs was obtained from the multiplication of the area of the water mirror by the blade evaporated in evaporimetric tanks Class A, being adopted the monthly values of the coefficient of the tank Kt estimated for the region of Caririparaibano (BRITO 2019).

Table 5: Average monthly evaporation at São JoãodoCariri station (mm).

Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**
228.54	202.38	200.12	174.24	153.57	119.4
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
128,84	159,6	197,16	250,53	238,64	238

Source: adapted Brito (2019).

Table 6 presents the 30-year average monthly precipitation, valid for the year 2019, collected at the climatological post of São João do Cariri, made available by AESA (2019).

Table 6: Average monthly precipitation at the São José doCariri post for 30 years (mm).

Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**
25.8	54	90.4	81.2	48.1	31
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
22.8	6.2	1.8	5.3	6.2	12

Source: adapted Brito (2019).

With the green ET defined, the volume of green water allocated to agriculture could be estimated, however, as the green water footprint is the volume of rainwater that is stored in the soil, the planted area of each crop during the year 2019 was considered. The results of the green footprint for the different crops considered in the agricultural plan can be seen through Table 7 below.

Therefore, the total Green Water Footprint in irrigated agriculture was obtained by the sum of all water volume absorbed by the crops in the region in the year 2019, totaling the value of 44,454,369 m^3.

In another twist, after the diagnosis of the green component in irrigated agriculture, it is possible to estimate the blue component destined for the sector under analysis. For this, the calculation of the blue Water Footprint of agriculture, also, the numeric of the area destined to planting in the year 2019 of each type of crop found in the sub-basin was used. Table 8 below shows the results of blue water consumption in irrigated agriculture for the different crops considered in the agricultural plan.

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Table 7: Green water footprint of irrigated agriculture.

Crops	Planted area (m^2)	ET_{green}(m/year)	Green water footprint (m^3/year)
Mango	490,000	0.13	65,435
Guava	400,000	0.13	53,416
Banana	330,000	0.13	44,068
Rice (s – es)	30,000	0.10	3,018
Potato (s – es)	2,210,000	0.12	264,007
Cassava (s – es)	1,400,000	0.10	140,840
Maize (s – es)	207,200,000	0.12	24,752,112
Sugarcane (s – es)	70,000	0.12	8,362
Beans	179,760,000	0.07	11,885,731
Fava Beans	13,960,000	0.07	923,035
Watermelon (s – es)	50,000	0.06	2,917
Sisal	46,330,000	0.13	6,186,908
Avocado	20,000	0.13	2,671
Tomato (s – es)	1,020,000	0.12	121,849

Source: Adapted from Municipal agricultural production (IBGE-WEBSITE) where s - harvest; es - off-season; Data obtained for 2019.

Table 8: Green water footprint of irrigated agriculture.

Crops	Planted area (m^2)	ET_{blue}(m/year)	Blue water footprint (m^3/year)
Mango	490,000	1.70	832,649
Guava	400,000	1.47	588,072
Banana	330,000	2.16	711,972
Rice (s – es)	30,000	1.27	37,978
Potato (s – es)	2,210,000	1.18	2,614,950
Cassava (s – es)	1,400,000	0.73	1,017,265
Maize (s – es)	207,200,000	1.35	279,111,868
Sugarcane (s – es)	70,000	1.35	94,294
Beans	179,760,000	1.05	188,866,102
Fava Beans	13,960,000	1.05	14,667,172
Watermelon (s – es)	50,000	1.21	60,496
Sisal	46,330,000	1.13	52,191,973
Avocado	20,000	1.81	36,277
Tomato (s – es)	1,020,000	1.10	1,124,195

Source: Adapted from Municipal agricultural production (IBGE-WEBSITE) where s - harvest; es - off-season; Data obtained for 2019.

Therefore, the total Blue Water Footprint in irrigated agriculture in the sub-basin was obtained by adding up all the blue water consumption in the different crops, totaling the value of 541,955,263 m^3 in the year 2019. This is the value of the total blue water footprint considering that irrigation is fully functioning.

