DYNAMICS OF ACTUAL CROP EVAPOTRANSPIRATION BASED IN THE COMPARATIVE ANALYSIS OF SEBAL AND EEFLUX-METRIC

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ABSTRACT: Obtaining spatial evapotranspiration requires that the user has knowledge of the energy balance equation, as well as digital image processing. This fact has made researchers look for a way to make actual evapotranspiration (ETa) available to the user community and thus, they created the EEFLUX (Earth Engine Evapotranspiration Flux). Based on this, the present work aimed to compare ETa from the SEBAL (ETa-SEBAL) algorithm, with ETa based on the METRIC algorithm, which is available by EEFLUX (ETA-EEFLUX). For this, 14 Landsat images were used throughout the 2018 crop season, for maize crop irrigated by central pivot, in western Bahia, Brazil. The results showed that the product available by EEFLUX presents a higher estimate of evapotranspiration, when compared to SEBAL, for the areas with lower NDVI values and higher surface temperature, and the opposite was also observed. In addition, the SEBAL algorithm was more correlated with the NDVI variables and surface temperature. However, ET-EEFLUX showed agreement with the results obtained by the SEBAL algorithm, being an important information available to the scientific community and decision makers in the practice of irrigated agriculture, since it does not require in-depth technical knowledge.

KEYWORDS: Water demand, crop monitoring, remote sensing.

DINÂMICA DA EVAPOTRANSPIRAÇÃO BASEADO NA ANÁLISE COMPARATIVA DO ALGORITMO SEBAL E DO EEFLUX-METRIC

RESUMO: A obtenção da evapotranspiração espacial requer que o usuário tenha conhecimento da equação do balanço de energia, bem como do processamento digital de

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imagens. Este fato fez com que os pesquisadores procurassem uma maneira de tornar a evapotranspiração real (ETa) disponível e, assim, criaram o EEFLUX (Earth Engine Evapotranspiration Flux). Baseado nisso, o presente trabalho teve como objetivo comparar a ETa proveniente do algoritmo SEBAL (ETa-SEBAL), com a ETa baseada no algoritmo METRIC, que está disponível pelo EEFLUX (ETa-EEFLUX). Para isso, utilizaram-se 14 imagens Landsat. Os resultados demonstraram que o produto disponível pelo EEFLUX apresenta uma estimativa maior de evapotranspiração, quando comparado com o SEBAL, para as áreas que apresentam valores de NDVI mais baixos e de temperatura da superfície mais elevada, sendo o contrário também observado. Além disso, o algoritmo SEBAL se mostrou mais correlacionado com as variáveis NDVI e temperatura da superfície. Entretanto, o ET-EEFLUX apresentou concordância com os resultados obtidos pelo algoritmo SEBAL, sendo uma importante informação disponível para comunidade científica e tomadores de decisão na prática da agricultura irrigada, visto que dispensa conhecimento técnico aprofundado.

PALAVRAS-CHAVE: Demanda hídrica, monitoramento de cultura, sensoriamento remoto.

INTRODUCTION

Evapotranspiration is a key variable in determining the water balance of agricultural crops, which makes it necessary to obtain this variable to use the available water resources in a sustainable way (Zhang; Kimball; Running, 2016). The determination of spatially detailed evapotranspiration for large irrigated areas requires the use of remote sensing techniques, in order to obtain this variable in an economically way with spatial detailed. A dense network of weather stations would be needed to obtain evapotranspiration with spatial detailed using only weather stations, which is inviable operationally.

Obtaining evapotranspiration by satellite images has been the subject of research by researchers for decades, which has led the development of several algorithms for this purpose. Among the algorithms developed, we can cite the Surface Energy Balance Algorithms for Land – SEBAL (Bastiaanssen et al., 1998) and the Mapping Evapotranspiration at high resolution with Internalized Calibration – METRIC (Allen et al., 2007), which are widely disseminated in the literature and referenced by the successful of actual evapotranspiration (ETa) estimation.

