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ANÁLISE DA TEMPERATURA DE SUPERFÍCIE ESTIMADA PELO ALGORITMO METRIC- EEFLUX DA CULTURA DA BABANA-NANICA IRRIGADA

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1 RESUMO

A análise espacial e temporal da temperatura de superfície em diferentes usos da terra pode fornecer subsídios para a gestão e planejamento ambiental. O objetivo do trabalho foi estimar e analisar a dinâmico espaço– temporal da temperatura de superfície, através da aplicação do algoritmo METRIC em sua versão automatizada disponibilizada no Google Earth o EEFlux, a partir de técnicas de sensoriamento remoto, em uma área irrigada com banana-nanica no município de Barbalha, CE. Na obtenção de tais estimativas foram utilizadas imagens do satélite Landsat-8 OLI/TIRS obtidas para o mês de outubro dos anos de 2022, 2023 e 2024. Os resultados obtidos revelaram consistências com dados da literatura bem como não houve grande variação temporal na área estudada. Verificou-se que dentro da área cultivada a temperatura superficial terrestre, variou entre 25,3 e 51,8 ºC, 41,6 e 53,7ºC e 39,8 e 55ºC, para os anos de 2022, 2023 e 2024, respectivamente. As mais altas temperaturas como esperado foram estimadas em pontos superficiais com pouca ou quase nenhuma vegetação. Conclui–se que as temperaturas de superfícies avaliadas pelo algoritmo METRIC- EEFlux são eficazes e eficientes na compreensão da dinâmica dos padrões espaciais, temporais e espectrais de regiões semiáridas.

Palavras-chave: Musa spp, sensoriamento remoto, cobertura vegetal, fruticultura irrigada, TM-Landsat 8.

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ANALYSIS OF SURFACE TEMPERATURE ESTIMATED BY THE METRIC-EEFLUX ALGORITHM OF THE IRRIGATED BABANA-NANICA CROP

2 ABSTRACT

Spatial and temporal analysis of surface temperature in different uses of it soil puede brindar apoyo a la environmental management and planning. The objective of this work is to analyze the spatiotemporal dynamics of surface temperature through the application of the del METRIC

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algorithm to the automated version available in Google Earth, EEFlux, using remote sensing techniques in an irrigated area with banana dwarf en el municipality of Barbalha, CE. They used Landsat-8 OLI/TIRS satellite images obtained for the month of October of the los year (2022, 2023 and 2024) to obtain these estimates. Mostraron consistency was obtained from data from the literature, and significant temporal variation in the hub was detected in the studied area. Within the cultivated area, the surface temperature of the soil varies between 25.3 and 51.8 °C, 41.6 and 53.7 °C, and 39.8 and 55 °C for 2022, 2023 and 2024, respectively. As expected, the highest temperatures were estimated en points of the surface con poca o casi ninguna vegetation. It is concluded that surface temperatures evaluated using the METRIC-EEFlux algorithm are effective and efficient for understanding the spatial, temporal and spectral dynamics of patrons in semiarid regions.

Keywords: Musa spp, remote sensing, vegetation cover, irrigated fruit farming, TM-Landsat 8.

3 INTRODUCTION

There are many advantages to using orbital remote sensing to identify changes in land use and the resulting climate change. These include the large spatial coverage, the ease of obtaining images, and the possibility of estimating some parameters that would normally be obtainable only with instruments used in experimental studies (Santos *et al.*, 2015).

The algorithms used to process the data provided by remote sensing are composed of equations adjusted to adapt techniques for different scales, generating applicable information without the need for physical contact and providing a better understanding of different targets (Ponzoni; Shimabukuro; Kuplich, 2012).

Currently, there is an online platform, namely, the Google Earth Engine. Evapotranspiration Flux (EEFlux) was designed and developed within the Google Earth Engine (GEE) (Gorelick). *et al*., 2017) based on the METRIC algorithm, which functions as a means of automating data entry and manipulation to accelerate the process and obtain ET (Costa, 2019).

