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WATER DEMAND FOR PRIORITY USES IN BRAZILIAN SEMIARID: ALTO PARAÍBA REGION AND TAPEROÁ SUB-BASIN

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ABSTRACT

The granting of water use rights is a control instrument of the Brazilian Water Resources Policy (Law Nº. 9,433/97). According to the Law Nº. 9,433/97,human supply and animal watering are priority uses. Information on water input and output in water system are fundamental for effective management control. This work aims to estimate the human and livestock use of water in the rural zone of Alto Paraíba Region and Taperoá River Sub-basin, both belonging to the Paraíba river Basin, Paraíba, Brazil. We compare the proportion of water consumption versus total demand in the sector. We used the database of the 2006 Agricultural Census and population data for 2007 and 2010, from the Brazilian Institute of Geography and Statistics – IBGE, and the information of availability water indexes by the2006 State Plan of Water Resources of Paraíba - PERH of 2006, which provides the demands of water in the studied hydrographic region.

Keywords: Gestão de Recursos Hídricos, Outorga, Quota *per capita* de água.

INTRODUCTION

Throughout the last few centuries, the society development disregarding the limits of nature has led to a strong relationship between population, the negative impact on natural resources and pollution (BRAGA et al., 2005).

The search for places with water supply was essential for the survival of the nomadic peoples since the beginning of humanity. Currently, the quest for quality and quantity of water is a need in developing and rich countries. Rich countries such as Australia, the United States, Spain, Japan and parts of the UK face the water scarcity caused by a combination of climate change, inadequate infrastructure and, reduced water management (PITTOCK, 2006).

The view of inexhaustible water availability has changed with a new developmental paradigm based on the sustainable use of natural resources (ARRUDA and TAVARES NETO, 2017). Under the sustainability principal, the water management of river basin is essential to reduce water loss and the rational use of water (UNESCO, 2016).

The current water resources management in Brazil reflects the political, social and economic realities, involving the society and public power and taking to account the environment conditions (AZEVEDO, 2011).

In the state of Paraíba, conflicts over the use of water are periodic as the case of the reservoir Epitácio Pessoa, the second largest in the State. The lack of water management associated with extreme drought events led to potentially conflicting situations in water use. Cities located in Paraíba River Basin often undergo rationing or cuts in public water supply, as occurred in the late 1990s (especially in the drought from 1998 to 2001) (AESA, 2016) and currently, facing the worst historical crisis (BRITO, 2008).

The State Water Resources Plan, approved on June 13, 2011, has the objective of "basing and guiding the implementation of resource management instruments required by Law 9,433/97 in accordance with State Legislation, Law 6,308/96". The plan has specific objectives: determine the availability and demand for water resources; guarantee the satisfactory balance between availability and demand for surface and underground water in quantity and quality, for the current and future scenario; promote, support and implement actions to organize and ensure the multiple and sustainable use of water according to local availability and demands; define grant guidelines, criteria and priorities (PERH, 2006).

In 2006, the IBGE published the Brazilian Agricultural Census revealing the agrarian reality in Brazil considering its interrelations with actors, scenarios, modes, and instruments of action (IBGE, 2006).

The granting of water use rights control the demands of different types of users according to the water quantity in the river basin. The information control of the inputs, storages, and outlets of water in a delimited system is fundamental for propositions of short, medium and long-term horizons in the management system. The priority demands, human and animal water (Article 1 of Law 9,433/97), are references that define the water supply to other types of users.

The Northeast of Brazil has a wide aptitude for livestock. Goat farming is a promising business in a region where economic opportunities are scarce (POMPONET, 2009). According to Carvalho (2003), the sheep and goat meat industry targets a booming consumer market, which at that time, was characterized as a "subsistence market" in which the producer did not have surpluses for sale.

