POTENTIAL EVAPOTRANSPIRATION ESTIMATES FOR NORTHEAST BRAZIL USING GOES-8 DATA

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RESUMO

Foi aplicado o método de regionalização de Ward a evapotranspiração potencial estimada por Thornthwaite-Mather (1948). Além disso, foi utilizado o método empírico desenvolvido por Caselles et al. (1992) - MCA para obter a evapotranspiração potencial (ETP) em escala regional. Utilizaram-se dados de radiação solar global à superfície inferidos a partir do modelo GL 1.0, que utiliza imagens do canal visível do satélite GOES-8 sobre o Nordeste do Brasil.. Os resultados foram comparados com os valores de ETP calculados a partir dos métodos de Jansen & Haise (1993) – MJH e do método combinado de Penman (1948) – MCP. O MCA apresentou melhores resultados do que o a ETP estimada usando dados de satélite mostrou-se satisfatória, apresentando um erro máximo de 20% em relação ao MCP.

INTRODUCTION

The latent heat of evaporation appears in the energy budget equation and it is a key parameter in microclimatological and agrometeorological studies. In addition, the evapotranspiration (ETP) is of great avail in agronomy because it makes possible to predict harvests with maximum saving of water. Different approaches have been used in determining the ETP with meteorological data (Brutsaert, 1982). Although the accuracy of these methods is good (1 mm of water per day, or 10% - 1%), they are more suitable for local applications (10 - 100 m2). The high cost of field experiments and the difficulties in measuring the surface fluxes in inaccessible regions forced the seek for alternative techniques in order to complement the meteorological data available.

In this regard, the Remote Sensing techniques have been intensively used to obtain estimates of the surface and atmospheric parameters, although constrained by the time and space resolutions of the multi-spectral sensors used. Among these techniques, it is important to mention those which allow large area measurements with sensors onboard environmental satellites. The ETP is one of the surface fluxes that is possible to estimate from satellite imagery and the numerous works on its estimation with onboard satellite sensors are all justified due to the importance of this parameter in agriculture, weather modification, etc.

In general, two classes of methods both using satellite data have been proposed.: 1) the semi empirical and statistical methods that relates ETP with surface temperature (Vidal and Perrier, 1989); 2) the analytical or numerical methods based on the solution of the inverse problem for both heat and mass transfers (Taconet et al., 1986). Important field experiments in the last decade were conducted aiming to combine in situ measurements with remote sensing data, within the framework of the International Satellite land-Surface Climatological Project (Becker et al., 1988). In addition, there are may studies on the estimation of the potential ETP for agricultural regions, using satellite data, such as Taconet et al., (1986); Caselles and Delegido (1987); Becker et al.(1988); Rosena and Fiselner (1990); Caselles et al. (1992a,b).

Unfortunately, there are relatively few studies on the use of remote sense data measured by orbital sensors, with agricultural applications for the case of Brazil. Within this context, the present study aims at the estimation of the potential ETP using an empirical formulation and surface global solar radiation data inferred from the visible channel of the meteorological satellite GOES-8.

DATA AND METODOLOGY

The monthly climatological air temperature data cover the period of 1912 through 1980, while the solar radiation data cover only 1968 through 1978. Regarding the daily climatological data, air temperatures refer to the 1961-1979 period and the solar radiation, collected by the solarimetric network of the Northeast Brazil, the 1970-1978 period.

The GOES-8 visible channel images utilized in this study were provided by the CPTEC (Center of Weather Forecasts and Climate Studies of the National Institute for Space Research) refer to September 1997. The 434 x 525 pixel images cover the Northeast Brazil, between 1ºS - 18ºS and 31ºW - 47ºW.

For the implementation methodology, the daily climatological data available for September 1977 were used. Besides, the potential ETP was calculated by the Penman Combined Method - MCP, by the method proposed by Caselles et al. (1992b) – MCA and the Jensen and Haise (1963) method (radiation method – MJH). The correlation was performed to assess the MJH and MCA, taking the ground truth the estimates made with the standard Penman combined method. A sensitivity analysis of the equations of Jensen and Haise (1993) and Caselles et al. (1992b) in terms of global solar radiation and the air temperature was carried out in the third part of this study. This analysis determined how much the ETP depends on the global solar radiation and the air temperature for both methods.

