English Version

Rainfall variability in and water availability in Fernandes Pinheiro, the central-southern state of Paraná

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Abstract

The present work had as objective to analyze the rainfall and preliminarily estimate the climatologic water balance of Fernandes Pinheiro city, Paraná. The series of the studied data comprehended the period from 1963 to 2004, of the Agrometereological Center of Fernandes Pinheiro, monitored by the Agronomic Institute of Paraná (IAPAR). The methodological procedures are guided by statistical calculation of the average, the standard deviation, the annual and monthly coefficient of variation, and the method of the climatologic water balance. The obtained results indicated that, independenton the rainfall amount, the presence of a water deficit on the soil is natural, and in despite of the little quantity of the annual rainfall variability, there is significant monthly rainfall variability in Fernandes Pinheiro.

Key-words: water balance; rain; evapotranspiration; climatological water balance.

Introduction

The dependence men have on water to their survival, organization and reorganization of space may be clearly seen when one observe the current consumption levels. Approximately 4,000 km^3 of water are withdrawn annually from natural resources as rivers, lakes and aquifers, appearing, therefore, as one of the natural resources most used by men (MARQUES, 1999).

The water scarcity in some regions of Brazil is a consequence of the spatial variability. While approximately 80% of the water resources of the country are located on Amazônia, where only 5% of the population lives, in Northeast 35% of the population has only 4% of the water resources of the country (MARQUES, 1999).

Water, frequently defined as infinite and renewable resource, must be as well considered as an economic resource, and its scarcity has been alerting the society about the risks of the imbalance of its availability and demand.

In the Central-southern region of the state of Paraná the Gross Domestic Product (GDP) of the municipalities is, mostly, resulting from agricultural activities. They are strongly influenced by the climate conditions, mainly by water availability. Thus, researches which aim to understand the water dynamics are fundamental since they provide information to make decisions aiming to prevent and mitigate the impacts, mainly those resulting from extreme events (scarcity or excess of water).

Rainfall is the water in its liquid or solid form that falls on the soil, as rain. As it is an important supply of water to living beings, rainfall is essential to vital activities and one of the most important control agents of the hydrologic cycle and the ecological and geographical conditions of the landscapes.

The rains are connected to the air rising and may occur due to the following factors: a) thermal convection; b) relief; and c) frontal mass action (STRAHLER, 1986). Rainfall is associated with *cumulonimbus* or *nimbostratus* clouds and present drops with diameter between 1 and 6 millimeters (AYOADE, 1991).

Rainfall ranges on space and time. The rainfall ranges have great importance in the characterization of the climate of a region, since they condition periods with excess and/or scarcity of water.

In order to know the hydric conditions, i.e. evaluate the occurrence of periods in which there is excess of water and periods in which there is water

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deficiency, it is used the method of water balance. Water balance is the accounting of soil water and results from the application of the principle of mass conservation to water in a volume of soil planted (PEREIRA et al., 1997). The range on water storage in soil is given by the balance between input and output water, input water basically comes from rainfall and output occurs mainly by evapotranspiration, surface runoff and deep drainage.

In Brazil it can be observed several types of water balance, from super humid regions in Amazônia and South, with an annual overall of excess of water, to semi-arid regions in Northeast, with water scarcity. According to Mota (1977), the duration of the dry season in the Tropical Brazil is related to the total of water deficiency, it has been used, thou, the latter value as climate index to identify different regions and water balances.

To agricultural activities, the knowledge about the water availability allows the farmer to choose strategies and alternatives, as well as plan the need or not of irrigation, obtaining, thou, a greater yield of the crops not only concerning quality but also quantity of production.

In this context, the present work had as objective to analyze the monthly and annual range of rainfall and to estimate the climatic water balance of dry and rainy year in Fernandes Pinheiro, South-center region of the state of Paraná.

Material and methods

The meteorological data used was temperature and rainfall from the Agrometereological Station of Fernandes Pinheiro/PR – monitored by the Agronomic Institute of Paraná (IAPAR) on the period from 1963 to 2004, located on the rural area of the municipality of Fernandes Pinheiro/PR, at 25º 27' of South latitude and 50º 35' of West longitude, 893 meters of altitude, identified by the code 02550025, according to the Meteorological System of Parana (SIMEPAR).

The climate in the municipality of Fernandes Pinheiros is classified as (Cfa) – Mesothermic Humid Subtropical, with hot summers, small frequency of frost, trend of rainfall concentration during the summer months, with annual averages that are: temperature of the warmest months superior to 22 °C and of the coldest inferior to 18º; annual temperature of 19º; rainfall between 1,500 and 1,600 mm; relative humidity of air at 80%; water index equal to 100; without water deficiency (SPVS, 1996).

