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EVAPOTRANSPIRACÃO REAL DA BANANA- NANICA DETERMINADA PELO ALGORITMO METRIC NO SEMIÁRIDO DO CEARÁ[1]

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1 RESUMO

O presente trabalho teve como objetivo estimar a evapotranspiração real (ET_r) diária através da aplicação do algoritmo METRIC (*Mapping evapotranspiration at high resolution with internalized calibration*) a partir de técnicas de sensoriamento remoto, numa área irrigada com banana-nanica no município de Barbalha, CE e comparar as estimativas da ET com o método de Penman-Monteith. Foram utilizadas imagens do satélite Landsat-8 OLI/TIRS e dados meteorológicos obtidos numa estação meteorológica automática. Feito o processamento das imagens, determinou-se as ET_r's diárias estimadas a partir da densidade de fluxo de calor latente (LE), obtida como resultado da equação do balanço de energia. As evapotranspirações diárias na área estudada apresentaram valores determinados pelo METRIC entre 5,0 e 6,8 mm dia^{-1}, os quais corroboram com resultados encontrados na bibliografia. Comparando os valores de ET_r estimados pelo METRIC e pelo método de Penman- Monteith, observou-se diferenças relativamente baixas, inferiores a 6,0%, o que enquadra como um nível de precisão satisfatório e aceitável, logo, essa é uma boa ferramenta para a determinação das necessidades de água das plantas e na tomada de decisões quanto ao uso dos recursos hídricos.

Palavras-Chave: sensoriamento remoto, uso consuntivo, *Musa spp.*

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REAL EVAPOTRANSPIRATION OF THE DWARF CAVENDISH BANANA DETERMINED BY THE METRIC ALGORITHM IN THE SEMIARID REGION OF CEARA

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2 ABSTRACT

The present work aimed to estimate the daily real evapotranspiration (ET_r) through the application of the METRIC (*Mapping evapotranspiration at high resolution and with internalized calibration*) algorithm by means of remote sensing techniques, in an irrigated area cultivated with dwarf cavendish banana in the municipality of Barbalha, CE and to compare the ET_r with the one calculated by the Penman-Monteith method. Landsat-8 OLI / TIRS satellite images and meteorological data obtained in an automatic meteorological station were used. After processing the images, the daily estimated ET_r's were determined from the latent heat flux density (LE), obtained as a result of the energy balance equation. The daily evapotranspiration's in the studied area presented values estimated by the METRIC algorithmic between 5.0 and 6.8 mm day^{-1}, which of them corroborate with the results found in the bibliography. Comparing the values of ET_r estimated by the METRIC in relation to the Penman-Monteith method, low differences were observed, less than 6.0%, which fits as satisfactory and acceptable level of precision, so this is a good tool for the determination of the crop water requirements and in the decisions-making regarding to the use of water resources.

Keywords: remote sensing, water consumption, *Musa spp*.

3 INTRODUCTION

Water, a finite and increasingly scarce resource that is facing quantity and quality problems, is not only an essential element for life but also a determining factor for economic development and social well-being (DINIZ, 2018).

factors cause a lack or scarcity of rainfall, which contributes to drought in semiarid regions, thus leading to the incidence of droughts. This makes the use of irrigation and drainage essential, practices that tend to meet the partial or total water needs of crops and promote the conservation of environmental resources. To rationalize irrigation, knowledge of crop water needs, or evapotranspiration, is essential (BRASIL, 2013).

There are several direct and indirect methods for estimating evapotranspiration. Direct methods involve *in situ measurements* of the soil water balance and soil moisture monitoring and are considered the most accurate methods for determining evapotranspiration (CAMARGO; CAMARGO, 2000). Indirect or empirical methods are based on meteorological data, with the Penman–Monteith method being the most accurate way to calculate reference evapotranspiration (ETo). According to Allen *et al*. (2002), direct and indirect methods for estimating evapotranspiration are highly reliable and accurate; however, they have limitations in regard to estimating evapotranspiration over large areas. These limitations encourage the use of techniques such as remote sensing, which allows, through satellite images, the coverage of large areas and evapotranspiration on a regional scale (BOEGH; SOEGAARD; THOMSEM, 2002; HAFEEZ *et al*., 2002).

The energy balance, which is carried out via remote sensing techniques, predicts that of the total energy available on the soil surface, part is allocated to heating the soil, part to heat the air, ~~and~~ the remainder is used for crop evapotranspiration (SILVA, 2019). The energy balance makes it possible to obtain the vertical flux of latent heat and, consequently, evapotranspiration through—the difference in fluxes, also vertical, of heat in the soil, sensible heat and the radiation balance.