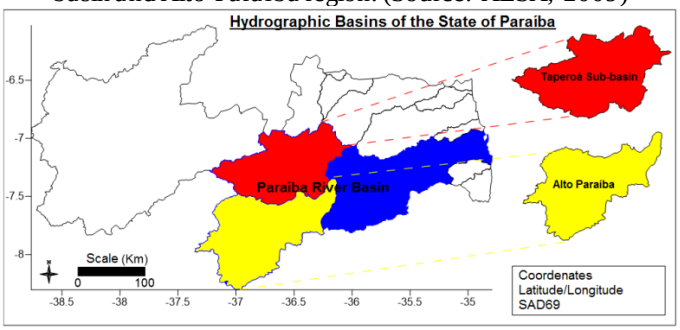
The production systems of goats and sheep are important for the sustainable development of arid and semi-arid regions since the climatic conditions affect the agricultural activities (VOLTOLINI et al., 2011). The production of small ruminants in Paraíba State is relevant for the local economy, concentrating in the region of CaririsParaibanos (SEBRAE, 2000).

Estimates of water demand for human and livestock sector are essential for the water management. Therefore, this work estimates the human and livestock demand of water in the rural zone of two areas of Paraíba River basin (Alto Paraíba region and Taperoá Sub-basin) and calculate the water availability indexes proposed by the Water Resources Plan of Paraíba State.

MATERIAL AND METHODS

Paraíba River Basin is divided into the Taperoá Sub-basin and three Regions: Alto Paraíba, MédioParaíba and BaixoParaíba (Figure 1).

Figure 1. Paraíba river basin, highlighting the Taperoá sub-basin and Alto Paraíba region. (Source: AESA, 2009)



According to the Water Resources Plan of the State of Paraíba (PERH, 2006), the Taperoá River Sub-basin comprises an area of 5,666.38 km², located between the latitudes 6º51'47" and 7º34'33" S and between the longitudes 36º00'10" and 37º14'00" W. Alto Paraíba Region has an area of 6,717.39 km²,

located between the south latitudes 7º20'48"– 8º18'12" and between the longitudes west 36º07'44" and 37º21'22".

The source areas of the Paraíba River Basin are in both regions Alto Paraíba and Taperoá River Sub-basin. These regions converge water supply to several reservoirs and later integrate into the Epitácio Pessoa dam, with a capacity of 411,686,287 m³ (AESA, 2018). The Epitácio Pessoa dam supplies the Metropolitan Region of Campina Grande, the second largest urban center of Paraíba, with a substantial economic impact.

The quantitative of the urban and rural population was obtained from IBGE Census (2010), and the percentage by category was calculated for each municipality of the studied region. Only the districts whose city are located in the Alto Paraíba and Taperoá Sub-basin were included in the study, according to 2007 census (IBGE, 2007).

The number of animals (cattle, goats, sheep, swine, and poultry) produced was obtained from Brazilian Agricultural Census (IBGE, 2006). Only the districts whose city are located in the Alto Paraíba and Taperoá Sub-basin were included in the study, according to 2007 census (IBGE, 2007).

For the human demand of consumption at the rural zone, we consider the per capita consumption proposed by the Northeastern Integrated Water Resources Utilization Plan - PLIRHINE - SUDENE (1980) (PERH, 2006), as 100 $L.inh^{-1}.day^{-1}$. The product of the per capita consumption by the estimated rural population resulted in the human population demand of each municipality.

The water consumption by the livestock sector was estimated using the methodology by BEDA - Equivalent Cattle for Water Demand methodology (SUDENE, 1980), which is the unitary water demand weighting for each species concerning the water consumption by bovine. The methodology considers as the basis for bovine consumption 50 $L.day^{-1}$, a similar value for buffaloes (BEDA/1). For: equines, mules and asinine, 40 $L.day^{-1}$ (i.e., BEDA/1.25); pigs, 10 $L.day^{-1}$ (BEDA/5); sheep and goats, 8.0 $L.day^{-1}$ (BEDA/6.25); rabbits, 0.25 $L.day^{-1}$ (BEDA/200); poultry, 0.20 $L.day^{-1}$ (BEDA/250). Therefore, the total demand in each category was estimated from the product water demand by the animal quantity.

RESULTS AND DISCUSSION

Table 1 shows the population of the municipalities whose cities are located in the Alto Paraíba and Taperoá Sub-basin, referring to 2007 (IBGE, 2007) and 2010 census (IBGE, 2010) and the urban and rural population in the 2010 census. There was population growth (more than 6%) in municipalities of Boqueirão, and São Domingos do Cariri, in Alto Paraíba Region, and 9.7% in the municipality of Boa Vista, 6.7% in the municipality of Pocinhos, both from Taperoá Sub-basin.

