Study of the behavior of dry and rainy periods in the city of Garanhuns, PE, with an agricultural planning as a goal

Antonio Ricardo S. de Andrade, Francisco J. R. Paixão, Carlos A. V. de Azevedo, Josivanda P.G. de Gouveia, José A. S. de Oliveira Júnior

Abstract

This study focuses on estimating the probable monthly precipitation with different levels of significance, and to determine the probability of occurrence of dry and rainy periods in Garanhuns, Pernambuco state. The study is based on the data of monthly pluviometric precipitation of one sequence of data that represents the period between the years of 1913 and 1987. Distinguishing criteria of dry and rainy periods are based on four classes of monthly accumulated rains: (D) dry month, from 0 to 50 mm; (NSR) not-so-rainy month, from 50 to 100 mm; (R) rainy month, from 100 to 200 mm; and (VR) very rainy month with more than 200 mm. It was using theoretical distribution of gamma probability for estimating the probable monthly precipitation, in the probability levels of 90, 80, 75, 70, 60, 50, 40 and 30%. It was possible to conclude that the gamma distribution presented a good adjustment to the values, favoring its use for estimating the probable monthly precipitation. The lower probable precipitations, below 50 mm per month, are recorded in the months of October, November and December, where the irrigated agriculture should be focused. It is also recommended that species and cultivate species of short cycle should be planted in October, and for those with a long cycle in August, in order to avoid damages during harvesting.

Key words: precipitation; probabilistic models; irrigation.

Introduction

In Brazil, especially in the Northeast region, almost all projects of irrigation and drainage come to help all the hydric necessitates of cultures, without paying special attention to the advantages of precipitation periods. The probable precipitation of a period is a regular element in agriculture, and the amount of rain and its distribution in certain region can determine the kind of agricultural activity to be developed in that region. Agricultural productions depend on interest weather variations, such as: total amount of rain, pluviometric distribution, temperature and relative humidity of the air. (ARAÚJO et al., 2001). Besides that, getting to know the basic aspects of fundamental calculus of a probable precipitation of one period is an essential necessity to determine the size of a barrage, the amount of water to be used in the agricultural planning and the measurement of the complemented system of irrigation.

Assuming that, the occurrence of dry or rainy days is associated with previous pluviometric conditions; here, we can use the probability theory. Several models of the probability theory have been used, targeting the probable estimated rainfall for different periods of occurrence. Among them stands out the normal distributions (ASSIS et al., 1996; ANDRADE JÚNIOR and BASTOS, 1997), gamma distribution (RODRIGUES and PRUSKI, 1996, Ribeiro and LUNARDI, 1997) and Gumbel (ASSIS et al., 1996). The authors recommend the use of probabilistic functions, and later checking the adjustment through tests of adhesion.

According to Cunha et al. (1996), a model that has been quite quoted in literature is the one of Gamma Distribution. Its use has to do with the facts that, the rainfalls from a statistical point of view, are not equally distributed around the average value, but they are asymmetrical, with huge gap regarding the average value (KREPPER et al., 1989).

According to Castro et al. (1994), the average rainfall in the dimensioning of agricultural projects used in Brazil, poses a risk to the producer. According to Bernardo (1995) to minimize the risks, the producer should not work with probabilities of occurrence of rain lower than 75 or 80%. However, these values can change when using an economic criterion, whose level of probability is associated

with a decrease in quality and quantity of production, resulting from water deficit due to lack of rain over a period of time (JENSEN, 1983).

Assis (1991) has developed theoretical models to describe the amount of daily rainfall in Pelotas - RS based on the Truncated Negative Binomial and gamma distributions. When analyzing the weekly totals of rainfall of Pelotas, RS, during the period of 1893 to 1991, it was possible to conclude that the amount of rain can be rightly represented with function of distribution of gamma probability. Many studies show that the gamma distribution represents the exact behavior of rain. Considering the influence that weather conditions have in many agricultural activities, this work took place with the goal to determine the probability of occurrence of dry (D) and rainy (R) periods in the city of Garanhuns, PE, considered to be a dry month, from 0 to 50 mm; not-so-rainy months, from 50 to 100 mm; rainy months, from 100 to 200 mm and very rainy months, over 200 mm.