Allen *et al.* (2005) reported that the new Google EEFlux tool is a new version of the METRIC algorithm capable of estimating values of biophysical parameters such as surface temperature comparable to the values found by the METRIC algorithm in its traditional version.

With respect to the use of satellite imagery for surface temperature studies, the most commonly used spectral range is the thermal range, which captures radiation emitted by surfaces (Pereira *et al.* 2012). However, according to Mendonça (2003), these studies still have limited diffusion in terms of climatology because of limitations arising from the presence of an atmosphere between the target (surface) and the sensor.
Surface temperature refers to the heat flow given as a function of the energy that enters and leaves the body and is of paramount importance for understanding the interactions between the Earth's surface and the atmosphere (Steinke; Steinke; Saito, 2010).

Analysis of apparent land surface temperature under different land uses and vegetation cover types can provide support for environmental management and planning. This study aims to perform a spatiotemporal analysis of irrigated vegetation areas of dwarf banana cultivation in a municipality in semiarid Northeast Brazil using surface temperature and remote sensing techniques with Landsat 8 orbital images.

4 MATERIALS AND METHODS

4.1 Area characterization

This study was conducted in an area with dwarf banana cultivation (*Musa* spp.) located in the municipality of Barbalha (Figure 1), in the Cariri Metropolitan Region of the state of Ceará, whose geographic coordinates are 07° 17' 07.91" South and 39° 12' 58" West (GOOGLE EARTH PRO, 2020).

The city of Barbalha is located 553 km from the state capital, at an altitude of 415 m above sea level, with an area of 569.51 km², a population of 55,533 inhabitants, situated at the foot of Chapada do Araripe, and a GDP equivalent to R$ 455,763.00 (IBGE, 2021).

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

Source: GOOGLE EARTH PRO (2023).

On the basis of the Köppen–Geiger classification, the climate in the study area is hot and humid (Aw). The average annual temperature is close to 24.9 °C, the relative humidity is above 80%, the sunshine duration is 2,848 hours annually, and the average wind speed is close to 1.90 m s^{-1}; however, the evaporation rate exceeds 2000 mm/year, reinforcing the importance of water supplementation via irrigation (Medeiros *et al*. 2013).

According to Matos *et al*. (2015), the average annual rainfall is 1,047.9 mm, with 66.3% of the rainfall occurring between January and April, a period characterized by Silva *et al*. (2013) as the rainiest four-month period.

4.2 Image acquisition

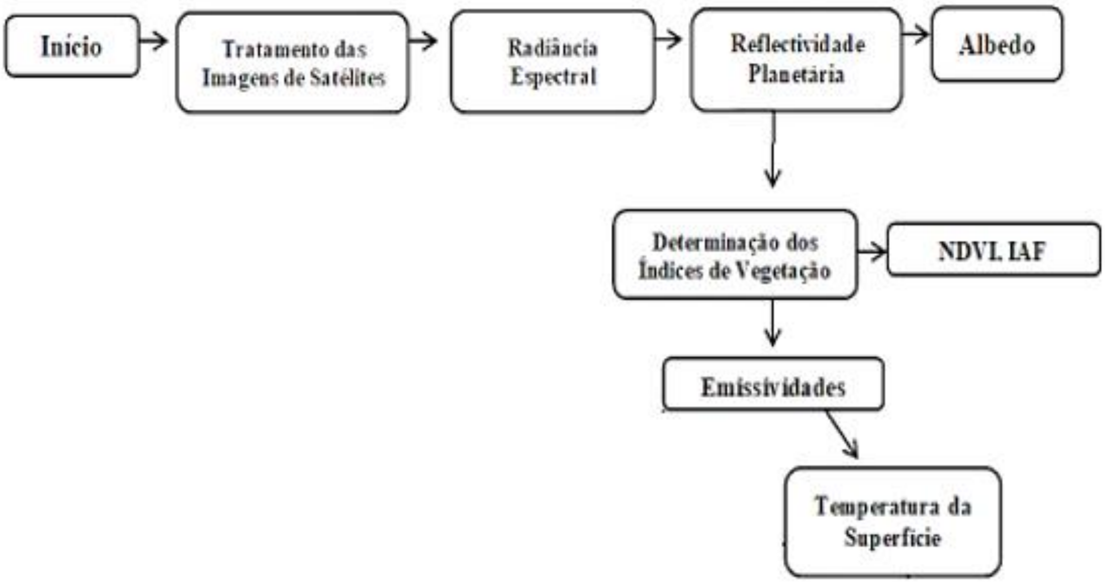
Operational Land Imager - OLI and Thermal were used. Infrared sensor - TIRS from the Landsat 8 satellite, orbit 217 and point 65, acquired from the EEFlux online platform, corresponding to the days (DSA = sequential day of the year) of October 30, 2022 (DSA 303), October 1, 2023 (DSA 274), and October 27, 2024 (DSA 301).