Table 1. Population in the municipalities of the Alto Paraíba and Taperoá River Sub-basin in the years 2007 (IBGE, 2007) and 2010 (IBGE, 2010).

Alto Paraíba Municipalities	2007	2010			Taperoá Municipalities	2007	2010		
	Total	Total	Urban	Rural		Total	Total	Urban	Rural
Amparo	2,007	2,088	1,062	1,026	Assunção	3,336	3,522	2,846	676
Barra de São Miguel	5,435	5,611	2,364	3,247	Boa Vista	5,673	6,224	3,205	3,019
Boqueirão	15,877	16,889	12,008	4,881	Cabaceiras	4,907	5,035	2,217	2,818
Camalaú	5,761	5,749	2,887	2,862	Cacimbas	6,787	6,814	1,641	5,173
Caraúbas	3,824	3,899	1,517	2,382	Desterro	7,929	7,991	4,889	3,102
Congo	4,770	4,692	2,944	1,748	Gurjão	2,985	3,159	2,128	1,031
Coxixola	1,705	1,771	782	989	Juazeirinho	15,899	16,776	9,124	7,652
Monteiro	29,980	30,844	20,259	10,585	Junco do Seridó	6,486	6,643	4,369	2,274
Ouro Velho	2,974	2,928	2,047	881	Livramento	7,105	7,164	3,752	3,412
Prata	3,,96	3,854	2,444	1,410	Olivedos	3,489	3,627	1,902	1,725
São Domingos do Cariri	2,265	2,420	1,034	1,386	Parari	1,245	1,256	699	557
São João do Tigre	4,578	4,396	1,529	2,867	Pocinhos	15,956	17,020	9,615	7,405
S. Sebast. do Umbuzeiro	3,061	3,239	2,097	1,142	Santo André	2,641	2,638	865	1,773
Sumé	16,456	16,072	12,240	3,832	São João do Cariri	4,438	4,344	2,347	1,997
Zabelê	2,024	2,075	1,472	603	São José dos Cordeiros	3,973	3,985	1,643	2,342
					Serra Branca	12,41	12,97	8,417	4,554

						3	1		
					Soledade	13,128	13,739	10,231	3,508
					Taperoá	14,715	14,938	8,941	5,997
					Tenório	2,806	2,816	1,676	1,140
Total	104,613	106,527	66,686	39,841		92,849	96,198	51,242	44,956

For the estimation of the rural population of 2007, we used the proportions of the inhabitants of the rural area of 2010 (IBGE, 2010). This proportion was applied to the data of the total population count of 2007 (IBGE, 2007). Table 2 shows the estimated rural population in Alto Paraíba Region and Taperoá River Sub-basin.

Table 2. Human rural population on the Alto Paraíba region and Taperoá river Sub-basin in 2007.

Alto Paraíba Municipalities	Population	Municipalities Taperoá sub-basin	Population
Total	39,135	Total	58,255
Amparo	986	Assunção	640
Barra de São Miguel	3,145	Boa Vista	2,752
Boqueirão	4,589	Cabaceiras	2,746
Camalaú	2,868	Cacimbas	5,153
Caraúbas	2,336	Desterro	3,078
Congo	1,777	Gurjão	974
Coxixola	952	Juazeirinho	7,252
Monteiro	10,288	Junco do Seridó	2,220
Ouro Velho	895	Livramento	3,384
Prata	1,425	Olivedos	1,659
São Domingos do Cariri	1,297	Parari	552
São João do Tigre	2,986	Pocinhos	6,942
São Sebastião do Umbuzeiro	1,079	Santo André	1,775
Sumé	3,924	São João do Cariri	2,040
Zabelê	588	São José dos Cordeiros	2,335
		Serra Branca	4,358
		Soledade	3,352
		Taperoá	5,907
		Tenório	1,136

Tables 3 and 4 show the animal numbers by municipalities in Alto Paraíba Region and Taperoá River Sub-basin, respectively. The data were obtained from the Agricultural Census of 2006 (IBGE, 2006).