Livestock Water Footprint Estimation

The livestock water footprint was estimated taking into account the blue component related to the direct use of water for animal desiccation and the green component related to the indirect consumption by feeding by grazing or specific feed. In this way, the PHazul in animal watering was calculated based on the quantity of the main types of animals raised in the sub-basin area in 2019, as shown in Table 9.

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Table 9: Livestockblue water footprint.

Category	Number of heads	Average daily consumption (liter/head/day)	Blue water footprint (m^3/year)
Cattle	102.679	20	2.053.580
Equines	7.061	18	127.098
Swine	33.664	5	168.320
Goats	204.007	3	612.021
Ovines	161.871	3	485.613
Gallinaceous	2.832.782	0,23	651.540

Source: Adapted from MunicipalLivestock Survey (IBGE-WEBSITE), EMATER and EMBRAPA; Data obtained for 2019.

Thus, the Blue Water Footprint of livestock was obtained by adding up the blue water consumption by the different types of animals, thus totaling 4,098,172 m^3 for the year 2019.

In addition, the PHgreen in food consumption by animals was estimated from the total consumption of silage. Thus, sorghum grass and corn were considered as the basis for silage (feed), as shown in Table 10 below:

Table 10: Average consumption of herds by type of silage.

Category	Number of heads	Average food consumption (Kg/head/day)	Type of silage
Cattle	102,679	15	Maize
Equines	7,061	7	Maize
Swine	33,664	3.2	Sorghumgrass
Goats	204,007	2.94	Sorghumgrass
Ovines	161,871	2.92	Sorghumgrass
Gallinaceous	2,832,782	0.13	Sorghumgrass

Source: Adapted from MunicipalLivestock Survey (IBGE-WEBSITE), EMATER and EMBRAPA; Data obtained for 2019.

To estimate the volume of green water absorbed in the year 2019 in the production of sorghum grass and maize consumed by the animals, the ETgreen obtained based on ETc and Pefet was calculated. The calculation also comprised, the corn crop coefficient (Table 4), the sorghum crop coefficient (Table 11), the average monthly evaporation in the sub-basin (Table 5) and the average monthly precipitation in the sub-basin (Table 6).

Table 5: Coefficient of sorghum grass cultivation.

Jan	Feb	Mar	Apr	May	Jun
0	0.4	0.75	1.1	0.8	0
Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
0	0.4	0.75	1.1	0.8	0

Source: Adapted from Aspersion and Dripping, GOMES (1999).ted Brito (2019).

Once the monthly green ET values for the two crops were defined, the volume of green water referring to the total consumption of corn and sorghum grass by the animals in 2019 (Table 12) was obtained by multiplying the green ET in m/year by the area to be planted. It is worth noting, that the area to be planted was defined based on the total consumption of silage and the average productivity of the two crops, thus, for corn the productivity adopted was 35 (ton/ha) and for sorghum grass 70 (ton/ha).

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 3 Mar 2022, pp: 640-652 www.ijaem.net ISSN: 2395-5252

Table 5: Livestock's green water footprint

Crops	Total silage consumption (ton/year)	Planted area (m^2/year)	ET_{green}(m/ano)	Green water footprint(m^3/year)
Maize	565,177	16,148	0.43	6,944
Sorghumgrass	580,208	8,289	0.40	3,315

Source: Adapted from Municipal agricultural production (IBGE-WEBSITE), where s - harvest; es - off-season and Aspersion and drip, GOMES (1999).

Therefore, the total green Water Footprint obtained in the year 2019 for the consumption of silage by animals in the Taperoá River sub-basin was 10,259 m^3.

Estimating the Total Water Footprint

The calculation of the total water footprint in the sub-basin was done by summing all estimates of the blue, green and grey components of the main water using sectors in the basin. Table 12 below shows in detail the value obtained for each sector and for each type of water, and at the end the sum of all to obtain the result.

Table 12:Total Water Footprint in the Taperoá River sub-basin.