However, the estimation of evapotranspiration using both SEBAL and METRIC requires specific knowledge of the relationships in the energy balance equation as well as the understanding the techniques of digital processing of satellite images (Allen et al., 2015; Reyes-González, 2018). These fact restricts the use of these methodologies in research and practical applications.

To facilitate the estimation of evapotranspiration to the end user, the METRIC algorithm was implemented in Google Earth Engine, being called Earth Engine Evapotranspiration Flux – EEFLUX (Allen et al., 2015). This implementation provides several satellite products, among them, the actual evapotranspiration. The evapotranspiration from the EEFLUX is processed for any image of the Landsat constellation, from 1984 to nowadays, to any region of the globe.

Based on the ETa product from the EEFLUX, the objective of the present study was to analyze the dynamics of the ETa-EEFLUX evapotranspiration product in relation to the actual evapotranspiration obtained by the SEBAL algorithm (ETa-SEBAL), in the maize crop irrigated by central pivot.

MATERIALS AND METHODS

The study was carried out in a commercial farm located in the municipality of São Desidério -BA, located in the upper right coordinates 12°25'31"S; 45°32'56"W and lower left coordinates of 12°31’12”S; 45°45’1”W, Datum WGS-84. The municipality of São Desidério is located in the western part of the state of Bahia, a region that belongs to the agricultural frontier MATOPIBA, which covers the states of Maranhão, Tocatins, Piauí and Bahia.

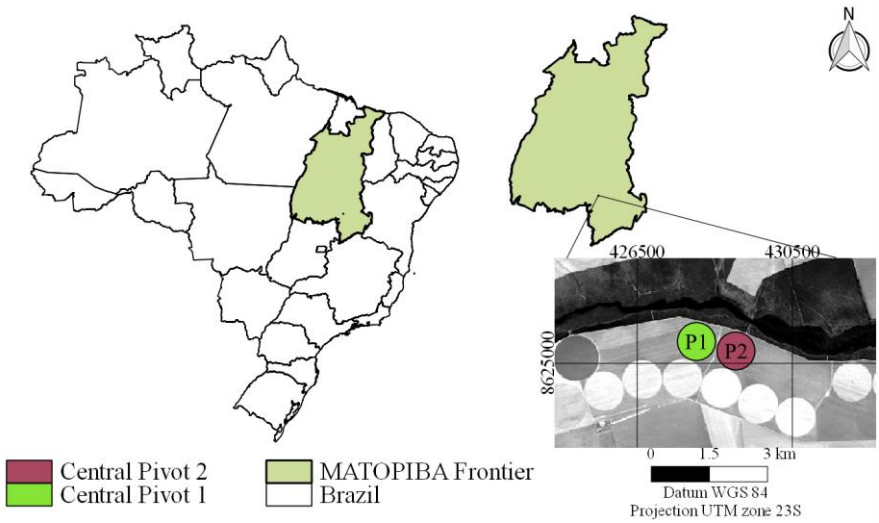

Figure 1. Localization of the study area in relation to Brazil and MATOPIBA agricultural frontier.

For the study, we utilized 14 images of the Landsat constellation, 7 images from Landsat-8 and 7 images from Landsat-7. These images were acquired in the period from May 1 to September 14, 2018. When the maize crop was cultivated in the study area. Maize sowing in central pivots occurred after 18/04/2018 and 11/05/2018, for central pivots 1 (upper one) and 2 (lower one) respectively, since this two dates.

In order to analyze the available evapotranspiration of the EEFLUX product, we estimated by SEBAL algorithm, the evapotranspiration for the maize crop in the region of study. The estimated evapotranspiration obtained by the SEBAL algorithm was performed according to Bastiaanssen et al. (1998) and for this, we used the software R (R Team, 2017) with the package Sebkc (Owusu, 2018). The meteorological data needed in the computation was acquired by an automatic weather station in localized in the farm, where the research was conducted.

