GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709
https://doi.org/10.47456/geo.v3i37.41491

Water poverty index of municipalities in the State of Tocantins, Brazil[1]

Índice de pobreza hídrica dos municípios no estado do Tocantins, Brasil

Índice de pobreza hídrica de los municipios del estado de Tocantins, Brasil

Indice de pauvreté en eau des municipalités de L'état du Tocantins, Brésil

ABSTRACT

Water scarcity is a prevalent issue in Brazil, and it is crucial to analyze it at the state level, such as in the case of Tocantins state This study aims to determine and analyze the conditions of water scarcity in 139 municipalities in Tocantins. Due to the diverse range of information included in this indicator, the values for each subcomponent were normalized using the maximum and minimum values based on the spatial scale. This allowed for a comparative analysis. The weights assigned to the components comprising this index were 1 for resource, access, and capacity, and 0.5 for the use component. These weights were applied in the equation that represents the water poverty index. According to the scale, which ranges from 0 for the most critical situation to 1 for excellent condition, most municipalities in Tocantins, as well as the average of this index for the state, are classified as good. The municipalities with the best conditions were Palmas (0.70), Porto Nacional (0.65), Miracema, and Pedro Afonso (0.63), and Paraíso do Tocantins (0.61), all located in the central portion of the state. On the other hand, municipalities with a high critical index were Praia Norte (0.29), Juarina (0.28), Aragominas (0.27), Piraquê (0.24), and Riachinho (0.22), located in the northern part of the state. The obtained result should not be interpreted as an abundance of water resources, but rather as a favorable combination of factors that enable favorable conditions for resources, access, capacity, utilization, and the environment.

KEYWORDS: spatial analysis; hydrological-socioeconomic condition; water management; Tocantins; Brazil.

RESUMO

A deficiência hídrica é uma questão presente no território brasileiro, sendo que, diante de sua distribuição irregular, a análise por estado relevante, tal como para o Estado do Tocantins. Assim, este trabalho visa determinar e analisar as condições de pobreza hídrica de 139 municípios tocantinense. Devido à diversidade de informações dos componentes que constituem este indicador, os valores obtidos em cada subcomponente foram normalizados, adotando-se valores máximos e mínimos de acordo com a escala espacial, permitindo assim realizar uma análise comparativa. O peso atribuído para os

1. *Article originated from doctoral thesis research funded by the Federal Institute of Education, Science and Technology of Tocantins through the Pro-qualify Program, Notice No. 17/REI/IFTO of 2020.*

Virgílio Lourenço Silva Neto
Instituto Federal de Educação, Ciência e Tecnologia do Tocantins
virgilio.neto@ifto.edu.br

Lucas Barbosa e Souza
Universidade Federal do Tocantins
lbsgeo@uft.edu.br

Marco Antonio Vieira Morais
Instituto Federal de Educação, Ciência e Tecnologia do Mato Grosso
marco.morais@ifmt.edu.br

Received:
06/15/2023
Accepted:
10/03/2023
Available online:
12/01/2023

componentes que compõem este índice foi de 1 para recurso, acesso, capacidade, e de 0,5 para o componente uso, aplicados na equação que representa o índice de pobreza hídrica. Conforme a escala, que parte de 0 para a situação mais crítica e atinge 1 para a condição excelente, a maior parte dos municípios tocantinenses, assim como a média deste índice para o estado do Tocantins é classificado como bom. Os municípios com as melhores condições foram Palmas (0,70), Porto Nacional (0,65), Miracema e Pedro Afonso (0,63) e Paraíso do Tocantins (0,61), todos na porção central do estado. Já os municípios que apresentaram este índice classificado como crítico foram Praia Norte (0,29), Juarina (0,28), Aragominas (0,27), Piraquê (0,24) e Riachinho (0,22), localizados na parte norte do Estado. O resultado obtido não pode ser interpretado como abundância de recursos hídricos, mas como uma combinação favorável de fatores que permite boas condições no que se refere aos recursos, acessos, capacidades, usos e meio ambiente.
PALAVRAS-CHAVE: análise espacial; condição hidrológica-socioeconômica; gestão da água; Tocantins; Brasil.

RESUMEN

La deficiencia hídrica es un problema presente en el territorio brasileño y, dada su distribución irregular, el análisis por estados es relevante, como por ejemplo para el estado de Tocantins. Este trabajo tiene como objetivo determinar y analizar las condiciones de pobreza hídrica de 139 municipios de Tocantins. Debido a la diversidad de información de los componentes que constituyen este indicador, se normalizaron los valores obtenidos en cada subcomponente, adoptando valores máximos y mínimos según la escala espacial, permitiendo así un análisis comparativo. El peso atribuido a los componentes que integran este índice fue de 1 para el componente recurso, acceso, capacidad y 0,5 para el componente uso, aplicado en la ecuación que representa el índice de pobreza hídrica. Según la escala, que parte de 0 para la situación más crítica y llega a 1 para el estado excelente, la mayoría de los municipios de Tocantins, así como la media de este índice para el estado de Tocantins, se clasifican como buenos. Sin embargo, este resultado no puede interpretarse como una abundancia de recursos hídricos, sino como una combinación favorable de factores que permite buenas condiciones en términos de recursos, acceso, capacidades, usos y medio ambiente. Los municipios con mejores condiciones fueron Palmas (0,70), Porto Nacional (0,65), Miracema y Pedro Afonso (0,63) y Paraíso do Tocantins (0,61), todos en la parte central del estado. Los municipios que presentaron este índice clasificado como crítico fueron Praia Norte (0,29), Juarina (0,28), Aragominas (0,27), Piraquê (0,24) y Riachinho (0,22), ubicados en el interior del estado.
PALABRAS-CLAVE: análisis espacial; condición hidrológico-socioeconómica; gestión del Agua; Tocantins; Brasil.

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

RÉSUMÉ

L'objectif de cette étude est de déterminer l'indice de pauvreté en eau des 139 communes de l'état du Tocantins, au Brésil, en visant la spatialisation de chaque composante et la représentation de cet indice, afin d'analyser les conditions des communes en termes de ressources en eau dans différents régions de l'état du Tocantins. En raison de la diversité des informations des composants qui constituent cet indicateur, les valeurs obtenues dans chaque sous-composant ont été normalisées, en adoptant des valeurs maximales et minimales en fonction de l'échelle spatiale, permettant ainsi une analyse comparative. Le poids attribué aux composantes qui composent cet indice était de 1 pour la ressource, l'accès, la capacité et de 0,5 pour la composante utilisation, appliqués dans l'équation qui représente l'indice de pauvreté en eau. Selon l'échelle, qui part de 0 pour la situation la plus critique et atteint 1 pour l'état excellent, la plupart des communes du Tocantins, ainsi que la moyenne de cet indice pour l'état du Tocantins, sont classées comme étant bonnes. Cependant, ce résultat ne peut être interprété comme une abondance de ressources en eau, mais comme une combinaison favorable de facteurs qui permet de bonnes conditions en termes de ressources, d'accès, de capacités, d'usages et d'environnement. Les municipalités avec les meilleures conditions étaient Palmas (0,70), Porto Nacional (0,65), Miracema et Pedro Afonso (0,63) et Paraíso do Tocantins (0,61), toutes dans la partie centrale de l'État. Les municipalités qui ont présenté cet indice classé comme critique sont Praia Norte (0,29), Juarina (0,28), Aragominas (0,27), Piraquê (0,24) et Riachinho (0,22), situées dans le nord de l'État.

MOTS-CLÉS : analyse spatiale ; condition hydrologique et socio-économique ; gestion de l'eau ; Tocantins ; Brésil.

INTRODUCTION

One of the most important and concerning themes for water resource planning and management revolves around the availability of water, regardless of its intended use. This is due to the increasing demand for water in recent decades and the expectation of further increases in demand in the near future (Santos, 2015).

Recognizing that water is a prerequisite for economic development, Sullivan (2002) asserts that although there is a vast literature focused on studying indicators that track environmental transformation and proposals for poverty alleviation, none specifically recognize the importance of water for all forms of life. According to the author, without sufficient and effective resources, specifically in areas where water scarcity is prevalent, any efforts to alleviate poverty will not be successful.

Although Tocantins has a significant abundance of water resources, the availability and access to these resources for the population in various municipalities are uneven throughout the entire extent of the Tocantins territory. This uneven distribution has a peculiar impact on the population of municipalities in different regions of the state. In a reflection on the paradox of water in the Brazilian Amazon, for example, Bordalo (2017) asserts that there is no crisis of freshwater availability, but rather a crisis of unequal access to drinkable water.

The Water Poverty Index (WPI) is an alternative tool that aims to provide a comprehensive understanding of the relationship between water resources and human development. It considers physical, social, and economic aspects to describe this relationship. The WPI can be used to diagnose the socio-economic conditions of municipalities in Tocantins about water supply. Additionally, it can assist in the planning and management of this vital resource. It "analyzes the extent of water poverty in a region provides managers with a comprehensive understanding of the issues associated with this context, enabling effective water management." (MORAIS et al., 2019, p. 29).

The WPI has been used in 147 countries, and its validation took place in 12 pilot areas in countries including South Africa, Tanzania, and Sri Lanka, addressing both urban and rural communities. In a global context, Luna (2007) identified strengths and weaknesses in water resources in various locations.

The concept of poverty considered here is based on the study conducted by Desai (1995), which defines poverty as a condition resulting from a lack of capability, stemming from the deprivation of essential conditions necessary for a life with met basic needs. In this sense, Sullivan et al. (2003) assert that limited water availability is directly related to health, as it affects personal hygiene and food production efficiency.