By the rainfall it was classified the standard year. If the rainfall distribution of an annual or seasonal period was similar to the average of many years of a particular place there is, thus, a normal standard. In case it has, in the annual or seasonal rainfall distribution, a negative deviation in relation to the average of the period, it can be classified as a dry year; in case there is a positive deviation, i.e. raining more than the local average, a rainy year.

To the classification of the standard years to the municipality of Fernandes Pinheiro/PR it was used the method of coefficient of variation of rainfall, proposed by Monteiro (1971) and adopted by Barrios e Hernándes (1992). The monthly deviation of rainfall and the coefficient of variation are given by:

$$Dm = T - Me \quad (1)$$

$$CVm = Dm * 100 / Me \quad (2)$$

In which: *Dm* is the monthly deviation of rainfall; *T* is the total monthly rainfall; *Me* the average of the monthly rainfall; and *CVm* is the coefficient of monthly variation of the rainfall.

The annual coefficient of the rainfall is obtained by the equation:

$$CVa = Scvn - Scvp / N^o \text{ of years} \quad (3)$$

In which: *Scvn* the sum of the negative coefficients and *Scvp* the sum of the positive coefficients

Through *CVm* and *CVa* the years and months were classified according to the typology proposed by Monteiro (1976): 1) *Normal year (N)* present positive or negative ranges to 15% (-15% to 15%); 2) *Normal year tending to dry (Ntc)* presents negative and positive deviations from 15% to 30% (-30% a –15%); 3) *Dry year (S)* present negative anomaly equal or superior to 30% (inferior or equal to -30%); 4) *Normal year tending to rainy (Ntc)* ranges between 15% to 30% and 5) *Rainy year (C)* presents anomalies equal or superior to 30% (superior or equal to 30%).

The method of climate water balance of Thornthwaite and Mather (1955) was used to account the water availability in soil, in the year that presented higher *CVa* positive and negative, and to the average data on the period studied. To its application, it was used a plan on the software *Microsoft® Office Excel®*, version 2003, elaborated by D'Angiolella and Vasconcellos (2002).

The potential evapotranspiration (*ETP)* is the amount of water transferred to the atmosphere through the evaporation and transpiration of a surface completely vegetated with vegetation of low stature and without restriction of water in soil. *ETP* was estimated by the method of Thornthwaite (1948), to a month of 30 days, each one having 12 hours of photoperiod (daily insolation), by the equations:

$$ETP = 16.\left(\frac{10.Ti}{I}\right)^a \quad (4)$$

$$I = \sum_{i=1}^{12}\left(\frac{Ti}{5}\right)^{1,514} \quad (5)$$

$$a = 6,75.10^{-7}.I^3 - 7,71.10^{-5}.I^2 + 1,7912.10^{-2}.I + 0,49239 \quad (6)$$

In which: *ETP* is the potential monthly average evapotranspiration not adjusted (mm month^{-1}); *Ti* the monthly average temperature (ºC); *I* the heat index; *a* a coefficient. The subscript *i* represents the month of the year, for instance *i* = 1 for January, *i* = 2 to February, etc. To estimate the *ETP* for a particular month, with a particular number of days per month (ND) and a number of hours with monthly average photoperiod (N), it must be made a simple correction: given by:

$$ETP_{corrigida} = ETP.\frac{N}{12}.\frac{ND}{30} \quad (7)$$

The calculation of the climatic water balance results in the information: *P-ETP* is the difference between the rainfall and the evapotranspiration; *NEG.AC* is the negative accumulation of water in the soil; *ARM* is the water storage in soil; *ALT* is the alteration between the *ARM* of the current month and the *ARM* of the anterior month; *ETR* is the real evapotranspiration; *DEF* is the deficiency; and *EXC* is the water surplus (MOTA, 1977; OMETTO, 1981).

The capacity of water storage in soil (*CAD*) adopted was 100 mm for the predominance on the studied region of soils Litólicos, Latossolos, Podzóis and Terras Roxas (SPVS, 1996), considered as soils with small capacity of retention (PRADO, 1995; SILVA et al., 2003).

Results and discussion

The annual average rainfall for the period from 1963 to 2004 was 1,601 mm. January was the rainiest moth, with an average of 179 mm, and August the driest, with an average of 80 mm (Figure 1). The rainiest months were January, October and December and the least rainy were August, April and July.

