CHAPTER

2

Normal climatological water balance in the microregion of alto teles pires - MT

Crossref https://doi.org/10.56238/alookdevelopv1-002

Pedro Hurtado de Mendoza Borges
Ph.D. in Agricultural Machinery from the University of Rostock, Germany
Institution: Federal University of Mato Grosso
Address: Av. Fernando Corrêa da Costa nº 2367, Boa Esperança, Cuiabá – MT, Brazil
ORCID: http://orcid.org/0000-0001-7603-8775
Email: pedrohmborges14@gmail.com

Pedro Hurtado de Mendoza Morais
Agronomistfrom the Federal University of Mato Grosso
Company RHD AGRO Agricultural Monitoring Ltda
Address: Rua Almirante Henrique Pinheiro Guedes nº 625, Cuiabá – MT, Brazil
TheRCID: http://orcid.org/0000-0003-2431-9262
Email: pedromorais08@hotmail.com

Zaíra Morais dos Santos Hurtado de Mendoza
PhD in Forest Science from the Federal University of Viçosa
Institution: Federal University of Mato Grosso
Address: Av. Fernando Corrêa da Costa nº 2367, Boa Esperança, Cuiabá – MT, Brazil
ORCID: http://orcid.org/0000-0002-0930-7928
Email: zairamorais09@gmail.com

Diandro Navarro Bezerra
Graduating in Agronomy from the Federal University of Mato Grosso
Institution: Federal University of Mato Grosso
Address: Av. Fernando Corrêa da Costa nº 2367, Boa Esperança, Cuiabá – MT, Brazil
Email: diandronavarro7@gmail.com

ABSTRACT

The microregion of Alto Teles Pires, in the Mato Grosso State, is located at an important national pole of irrigation by center pivot systems, whose municipalities have presented relevant agricultural production. Thus, the management of water resources for consumptive uses in agricultural activities in this geographical area deserves special attention. Among the main tools for the management of water resources, the climatological water balance can be mentioned since it makes it possible to establish a relationship between the input of water from precipitation and its storage capacity in the soil. This theme motivated the realization of this research, which aimed to carry out the climatological water balance for the municipalities of this microregion. The study used historical series of hourly and daily meteorological data, obtained from the National Institute of Meteorology. The reference evapotranspiration was estimated using the Penman-Monteith-FAO. The climatic data were analyzed by the EXCEL spreadsheet, determining the main daily descriptive statistics of each variable, as well as the monthly averages of precipitation and evapotranspiration. Then, the climatological water balance was performed with its graphic representation of excess or deficiency of water and its alterations. The volume of precipitation and total annual evapotranspiration in Sorriso was around 10% and 2% higher than estimated, respectively, for the municipality of Nova Ubiratã. However, in the municipality of Sorriso, the volume of precipitation was greater than evapotranspiration, while in Nova Ubiratã there was an inversion of this relationship, resulting in a water deficit throughout the year. The monthly climatological water balance made it possible to define the year with excess and deficiency of water in the soil, as well as the beginning and end of its withdrawal and replacement for the municipalities of the referred microregion. Therefore, estimating the mentioned balance is a useful and viable tool for planning agricultural activities. The results obtained in this research showed that the soil class, the climatic conditions, given by the type of biome and geographic location, and the size and period of collection of the historical series of meteorological data can influence the climatological water balance.

Keywords: Evapotranspiration, Penman-Monteith-FAO, Thornthwaite, and Mather.

1 INTRODUCTION

The microregion of Alto Teles Pires, in the state of Mato Grosso, is in an important national pole of irrigation by central pivot systems, being classified as emerging with a high prospect of expansion (ANA, 2019). To this microregion belong the municipalities of Ipiranga do Norte, Itanhangá, Lucas do Rio Verde, Nobres, Nova Mutum, Nova Ubiratã, Santa Rita do Trivelato, Sorriso and Tapurah, which have presented relevant agricultural production, according to the 2021 Agricultural Census conducted by the Brazilian Institute of Geography and Statistics (IBGE, 2021). In this sense, the management of water resources for consumptive uses in the agricultural activities of this geographical area deserves special attention.

Among the main tools for the management of water resources can be mentioned the climatological water balance, since it makes it possible to establish a relationship between the entry of water from precipitation and the capacity of its storage in the soil. This aspect is a premise of paramount importance for agricultural planning, aiming at the need for irrigation of annual and perennial crops, some of which can be used as raw material for silage, such as corn, sorghum and millet. Thus, the irrigation depth can be estimated using the climatological water balance. In this context, several studies have been carried out, highlighting the importance of water balance applied to agricultural planning (NIED et al., 2005; CARVALHO et al., 2009 and 2011; FENNER et al., 2014a, 2014b; SOBENKO et al., 2016; SILVA et al., 2017, 2020a; LUIS et al., 2023).

The water availability for irrigation of cultivated pastures should be taken into account due to its great expansion and development of new forage cultivars, especially the *Panicum*, *Andropogon*, *Stylozanthes*, and *Brachiaria*, which have contributed to the production in beef cattle systems and the reduction of your costs. In addition, the evolution in the production of soybeans, corn and other raw materials used in the preparation of rations associated with genetic improvement has favored the progress of poultry and swine farming in several regions of Brazil. Recent studies in the field of water availability for agricultural purposes can be found in Borges et al. (2022a, 2022b, 2022 c, and 2023).