The choice of images was based on selecting images with low cloud cover, providing better processing quality and meeting the research requirements.

4.3 Image processing

The process began after the images were obtained from the platform. The computational steps employed follow the same steps used to obtain the surface temperature using the automated version of the METRIC-EEFlux algorithm, as shown in the diagram in Figure 2.

Figure 2. Diagram of the computational steps in the processing to obtain the surface temperature using the METRIC-EEFlux algorithm.



Source: The author (2024).

4.4 Surface temperature (Ts)

The equation for determining the surface temperature was obtained in Kelvin (Equation 1) (Allen *et al*., 2002) as follows:

$$T_S = \frac{K_2}{\ln\left(\frac{\varepsilon_{NB}.K_1}{L_{b,10c}}+1\right)} \quad (1)$$

where $L_{b,10c}$ is the spectral radiance of the Landsat 8 thermal band of the TIRS sensor, ε_{NB} is the emissivity, and K_1 and K_2 are the calibration constants of the Landsat 10 thermal band. 8 TIRS (K_1= 774.89 e K_2= 1321.08 W m^{-2} sr^{-1} μm^{-1}), extracted from the metadata of the processed images.

After the temperature estimates in Kelvin are obtained, the conversion to Celsius is performed (Equation 2):

$$T_C = T_K - 273{,}15 \quad (2)$$

Given: T_C the temperature in degrees Celsius and T_K the temperature in Kelvin.

4.5 Emissivity

Since each pixel by itself does not emit electromagnetic radiation like a black body does, it is necessary to add to the emissivity of each pixel in the thermal band spectral domain – ε_{NB}(10.4–12.5 µm).

According to (Allen; Tasumi; Trezza, 2007), ε NB can be obtained and validated according to the equation below (Equation 3).

$$\varepsilon_{NB} = 0{,}97 + 0{,}0033.\text{IAF} \quad (3)$$

where ε_{NB} is the emissivity and IAF is the leaf area index.

4.6 Atmospheric correction ($L_{b,10c}$)

Atmospheric correction is crucial for accurate estimation of the actual energy emitted by the Earth's surface, allowing the elimination of atmospheric "noise" such as gases (CO_2 and O_3), water vapor, and clouds that absorb and reemit thermal radiation into the atmosphere. This interaction alters the intensity of radiation leaving the surface, necessitating correction. In satellite imagery, the atmosphere alters the radiation reaching the sensor, and correction is needed to map the true surface temperature.

The correction method should be applied to the spectral radiance of the thermal band of the Landsat 8 TIRS sensor (Equation 4) (Allen *et al*., 2007):

$$L_{b,10c} = \left(\frac{L_{b,10} - R_p}{\tau_{NB}}\right) - (1 - \varepsilon_{NB}).R_{sky} \quad (4)$$