The rainiest months in the municipality of Fernandes Pinheiro/PR, located on the natural geographic region named *second plateau* or *plateau of Ponta Grossa* by Maack (2002), coincide with the municipalities of Guarapuava (THOMAZ e VESTENA, 2003) and Pitanga (VESTENA e LANGE FILHO, 2008), in the natural geographic region of the *third plateau* or *trapp plateau of Paraná*, both located on the center region of Paraná. On the other hand, the driest months, with lower rainfall index, respectively in Fernandes Pinheiro were August, April and July, in Guarapuava were August, July and June (THOMAZ e VESTENA, 2003); and in Pitanga August, July and March (VESTENA e LANGE FILHO, 2008).

The coefficient of rainfall annual variation showed positive and negative annual rainfall range. Even though there was no year which presented CVa lower than -15%, the values which were closest (above -10%) were the years 1968, 1974 and 1985, with -19.7%, -14.0% and -10.1%, respectively. Years 1983, 1990 and 1998 presented the highest positive annual rainfall ranges, regarding to the annual average on the period from 1963 to 2004, which were 16.4%, 11.9% and 13.9%, respectively (Table 1).

In Table 1 it can be seen that only the years 1968 and 1983 presented ranges superior to -15% and 15%, respectively, being considered, thus, as *a normal year tending to dry* (1968) and *a year tending to*

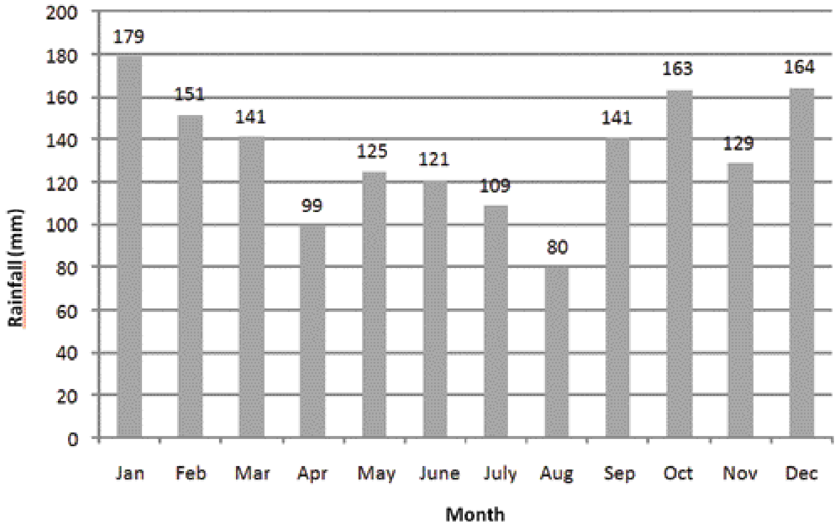

Figure 1. Average monthly rainfall on the period from Jan/1963 to Dec/2004

rainy (1983), and the other years did not show ranges superior to 15% and -15%, and thus are considered *normal years*.

In Figure 2 (A) it is presented the monthly, minimum and maximum average rainfall, registered on the period of January 1963 to December 2004 and in Figure 2 (B) the monthly rainfall on the years 1968 and 1983 compared to the period average. In it, it can be verified that the rainfall on the months of May, September and December in 1983, year classified as tending to rainy were superior to the monthly average. At the same time, the year 1968, year tending to dry, with the exception of the month of April which presented rainfall next to the month average, the rainfall index was inferior to the average.

The classification of the months using the typology suggested by Monteiro (1976) to classify the standard-years showed that in a general way the highest occurrence is of dry month (32%) and the lowest is of normal tending to rainy (7%), from the classification of 504 months, on the period from 1963 to 2004 (Table 2 and Figure 3). Most of the months, which is 78% percent of them, presented significant variation, i.e., coefficient of variation superior to 15% for more of less on the average of the period.

From the 504 months analyzed, 162 were classified as *dry*, 124 *rainy*, 113 *normal,* 70 *normal tending to dry* and 35 *normal tending to rainy*. In Figure 4 it can be verified that, despite the variation, in a general way there was an order on the number of incidence. The months March, April, May, June, July, August, September and November presented highest incidence of the typology *dry*, while months classified as *normal tending to rainy* presented less incidence, with the exception of the month of September. October was the month most normal month.

By the average of classification of the months concerning rainfall, it can be affirmed that in average 3.96 of the months are dry (32%), 2.95 rainy (25%), 2.69 normal (22%), 1.67 normal tending to dry (14%) and 0.83 normal tending to rainy (7%). Through the data analysis, it can be verified a temporal variability considerable of the monthly precipitation volume over the year.

In order to evaluate the water availability over the year, it was used the method of climatic water balance to the year 1968, year which presented the lowest rainfall index on the period studied (1963-2004), and, except the month of April, the other months presented index inferior to the monthly average of the studied period. The occurrence in 1968 of the lowest negative *CVa* reversed the indication that in an year of occurrence of the phenomenon *El Niño* there is abundant rainfall in the South region of Brazil, mainly in spring and intensive rainfall from May to July (INPE, 2003).