The use of SEBAL was chosen because it is an algorithm widely used in the most different regions of the globe. The ETa-EEFLUX product is directly available at: https://eeflux-level1.appspot.com/. This fact that makes this product an important source of information, since it is ready to use without the need of in-depth technical knowledge.

The products available in the EEFLUX are based on the METRIC algorithm proposed by Allen et al. (2007), which was implemented in the Google Earth Engine system and made available as EEFLUX. Evapotranspiration from EEFLUX is processed for any Landsat image after 1984, anywhere on the terrestrial globe.

In order to analyze the agreement of the evapotranspiration products for the study region, we performed the difference between ETa-SEBAL and ETa-EEFLUX and we proceed with a quantitative analysis by linear regression between the two products. To go further in the analysis of the two products we also presented the NDVI and surface temperature images as well as the correlation of them with the evapotranspiration methods.

RESULTS AND DISCUSSION

Figure 2 show the NDVI along the two center pivots of the study area along the season, this product is an important to understand the phenology of the crop and its necessities in the dates of monitoring (Zhang et al., 2003).

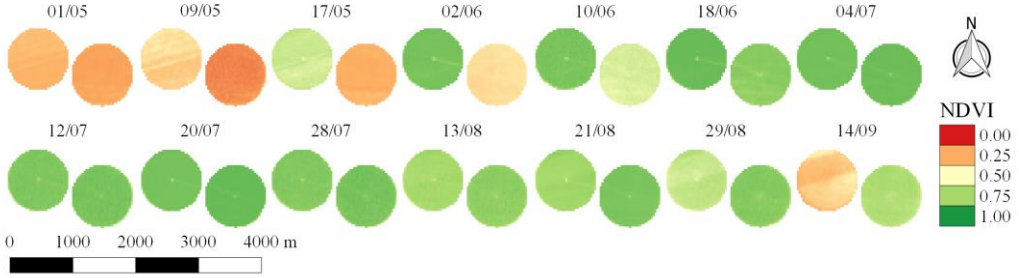

Figure 2. NDVI for the maize crop season.

The NDVI (Figure 2) and the surface temperature (Ts), shown in Figure 3, are important to help us to understand the behavior of the two products of evapotranspiration (ET-SEBAL and ET-EEFLUX), since NDVI and Ts are one of the key parameters in evapotranspiration phenomena (Filgueiras et al., 2019a, 2019b; Schirmbeck; Fontana; Schirmbeck, 2017, 2018).

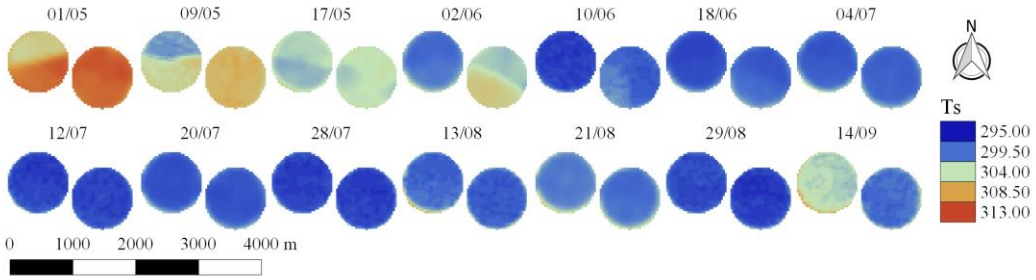

Figure 3. Surface temperature (Ts) for the maize crop season.

Figure 4 shows the evapotranspiration of maize crop during the 2018 crop season, estimated by the SEBAL algorithm and the EEFLUX product. In general, the same spatial pattern is observed in the central pivots along the dates imaged for the two methodologies. This fact demonstrates that the two products show agreement among themselves, which reinforces the applicability of the EEFLUX product to the study region.

