



Tables of probabilities of reference evapotranspiration for the region of Mossoró, RN, Brazil

Tabelas de probabilidades da evapotranspiração de referência para a região de Mossoró, RN, Brasil

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ABSTRACT - The aim of this work was to construct probability tables of reference evapotranspiration in mm, accumulated at twenty, fifteen (biweekly) and ten days (decennial) in Mossoró, RN, Brazil, from the daily records of evapotranspiration obtained from the Meteorological Station of the University Federal Rural do Semi-Arido (UFERSA) in Mossoró, RN, using the Penman-Monteith method. No prior transformation of data was necessary, since the construction of the tables is based on the approximation of the variable to Normal distribution. The probabilities were estimated by the Normal distribution for the levels of 1% to 95%. The tables were constructed with data from 1970 to 2007, taking into account the results of the tests of chi square and Kolmogorov-Smirnov at 10% probability. It can conclude of the suitability of the construction of the tables and that these tables represent subsidies important in the planning of the farming and livestock activities in the region, taking the most advantage of its benefits and avoiding its harmful effects.

Keywords: climatology; probability distribution; adherence tests.

RESUMO - O objetivo desse trabalho foi construir tabelas de probabilidades da evapotranspiração de referência em milímetros, acumuladas aos vinte, quinze (quizenal) e dez (decennial) dias em Mossoró, RN, Brasil, a partir dos registros diários das evapotranspirações obtidas na Estação Meteorológica da Universidade Federal Rural do Semi-Árido (UFERSA), em Mossoró, RN, usando o método de Penman-Monteith. Nenhuma transformação prévia dos dados se fez necessária, visto que a construção das tabelas se baseia na aproximação da variável à distribuição Normal. As probabilidades foram estimadas pela distribuição Normal para os níveis de 1% a 95%. As tabelas foram construídas com os dados de 1970 a 2007, levando-se em conta os resultados dos testes de Qui-quadrado e Kolmogorov Smirnov a 10 % de probabilidade. Pode-se concluir da adequabilidade do processo de construção das tabelas e que estas representam importantes subsídios no planejamento das atividades agropecuárias na região, tirando o máximo proveito dos seus benefícios e evitando seus efeitos danosos.

Palavras-chave: climatologia; distribuição de probabilidade; testes de aderência.

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INTRODUCTION

The interaction of a culture with some meteorological parameters such as solar radiation, insolation, air temperature, the relative humidity and precipitation, stimulates the plant transpiration and soil evaporation (OMETTO, 1981).

In this case the Etp depends only on the meteorological variables, being, therefore, the Etp a meteorological variable, which expresses the potential of evapotranspiration for the prevailing weather conditions (SENTELHAS; ANGELOCCI, 2007). The reference evapotranspiration (Etp) is used, among other purposes, in climatological and water balances in the prediction of development and harvests of crops, in drought monitoring and in establishment of agricultural zoning (MOTA, 1986). In the impossibility of obtaining experimentally Etp, its determination is made employing meteorological methods, being the Penman-Monteith currently considered the standard method for calculating the Etp (SEDYAMA, 1996; ALLEN et al., 1998; PEREIRA; ANGELOCCI; SENTELHAS, 2002; ITENFISU et al. 2003).

Their study, also calls for a time scale "small" (less than one month) for that its effect is properly assessed (PALMER, 1968; HAYES et al., 1999).

The study of quantitative samples, historical and temporal series of evapotranspiration is a study of random variables, as all hydrological processes, meaning that their achievements cannot be known (LANNA, 2001; CATALUNHA et al., 2002).

Several studies have demonstrated that the frequency distribution of reference evapotranspiration (Etp), fits the normal distribution (SAAD; SCALOPPI, 1988; SAAD, 1990; PEREIRA; FRIZZONE, 1994), log-normal (MCGUINNESS; PARMELE, 1972; PEREIRA; FRIZZONE, 1994) and beta (SAAD, 1990; PEREIRA; FRIZZONE, 1994).

Saad (1990), through the use of Kolmogorov-Smirnov test, found that a historical series of reference evapotranspiration accumulated in 5, 10, and 15 days, calculated using the Penman-Monteith, can be set to normal and beta distributions in the region of Piracicaba in the months from March to September. Vellame, Queiroz and Oliveira (2012) found that the beta distribution presented a better fit to the data of potential evapotranspiration in relation to the normal distribution.

In this case is convenient that the projects are designed considering supplemental irrigation, which is based on the maximum value of the difference between evapotranspiration and precipitation in the period considered, which can be estimated from historical series (FARIA et al., 2002; ANDRADE et al., 2009).