Table 3. Quantitative of animals in the Region of Alto Paraíba by municipality (IBGE, 2006)

Municipality	Animals				
	Cattle	Goats	Sheeps	Swine	Poultry
Amparo	1,300	1,544	1,426	74	3,269
Barra de São Miguel	6,892	14,850	9,881	559	4,298
Boqueirão	9,225	5,151	4,688	782	10,343
Camalaú	4,499	15,093	10,196	785	32,753
Caraúbas	4,068	18,651	8,709	239	5,642
Congo	3,216	11,592	7,679	622	7,996
Coxixola	1,193	4,337	5,513	45	2,175
Monteiro	21,023	18,155	15,817	2,115	131,763
Ouro Velho	3,810	1,617	1,413	162	252,931
Prata	4,710	4,681	3,133	144	3,984
São Domingos do Cariri	1,834	5,358	3,146	122	3,483
São João do Tigre	5,742	23,185	6,337	374	8,200
São Sebastião do Umbuzeiro	2,951	12,337	3,469	238	3,651
Sumé	8,438	16,989	16,502	550	102,893
Zabelê	2,258	5,851	2,082	240	5,784

Table 4. Quantitative of animals in Taperoá Sub-basin by municipality (IBGE, 2006)

Municipality	Animals				
	Cattle	Goats	Sheeps	Swine	Poultry
Assunção	1,582	1,071	471	272	1,966
Boa Vista	7,736	8,950	7,147	682	236,406
Cabaceiras	7,527	14,667	8,340	215	9,951
Cacimbas	1,663	2,649	397	535	9,727
Desterro	2,928	1,117	430	250	10,604
Gurjão	5,286	8,613	5,294	447	4,805
Juazeirinho	7,271	4,988	2,263	967	19,900
Junco do Seridó	2,095	827	136	678	6,589
Livramento	5,449	3,425	3,023	301	11,289
Olivedos	6,512	7,005	6,120	483	4,477
Parari	1,282	2,604	1,718	14	1,473
Pocinhos	9,395	12,276	10,032	811	1,078,967
Santo André	3,695	4,219	4,164	284	7,579

São João do Cariri	6,820	13,886	12,844	388	12,067
São José dos Cordeiros	5,526	6,104	4,124	310	8,578
Serra Branca	7,510	13,638	19,225	561	13,995
Soledade	11,469	12,774	10,290	1,206	105,297
Taperoá	12,309	8,916	7,774	790	23,853
Tenório	1,112	839	310	205	4,697

Tables 5 and 6 show the estimation of the demand for priority uses of water (human consumption and animal watering) in municipalities located in the Alto Paraíba Region and Taperoá River Sub-basin, in m3.day^{-1}, and the total animal demand. The estimated demand of animal watering was obtained by the product of animal count (Tables 3 and 4) and the equivalent BEDA (see methodology).

Table 5. Estimated water demand for priority uses (human consumption and animal watering) in Alto Paraíba Region by municipality (m^3.day^{-1})

Municipality	Human	Animals						Total
		Cattle	Goats	Sheeps	Swine	Poultry	Total	
Amparo	98.6	65.00	12.35	11.41	0.74	0.65	90.15	188.75
Barra de São Miguel	314.5	344.60	118.80	79.05	5.59	0.86	548.90	863.40
Boqueirão	458.9	461.25	41.21	37.50	7.82	2.07	549.85	1,008.75
Camalaú	286.8	224.95	120.74	81.57	7.85	6.55	441.66	728.46
Caraúbas	233.6	203.40	149.21	69.67	2.39	1.13	425.80	659.40
Congo	177.7	160.80	92.74	61.43	6.22	1.60	322.79	500.49
Coxixola	95.2	59.65	34.70	44.10	0.45	0.44	139.34	234.54
Monteiro	1,028.8	1,051.15	145.24	126.54	21.15	26.35	1,370.43	2,399.23
Ouro Velho	89.5	190.50	12.94	11.30	1.62	50.59	266.95	356.45
Prata	142.5	235.50	37.45	25.06	1.44	0.80	300.25	442.75
São Domingos do Cariri	129.7	91.70	42.86	25.17	1.22	0.70	161.65	291.35
São João do Tigre	298.6	287.10	185.48	50.70	3.74	1.64	528.66	827.26
São Sebastião do Umbuzeiro	107.9	147.55	98.70	27.75	2.38	0.73	277.11	385.01
Sumé	392.4	421.90	135.91	132.02	5.50	20.58	715.91	1,108.31
Zabelê	58.8	112.90	46.81	16.66	2.40	1.16	179.92	238.72
Total	3,913.5	4,058.0	1,275.1	799.9	70.5	115.8	6,319.3	10,232.8