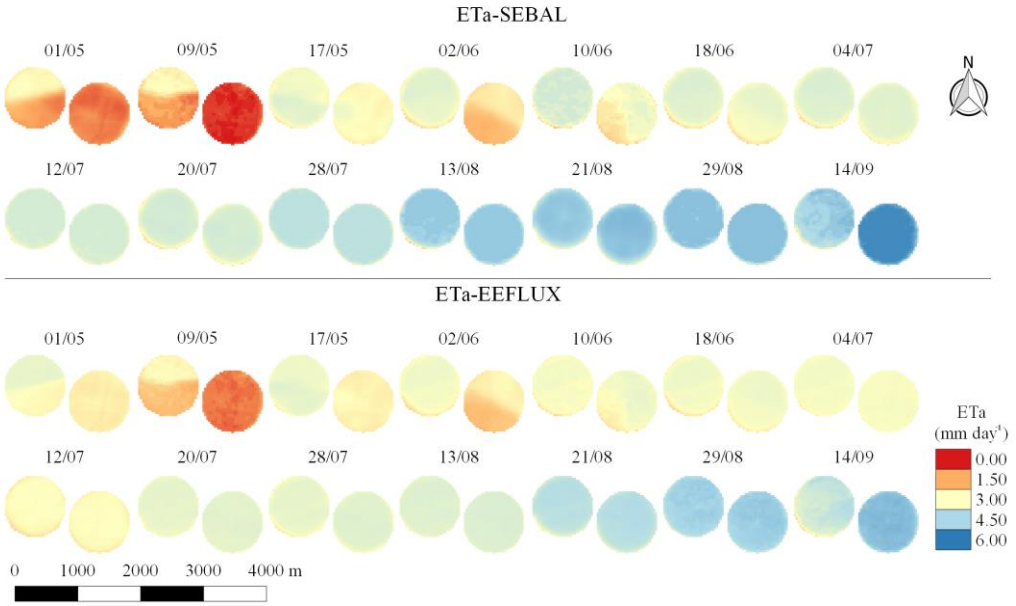

Figure 4. Evapotranspiration for the maize crop season estimated by the SEBAL algorithm and the EEFLUX.

Analyzing Figure 4, it can be observed that at the beginning of the sowing period (dates 01/05 and 09/05) the product ETa-EEFLUX obtained higher evapotranspirative rates when compared to the ETa-SEBAL. At these dates the central pivots were with exposed soil. However, it was observed that the highest values of evapotranspiration for the maize crop were obtained for the central pivot 2, on date 14/09. This fact can be probably explained by Figure 2, in spite of the information of sowing in this area is 11/05, we can see by Figure 2 that in the date of 17/05 the NDVI values corresponds a values of bare soil, being the presence of vegetation clearly noticed in the date of 02/06.

In order to facilitate the spatial and temporal analysis of the agreement of the products during the study season, the difference between ETa-SEBAL and ETa-EEFLUX for the study region is presented in Figure 4.

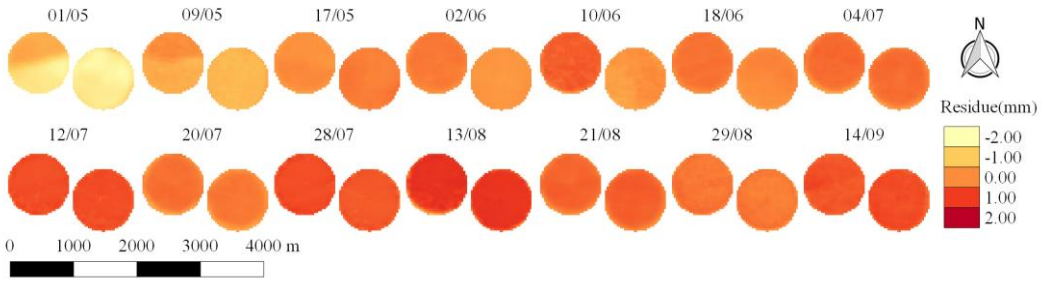

Figure 5. Difference between ETa-SEBAL and ETa-EEFLUX for the days of the crop season.

