

EVAPOTRANSPIRATION TREND ANALYSIS FOR THE BRAZILIAN SEMI-ARID REGION

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ABSTRACT: Monitoring temporal variations in climatic elements and reference evapotranspiration and quantifying any trends provides valuable information on hydrology, agricultural water demand, and water resource management. The study was conducted using meteorological data from states in northeastern Brazil. The objective of this study was to analyze the trend in reference evapotranspiration in northeastern Brazil. Data from conventional meteorological stations in 94 municipalities in the conventional station network of the National Institute of Meteorology (INMET) were used. The Penman–Monteith method was used to estimate reference evapotranspiration (ET_o), which is the standard method for many international organizations such as the FAO (Food and Agriculture Organization of the United Nations) and the American Society of Civil Engineers (ASCE). Climate variable trends were analyzed at all stations. For this purpose, climate elements were determined by the Mann-Kendall test statistics and the Sen estimator. The analysis revealed a strong relationship between the increase in ET_o and the increase in air temperature, associated with a reduction in relative humidity. The magnitude of the trends ranged from -0.38 mm/year to +1.87 mm/year.

KEYWORDS: northeast. temperature. zoning.

ANÁLISE DA TENDÊNCIA DE EVAPOTRANSPIRAÇÃO PARA O SEMIÁRIDO BRASILEIRO

RESUMO: O monitoramento das variações temporais dos elementos climáticos e da evapotranspiração de referência e a quantificação de quaisquer tendências oferecem

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informações valiosas sobre hidrologia, demanda de água agrícola e gerenciamento de recursos hídricos. O estudo foi realizado utilizando dados meteorológicos dos estados que fazem parte do nordeste brasileiro. O objetivo desse estudo foi analisar a tendência da evapotranspiração de referência no nordeste brasileiro. Foram utilizados dados provenientes de estações meteorológicas convencionais de 94 municípios da rede de estações convencionais do Instituto Nacional de Meteorologia (INMET). O método Penman–Monteith foi empregado para a estimativa da evapotranspiração de referência (ET_o), sendo o método padrão para muitas organizações internacionais como a FAO (Organização das Nações Unidas para Alimentação e Agricultura) e a Sociedade Americana de Engenheiros Civis (ASCE). As tendências das variáveis climáticas foram analisadas em todas as estações. Por este propósito, os elementos climáticos foram determinados pela estatística do teste de Mann-Kendall e pelo estimador de Sen. A análise revelou forte relação entre o aumento da ET_o e o incremento da temperatura do ar, associado à redução da umidade relativa. A magnitude das tendências variou de -0,38 mm/ano a +1,87 mm/ano.

PALAVRAS-CHAVE: nordeste. temperatura. zoneamento.

INTRODUCTION

As the global climate changes, different degrees of variation in climatic elements will have various impacts on agricultural production, leading to suitable or unsuitable conditions for the development of agriculture (Dong et al., 2019).

In the last century, climate variables have shown changes associated with changes in the global climate, for example in the northeast region, there are predictions of an increase in temperature and a decrease in rainfall (Sales et al., 2015).

Thus, one of the expected consequences of climate change is an increase in surface temperature, which, depending on the sensitivity of this parameter, can lead to an increase in evaporative demand. From different sensitivity analyses, it was noted that the increase in temperature would encourage an increase in evapotranspirative demand (Biazar, 2019), causing a greater demand for water for agricultural production.

Determining the trend in climatological time series plays an important role all over the world. There are many tests for detecting trends in time series. The existing tests can be classified as parametric and non-parametric (Zhang et al., 2016). In view of the above, the aim of this work is to analyze the trend of reference evapotranspiration in northeastern Brazil.

MATERIALS AND METHODS

The study used historical meteorological data from 97 stations of the National Meteorological Institute (INMET), covering the nine states of the Brazilian Northeast.

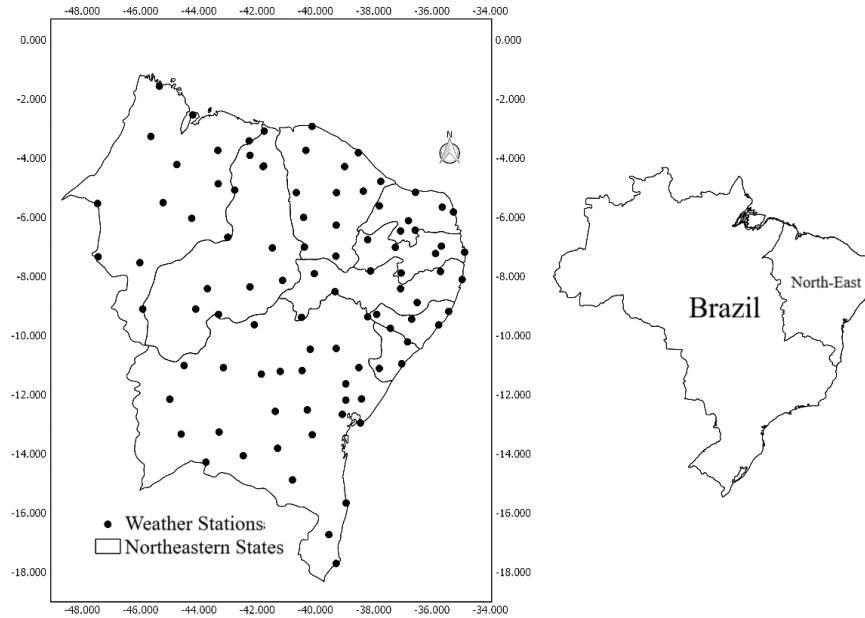


Figure 1 - Geographical location of the weather stations used in the study.