The surface global solar radiation was obtained with the radiation model GL1.0, using the VIS channel data from the meteorological satellite GOES-8.

The method of Caselles et al (1992b) is described below, together with considerations on the method used to obtain the regionalization and the method to estimate the global solar radiation (radiation model GL1.0).

According Caselles et al. (1992b), the potential ETP is calculated by:

$$ETP = (A\ Ta + B)\ Rg + C \qquad (1)$$

where A, B and C are empirical constants determined for each region since they depend on the altitude, relative humidity and wind speed; Ta is the air temperature and Rg is the global solar radiation, the two last parameters being calculated with satellite images. The numerical values of the constants are $A = 5{,}99 \times 10^{-4}$, $B = 5{,}06 \times 10^{-6}$ and C = 0,37 the same values used for the region of La Mancha, Spain.

The GL1.0 is a physical model. Its first version was developed at hte Federal University of Pariba (UFPb) for the VIS channel images of the Meteosat 4 satellite (Ceballos e Moura, 1997) and, later adapted to the VIS channel of the GOES by researchers from the Department of Meteorological Sciences of the INPE and the UFPb (Bastos et al., 1996). The preliminary version was implemented at CPTEC/INPE with some modifications and it provides daily, weekly and monthly distributions of global solar radiation.

By regionalization is meant the procedure of gathering samples in distinct classes, with each individual of a given group exhibiting the same characteristics. There are two methods of classification: the hierarchical and the non-hierarchical ones. The hierarchical method divides the classes into sub-classes of higher classes, indicating the relations among the different groups. The non- hierarchical classifications simply form groups with similar individuals, not attempting to establish any relationship among the various groups.

The cluster analysis is an hierarchical method used to obtain the classification of some sample when there is no a priori hypothesis on this sample. There are several types of methods in the cluster analysis to perform the interpolation; among them the method of Ward (Everitt, 1974) being the one most frequently utilized. The method of Ward uses the sum of the squared errors as a basis for the decision of the grouping criterion. The Euclidean distance is used as the grouping function, while the aggregation criterion é given by the value of the increment obtained through the dispersion matrix.

In the agglomerate method, the process is started with each individual (station) as part of a given group. They merge to each other, with the most similar ones first, till they form one single group. The final result is obtained as a dendrogram, showing the successive mergings of the individuals that culminates in the stage for which all the individuals belong to the same group. The aggregation level increases as the number of groups decreases. The cut in the dendrogram is made according to the maximum slant of the inertia curves, which are introduced to aid the researcher in defining the number of groups to be chosen.

RESULTS

The results and the discussions presented here refer to: 1) the spatial grouping of the potential ETP for Northeast Brazil, using the Ward’s method; 2) sensitivity test: assessment of the methods used to estimate the potential ETP.

The Ward’s method was applied to the potential ETP matrix for the Northeast Brazil. It contained 30 lines, corresponding to the values of ETP for each year and 73 columns, corresponding to the total of stations deployed in the region of the Northeast Brazil. It worthy emphasizing that the ETP was estimated from the Thornthwaite-Mather (1948) equation, which uses only the air temperature. The final result obtained with the Ward’s method is given under a dendrogram, in which there exist subdivisions of the groups with the same characteristics, thus forming one single group. A number of groups were chosen by analyzing the dendrogram so to best define the sub-regions in the Northeast Brazil, as shown in Figure 1. The dashed area designated as sub-region 1 shows the regionalization of the ETP for the hinterland and the northern shoreline of the Northeast Brazil; the sub-region 2, not dashed, shows the regionalization of the ETP for the eastern coastline of the Northeast Brazil. Analyzing the dendrogram shown in Figure 1 identified these two homogenous regions.

It is possible to affirm that the ETP is more significant along the eastern and northern coasts and the hinterlands of the Northeast Brazil. The number of stations for each group, after the regionalization was of 33 for the eastern coast and 40 for the northern coast and the hinterlands, totaling 73 stations. The northern coastal area and the hinterlands have higher air temperature than the eastern coast, thus the evapotranspiration rate is distinct for these regions, according to the regionalization. The eastern coastal area is more affected by various weather systems such as the sea breeze, eastern waves, cold fronts from the southern part of the country while the atmospheric circulation over the hinterlands is driven primarily by orographic effects.