Table 6. Estimated water demand for priority uses (human consumption and animal watering) in Taperoá Sub-basin, by municipality ($m^3.day^{-1}$)

Municipality	Human	Animals						Total
		Cattle	Goats	Ovinos	Suínos	Cattle	Goats	
Assunção	64.0	79.10	8.57	3.77	2.72	0.39	94.55	158.55
Boa Vista	275.2	386.80	71.60	57.18	6.82	47.28	569.68	844.88
Cabaceiras	274.6	376.35	117.34	66.72	2.15	1.99	564.55	839.15
Cacimbas	515.3	83.15	21.19	3.18	5.35	1.95	114.81	630.11
Desterro	307.8	146.40	8.94	3.44	2.50	2.12	163.40	471.20
Gurjão	97.4	264.30	68.90	42.35	4.47	0.96	380.99	478.39
Juazeirinho	725.2	363.55	39.90	18.10	9.67	3.98	435.21	1.160.41
Junco do Seridó	222.0	104.75	6.62	1.09	6.78	1.32	120.55	342.55
Livramento	338.4	272.45	27.40	24.18	3.01	2.26	329.30	667.70
Olivedos	165.9	325.60	56.04	48.96	4.83	0.90	436.33	602.23
Parari	55.2	64.10	20.83	13.74	0.14	0.29	99.11	154.31
Pocinhos	694.2	469.75	98.21	80.26	8.11	215.79	872.12	1.566.32
Santo André	177.5	184.75	33.75	33.31	2.84	1.52	256.17	433.67
São João do Cariri	204.0	341.00	111.09	102.75	3.88	2.41	561.13	765.13
São José dos Cordeiros	233.5	276.30	48.83	32.99	3.10	1.72	362.94	596.44
Serra Branca	435.8	375.50	109.10	153.80	5.61	2.80	646.81	1.082.61
Soledade	335.2	573.45	102.19	82.32	12.06	21.06	791.08	1.126.28
Taperoá	590.7	615.45	71.33	62.19	7.90	4.77	761.64	1.352.34
Tenório	113.6	55.60	6.71	2.48	2.05	0.94	67.78	181.38
Total	5,825.5	5,358.4	1,028.5	832.8	94.0	314.4	7,628.1	13,453.6

The livestock demand was higher than human demand in Alto Paraíba Region, 61.76% of the total water supply (Table 5). Cattle demand account for 64.2% of total animal demand, 32.8% for goats and sheep, and 3% for swine and

poultry (Table 5). The animal demand was also higher than human demand for the Taperoá river Sub-basin, account for 56.7% (Table 6). Bovine demand was 70.2% of total animal need, and goats and sheep 24.4%.

The Water Resources Plan of Paraíba State (PERH, 2006), at the time, indicated the reservoir system of the Taperoá river Sub-basin was insufficient to meet the current primary demands and could compromise the water availability for the Epitácio Pessoa reservoir (Boqueirão), warning for a possible water collapse for urban supply of the localities served. The plan recommended avoiding the use of water to meet other demands (diffuse).

The plan also reported that only Olivedos and Mucutu reservoirs presented 100% human supply guarantees. Among the guarantees of 95% and 99% were the reservoirs: Taperoá II, Jeremias, Livramento, Serra Branca I and Gurjão, in descending order, with a lower percentage for the Serra Branca II reservoir.

According to the Water Resources Plan, contrary to the limitation of water supply by the Taperoá river sub-basin, the average flow rate of Alto Paraíba for Epitácio Pessoa reservoir was estimated at 3.36 m^3s^{-1}, for the year of 2003, even meeting the demand of irrigation with a unit consumption average of 0.42 $L.s^{-1}ha^{-1}$.