Crispim (2015) analyzed the water situation in rural communities in the municipality of Pombal,

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

in the State of Paraíba. The study determined the Water Poverty Index (WPI) for 14 communities, utilizing 21 subcomponents and 61 indicators that encompassed the 5 main components. Adapting the procedures used in this study, Brito et al. (2020) assessed the access and use of water on Cotijuba Island, located in the municipality of Belém-PA, to determine the local Water Poverty Index (WPI).

In Tocantins, Morais et al. (2019) determined the WPI for two cities in the southeast of the State: Aurora do Tocantins and Paranã. The authors describe the challenge of obtaining information on water demand, which led them to only consider per capita water availability (m³ hab-1 $^{\text{year-1}}$) in the resource category. As a result, the sample size representing this index is small.

Sullivan et al. (2003) state that the WPI integrates information on water resources, access, usage, social and economic capacity, and environmental quality. This index is used by local communities and water development agencies to track advancements in water supply.

It is important to note that the WPI results from the simple or weighted average of the components: resource (R), access (A), capacity (C), use (U), and environment (MA) (Torres & Álvares, 2020).

Morais et al. (2019) state that

> The evidence presented through the construction of these categories enables managers to identify problems directly or indirectly related to water scarcity. It can establish connections between poverty, social exclusion, environmental integrity, health, and water availability, and formulate public policies that facilitate appropriate mitigation measures to address water scarcity (MORAIS et al., 2019, p. 29).

In light of the above, the objective of this study is to determine the WPI for the 139 municipalities in Tocantins. The aim is to spatialize each component and represent the WPI. This will enable the analysis of water resources and socioeconomic factors in different regions of the state of Tocantins, specifically focusing on the conditions of the municipalities.

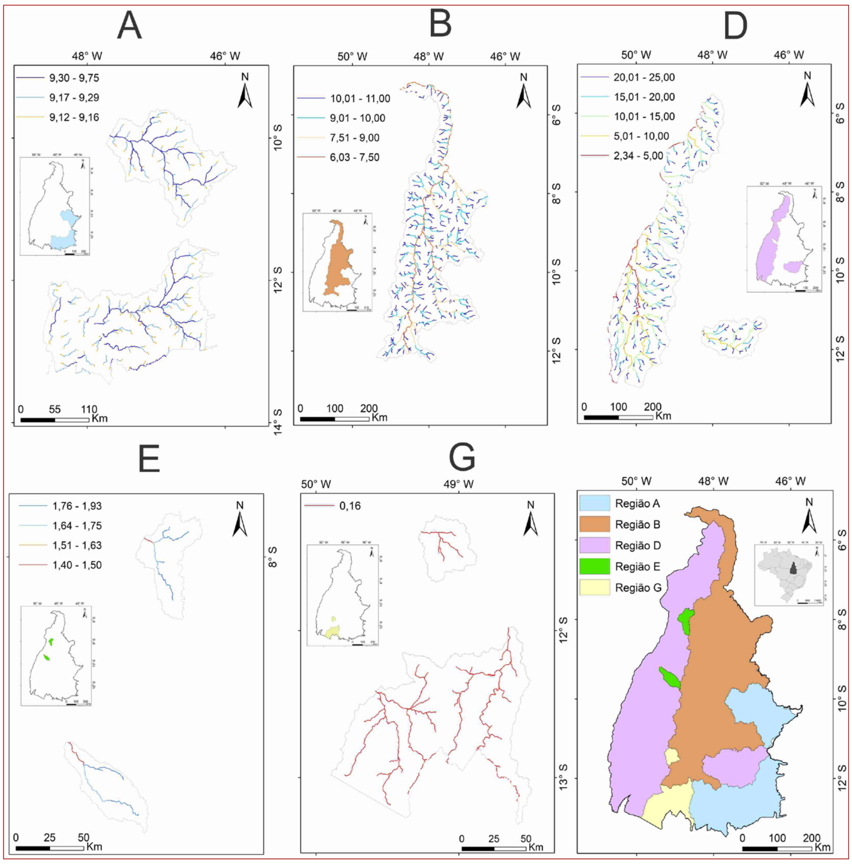
METHODOLOGY

LOCATION AND CHARACTERIZATION OF THE STUDY AREA

The study was conducted considering all 139 municipalities in the state of Tocantins, located in the Northern Region of Brazil. These municipalities have coordinates between parallels 5º10’06” and 13º27’59” south latitude and meridians 45º44’46” and 50º44’33” west longitude. The state covers an area of 277,620.9 km² (SILVA NETO et al., 2020) and has an estimated population of 1,607,363 (IBGE, 2021).

According to Silva Neto et al. (2021), the majority of the accumulated precipitation in Tocantins occurs during the months of December to March, showing an increase in the southeast to northwest direction. In many ways, Tocantins proves to be an area of climatic transition, even when considering the air masses. (SILVA NETO et al., 2021. p. 12).

Figure 1. Representation of water resources through the regionalization of flows in the state of Tocantins based on RE_{90} in Ls^{-1} km^{-2}, covering the hydrographic regions A, B, C, D, E, and G



Source: Silva Neto (2023).

It is important to highlight that the entire western portion of Tocantins is influenced by various factors that generate abundant rainfall, such as the Equatorial Atlantic Mass (mEa), the South Atlantic Convergence Zone (ZCAS), the Continental Instability Lines (LICON), and the Upper-Level Cyclonic Vortex (VCAN). These factors are predominantly active between October and April (TOCANTINS, 2020, p. 55).

Viola et al. (2014) state that the rainfall regime in the state of Tocantins is characterized by different regions. In an extensive strip extending from the north of Bananal Island (southwest of the state) to the south of the Bico do Papagaio region, rainfall is evenly distributed throughout the year. However, in the southern and far northern regions, rainfall is more concentrated between December and March.

The water resources of Tocantins are represented by the Specific Yield, which is based on the reference flow of 90% (RE90) for the driest months of the year. (Figure 1).

METHODOLOGY

The present study adopted a qualitative-quantitative approach articulated through bibliographic research, using government websites, books, theses from national and foreign collections, and journal portals as sources, similar

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

to the procedure carried out by Morais et al. (2019).

The WPI was determined based on the methodology proposed by Sullivan et al. (2003), using a combination of five components (Table 1).

All the information encompassed by each component is important for characterizing the relationships between the population of each municipality and the environment in which they are situated (MARANHÃO, 2010). The database used in this study (Table 1) is an adaptation of studies conducted in various locations. For the specific case of Tocantins, there was a need to add or remove information recommended in the existing literature. This was necessary either because the information was not available for the municipalities of Tocantins or because it was specifically produced for this study (Silva Neto et al., 2021; Silva Neto, 2023).

The temporal scope considered in this study includes information from the years 2000 to 2014 for flow rates and from

Table 1. WPI components for the municipalities of Tocantins

Components	Definition	Data used (reference, year)
I Resource (R)	Physical availability of water, considering the variability and spatial distribution of water.	1. Precipitation in the dry season (Silva Neto et al., 2021). 2. Rainfall in the rainy season (Silva Neto et al., 2021). 3. Water production from RE_{90} in the dry season (Silva Neto, 2023). 4. Water production from RE_{90} in the dry season (Silva Neto, 2023);
II Access (A)	Level of access to water for human use. In this study, access to water also takes into account the human waste disposal system and the number of homes with treated sewage.	5. % of the population in households with piped water (IBGE, 2010; LEMOS, 2012). 6. % of the population in households with a bathroom or toilet and sanitary sewage (IBGE, 2010; LEMOS, 2012). 7. % of the population in households with garbage collection (IBGE, 2010; LEMOS, 2012).
III CAPACITY (C)	It pertains to the ability to effectively manage water resources, which enables access to health, education, and durable goods through water-related interactions. It is directly linked to the economic and social conditions of the resident communities.	8. Literacy rate of people aged 10 years or older (IBGE, 2010). 9. % of 18 years or older with complete elementary school (IBGE, 2010). 10. *Per capita* income (IPEA, 2015). 11. Infant mortality rate, up to 5 years of age (IBGE, 2010). 12. Gini Index (IPEA, 2015);
IV Use (U)	It considers the efficiency of water resource utilization in various sectors, including domestic use, agriculture, and industry.	13. Human consumption flow (urban and rural) in Ls^{-1} (ANA, 2019). 14. Water consumption *per capita*/day, (SNIS, 2021). 15. Irrigated area (ha) (ANA 2019). 16. Livestock expressed by the cattle herd (LAPIG, 2022). 17. Consumption flow for animal watering in Ls^{-1} (ANA, 2021). 18. Consumption flow of the manufacturing industry Ls^{-1} (ANA, 2021).
V Environment (MA)	Assessment of environmental integrity in relation to water and agricultural productivity and the sustainable use of natural resources.	19. % native forest in relation to the total area (LAPIG, 2022). 20. Support capacity, (LAPIG, 2022).

Source: Adapted from Sullivan et al. (2003); Maranhão (2010); Torres and Álvares (2020).

1988 to 2019 for precipitation (component R). For the remaining components, the gathered information pertains to the period from 2000 to 2019.