The probability levels should be selected based on economic criteria. Normally, high levels (80-90%) are only adopted for irrigated crops with high economic value and with shallow root system (JENSEN; BURMAN; ALLEN, 1989). According to Saad and Scaloppi (1988), in the irrigation conditions of the central-southern region

of Brazil, hardly justified adopt economically levels exceeding 90%, being normally used, levels ranging from 50-75%. The same authors found that the frequency and the data distribution of reference evapotranspiration in the region of Cruz das Almas, had better fit to the probabilistic models Normal, Lognormal and Beta. Doorenbos and Pruitt (1977) consider that in most of regions irrigated these levels were between 75 and 80%.

The criterion of choice the level of probability must be based on an economic analysis, considering the losses associated with the reduction of the quantity and quality of the production, derived from hydric deficiency and increase of the system costs to meet higher levels of probability. Generally, higher levels of probability (80-90%) are selected for crops with high economic value and reduced conditions of available water in the soil (PRUITT, von OETTINGEN; MORGAN, 1972; JENSEN, 1974).

The objective of this paper was to elaborate tables of probabilities of the occurrence of values of reference evapotranspiration (Etr) monthly mm.day^{-1} , using for estimation the model of normal probability density distribution, in accumulated periods of 10 (ten), fifteen (15) and twenty (20) days.

MATERIALS AND METHODS

Data were obtained from a series of 38 years (1970-2007), derived from the records of the Meteorological Station of the Federal Rural University of the Semi-Arid (UFERSA) in Mossoró, RN, whose geographical coordinates are: 5 \circ 11' S and 37 \circ 20' W with 18 m high, with an average annual temperature around 27.5 \circ C and relative humidity of 68.9% (CARMO FILHO; ESPÍNOLA SOBRINHO; MAIA NETO, 1991). According to Köppen climate classification, the climate of Mossoró is the type Bsw, ie, warm and dry.

The values of Eto (reference evapotranspiration) were accumulated in consecutive periods of 20, 15 and 10 days, and then analyzed using the R program to check the fit of the estimates of Eto to the distribution model density of probability normal, whose adjustments were performed through the tests nonparametric of Chi-square and Kolmogorov-Smirnov to 10% probability.

According Bussab and Morettin (2003), normal probability density distribution or Gaussian is one of the most important models to represent the continuous random variables, whose distribution is called normal or Gaussian distribution, which serves as the distribution model for many real life problems, but also appears in many theoretical investigations, because their importance in mathematical analysis results from the fact that many statistical techniques such as analysis of variance and regression besides some hypothesis tests assume or require data normality. The random variable X, which takes all real values, has a normal distribution (or Gaussian) if its probability density function is of the form:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \cdot \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right], \quad \text{for}$$

$$-\infty < X < +\infty,$$

where: μ refers to the average of the observations in the data series, and σ the standard deviation of the observations in the data series. The probability that a random variable x takes values less than or equal to x when she has normal distribution with mean μ and variance σ^2 [N(μ , σ^2)], is estimated by,

$$P(a \leq X \leq b) = \frac{1}{\sigma\sqrt{2\pi}} \int_a^b e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx \quad (\text{MEYER, 1969}).$$

This equation cannot be analytically solved without the use of approximate integration. For this reason, it uses the transformation $Z = (x-\mu) / \sigma$, being that this variable Z has standard normal distribution with mean zero and variance one [N (0,1)]. The variable Z is called reduced, and the equation can be rewritten in the following form:

$$F(Z) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^Z \exp\left[-\frac{1}{2}(Z)^2\right], \quad \text{for}$$

$$-\infty < Z < +\infty.$$

The adherence test of Chi-square (χ^2) is a statistics application which aims to determine whether a set of observed data is compatible with the expected values, and for this, it test the null hypothesis assuming that the distribution is that specified and used in the study (normal, log-normal and gamma, etc), with its parameters estimated based on sample data. The hypothesis is tested by making the comparison between the observed frequencies and theoretical frequencies or expected frequency in each class frequency data through the test

$$\text{statistic } (\chi^2) \text{ given by } \chi^2 = \sum_{i=1}^K \left[\frac{F_{O_i} - F_{e_i}}{F_{e_i}} \right], \text{ wherein,}$$

K is the number of classes, F_o the observed frequency and F_e the expected frequency under the hypothesis H_o according to the distribution that is being tested (CAMPOS, 1983). The critical values or tabulated of χ^2 for some significance levels α are described by specific tables.

It is worth noting that this statistic is associated with a degree of freedom defined by subtracting of the classes number of the distribution of frequency of the parameters number estimated and of minimum expected frequency.

