DISTRIBUTION AND FREQUENCY OF PRECIPITATION AND EVAPOTRANSPIRATION FOR THE NORTHERN REGION OF ESPIRITO SANTO

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ABSTRACT: Good agricultural planning requires many statistical tools for historical series analysis, in order to provide consistent results to decision making regarding the rational and sustainable use of water resources. The probability distribution function (PDF) is widely used for studies of rainfall precipitation and some irrigation model systems are based on a probabilistic analysis of evapotranspiration frequency distribution and predictions about water consumption by the crop. This study was carried out for the cities of Boa Esperança, Linhares, Marilândia and São Gabriel da Palha. Data from the meteorological stations located in those locations were used. Evapotranspiration was estimated by the method of Hargraves and Samani (1985). Therefore, the objective of this work is to demonstrate the potential need for irrigation based on precipitation probability studies and potential evapotranspiration estimation, in order to subsidize the planning and technical assistance agencies for their decision making and use in a more appropriate way of water resources.

KEYWORDS: precipitation, evapotranspiration, statistics.

DISTRIBUIÇÃO E FREQUENCIA DA PRECIPITAÇÃO E EVAPOTRANSPIRAÇÃO PARA A REGIÃO NORTE DO ESPÍRITO SANTO

RESUMO: Um bom planejamento agrícola, necessita cada vez mais do uso de ferramentas estatísticas para análise de séries históricas, com a finalidade de fornecer resultados consistentes à tomada de decisão quanto ao uso racional e sustentável dos recursos hídricos. A função de distribuição de probabilidade (PDF) é largamente utilizada para estudos de

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precipitação pluviométrica e alguns modelos de sistemas de irrigação são embasados em análise probabilística de distribuição de frequência de evapotranspiração e em previsões acerca do consumo de água pela cultura. O estudo foi realizado para os municípios de Boa Esperança, Linhares, Marilândia e São Gabriel da Palha. Foram utilizados dados das estações meteorológicas localizadas nas localidades citadas anteriormente. A evapotranspiração foi estimada através do método de Hargraves e Samani (1985). Sendo assim, o objetivo deste trabalho é demonstrar a necessidade potencial de irrigação com base em estudos de probabilidade de precipitação e estimativa de evapotranspiração potencial, afim de subsidiar os órgãos de planejamento e assistência técnica para suas tomadas de decisões e na utilização de modo mais adequado dos recursos hídricos.

PALAVRAS-CHAVE: precipitação, evapotranspiração, estatística.

INTRODUCTION

A reasonable business model uses tools for the analysis of historical series, looking for consistent results in decision making on the rational and sustainable use of water resources, at construction activities, tourism, logistics and transportation and, especially, on the design of crop irrigation systems.

The probability distribution functions (PDF) in meteorological data are widely used in studies of precipitation frequency. Among the probability functions used, the most common is the gamma function (CASTRO, 1994; RIBEIRO & LUNARDI, 1997; ARAÚJO et al., 2001 e CASTELLVÍ et al., 2004), but there is some other PDF that allow one to achieve a better adjustment when compared to the gamma function. However, this adjustment is directly proportional to the climatic precipitation distribution of a given area (LYRA et al., 2006; SILVA et al., 2007).

Barger & Thom (1949) recommendation is to use the gamma function to study the monthly or daily/hourly precipitation distribution. However, this function may be good enough to investigate longer time series for regions with average low precipitation, as the northern State of Espirito Santo.

The knowledge of evapotranspiration is fundamental for good performance in irrigated crops. The base for some models for designing irrigation systems is on the probabilistic analysis of evapotranspiration frequency distribution and forecasts about the water consumption by the crop.

Jensen (1974) presented a system design model, which considers the probabilistic occurrence of evapotranspiration and pluviometric precipitation. In his study, Jensen points out that the design of an irrigation system depends directly of the expected monthly evapotranspiration and this, in turn, depends on the duration time of the maximum water requirement of the crop, which in the case of annual crops, the maximum period water requirement can range from two to three weeks. Saad and Scaloppi (1988) suggest as reasonable, for annual cycle crops, to allow a period between 10 and 30 days for maximum water requirement of the crop.