Due to the diverse range of information for each component that makes up the IPH, the values obtained for each subcomponent were normalized using Equation 1. This involved adopting maximum and minimum values based on the spatial scale. This allows for a comparative analysis (Morais et al., 2019).

$$(1)\ In = \frac{Va - Vmi}{Vma - Vmi}$$

In the equation, in represents the normalized index, Va is the value being analyzed, Vmi is the minimum value of the researched universe, and Vma is the maximum value of the researched universe. Based on the values obtained in this first step, we adopted the mathematical model originally developed by Sullivan et al. (2003), which consists of the median of the data quantifying the components. Both the original model and its simplified version are represented by Equations 2 and 3, respectively.

$$(2)\ IPH = \frac{\sum_{i=1}^{N} w_{X_i} X_i}{\sum_{i=1}^{N} w_{X_i}}$$

$$(3)\ Am = \frac{Vma - Vmi}{Qcl}$$

Where w is the weight assigned to the components used for generating the WPI, and X represents the value of each of the following components: R, A, C, U, and MA. In some studies, the value of the WPI may range from 0 to 100. In this study, however, it was adopted the scale from 0 to 1, as proposed by Sullivan et al. (2003) and Morais et al. (2019).

The weight assigned to the components that make up the WPI was 1 for R, A, C and MA, and 0.5 for component U (Equation 3). Initially, this study considered using the same weight for all components of the WPI in Tocantins, a procedure adopted in various studies such as Luna (2007), Maranhão (2010), and Morais et al. (2019). Nonetheless, according to Sullivan et al. (2003), this methodology allows for different weights and different components of the WPI to be used in different situations, adapting the index to the local needs and data availability.

Two aspects were considered in this study to justify assigning a different weight to component U, with a value corresponding to half the weight of the other components of the WPI. First, the study took into account the underdeveloped (and even non-existent) industrial transformation activity in many municipalities of Tocantins, which could distort the final result of the WPI. Second, the study considered that municipalities with an economic base concentrated on agribusiness (animal watering and irrigation) would have the values of this component overestimated within the observed context. Therefore, the decision was made to reduce the weight of this component compared to the others in the final composition of the index.

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

The component R used in this study does not consider water availability, but rather precipitation during two distinct periods: dry and rainy. The precipitation class values presented by Silva Neto et al. (2021) were converted into class intervals ranging from 0 to 1 using statistical amplitude (Equation 4). This conversion was based on an adaptation of the procedure adopted by Santos (2015) as shown in Table 2.

$$(4)\ Am = \frac{Vma - Vmi}{Qcl}$$

The fact that water availability (surface and groundwater) was not considered does not pose a limitation to the development of the study, as Sullivan et al. (2003) state that

> his approach has the advantage that the index can be calculated even when some of the data is not available. There is always the possibility that this may happen, and the flexibility in the methodology allows this issue to be overcome, although there may be some loss of strict comparability between different locations (SULLIVAN et al. 2003, p. 195). 2003, p. 195).

Table 2. Suitability of classes for the Precipitation attribute

Classification	Dry period		Rainy Season	
Grade	P (mm)	Assigned value	P (mm)	Assigned value
Critical	< 479	0,3	< 840	0,3
Poor	480 - 591	0,4	841 - 940	0,4
Good	592 - 645	0,6	941 - 1023	0,6
Very Good	646 - 700	0,8	1024 - 1104	0,8
Excellent	> 700	1	> 1105	1

Source: Adapted from Santos (2015) and Silva Neto (2023). Elaboration: the author.

Where Am is the statistical amplitude, Vma is the maximum value, Vmi is the minimum value, and Qcl is the number of adopted classes, which in this study corresponds to 5. Also, in the data treatment of component R, the water production was determined based on the area of the municipalities in Tocantins, using the flow regionalization functions described by Silva Neto (2023). These values were then normalized for the composition of the WPI.

Component A was determined based on information related to basic sanitation in each municipality where the population is located. It was calculated through normalized data on sanitation, considering the state scale for the maximum and minimum values of basic sanitation service coverage in the universe of the 139 municipalities in Tocantins.

Component C was obtained by normalizing data related to education, income, and infant mortality, thus characterizing the human development of each municipality. It is important to emphasize that infant mortality and the Gini index, due to their indirect relationships with the WPI, had their values determined (Equation 5) before the composition of the WPI.

$$(5)\ i = X^{-1}$$

Table 3. Score of the Environment category, based on the ranges of native vegetation cover

Native vegetation cover (%)	Score
> 75	5
54 – 75	4
32 – 54	3
15 – 32	2
< 15	1

Source: Adapted from Maranhão (2010); Morais et al. (2019). Org.: the author.

Where i is the information obtained for each municipality and X is the value obtained for the composition of the WPI.

Component U, in this study, encompasses the various forms of water resource utilization, based on the framework proposed by Sullivan et al. (2003). This component includes data on water used for human consumption, agricultural purposes, animal watering, and industrial use (including water consumed by the manufacturing industry).

Finally, component MA considers the proportion of native forest in the total area of the municipality (in hectares). The values were obtained from the compilation of mappings organized by the Image Processing and Geoprocessing Laboratory of the Federal University of Goiás (LAPIG/UFG). For the Amazon and Cerrado biomes, the data refers to the year 2012 (LAPIG, 2022).

Upon obtaining the information regarding the area of native vegetation cover (in ha), the percentage of this cover about the total area of each municipality was determined. From this data, a score ranging from 1 to 5 was applied for subsequent data normalization (Table 3), which is an adaptation from the studies of Maranhão (2010) and Morais et al. (2019).

Regarding the MA component, since the information originally proposed by Sullivan et al. (2003), such as reports of crop losses in the last 5 years or reports of soil losses, were not available, another variable was considered: carrying capacity. Carrying capacity is expressed in terms of the maximum number of animals supported by pasture without causing its degradation

Table 4. Classification of the Water Poverty Index (WPI)

Grau	Classes
Crítico	0,00 ├ 0,30
Pobre	0,30 ├ 0,40
Bom	0,40 ├ 0,60
Muito Bom	0,60 ├ 0,90
Excelente	0,90 ├ 1,00

Source: Adapted from El-Gafy (2018); Morais et al. (2019). Org.: the author.

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

(in AU ha-1). These data were also obtained from LAPIG/UFG (LAPIG, 2022), but were produced by CSR/UFMG and LAGESA/UFMG. The data were then normalized.

The WPI of the municipalities in Tocantins was determined based on the class intervals shown in Table 4.

RESULTS AND DISCUSSION

The WPI values and the position were obtained according to the situation of each municipality of Tocantins (Table 5).

Considering the 139 municipalities in the state of Tocantins, Table 5 shows that 3.6% (5 municipalities) have an WPI classified as "very good," 61.9% (86 municipalities) have an IPH classified as "good," 30.9% (43 municipalities) have an WPI classified as "poor," and 3.6% (5 municipalities) have an WPI classified as critical. No municipality in Tocantins achieved an "excellent" score on the WPI scale. The WPI values for the municipalities in Tocantins ranged from 0.22 to 0.70, and all of these results were mapped (Figure 2).

Analyzing the information in Table 5 in light of the concept of environmental injustice[2] described by Herculano (2008), the municipality of Campos Lindos stands out for having the largest area of corn and soybean cultivation. It is also the municipality with the highest contribution to the GDP through the production of these and other commodities, generating around 203 million reais in 2018 (IBGE, 2017).

Tabela 5. Water Poverty Index (WPI) and position according to the situation of each municipality of Tocantins

MUNICIPALITIES	WPI	Order	MUNICIPALITIES	WPI	Order
Abreulândia	0,50	24º	Crixás do Tocantins	0,42	71º
Aguiarnópolis	0,40	84º	Darcinópolis	0,32	127º
Aliança do Tocantins	0,51	23º	Dianópolis	0,55	11º
Almas	0,46	46º	Divinópolis do Tocantins	0,49	34º
Alvorada	0,48	39º	Dois Irmãos do Tocantins	0,38	96º
Ananás	0,38	99º	Dueré	0,51	19º
Angico	0,35	115º	Esperantina	0,31	131º
Aparecida do Rio Negro	0,49	33º	Fátima	0,52	17º
Aragominas	0,27	137º	Figueirópolis	0,42	69º
Araguacema	0,49	29º	Filadélfia	0,45	50º
Araguaçu	0,46	44º	Formoso do Araguaia	0,56	10º
Araguaína	0,57	8º	Fortaleza do Tabocão	0,48	36º
Araguanã	0,37	104º	Goianorte	0,35	116º
Araguatins	0,40	90º	Goiatins	0,37	101º
Arapoema	0,51	21º	Guaraí	0,56	9º
Arraias	0,49	31º	Gurupi	0,59	6º
Augustinópolis	0,40	86º	Ipueiras	0,43	64º
Aurora do Tocantins	0,44	58º	Itacajá	0,50	26º
Axixá do Tocantins	0,36	109º	Itaguatins	0,37	105º
Babaçulândia	0,38	98º	Itapiratins	0,40	88º
Bandeirantes do Tocantins	0,37	106º	Itaporã do Tocantins	0,47	43º
Barra do Ouro	0,36	107º	Jaú do Tocantins	0,41	76º
Barrolândia	0,57	7º	Juarina	0,28	136º
Bernardo Sayão	0,39	94º	Lagoa da Confusão	0,54	12º
Bom Jesus do Tocantins	0,51	22º	Lagoa do Tocantins	0,40	85º

Continues on the next page...