Table 1. Coefficient of annual rainfall variation, standard deviation and standard-years

Year	Annual Rainfall (mm)	Standard deviation (mm)	Coefficient of annual rainfall variation (%)	Typology for standard years
1963	1401.7	199.7	-5.4	Normal
1964	1478.5	122.9	-0.9	Normal
1965	1786.6	-185.2	4.1	Normal
1966	1472.1	129.3	-3.4	Normal
1967	1291.2	310.2	-5.9	Normal
1968	979.3	622.1	-19.7	Normal tending to dry
1969	1550.6	50.8	-1.1	Normal
1970	1585	16.4	-2.8	Normal
1971	1710.5	-109.1	1.9	Normal
1972	1625.0	-23.6	0.4	Normal
1973	1804.2	-202.8	5.4	Normal
1974	1206.7	394.7	-14.0	Normal
1975	1362.2	239.2	-9.3	Normal
1976	1901.1	-299.7	6.0	Normal
1977	1403.0	198.4	-3.6	Normal
1978	1386.1	215.3	-3.1	Normal
1979	1748.3	-146.9	2.4	Normal
1980	1834.3	-232.9	4.7	Normal
1981	1226.7	374.7	-7.6	Normal
1982	1793.5	-192.1	4.2	Normal
1983	2451.5	-850.1	16.4	Normal tending to rainy
1984	1723.3	-121.9	4.6	Normal
1985	1012.8	588.6	-10.1	Normal
1986	1537.5	63.9	-2.3	Normal
1987	1563.0	38.4	-0.5	Normal
1988	1173.8	427.6	-8.0	Normal
1989	1607.5	-6.1	0.3	Normal
1990	2153.7	-552.3	11.9	Normal
1991	1374.4	227	-4.5	Normal
1992	1721.3	-119.9	3.6	Normal
1993	1926.0	-324.6	4.3	Normal
1994	1633.4	-32	0.2	Normal
1995	1583.4	18	-2.3	Normal
1996	2087.7	-486.3	6.4	Normal
1997	1709.5	-108.1	1.2	Normal
1998	2262.2	-660.8	13.9	Normal
1999	1487.9	113.5	-2.8	Normal
2000	1672.0	-70.6	-0.1	Normal
2001	1700.0	-98.6	1.8	Normal
2002	1528.2	73.2	-1.3	Normal
2003	1416.6	184.8	-4.3	Normal
2004	1385.4	216	-4.0	Normal

Font: Rainfall data(IAPAR, 2005)

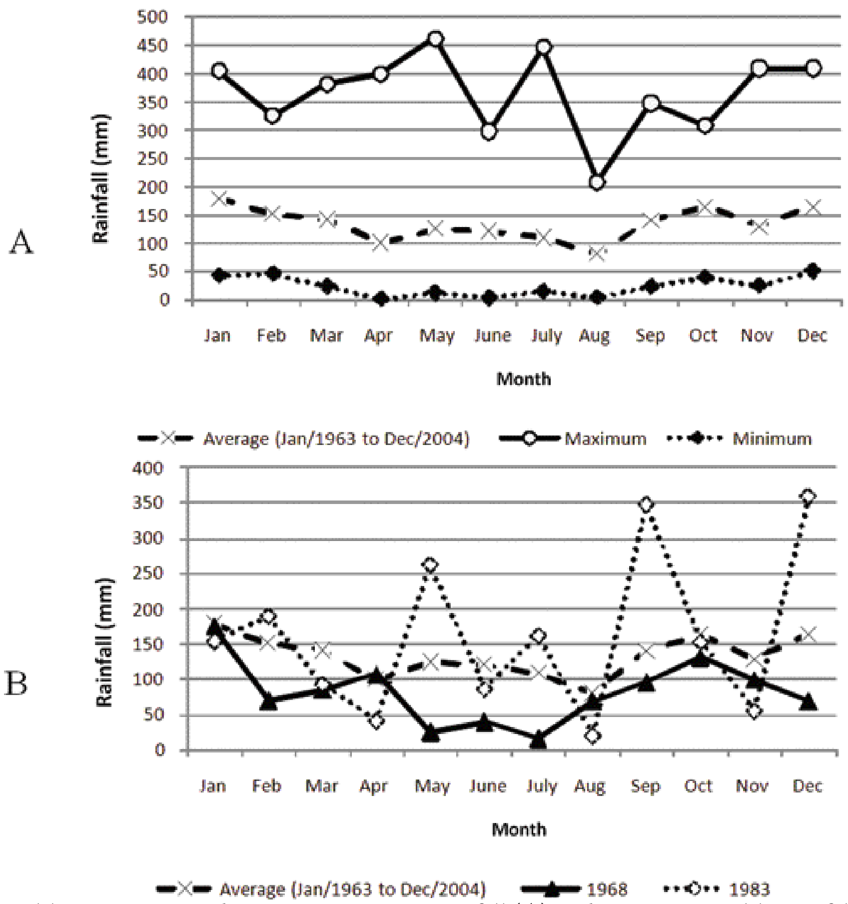

Figure 2. Monthly, minimum and maximum average rainfall (A) and average monthly rainfall of 1968 (year tending to dry) and 1983 (year tending to rainy) (B)