In the last two decades, different remote sensing techniques have been developed to determine ETr. Among these techniques, the “surface energy balance algorithm for land” (SEBAL) (BASTIAANSSEN *et al*., 1998) and the “mapping evapotranspiration at high resolution with internalized calibration” (METRIC) (ALLEN; TASUMI; TREZZA, 2007) stand out.

The METRIC algorithm was developed by Allen *et al*. (2005) and Tasumi *et al*. (2005), which was designed to estimate the energy balance and calculate evapotranspiration via procedures very similar to SEBAL, with some particularities related to the choice of the humid pixel and the calculation of the temperature difference in this pixel. Furthermore, another difference between these two methods concerns the estimation of daily evapotranspiration (GIONGO; VETTORAZZI, 2011).

METRIC follows all the steps of SEBAL and has the advantage of not requiring many meteorological variables at the surface level where the cold pixel is selected within an irrigated area (ALLEN *et al*. 2005; LIRA, 2008; TASUMI *et al*., 2005).

The objectives of this work were to estimate and compare the evapotranspiration of a banana crop in an irrigated area of the municipality of Barbalha, CE, via the METRIC algorithm with that via the standard Penman–Monteith method.

4 MATERIALS AND METHODS

The area in which the study was carried out is cultivated with dwarf bananas (*Musa* spp.) and is located on the border of the municipalities of Barbalha and Missão Nova (Figure 1), in the southern region of the state of Ceará, whose geographic coordinates are 07° 17' 07.91" South and 39° 12' 58" West, with an altitude of 398 meters above sea level (GOOGLE EARTH PRO, 2020).

Figure 1. Location of the experimental area in Barbalha, CE, highlighting the sample plot with irrigated cultivation of dwarf banana (in red).

Source: Google Earth Pro (2020)

The local soil is associated with dystrophic red Latosols (ARAÚJO *et al*., 2013). On the basis of the Koppen–Geiger classification, the climate in the study location is hot and humid (Aw) (MEDEIROS *et al*., 2013). The climate information collected was obtained from the automatic meteorological station in Barbalha, Ceará (INSTITUTO NACIONAL DE METEOROLOGIA, 2016). Three images generated by the *Operational Land Imager* were used. - *OLI* and *Thermal Infrared Sensor - TIRS of the* Landsat 8 satellite, orbit 217 and point 65, acquired from the *United States Geological Survey* (USGS), corresponding to the following days: May 22 (days after sowing (DAS) 143), August 10 (DAS 223), and October 29 (DAS 303) of 2016.

The images were selected on the basis of low cloud cover, aiming for better processing quality, meeting the research requirements, and the dates represent land cover conditions during rainy and dry periods. The data obtained from the meteorological stations are described in Table 1.

Table 1. Meteorological data used to obtain reference evapotranspiration (ET $_\theta$) according to the P enman–Monteith method for the Barbalha region, CE.

Date of images	**Temperature (°C)**		**relative U. (%)**		**Speed of the Wind (m/s)**	**Radiation Global MJ/m ^{2}/d**
	Max.	**Min.**	**Max.**	**Min.**		
May 22, 2016	28.4	26.7	75.0	71.0	2.1	22.9
10/08/2016	23.3	19.6	69.0	63.3	2.2	23.5
October 29, 2016	24.8	21.0	57.6	51.3	2.1	27.9

U: Humidity; Max: Maximum; Min: Minimum.
Source: Organization of the authors (2021).

Using the data described above, it was possible to determine the reference evapotranspiration (ET_θ) via the Penman–Monteith method via Equation (1).

$$ET_\theta = \frac{0{,}408 \, . \, \Delta .(R_n - G) + \gamma .\left(\frac{900}{T_{ar}+273}\right).U_2}{\Delta + \gamma .(1+0{,}34.U_2)} . (e_s - e_a) \quad (1)$$

where ET_θ is the reference evapotranspiration (mm.day $^{-1}$); R_n is the net radiation (MJ.m $^{-2}$ day $^{-1}$); G is the ground heat flux (MJ.m $^{-2}$ day $^{-1}$), which is considered an insignificant value when daily calculations are used; T is the average daily air temperature (°C); U_2 is the average daily wind speed at 2 m height (ms $^{-1}$) *and* the vapor pressure at saturation (kPa); $_a$ is the current average daily vapor pressure (kPa); Δ is the slope of the vapor pressure curve (kPa/°C); and γ is the psychrometric coefficient, which is considered constant, γ = 0.0622 kPa ° C $^{-1}$. The psychrometric coefficient remains constant because it is a function of atmospheric pressure, which varies little throughout the year (95.03 kPa), and of the latent heat of evaporation of water, which is little affected by temperature.