2. *Environmental injustice arises from the perverse logic of a production system, land occupation, ecosystem destruction, and spatial allocation of polluting processes that penalize the health conditions of the working population residing in impoverished neighborhoods, excluded by large-scale development projects (MOURA, 2009, p. 3).*

MUNICIPALITIES	WPI	Order	MUNICIPALITIES	WPI	Order
Brasilândia do Tocantins	0,50	27º	Lajeado	0,54	13º
Brejinho de Nazaré	0,49	32º	Lavandeira	0,43	63º
Buriti do Tocantins	0,34	120º	Lizarda	0,33	124º
Cachoeirinha	0,43	67º	Luzinópolis	0,40	87º
Campos Lindos	0,32	130º	Marianópolis do Tocantins	0,43	62º
Cariri do Tocantins	0,41	75º	Mateiros	0,42	74º
Carmolândia	0,34	121º	Maurilândia do Tocantins	0,34	123º
Carrasco Bonito	0,35	117º	Miracema do Tocantins	0,63	3º
Caseara	0,45	54º	Miranorte	0,48	37º
Centenário	0,34	122º	Monte do Carmo	0,40	83º
Chapada da Natividade	0,39	93º	Monte Santo do Tocantins	0,44	60º
Chapada de Areia	0,41	80º	Muricilândia	0,30	134º
Colinas do Tocantins	0,50	25º	Natividade	0,51	18º
Colméia	0,40	82º	Nazaré	0,40	91º
Combinado	0,48	40º	Nova Olinda	0,37	102º
Conceição do Tocantins	0,36	108º	Nova Rosalândia	0,49	30º
Couto Magalhães	0,35	118º	Novo Acordo	0,54	14º
Cristalândia	0,53	15º	Novo Alegre	0,46	45º
Novo Jardim	0,43	65º	Santa Maria do Tocantins	0,45	56º
Oliveira de Fátima	0,48	35º	Rio Sono	0,41	77º
Palmas	0,70	1º	Sampaio	0,38	97º
Palmeirante	0,36	113º	Sandolândia	0,44	59º
Palmeiras do Tocantins	0,36	112º	Santa Fé do Araguaia	0,48	38º
Palmeirópolis	0,47	41º	Santa Rita do Tocantins	0,47	42º
Paraíso do Tocantins	0,61	5º	Santa Rosa do Tocantins	0,33	125º
Paranã	0,45	49º	Santa Tereza do Tocantins	0,51	20º
Pau D'Arco	0,37	103º	Santa Terezinha do Tocantins	0,36	111º
Pedro Afonso	0,63	4º	São Bento do Tocantins	0,33	126º
Peixe	0,43	68º	São Félix do Tocantins	0,41	78º
Pequizeiro	0,32	128º	São Miguel do Tocantins	0,32	129º
Pindorama do Tocantins	0,45	57º	São Salvador do Tocantins	0,40	81º
Piraquê	0,24	138º	São Sebastião do Tocantins	0,30	133º
Pium	0,50	28º	São Valério	0,39	92º
Ponte Alta do Bom Jesus	0,37	100º	Silvanópolis	0,41	79º
Ponte Alta do Tocantins	0,46	48º	Sítio Novo do Tocantins	0,35	119º
Porto Alegre do Tocantins	0,42	72º	Sucupira	0,35	114º
Porto Nacional	0,65	2º	Taguatinga	0,43	66º
Praia Norte	0,29	135º	Taipas do Tocantins	0,42	73º
Presidente Kennedy	0,44	61º	Talismã	0,40	89º
Pugmil	0,53	16º	Tocantínia	0,45	53º
Recursolândia	0,31	132º	Tocantinópolis	0,45	51º
Riachinho	0,22	139º	Tupirama	0,45	52º
Rio da Conceição	0,46	47º	Tupiratins	0,45	55º
Rio dos Bois	0,42	70º	Wanderlândia	0,36	110º

Elaboration: the author.

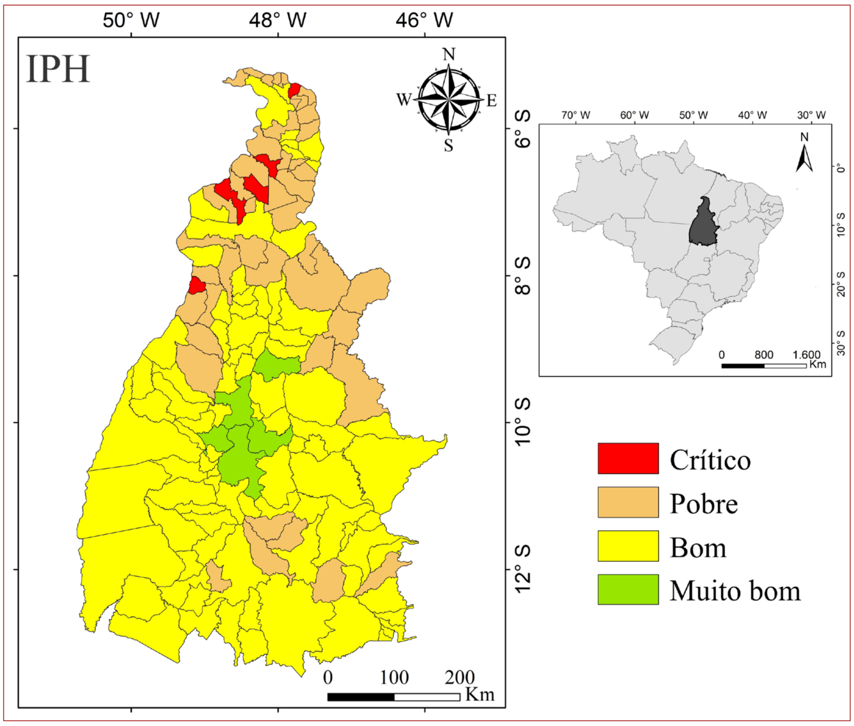
In the group of municipalities with a "very good" WPI, we find: Palmas (0.70), Porto Nacional (0.65), Miracema, and Pedro Afonso (0.63), and Paraíso do Tocantins (0.61), all located in the central portion of the state. Except for Pedro Afonso, other municipalities in this group make up the metropolitan region of Palmas, which influences the good indicators related to access to piped water, sewage, and garbage collection.

In the group of municipalities with a critical WPI, we find: Praia Norte (0.29), Juarina (0.28), Aragominas (0.27), Piraquê (0.24), and Riachinho (0.22), concentrated in the northern part of the state.

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

Figure 2. Water Poverty Index (WPI) of the municipalities of Tocantins



Source: the author.

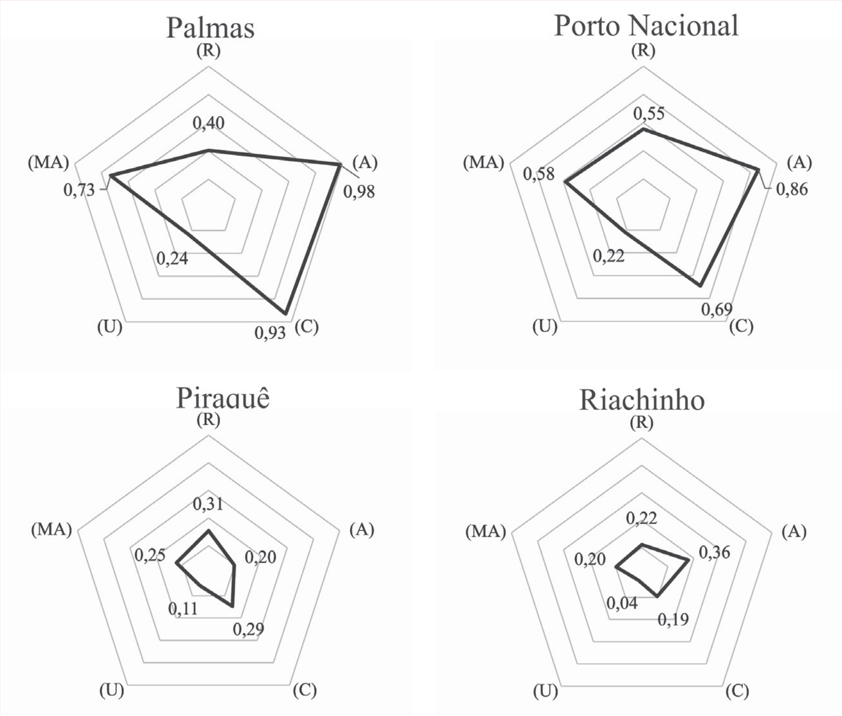
In the group of municipalities with a "good" WPI, we find municipalities ranked between 6th and 91st in Table 5, while municipalities with a "poor" WPI are ranked between 92nd and 134th.

Recognizing water as a vital resource, it is necessary to discuss environmental justice as a set of principles that ensure that no group of people bears a disproportionate share of the negative environmental consequences of economic operations, federal, state, and local policies and programs, as well as the result of the absence or omission of such policies (HERCULANO, 2008, p. 2).

However, it can be noted that in the MA component, it only ranks 74th out of 139 municipalities. Furthermore, if we also consider socioeconomic injustices, Campos Lindos has the 4th highest income concentration in the state (IPEA, 2015) and the 33rd worst performance in per capita income (IBGE, 2010) among the municipalities in Tocantins. Justifying the limited analysis of Campos Lindos, this municipality is the best example, for Tocantins, that economic production does not translate into human development.

The graphical polygon representation shows the results for the state capital, Palmas, and the city of Porto Nacional, which had the best conditions for the WPI (Figure 3). The cities of Piraquê and Riachinho, with the most critical values, were also represented. It is worth noting that, as described by Torrez and Álvares (2019), "the ideal polygon is one in which all components of the WPI reach values of 1 and form a regular polygon, as the conditions for water availability would be optimal for the population's acceptable development" (Torrez & Álvares, 2020, p. 16).