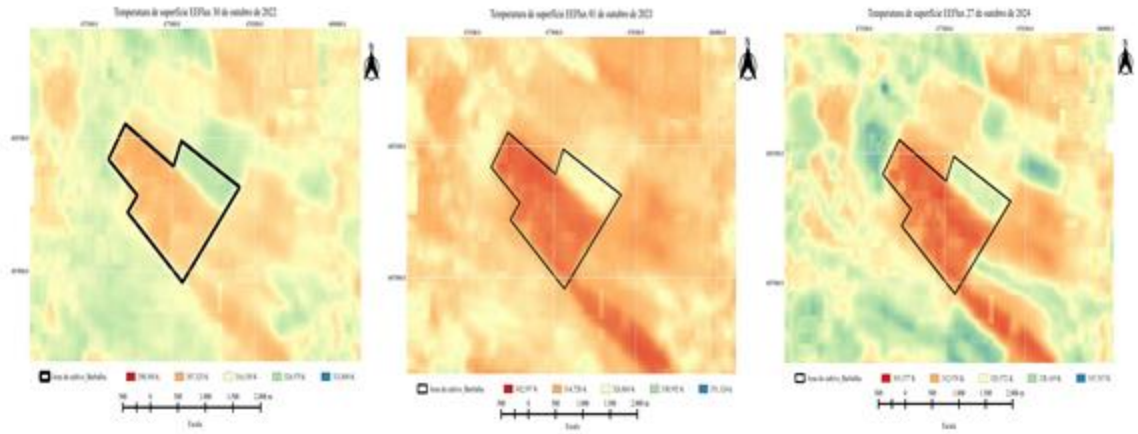
where $L_{b,10c}$ is the thermal band radiance obtained at the orbital level (W m^{-2} sr^{-1} um^{-1}), $L_{b,10}$ is the path radiance in the spectral range of band (W m^{-2} sr^{-1} um^{-1}), τ_{NB} is the atmospheric transmittance of the thermal band, ε_s ε_{NB} is the emissivity of each pixel (Equation 23), and R_{sky} is the longwave radiance emitted by the atmosphere in the direction from the surface to a clear sky. The values for R_p and τ_{NB} require the use of an atmospheric radiation transfer simulation model, such as MODTRAN (Moderated Transparency International). Resolution Atmospheric (Transmission). In the absence of an atmospheric correction model, corrections in the calculation of $L_{b,10c}$ are ignored when Rp = 0, τ_{NB}= 1 and Rsky = 0 (Allen *et al*., 2007).

5 RESULTS AND DISCUSSION

In the banana cultivation area, the surface temperatures were 43, 47.6, and 47.4 °C for the dates of October 30, 2022 (A), October 1, 2023 (B), and October 27, 2024 (C), respectively (Figure 3). The darker shades of red indicate the lowest surface temperatures, representing the more vegetated areas, whereas areas with little vegetation and exposed soil are shown in shades of beige and blue, corroborating the findings of Silva *et al*. (2015), who, when analyzing the temperature in an area of the semiarid region in the state of Paraíba, reported that the lowest temperatures were estimated in areas with taller vegetation, ranging between 21.8 and 34.76 °C, with an average of 31.5 °C and with the highest estimated temperature value in the month of October.

As expected, in general, the highest temperatures were found on surfaces with little or no vegetation; for all the images analyzed in the month of October, during the study period, a month that belongs to the dry season in the region and the prerainy season in the state of Ceará.

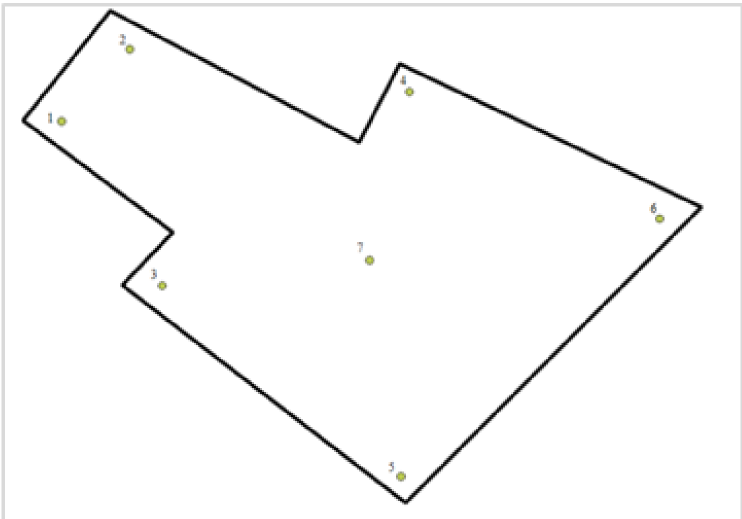
Figure 3. Thematic maps of soil surface temperature (T_S - METRIC- EEFlux) in the municipality of Barbalha – CE: October 30, 2022 (A), October 1, 2023 (B) and October 27 (C) of 2024.