It can be seen from the analysis of Figure 5, that the moments of bigger discrepancy between the evapotranspiration products occurred for the beginning of the crop cycle, when the areas were still with exposed soils. In general, the mean difference between the ETa-

SEBAL product and the ETA-EEFLUX product was 0.20 mm. To help us to understand this behavior, we did a correlation between the different methods of evapotranspiration with the NDVI and Ts. Based on Figure 6, we can noticed that the ET-SEBAL is more related to NDVI and Ts, then the ET-EEFLUX, which can explain the fact that the bigger discrepancy of the evapotranspiration products occurred in exposed soil situation. In this situation , the NDVI is lower and Ts is higher (Figure 2 and Figure 3), fact that will respond with more prominence in the ET-SEBAL.

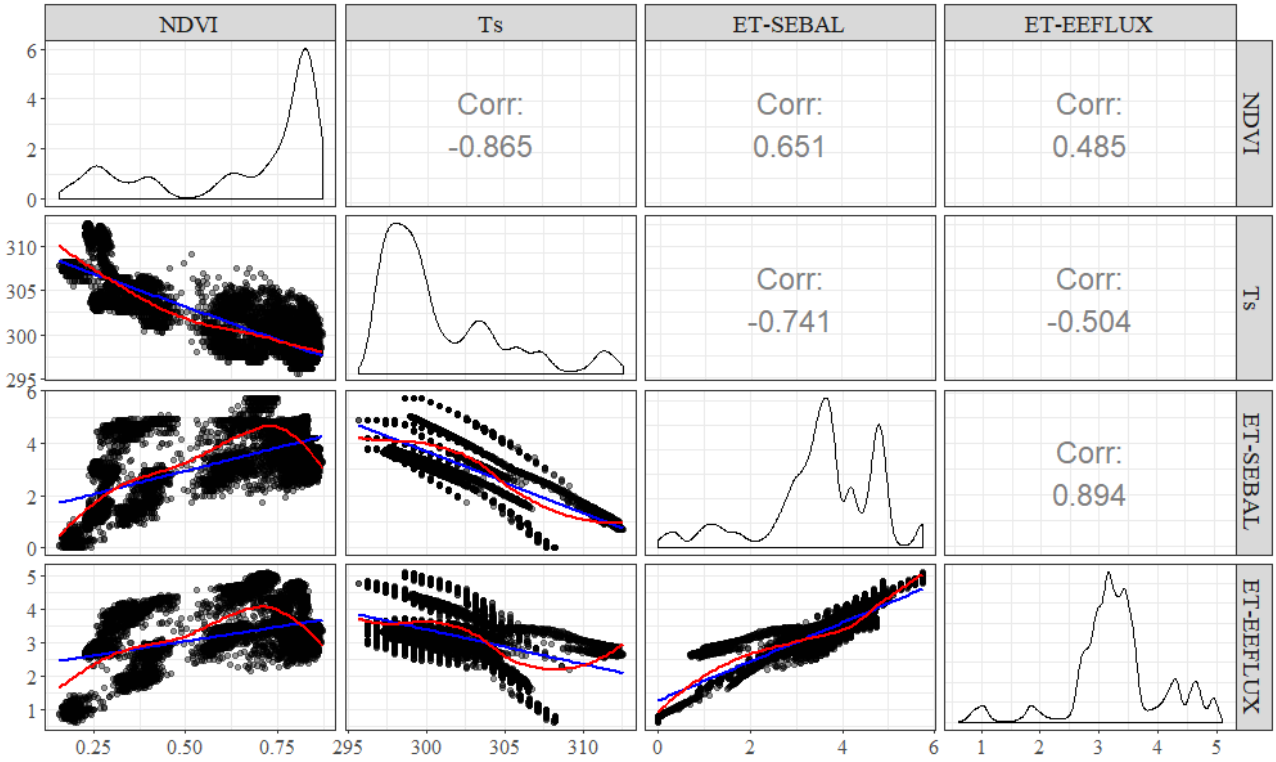

Figure 6. Correlation between the ET methods (mm day^{-1}), NDVI and Ts (K), where the blue line is the linear adjusted model and the red line is the adjusted local regression model-Loess.