ETo was estimated using the Penman-Monteith method (FAO-56), as recommended by the FAO. This method combines data on net radiation, average daily temperature, wind speed and vapor pressure deficit.

The Penman-Monteith FAO-56 equation can be written as (ALLEN et al., 1998):

$$ETO^{PM} = \frac{0,408\Delta(R_n - G) + \gamma \left(\frac{C_n}{T_{med} + 273} \right) u_2 (e_s - e_a)}{\Delta + \gamma(1 + C_d u_2)}$$

Where: EToPM – reference evapotranspiration obtained by the Penman-Monteith method, mm day⁻¹; R_n – total net radiation of the lawn, MJ m⁻² day⁻¹; G – soil heat flux density, MJ m⁻² day⁻¹; T_{med} – average daily air temperature, °C; u₂ – average daily wind speed at 2 m height, m s⁻¹; e_s – vapor saturation pressure, kPa; e_a – partial vapor pressure, kPa; e_s-e_a – vapor saturation deficit, kPa; Δ - slope of the vapor pressure curve at the T_{med} point, kPa°C⁻¹; γ - psychrometric coefficient, kPa°C⁻¹; C_n and C_d are constants that vary with the type of reference crop (surface resistance and aerodynamic roughness of the surface) using values of 900 for C_n and 0.34 for C_d.

To assess the temporal trend of ETo, two nonparametric statistical methods were applied: the Mann-Kendall (MK) test, used to detect the presence of a trend (increasing or decreasing) in the time series,

Which is calculated by:

$$Zmk = \left\{ \begin{array}{l} \frac{S - 1}{\sqrt{Var(S)}} \text{ if } S > 0 \\ 0 \text{ if } S = 0 \\ \frac{S - 1}{\sqrt{Var(S)}} \text{ if } S < 0 \end{array} \right\}$$

Positive ZMK values indicate upward trends, while negative ZMK values indicate downward trends. At a significance level of $\alpha = 0.05$, if $|ZMK| > Z_{1-(\alpha/2)}$, the null hypothesis (H0) that there is no significant trend is rejected, and there is a significant trend in the time series (Feng et al., 2016).

The direction and magnitude of the trend in the time series data will be quantified using the nonparametric trend slope estimator proposed by Sen (1968). To derive an estimate of the slope β , the slopes of all data pairs will be calculated by:

$$\beta_i = \frac{x_j - x_k}{j - k} \text{ for } i = 1, \dots, N$$

The median of the N values of β_i is Sen's slope estimator. If N is odd, Sen's estimator will be calculated by:

$$\beta_{med} = \beta_{[(N+1)/2]}$$

If N is even, Sen's estimator will be calculated by:

$$\beta_{med} = \frac{1}{2} \left(\beta_{[N/2]} + \beta_{[(N+2)/2]} \right)$$

The analysis was carried out on an annual scale, with a significance level of 5%.

The PROGRAM FOR TREND ANALYSIS OF CLIMATE AND WEATHER ELEMENTS was used to process the data and determine the trends found, which were then allocated to specific points on the map.

RESULTS AND DISCUSSION

As can be seen in the figure, the values of the ZMK parameter for the annual average of reference evapotranspiration obtained by the Penman-Monteith method (EToPM) showed a variation of increasing and decreasing trends. 75 stations showed ZMK values greater than zero, i.e. a positive trend.

However, only 26 (26.8%) locations had ZMK values greater than the critical ZMK value, i.e. there is a trend within the time series that is statistically significant at the 5% probability level.

As for the negative trends, only the Água Branca-AL, Morada Nova-CE and Salvador-BA stations obtained statistically significant ZMK values, similar results were observed by Amirataee; Montaseri; Sanikhani (2016) studying the variations in annual ETo trends at 14 stations located in northwestern Iran.

Assessing changes in ETo is essential for planning adaptation and mitigation to combat the implications of climate change on water resources, agriculture and ecology (Jerin et al., 2021).