The adherence test of Kolmogorov-Smirnov (KS) is a nonparametric test that features as basis the difference between the functions of accumulated probabilities, empirical and theoretical. It is worth noting that it is not applied to discrete random variables, only to continuous distributions. This adjustment test is used to assess the

homogeneity of a set of data distributions. It was designed in response to the shortcomings of the Chi-square test, which produces accurate results only for discrete distributions. The KS test has the advantage of no making assumption about the rows of the data sets to be compared, removing the arbitrariness and loss of information accompanying the selection process, ie, adjusts the observed values with those estimated by probability distributions (CAMPOS, 1983).

In accordance with what has been explained before, the mathematical model that represents the KS test can be expressed as shows the following equation:

$$D = KS = \max_{-\infty < x < \infty} |F_N(x) - F_o(x)| \quad (\text{TIBERIUS; BORRE, 1999}).$$

From the calculated value D of the Kolmogorov-Smirnov test, and of the tabulated value D_k , which is obtained in function of the number of elements of the sample, and the level of significance, verifies whether the null hypothesis is accepted or rejected, ie, if $FN(x)$ and $F0(x)$ are equal or not (TIBERIUS; BORRE, 1999).

The estimated values of monthly potential evapotranspiration were obtained through the standard method of Penman-Monteith, which fits well to the data of the region of Mossoró, RN. The combined method of Penman-Monteith for the calculation of E_{tp} of hypothetical culture, when incorporated into the surface resistance of 70 sm^{-1} and with the aerodynamic resistance fixed to grass, in 0.12 m of uniform height, can be expressed, for purposes of standardization of the calculations procedures (SEDIYAMA, 1996), by the following equation:

$$ETp = \frac{0.408 \cdot S(R_n - G) + \frac{\gamma \cdot 900 \cdot V_2 \cdot (e_s - e)}{t + 273}}{S + \gamma(1 + 0.34V_2)}$$

where R_n is the daily total net radiation ($\text{MJ m}^{-2} \text{d}^{-1}$), G is the heat flow in soil ($\text{MJ m}^{-2} \text{d}^{-1}$), $\gamma = 0,063 \text{ kPa } ^\circ\text{C}^{-1}$ is the psychrometric constant, t is the average temperature of the air ($^\circ\text{C}$), V_2 is the wind speed at 2 m height (m/s), e_s is the saturation pressure (kPa), e is the actual pressure of the water vapor (kPa) and S is the slope of the vapor pressure curve in air temperature ($^\circ\text{C}$) in kPa, calculated by

$$S = \frac{4098 \cdot e_s}{(t + 273)^2}.$$

Bertoni and Tucci (2001) reported that the period of payback or recurrence (Tr) can be interpreted as the average number of years during which it is expected that potential evapotranspiration analyzed is equaled or exceeded. The period of return can be obtained by the

$$\text{following equation: } Tr = \frac{1}{P}, \text{ where } P \text{ is the probability of}$$

the variable under study to be equaled or exceeded. To analyze the minimum values of some hydrological

variable or any random variable, it should change the interpretation in the sense of occurrence of lower values to that analyzed, ie, it should calculate the cumulative probability of the variable. The payback period in this case is the inverse of the probability of not being exceeded.

RESULTS AND DISCUSSION

Adjusting up the statistical model to infer the behavior of evapotranspiration in each studied period, it was found that the normal distribution was the best model to represent the behavior of the reference evapotranspiration, due to the simplicity of its equation, low number of parameters to be estimated, ease of estimation, their extensive use in the studies of statistical inference, as well as the highest percentage of adherence to the series studied. Similar studies were highlighted by Costa Neto (2002), Abumanssur (2006), Silva et al. (1998) Arraes et al. (2009) and Blain and Brunini (2007).

In the Tables 1 to 4 are presented the values of the reference evapotranspiration (Etp) for different levels of probability and return periods. The interpretation of these informations may be made as follows: for an Etp accumulated period of 10 days and the occurrence probability of 95% (return period of 20 years) the value of Etp corresponds to 6.13 mm day⁻¹. Therefore, there is a 95% probability of that the value of Etp for the first ten days of January does not exceed 6.13 mm to day⁻¹, or still for the same period, in only one out of each twenty years, the value of Etp will be equal to or greater than 6.13 mm day⁻¹.