Water sectors considered	Blue Footprint (m^3/year)	Green Footprint (m^3/year)	Gray Footprint (m^3/year)	Total sectors (m^3/year)
Human Supply	36,647,896	-	-	36,647,896
Human Supply	-	-	912,576,387	912,576,387
Irrigated Agriculture	541,955,263	44,454,369	-	586,409,632
Livestock	4,098,172	10,259	-	4,108,431
TOTAL WATER FOOTPRINT (m^3/year)	582,701,331	44,464,628	912,576,387	1,539,742,346

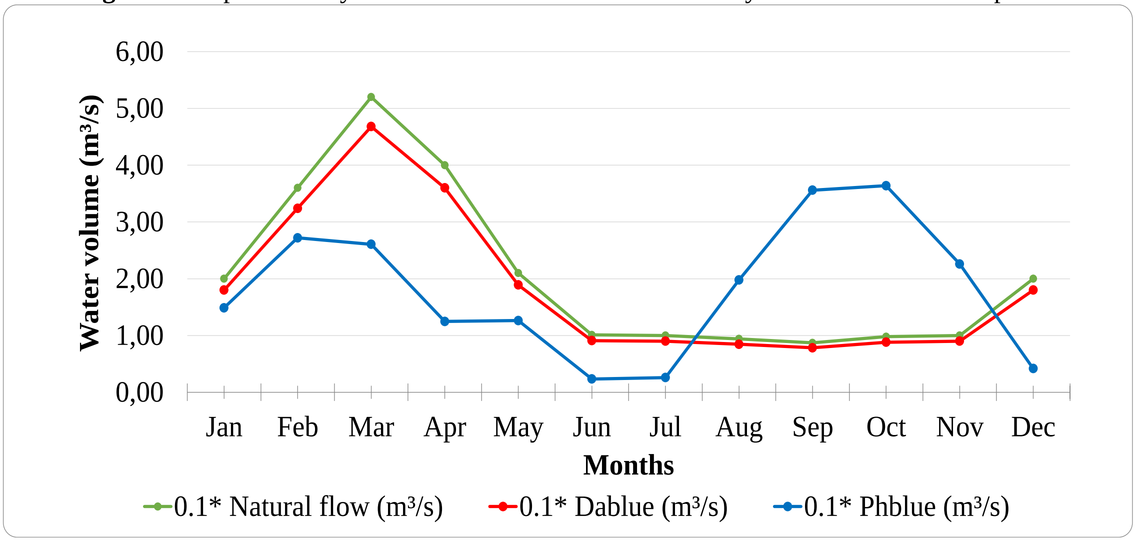
Therefore, the value found for the total water footprint of the Taperoá River sub-basin in the year 2019 was 1,539,742,346 m^3. Thus, the largest contribution of the Water Footprint in the sub-basin was attributed to gray water, which represented approximately 59.26% of the total footprint.

The blue Water Footprint corresponded to 37.84% of the total Water Footprint and 2.90% was attributed to green water. Regarding the sector-specific Water Footprint assessed in the sub-basin, sanitation represented 59.26% of the total Water Footprint, followed by irrigated agriculture represented 38.08%. The water footprints of livestock and supply were equal to 0.26% and 2.40% of the total, respectively.

