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POTENCIAL DA ÁREA IRRIGÁVEL DA BACIA HIDROGRÁFICA DO RIO VERDÃO, REGIÃO SUDOESTE DO ESTADO DE GOIÁS

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1 RESUMO

A quantificação da disponibilidade hídrica pode propiciar a tomada de decisão na gestão e planejamento dos recursos hídricos ou até mesmo na aquisição de novas áreas agrícolas que possuem o propósito de fazer agricultura irrigada. Portanto, o objetivo desse trabalho foi determinar o potencial de área irrigável da bacia hidrográfica do Rio Verdão (BHRV), região sudoeste do estado de Goiás. As outorgas utilizadas foram de captação direta superficial de fevereiro de 2019 destinadas as atividades de irrigação, bombeamento, abastecimento público e piscicultura. A vazão específica foi definida pela Instrução Normativa vigente e o processamento dos dados georreferenciados foi realizado através do *Software ArcGis* 10.5. As sub-bacias hidrográficas com maior potencial de irrigação são as dos Rios São Tomás (6.471 L s^{-1}), Verdinho (5.652 L s^{-1}) e Ponte de Pedra (2.172 L s^{-1}). Há 125 sub-bacias hidrográficas que ainda não há usuários da água. A BHRV possui disponibilidade hídrica para irrigar 33,5% da área apta para implantação de sistemas de irrigação distribuídas em toda a sua extensão, exceto nas bacias que apresentaram índices de comprometimento acima de 50%. O potencial de área irrigável total da bacia é de 33.898 ha, podendo assim, gerar aproximadamente 50,4 mil empregos e renda na região.

Palavras-chave: vazão, captação, outorga, irrigação, sensoriamento remoto.

CASTRO, P. A. L. de; SANTOS, G. O.
POTENTIAL OF THE IRRIGABLE AREA OF THE RIO VERDÃO HYDROGRAPHIC BASIN, SOUTHEAST REGION OF THE STATE OF GOIÁS

2 ABSTRACT

The quantification of water availability can promote decision-making in the management and planning of water resources or even in the acquisition of new agricultural areas that have the purpose of making irrigated agriculture. Therefore, the objective of this work was to determine the irrigable area potential of the Rio Verdão hydrographic basin (BHRV), southwest region of the state of Goiás. The grants used were for direct surface capture from February 2019, unlocking the irrigation, pumping, public supply and pisciculture. The specific flow was defined by the current Normative Instruction and the processing of georeferenced data was performed using the ArcGis 10.5 Software. The hydrographic sub-basins with the greatest irrigation potential are those of the São Tomás Rivers (6,471 L s^{-1}), Verdinho (5,652 L s^{-1}) and

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Ponte de Pedra (2,172 L s^{-1}). There are 125 sub-basins that do not yet have water users. BHRV has water availability to irrigate 33.5% of the area suitable for implantation of irrigation systems distributed over its entire length, except in basins with levels of impairment above 50%. The total irrigable area potential of the basin is 33,898 ha, thus being able to generate approximately 50.4 thousand jobs and income in the region.

Keywords: flow rate, capture, grant, irrigation, remote sensing.

3 INTRODUCTION

The intensive use of water and the competition between irrigation and the public supply give rise to disputes between users, both for collection and effluent dilution. To this end, integrated water resource planning has become essential given the obstacles to water management. The Water Law requires multiple uses and considers economic, social, and environmental values. One of the main challenges is ensuring water quantity and quality for current and future generations.

Irrigated agriculture is an important tool for increasing productivity and off-season production, reducing pressure on new areas for cultivation and the risks of production due to climatic influences, and increasing job creation (CASTRO; SANTOS, 2021; LOPES SOBRINHO et al., 2020), in addition to its role in food and nutritional security (ANA, 2017). According to Pereira et al. (2015), the use of irrigation systems is a technique of significant value, which, if well planned and managed, can significantly increase profitability and productivity.

Brazil has 8.2 Mha of irrigated land and is the sixth-largest country in the world with an area equipped with irrigation systems (ANA, 2021), with a potential increase of up to 65% in the next five years (LOPES SOBRINHO et al., 2020). The state of Goiás stands out as a region with great potential for increasing irrigated areas (ANA, 2017) but with a deficiency in identifying these areas due to favorable conditions for installing systems associated with grantable flow.

Water withdrawal for use in irrigated agriculture is consumptive and therefore requires a water permit (ANA, 2017), as established in Law 9,433/97. In the state of Goiás, the criteria to be followed are regulated by Normative Instruction No. 004/2015, of July 31, 2015. Through permits, it is possible to control the use of water resources, regardless of the methodology adopted in each state or federation. This methodology can present flaws when there are clandestine withdrawals of significant use.

Despite the large volume of water in the country, availability has been lower, and rainfall has been poorly distributed in space and time, causing dry spells at crucial times for crop development. This demands a greater volume of water for irrigation, especially during periods of lower availability. This is one of the concerns that could compromise the food supply. In the municipality of Rio Verde, Goiás, rainfall averages 1,600 mm year $^{-1}$ but has poor spatial and temporal distributions (CASTRO; SANTOS, 2017). The rainy season (October--March) accounts for 85% of the total rainfall (CASTRO; SANTOS, 2021). The interval between days without rain in the municipality is 93±25 days, which makes dryland agriculture impossible (THIESEN et al., 2018).