The advantage of the values estimated by the normal distribution is to guide the researcher in the sizing of irrigation systems, conduct statistical inference through estimation of values, make probabilistic forecasts, compare periods accumulated of Etp and of return through the construction of confidence intervals, ie, make estimatives with high reliability for an error of estimation or fixed sampling, of the application of hypothesis tests, application of regression models for prediction, measure the variability or heterogeneity, estimate the degree of skewness and kurtosis of the responses as well as assess the risks inherent to this important random variable for agriculture of the region. For example, through the Tables 1 and 2 it appears that, taking the first ten days of January, the higher the value of the probability or risk, the lower the estimated value of the reference evapotranspiration in this period. Moreover, the data show that there is at least 75% of probability that the value of the evapotranspiration of reference assumes 6.31 mm day⁻¹. Considering now, the last ten days of December, observed that there is a maximum probability of 75% that the value of the evapotranspiration of reference does not exceed 6.23 mm day⁻¹, showing thus, that the use of the model, can help of safe form, the management of farming and livestock activities, as an example, sizing of irrigation systems, hydric requirement of crops, cost estimation, procurement

of materials, crop forecasting, estimation of production, and present and future needs (MEYER, 1969; DOORENBOS; KASSAM, 1976, HANN, 1994; LANNA, 2001; COSTA NETO, 2002; BUSSAB; MORETTIN, 2003).

The Etp values multiplied by the respective coefficients of crop, can be used as a parameter for dimensioning of irrigation systems in the region of Mossoró, RN, Brazil. For example, in maize crop, the flowering is the period of maximum hydric requirement, with lasting about 20 days and crop coefficient of 1.05 (DOORENBOS; KASSAM, 1976). In these conditions, adopting 75% as probability level (return period of 4 years), the evapotranspiration recommended as a parameter for dimensioning of irrigation systems for the region of Dourados is 6.18 mm day⁻¹ (5.89 x 1.05). In Mossoró, RN, for example, in October, for a period of maximum hydric requirement, taking the first two weeks, using the same culture, adopting a level of probability or risk of 75% (period Return of 4 years), the Etp recommended as a parameter in the sizing of irrigation systems is 7.84 mm day⁻¹ (7.47 x 1.05). So, in this case there is 75% probability that the value of Etp for a period corresponding to the first fortnight of October, does not exceed to 7.84 mm day⁻¹, or still, for the same period, in only one of every four years, the Etp value is equal to or greater than 7.84 mm day⁻¹.

According to the results in Table 4 it can be seen that the values of the evapotranspiration of reference estimated with 75% probability through the normal distribution, vary according to the periods considered (twenty days). Marques, Jr., and Moura Saad (1995) appropriated of the concept of dependent precipitation citing Doorenbos and Pruit (1976), to apply the determination of the called evapotranspiration of sizing obtained at the level of 75% probability within a series of data and explain further that this value is the used in irrigated agriculture. Also in this Table, the probability levels represent limits of occurrence of values equal to or lower than the established. Thus, for example, for an accumulated period from evapotranspiration in the first twenty days of the year, there is 75% of probability that the value of the evapotranspiration is not greater than 6.06 mm day⁻¹, or, even, for the same period, in only one in every four days the value of the evapotranspiration will be equal to or greater than 6.06 mm day⁻¹. Similar results were obtained by other authors, such as, Silva et al. (1998), Abumanssur (2006) and Arraes et. al. (2009).

As to the criteria for adjusting, there was a high approval of Kolmogorov-Smirnov tests and Chi square test at the level of 10% of probability. In the Kolmogorov-Smirnov test observed that, regardless of the capacity of the distribution to estimate the observed frequencies and of the number of classes, the tabulated critical value depends solely on the number of observations, which does not vary from distribution to distribution depending only of the series under test.

Considering now the Chi-square test, it was found that the degree of freedom depends on the parameters of the distribution, around two or three, and of the number of classes (data characteristics). This number reduces when the distribution underestimates the final classes, due to the grouping of some classes in other classes, and the degree of freedom becomes smaller, reducing the tabulated critical value. This shows that the critical value for the Chi-square depends on the ability of the distribution in estimating the frequencies observed

which does not occur in the Kolmogorov-Smirnov test. According Catalonia et al. (2002), this happens, despite the Kolmogorov-Smirnov test be widely used for analysis of adhesions of the distributions in climate studies. However, the level of approval of a distribution under test is very high, which creates some uncertainty regarding test criteria, as described before. In view of the characteristics presented by the Chi-square test, it was opted by its choice as reference in analyzes performed in this work.

Table 1. Decennial values for the first semester estimated of the variable reference evapotranspiration (ETp) in mm day⁻¹ by Penman-Monteith method for certain levels of probability [(p (X ≤ x))] following the normal distribution, to the town of Mossoró, RN, from 1970 to 2007.