Figure 3. WPI polygon for municipalities with better and worse conditions, respectively



Source: prepared by the author.

Regarding the polygons of Palmas and Porto Nacional, despite having average or high values for most components, they have lower values for the Usage component. This results in the polygons being less regular. On the other hand, Piraquê and Riachinho have all components with low values, which makes their polygons more regular, despite their small size. In the cases of Palmas and Porto, improvements in the Usage component could significantly increase the WPI's overall value Meanwhile, in the other two municipalities, all components need improvement, which complicates the task further. However, the size of these municipalities should be considered, as we are dealing with quite distinct situations within the state. Palmas has the largest population, Porto Nacional ranks fourth, while Piraquê and Riachinho have among the smallest populations.

The average value of the WPI for the municipalities of Tocantins is 0.43, which is considered "good" on a scale that ranges from 0 to 1. Crispim (2015) found that the average value in rural communities in the municipality of Pombal was 5.6, based on a scale ranging from 0 to 10. In studies conducted by Torrez and Álvares (2020) to determine the WPI of the Middle Zone of the Mexican city of San Luís Potosí, an average value of 0.55 was obtained, using a similar scale. Also, on a scale from 0 to 1, Santos and Ferreira (2016) obtained an WPI of 0.74 for the Gargaú community in São Francisco do Itabapoana, in the state of Rio de Janeiro. Ogata (2014) determined WPI values ranging from 0.45 to 0.52 for the Paraíba River watershed. Olivas-Palma

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

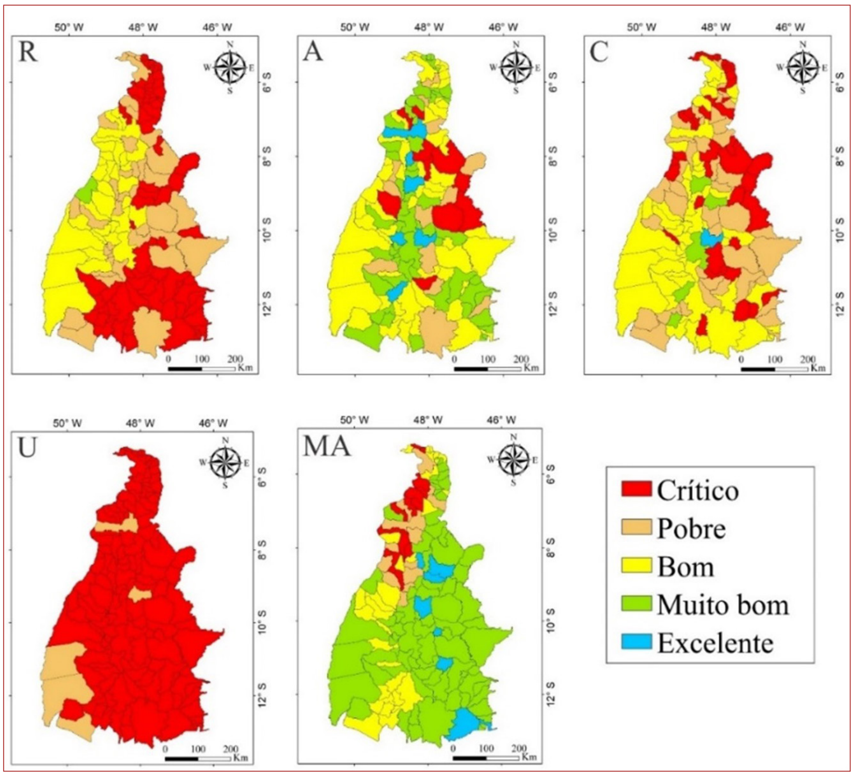
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

and Camberos-Castro (2021) determined the WPI values for 78 municipalities in northwest Mexico, with values ranging from 0.36 to 0.71.

In studies conducted in the Southeast of Tocantins, specifically in the cities of Aurora do Tocantins and Paranã, Morais et al. (2019) determined WPI values of 0.36 and 0.32, respectively. These values were classified as "high" WPI, which is equivalent to "poor" in the classification used in this study. In this study, these municipalities have WPI values of 0.44 and 0.45, respectively, classified as "good" WPI (equivalent to "moderate" in Morais et al., 2019).

Figure 4. Situation of the municipalities of Tocantins for each component: Resource (R), Access (A), Capacity (C), Use (U) and Environment (MA)



Source: the author.

The results of each WPI component for the municipalities in Tocantins were also spatialized (Figure 4).

It is important to emphasize that comparing the results obtained for the municipalities of Tocantins with the WPI values obtained for other regions of Brazil and the world does not limit the analysis of water poverty in Tocantins. This is because the research adopts a qualitative approach, which justifies the use of a multiscale approach.

For component R, it can be stated that Araguacema (0.62) in western Tocantins achieved a classification of "very good" for this component. The municipalities where this component is considered critical are predominantly located in the southeastern, southern, and eastern portions of

Bico do Papagaio (far north), as well as eastern Tocantins. This demonstrates that municipalities drained by the hydrographic system of the Tocantins River have a worse situation compared to those drained by the hydrographic system of the Araguaia River (in the western part of the state), which is predominantly classified as “good”. This can be explained by the results obtained by Silva Neto (2023) regarding the water availability of the Tocantins River hydrographic system, which, on average, has a higher specific yield (flow rate in l^{s-1} km^{-2}) than the Araguaia River hydrographic system.

It must be considered that the R component is an indicator composed of precipitation during both dry and rainy periods. As well as the flow determined by regionalization equations, which depend on the area in the mentioned periods, this case is applied to the territorial extension of the municipality. Therefore, it is important to emphasize that factors such as flow regulation or proximity to water bodies are not taken into account. This omission prevents the representation of a subcomponent obtained by water availability per inhabitant.

Thus, it can be observed that for this component, the municipality of Araguacema, located in the protected area Ilha do Bananal/ Cantão, depicted the best situation with a value of 0.62 (very good), while 51% of the municipalities in Tocantins have a critical situation. The worst situations were found in the municipalities of Novo Alegre and Conceição do Tocantins (0.04), Aurora do Tocantins (0.05), Combinado, Taguatinga, and Lavandeira with 0.07, all located in the southeastern part of the state. 25.1% of the municipalities had a “good” situation, while 25.2% had an index for this component classified as “poor”.

If we consider the same scale, Sullivan (2003) obtained values for this component ranging from 0.10 (in the urban areas of Majengo, Tanzania, and Awarakotuwa, Sri Lanka) to 0.50 (in the urban area of Wembezi and the rural area of Ethembeni, both in South Africa). Luna (2007), in studies on the WPI of municipalities located in the Rio Salgado basin (southern state of Ceará), obtained values between 0.00 and 0.50. Morais et al. (2019) obtained values from 0.26 to 0.58 for the southeast of Tocantins, in Paranã and Aurora do Tocantins, respectively, in studies on WPI for these municipalities.

For component A, the municipalities that showed the highest WPI scores were Palmas (0.98), Colinas do Tocantins (0.96), Paraíso do Tocantins (0.94), Gurupi (0.93), Araguaína (0.93), and Guaraí (0.90). These municipalities were classified as “excellent” due to their favorable conditions. These municipalities are located along the central axis of the state, running in a north-south direction. The municipalities that had lower values (critical) for this component were Goiatins (0.26), Dois Irmãos do Tocantins, Santa Rosa do Tocantins, Lizarda, and Rio Sono (0.24), Recursolândia and Itapi-

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

ratins (0.23), Aragominas (0.22), Piraquê (0.20), and Palmeirante (0.09). These municipalities are predominantly located in the eastern part of Tocantins.

In the studies conducted by Olivas-Palma and Camberos-Castro (2021) to determine the WPI of 78 municipalities in the northwest region of Mexico, the values for component A ranged from 0.18 to 0.98. For 14 rural communities in the municipality of Pomba, in the State of Paraíba, Crispim (2015) found that this component was classified as "regular" (good) for 12 rural communities and "poor" for 2 rural communities, with values ranging from 0.39 to 0.64, using a similar scale to the present study.

This component takes into account the percentage of the population with access to piped water. The best situations, as indicated by normalized values, are observed in the municipalities of Palmas (1.00), Buriti do Tocantins, and Araguaína (0.97). The worst situations were observed in Itapiratins (0.00), Sandolândia (0.02), and Santa Rita do Tocantins (0.04). However, it should be clarified that these values correspond to 34.04%, 35.31%, and 36.18%, respectively. The fact that they are equal or close to the value 0.00 is due to the normalization process of this data, which takes into account the universe in which the municipalities are included.

Additionally, it also considers the percentage of the population in households with access to a bathroom and sanitary sewage. The areas with the best conditions were observed in Alvorada (1.00), Gurupi (0.99), Paraíso do Tocantins, and Fortaleza do Tabocão (0.98). In this aspect, the worst conditions were recorded in Rio Sono (0.16), Goiatins (0.09), and Recursolândia (0.00). Finally, this component also takes into account the percentage of the population in households with garbage collection. In this case, Palmas (1.00), Gurupi (0.99), and Paraíso do Tocantins (0.98) exhibited the most favorable conditions. Cachoeirinha (0.20), Lizarda (0.08), and Palmeirante (0.00) presented the worst situations in this regard. However, as emphasized in the previous paragraph, without considering data normalization, these values correspond to 32%, 23%, and 17% of the population served, respectively.