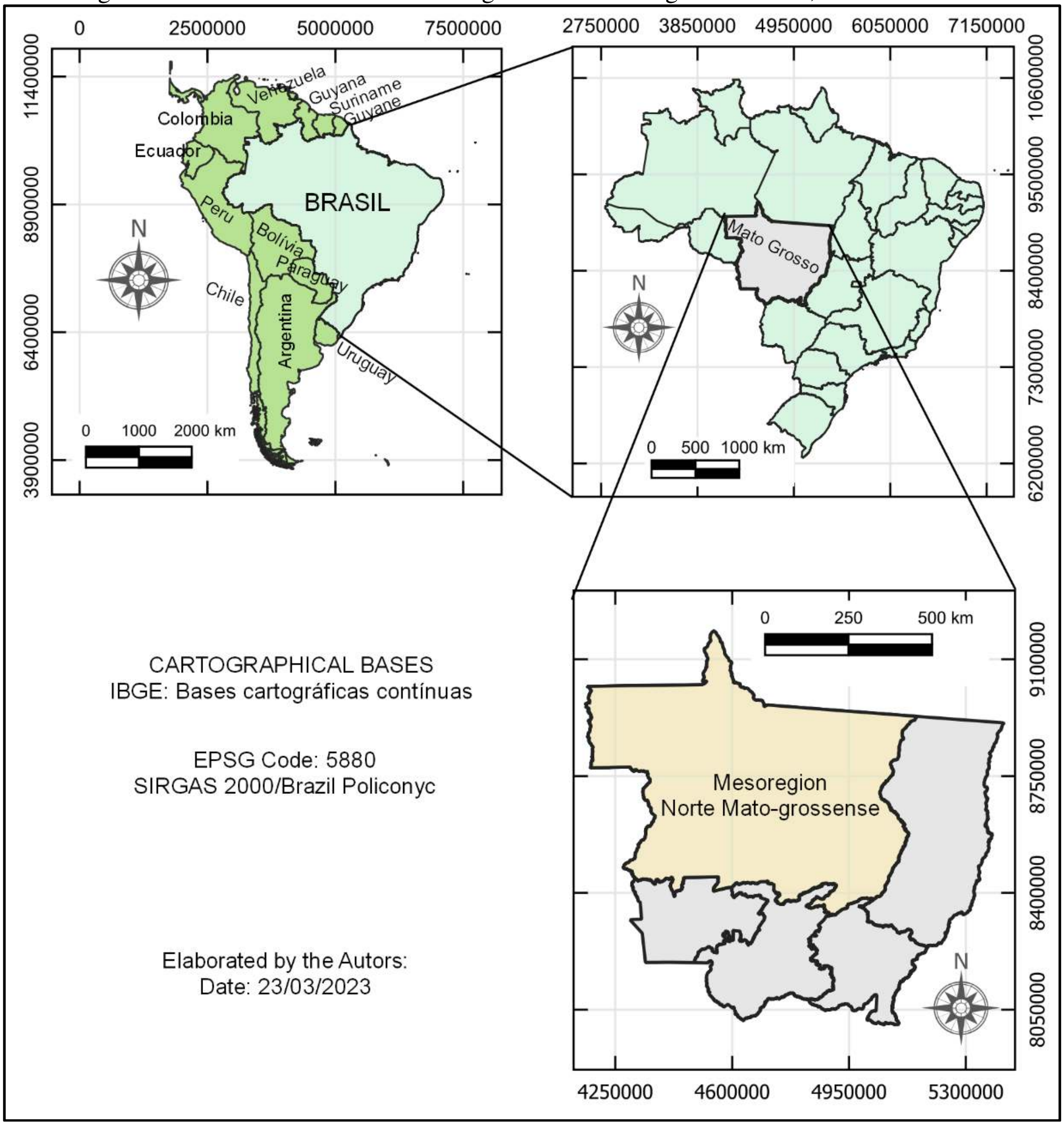
The total precipitation in the period and the water storage capacity in the soil, as well as the estimate of potential evapotranspiration, constitute the main variables of the climatological water balance. Potential or reference evapotranspiration can be determined using several methodologies. However, the Penman-Monteith method is currently suggested as the standard procedure to calculate the aforementioned variable, being parameterized by the Food and Agriculture Organization of the United Nations (FAO), according to Allen et al. (1998). Therefore, the climatological water balance can be obtained, depending on variables available in meteorological stations in the region, such as: temperature, humidity and air speed, global solar radiation, precipitation, atmospheric pressure and altitude.

Having as a reference the bibliography consulted, this research is based on the hypothesis that the climatological water balance allows inferring about the deficiency or surplus of water, as well as its storage in the soil from variables obtained in meteorological stations located in the region. Thus, its calculation can serve as a subsidy to define the water depth needed in the irrigation of crops and pastures intended for animal consumption, aiming at the rational use of water resources. The theme addressed motivated the realization of the present study, which aimed to carry out the climatological water balance for the municipalities of the Alto Teles Pires microregion, in the state of Mato Grosso.

2 MATERIAL AND METHODS

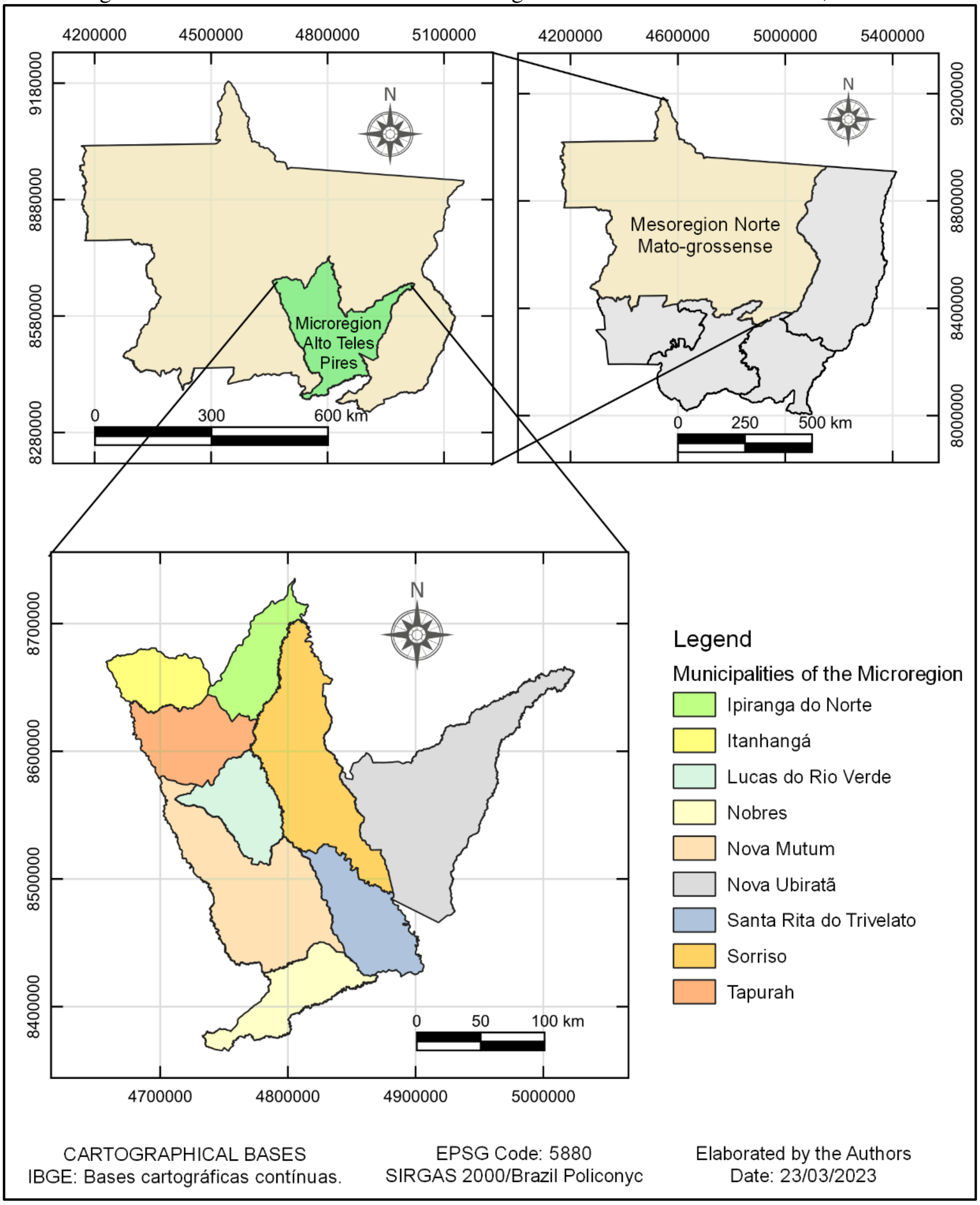
For this research was selected the Microregion of Alto Teles Pires - MT. This geographical zone is inserted in the North Mesoregion Mato-grossense, in the state of Mato Grosso, Brazil (Figure 1). Ness and territory predominate the climate Am or tropical monsoon, called humid tropical climate or tropical climate of monsoon and trade winds, which is characterized by presenting two seasons in the year, hot and dry (PEEL et al., 2007; ALVARES et al., 2013). The average annual temperature in the microregion varies between 19 °C and 33 °C, while the total annual rainfall is 1 472 to 1894 mm (INMET, 2023).