In order to understand how a product explains the variability of the other and to analyze this degree of explanation in relation to the development of the culture, a linear regression between ETa-SEBAL and ETa-EEFLUX, with the NDVI values is shown in Figure 7. Analyzing Figure 3 it is apparent that the two products are related, fact that is evident by the high coefficient of determination (R^2 = 0.80) obtained between them. It is also noticeable from the regression analysis that the ETa-EEFLUX values were higher than the ETa-SEBAL values at the beginning of the maize crop cycle, where there were low evapotranspiration rates (Figure 4), low NDVI values (Figure 2) and high Ts values (Figure 3). However, for higher ETa values, the ETa-SEBAL product estimated higher evapotranspirometric rates when compared to ETa-EEFLUX, which values were mostly related to higher NDVI values.

Between 2.5 and 3.5 mm of evapotranspiration rate was the interval that had the highest agreement of the values of ETa between the products. Singh and Senay (2015) compared different energy balance models to estimate ETa, and they reported that is some degree of linear relation among the models tested, emphasizing this trend for the relation between METRIC and SEBAL.

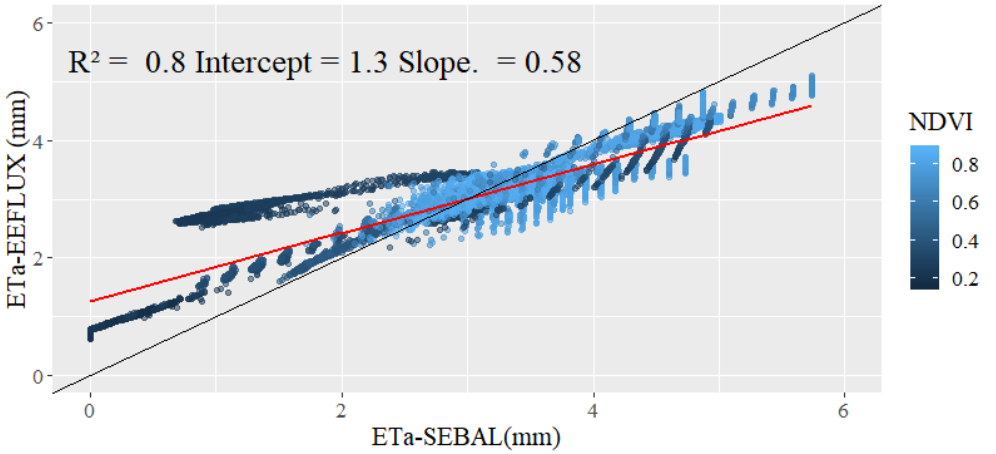

Figure 7. Regression between evapotranspiration obtained by SEBAL and that available by EEFLUX, along different values of NDVI.

Although, we did not compared the two ET methods with a pattern one, to know which is better, we noticed that the both product are responsive to each other. This is a good find, since the EEFLUX is available free, and without any need of technical knowledge to get the ET values.

Based on the comparative analyzes, the ETa-EEFLUX showed to be a sensitive product to obtain the ETa and, therefore, extremely useful as a source of information for decision making regarding irrigated agriculture, both for practical users and for scientists.

CONCLUSIONS

ETa from the EEFLUX, for the study region, tends to be higher than that of SEBAL for the lowest evapotranspiration rates, and lower than the SEBAL ETa for the highest evapotranspiration rates. The largest discrepancies of the estimates were found for lower NDVI and higher surface temperature values.

The evapotranspiration provided by the EEFLUX was qualitatively and quantitatively compatible with that obtained by the SEBAL algorithm, a fact that demonstrates the

importance of this product to the end user, since it is available freely and dispenses with the in-depth technical knowledge for estimating evapotranspiration.

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