Material and methods

All the used data were got from daily rainfall records of the city Garanhuns, PE, available in the Department of Agriculture - the DEPA from UFRPE, Campus *dois Irmãos,* of a 75 year-period of observation in the Agrometeorological Station of this campus, during the years of 1913 to 1987. The city of Garanhuns is located in the South of the Chapada Borborema, in the mesoregion of Agreste Pernambuco, in an average altitude of 896 m, reaching 1,030 m at its highest point, having in this part a less arid climate than the one that prevails in the country of the State and in the West part of the city. The annual average temperature oscillates around 20-Centigrade degrees and it can reach a high of 30 ° C during the hottest days and a low of 15°C in the coolest nights of the year. The relative humidity of air in the urban area varies from 75 to 83%. The probable monthly estimate of rainfall was obtained to levels of 90, 80, 75, 70, 60, 50, 40 and 30% of probability, using the function of gamma distribution, as presented by Assis et al. (1996). The gamma distribution of probability is mostly used to adjust total monthly periods of rain or less. Its function density of probability is presented in the following way:

$$f(x) = \begin{cases} \dfrac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}, 0 < x < \infty \\ 0, \text{c.c.} \end{cases} \quad (1)$$

The parameters of α and β that provide the gamma distribution to a given random variable, were estimated through Verisimilitude Method according to (ASSIS et al., 1996):

$$\alpha = \frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right) \quad (2)$$

$$\beta = \frac{\overline{X}}{\alpha} \quad (3)$$

$$a = h\ \overline{X} - X_g \quad (4)$$

$\overline{X}$ e $\overline{X}_g$ are respectively, the arithmetic and geometric averages of observations.

To estimates of the values of probable precipitation, it was used the SISVAR 4.3 program, which returns the inverse of the accumulated gamma distribution from the values of the average (μ), standard deviation (σ), α, β and the levels of confidence of 90, 80 , 75, 70, 60, 50, 40 and 30%.

We created four classes to classify the monthly-accumulated rain. It was considerate to be a dry month, from 0 to 50 mm; not so rainy month, from 50 to 100 mm; rainy month, from 100 to 200 mm and very rainy month, over 200 mm. Therefore, we analyzed the total of each month within the two classes of accumulated rain, previously presented, and it was checked the percentage of occurrence. The probabilities (P) to occur dry periods (D), a not so rainy (NR), rainy (R), very rainy (VR) and the conditional probabilities, dry days due to the also previous dry day (D/D) and rainy days due to the previous rainy day (R/R) were determined by the frequency of dry days (FD), not so rainy days (FNR), rainy (FN), very rainy day (FVR),dry days preceded of dry days (FDD) and rainy preceded by rainy day (FRR) as models proposed by Robertson (1976) and Fietz et al. (1998). The probabilities to

happen dry consecutive periods (P(D,D,D…n)) and rainy (P (R,R,R…n)) were determined by following expressions (ROBERTSON, 1976):

$$P(S,S,S...n) = P(S)\, P(S/S)^{n-1}.100..... \quad (5)$$

$$P(C,C,C...n) = P(C)\, P(C/C)^{n-1}.100. \quad (6)$$

Here, n is the number of consecutive days of the period. To evaluate the adjustment from data of the observed precipitation by the estimated distribution of theoretic gamma probability, it was applied the **test** of **adherence** by the method of **Kolmogorov-Smirnov** (KS) to the significance level of 5% in order to check if the observed samples values of monthly precipitation may be considered as consequence of distribution of one population with that theory of gamma distribution (CAMPOS, 1979).

Results and discussions

According to a climatological sequence it was observed, for Garanhuns, PE, an annual average of precipitation of 64.10 mm, and the of 1951 was the rainiest year, with 349.8 mm, and the year of 1970 as less rainy, with 0.1 mm of precipitation . The coefficients of variation from monthly averages and the standard deviation were high, proving a big variance in precipitation, being lower between the months of October to December, and the higher ones between the months of May to August that corresponds to the drier and rainy period, respectively (Table 1).

In figure 1 is presented the distribution of precipitation in the city of Garanhuns, a monthly average of 75 years. Looking to that figure, we can see that this city had a period of concentrated rain during the fall-winter season, proving to be a dynamic region. It appears that the highest values of rainfall occur in May, June and August, especially in July. It was also noted that October, November and December are the months with the lowest precipitation.