Figure 1. Location of the North Mato-grossense mesoregion in Brazil, South America.



In the study were used the historical series of meteorological data hours and diaries obtained at the National Institute of Meteorology, and may mention: temperature and relative humidity of the air, precipitation, global solar radiation and wind speed (INMET, 2023). In addition, several vector files ("*Shapefiles*") were acquired to represent the selected microregion and its municipalities, available in the continuous cartographic bases in the section of geosciences of the Brazilian Institute of Geography and Statistics (IBGE, 2023). Then, with the help of the open source program for QGIS geoprocessing and the aforementioned vector files, Figure 2 was elaborated, in which the location of this geographic zone and its municipalities is presented (QGIS, 2021).

Figure 2. Location of the Alto Teles Pires region in the state of Mato Grosso, Brazil.



For the estimation da and reference evapotranspiration (ET_o) we opted for the Penman-Monteith-FAO method, which is based on the equation developed by Allen et al. (1998) and recommended by Conceição (2006), given by:

$$ET_0 = \frac{0{,}408 \cdot \Delta \cdot (R_n - G) + \gamma \cdot \frac{900}{T_{ar} + 273{,}15} \cdot U_2 \cdot (e_s - e_a)}{\Delta + \gamma \cdot (1 + 0{,}34 \cdot U_2)}$$

Where:

ET_0 = Reference evapotranspiration (mm·day^{-1});

Δ = Declecivity of the saturation pressure curve (kPa·$^{oC-1}$);

R_n = Saldo daily surface radiation (MJ·m-2·$^{d-1}$);

G = Fdaily total heat in the ground (MJ·m-2·$^{day-1}$);

ɣ = Psychrometric constant (kPa·$^{oC-1}$);

T_{air} = Average air temperature (°C);

U_2= Velocity at 2 m height (m·$^{s-1}$);

e_s = Vapor saturation pressure (kPa);

e_a = Current steam pressure (kPa).

In the sequence, the values corresponding to each climatic variable are determined using the expressions described below:

$$\Delta = \frac{4098 \cdot \left[0{,}6108 \cdot e^{\left(\frac{17{,}27 \cdot T_{ar}}{T_{ar} + 237{,}3}\right)}\right]}{(T_{ar} + 237{,}3)^2}$$

$$\gamma = 0{,}665 \cdot 10^{-3} \cdot P_{atm}$$

$$P_{atm} = 101{,}3 \cdot \left(\frac{293 - 0{,}0065 \cdot z}{293}\right)^{5{,}26}$$

$$e_s = 0{,}6108 \cdot e^{\left(\frac{17{,}27 \cdot T_{ar}}{T_{ar} + 237{,}3}\right)}$$

$$e_a = \frac{e_s \cdot UR}{100}$$

Where:

P_{atm} = Plocal atmospheric resonance (kPa);
z = Altitude of the site (m);
RH = mean relative humidity (%).

According to Allen et a l. (1998), the small magnitude of the heat flux in the ground, concerning the radiation balance for the observation of a day, can be considered null, ist is, one can adopt the valor of G as zero (G=0). However, the daily level of surface radiation cannot be obtained directly at climatological stations, which is why it was determined, as a function of other variables, using the following equations:

$$R_n = R_{ns} - R_{nl}$$

$$R_{ns} = (1 - \propto) \cdot R_s$$

$$R_{nl} = \sigma \cdot \left[\frac{(T_{max} + 273{,}15)^4 + (T_{min} + 273{,}15)^4}{2}\right] \cdot (0{,}34 - 0{,}14 \cdot \sqrt{e_a}) \cdot (1{,}35 \cdot \frac{R_s}{R_{so}} - 0{,}35)$$

$$R_{so} = (0{,}75 + 2 \cdot 10^{-5} \cdot z) \cdot R_a$$

$$R_a = \frac{118{,}08}{\pi} \cdot dr \cdot [\omega_s \cdot sen(\varphi) \cdot sen(\delta) + cos(\varphi) \cdot cos(\delta) \cdot sen(\omega_s)]$$
$$dr = 1 + 0{,}033 \cdot cos(\frac{2 \cdot \pi}{365} \cdot J)$$
$$\delta = 0{,}409 \cdot sen(\frac{2 \cdot \pi}{365} \cdot J - 1{,}39)$$
$$\omega_s = \frac{\pi}{2} - arctan\left[\frac{-tan(\varphi) \cdot tan(\delta)}{\sqrt{X}}\right]$$
$$X = 1 - [tan(\varphi)]^2 \cdot [tan(\delta)]^2$$

Where:

R_{ns} = shortwave radiation balance (MJm-2· ·$^{day-1}$);
R_{nl} = long-wave radiation balance as (MJm-2· ·$^{day-1}$);
α= vegetation reflection coefficient (albedo);
α= 0.23 for the reference crop (gram);
σ= Stefan-Boltzmann constant (σ = 4.90310-9· (MJm-2· ·$^{day-1}$);
T_{min} = Minimum temperature of the day (°C);
T_{max} = Maximum temperature of the day (°C);
R_s = global solar radiation (MJm-2· ·$^{day-1}$);
R_{so} = incident solar radiation in the absence of clouds (MJm-2· ·$^{day-1}$);
R a = solar radiation at the top of the atmosphere (MJm-2· ·$^{day-1}$);
d_r = relative inverse distance between the Earth and the Sun (rad);
J = Day of the year in the calendar Julian (dimensionless);
δ = Solar declination (rad);
ω = hourly angle at sunrise (rad);
φ = Local latitude (rad).