The Penmann–Monteith method allows the actual crop evapotranspiration (ET_c) to be calculated by multiplying ET_θ by the crop coefficient (K_c), according to the recommendations of Allen *et al*. (1998) in accordance with Equation 2.

$$ET_c = ET_\theta \, . K_c \quad (2)$$

$_C$ values vary depending on the stages of the crop analyzed. The average crop coefficient K_c of irrigated banana plants in the semiarid region of Brazil is 1.21, which is the value recommended by Oliveira *et al*. (2012) for banana plants in intermediate growth stages.

ET_a was determined through the energy balance equation, which is calculated as the residual difference between the net radiation to the surface and the losses due to sensible heat flux (energy used to heat the air) and soil heat flux (energy stored in the soil and vegetation), according to Equation 3.

$$\mathrm{LE} = \mathrm{R_n} - \mathrm{G} - \mathrm{H} \quad (3)$$

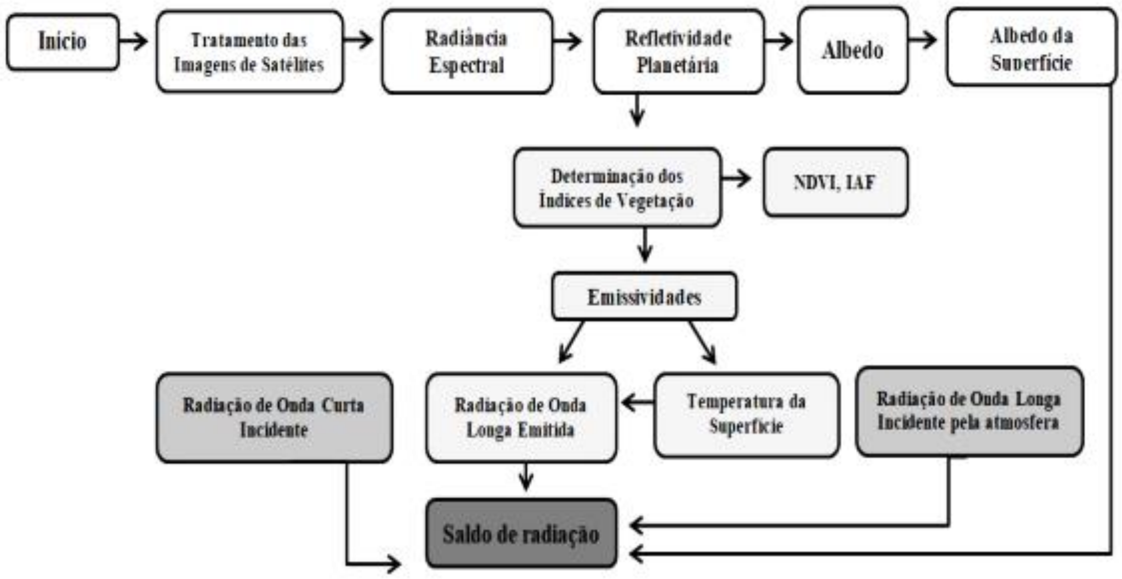
where LE is the latent heat flux (W. m $^{-2}$); R_n is the net radiation at the surface (W. m $^{-2}$); G is the ground heat flux (W. m $^{-2}$); and H is the sensible heat flux (W. m $^{-2}$).

To estimate the different components of the energy balance, the METRIC algorithm was used, in which the net radiation at the surface or, more commonly, the radiation balance R_n (W. m $^{-2}$) of a surface represents the amount of energy in the form of electromagnetic waves available to be distributed among the energy fluxes required for the processes of evapotranspiration, air heating, soil heating and photosynthesis (MACHADO *et al*., 2014). The radiation balance R_n was obtained from Equation (4) with sequential steps, as shown in the diagram in Figure 2.

$$\mathrm{R_n} = \mathrm{R_{s,inc}}.(1 - \alpha_s) - \mathrm{R_{ol,emi}} + \mathrm{R_{ol,atm}} - (1 - \varepsilon_0).\mathrm{R_{ol,atm}} \quad (4)$$

where $R_{s,inc}$ is the incident shortwave radiation; α_s is the surface albedo of each pixel; $R_{ol,emi}$ is the longwave radiation emitted by each pixel; $R_{ol,atm}$ is the longwave radiation emitted by the atmosphere in the direction of each pixel; and ε_o is the emissivity of each pixel.