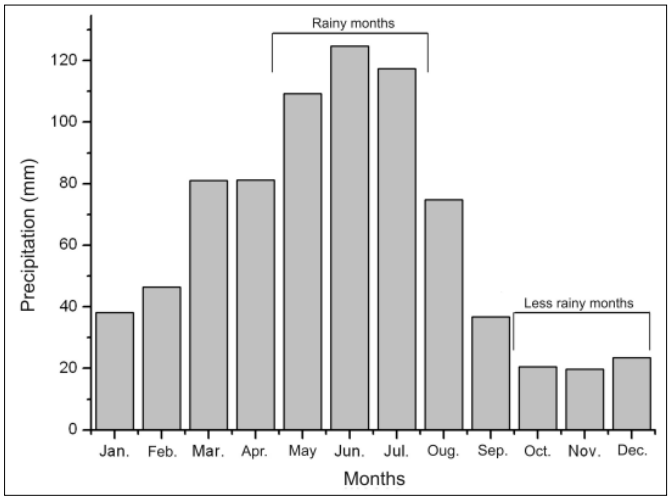
Table 2 presents the parameters (α, β) from gamma distribution and estimates of probable monthly rainfall in different levels of probability, which becomes a useful tool for a possible program of additional irrigation, if necessary. For agricultural purposes the rainfall average of a specific place is not an appropriate measure to be used, since the probability of their occurrence with a value equal or above the average is around 30%, which is considered low (CASTRO NETO and SILVEIRA, 1981). According to Bernardo (1995) the level of 50 to 70% of probability of rain is the most trustable in measuring agricultural projects or irrigation. Medina and Milk (1984) recommend that, to minimize the risks in a rational agriculture plan, it should not be used the probability of occurrence of rain below 50%.

Comparing the monthly average of rainfall presented in this study, with the level of probability

Table 1. Monthly averages, standard deviation, coefficient of variation (CV) and the extreme values of pluviometric precipitation and year of occurrence in Garanhuns, PE for the period from 1913 to 1987.

Month	Ave. (mm)	SD	CV (%)	Max. (mm)	Year ocorrido	Min. (mm)	Ano ocorrido
Jan.	38.14	44.34	86.03	289.5	1914	1.3	1976
Feb.	46.46	45.70	101.67	203.9	1924	1.3	1924
Mar.	76.96	65.97	116.66	289.0	1941	1.2	1913
Apr.	81.14	66.72	121.60	287.8	1920	2.7	1926
May	109.29	69.27	157.76	317.9	1945	16.9	1985
Jun.	124.66	61.49	202.72	349.8	1951	32.6	1939
Jul.	117.43	54.27	216.39	282.2	1919	34.3	1933
Aug.	74.81	47.59	157.22	222.3	1914	11.1	1927
Sep.	36.69	27.44	133.70	97.4	1918	23.3	1937
Oct.	20.51	35.79	57.31	211.9	1965	0.5	1970
Nov.	19.70	36.29	54.29	190.8	1947	0.1	1970
Dec.	23.43	32.77	71.50	154.9	1915	0.2	1971
Period	64.10	62.65	102.32	349.8	1951	0.1	1970

Figure 1. Histogram of distribution of rainfall in the city of Garanhuns, PE: monthly average of historical sequence of 1913 to 1987.



usually recommended when studying the probable rainfall in most regions of Brazil, the values found, to probable occurrence of average values of monthly rainfall, happen near the level of 60% of probability, confirming what these authors say, that is very above the recommended level, this fact is assign to a positive asymmetry presented by rainfall during the periods studied, emphasizing the good adherence of data to the gamma distribution, that means that high frequencies were expected in the dry period (DP) with precipitation from 0 to 50 mm and small frequencies expected in the very rainy period (VRP),

Table 2. Estimates of gamma distribution parameters (α, β), the monthly average of rainfall (mm) and probable monthly average of rainfall (mm) for different levels of probability and in different months of the year in Garanhuns, PE (1913 to 1987).