The climatic data were analyzed with the aid of the EXCEL spreadsheet, which made it possible to determine the minimum, maximum and average daily values of each variable, as well as the monthly averages of precipitation and evapotranspiration. Then, a simple and complete climatological water balance was performed with the corresponding graphic representation of the excess or deficiency of water and its alterations. In addition, using the QGIS program, a map of the microregion was elaborated with the location of the municipalities and the automatic climatological stations (QGIS, 2021).

Taking as a reference the works of Lima and Aparecido (2020); Pereira et al. (2007); Silva et al. (2017; 2020b); Souza et al. (2017); Tomasella and Rossato (2005) were determined the main components of the monthly climatological water balance, such as the accumulated negative (NAC), the storage (ARM), the alteration (ALT), the real evapotranspiration (ETR), the deficiency water (DEF) and excess water (EXC), as described below:

a) The difference between precipitation and reference evapotranspiration is calculated:

$P - ET_0$

b) The value of the accumulated negative in the current month (NAC_{atu}) is determined by:

If $P - ET0 < 0$, then $NAC_{acts} = (P - ET_0) + NAC_{ant}$

Otherwise ($P - ET0_{\geq 0}$), still, one should question:

S and $NAC_{ant} < 0$ and $(P - ET_0) \leq CAD$, then $NAC_{atu} = CAD \cdot \ln\left(\frac{ARM_{atu}}{CAD}\right)$

Otherwise, then $NAC_{atu} = 0$

c) The value of current storage (ARM_{atu}) is estimated, given by:

If $P - ET_0 \geq CAD$, then $ARM_{atu} = CAD$

Otherwise ($P - ET_0 < CAD$), still, one should question the:

S and $(P - ET0)ant < 0$and $(P - ET0) \geq 0$, then $ARM_{atu} = ARM_{ant} + (P-ET_0)_{atu}$

Otherwise, then $ARM_{atu} = CAD \cdot e^{\left(\frac{NAC_{atu}}{CAD}\right)}$

d) The value of the current change (ALT_{atu}) is calculated, given by:

$ALT_{atu} = ARM_{atu} - ARM_{ant}$

e) The value of the current actual evapotranspiration (ETR_{atu}) is determined, given by:

If $P - ET0 \geq 0$, then $ETR_{atu} = ET_0$

Otherwise ($P - ET0_{< 0}$), then $ETR_{atu} = P - ALT_{atu}$

f) Estimates and the value of the current water deficiency (DEF_{atu}), given by:

$DEF_{atu} = ET_0 - ETR_{atu}$

g) The value of the current water excess (EXC_{atu}) is calculated, given by:

If $ARM_{atu} < CAD$, then $EXC_{atu} = 0$

Otherwise ($ARM_{atu} \geq 0$), then $EXC_{atu} = (P - ET_0)atu - ALT_{atu}$

Where:

P = Monthly precipitation (m m);

ET_0 = Monthly evapotranspiration (m m);

ETR_{atu} = Current monthly evapotranspiration (m m);

CAD = Available water capacity in the soil (m m);

NAC_{atu} = Cumulative negative value n the current month (m m);

NAC_{ant} = Cumulative negative value n the previous month (m m);

ARM_{atu} = Accumulated storage value n the current month (m m);

RM_{ant} = Value of accumulated storage n the previous month (m m);

$TheLT_{atu}$ = Value of the water change n the current month (m m);

DEF_{atu} = Value of water deficiency in the current month (m m);

$EXC\ at_u$ = Value of water excess no month actual (m m);

3 RESULTS AND DISCUSSION

In the microregion of Alto Teles Pires, Mato Grosso, only two climatological and automatic stations were made available by the National Institute of Meteorology, installed in the municipalities of Sorriso and Nova Ubiratã (Figure 3). The data regarding the geographical location and the interval of the historical series obtained are shown in Table 1. It should be noted that the initial date corresponds to the inauguration of the station.

Figure 3. Location of automatic climatological stations in the Alto Teles Pires Microregion, MT.