The reservoirs that were not meeting the required demand for urban human populations were also reported by the Water Resource Plan (PERH, 2006). Ouro Velho and São Paulo, Lagoa de Cima, Campos, Bichinho, Santo Antônio and São Domingos, from the Alto Paraíba – Prata Region, which supplies the municipalities of Prata, Ouro Velho, Coxixola, Caraúbas, Barra de São Miguel, Zabelê and São Domingos. In Taperoá river Sub-basin, the reservoirs were Livramento, Gurjão, São José, Jeremias and Manoel Marcolino that respectively supply the municipalities of Livramento, Gurjão, São José dos Cordeiros, Desterro, and Taperoá.

The indices that relate demands to availabilities are (PERH, 2006):

- Availability Activation Indices (IAD), the ratio between current availability and maximum availability;
- Availability Utilization Indices (IUD) - Ratio between Demand and Availability
- Maximum utilization of the available (IUD_M)
- Current utilization of the available (IUD_A)
- Utilization of the available by sectors (IUD_S)

The Availability Activation Indices and Availability Utilization Indices for Alto Paraná and Taperoá river Sub-basin are shown in Tables 7 and 8.

Table 7: Availability Activation Indices (IAD) (PERH, 2006)

Hidrographic region	IAD		
	Underground	Superficial +Underground	
		Without small man-made lakes	With small man-made lakes
Alto Paraíba	0.01	0.71	0.80
Taperoá	0.01	0.10	0.32

Table 8. Availability Utilization Indices (IUD) (PERH, 2006)

Hidrographic region	IUD- Availability Utilization Indices		
	IUD_M (Maximum)	IUD_A (Current)	IUD_S (by Sector)

	Without small man-made lakes	With small man-made lakes	Without small man-made lakes	With small man-made lakes	Human	Industry	Livestock	Irrigation
Alto Paraíba	0.63	0.44	0.89	0.55	0.58	0.007	0.026	0.709
Taperoá	0.21	0.16	2.10	0.49	0.19	0.062	0.066	3.221

We verified a water scarcity of underground storage on both Alta Paraíba and Taperoá river Sub-basin, as well water deficiency in the Taperoá Sub-basin, regarding groundwater and surface waters, even including small dams (Table 7).

Table 8 shows a water demand of 110% more than the available at the Taperoá Sub-basin. Demands of water for animal use represent 2.6% of the availability in the Alto Paraíba and 6.6% in the Taperoá Sub-basin. The demands of the human sector (including urban and rural users) is 58% in Alto Paraíba and 19% of the availability in Taperoá Sub-basin.

The proportions of demand for animal watering were higher than the human demand in the rural area. However, the index that relates the demand by sector reveals a demand less than 5% of the availability (PERH, 2006). Comparing the proportions of human consumption demands in the rural sector with animal watering, we estimated an Index of Utilization of Availabilities (IUD) for rural human consumption sector of 0.042 in Alto Paraíba and 0.0864 at Taperoá. Therefore, we observe that irrigation and urban human consumption are superior to the priority demands in rural area.

Our results are important to support management tools, such as the granting and charging for the use of water, integrating water control to guarantee priority demands and a differentiated economic valuation in the face of consumptions that generate fewer impacts on water potential of the hydrographic basin.

We pointed out that water with a tolerable salubrity content derived from aquifers can be considered for animal watering, during periods of absence or rationing, reducing, even more, the demand for animal use.

CONCLUSION

Our results demonstrate that the priority demand expressed the need for improvements in the water potential in the Taperoá river Sub-basin and high requirements for human consumption in Alto Paraíba, using the population of 2007 and 2010 (IBGE 2007, 2010), animal count (IBGE 2006) and the water availability reported at the Water Resource Plan (PERH, 2006). Estimates of animal demand calculated by the Agricultural Census of 2006, reflect the substantial contribution of animal water consumption concerning to the demand for human consumption in the rural area. However, urban human supply and irrigation demands have a higher impact than rural human consumption and animal watering.

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