Source: The author (2024).

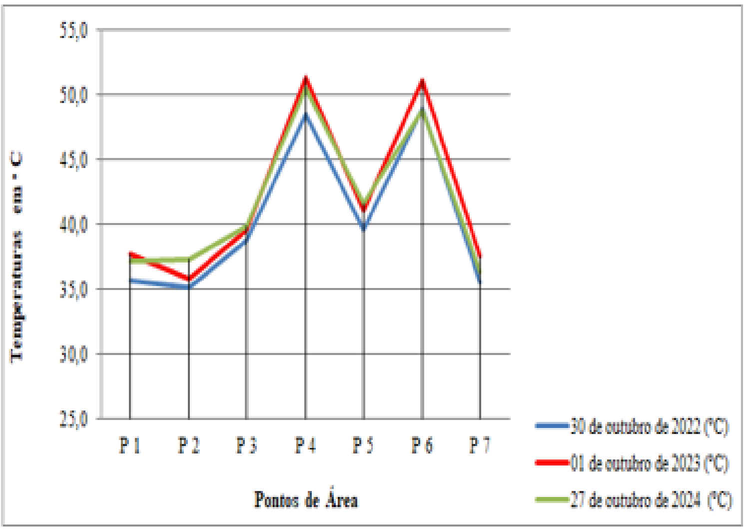
Spatial variations in temperature were estimated and analyzed at 7 control points distributed within the cultivated area (Figure 4). Land surface temperatures varied from P1 to P7 between 35.2 and 49 °C in 2022, between 35.8 and 51.4 °C in 2023, and between 36.3 and 50.6 °C in 2024 (Figure 5).

Figure 4. Diagram of surface temperature control points (in green).



Source: The author (2025).

Figure 5. Variation in surface temperature control points (P1 to P7) at °C for October 30, 2022 (blue), October 1, 2023 (red), and October 27, 2024 (green).



Source: The author (2025).

In terms of the location of the control points and the temperatures detected in the image, the surface temperature of the soil was the highest overall at points 4 and 6, both of which were located in the northeastern region of the cultivated area. According to Gartland (2010), higher temperatures are related to low or no soil cover, resulting in a constant incidence of solar radiation and a high thermal amplitude; thus, the temperature increases rapidly during periods of solar exposure, causing the temperature to increase during the day and increasing heat radiation and temperature. The lowest estimated temperatures overall were found at points 2 and 7.

The surface temperature among the analyzed collection points in 2022 varied between 28.8 and 30.3°C, with a predominant temperature of 35.5°C. In 2023, it varied from 35.8 to 51.4°C, and in 2024, the variation was between 36.3 and 50.6°C, with a predominant average of 37.6°C. According to Diniz *et al*. (2021), October is a month within the dry season, with a rainfall deficit, which results in high estimated air temperatures and increasing surface temperatures, even in irrigated areas.

6 CONCLUSION

Thematic maps produced from surface temperature data derived from LANDSAT 8 satellite images and the EEFlux online platform allowed for the detection of varying degrees of vegetation cover in the irrigated banana area. These maps also offer data with potential applications for individuals, public authorities, and academics, providing input for decision-making aimed at reducing excessive water resource use. The use of remote sensing enabled the identification of differences in spatial and temporal patterns in response to land use and occupation, proving to be a promising technique for managing agricultural areas by reducing costs and time.

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