This paper goal is to demonstrate the potential need for irrigation for the northern region of Espirito Santo, based on studies on the probability of precipitation and estimation of potential evapotranspiration, perhaps helping on the decision-making and most appropriate use of resources over the northern State of Espirito Santo.

MATERIAL AND METHODS

The study was carried out for the cities of Boa Esperança, Linhares, Marilândia and São Gabriel da Palha, located in the northern State of Espirito Santo (Brazil). According the climatic classification proposed by Köppen, the mentioned cities have AW climate, i.e., tropical humid climate, with dry winter (NOBREGA et al., 2008, a, b, c, d.). According to the 1984-2014 climatology (INCAPER, 2018), The State of Espirito Santo presents a dry season between April and September, and a rainy season, which includes the period from October to March, with a break at February, that is significantly dryer than the other rainy months.

Precipitation and temperature data from the Instituto Nacional de Meterologia (INMET) weather stations was used as follows (cities (years)): Linhares (1976-2018), Marilândia (1979-2018), Boa Esperança (1987-2018) and São Gabriel da Palha (1977-2018). The monthly data was organized in a spreadsheet and submitted to a quality control in order to detect possible erroneous data or failures from the instruments/sensors.

In order to fill the fails or nonexistent precipitation data, we used the monthly data obtained at the climate monitoring products from the Centro de Previsão de Tempo e Estudos Climáticos of the Instituto Nacional de Pesquisas Espaciais (CPTEC/INPE, 2019).

To fill the faults in the monthly average temperature data used to perform evapotranspiration calculation data from the nearest meteorological station with similar weather characteristics of the station of origin were used.

For the calculation of the evapotranspiration, the methodology of HARGRAVES and SAMANI (1985) was used, according to the following equation:

$$ET_0 = 0{,}0023 * Q_0 * (T_{Máx} - T_{Mín})^{0{,}5} * (T + 17{,}8) \qquad (1)$$

Where ET_0 is the evapotranspiration $(mm.d^{-1})$, Q_0 is the monthly averaged extraterrestrial solar radiation in mm of equivalent evaporation, $T_{Máx}$ is the monthly average maximum temperature in °C, $T_{Mín}$ is the monthly average minimum temperature in °C and T is the average monthly temperature in °C.

To determine the monthly precipitation probability for 50%, 60%, 75%, 80%, 90% and 95%, the gamma function, given by the probability density function (2) and the cumulative distribution function (3), as follows:

$$f(x) = \frac{x^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)} exp(-x/\beta) \quad where\ x, \alpha, \beta > 0 \qquad (2)$$

Where:

α shape parameter,

β scale parameter.

Γ (α) Gamma function

$$F(x) = \frac{\Gamma_{x/\beta}(\alpha)}{\Gamma(\alpha)} \qquad (3)$$

The three-parameter Log-Normal distribution was used to determine the monthly evapotranspiration estimate given by the probability density function (4) and cumulative distribution function (5), as follows:

$$f(x; \mu, \sigma, \gamma;) = \frac{exp\left(-\frac{1}{2}\left(\frac{ln(x-\gamma)-\mu}{\sigma}\right)^2\right)}{(x-\gamma)\sigma\sqrt{2\pi}} \qquad (4)$$

where $x > \gamma \geq 0$, $-\infty < \mu < \infty$, $\sigma > 0$, and γ is the threshold parameter or location parameter that defines the point where the support set of the distribution begins; μ is the scale parameter that stretch or shrink the distribution and σ is the shape parameter that affects the shape of the distribution. If X is a random variable that has a three-parameter log-normal probability distribution, then $Y = \ln(X - \gamma)$ has a normal distribution with mean μ and varianceσ^2 . The two-parameter lognormal distribution is a special case of the three-parameter lognormal distribution when $\gamma = 0$.

$$F(x) = \phi\left(\frac{ln(x-\gamma)-\mu}{\sigma}\right), \quad x > 0 \qquad (5)$$

where ϕ is the cumulative distribution function of the standard normal distribution (i.e. N(0,1)).