In agricultural planning for a geographic unit, which aims to increase irrigated areas, in addition to the allotted flow and crop water demand (CASTRO; SANTOS; DINIZ, 2019), geographic mapping of locations with potential for irrigation systems is essential. According to Barros et al. (2020), knowledge of land use and occupation, terrain slope, soil types, and proximity to water resources is crucial for efficient irrigation system planning. Remote sensing data provide a basis for short-term decision-making, enabling cost reduction and increasing agricultural productivity (PEREIRA; SILVA; PAMBOUKIAN, 2016).

The identification of areas suitable for the installation of irrigation systems associated with grantable flow is necessary (XAVIER et al., 2021), as it will lead to an increase in food production in the municipality, making up for the spatial and temporal irregularity of rainfall, in addition to favoring the cultivation of the third harvest.

According to ANA (2017), the municipality of Rio Verde is located in one of the emerging hubs with the greatest prospects for the expansion of irrigated agriculture. It also ranks 23rd in the country in terms of irrigated area, with 49.7% of the area being sugarcane, 19.7% other crops under central pivots, and 30.6% other crops and systems. It also boasts a strategic location for the transportation of food production with the implementation of the multimodal platform (north–south railway). However, this information will contribute to the identification of the potential for irrigable areas in the municipality, identifying them and providing, among other benefits, the cultivation of the third harvest, increased productivity, and the generation of jobs and income in the region. Therefore, this study aimed to determine the potential for irrigable areas in the Rio Verdão watershed in the southwestern region of the state of Goiás.

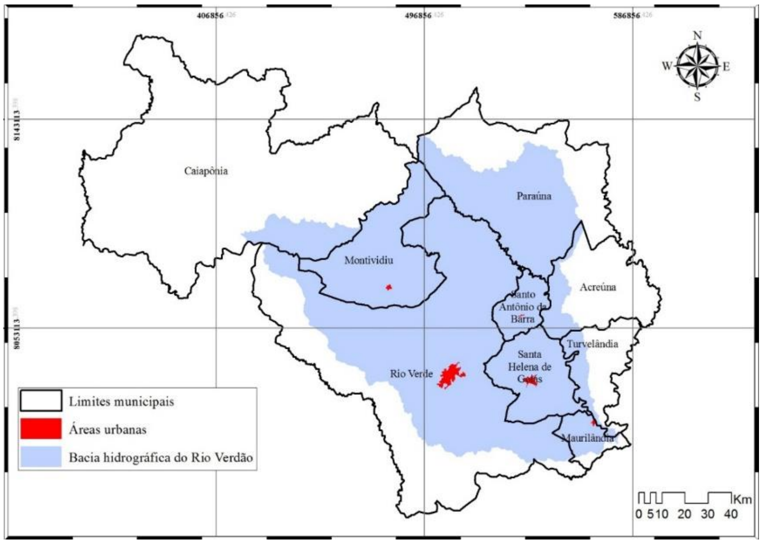
4 MATERIALS AND METHODS

This study covers the Verdão River Basin (BHRV), which is located in the Paraná hydrographic region, accounting for 1.05% of its area, and is located in Zone 22K of the Universal Transverse Mercator (UTM) grid of the southern hemisphere, with a drainage area of 12,912 km².

The Verdão River is the main river and the name of the BHRV; its source is located in the Serra do Caiapó, in the municipality of Caiapônia, with a length of 406.3 km, with points up to 115 m wide. Positioned in the southwest region of the State of Goiás, it occupies approximately 3.8% of the territory of Goiás and fully includes the municipalities of Montividiu, Santo Antônio da Barra and Santa Helena de Goiás and, in part, the municipalities of Caiapônia (6.4%), Paraúna (57.9%), Acreúna (21.9%), Turvelândia (31.1%), Maurilândia (77.7%) and Rio Verde (69.0%). Of these, five municipal headquarters are located within the limits of the basin (Figure 1).

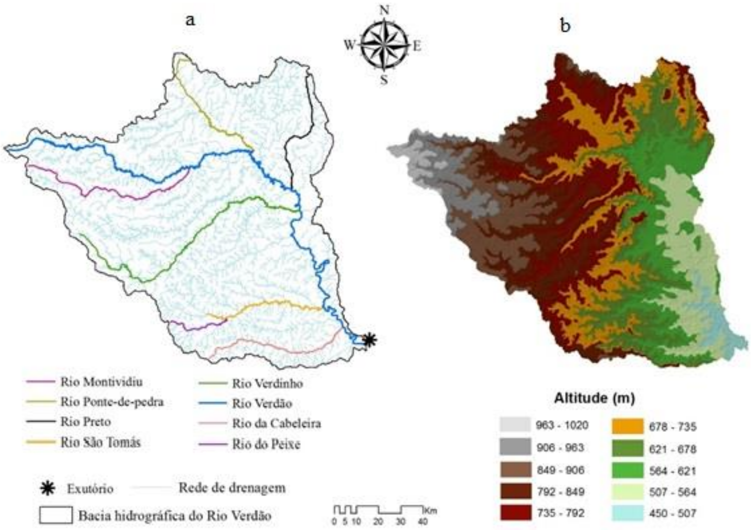
The Montividiu, Ponte de Pedra, Preto, São Tomás, Verdinho, Cabeleira and Peixe rivers form the Verdão River (Figure 2a). Its source is located in the municipality of Caiapônia, at an altitude of 1,020 m (Figure 2b). It runs for 406.3 km until its confluence with the Rio dos Bois, at an altitude of 450 m, the basin's mouth, to form the Paranaíba River.