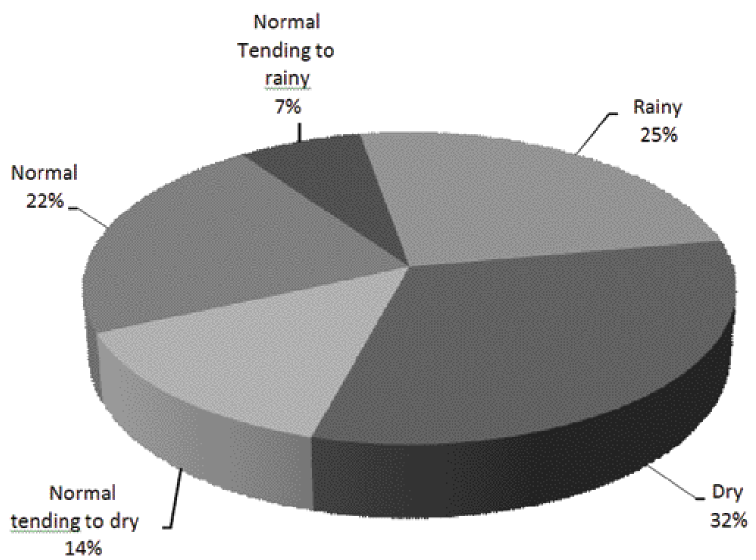

Figure 3. Distribution of the monthly rainfall classification (Jan/1963 to Dec/2004)

Table 2. Coefficient of monthly variation (*CVm*), on the period from Jan/1963 to Dec/2004