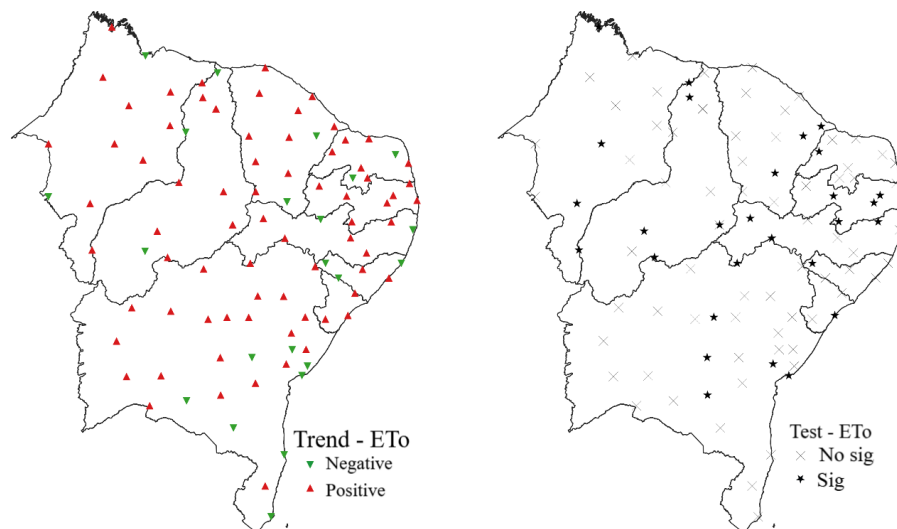


Figure 2 - Analysis of the results for the annual average reference evapotranspiration (ETo): (a) Trend using the Mann-Kendall test; (b) Statistical test of significance at the 0.05 level.

In terms of the magnitude of the trend, the greatest increases in ETo were recorded at stations with values of the Beta Sen parameter in the range of $0.35 \text{ mm year}^{-1}$ (3.5 mm/decade) to $1.87 \text{ mm year}^{-1}$ (3.5 mm/decade). It can be seen that there are stations belonging to the range of higher values of Sen's slope estimator in almost all the states analyzed; the only states that did not have any stations belonging to this class were the states of Alagoas and Sergipe.

While the negative trends ranged from $-0.38 \text{ mm year}^{-1}$ to $-0.0084 \text{ mm year}^{-1}$ for ETo. The stations located in the states of Paraíba and Sergipe showed no downward trend in ETo.

The state of Sergipe showed the least variation in the values of Sen's Beta parameter, given the smaller interquartile range.

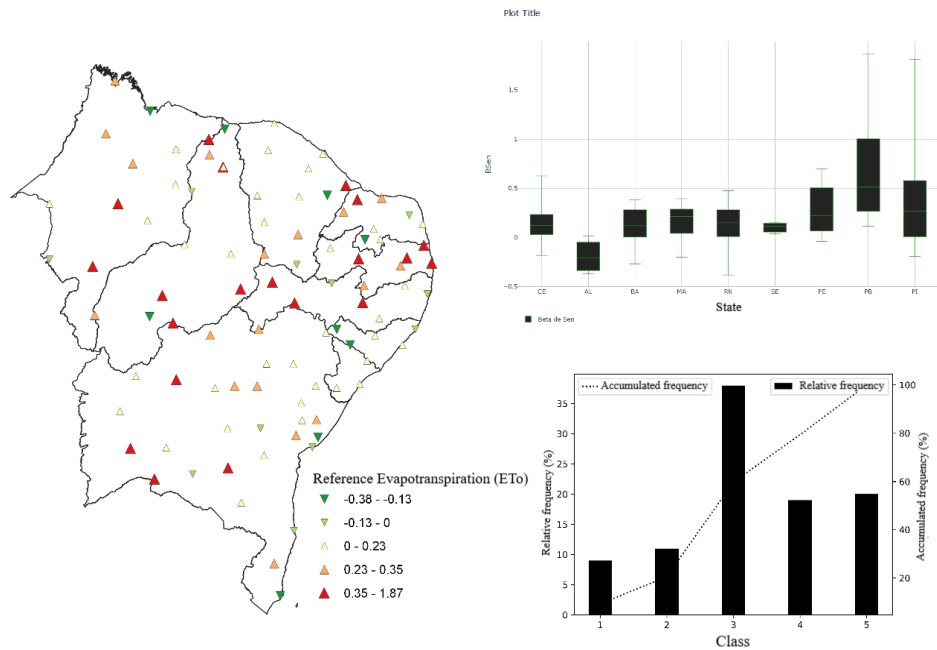


Figure 3 - Result of the magnitude of the trend for the annual average reference evapotranspiration (ETo): (a) Sen's Beta parameter values; (b) Boxplot of Sen's Beta parameter values by state; (c) Frequency distribution of Sen's Beta parameter values.

Pour et al. (2020) observed that the influence of the annual average minimum temperature and wind speed were the meteorological elements that most influenced the ETo trend compared to the other meteorological variables at ten stations located in Malaysia.

CONCLUSIONS

The trend analysis of reference evapotranspiration in the Brazilian semi-arid region reveals that, despite the predominance of positive trends, statistical significance was limited to a quarter of the stations analyzed. The upward trend in ETo is strongly associated with an increase in temperature and a reduction in relative humidity. The Penman-Monteith equation showed low sensitivity to wind speed in this region.

The results reinforce the need for continuous monitoring of ETo as a subsidy for public policies, adaptive agricultural practices and water management in the face of climate change.

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