Figure 1. Municipalities covered by the Verdão River basin , southwestern region of the state of Goiás.



Source: The authors (2020).

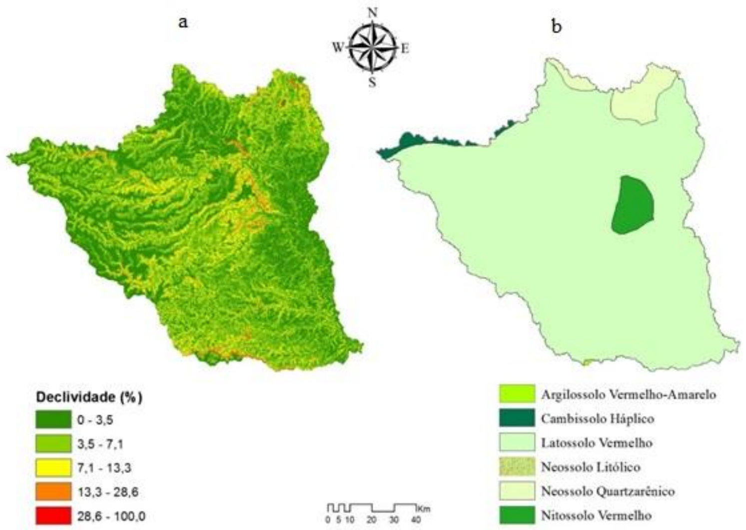
Figure 2. Drainage network and altitudes of the Verdão River basin , southwestern region of the state of Goiás.



Source: The authors (2020).

The average slope of the BHRV is 4.3%, with a standard deviation of 3.7%. The area with the greatest slope is concentrated in the municipality of Rio Verde, where the soil is classified as Red Nitosol (Figure 3a). The BHRV is predominantly Red Latosol (91.78%), is suitable for irrigation due to its deep and porous soils, and includes Red–Yellow Argisol (0.05%) and Cambisol (0.05%). Haplic (1.09%), Neosol Litholic (0.02%), Neosol Quartzsand (4.27%) and Red Nitosol (2.79%; Figure 3b).

Figure 3. Slope and soil type of the Verdão River basin , southwestern region of the state of Goiás.



Source: The authors (2020).

The slope levels for the subbasins with concessions were evaluated according to Moreira (2018), highlighting the slope of the terrain and the degree of limitation it provides to the irrigation systems (Table 1).

Table 1. Classification, level of terrain slope and degree of limitation to irrigation systems.

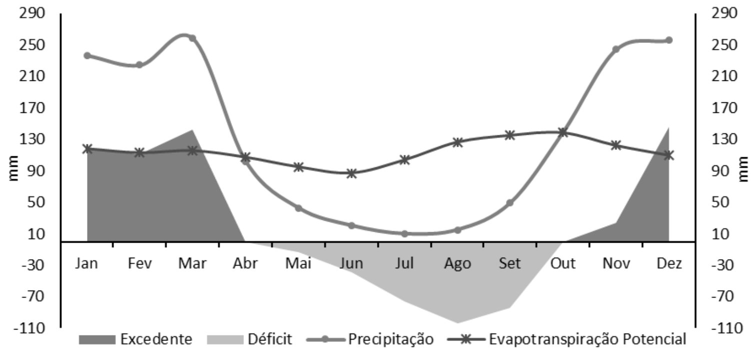
Classification	Slope	Degree of limitation
Flat	0 and 3%	Null
Soft wavy	3 and 6%	Light
Wavy	6 and 12%	Moderate
Strong wavy	12 and 20%	Strong
Mountainous	> 20%	Very strong

Source: Moreira (2018).

The climate in BHRV, according to the Köppen climate classification, is type Aw (LOPES SOBRINHO et al., 2020), which is characterized by a hot tropical climate in all seasons of the year, with an average monthly temperature greater than or equal to 18°C and a dry winter. According to Castro and Santos (2017), the average daily potential evapotranspiration (ETo) via the standard *Penman–Monteith (PM)* method is 3.8 mm, which is based on historical data for the municipality of Rio Verde and ranges from 2.9 mm day $^{-1}$ (June) to 4.5 mm day $^{-1}$ (September and October).

The dry season for the municipality of Rio Verde is from April to September, with a water deficit of 317 mm year $^{-1}$ (Figure 4), and from October to March, the rainy season, with an average water surplus of 543 mm year $^{-1}$ (CASTRO; SANTOS, 2017; CASTRO; SANTOS, 2021).

Figure 4. Extract of the normal climatological water balance, precipitation and average potential evapotranspiration for the municipality of Rio Verde, Goiás, from 1972--



2016 .
Source: Castro and Santos (2017).