Figure 2. Diagram of the computational steps of processing to obtain the surface radiation balance (R_n) via the *mapping algorithm evapotranspiration at high resolution with internalized calibration* (METRIC).



Source: Organization of authors (2021)

The soil heat flux (G) is the rate of heat stored by the soil and vegetation and was calculated via Equation 5, developed by Bastiaanssen (2000), which represents values close to noon.

$$G = \left[\frac{T_s}{\alpha_s} . (0{,}0038.\alpha_s e + 0{,}0074.\alpha_s^2).(1 - 0{,}98.NDVI^4)\right].R_n \quad (5)$$

where T $_s$ is the surface temperature and α $_s$ is the surface albedo for the purpose of correcting the heat flux values in the soil for water bodies, in which the *normalized difference vegetation index* (NDVI) < 0 can be expressed as follows: G = $0.5.R_n$ according to Allen *et al*. (2002).

The sensible heat flux H (W/m2) is determined on the basis of the concept of a temperature difference dT close to the ground surface between two points with extreme temperature and humidity conditions (cold and hot pixels) within the study area, as determined via Equation (6).

$$d\mathrm{T} = a + b.T_s \quad (6)$$

where a and b are coefficients of the linear relationship and are obtained in this process through the components of the energy balance in the cold and hot pixels, and T $_s$ is the surface temperature at each pixel. The pixels, also called anchors, were selected visually. The hot pixel was selected in an area of exposed soil, and the cold pixel was selected in an agricultural area with banana crops in full development.

The coefficients a and b are determined via two pairs of values for *d* T and T $_s$ via Equations (7) and (8):

$$a = \frac{dT_q - dT_f}{T_{s_q} - T_{s_f}} \quad (7)$$

$$b = \frac{dT_q - a}{T_{s_q}} \quad (8)$$

where T_{S_q} and T_{S_f} are the surface temperatures at the hot and cold pixels, respectively, adjusted to the elevation datum for each pixel in the image via the digital elevation model.

The cold pixel is selected in an agricultural area with crops in full development, with characteristics similar to those of the reference crop in which LE = 1.05 × ET_{θ} is considered (where ET_{θ} is the reference evapotranspiration estimated by the Penman–Monteith method (ALLEN; TASUMI; TREZZA, 2007; GIONGO and VETTORAZZI, 2011), $H_f = (R_n - G)_f - LE_f$, and d T at the cold pixel is calculated via Equation 9.

$$dT_f = \frac{H_f \cdot r_{ah_f}}{\rho_f . C_p} \tag{9}$$

where r_{ah_f} is estimated for the stability conditions and for the surface roughness of the cold pixel; ρ_f is the air density calculated for the cold pixel; and C_p is the specific heat of air at constant pressure (J kg^{-1} k^{-1}).

With the knowledge of dT and the resistance map r_{ah}, an initial map of H can be obtained. The values obtained do not adequately represent the H of each pixel and serve only as initial values of a process of repetitive steps, in which, in the subsequent steps, the stability conditions of each pixel are effectively considered. Depending on the atmospheric conditions, the values of the stability corrections for the transport of momentum (ψ_m) and heat (ψ_h) must be considered. For this purpose, the formulations of Paulson (1970) and Webb (1970) were used, given the neutrality condition (for L_{monin}= 0): $\Psi_m = 0$ and $\Psi_h = 0$. The corrected value for the friction velocity (u_*, ms $^{-1}$) is given by Equation (10).

$$u_* = \frac{k. u_{200}}{\ln\left(\frac{200}{Z_{om}}\right) - \Psi_{m(200m)}} \tag{10}$$

where k is the Von Karman constant (0.41), u_{200} is the wind speed at 200 m (ms $^{-1}$), Z_{om} is the roughness coefficient of each pixel (m), and $\Psi_{m(200m)}$ is the stability correction for *momentum transport* at 200 m.

When the u_* correction is obtained, it is possible to obtain the corrected value for the aerodynamic resistance to heat transport (r_{ah}, sm $^{-1}$) via Equation (11).

$$r_{ah} = \frac{\ln\left(\frac{Z_2}{Z_1}\right) - \Psi_{h(Z_2)} + \Psi_{h(Z_1)}}{u_* . k} \tag{11}$$

where $Z_2 = 2.0$ m, $Z_1 = 0.1$ m $\Psi_{h(Z_2)} = 2,0$ mand $\Psi_{h(Z_1)} = 0{,}1$ mall these values are equivalent to stability corrections for heat transport.