Year	COEFFICIENT OF MONTHLY VARIATION (%)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
1963	11.3	7.7	114.1	-76.9	-84.4	-69.0	-87.0	-52.4	-52.8	52.9	53.4	-43.9
1964	-72.6	20.2	75.1	-13.8	-55.9	58.7	-26.5	85.0	-36.1	-56.9	-33.1	18.3
1965	-22.4	40.7	-6.2	153.1	24.4	-64.2	120.5	-42.9	-48.3	36.2	-23.2	5.4
1966	-44.0	115.0	-45.9	-26.5	-37.3	-19.8	-64.3	-19.1	-38.8	76.7	-35.2	-2.0
1967	0.5	34.4	-12.3	-59.2	-85.9	49.7	-18.9	-30.1	-50.5	-56.9	-4.4	-15.7
1968	-2.3	-53.9	-40.3	7.5	-79.7	-67.3	-85.4	-13.8	-32.1	-20.0	-22.6	-58.4
1969	-17.0	-19.7	0.9	47.8	-27.6	4.0	-34.5	-52.4	24.7	12.7	43.7	-25.7
1970	-70.4	-45.6	-70.4	-43.2	5.6	114.6	-23.0	-70.3	-5.9	-10.2	-49.2	149.5
1971	3.7	0.9	83.7	18.9	55.2	21.5	45.1	-67.0	26.5	-57.5	-52.4	-1.1
1972	27.6	89.1	-55.5	-41.4	-84.7	-11.4	-10.2	116.6	-3.2	32.9	-41.6	0.1
1973	20.8	-16.4	-7.9	52.0	0.6	32.8	43.1	123.3	44.0	-25.9	-25.0	-14.1
1974	-2.3	-13.2	-293.2	-30.4	-57.4	35.1	-60.1	5.3	-77.7	-8.7	-23.7	-60.1
1975	-42.0	-30.8	-29.8	-20.1	-69.9	-36.6	-43.3	-175.2	22.1	-7.1	57.1	-16.9
1976	47.7	-16.2	5.8	-9.2	43.5	20.7	-12.6	110.3	-7.0	-23.9	43.3	48.5
1977	-27.8	12.5	103.7	6.3	-86.7	-17.8	-44.0	-22.9	-59.1	-17.0	39.1	-39.1
1978	-35.3	-70.2	59.9	-100.0	-16.6	-18.8	79.0	40.0	-18.6	-44.7	4.0	-6.9
1979	-16.6	-15.4	5.1	-34.6	131.7	-82.0	-44.8	22.1	88.9	69.2	16.7	-40.5
1980	51.1	-4.0	-36.4	-12.4	-33.5	-26.3	67.1	98.0	77.7	-2.3	-3.2	19.4
1981	12.8	-30.3	-41.0	17.6	-60.2	-47.9	-83.9	-57.6	-44.5	-17.1	18.6	15.4
1982	-76.4	-28.0	-24.6	-29.8	-30.1	147.1	56.7	-29.0	-84.6	62.4	218.3	-4.1
1983	41.5	-41.1	70.1	68.7	208.9	79.3	309.7	-96.1	78.2	4.7	8.4	-44.8
1984	-26.9	-55.3	69.5	60.8	-20.7	57.7	-41.2	144.6	-8.5	-76.4	73.6	13.8
1985	-63.4	-5.9	1.3	94.2	-71.2	-75.4	-43.5	-92.3	-38.6	-51.8	-6.4	-69.5
1986	47.7	-53.6	1.2	-10.1	54.9	-97.8	-88.2	13.8	-19.1	-27.2	-23.6	107.5
1987	2.6	10.0	-83.7	-9.7	230.8	-1.5	-40.3	-25.3	-57.3	-24.2	-7.0	-14.0
1988	-13.6	-46.5	-75.2	8.1	139.4	-28.1	-86.6	-75.8	-49.0	-24.1	-81.5	-4.0
1989	33.9	74.4	-26.7	-10.2	49.2	-62.2	46.6	20.4	25.7	-32.1	-44.8	-60.0
1990	112.0	-10.7	-24.6	90.7	-20.6	23.2	91.4	160.0	20.4	8.0	108.7	-60.1
1991	-26.5	-61.8	-48.5	6.6	-68.7	114.4	-85.0	-29.1	-63.3	31.9	-19.3	61.5
1992	-52.4	26.7	48.5	-39.6	270.4	-45.2	15.2	62.8	-30.9	-14.3	-24.3	-64.9
1993	-13.6	25.2	-34.1	-58.1	110.8	-28.0	48.8	-73.6	147.1	-6.2	-56.7	118.6
1994	-10.7	58.4	-54.6	22.5	-10.4	57.2	81.6	-93.4	-77.3	1.7	9.3	25.1
1995	126.3	44.3	-76.3	-44.3	-79.4	-2.3	21.6	-67.6	70.4	-4.1	-56.6	-28.3
1996	62.7	107.3	119.5	-72.4	-90.9	6.9	-12.9	1.1	54.5	32.8	-15.0	74.6
1997	9.3	-12.4	-58.3	-76.7	-47.1	45.6	-29.3	29.0	27.0	88.0	64.3	10.2
1998	4.9	-7.7	170.5	302.0	-58.9	-40.3	16.9	110.5	132.6	50.3	-78.9	-17.9
1999	-12.1	48.0	-26.9	-15.9	-32.4	86.8	5.8	-91.5	-7.6	-33.0	-46.7	10.2
2000	59.6	23.9	-19.3	-72.3	-75.8	26.7	-20.9	-2.8	133.7	-8.2	-44.7	-1.7
2001	-9.6	3.7	-16.3	-13.7	36.7	-13.9	36.5	9.9	2.9	33.0	-14.1	18.4
2002	35.1	-61.6	-38.3	-18.3	60.0	-80.4	-39.9	21.5	29.0	-17.4	72.9	-17.1
2003	-14.0	-7.0	-27.5	-23.3	-72.4	-13.7	30.7	-75.4	-36.2	4.3	-5.3	59.2
2004	-40.0	-35.9	-22.1	3.5	37.2	-31.0	10.3	-67.8	-57.5	70.4	7.7	-44.3

Font: Rainfall data (IAPAR, 2005)