Month	α	β	Average (mm)	Probability level P(X ≥ xi)							
				90	80	75	70	60	50	40	30
Jan.	2.08	21.62	38.14	86.70	67.05	60.42	54.84	45.64	38.04	31.34	25.12
Feb.	1.99	28.43	46.46	110.29	84.87	76.31	69.12	57.28	47.52	38.96	31.05
Mar.	1.97	40.81	76.96	156.82	120.50	108.27	98.00	81.12	67.21	55.02	43.77
Apr.	1.62	57.23	81.14	189.54	142.16	126.39	113.24	91.83	74.44	59.45	45.88
May	3.19	54.88	109.29	228.58	177.77	160.57	146.08	122.15	102.28	84.73	68.38
Jun.	3.87	34.48	124.66	224.23	184.56	170.78	158.99	139.07	122.03	106.45	91.35
Jul.	3.38	36.95	117.43	216.14	175.77	161.82	14.92	129.93	112.92	97.48	82.63
Aug.	2.38	33.73	74.81	150.04	117.80	106.83	97.58	82.22	69.41	58.03	47.34
Sep.	2.62	11.52	36.69	71.04	58.13	53.65	49.83	43.39	37.90	32.89	28.05
Oct.	2.71	13.28	20.51	65.31	51.98	47.42	43.55	37.10	31.68	26.82	22.22
Nov.	2.54	9.61	19.70	58.23	47.55	43.86	40.70	35.39	30.86	26.73	22.76
Dec.	2.70	12.10	23.43	64.45	51.82	47.48	43.79	37.61	32.39	27.68	23.18
Per.	1.63	44.93	64.10	149.88	112.55	100.12	89.75	72.86	59.13	47.28	36.55

with values of rainfall above 200 mm over the years in each month (Figure 2). This fact was also observed by Saad (1990) and Fietz et al. (1998) and they suggest that the use of these values in a planning of an irrigation system even that supplemental, will lead to a sub measurement of equipment and facilities.

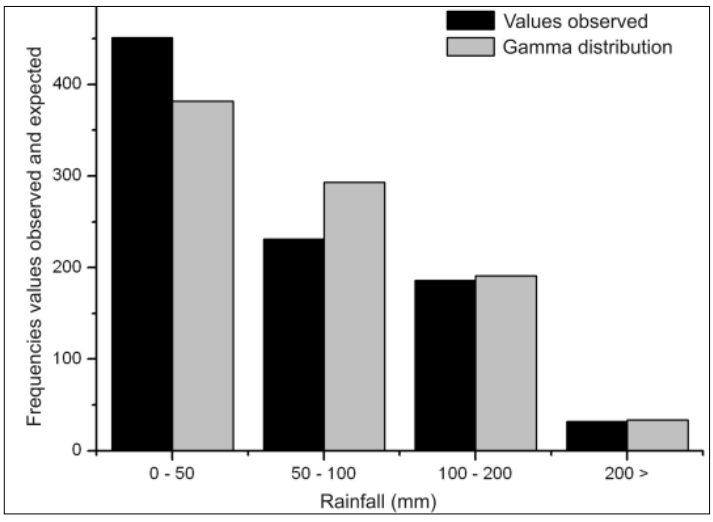
In table 2, it is possible to see that the estimated values from parameter α were lower during the period of dry months (February, March and April), and higher in more rainy months (May, June and July), this fact suggests that the highest values of α are associated with more precipitation. After saying that, this parameter could be used as an indicator of monthly rainfall in the region, estimates minors and equal to 3, suggest monthly rainfall lower than 20 to 100 mm, values higher than 3, rainfall exceeding 100 mm. Useful for a possible program of a complementary irrigation, if necessary. These results are in agreement with Botelho and Morais (1999), and according to these authors, this can be explained by the pronounced positive asymmetry during the driest months since the asymmetry is proportional to α.

The values of parameter β did not exceed the value 100 in any month, letting possible to use, in the gamma distribution, an estimate sum for probable monthly rainfall to Garanhuns - EP. According to THOM (1958), for values above 100 is not used incomplete Gamma Distribution. You can see that the highest values of β (30 to 60) happen during the rainy months. These findings reinforce those found by MURTA, et al. (2005) that found lower values of parameter β in the period of driest months.

The distribution values of frequency of events, observed and probable to the four classes of accumulated monthly rainfall can be seen in figure 2. It can be noticed that, the gamma distribution function, according to the Kolmogorov-Smirnov test, fitted well into this four studied classes of accumulated monthly rain, (D) dry months from 0 to 50 mm; (NSR) not so rainy month 50 to 100 mm (R) rainy month from 100 to 200 mm and (VR)very rainy month above 200 mm the entire period, with 1% of probability. We can seen in figure 2, that the amount of monthly rainfall above 200 mm (classed qualified as very rainy) during the 75 years of sample, had the lowest number of frequency without rain, totaling 32 the 900 observed values (75 years x 12 months), which represents 4% of the series, approximately every 25 years 1 with no rain.