The values obtained for the capacity component (C), which considers the literacy rate of individuals aged 10 and above (%), individuals over 18 with completed primary education (%), per capita income, mortality of children under 5 years of age, and the Gini index, ranging from 0.07 to 0.96. The best conditions were observed in the city of Palmas (0.96) (excellent), followed by the municipalities of Gurupi (0.84) and Pedro Afonso (0.73). The worst situations for this component were observed in Recursolândia (0.07), Praia Norte (0.10), and Centenário (0.11) (critical).

Palmas exhibited the most favorable conditions across all variables comprising this component, except child mortality under 5 years and the Gini index. Its position in the urban hierarchy of Tocantins, as the state capital, is important to comprehend its indicators. Municipalities with the poorest indicators for this component are primarily located in the northeast and far north of Tocantins, bordering the state of Maranhão.

In studies conducted on WPI in the Seridó River Basin, the states of Rio Grande do Norte and Paraíba, Senna (2015) obtained values for component C ranging from 0.10 (Cubati, in the State of Paraíba) to 0.98 (Caiacó, in the State of Rio Grande do Norte). Morais et al. (2019), studies on WPI for two cities in southeast Tocantins, reached values of 0.48 (Aurora do Tocantins) and 0.43 (Paranã). In the present study, values of 0.41 and 0.47 were determined for these municipalities, respectively. Prince et al. (2021), in studies on WPI to assess water conditions in the Nagapattinam district, Tamil Nadu, and the Karaikal district, Puducherry, southern India, determined component C values ranging from 0.59 to 0.70.

The component U warrants special attention, as 134 municipalities fell into the "critical" classification for this component, and 5 in the "poor" classification, considering the efficiency of water resource utilization for domestic, agricultural, and industrial purposes (Table 5).

The values for this component ranged from 0.01 to 0.37. However, it is important to note that the assignment of weight is only done in the final composition to obtain the WPI. The low values can be explained by the relatively small population of the state, which has about 1.38 million inhabitants (IBGE, 2010), and the low usage of water by the industrial activity in the state. It is also worth considering that the irrigated area in Tocantins municipalities exhibits significant disparities depending on the economic activities in each municipality. This is also true for livestock farming, as indicated by the size of the bovine herd. This reality justifies the reduction in the weight of this component.

Olivas-Palma and Camberos-Castro (2021), in their studies, to determine the WPI of 78 municipalities in the northwest region of Mexico, obtained values for component U ranging from 0.19 to 0.68. Morais et al. (2019), in southeast Tocantins, determined values of 0.01 and 0.03 for Paranã and Aurora do Tocantins, respectively. The results in this study for this component were 0.16 and 0.06, respectively. When observing the municipalities with the highest values for this component, we find Pedro Afonso, Formoso do Araguaia, and Araguaçu (0.37), Araguaína (0.35), and Lagoa da Confusão (0.30), where the predominance of agricultural activity in the economy of these municipalities can be identified.

Lastly, MA presented the best situations among the components that make up the WPI of the municipalities in Tocantins. The variables considered by component MA, as previously described, are native forests about the municipality's area (ha) (%) and carrying capacity (UA ha^{-1}).

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

The obtained values range from 0.10 to 0.98. Municipalities classified as "excellent" in this component are Lavandeira (0.98), Itacajá (0.95), Santa Maria do Tocantins, and Santa Tereza do Tocantins (0.94), Arraias (0.93), Tocantínia, Tupiratins, and Pindorama do Tocantins (0.90). The poorest results (critical classification) were obtained for 15 municipalities predominantly located in the north and northwest of the state, with the most challenging situations identified in Araguanã (0.15), Xambioá (0.14), and Juarina (0.10). In general terms, it can be stated that 5.8% of the municipalities have the index for this component classified as "excellent." The majority of municipalities (52.5%) have a component classified as "very good," 21.5% as "good," 9.4% as "poor," and 10.8% as "critical."

Considering the variable "income loss due to floods" for component MA, Santos and Ferreira (2016), in studies on the WPI for the Gargaú community, São Francisco do Itabapoana-RJ, obtained a value of 0.92 for this component. Morais et al. (2019) obtained values for Aurora do Tocantins and Paranã of 0.53 and 0.73, respectively, noting that the authors considered the variables Percentage of native vegetation cover (%), electrical conductivity of water (μS/cm), and dissolved oxygen (mg/L). In the present study, these municipalities located in the southeast of the state expressed the MA component with values of 0.83 and 0.80, respectively.

The difference can be explained by the variables used by the cited authors, which differ from those used in this study, such as electrical conductivity, which led to the reduction of the value of this component in Morais et al. (2019). (2019). In addition, there was a discrepancy in the sources used by the authors regarding the percentage of deforested areas in the municipalities. The data from SEPLAN Tocantins referred to 2007, while this research utilized data from LAPIG (2022) for the year 2012.

CONCLUDING REMARKS

The majority of municipalities in Tocantins exhibit a WPI classified as "good," as observed when considering the average of municipalities to determine the WPI of Tocantins. However, this result cannot be simply interpreted based on the abundance of water resources in the state. More specifically, it reflects a combination of factors that indicate favorable conditions regarding water availability, the means of accessing it, capacities to manage it appropriately, patterns of use, and other environmental circumstances directly linked to water conservation.

Among all municipalities in the state, the component with the best conditions was the environment (MA), while usage (U) exhibited the poorest conditions.

Regarding the MA component, this could be a result of the limited number of variables considered, specifically only native vegetation and carrying capacity. However, this is not a limitation, as there is literature that focuses solely on native vegetation. As for the U component, the explanation for this, as mentioned earlier, lies in the disparity characterizing water usage when comparing the realities of municipalities in the state. Some municipalities have large areas of irrigation, while others have virtually none.

It is also worth considering that the prevailing ethos of rural oligarchies in Tocantins may distort the results of the WPI, depending on criteria such as the education and income of the population. This is because social values in these areas are strongly associated with the idea of exploiting nature and private land ownership, which can have a negative impact on the composition of this index.

This study aimed to contribute to water resource planning and management in Tocantins. This may involve the development of specific public policies for this purpose, as well as policies related to tangential issues such as health and education. Furthermore, it can assist in the strategic design of environmental monitoring and enforcement, including the continuous tracking of the WPI over time.

Finally, the WPI of the 139 municipalities in Tocantins was determined. This allows us to conclude that the research objectives were achieved, providing valuable information for public authorities to make informed investment decisions. These decisions can be tailored to the specific needs of each region and municipality in the state, whether it be in the areas of education, infrastructure, or environmental conservation. This ensures the development of each municipality and guarantees water security in every region of Tocantins. ●

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

REFERENCES

ANA - Agência Nacional das Águas. Manual de Usos Consuntivos da Água no Brasil. Brasília: ANA, 2019. Disponível em: <http://snirh.gov.br/usos-da-agua/>. Acesso: 12 mai. 2022.

______. Agência Nacional das Águas e Saneamento Básico (Brasil). *Atlas Irrigação:* uso da água na agricultura irrigada, 2. ed. Brasília: 2021. 130 p.

BORDALO, C. A. O paradoxo da água na região das águas: o caso da Amazônia brasileira. *Geousp - Espaço e Tempo (Online)*, v. 21, n. 1, p. 120-137, 2017. <https://doi.org/10.11606/issn.2179-0892.geousp.2017.107531>.

BRITO, F. S. L. *et al.* Uso de indicador hídrico na Ilha de Cotijuba, município de Belém-PA. *Revista de Gestão de Água da América Latina*, v. 17, n. 2020, p. e11, 2020. <https://doi.org/10.21168/rega.v17e11>.

CRISPIM, D. L. *Estudo da situação hídrica da população rural do município de Pombal - PB*. 2015. 103 p. Dissertação de Mestrado em Sistemas Agroindustriais (Mestrado em Sistemas Agroindustriais). Programa de Pós-Graduação em Sistemas Agroindustriais, Universidade Federal de Campina Grande.

DESAI, M. *Poverty, famine and economic development:* the selected essays of Meghnad Desai, Volume II. Aldershot: Edward Elgar Publishing Ltd., 1995. 240 p.

EL-GAFY, I. K. E.-D. The water poverty index as an assistant tool for drawing strategies of the Egyptian water sector. *Ain Shams Engineering Journal*, v. 9, n. 2, p. 173-186, 2018. <https://doi.org/10.1016/j.asej.2015.09.008>.

HERCULANO, S. O clamor por justiça ambiental e contra o racismo ambiental. *Revista de gestão integrada em saúde do trabalho e meio ambiente*, v. 3, n. 1, p. 01-20, 2008.

IBGE. Instituto Brasileiro de Geografia e Estatística. *Pesquisa Nacional por amostra de domicílios - PNAD, 2010*. Disponível em: <https://sidra.ibge.gov.br/home/pnadcm>. Acesso: 01 jun.

______. Instituto Brasileiro de Geografia e estatística. *Censo Agropecuário 2017*. Rio de Janeiro, p. 108, 2017. 2021. Disponível em: <https://sidra.ibge.gov.br/pesquisa/censo-agropecuario/censo-agropecuario-2017>. Acesso: 04 jan.

______. *Cidades*. 2021. Disponível em: <https://www.ibge.gov.br/cidades-e-estados/to.html>. Acesso: 16 mai. de 2023.

IPEA. *Atlas da vulnerabilidade social nos municípios brasileiros.* Brasília: IPEA, 2015. 77 p.

LAPIG. Laboratório de processamento de imagem e geoprocessamento - LAPIG (2022). *Atlas das pastagens*. (base digital georeferenciada). Goiânia, Brasil: LAPIG/UFG. 2021. Disponível em: <http://maps.lapig.iesa.ufg.br/lapig.html>. Acesso: 03 mar. 2022.