The analysis of the method to estimate the ETP in function of the variability of the surface solar radiation and the air temperture is of great importance. To perform such an analysis the MCA and MJH equations were derived with respect to the temperature and surface global radiation. Is was observed that a variation of 18 W m^{-2} in the global solar radiation implied a change of about 9% in tem ETP estimate, and a variation of 2oC in the air temperature produced a change of 6% in this estimate (for the MCA method).

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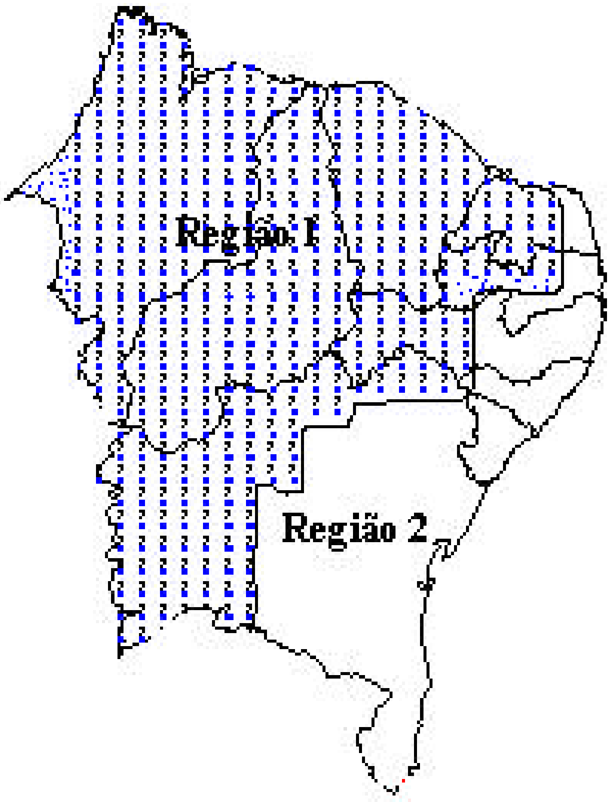

Figure 1 - Regionalization of the ETP for the Northeast-Brazil region.

Figures 2 and 3 show the changes in the ETP estimates as a function of global solar radiation and the air temperature. For higher values of the global solar radiation, the ETP changes more rapidly as a function of the temperature, than in the case of lower values of the solar radiation. This was observed for both MCA and MJH estimates. The estimates of the ETP using the MCA method was found to be larger, of order of 1mm, than those obtained with the MJH method.

An estimate for the daily ETP for September, 1997 was obtained using the three methods: the Penman's combined method - MP , the MCA and the MJH methods. The MP method was one of the firsts to consider energy supply and turbulent transport, hence its name "combined". Among the radiation methods, the MJH is one that includes not only the solar radiation but also the air temperature and whose original formulation was based on the data gathered over the arid areas of the western part of the USA.

Although the MCA method was developed for the region of La Mancha, Spain its results may be considered satisfactory and justify the use of this method to estimate potential ETP in the Northeast Brazil. Nevertheless, the discrepancies found between the MCA x MP and MJH x MP correlation studies are suggestive that adjustments be made in order to use the method in agronomic, agrometeorological and meteorological applications.

Figure 4 shows curves of daily ETP for September, 1997 calculated using the MP method (potential ETP), the MCA method using surface meteorological data (ETPCSUP) and the same method again using global solar radiation data (ETPCSAT). There is a reasonable consistency but the MCA calculated values overestimate the MP results, but as mentioned in the literature, the empirical methods always do that. In general, the differences are smaller than 20% or 1,5 mm/day. It was also observed that there are days with a pronounced discrepancy because when the potential ETP increases the ETPCSAT decreases and vice–versa, probably due to the days with few images what introduces errors in the determination of the surface global solar radiation.

CONCLUSION

The main results achieved by this study maybe summarizes as follows:

1) There are two distinct regions in the Northeastern Brazil regarding the distribution of ETP;
2) The MCA method yields better results than the MJH method;