The strips of permanent preservation areas (APPs) were defined according to the average width of the watercourses, characterized as streams, rivers and creeks, with their APP strips delimited at 30, 50 and 100 m, respectively.

The springs and dams, whether natural or not, delimited the APP strip in accordance with the Forest Code - Law 12.651/2012 at 50 m.

The grants used in this study are for direct surface capture and are active with the State Secretariat for the Environment and Sustainable Development of the State of Goiás (SEMAD) in February 2019, from which the geographic coordinates, flow and validity of each grant were made available.

The permanence flow (Q95%; Equation 01) was determined from the product of the basin area and the specific flow of the region defined by Normative Instruction No. 004/2015, of July 31, 2015, where the Verdão River basin is located, at 4.53 L s $^{-1}$ km $^{-2}$. The available flow was determined by the difference between the permanence flow and the granted flow (Equation 2). The potential irrigable area (PAI) was determined from the available grantable flow (Equation 03) and the average water demand of the region (ETo).

$$Q95\% = (Ad \times Qesp) \times 86400 \quad (1)$$

$$Qdisp = Q95\% - Qout \quad (2)$$

$$PAI = \frac{Qdisp}{ETo}\, x\, 10^{-4} \quad (3)$$

where Q95% is the flow rate with 95% permanence in time (L d $^{-1}$); Ad is the drainage area (km²); Qesp is the specific flow rate, fixed at 4.53 L s $^{-1}$ km²; Qdisp is the grantable flow rate in the basin section (L d $^{-1}$); Qout is the granted flow rate (L d $^{-1}$); PAI is the potential irrigated area (ha); and ETo is the potential evapotranspiration, fixed at 3.8 mm day $^{-1}$ (CASTRO; SANTOS, 2017).

The abstractions were ordered from upstream to downstream in reference to the Verdão River. The flows abstracted upstream of each authorized point were added by subbasin and in their entirety for direct abstraction from the Verdão River.

The basin commitment indicator was calculated via Equation 04, according to the Secretariat of Environment and Water Resources (2012).

$$I = \left[\frac{(Quso+Qmont)}{Qdisp}\right] x\; 100 \quad (4)$$

where I is the basin commitment indicator (%); Quso is the user's individual catchment flow rate (L s $^{-1}$); and Qmont is the sum of the catchment flows of all upstream users (L s $^{-1}$).

The procedures regarding the decision on the grant request by SEMAD are different for each situation in the basin and are based on its commitment indicator, which is classified according to Table 2.

Table 2. Classification of the indications of hydrographic basin compromise.

Classification	Values
Normal	I < 50%
Alert	50% < I < 80%
Moderately critical	80% < I < 100%
Highly critical	I > 100%

Source: SEMARH (2012).

The processing of the georeferenced data was carried out *with ArcGis 10.5 software. The raster* image used to create the vectorized layers was extracted from the Brazilian Geomorphometric Database (TOPODATA), and the vectorization was performed in a plane coordinate system (Sirgas 2000).

software database *ArcGIS*. Consolidated areas without buildings were defined as suitable for irrigation, and areas designated for permanent preservation areas (APPs), native vegetation, buildings, urban perimeters, dams, and mining were classified as nonirrigable.

5 RESULTS AND DISCUSSION

In addition to the Verdão River, the BHRV is composed of 16 other hydrographic subbasins (SHs). The hydrographic basin has 156 granted direct intakes, 19.2% of which are in the Verdão River itself, with a flow rate of 3.9 thousand L s $^{-1}$ (Table 3). The SH of the Montividiu River has the highest intake (13.5%), and the SHs of the Cachoeirinha, Formosa, Barra, and Boa Esperança streams have the lowest rates (0.7%).

Water extraction in the BHRV is concentrated in the northern, southern, and western regions. The watershed with the largest authorized volume per abstraction is the Rio Verdinho SH, with 241.78 L s $^{-1}$ per abstraction, and the lowest volume was found in the Córrego da Boa Esperança SH, with 15 L s $^{-1}$ per abstraction. This variation may be due to the low adoption of irrigation systems or the available authorized flow, which is a function of the area of influence up to the point of abstraction.

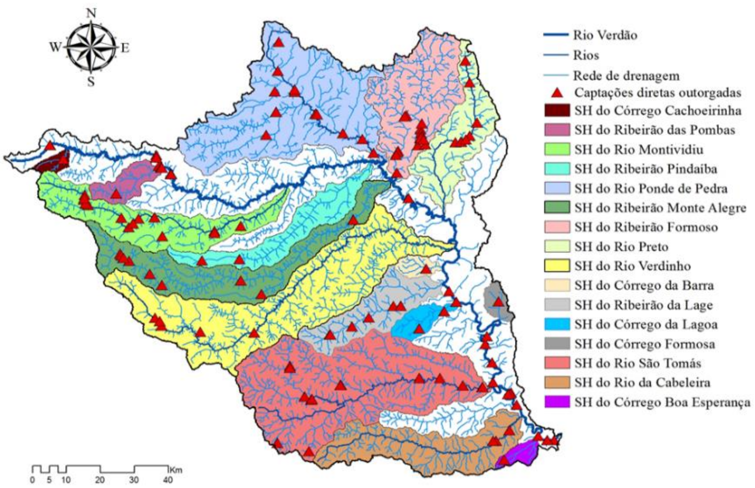
Table 3. Flow captured, total area and direct captures granted in the Verdão River basin , southwest region of the state of Goiás.