Looking to values of P (R) presented in table 3 you can identify the months in which it is expected more dry days. In October, November and December are expected more dry days. June was the month with a minor incidence of dry days that correspondents to 5.3 of probability. On that matter, based in the P (NSR), it was found that July and August had the highest probability of occurrence of rainy months (about 36 and 49.3% respectively). In the months of May and June is expected a higher number of days

Figure 2. Number of monthly rainfall in the city of Garanhuns, PE, adjusted to gamma distribution for the period of 1913 to 1987.



with a lot of rain of the year (about 9.3%). With the expressions proposed by Robertson (1976) you can determine the probability of occurrence of continuous dry or rainy periods, lasting up to four days. For example, in table 3 it can be seen that the probability to happen 4 following days without rain in the month of November is 56.7% (0.8644 x 0880 x 100) or one every four years. That way, the probability to happen 4 consecutive days of rain in June, in Garanhuns, is from 11.5% (0.6004 x 0533 x 100).

Table 3. Probabilities of occurrence (P) of rainfall from dry days (D),not so rainy (NSR), rainy (R), very rainy (VR), and dry says when the previous day was also dry (D/D) and rainy days when the previous day was also rainy (R/R) in Garanhuns, PE during the time of 1913 to 1987.

Month	Average (mm)	Rainfall ocurrence probability (P)							
		P(S)	P(C)	P(PC)	P(BC)	P(S/S)	P(C/C)	P(S,4)	P(C,4)
Jan.	38.14	0.760	0.160	0.067	0.013	0.754	0.200	0.326	0.001
Feb.	46.46	0.587	0.293	0.107	0.013	0.545	0.000	0.095	0.000
Mar.	76.96	0.373	0.360	0.240	0.027	0.286	0.278	0.009	0.005
Apr.	81.14	0.387	0.253	0.293	0.067	0.379	0.364	0.021	0.014
May	109.29	0.200	0.253	0.453	0.093	0.133	0.559	0.000	0.079
Jun.	124.66	0.053	0.320	0.533	0.093	0.000	0.575	0.001	0.115
Jul.	117.43	0.080	0.360	0.480	0.080	0.167	0.333	0.000	0.018
Aug.	74.81	0.293	0.493	0.187	0.027	0.409	0.214	0.020	0.002
Sep.	36.69	0.667	0.333	0.000	0.000	0.680	0.000	0.026	0.000
Oct.	20.51	0.880	0.080	0.027	0.013	0.864	0.000	0.182	0.000
Nov.	19.70	0.880	0.080	0.040	0.000	0.864	0.000	0.567	0.000
Dec.	23.43	0.853	0.093	0.053	0.000	0.828	0.000	0.513	0.000
Period	64.10	0.501	0.257	0.207	0.036	0.663	0.382	0.103	0.012

Conclusion

Based on the results, we can draw the following conclusions of behaviour of dry and rainy periods in the city of Garanhuns:

a) Data from rainfalls to all periods adjust to the gamma distribution, and therefore, can be use to estimate the probable monthly rainfall in different levels of probability, and them can be use on planning agricultural projects in the region of Garanhuns;

b) Despite the fact that during May and June was the rainy period, it was possible to record significant rainfall, above 50mm / month with 60% probability to happen, from February to August, in which it is recommended the practice of a dry agriculture;

c) The lower probable rainfall, below 50 mm /month are recorded in the months of October, November and December, in which should be focus the irrigated agriculture, recommending species and plants from short-cycle to be seeding in October, and those from a long cycle in August in order to avoid losses during cropping;

d) In the months of October, November and December are expected more dry days with a probability near 88%. June, July and August are the months where it is expected more rainy days with probabilities of 32, 36 and 49.3%.

References

ANDRADE JÚNIOR, A.S. DE; BASTOS, E.A. Precipitação pluviométrica provável em municípios do cerrado piauiense. Teresina: EMPRABA-CPAMN, 1997. 22p. Documentos, 25

ARAÚJO, WELLINGTON F.; JÚNIOR, A. S. A.; MEDEIROS, R. D.; SAMPAIO, R. A. Precipitação pluviométrica mensal provável em Boa Vista, Estado de Roraima, Brasil. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.5, n.3, p.563-567, 2001.