Fixed values of $u_*$and r_{ah} return to the determination of the temperature difference function, repeating the calculations mentioned previously, in which stability was consequently gained in the successive values of the temperature difference (d T) and aerodynamic resistance (r_{ah}) in each pixel of the image.

In determining daily evapotranspiration (ET_{ins}) at the time of the satellite image, the calculation is performed for each pixel, dividing the latent heat flux LE (JKg $^{-1}$) by the latent heat of vaporization (JKg $^{-1}$), giving rise to Equation (12):

$$ET_{ins} = 3600 . \frac{LE}{\lambda \rho_w} \tag{12}$$

where ET_{inst} is the daily evapotranspiration (mm $^{h-1}$); 3,600 is the conversion from seconds to hours, ρ_w and the density of water ($^{1000\ kg-3}$); and λ is the latent heat of vaporization ($^{Jkg-1}$), which is calculated via Equation (13):

$$\lambda = [2{,}501 - 0{,}00236(T_s - 273{,}15)]\,.\,10^6 \quad (13)$$

The reference evapotranspiration fraction ($ET_r F$) is calculated as the ratio of the calculated instantaneous daily ET (ET_{inst}) of each pixel and the reference evapotranspiration (ET_r) calculated via the Penmann–Monteith model, Equation 14, according to Allen *et al*. (2007), who assume that $ET_r F$ remains constant throughout the day.

$$ET_r F = \frac{\mathrm{ET_{inst}}}{\mathrm{ET}_r} \quad (14)$$

where ET_{inst} is the instantaneous daily evapotranspiration, Equation (12) ($mm\ h^{-1}$), and ET_r is the hourly reference evapotranspiration according to the Penmann–Monteith method (ALLEN *et al*., 1998). In the calculation of $ET_r F$ in Equation (14), each pixel refers to a single value for ET_{inst}, which is derived from a common value for ET_r, which in turn is derived from the representative weather station data. Finally, ET_{r24h} (mm/day) is calculated via Equation (15) for each pixel in the image:

$$\mathrm{ET}_{r24h} = C_{rad}\,(\mathrm{ET}_r F)(\mathrm{ET}_{r_{24}}) \quad (15)$$

where $ET_r F$ is assumed to be equal to the $ET_r F$ determined at the time of satellite passage; ET_{r_24} is the daily reference evapotranspiration; and C_{rad} is the correction term used in sloping terrain for 24-hour variation versus instantaneous energy availability (ALLEN; TASUMI; TREZZA, 2007). For horizontal areas, as in this case, $C_{rad} = 1.0$.

4.1 Comparative analysis

The comparison between the evapotranspiration values obtained via METRIC and the Penman–Monteith method was made by calculating the mean absolute error (MEA) and mean relative error (MRE), which were obtained via Equations 16 and 17, respectively, as described below:

$$EAM = \frac{1}{N}\sum_{i=1}^{N} \left|\mathrm{ET_{Metric}} - \mathrm{ET_{Penman}}\right| \quad (16)$$

$$EMR = \frac{100}{N}\sum_{i=1}^{N} \left|\frac{\mathrm{ET_{Metric}} - \mathrm{ET_{Penman}}}{\mathrm{ET_{Penman}}}\right| \quad (17)$$

where the ET metric and ET Penman correspond, respectively, to the evapotranspiration values through the METRIC model and the Penman–Monteith method.

5 RESULTS AND DISCUSSION

5.1. Actual evapotranspiration via the Penmann–Monteith method

Table 2 presents the values of actual evapotranspiration (ETr_{FAO}, mm day^{-1}) calculated by the product of the reference evapotranspiration (ET_θ, mm. day^{-1}) determined by the FAO-56 standard physical model (Penmann–Monteith) and the crop coefficient (Kc) for the area of Barbalha, CE, on the dates of May 22, August 10 and October 29 of 2016.

Table 2. Actual evapotranspiration data from the FAO-56 standard physical model (PENMAN-MONTEITH) for Barbalha, CE.