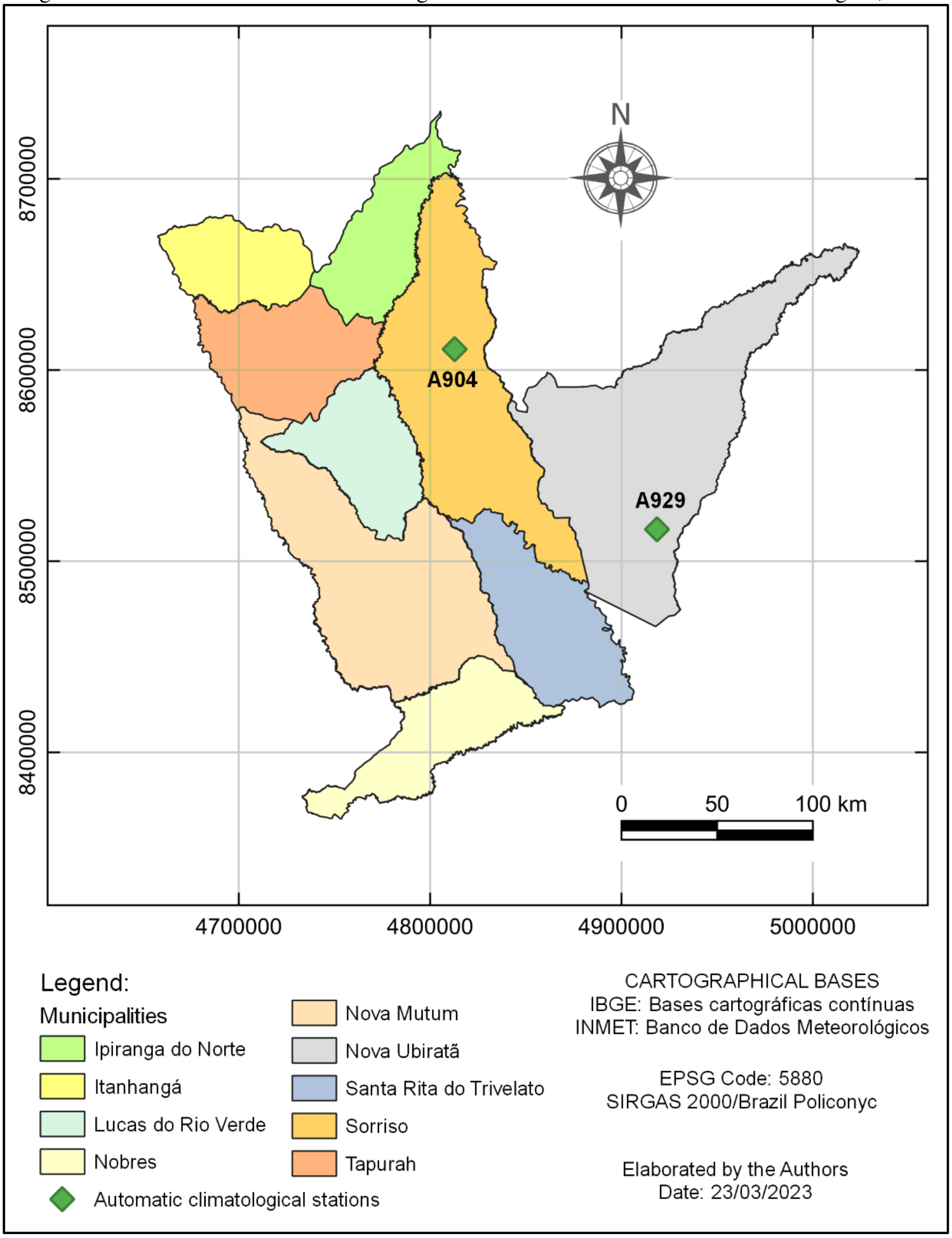


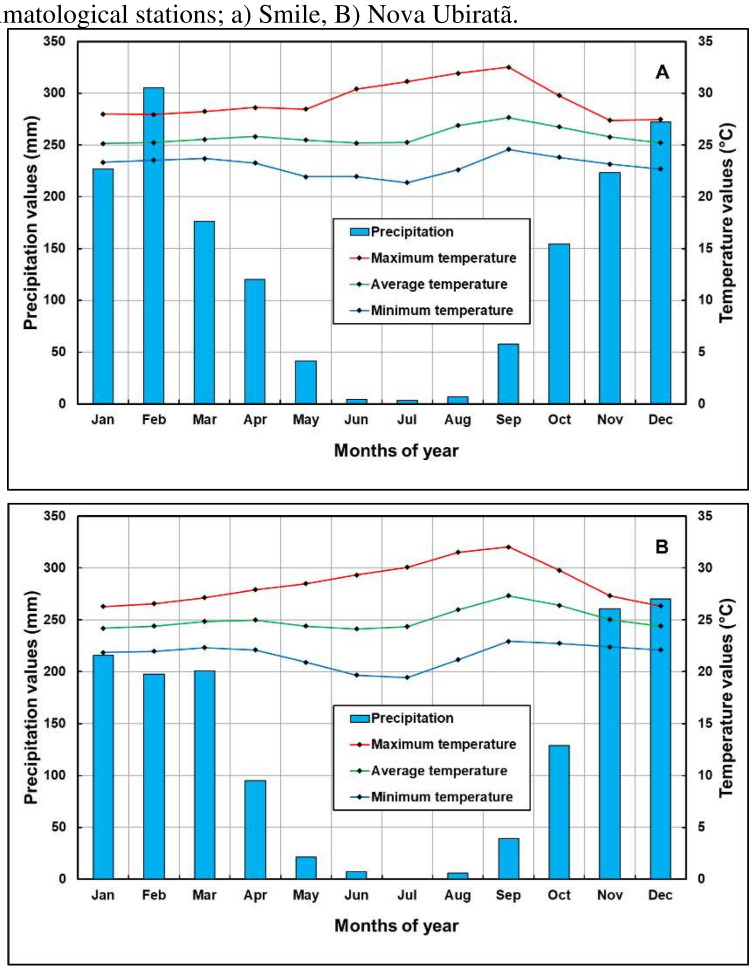
Table 1. General information about the automatic climatological stations located in the Alto Teles Pires microregion, state of Mato Grosso.

Code	Municipality	Altitude (m)	Geographical coordinates (°)		The interval of the historical series	
			Latitude (S)	Longitude (W)	Initial	Final
A904	Smile	379,31	12,555000	55.722777	15/12/2002	02/28/2023
A929	New Ubiratan	446,48	13.411111	54.752222	12/04/2008	28/02/2023

Source: Prepared by the authors, from INMET (2023).

The climograms corresponding to the municipalities of Sorriso and Nova Ubiratã were elaborated from the historical series obtained (Figure 4). In this Figure, the observe a similar trend for precipitation values and has features (minimum, average, and maximum). However, in the municipality of Sorriso, there is a high average rainfall in February. Although both municipalities are inserted in the same region and nearby, this discrepancy may be associated with the characteristics of the relief, as well as with the use and coverage of the soil, which could interfere with the hydrological cycle.

Figure 4. Climograph // Weather by Months of the municipalities of the Alto Teles Pires Microregion in the state of Mato Grosso with automatic climatological stations; a) Smile, B) Nova Ubiratã.



Tables 2 and 3 summarize the monthly mean values of the climatological water balance for the municipalities of Sorriso and Nova Ubiratã. According to these Tables, the volume of precipitation and total annual evapotranspiration in Sorriso was around 10% and 2% higher than estimated for the municipality of Nova Ubiratã, respectively. However, in the municipality of Sorriso, the volume of precipitation was higher than evapotranspiration, while in Nova Ubiratã there was an inversion of this relationship, resulting in a water deficit throughout the year.

Table 2. Monthly average values of the climatological water balance for the municipality of Sorriso.

MONTHS	P	ETP	P-ET$_0$	NAC	ARM	ALT	ETR	DEF	EXC
January	226,67	122,50	104,17	0,00	100,00	0,00	122,50	0,00	104,17
February	305,18	111,06	194,12	0,00	100,00	0,00	111,06	0,00	194,12
March	176,01	122,69	53,32	0,00	100,00	0,00	122,69	0,00	53,32
April	120,24	108,63	11,61	0,00	100,00	0,00	108,63	0,00	11,61
May	41,44	121,41	-79,97	-79,97	44,94	-55,06	96,49	-24,92	0,00
June	4,58	124,97	-120,39	-200,36	13,48	-31,46	36,04	-88,93	0,00
July	3,51	141,83	-138,32	-338,68	3,38	-10,10	13,61	-128,22	0,00
August	6,69	158,95	-152,26	-490,95	0,74	-2,64	9,33	-149,62	0,00
September	57,90	151,82	-93,92	-584,87	0,29	-0,45	58,35	-93,47	0,00
October	154,40	135,34	19,06	-164,26	19,35	19,06	135,34	0,00	0,00
November	223,33	111,97	111,36	0,00	100,00	80,65	111,97	0,00	30,71
December	272,31	117,18	155,13	0,00	100,00	0,00	117,18	0,00	155,13
Total	**1592,25**	**1528,35**	**63,90**	**-1859,09**	**682,19**	**0,00**	**1043,19**	**485,16**	**549,06**

Table 3. Monthly average values of the climatological water balance for the municipality of Nova Ubiratã.