ASSIS, F. N. Modelagem de ocorrência e da quantidade de chuva e dias secos em Piracicaba - SP e Pelotas-RS. 134 p. Tese (Doutorado em Agronomia) Escola Superior de Agricultura de Luiz de Queiroz, Piracicaba. 1991.

ASSIS, F.N. et al. **Aplicações de estatística à climatologia:** teoria e prática. Pelotas: UFPel, 1996.

BERNARDO, S. **Manual de irrigação**. 6.ed. Viçosa: Imprensa Universitária, 1995. 657p.

BOTELHO, V. A.; MORAIS, A. R. Estimativas dos parâmetros da distribuição gama de dados pluviométricos do Município de Lavras, Estado de Minas Gerais. **Ciência e Agrotecnologia**, v. 23, p. 697-706, 1999.

CAMPOS. H. **Estatística experimental não paramétrica**. Piracicaba: ESALQ, 1979, 343p.

CASTRO NETO, P., SILVEIRA, J.V. Precipitação provável para Lavras, região sul de Minas Gerais baseada na função de distribuição de probabilidade Gama. l. **Ciência Prática**, n. 5, v. 2, p. 144-151, 1981.

CASTRO, L.H.R.; MOREIRA, A.N.; ASSAD, E.D. Definição e regionalização dos padrões pluviométricos dos cerrados brasileiros. In: Assad, E.D. (coord.) **Chuvas no cerrados:** análise e espacialização. Brasília: Embrapa, CPAC; Embrapa, SPI, 1994. p.13-23.

CUNHA, A.R.; MARTINS, D.; PASSOS, J.R.S. O modelo Gama de probabilidade aplicado ao estudo da distribuição da chuva na região administrativa de Bauru, SP. In: Congresso Brasileiro de Engenharia Agrícola, 25, 1996, Bauru. **Anais...** 1996. *CD Rom.*

FIETZ, C.R., FRIZZONE, J.A., FOLEGATTI, M.V. Precipitação esperada, em diferentes níveis de probabilidade, na região de Dourados, MS. **Ciência Rural**, v. 28, n. 1, p. 29-34, 1998.

JENSEN, M.E. Design and operation of farm irrigation system. New York: ASAE. 1983. 829p. Thornthwaite, C.W; Mather, J.R. The water balance. New Jersey:

KREPPER, C. M.; SCIAN, B. V.; PIERINI, J. O. Time and space variability of rainfall in central East Argentina. **Journal of Climate**, v. 2, p. 39-47, 1989.

MEDINA, B. F., LEITE, J. A. Probabilidade de chuva em Boa Vista-RR. **Pesquisa Agropecuária Brasileira**, v. 12, p. 1437-1441, 1984.

MURTA, R.M.; TEODORO, S.M.; BONOMO,P. Precipitação pluvial mensal em níveis de probabilidade pela distribuição gama para duas localidades do sudoeste da Bahia**. Ciência e Agrotecnologia**, v. 29, n. 5, p. 988-994, 2005.

RIBEIRO, A.M. DE A.; LUNARDI, C. A precipitação mensal provável para Londrina, PR, através da função gama. **Energia na Agricultura**, v.12, p.37-44. 1997.

ROBERTSON, G. W. Dry and wet spells: Project Field Report Agrometeorology A-6: UNDP/FAO Technical Assistence to the Federal Land Development Authotity. Jerantut: Tun Razak Agriculture Reserch Centre, 1976. 30 p.

RODRIGUES, L.N.; PRUSKI, F.F. Precipitação provável para João Pinheiro, Minas Gerais, utilizando funções de distribuição de probabilidade gama e log-normal. In: Congresso Brasileiro de Engenharia Agrícola, 25, 1996, Bauru. **Anais...** 1996. *CD-Rom*

SAAD, J.C.C. Estudo das distribuições de freqüência da evapotranspiração de referência e da precipitação pluvial para fins de dimensionamento de sistemas de irrigação. 124 p. Dissertação (Mestrado em Irrigação e Drenagem) – Curso de Pós-Graduação em Agronomia, Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo- ESALQ/USP- Piracicaba. 1990.

THOM, H. C. S. A note on the gama distribuition. **Monthly Weather Review**, Washington, v. 86, p. 117-22, 1958.