MONT H	DEC	LEVELS OF PROBABILITY																			
		1%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
JAN	J1	6.86	6.73	6.67	6.62	6.59	6.56	6.53	6.50	6.48	6.45	6.43	6.41	6.39	6.36	6.34	6.31	6.28	6.24	6.20	6.13
	J2	6.96	6.71	6.58	6.49	6.42	6.36	6.31	6.26	6.21	6.16	6.12	6.07	6.03	5.98	5.93	5.88	5.81	5.74	5.66	5.52
	J3	6.30	6.18	6.11	6.07	6.04	6.01	5.98	5.95	5.93	5.91	5.89	5.86	5.84	5.82	5.79	5.77	5.74	5.70	5.66	5.59
FEB	F1	6.12	6.03	5.99	5.95	5.93	5.90	5.88	5.87	5.85	5.83	5.82	5.80	5.78	5.76	5.75	5.73	5.70	5.68	5.64	5.60
	F2	5.71	5.63	5.59	5.57	5.54	5.52	5.51	5.49	5.48	5.46	5.45	5.43	5.42	5.40	5.39	5.37	5.35	5.33	5.30	5.26
	F3	6.09	5.90	5.80	5.73	5.68	5.64	5.60	5.56	5.52	5.49	5.45	5.42	5.38	5.35	5.31	5.27	5.22	5.17	5.10	5.00
MAR	M1	5.55	5.45	5.40	5.36	5.34	5.31	5.29	5.27	5.25	5.24	5.22	5.20	5.18	5.16	5.14	5.12	5.10	5.07	5.04	4.99
	M2	5.13	5.04	4.98	4.95	4.92	4.90	4.88	4.86	4.84	4.82	4.81	4.79	4.77	4.75	4.73	4.71	4.69	4.66	4.63	4.57
	M3	4.96	4.84	4.78	4.74	4.70	4.67	4.65	4.62	4.60	4.58	4.56	4.54	4.51	4.49	4.47	4.44	4.41	4.38	4.34	4.28
APR	A1	4.84	4.76	4.71	4.68	4.66	4.64	4.62	4.60	4.59	4.57	4.56	4.54	4.52	4.51	4.49	4.47	4.45	4.43	4.40	4.35
	A2	4.93	4.83	4.77	4.74	4.71	4.68	4.66	4.64	4.62	4.60	4.59	4.57	4.55	4.53	4.51	4.49	4.46	4.43	4.40	4.34
	A3	4.90	4.78	4.72	4.68	4.64	4.61	4.59	4.56	4.54	4.52	4.50	4.47	4.45	4.43	4.40	4.38	4.35	4.31	4.27	4.21
MAY	M1	4.87	4.77	4.72	4.68	4.65	4.63	4.61	4.59	4.57	4.30	4.53	4.55	4.50	4.48	4.46	4.44	4.41	4.38	4.35	4.30
	M2	5.07	4.94	4.87	4.82	4.78	4.75	4.72	4.69	4.67	4.64	4.62	4.59	4.57	4.54	4.52	4.49	4.46	4.42	4.37	4.30
	M3	5.36	5.18	5.08	5.02	4.96	4.92	4.88	4.84	4.81	4.77	4.74	4.71	4.67	4.64	4.60	4.56	4.52	4.47	4.40	4.30
JUN	J1	4.86	4.77	4.72	4.68	4.66	4.64	4.61	4.60	4.58	4.56	4.54	4.53	4.51	4.49	4.47	4.45	4.43	4.40	4.37	4.32
	J2	5.02	4.91	4.85	4.81	4.78	4.76	4.73	4.71	4.69	4.38	4.65	4.67	4.61	4.59	4.56	4.54	4.51	4.48	4.44	4.38
	J3	5.08	4.97	4.91	4.88	4.85	4.82	4.79	4.77	4.75	4.45	4.71	4.73	4.67	4.65	4.63	4.61	4.58	4.55	4.51	4.45

SOURCE: Decennial data of probability obtained by the research.

Table 2. Decennial values of the second semester estimated of the variable reference evapotranspiration (ETp) in mm day⁻¹ by Penman-Monteith method for certain levels of probability [(p (X ≤ x))] following the normal distribution, to the town of Mossoró, RN, in the period 1970-2007.