Direct funding granted	Captured flow (L s $^{-1}$)	Total area km ^{2}	Collections points
SH of Cachoeirinha Stream	42.0	45.4	1
SH of Ribeirão das Pombas	269.6	148.6	4
SH of the Montividiu River	1,097.2	694.9	21
SH of the São Thomas River	1,054.6	1,722.1	18
SH of Rio Verdinho	1,208.9	1,631.1	5
SH of the Stone Bridge River	2,442.0	1,499.9	17
SH of Ribeirão Monte Alegre	1,119.2	835.2	14
SH of Ribeirão Formoso	935.0	787.2	16
SH of Rio da Cabeleira	704.7	681.4	5
SH of Rio Preto	550.0	524.3	8
SH of Ribeirão da Lage	884.3	442.3	9
SH of Ribeirão Pindaíba	131.2	431.2	3
SH of Lagoa Stream	72.0	114.5	2
SH of Formosa Stream	13.8	78.4	1
SH of Barra Stream	22.2	69.5	1
SH of the Good Hope Stream	15.0	64.1	1
Verdão River	3,886.4	12,912.0	30
Verdão River Basin	14,448.1	12,912.0	156

SH: Hydrographic subbasin. Source: The authors (2020).

Among the SHs, the São Tomás River is the largest drainage area (13.3%), followed by the SHs of the Verdinho River (12.6%) and Ponte de Pedra River (11.6%), and the smallest SH is that of the Cachoeirinha Stream (0.4%). The SHs of the Ponte de Pedra River, Ribeirão Formoso, Rio Preto and Córrego Formosa, are located on the left bank of the BHRV, corresponding to 27% of the intakes and 22.4% of the total area of the basin, representing a greater number of intakes per area in relation to the other SH on the right bank (Figure 5).

Figure 5. Locations of hydrographic subbasins (SHs), with active grants, of the Verdão River hydrographic basin , southwestern region of the state of Goiás.

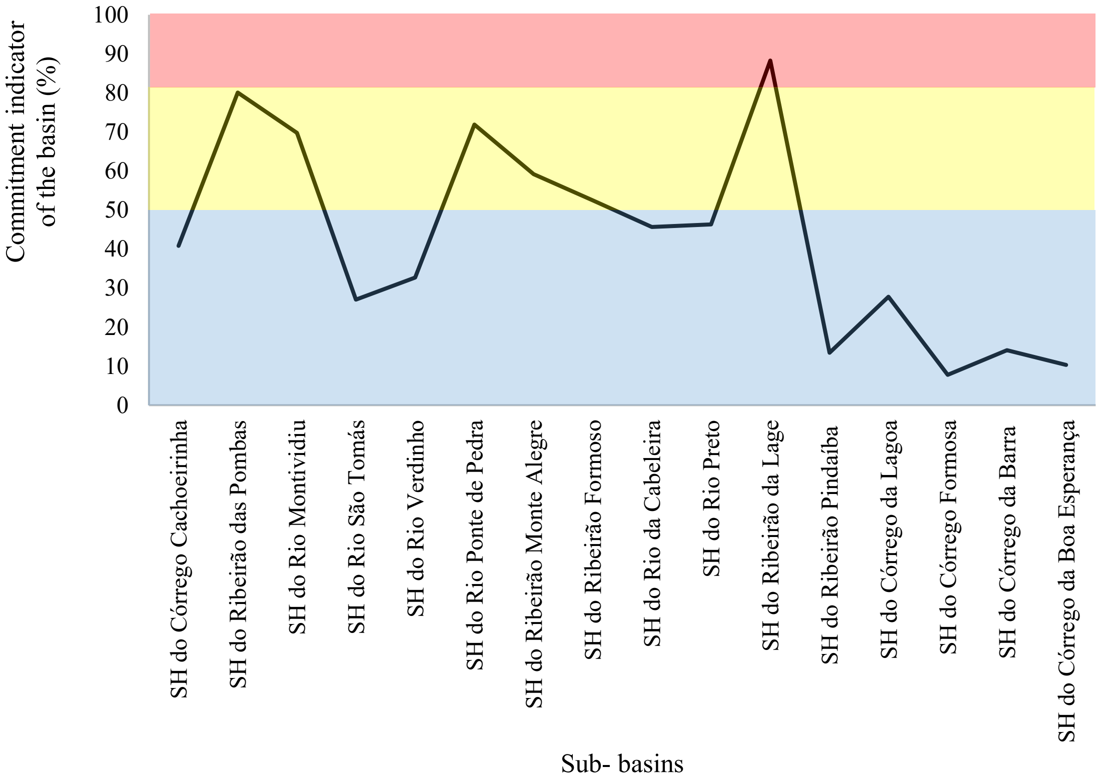


Source: The authors (2020).

The use of water collected at BHRV totals 14,448.1 L s $^{-1}$ and is intended for four activities, irrigation (61%), pumping (31%), public supply (7%) and fish farming (1%), with flows of 8,687.3, 4,905, 854.4 and 1.4 L s $^{-1}$, respectively.