Analysis of the Sustainability of the Water Footprint

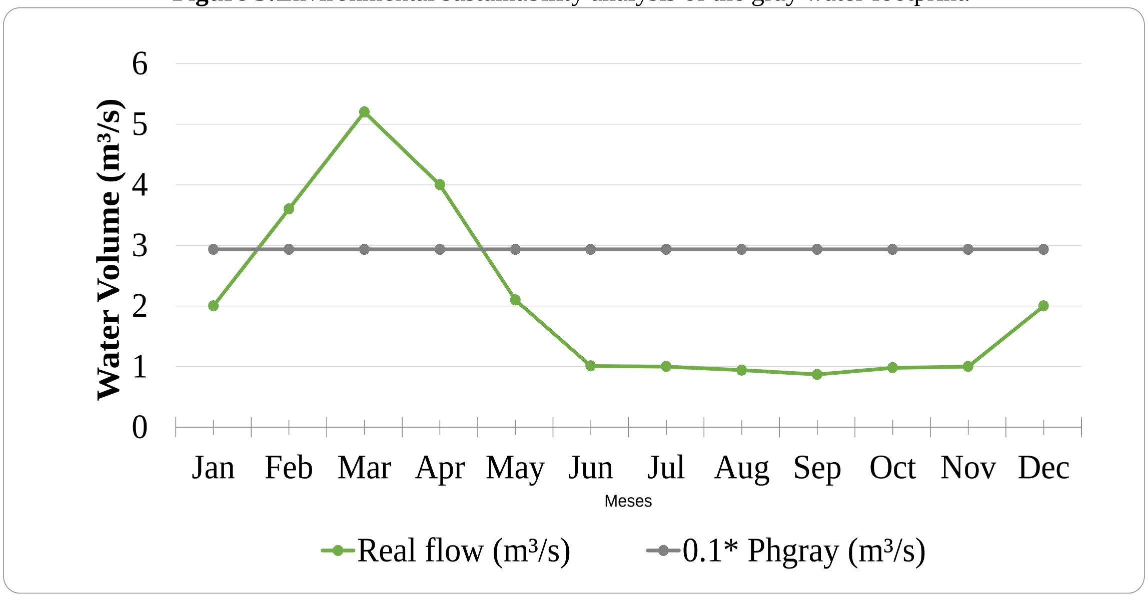
The sustainability of the water footprint in the studied sub-basin was analyzed from the environmental perspective. From the results obtained, applied through Equation 10, it was possible to elaborate a graph to facilitate the better understanding of the data, as shown in Figure 2, referring to blue environmental sustainability in the sub-basin of the Taperoá River in the year 2019.

Figure 2: Graphical analysis of the environmental sustainability of the blue water footprint.



As observed in Figure 2, the total water consumption is unsustainable in the months of August, September, October and November. Accordingly, these are the months that present the lowest precipitation and highest evaporation rates. On the other hand, the months of February, March and April have the highest availability of blue water, a period that coincides with the months that have the highest monthly precipitation. Therefore, it is a suitable time to implement actions aimed at storing water to reduce concerns about the drought period, thus it is feasible to create and execute a long-term planning that can decrease consumption in unsustainable periods.

Figure 3: Environmental sustainability analysis of the gray water footprint.



By analyzing the Sustainability of the Grey Footprint (Figure 3) it can be seen that it presents itself during most of the period under study as unsustainable, leaving the sub-basin in a critical state, since there is difficulty in assimilating the water bodies, prolonging it for consecutive months. At the same time, it is possible to observe a considerable growth in the flow between February and April, the only period (three months) in which the level of water pollution does not exceed the water demand.

III. CONCLUSION

From what has been proposed, this research gives us access to understand the importance of developing an integrated management of water resources, which aims to reduce consumption rates and enhance efficiency in water use, since from now on we have knowledge of the consumption pattern of the sub-basin studied.

For this reason, it makes current the preference for actions and methodologies that aim at: the reduction of losses in the water supply system; the precision in monitoring the real flow of the rivers in the region; the incentive for the registration of water use permits, with the objective of verifying the real demand for water in the sub-basin; the creation of public policies related to the reduction of water waste and pollution; the increase in the use of social technologies for water capture and storage; the implementation of management tools based on indicators of sustainability of water use, among others.

To this end, the hypothesis raised is true, since it allowed to know the level of environmental sustainability on an annual and monthly scale, being for the year analyzed as sustainable and taking into account the monthly scale becomes unsustainable between the months of June to November. Thus, the implementation of a more efficient management in the sub-basin of the Taperoá River/PB on the demands will adapt to the natural load capacity of the environment, with the use of efficient techniques which preserve the affluent flows of the system analyzing and allowing the visualization that the volume of water available is insufficient to assimilate the waste flows of the productive activity of the sub-basin studied.

Therefore, it is strongly believed that the results of this research can serve as a guide for planning the efficient use of water, as well as to alert the population, companies and environmental managers about the pattern of water consumption in the various sectors and where it can be reduced so that there is no shortage of water resources, since it is an essential asset for human life on earth, for the production of goods and services.

ACKNOWLEDGMENTS

This work was carried out with the support of the National Council for Scientific and Technological Development (CNPq).

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