RESULTS AND DISCUSSION

Table 1. Averaged precipitation and probable precipitation at 75% of probability.

Months	Linhares		B. Esperança		Marilândia		S.G. da Palha	
	Med.	**75%**	**Med.**	**75%**	**Med.**	**75%**	**Med.**	**75%**
JAN	153.6	56.1	92.1	57.3	158.6	74.3	143.6	64.7
FEB	95.0	50.3	50.7	41.3	100.1	51.0	97.7	61.6
MAR	126.1	63.6	118.3	63.9	133.0	67.4	116.1	64.0
APR	91.4	43.0	58.7	38.2	66.6	31.5	53.3	32.1
MAY	55.0	26.7	26.9	18.3	35.2	9.0	25.7	16.5
JUN	40.4	15.1	24.5	13.4	34.2	6.7	22.4	11.7
JUL	55.3	26.0	24.5	15.9	31.3	10.7	22.6	12.1
AUG	47.0	18.9	28.9	12.3	37.1	9.6	27.2	13.7
SEP	56.8	20.7	27.6	18.9	33.5	9.2	23.6	14.3
OCT	115.0	48.3	62.5	44.2	87.8	40.2	71.0	39.6
NOV	216.6	136.6	221.2	116.6	184.4	120.9	177.7	118.7
DEC	200.7	116.2	156.6	106.2	202.9	121.3	183.4	126.4
YEAR	1252.9	1039.7	1007.1	917.1	1104.8	913.4	1187.7	948.6

Table 2. Averaged evapotranspiration and probable evapotranspiration at 75% of probability.

Months	Linhares		B. Esperança		Marilândia		S.G. da Palha	
	Med.	**75%**	**Med.**	**75%**	**Med.**	**75%**	**Med.**	**75%**
JAN	155	164.3	180.6	188.1	177.8	189.5	177.1	195.9
FEB	142	148.8	158.5	166.1	159.6	169.0	160.2	167.3
MAR	140.7	147.5	159.7	164.6	153.8	160.2	157.8	162.5
APR	112.1	116.8	123.3	128.1	120.9	126.4	123.6	128.3
MAY	95.6	99.8	107.4	111.1	104.8	109.0	108.9	116.2
JUN	83.6	86.7	90.5	95.2	89	92.8	92.5	95.5
JUL	87.7	91.1	97.1	102.2	95.9	100.9	99.3	103.1
AUG	102.3	106.2	112	116.6	112.1	117.5	115.4	120.8
SEP	113.6	118.3	132.4	138.1	127.3	133.6	128	137.6

OCT	131.2	137.7	156.1	170.7	146.8	158.3	154.2	170.8
NOV	134.4	140.9	155.6	167.8	156.5	165.3	154	162.7
DEC	148.7	143.6	170.3	180.4	169.7	177.0	170.4	178.7
YEAR	1444.7	1485.0	1638.7	1696.4	1614.3	1659.3	1636.6	1693.0

Looking at the precipitation (Table 1) average and its 75% probability values, one can see that the maximum values occur in November for the cities of Linhares and Boa Esperança and in December for Marilândia and Sao Gabriel da Palha.

The evapotranspiration range for different levels of probability is smaller when compared to the results found looking just to the precipitation. This is possible because of the large interannual variability: in some cases, it is possible to observe positive or negative anomalies greater than 100% when compared to the climatological average, while the temperature does not presents that behavior.

CONCLUSION

The results show that the precipitation probability brings more security for the irrigation systems structural dimensioning, since that precipitation has a great interannual variability over the northern State of Espirito Santo. Despite the evapotranspiration small difference between its average and probable values, the use of probability also contributes to increased safety at irrigation systems building. Thus, we can say that the results based on probabilistic parameters are safer than the average historical series alone.

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