LEMOS, J. D. J. S. *Mapa da exclusão social no Brasil*: radiografia de um país assimetricamente pobre. Fortaleza: Banco do Nordeste do Brasil, 2012. 253 p.

LUNA, R. M. *Desenvolvimento do índice de pobreza hídrica (IPH) para o semi-árido brasileiro*. 2007. 138 p. Tese de Doutorado em Recursos Hídricos (Doutorado em Recursos Hídricos). Programa de Pós-Graduação em Recursos Hídricos, Universidade Federal do Ceará.

MARANHÃO, R. M. R. *Índice de Pobreza Hídrica (IPH) aplicado a municípios dos sertões dos Inhamuns no semiárido do Ceará-Brasil.* 2010. 95 p. Dissertação de Mestrado em Geografia (Mestrado em Geografia). Programa de Pós-Graduação em Geografia, Universidade Federal do Ceará.

MORAIS, F. D. *et al.* Escassez hídrica e políticas públicas no sudeste do Tocantins. In: SCAPIN, E.; RAMBO, M. K. D.; SANTOS, M. G. D. (Ed.). *Água e sustentabilidade na Amazônia*. Palmas: EDUFT, 2019. p. 139.

MOURA, D. V. Justiça ambiental: um instrumento de cidadania. Qualit@s Revista Eletrônica, v. 9, n. 1, p. 1-10, 2009.

OGATA, I. S. *Desenvolvimento do índice de pobreza hídrica para bacia hidrográfica do Rio Paraíba.* 2014. 104 p. Dissertação de Metrado em Engenharia Civil e Ambiental (Metrado em Engenharia Civil e Ambiental). Programa de Pós-Graduação em Engenharia Civil e Ambiental, Universidade Federal de Campina Grande – UFCG.

OLIVAS-PALMA, M. J.; CAMBEROS-CASTRO, M. Pobreza hídrica en 78 municipios del Noroeste de México: una reflexión a partir del Índice de Pobreza Hídrica y la Pobreza Multidimensional, 2015. *Revista IDeAS*,

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

v. 15, n. 1, p. e021005-e021005, 2021. <https://doi.org/10.31908/19098367.1848>.

PRINCE, B. C. *et al.* A statistical and spatial analysis of water poverty using a modified Water Poverty Index. *International Journal of Water Resources Development*, v. 37, n. 2, p. 339-356, 2021. <https://doi.org/10.1080/07900627.2020.1768829>.

SANTOS, A. M. D. *Vulnerabilidade hidrológica das populações residentes na bacia hidrográfica do rio UNA (Pernambuco) frente aos cenários de mudanças climáticas.* 2015. 129 p. Tese (Doutorado em Geografia). Programa de Pós-Graduação em Geografia, Universidade Federal de Pernambuco.

SANTOS, R. D. S. F.; FERREIRA, M. I. P. Índice de Pobreza Hídrica e sua adaptação às condições da comunidade de Gargaú, São Francisco do Itabapoana/RJ. *Boletim do Observatório Ambiental Alberto Ribeiro Lamego*, v. 10, n. 2, p. 191-206, 2016. <https://doi.org/10.19180/2177-4560.v10n22016p191-206>.

SENNA, L. D. D. *Uso do Índice de Pobreza Hídrica (WPI) através da análise de componentes principais.* 2015. 41 p. Dissertação de Mestrado em Engenharia Sanitária (Mestrado em Engenharia Sanitária). Programa de Pós-graduação em Engenharia Sanitária, Universidade Federal do Rio Grande do Norte.

SILVA NETO, V. L. *Recursos Hídricos no Tocantins: Índice de Pobreza Hídrica dos municípios tocantinenses e a pressão do Agronegócio.* 2023. 160 p. Tese de Doutorado em Ciências do Ambiente (Doutorado em Ciências do Ambiente). Programa de Pós-Graduação em Ciências do Ambiente, Universidade Federal do Tocantins - UFT.

SILVA NETO, V. L. *et al.* Variabilidade espacial e temporal da precipitação no Estado do Tocantins, Brasil. *Research, Society and Development*, v. 10, n. 3, p. 1-11, 2021. <https://doi.org/10.33448/rsd-v10i3.13545>.

SILVA NETO, V. L. *et al.* Precipitação máxima provável no Estado do Tocantins: primeira aproximação pelo método estatístico de Hershfield. *Revista Brasileira de Climatologia*, v. 27, p. 660-679, 2020. <http://dx.doi.org/10.5380/abclima.v27i0.69590>.

SNIS. Sistema Nacional de Informações sobre Saneamento. *Painel de Saneamento*. 2022. Disponível em: <http://appsnis.mdr.

gov.br/indicadores/web/agua_esgoto/mapa-agua>. Acesso: 10 jan. 2022.

SULLIVAN, C. Calculating a water poverty index. *World development*, v. 30, n. 7, p. 1195-1210, 2002. <https://doi.org/10.1016/S0305-750X(02)00035-9>.

SULLIVAN, C. A. *et al.* The Water Poverty Index: Development and application at the community scale. *Natural Resources Forum*, v. 27, p. 189-199, 2003.<https://doi.org/10.1111/1477-8947.00054>.

TOCANTINS. Secretaria da Fazenda e Planejamento. Superintendência de Planejamento Governamental. Diretoria de Gestão de Informações Territoriais e Socioeconômicas. Gerência de Zoneamento Territorial. Palmas: SEFAZ/GZT. Projeto de Desenvolvimento Regional Integrado e Sustentável. Elaboração das Cartas Climáticas do Estado do Tocantins, (1). 464 p., Ilust.

TORRES, D. J. S. M.; ÁLVAREZ, B. L. Cálculo del índice de pobreza del agua en la Zona Media de San Luis Potosí. *Revista de El Colegio de San Luis*, v. 10, n. 21, p. 1-28, 2020. <https://doi.org/10.21696/rcsl102120201176>.

VIOLA, M. R. *et al.* Distribuição e potencial erosivo das chuvas no Estado do Tocantins. Pesquisa Agropecuária Brasileira, v. 49, p. 125-135, 2014. <https://doi.org/10.1590/S0100-204X2014000200007>.

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

ATTACHMENT

Values of the individual components resource (R), access (A), capacity (C), use (U), environment (E) and Water Poverty Index (WPI) and position according to the WPI for municipalities in Tocantins

MUNICIPALITIES	R	A	C	U	E	WPI	Rank
Abreulândia	0,48	0,56	0,59	0,08	0,59	0,50	24º
Aguiarnópolis	0,08	0,73	0,43	0,04	0,56	0,40	84º
Aliança do Tocantins	0,40	0,71	0,45	0,09	0,68	0,51	23º
Almas	0,27	0,63	0,33	0,08	0,81	0,46	46º
Alvorada	0,15	0,87	0,67	0,09	0,43	0,48	39º
Ananás	0,30	0,72	0,40	0,26	0,17	0,38	99º
Angico	0,23	0,60	0,34	0,04	0,39	0,35	115º
Aparecida do Rio Negro	0,31	0,73	0,38	0,05	0,75	0,49	33º
Aragominas	0,42	0,22	0,19	0,10	0,32	0,27	137º
Araguacema	0,62	0,46	0,39	0,10	0,70	0,49	29º
Araguaçu	0,34	0,67	0,36	0,37	0,54	0,46	44º
Araguaína	0,54	0,93	0,56	0,35	0,35	0,57	8º
Araguanã	0,30	0,77	0,39	0,09	0,15	0,37	104º
Araguatins	0,33	0,49	0,57	0,19	0,30	0,40	90º
Arapoema	0,45	0,75	0,45	0,16	0,56	0,51	21º
Arraias	0,15	0,58	0,43	0,20	0,93	0,49	31º
Augustinópolis	0,22	0,73	0,36	0,09	0,46	0,40	86º
Aurora do Tocantins	0,05	0,68	0,41	0,06	0,83	0,44	58º
Axixá do Tocantins	0,15	0,69	0,23	0,03	0,54	0,36	109º
Babaçulândia	0,26	0,31	0,33	0,08	0,79	0,38	98º
Bandeirantes do Tocantins	0,44	0,58	0,35	0,15	0,20	0,37	106º
Barra do Ouro	0,17	0,44	0,24	0,04	0,76	0,36	107º
Barrolândia	0,45	0,86	0,41	0,09	0,82	0,57	7º
Bernardo Sayão	0,44	0,62	0,29	0,12	0,32	0,39	94º
Bom Jesus do Tocantins	0,29	0,58	0,49	0,05	0,89	0,51	22º
Brasilândia do Tocantins	0,41	0,82	0,49	0,05	0,50	0,50	27º
Brejinho de Nazaré	0,33	0,69	0,48	0,05	0,68	0,49	32º
Buriti do Tocantins	0,38	0,65	0,25	0,04	0,25	0,34	120º
Cachoeirinha	0,24	0,58	0,31	0,05	0,76	0,43	67º
Campos Lindos	0,15	0,36	0,22	0,05	0,68	0,32	130º
Cariri do Tocantins	0,21	0,57	0,48	0,08	0,56	0,41	75º
Carmolândia	0,29	0,61	0,40	0,04	0,20	0,34	121º
Carrasco Bonito	0,23	0,77	0,13	0,03	0,43	0,35	117º
Caseara	0,39	0,57	0,46	0,05	0,57	0,45	54º
Centenário	0,25	0,35	0,11	0,04	0,79	0,34	122º
Chapada da Natividade	0,23	0,33	0,34	0,06	0,83	0,39	93º
Chapada de Areia	0,44	0,53	0,25	0,06	0,57	0,41	80º
Colinas do Tocantins	0,42	0,96	0,57	0,15	0,22	0,50	25º
Colméia	0,37	0,71	0,42	0,12	0,25	0,40	82º
Combinado	0,06	0,84	0,46	0,06	0,75	0,48	40º
Conceição do Tocantins	0,04	0,53	0,21	0,04	0,83	0,36	108º
Couto Magalhães	0,51	0,40	0,29	0,07	0,34	0,35	118º
Cristalândia	0,45	0,82	0,50	0,12	0,57	0,53	15º
Crixás do Tocantins	0,38	0,50	0,43	0,04	0,55	0,42	71º
Darcinópolis	0,24	0,58	0,24	0,02	0,39	0,32	127º
Dianópolis	0,17	0,84	0,58	0,08	0,82	0,55	11º
Divinópolis do Tocantins	0,40	0,66	0,48	0,13	0,59	0,49	34º
Dois Irmãos do Tocantins	0,58	0,24	0,34	0,18	0,47	0,38	96º
Dueré	0,27	0,66	0,58	0,19	0,69	0,51	19º
Esperantina	0,40	0,42	0,17	0,04	0,40	0,31	131º
Fátima	0,37	0,75	0,53	0,03	0,68	0,52	17º
Figueirópolis	0,21	0,70	0,38	0,12	0,55	0,42	69º
Filadélfia	0,32	0,48	0,37	0,11	0,81	0,45	50º
Formoso do Araguaia	0,42	0,59	0,48	0,37	0,83	0,56	10º
Fortaleza do Tabocão	0,40	0,88	0,46	0,09	0,39	0,48	36º
Goianorte	0,46	0,36	0,36	0,11	0,35	0,35	116º