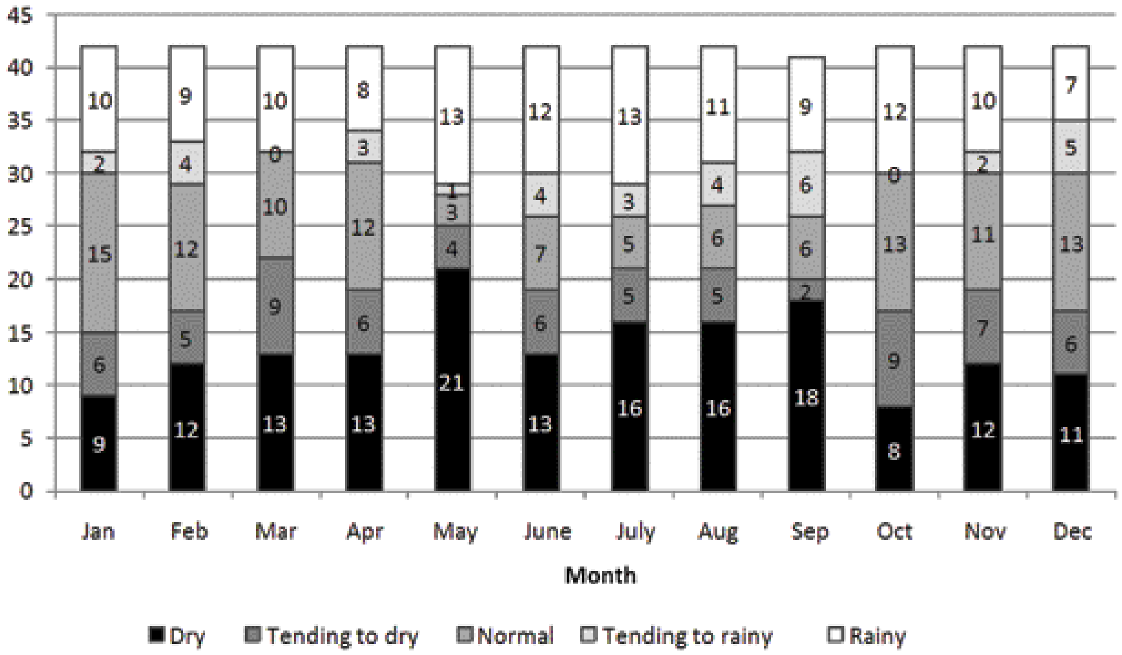

Figure 4. Number of incidence of months according to the typology

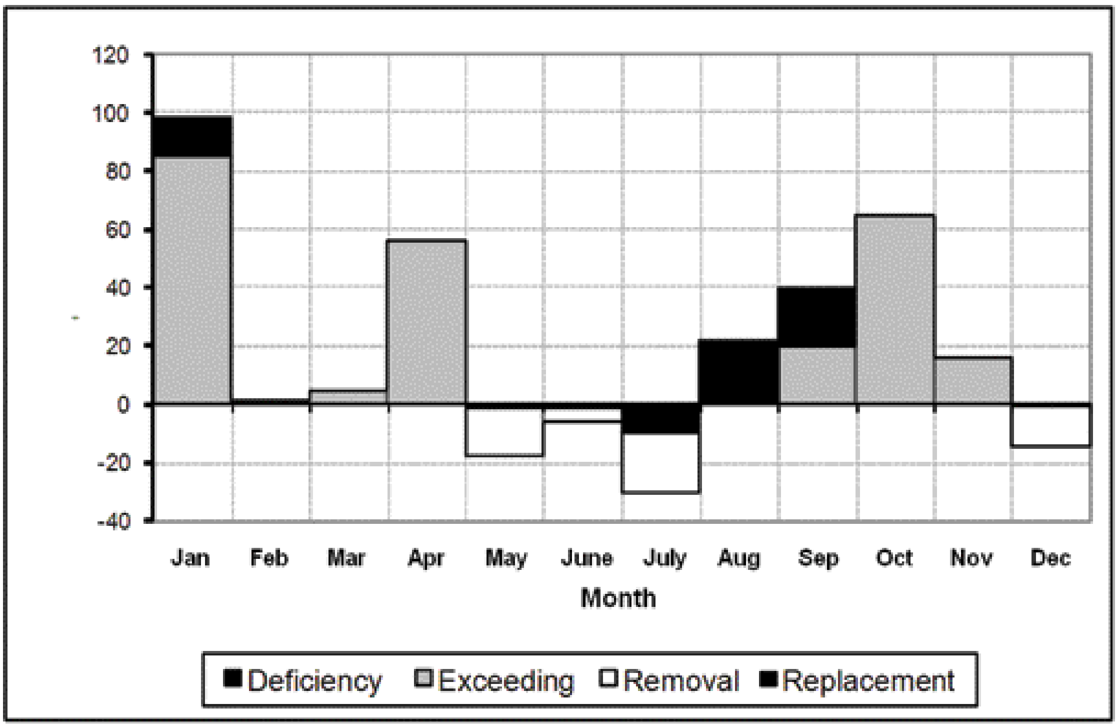

Figure 5. Water balance of 1968

Table 3. Water balance of the year 1968

MÊS	ETP (mm)	P-ETP (mm)	NEG-AC (mm)	ARM (mm)	ALT (mm)	ETR (mm)	DEF (mm)	EXC (mm)
Jan.	76.05	98.7	0.0	100.00	0.00	76.0	0.0	98.7
Feb.	68.79	1.0	0.0	100.00	0.00	68.8	0.0	1.0
Mar.	79.76	4.4	0.0	100.00	0.00	79.8	0.0	4.4
Apr.	51.04	56.0	0.0	100.00	0.00	51.0	0.0	56.0
May	42.99	-17.7	-17.7	83.79	-16.21	41.5	1.5	0.0
June	45.03	-5.6	-23.3	79.20	-4.58	44.0	1.0	0.0
July	46.25	-30.3	-53.7	58.47	-20.73	36.6	9.6	0.0
Aug.	47.40	21.6	-22.2	80.07	21.60	47.4	0.0	0.0
Sep.	55.90	39.5	0.0	100.00	19.93	55.9	0.0	19.6
Oct.	66.20	64.5	0.0	100.00	0.00	66.2	0.0	64.5
Nov.	83.63	16.0	0.0	100.00	0.00	83.6	0.0	16.0
Dec.	82.56	-14.3	-14.3	86.71	-13.29	81.6	1.0	0.0
Total	745.59	233.7	-	1088	-13.29	732.5	13.1	260.1
Média	62.13	19.5	-	90.7	-	61.0	1.1	21.7

Basic data: IAPAR (2005)