MONTH	DEC	LEVELS OF PROBABILITY																			
		1%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%
JUL	J1	5.35	5.22	5.15	5.11	5.07	5.04	5.01	4.99	4.96	4.94	4.91	4.89	4.87	4.84	4.82	4.79	4.76	4.72	4.67	4.61
	J2	5.60	5.49	5.43	5.39	5.36	5.33	5.31	5.28	5.26	5.24	5.22	5.20	5.18	5.16	5.13	5.11	5.08	5.05	5.01	4.95
	J3	6.02	5.88	5.80	5.75	5.71	5.67	5.64	5.61	5.58	5.55	5.53	5.50	5.47	5.45	5.42	5.38	5.35	5.31	5.25	5.18
AUG	A1	6.59	6.47	6.40	6.36	6.32	6.29	6.27	5.61	6.24	6.22	6.19	6.17	6.15	6.12	6.10	6.07	6.05	6.02	5.98	5.94
	A2	6.83	6.73	6.69	6.65	6.63	6.60	6.58	6.56	6.54	6.53	6.51	6.49	6.48	6.46	6.44	6.42	6.39	6.37	6.33	6.29
	A3	7.15	7.06	7.01	6.98	6.96	6.93	6.91	6.90	6.88	6.83	6.85	6.83	6.81	6.79	6.78	6.76	6.73	6.71	6.68	6.63
SEP	S1	7.15	7.06	7.01	6.98	6.96	6.93	6.91	6.90	6.88	6.98	6.85	6.83	6.81	6.79	6.78	6.76	6.73	6.71	6.68	6.63
	S2	7.61	7.51	7.45	7.41	7.38	7.36	7.33	7.31	7.29	7.23	7.25	7.23	7.21	7.19	7.17	7.15	7.12	7.09	7.06	7.00
	S3	7.55	7.56	7.52	7.49	7.47	7.46	7.44	7.43	7.41	7.40	7.39	7.37	7.36	7.35	7.33	7.32	7.30	7.28	7.26	7.22
OCT	O1	7.70	7.63	7.59	7.57	7.54	7.53	7.51	7.50	7.48	7.44	7.46	7.44	7.43	7.42	7.40	7.39	7.37	7.35	7.32	7.29
	O2	7.63	7.59	7.57	7.55	7.54	7.53	7.52	7.51	7.50	7.49	7.48	7.48	7.47	7.46	7.45	7.44	7.43	7.42	7.40	7.38
	O3	7.74	7.64	7.59	7.56	7.53	7.50	7.48	7.46	7.44	7.42	7.41	7.39	7.37	7.35	7.33	7.31	7.28	7.25	7.22	7.17
NOV	N1	7.56	7.46	7.40	7.36	7.33	7.31	7.28	7.26	7.24	7.22	7.20	7.18	7.16	7.14	7.12	7.10	7.07	7.04	7.00	6.95
	N2	7.39	7.31	7.27	7.24	7.21	7.19	7.18	7.16	7.15	7.10	7.12	7.10	7.09	7.07	7.05	7.04	7.02	6.99	6.97	6.92
	N3	7.42	7.28	7.21	7.16	7.13	7.09	7.06	7.04	7.01	6.94	6.96	6.94	6.91	6.89	6.86	6.83	6.80	6.76	6.71	6.64
DEC	D1	6.87	6.78	6.73	6.70	6.67	6.65	6.63	6.61	6.60	6.54	6.56	6.55	6.53	6.51	6.49	6.47	6.45	6.43	6.39	6.35
	D2	6.85	6.71	6.63	6.58	6.54	6.51	6.48	6.45	6.42	6.40	6.37	6.35	6.32	6.29	6.26	6.23	6.20	6.16	6.11	6.03
	D3	6.85	6.71	6.63	6.58	6.54	6.51	6.48	6.45	6.42	6.40	6.37	6.35	6.32	6.29	6.26	6.23	6.20	6.16	6.11	6.03

Table 3. Biweekly values estimated of reference evapotranspiration (ETp) in mm day⁻¹ by Penman Monteith method, for certain levels of probability [p (X ≤ x)] following the normal distribution, to the town of Mossoró, RN, from 1970 to 2007.