Date of images	ET_0 Reference (mm)	$ET_{r\,FAO}$ Current* (Kc = 1.21) (mm)
May 22, 2016	4.1	5.0
10/08/2016	4.5	5.4
October 29, 2016	5.9	7.1

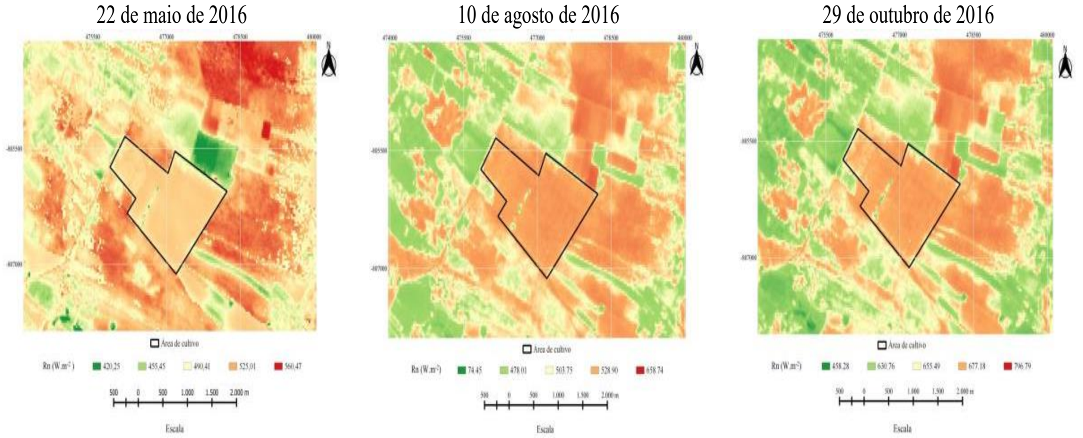
* $ET_{r\,FAO} = ET_0$ (Penman) $*$ Cultivation Coefficient Kc

Source: Organization of authors (2021)

5.2. Instantaneous net radiation (Rn)

Figure 3 shows thematic charts of the instantaneous radiation balance at the surface for May 22 (A), August 10 (B) and October 29 (C) of 2016. The Rn values were between 420 and 797.8 Wm $^{-2}$, with higher values within the cultivated area of 525.0 Wm $^{-2}$ (May 22), 528.9 Wm $^{-2}$ (August 10) and 677.2 Wm $^{-2}$ (October 29).

Figure 3. Thematic chart of the surface radiation balance (Rn) - METRIC (*mapping evapotranspiration at high resolution with internalized calibration*) for the municipality of Barbalha, CE, on May 22, August 10 and October 29, 2016.



Source: Organization of authors (2021)

Silva, Silva and Silva (2015) also reported the highest values for Rn in cultivated areas, with average balance values found in areas with relatively large vegetation, with values equivalent to 618.94 W m $^{-2}$, a minimum result of 532.21 W m $^{-2}$ and a maximum value of 732.65 W m $^{-2}$. Santos and Silva (2010), in a study carried out in irrigated areas, also with banana crops, reported that Rn varied between 600 and 780 W m $^{-2}$.

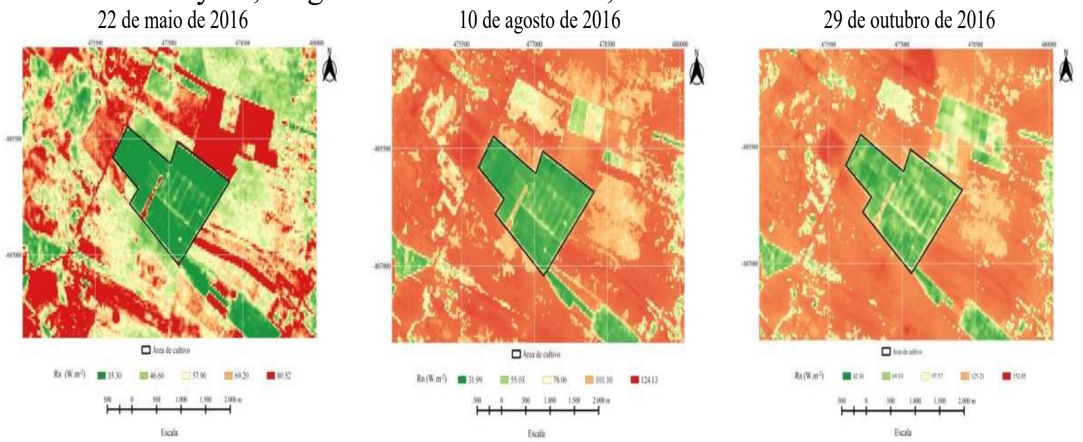
5.3. Soil heat flux (G)

Figure 4 presents thematic maps of the soil heat flux for the dates of May 22

(A), August 10 (B) and October 29 (C) of 2016 in Barbalha, CE. Both maps clearly show the wide predominance of the green tone, corresponding to low G values in the cultivated area for the three dates evaluated, whose G values were 35.30 W m $^{-2}$ (May 22), 31.99 W m $^{-2}$ (August 10) and between 42.3 and 69.93 Wm $^{-2}$ (October 29).