MONTHS	P	ETP	P-ET$_0$	NAC	ARM	ALT	ETR	DEF	EXC
January	215,89	118,62	97,27	0,00	100,00	0,00	118,62	0,00	97,27
February	197,76	107,86	89,90	0,00	100,00	0,00	107,86	0,00	89,90
March	200,73	120,30	80,43	0,00	100,00	0,00	120,30	0,00	80,43
April	95,17	106,60	-11,43	-11,43	89,20	-10,80	105,97	-0,63	0,00
May	21,15	120,36	-99,21	-110,64	33,08	-56,13	77,28	-43,08	0,00
June	7,56	120,29	-112,73	-223,37	10,71	-22,36	29,92	-90,37	0,00
July	0,02	137,23	-137,21	-360,58	2,72	-8,00	8,02	-129,21	0,00
August	6,10	155,44	-149,34	-509,92	0,61	-2,11	8,21	-147,23	0,00
September	39,42	148,13	-108,71	-618,63	0,21	-0,40	39,82	-108,31	0,00
October	128,98	134,26	-5,28	-623,91	0,20	-0,01	128,99	-5,27	0,00
November	260,64	111,16	149,48	0,00	100,00	99,80	111,16	0,00	49,68
December	270,04	115,43	154,61	0,00	100,00	0,00	115,43	0,00	154,61
Total	**1443,46**	**1495,68**	**-52,22**	**-2458,49**	**636,72**	**0,00**	**971,57**	**524,11**	**471,89**

Based on the values of accumulated negative and monthly storage, it can be stated that the municipality of Sorriso presented a more favorable situation regarding water availability in the soil.

Note that the two most critical months in both municipalities were August and September for Sorriso, as well as September and October for Nova Ubiratã (Tables 2 and 3). The water deficiency in Nova Ubiratã was 7.43% higher, while the excess water was 14.05% lower when compared to the values obtained for Sorriso. These differences may be related to several factors, among which we can mention the soil class d, as well as its use and cover, which can interfere with the speed of water infiltration in the soil and its interception by the leaves, which in turn could influence the evaporation process.

The simplified climatological water balance for the municipalities in the Alto Teles Pires Microregion, Mato Grosso, is shown in Figure 5. The greatest inequality can be observed in the value of the water excess during February, in which twice as much as the variable was reached. And however, water deficiency begins in April and extends until October with a similar trend for both municipalities, with August being the most critical. From October, the two municipalities showed excess water with very close values, especially in December.

Figure 5. Simplified water balance for the municipalities of the Alto Teles Pires Microregion in the state of Mato Grosso with automatic climatological stations; a) Smile, B) Nova Ubiratã.

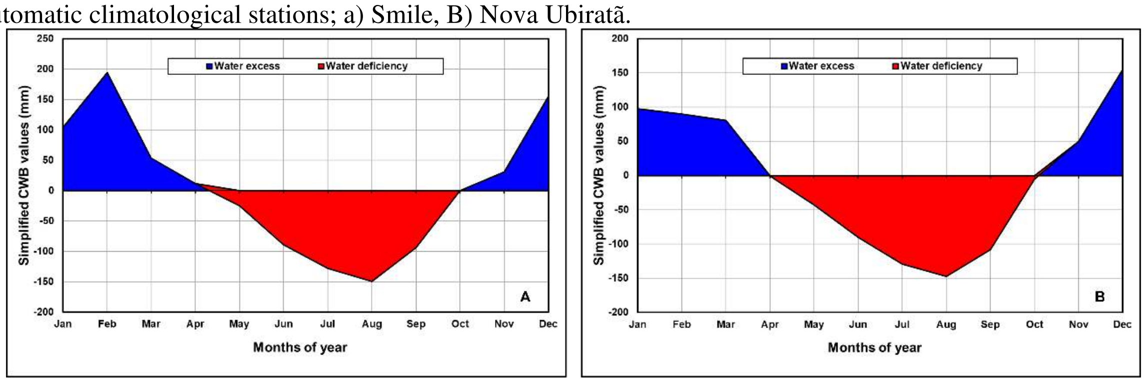
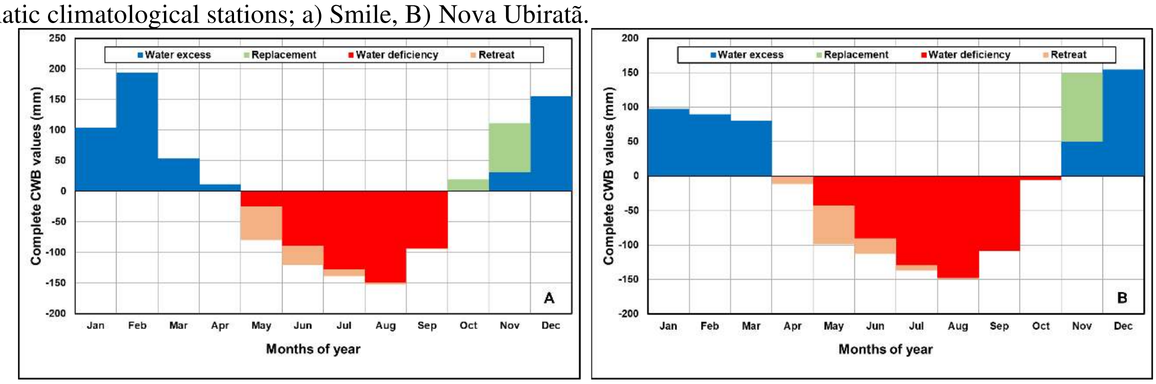


Figure 6 shows the complete climatological water balance for the municipalities of Sorriso and Nova Ubiratã, Mato Grosso, which allows us to infer both about water deficiency and excess, as well as about the process of withdrawal and replacement of water in the soil. In this sense, there was a notable disagreement between the two graphs, especially in the values and trend of water excess and the process of water replacement. In the municipality of Sorriso, there was water excess during the first four months of the year, but in a very variable way.

Figure 6. Water balance for the municipalities of the Alto Teles Pires Microregion in the state of Mato Grosso with automatic climatological stations; a) Smile, B) Nova Ubiratã.