MONT H	DE C	LEVELS OF PROBABILITY																			
		1%	5%	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95
JAN	J1	6.8	6.6	6.61	6.57	6.53	6.49	6.46	6.44	6.31	6.39	6.36	6.34	6.31	6.29	6.26	6.23	6.20	6.16	6.11	6.04
	J2	6.6	6.4	6.33	6.26	6.19	6.14	6.09	6.05	6.01	5.97	5.93	5.89	5.85	5.81	5.77	5.72	5.67	5.60	5.53	5.41
FEB	F1	6.1	6.0	5.97	5.91	5.87	5.84	5.80	5.77	5.74	5.72	5.69	5.66	5.63	5.61	5.58	5.54	5.51	5.46	5.41	5.33
	F2	5.9	5.8	5.75	5.69	5.65	5.61	5.57	5.54	5.51	5.48	5.45	5.48	5.40	5.37	5.33	5.30	5.26	5.22	5.16	5.08
MAR	M1	5.6	5.4	5.38	5.32	5.27	5.24	5.20	5.17	5.14	5.11	5.08	5.05	5.02	4.99	4.95	4.92	4.88	4.83	4.78	4.69
	M2	5.1	4.9	4.92	4.87	4.82	4.79	4.76	4.73	4.70	4.67	4.64	4.62	4.59	4.56	4.53	4.50	4.46	4.42	4.37	4.29
APR	A1	4.8	4.7	4.72	4.69	4.66	4.64	4.62	4.60	4.59	4.53	4.55	4.53	4.52	4.50	4.48	4.46	4.44	4.41	4.38	4.33
	A2	4.8	4.8	4.76	4.72	4.68	4.65	4.63	4.60	4.58	4.56	4.54	4.52	4.50	4.47	4.45	4.42	4.39	4.36	4.32	4.26
MAY	M1	4.9	4.8	4.77	4.73	4.70	4.67	4.64	4.62	4.60	4.58	4.56	4.54	4.52	4.50	4.48	4.45	4.43	4.40	4.36	4.30
	M2	5.2	5.1	5.03	4.97	4.92	4.87	4.83	4.80	4.77	4.73	4.70	4.67	4.64	4.60	4.57	4.53	4.49	4.44	4.38	4.28
JUN	J1	4.8	4.7	4.72	4.69	4.66	4.64	4.62	4.60	4.58	4.57	4.55	4.54	4.52	4.50	4.48	4.46	4.44	4.42	4.39	4.34
	J2	5.0	4.9	4.92	4.88	4.85	4.82	4.80	4.78	4.76	4.74	4.72	4.70	4.68	4.66	4.63	4.61	4.58	4.55	4.52	4.46
JUL	J1	5.6	5.4	5.34	5.28	5.23	5.19	5.15	5.12	5.09	5.06	5.02	4.99	4.96	4.93	4.89	4.86	4.81	4.77	4.71	4.61
	J2	5.9	5.8	5.72	5.67	5.62	5.58	5.54	5.51	5.48	5.45	5.42	5.39	5.36	5.32	5.29	5.25	5.21	5.17	5.11	5.02
AUG	A1	6.7	6.6	6.52	6.47	6.43	6.40	6.37	6.34	6.31	6.29	6.26	6.23	6.21	6.18	6.15	6.12	6.09	6.05	6.00	5.92
	A2	7.1	7.0	6.99	6.94	6.91	6.88	6.85	6.83	6.80	6.78	6.76	6.73	6.71	6.69	6.66	6.64	6.60	6.57	6.53	6.46
SEP	S1	7.5	7.3	7.32	7.27	7.24	7.20	7.17	7.15	7.12	7.09	7.07	7.05	7.02	6.99	6.97	6.94	6.90	6.87	6.82	6.75
	S2	7.6	7.5	7.53	7.50	7.47	7.45	7.43	7.41	7.39	7.38	7.36	7.34	7.33	7.31	7.29	7.27	7.25	7.23	7.19	7.15
OCT	O1	7.6	7.6	7.59	7.56	7.54	7.53	7.51	7.50	7.49	7.48	7.47	7.45	7.44	7.43	7.42	7.40	7.39	7.37	7.35	7.31
	O2	7.7	7.6	7.60	7.30	7.54	7.52	7.50	7.48	7.46	7.45	7.43	7.42	7.40	7.38	7.36	7.34	7.32	7.30	7.27	7.22
NOV	N1	7.5	7.4	7.36	7.32	7.29	7.27	7.24	7.22	7.20	7.18	7.16	7.14	7.12	7.10	7.08	7.05	7.03	7.00	6.96	6.90
	N2	7.4	7.3	7.27	7.23	7.19	7.16	7.13	7.10	7.08	7.05	7.03	7.00	6.98	6.95	6.93	6.90	6.87	6.83	6.78	6.71
DEC	D1	6.9	6.7	6.73	6.69	6.66	6.63	6.61	6.59	6.57	6.55	6.53	6.51	6.49	6.47	6.44	6.42	6.39	6.36	6.32	6.26
	D2	6.8	6.7	6.70	6.68	6.66	6.64	6.62	6.61	6.60	6.58	6.57	6.56	6.54	6.53	6.52	6.50	6.48	6.46	6.44	6.40

Table 4. Values for periods twenty and twenty days estimated reference evapotranspiration (ETp) in mm day⁻¹ by Penman Monteith method, for certain levels of probability [p (X ≤ x)] following the normal distribution, to the town of Mossoró, RN, from 1970 to 2007.