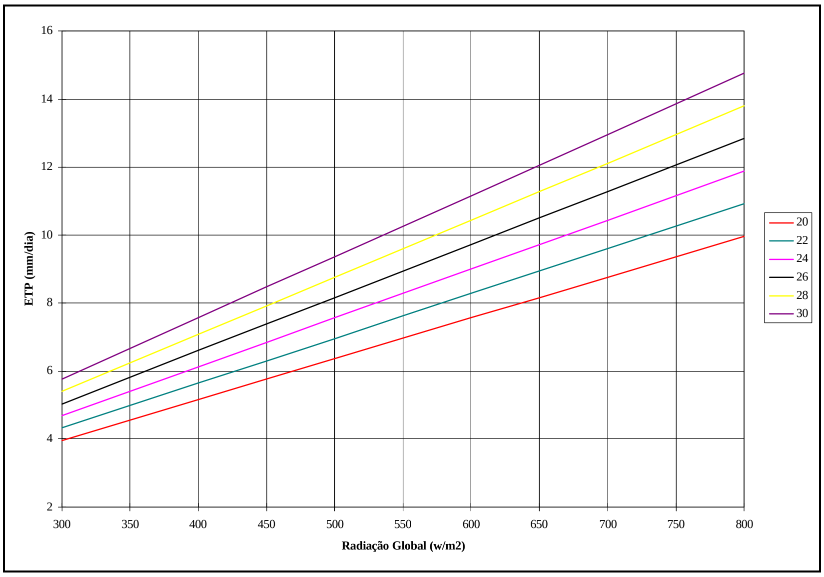

Figure 2 - Variation of the ETP with global solar radiation for different air temperature using MCA method.

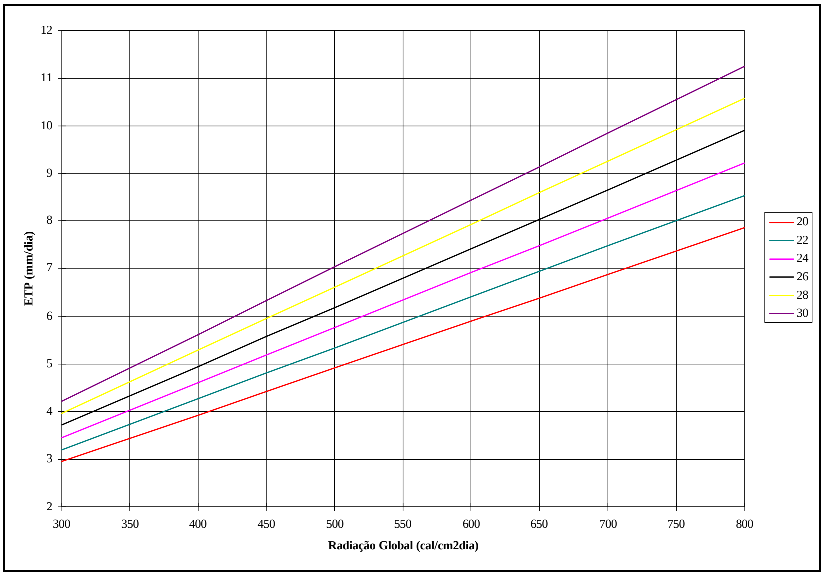

Figure 3 - Variation of the ETP with global solar radiation for different air temperature using MJH method.

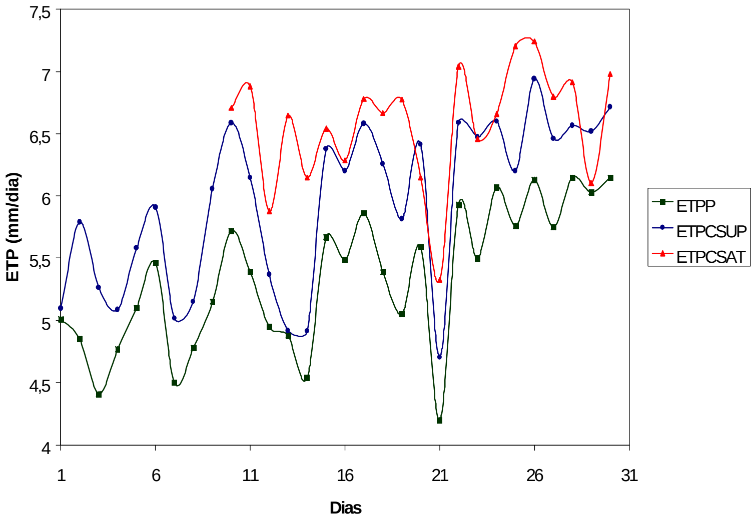

Figure 4 – Comparison between the ETP estimates by MCP (ETPP) and MCA (ETPCSUP and ETPCSAT)

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