The orange and reddish tones correspond to the highest values (between 80.5 and 152.85 W m $^{-2}$) of G, which stood out in the scene with greater extent for the days of August 10 and October 29 of 2016, characterizing points that present little vegetation cover and exposed soil.

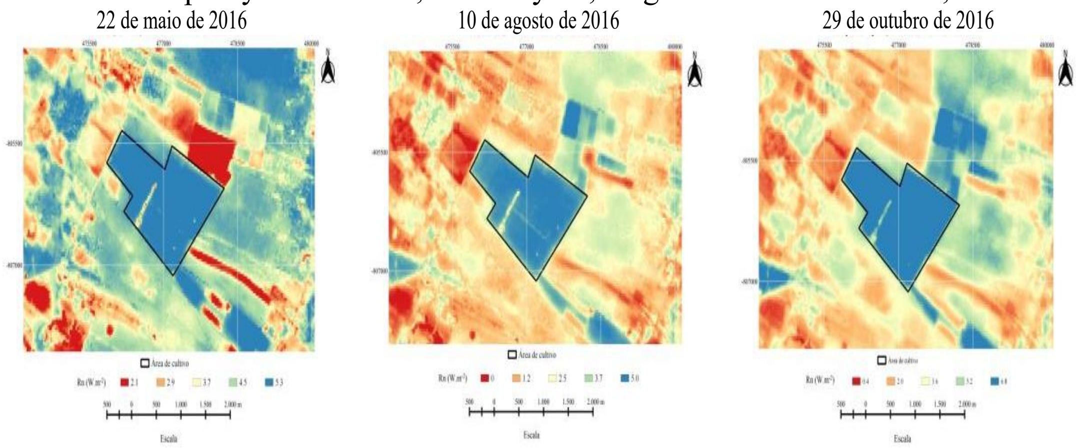
Figure 4. Thematic chart of soil heat flux (G) - METRIC (mapping evapotranspiration at high resolution with internalized calibration) in the municipality of Barbalha, CE: May 22, August 10 and October 29, 2016.



5.4. Evapotranspiration (ETr $_{24\ h}$)

Figure 5 shows the thematic maps of real daily evapotranspiration ETr $_{24\ h}$ (mm day $^{-1}$) in the municipality of Barbalha, CE for the dates May 22 (D), August 10 (E) and October 29 (F) of 2016, obtained via the METRIC algorithm.

Figure 5. Thematic chart of daily actual evapotranspiration ($ETr_{24\ h}$) - METRIC (*mapping evapotranspiration at high resolution with internalized calibration)* in the municipality of Barbalha, CE: May 22, August 10 and October 29, 2016.



Source: Organization of authors (2021)

The actual daily evapotranspiration for the banana plantation area was 5.3 mm day^{-1} on May 22, 5.0 mm day^{-1} on August 10, and 6.8 mm day $^{-1}$ on October 29, 2016. The highest evapotranspiration rates should be found in August, as they are directly correlated with the rainy season in the previous month. In October, which is characterized by dryness due to rainfall deficits, a reduction in soil moisture should occur, resulting in a greater extent of uncovered soil and, consequently, a reduction in the evaporation rate of the plants.

The 24-hour ETr in the cultivated area, represented by the color blue, varied between 5.0 and 6.8 mm day $^{-1}$. Santos, Fontana and Alves (2010), studying the evapotranspiration of banana plants in a semiarid region, reported daily values on the order of 5.81 to 7.81 mm day $^{-1}$, corroborating the results of the present study. Similar values were obtained by Silva, Silva and Gomes (2010) in the Jaguaribe Basin, Ceará state, via TM–Landsat 5 images, with a variation in ET of 5.5–6.9 mm day^{-1}.

The $_{24\ h}$ ETr values lower than 2.0 mm day^{-1}, represented by the color blue, are typical of areas with exposed soil or little vegetative cover.

In all images, there is a large presence of pixels with values below 3.6 mm day $^{-1}$ in beige/orange, which increases noticeably in August and October, resulting from the significant reduction in water availability in dryland areas. When the images between the study dates (May, August, and October) were analyzed, it was clear that the estimated 24-hour ET_r value for May 22 was visibly higher than that for the other two dates.