The BHRV has 24.7% of its flow compromised, classified according to the indication of compromise as a normal condition (Table 2), which is very favorable for new grant requests. Analyzed by the SH, the same occurs with the SH of the Cachoeirinha Stream, the São Tomás River, the Verdinho River, the Cabeleira River, the Preto River, the Pindaíba Stream, the Lagoa Stream, the Formosa Stream, the Barra Stream and the Boa Esperança Stream. The SHs of the Montividiu River, the Ponte de Pedra River, the Monte Alegre Stream and the Formoso Stream are in a state of alert, and the SHs of the Lage Stream and Pombas Stream have the greatest compromises, 88.3% and 80.1% (Figure 6), respectively, classified as moderately critical favorable opinions for the grant.

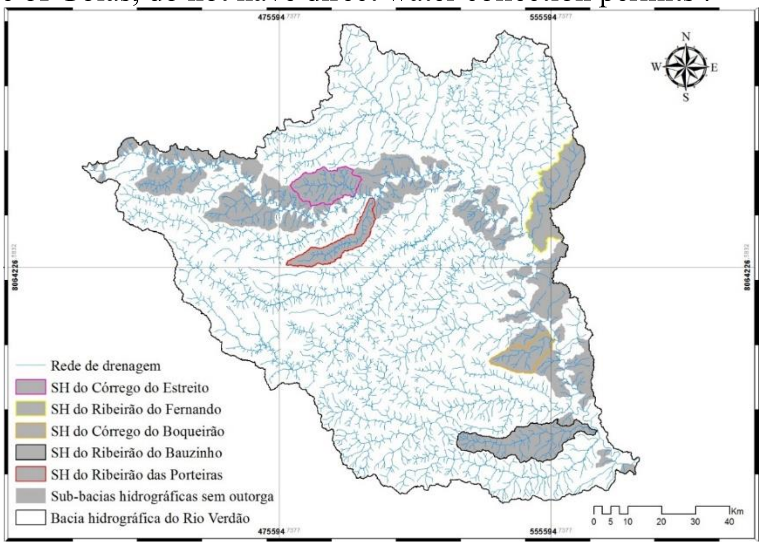
Figure 6. Indicator of impairment of the hydrographic subbasins (SH) of the Verdão River , southwestern region of the state of Goiás.



Source: The authors (2020).

Analyzing only the smaller SHs, without a defined main channel, which are tributaries of the Verdão River as its main channel (SH Rio Verdão), there are 125 SHs that have no water users, that is, no direct abstraction (Figure 7). This area accounts for 481 watercourses, totaling 1,240 km in length, the largest of which is the Ribeirão do Bauzinho, at 51.7 km, followed by the Ribeirões do Fernando and Ribeirões das Porteiras, at 39.3 and 34.5 km, respectively. The drainage area of the SHs without water abstraction is 2,420 km², with 4% of the SHs over 100 km², 7.2% between 30 and 99 km², and 88.8% with areas smaller than 30 km².

Figure 7. The subbasins (SH) of the Verdão River, which is located in the southwest region of the state of Goiás, do not have direct water collection permits .



Source: The authors (2020).

The SHs without concession points total a drainage area (AD) of 2,400 km², with a PAI corresponding to 0.5% of this area. Among the 125 SHs, those with the highest PAI are the Bauzinho and Fernando streams, with 1,337.7 and 1,366.3 ha, respectively. These SHs have concessions available at any point in the SH. Depending on the size of the AD, 100% of the available flow is available; the opposite occurs with the SHs that already have concession points, which require prior analysis of whether water availability is downstream or upstream of existing intakes.

The Verdão River (main channel), which gives the name BHRV, is the source with the highest water demand. Of the total flow captured by the BHRV, 26.9% is directly from the Verdão River. However, there is still water availability with the potential to irrigate an area of approximately 33,898 ha (Table 4), representing 2.6% of its total area, with water use concentrated in irrigation areas. The Verdão River has 30 direct abstraction points, with a total withdrawal of 3,886.4 L s^{-1}.

The BHRV has an irrigable area of 1,012,100 ha, and the potential irrigable area corresponds to 3.3% of this area (33,600 ha). The intake points are distributed along the river course (Figure 8), with the highest flow at points 189 and 42 (500 L s^{-1}), approximately 343 km from the source. The areas unfavorable for the implementation of irrigation systems in the basin total 279,100 ha.

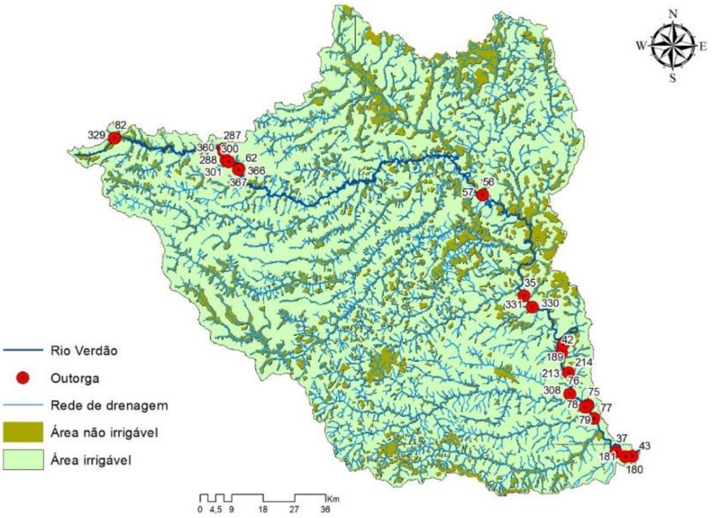
Table 4. Basin area, flow rates and irrigable potential of the Verdão River , southwestern region of the state of Goiás.