Continues on the next page...

MUNICIPALITIES	R	A	C	U	E	WPI	Rank
Goiatins	0,39	0,26	0,19	0,07	0,79	0,37	101º
Guaraí	0,48	0,90	0,71	0,14	0,38	0,56	9º
Gurupi	0,25	0,93	0,84	0,16	0,57	0,59	6º
Ipueiras	0,23	0,66	0,35	0,02	0,69	0,43	64º
Itacajá	0,38	0,53	0,34	0,09	0,95	0,50	26º
Itaguatins	0,16	0,50	0,27	0,07	0,68	0,37	105º
Itapiratins	0,36	0,23	0,30	0,06	0,86	0,40	88º
Itaporã do Tocantins	0,44	0,59	0,46	0,11	0,55	0,47	43º
Jaú do Tocantins	0,15	0,45	0,46	0,13	0,72	0,41	76º
Juarina	0,46	0,40	0,29	0,04	0,10	0,28	136º
Lagoa da Confusão	0,60	0,43	0,41	0,30	0,86	0,54	12º
Lagoa do Tocantins	0,17	0,59	0,20	0,02	0,85	0,40	85º
Lajeado	0,29	0,72	0,53	0,02	0,86	0,54	13º
Lavandeira	0,06	0,58	0,31	0,04	0,98	0,43	63º
Lizarda	0,31	0,24	0,23	0,03	0,72	0,33	124º
Luzinópolis	0,17	0,65	0,30	0,02	0,68	0,40	87º
Marianópolis do Tocantins	0,41	0,57	0,37	0,10	0,56	0,43	62º
Mateiros	0,33	0,49	0,30	0,03	0,73	0,42	74º
Maurilândia do Tocantins	0,16	0,42	0,17	0,03	0,75	0,34	123º
Miracema do Tocantins	0,49	0,86	0,58	0,17	0,81	0,63	3º
Miranorte	0,39	0,88	0,46	0,11	0,38	0,48	37º
Monte do Carmo	0,30	0,34	0,26	0,09	0,87	0,40	83º
Monte Santo do Tocantins	0,45	0,46	0,40	0,08	0,63	0,44	60º
Muricilândia	0,42	0,47	0,18	0,07	0,24	0,30	134º
Natividade	0,19	0,72	0,53	0,09	0,83	0,51	18º
Nazaré	0,15	0,61	0,34	0,05	0,65	0,40	91º
Nova Olinda	0,32	0,62	0,33	0,10	0,33	0,37	102º
Nova Rosalândia	0,40	0,68	0,41	0,02	0,70	0,49	30º
Novo Acordo	0,36	0,76	0,41	0,03	0,86	0,54	14º
Novo Alegre	0,04	0,79	0,52	0,05	0,71	0,46	45º
Novo Jardim	0,07	0,80	0,22	0,02	0,84	0,43	65º
Oliveira de Fátima	0,36	0,76	0,46	0,02	0,58	0,48	35º
Palmas	0,40	0,98	0,93	0,24	0,73	0,70	1º
Palmeirante	0,43	0,09	0,22	0,06	0,82	0,36	113º
Palmeiras do Tocantins	0,13	0,46	0,40	0,05	0,60	0,36	112º
Palmeirópolis	0,10	0,78	0,50	0,10	0,70	0,47	41º
Paraíso do Tocantins	0,46	0,94	0,54	0,15	0,74	0,61	5º
Paranã	0,38	0,30	0,47	0,16	0,80	0,45	49º
Pau D'Arco	0,50	0,51	0,36	0,10	0,25	0,37	103º
Pedro Afonso	0,26	0,87	0,73	0,37	0,77	0,63	4º
Peixe	0,26	0,51	0,47	0,24	0,57	0,43	68º
Pequizeiro	0,50	0,34	0,32	0,12	0,24	0,32	128º
Pindorama do Tocantins	0,23	0,57	0,27	0,07	0,90	0,45	57º
Piraquê	0,31	0,20	0,29	0,11	0,25	0,24	138º
Pium	0,45	0,53	0,43	0,25	0,69	0,50	28º
Ponte Alta do Bom Jesus	0,10	0,36	0,31	0,06	0,89	0,37	100º
Ponte Alta do Tocantins	0,33	0,53	0,34	0,09	0,82	0,46	48º
Porto Alegre do Tocantins	0,11	0,56	0,34	0,03	0,85	0,42	72º
Porto Nacional	0,55	0,86	0,69	0,22	0,71	0,65	2º
Praia Norte	0,15	0,48	0,10	0,05	0,55	0,29	135º
Presidente Kennedy	0,38	0,75	0,45	0,05	0,36	0,44	61º
Pugmil	0,39	0,78	0,46	0,02	0,72	0,53	16º
Recursolândia	0,20	0,23	0,07	0,05	0,87	0,31	132º
Riachinho	0,22	0,36	0,19	0,04	0,20	0,22	139º
Rio da Conceição	0,08	0,89	0,39	0,01	0,70	0,46	47º
Rio dos Bois	0,42	0,44	0,21	0,04	0,81	0,42	70º
Rio Sono	0,39	0,24	0,32	0,08	0,85	0,41	77º
Sampaio	0,22	0,73	0,18	0,02	0,58	0,38	97º
Sandolândia	0,36	0,50	0,38	0,18	0,66	0,44	59º
Santa Fé do Araguaia	0,38	0,67	0,36	0,11	0,70	0,48	38º
Santa Maria do Tocantins	0,26	0,44	0,34	0,05	0,94	0,45	56º

Continues on the next page...

GEOGRAFARES
Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES
Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

GEOGRAFARES

Revista do Programa de Pós-Graduação em Geografia e do Departamento de Geografia da UFES

Volume 3, no. 37
July-December, 2023
ISSN: 2175-3709

MUNICIPALITIES	R	A	C	U	E	WPI	Rank
Santa Rita do Tocantins	0,51	0,36	0,49	0,12	0,69	0,47	42º
Santa Rosa do Tocantins	0,24	0,24	0,31	0,04	0,68	0,33	125º
Santa Tereza do Tocantins	0,23	0,65	0,46	0,03	0,94	0,51	20º
Santa Terezinha do Tocantins	0,15	0,55	0,27	0,03	0,62	0,36	111º
São Bento do Tocantins	0,28	0,37	0,41	0,04	0,40	0,33	126º
São Félix do Tocantins	0,22	0,55	0,33	0,02	0,72	0,41	78º
São Miguel do Tocantins	0,18	0,45	0,22	0,04	0,56	0,32	129º
São Salvador do Tocantins	0,12	0,57	0,28	0,04	0,83	0,40	81º
São Sebastião do Tocantins	0,36	0,54	0,20	0,04	0,23	0,30	133º
São Valério	0,20	0,54	0,34	0,07	0,66	0,39	92º
Silvanópolis	0,22	0,58	0,27	0,05	0,72	0,41	79º
Sítio Novo do Tocantins	0,15	0,40	0,29	0,07	0,68	0,35	119º
Sucupira	0,15	0,51	0,34	0,06	0,57	0,35	114º
Taguatinga	0,06	0,62	0,40	0,13	0,79	0,43	66º
Taipas do Tocantins	0,07	0,72	0,24	0,03	0,83	0,42	73º
Talismã	0,22	0,52	0,42	0,14	0,56	0,40	89º
Tocantínia	0,42	0,33	0,36	0,02	0,90	0,45	53º
Tocantinópolis	0,14	0,77	0,40	0,06	0,69	0,45	51º
Tupirama	0,37	0,48	0,42	0,03	0,73	0,45	52º
Tupiratins	0,35	0,49	0,26	0,03	0,90	0,45	55º
Wanderlândia	0,24	0,58	0,31	0,06	0,45	0,36	110º
Xambioá	0,35	0,70	0,47	0,12	0,14	0,38	95º