DAYS	PERIODS	LEVELS OF PROBABILITY																				
		1%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	
1	20	V1	7.03	6.81	6.69	6.61	6.55	6.50	6.45	6.40	6.36	6.32	6.28	6.23	6.19	6.15	6.10	6.06	6.00	5.94	5.86	5.74
21	40	V2	6.22	6.11	6.06	6.02	5.99	5.96	5.93	5.91	5.89	5.87	5.85	5.83	5.81	5.79	5.77	5.74	5.72	5.68	5.64	5.59
41	60	V3	5.93	5.79	5.71	5.66	5.62	5.59	5.56	5.53	5.50	5.48	5.45	5.42	5.40	5.37	5.34	5.31	5.28	5.24	5.19	5.11
61	80	V4	5.59	5.42	5.33	5.27	5.22	5.18	5.14	5.11	5.07	5.04	5.01	4.98	4.95	4.92	4.88	4.84	4.80	4.75	4.69	4.60
81	100	V5	4.91	4.80	4.75	4.71	4.68	4.66	4.64	4.61	4.59	4.58	4.56	4.54	4.52	4.50	4.48	4.46	4.43	4.40	4.36	4.31
101	120	V6	4.93	4.81	4.75	4.71	4.68	4.65	4.63	4.60	4.58	4.56	4.54	4.52	4.50	4.48	4.45	4.43	4.40	4.37	4.33	4.27
121	140	V7	4.98	4.87	4.80	4.76	4.72	4.69	4.67	4.64	4.62	4.60	4.58	4.55	4.53	4.51	4.48	4.46	4.43	4.39	4.35	4.29
141	160	V8	5.18	5.02	4.94	4.88	4.84	4.80	4.76	4.73	4.70	4.67	4.64	4.61	4.58	4.55	4.52	4.49	4.45	4.40	4.34	4.26
161	180	V9	5.06	4.95	4.89	4.85	4.82	4.79	4.77	4.74	4.72	4.70	4.68	4.66	4.64	4.62	4.59	4.57	4.54	4.51	4.47	4.41
181	200	V10	5.61	5.45	5.37	5.31	5.26	5.22	5.19	5.16	5.13	5.10	5.07	5.04	5.01	4.98	4.94	4.91	4.87	4.83	4.77	4.68
201	220	V11	6.73	6.47	6.33	6.24	6.17	6.10	6.05	5.99	5.94	5.90	5.85	5.80	5.75	5.70	5.65	5.59	5.53	5.46	5.36	5.23
221	240	V12	7.18	7.03	6.95	6.90	6.86	6.82	6.79	6.76	6.73	6.70	6.68	6.65	6.62	6.59	6.56	6.53	6.50	6.45	6.40	6.32
241	260	V13	7.63	7.48	7.40	7.35	7.31	7.27	7.24	7.21	7.18	7.16	7.13	7.10	7.08	7.05	7.02	6.99	6.95	6.91	6.86	6.78
261	280	V14	7.68	7.60	7.56	7.54	7.51	7.50	7.48	7.46	7.45	7.44	7.42	7.41	7.39	7.38	7.36	7.35	7.33	7.31	7.28	7.24
281	300	V15	7.72	7.64	7.60	7.57	7.54	7.52	7.51	7.49	7.47	7.46	7.44	7.43	7.41	7.40	7.38	7.36	7.34	7.32	7.29	7.25
301	320	V16	7.49	7.40	7.34	7.31	7.28	7.26	7.24	7.21	7.20	7.18	7.16	7.14	7.12	7.10	7.08	7.06	7.04	7.01	6.97	6.92
321	340	V17	7.37	7.19	7.10	7.03	6.98	6.94	6.90	6.86	6.83	6.79	6.76	6.73	6.70	6.66	6.63	6.59	6.54	6.49	6.43	6.33
341	360	V18	6.74	6.59	6.50	6.44	6.40	6.36	6.32	6.29	6.26	6.23	6.20	6.17	6.14	6.11	6.08	6.04	6.00	5.96	5.90	5.82

SOURCE: Data for periods twenty and twenty days of probability obtained by the research.

CONCLUSIONS

The normal probability density distribution showed a good fit to the historical series of 42 years of reference evapotranspiration for consecutive periods of 10, 15 and 20 days in Mossoró, RN, thus allowing, to use the model for point estimates of the amount of reference evapotranspiration likely at different levels of probability and return periods, besides favoring the sizing of irrigation systems, conduct statistical inference, compare periods accumulated of Etp and of return through the construction of confidence intervals, ie to make estimatives with high reliabilities for an error estimation or sampling fixed, apply hypothesis tests, adjust regression models for forecasts, measure the variability or heterogeneity of values of Etp, estimate the degree of skewness and kurtosis of the responses of Etp, as well as, assess risks inherent in this random important variable for agriculture of the region.

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