MC	P	Ab	Q95%	Q50%	Qc	Qm	Qo	Q	PAI
		km²			L s⁻¹			m³ dia⁻¹	ha
Rio Verdão	329	67,9	307,8	153,9	15,0	0,0	138,9	12.000	316
	82	68,0	307,8	153,9	120,0	15,0	18,9	1.634	43
	287	427,7	1.937	968,7	195,0	177,0	596,7	51.556	1.356
	360	429,1	1.944	971,8	98,3	372,0	501,6	43.335	1.104
	361	429,1	1.944	971,8	40,7	470,3	460,9	39.819	1.047
	288	438,2	1.985	992,6	200,0	511,0	281,6	24.332	640
	300	439,5	1.991	995,6	160,0	711,0	124,6	10.764	283
	301	439,5	1.991	995,6	28,0	871,0	96,6	8.345	220
	62	627,5	2.842	1.421	64,7	1.168	188,0	16.243	427
	366	628,8	2.849	1.421	46,9	1.233	144,2	12.456	328
	367	628,8	2.849	1.421	64,6	1.280	79,6	6.877	181
	56	6.018	27.261	13.631	25,0	7.069	6.536	564.746	14.861
	57	6.018	27.261	13.631	87,0	7.094	6.449	557.229	14.664
	55	9.284	42.058	21.029	202,0	9.847	10.980	948.690	24.965
	330	9.341	42.313	21.157	111,6	10.049	10.996	950.078	25.002
	331	9.341	42.313	21.157	55,4	10.160	10.941	945.289	24.876
	189	9.828	44.521	22.260	500,0	10.302	11.459	990.040	26.054
	42	9.871	44.717	22.359	500,0	10.802	10.057	955.312	25.140
	213	9.950	45.072	22.536	145,0	11.302	11.090	958.148	25.214
	214	9.950	45.072	22.536	125,0	11.447	10.965	947.647	24.930
	76	10.016	45.375	22.687	94,6	11.572	11.021	952.216	25.058
	308	10.016	45.375	22.687	124,6	11.666	10.896	941.455	24.775
	75	11.795	53.430	26.715	112,9	12.845	13.757	1.188,590	31.279
	78	11.795	56.433	26.716	113,8	12.958	13.644	1.178,867	31.023
	79	11.796	53.436	26.718	124,0	13.072	13.522	1.168.284	30.744
	77	11.817	53.532	26.766	136,7	13.196	13.433	1.160.638	30.543
	37	12.808	58.019	29.009	129,4	14.037	14.843	1.282.399	33.747
	180	12.888	58.381	29.190	116,0	14.052	15.022	1.297.888	34.155
	181	12.888	58.381	29.190	130,0	14.168	14.892	1.286.656	33.859
	43	12.904	58.446	29.228	20,4	14.298	14.909	1.288.136	33.898
Total		-	-	-	3.886,4	-	-	-	-

MC: Catchment source; P: Point; Ab: Basin area; $Q_{95\%}$: Flow with 95% permanence in time; $Q_{50\%}$: 50% of the $Q_{95\%}$ flow; Qc: Captured flow; Qm: Upstream flow; Qo: Grantable flow; Q: Flow; PAI: Potential irrigable area. **Source:** The authors (2020).

BHRV has water availability to irrigate 33.5% of the area suitable for the implementation of irrigation systems distributed throughout its entire length, except in basins that presented impairment rates above 50% (alert to highly critical status).

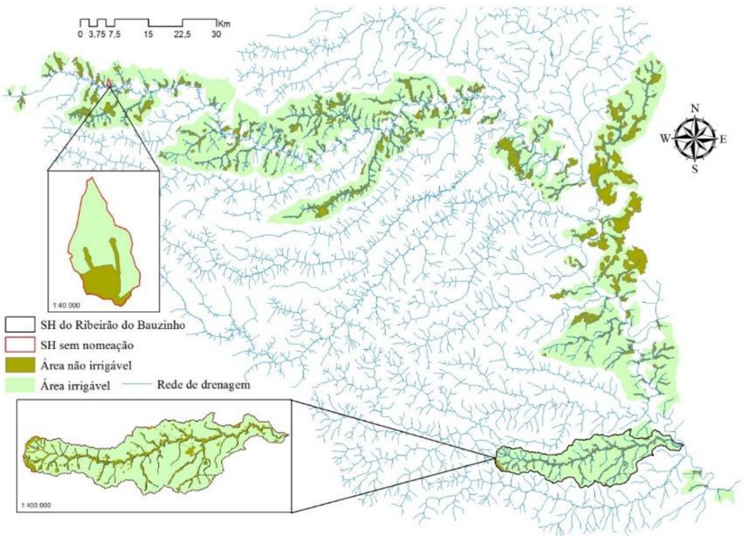
Figure 8. Catchment points on the Verdão River and irrigable and nonirrigable areas of the Verdão River basin , southwest region of the state of Goiás.