It is also worth mentioning that in February the water excess doubled the value of the available water capacity (CAD), which may favor the process of soil erosion (Figura 6). This situation was not observed in the municipality of Nova Ubiratã, in which the water excess was lower than the available water capacity (CAD) during the first four months of the year. Already, the withdrawal of water began in May and ended in July for the municipality of Sorriso, while in the municipality of Nova Ubiratã, this process began in April and culminated in July.

On the other hand, water replacement had a better distribution in Sorriso, occurring during two months with lower intensity (October and November), different from the occurrence of this process in Nova Ubiratã, where it was only in November more accentuated (Figure 6). This aspect has extraordinary importance for the planning of irrigated agriculture, because it can be estimated the need for the real depth to be applied, conforms to the requirements of the crop. It should be noted that excess water and replacement should be considered in the adoption of soil conservation practices, aiming at its protection and preservation.

The trend of monthly precipitation for the municipality of Sorriso evidenced in this research was different from that observed by Fenner et al. (2014a). These discrepancies may be associated with the period of the study, as well as the period corresponding to the historical series, which may interfere with precipitation volumes. However, the temperature showed similar behavior. In addition, the monthly climatological water balance presented by these authors contains values analogous to those calculated in this study, except for January. These results may have been influenced by the available water capacity in the soil and the volume of precipitation during that month.

Ferreira et al. (2017) estimated the climatological water balance for the municipality of Lupércio, SãoPaulo. In the study, it was found that the excess and water deficiency was different from the values obtained in the present research, especially in May, June, and the period from July to September. These divergences may arise from the rainfall regime, the accumulated water content in the soil, and the land cover and use, among other, factors that interfere with the climatological water balance. It should also be highlighted other elements such as the geographical position, mainly, the altitude and the latitude, as well as the type of biome, that is, in Sorriso the Cerrado predominates, while in Lupércio the Atlantic Forest.

The probable influence of the type of biome on the climatological water balance can be noticed when comparing the results of this study with those obtained by Martins et al. (2021). These authors estimated the climatological water balance for the city of Humaitá, the state of the Amazon, in which it was found that there was a high water excess between January and April, followed by the withdrawal of water from May to October. Parallel to the withdrawal, the period of water deficiency began between June and October. However, the replacement occurred only in January, November, and December intensely. It should be mentioned that the high water excess and the intense replacement can favor erosion because of surface runoff after the soil reaches its available water capacity. The characteristics of the climatological water balance of this region differed from those evidenced in this study.

4 CONCLUSIONS

The monthly climatological water section made it possible to define the year with excess and deficiency of water in the soil, as well as the beginning and end of its withdrawal and replacement for the municipalities of the Alto Teles Pires microregion, in the state of Mato Grosso. Therefore, the estimation of the aforementioned balance is a useful and viable tool for the planning of agricultural activities, especially irrigated agriculture and rational crop management. The results obtained in this research showed that soil class, the climatic conditions, given by the type of biome and geographical location, and the size and period of collection of the rhetorical series of meteorological data can influence the climatological water balance.

ACKNOWLEDGMENT

To the National Institute of Meteorology (INMET) for allowing the consultation of climate data from the municipalities of Sorriso and Nova Ubiratã, Mato Grosso, Brazil. To the Brazilian Institute of Geography and Statistics (IBGE) for allowing continuous cartographic bases.

REFERENCES

ALLEN, R. G.; PEREIRA, L. S.; RAES, D.; SMITH, M. **Crop evapotranspiration: guidelines for computing crop water requirements**. Rome: FAO, Irrigation, and Drainage Paper 56. 300p.1998.

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVES, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v.22, n.6, p.711–728, 2013.
DOI: http://dx.doi.org/10.1127/0941-2948/2013/0507

BORGES, P. H. M.; MENDOZA, Z. M. S. H.; MORAIS, P. H. M.; CAVALCANTE, C. E. Consumo de agua por la ganadería lechera y disponibilidad hídrica en la microrregión Aripuanã de Mato Grosso. **Brazilian Journal of Animal and Environmental Research**,
Curitiba, v.5, n.1, p. 1017-1034, 2022a. **DOI:** http://doi.org/10.34188/bjaerv5n1-076

BORGES, P. H. M.; FAVERA, R. N. D.; MENDOZA, Z. M. S. H.; MORAIS, P. H. M. Water demand and availability for livestock in the microregion of Alto Teles Pires – MT, Brazil. **South Florida Journal of Environmental and Animal Science**, Miami, v.2, n.3, p. 275-292, 2022b. **DOI:** http://doi.org/10.53499/sfjeasv2n3-004

BORGES, P. H. M.; CAVALCANTE, C. E.; MORAIS, P. H. M.; MENDOZA, Z. M. S. H. Demanda e disponibilidade hídrica para a pecuária na microrregião de Aripuanã, Mato Grosso, Brasil. **Brazilian Journal of Animal and Environmental Research**, Curitiba, v.5, n.3, p. 3153-3170, 2022c. **DOI:** http://doi.org/10.34188/bjaerv5n3-046

BORGES, P. H. M.; MORAIS, P. H. M.; MENDOZA, Z. M. S. H. Demanda e disponibilidade hídrica para sistemas de pivô central na microrregião de Primavera do Leste - MT. **Brazilian Journal of Development**, Curitiba, v.9, n.1, p. 210-231, 2023.
DOI: http://doi.org/10.34117/bjdv9n1-015

CARVALHO, H. P.; DOURADO NETO, D.; TEODORO, R. E. F.; MELO, B. Balanço hídrico climatológico, armazenamento efetivo da água no solo e transpiração na cultura de café. **Bioscience Journal**, Uberlândia, v. 27, n. 2, p. 221-229. 2011. Disponível em:
https://seer.ufu.br/index.php/biosciencejournal/article/view/8070/7227

CARVALHO, M. A.; MÉLLO JÚNIOR, A. V.; SCHARDONG, A.; PORTO, R. L. L. Sistema de suporte à decisão para alocação de água em projetos de irrigação. **Revista Brasileira de Engenharia Agrícola e Ambiental**, Campina Grande, v. 13, n. 1, p. 10-17, 2009.
DOI: http://doi.org/10.1590/S1415-43662009000100002

CONCEIÇÃO, M. A. F. **Roteiro de cálculo da evapotranspiração de referência pelo método de Penman – Monteith – FAO**. Circular Técnica 65 – EMBRAPA, Bento Gonçalves. 8p. 2006.