5.5 Validation of current evapotranspiration obtained via METRIC and the Penman–Monteith method

Table 3 presents a comparison of the daily reference evapotranspiration (ET_θ, mm day $^{-1}$) determined by the FAO-56 standard physical model (the Penmann–Monteith method) and by means of the daily real evapotranspiration ($ET_{r\ 24\ h}$, mm day $^{-1}$) obtained by the METRIC algorithm in an area located in Barbalha, CE, on the dates of May 22, August 10 and October 29, 2016.

Table 3. Comparison between the daily actual evapotranspiration ($_{ETo}$) obtained via the FAO-56 standard physical model (Penman - Monteith) and the average daily actual evapotranspiration ($_{ETr}$) obtained via the *mapping algorithm Evapotranspiration at High Resolution with Internalized Calibration* (METRIC) for a banana plantation located in Barbalha, CE.

Date	ET r (METRIC)	ET the (Penman)	Absolute error (mm day $^{-1}$)	Error relative (%)
May 22, 2016	5.3	5.0	0.3	6.0
10/08/2016	5.0	5.4	0.4	7.4
October 29, 2016	6.8	7.1	0.3	4.4

Source: Organization of authors (2021)

ET $_r$ estimates obtained via the METRIC algorithm with the daily ET $_r$ inferred via Penman–Monteith, values of 5.3 and 5.0 mm day ^{1} were observed for May 22, 2016, with a difference of 0.3 mm day^{-1} or a percentage difference of 7.4%. For August 10, 2016, evapotranspiration values of 5.0 and 5.4 mm day^{-1} were observed, with a difference of 0.4 mm day $^{-1}$ or a percentage of 7.4. On October 29, 2016, values of 6.8 and 7.1 mm day $^{-1 \text{ were obtained}}$.-with a difference of 0.3 mm day $^{-1}$ or 4.4% (percentage difference).

Similar values for the current evapotranspiration of banana plants were obtained by Silva (2019), who reported values between 5.0 and 7.1 mm day^{-1}. They also corroborate the results obtained by Silva, Silva and Gomes (2010), whose evapotranspiration records varied between 3.7 and 6.0 mm day^{-1}. and Santos, Fontana and Alves (2010), who reported daily evapotranspiration values for banana plants ranging from 5.81 to 7.81 mm day $^{-1}$.

When comparing the evapotranspiration determination methods, it was observed that, with the exception of May 22, 2016, the average daily actual evapotranspiration obtained by the METRIC algorithm was lower than the daily evapotranspiration calculated by the Penman–Monteith model. However, the differences found between both methods were less than 0.4 mm day $^{-1}$, equivalent to an average percentage difference of 5.9%, which is considered a satisfactory and acceptable level of accuracy within the acceptable threshold reported in the literature fomremote sensing data (GLENN *et al*., 2007).

Thus, for the dates evaluated, the METRIC algorithm performed similarly to the Penman–Monteith method, which was developed through the work of several experts and researchers in collaboration with the International Commission for Irrigation and Drainage and the World Meteorological Organization. ~~This~~ method is considered the standard for estimating reference evapotranspiration from meteorological data.

Trezza (2002), after comparing lysimetric measurements with estimates obtained via remote sensing techniques, reported absolute errors of less than 1 mm day $^{-1}$ in agricultural areas, whereas Wang, Kimura and Bastiaanssen (2005) reported absolute errors of approximately 0.5 mm day $^{-1.}$ Relative errors between 4% and 10% were reported by Bezerra, Silva and Ferreira (2008), who compared the results obtained with the Bowen ratio and with those of SEBAL. Thus, the results obtained in this research were very satisfactory.

In this sense, with the results obtained via the METRIC algorithm, it can be considered a useful remote sensing tool, as it provides specialized data for monitoring ET dynamics in agricultural areas and natural vegetation, contributing to the understanding of the complex dynamics of biophysical processes, as well as weather and climate forecasts.

6 CONCLUSION

Remote sensing allows estimation of, in addition to the components of the water balance, the actual daily evapotranspiration through the METRIC algorithm, obtaining results in line with those found in the bibliography for the irrigated banana area, which were also ~~and~~ similar to the values empirically determined by the Penmann–Monteith method, which is considered the standard method by the FAO. The differences between the methods were relatively low, i.e., less than 7.5%, indicating a satisfactory and acceptable level of accuracy. Therefore, the use of the METRIC algorithm can be considered a practical, economical, and efficient tool for determining plant water requirements and for making decisions regarding the allocation and management of water resources.

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