Source: The authors (2020).

In the Verdão River alone, the AI of unlicensed SHs is 193,800 ha (Figure 9), and the available flow allows for the irrigation of 6.4% of this area (12,400 ha). The ANI comprises 47.7 ha, 19.8% of the unlicensed SHs. The smallest (no known designation) and the largest (Ribeirão do Bauzinho) ungranted SHs have 1,300 ha and 265,300 ha of Ad, respectively. The PAI of the smallest SH corresponds to 73.1% of its AI, and that of Ribeirão do Bauzinho corresponds to 86.3%.

Figure 9. Irrigable and nonirrigable areas of the hydrographic subbasins (SH) of the Verdão River, southwestern region of the state of Goiás, which do not have direct abstraction permits.



Source: The authors (2020).

The largest drainage areas belong to the SHs of the São Tomás (13.3%), Verdinho (12.6%) and Ponte de Pedra (11.6%) Rivers, with water availability rates of 2,846, 2,485.8 and 955.2 L s $^{-1}$, respectively.

The municipalities that comprise the BHRV are major references in agriculture; thus, with the implementation of efficient irrigation systems, the potential tends to grow in terms of productivity and job creation and, consequently, the gross domestic product (GDP) of the municipalities.

Considering only irrigation systems in use, the current demand for jobs is 39,500, and the basins that already have permits can expand by up to 19,830 hectares (Table 5), in addition to the available flow from other basins, reaching a growth of up to 33,898 hectares. Considering the SHs that do not yet have irrigation systems, in this area alone, an additional 50,467 people would be needed, who would boost the local economy through housing, food, and transportation, among other services, in addition to producing wealth in the region. It is estimated that Brazilian irrigated agriculture is responsible for 1.4 million direct jobs and 2.8 million indirect jobs. According to Lima, Ferreira, and Christofidis (1999), each irrigated hectare generates approximately 1.5 jobs.

Table 5. Potential for irrigable area and job creation for the Verdão River basin , southwest region of the state of Goiás.

Granted hydrographic subbasins	FATHER (ha)	Jobs (people)
SH of Cachoeirinha Stream	138.3	207
SH of Ribeirão das Pombas	152.5	229
SH of the Montividiu River	1,083.9	1,626
SH of Ribeirão Pindaíba	1,922.3	2,884
SH of the Stone Bridge River	2,171.8	3,258
SH of Ribeirão Monte Alegre	1,756.7	2,635
SH of Ribeirão Formoso	1,927.6	2,891
SH of Rio Preto	1,449.4	2,174
SH of Rio Verdinho	5,652.0	8,478
SH of Barra Stream	307.5	461
SH of Ribeirão da Lage	267.0	400
SH of Lagoa Stream	425.7	639
SH of Formosa Stream	372.5	559
SH of the São Thomas River	6,470.9	9,706
SH of the Cabeleira River	1,906.7	2,860
SH of the Good Hope Stream	296.0	444
Total	19,830	39,451

PAI: Potential irrigated area. **Source:** The authors (2020).

The SHs of the São Tomás and Verdinho Rivers stand out in terms of job creation if the AIs are allocated to irrigated agriculture, which would lead to the growth of the surrounding municipalities (Table 6). The smallest basin, in relation to its Ad, the SH of the Córrego da Cachoeirinha, is capable of producing 207 more jobs with the use of irrigated agriculture throughout its PAI.

Irrigation must be carried out with the aim of increasing productivity and profit, respecting environmental limits, and for this to be effective, the quality of the water used in irrigation needs to be analyzed mainly by the total amount of dissolved salts and their ionic composition.

The collection points close to the mouths of the SHs require attention because of the possible poor quality of the water, which interferes with the efficiency of the irrigation system (ANA, 2015).

In agreement with Xavier et al. (2021), spatial analysis tools through GIS have proven to be efficient in manipulating and integrating data used to identify and quantify areas suitable for the implementation of irrigation systems and may constitute a viable alternative for studies on irrigation suitability.

The expansion of irrigated agriculture will foster off-season production, increasing commercial value by filling the region's six-month water shortage period. Furthermore, it will generate jobs and income in the region. However, these requests must be analyzed in advance to determine whether specific points in the SH still have water availability or whether they are upstream or downstream of the point analyzed in this study, depending on the validity, renewal, and issuance of new permits.

Therefore, the potential for expanding irrigated areas must be observed with caution and is useful for planning the Verdão River basin; however, the use of groundwater and damming must be analyzed, which were not accounted for through the methodology used.

6 CONCLUSION

BHRV has water resources available to irrigate 33.5% of the area suitable for irrigation systems distributed throughout its entirety, except in basins that presented impairment rates above 50%. The basin's total irrigable area potential is 33,898 hectares, potentially generating approximately 50,400 jobs and income in the region.

7 ACKNOWLEDGMENTS

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