FENNER, W.; MOREIRA, P. S. P.; FERREIRA, F. S.; DALLACORT, R.; QUEIROZ, T. M.; BENTO, T. S. Análise do balanço hídrico mensal para regiões de transição de Cerrado-Floresta e Pantanal, Estado de Mato Grosso. **Acta Iguazu**, Cascavel, v. 3, n. 1, p. 72-85, 2014a. Disponível em: https://e-revista.unioeste.br/index.php/actaiguazu/article/view/9649/7082

FENNER, W.; DALLACORT, R.; MOREIRA, P. S. P.; QUEIROZ, T. M.; FERREIRA, F. S.; BENTO, T. S.; CARVALHO, M. A. C. Índices de satisfação de necessidade de água para o milho

segunda safra em Mato Grosso. **Revista Brasileira de Climatologia**, Dourados, v. 15, n. 10, p. 109-121, 2014b.
DOI: https://doi.org/10.5380/abclima.v15i0.37309

FERREIRA, I. A.; MONTEIRO, R. N. F.; CORREIA, E. C. S. S.; FONTANA, L. F.; LEITE, K. N. Balanço hídrico climatológico e classificação climática para o município de Lupércio – SP. Revista Mirante, Anápolis (GO), v. 10, n. 5a, p. 1-14, 2017.
Disponível em: https://www.revista.ueg.br/index.php/mirante/issue/view/377

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATISTICA. **Produção Agropecuária – Censo 2021**. Rio de Janeiro: 2023. Disponível em:
https://www.ibge.gov.br/explica/producao-agropecuaria/mt

IBGE - INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATISTICA. **Bases Cartográficas Contínuas**. Rio de Janeiro: 2023. Disponível em:
https://www.ibge.gov.br/geociencias/cartas-e-mapas/bases-cartograficas-continuas.html

INMET - INSTITUTO NACIONAL DE METEOROLOGIA. **BDMEP: Banco de Dados Meteorológicos para Ensino e Pesquisa**. Brasília: 2023.
Disponível em: https://bdmep.inmet.gov.br/

LIMA, R. F.; APARECIDO, L. E. O. Caracterização climática e sua influência na biodiversidade da região Centro-oeste do Brasil. **In: IV ENCONTRO INTERNACIONAL DE GESTÃO, DESENVOLVIMENTO E INOVAÇÃO**, 2020. Edição Online. **Anais**...2020, p.1-21. Disponível em:
https://periodicos.ufms.br/index.php/EIGEDIN/article/view/11253/8219

LUIS, B. P.; TRUCIDO, L. L.; SAINZ, M. A.; PASINI, F. RIEDER, E. Balanço hídrico de duas sub bacias com distintos usos do solo localizadas na região nordeste do Uruguai utilizando dados de satélite. **Brazilian Journal of Development**, Curitiba, v. 9, n. 1, p. 02-13, 2023. **DOI:** https://doi.org/10.34117/bjdv9n1-001

MARTINS, P. A. S.; NUNES, D. D.; QUERINO, A. S.; SILVA, P. C. S. Balanço hídrico climatológico pelo método de Thornthwaite e Mather (1955) para a cidade de Humaitá - Mesorregião sul do estado do Amazonas. **In: XIV ENCONTRO NACIONAL DE PÓS-GRADUAÇÃO E PESQUISA EM GEOGRAFIA**, 2021. On-line. **Anais**... 2021.
Disponível em:
https://editorarealize.com.br/artigo/visualizar/81908

NIED, A. H.; HELDWEIN, A. B.; ESTEFANEL, V.; SILVA, J. C.; ALBERTO, C. M. Épocas de semeadura do milho com menor risco de ocorrência de deficiência hídrica no município de Santa Maria, RS, Brasil. **Ciência Rural**, Santa Maria, v. 35, n. 5, p. 995-1002, 2005.
DOI: http://doi.org/10.1590/S0103-84782005000500003

PEEL, M. C.; FINLAYSON, B. L.; MCMAHON, T. A. Updated world of the Köppen-Geiger climate classification. **Hydrology and Earth System Sciences**, Göttingen, v.11, n.5, p.1633-1644, 2007. **DOI:** https://doi.org/10.5194/hess-11-1633-2007

PEREIRA, A. R.; ANGELOCCI, L. R.; SENTELHAS, P. C. **Meteorologia Agrícola**. Edição revisada e ampliada, Piracicaba: USP, 191p. 2007.

QGIS DEVELOPMENT TEAM. **QGIS Geographic Information System**. Open Source Geospatial Foundation Project. Versão 3.16.0-Hannover. 2021.

SILVA, A. T.; RANGEL, L. C.; SOUSA, E. F.; LUGON JUNIOR, J.; TELLES, W. R. Balanço hídrico climatológico do município de Itaperuna/RJ. **In: II ENCONTRO NACIONAL DE DESASTRES**, 2020. Virtual. **Anais**… 2020b, p. 1-4. Disponível em: https://anais.abrhidro.org.br/job.php?Job=7342

SILVA, P. D.; MARTINS, J. V. S.; ARAÚJO, D. B.; BORGES, P. F. Balanço hídrico climatológico como ferramenta ao planejamento agropecuário na região de Sobral - CE. **Revista Científica Rural**, Bagé-RS, v. 22, n.1, 2020a. DOI: https://doi.org/10.30945/rcr-v22i1.3129

SILVA, G. N.; SILVA, J. G. F.; SANTANA, W. M. Estimativa do balanço hídrico climatológico: Um estudo de caso. **Vivências**. v. 13, n. 25, p.117-127, 2017. Disponível em: http://www2.reitoria.uri.br/~vivencias/Numero_025/artigos/pdf/Artigo_12.pdf

SOBENKO, L. R.; FANAYA JÚNIOR, E. D.; SANTOS, O. N. A.; MARQUES, P. A. A. Estimativa da necessidade de irrigação na cultura do milho safrinha em Sorriso-MT por métodos agroclimatológicos. **Revista Brasileira de Milho e Sorgo**, v.15, n.3, p. 544-557, 2016. **DOI:** http://dx.doi.org/10.18512/1980-6477/rbms.v15n3p543-556

SOUZA, J. L. M.; JERSZURKI, D.; SCHAFER, R.; GURSKI, B. C.; SCHAFER, H. Balanço hídrico climatológico: precipitação e evapotranspiração de referência estimadas com metodologia alternativa. **Revista Brasileira de Climatologia**, Dourados, v.20, n. 13, p. 284-298, 2017. **DOI:** http://dx.doi.org/10.5380/abclima.v20i0.45385

TOMASELLA, J.; ROSSATO, L. **Balanço hídrico**: **Tópicos em Meio Ambiente e Ciências Atmosféricas**. INPE, São José dos Campos, 12p. 2005.