Based on the Figure 5 and Table 3 it can be observed the data obtained by the water balance of 1968, in which it was verified that months of May, June, July and December presented water deficiency, and months of January, February, March, April, September, October and November, excess of water in soil.

The presence of months with water *deficit* in the municipality of Fernandes Pinheiro/PR is different from the appointment of SPVS (1996), that there is no water deficiency in the region. The great temporal and spatial variability of the rainfall demand studies in local scale (municipality, district, town) to the detriment of regional studies, as well as

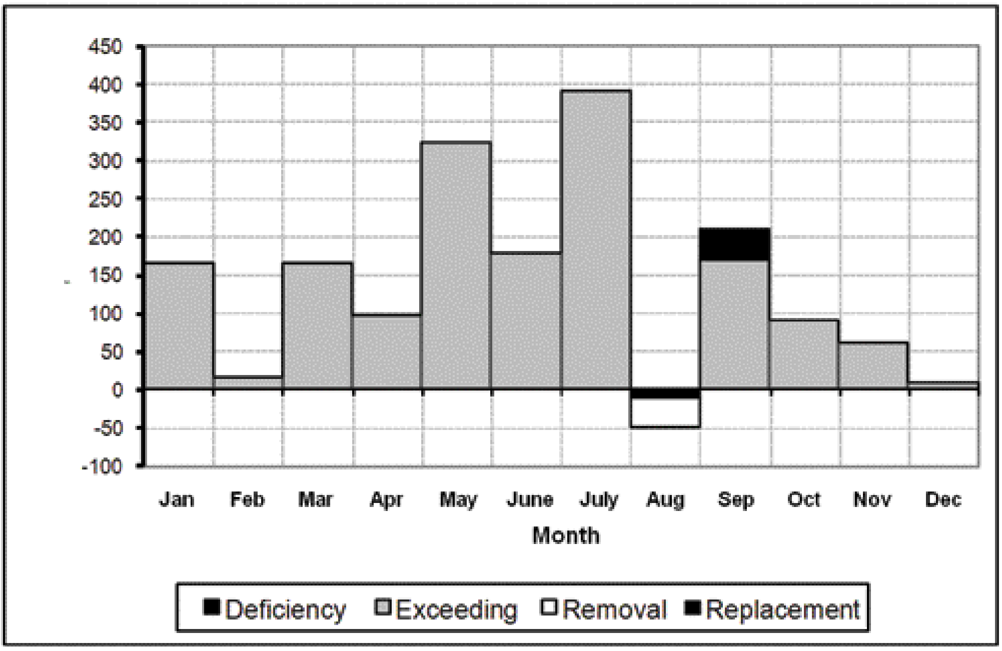

Figure 6. Water balance of 1983

Table 4. Water balance of the year 1983

MONTH	ETP (mm)	P-ETP (mm)	NEG-AC (mm)	ARM (mm)	ALT (mm)	ETR (mm)	DEF (mm)	EXC (mm)
Jan.	86.14	167.0	0.0	100.00	0.00	86.1	0.0	167.0
Feb.	73.41	15.7	0.0	100.00	0.00	73.4	0.0	15.7
Mar.	73.51	166.5	0.0	100.00	0.00	73.5	0.0	166.5
Apr.	68.89	99.0	0.0	100.00	0.00	68.9	0.0	99.0
May	60.86	323.7	0.0	100.00	0.00	60.9	0.0	323.7
June	36.96	179.0	0.0	100.00	0.00	37.0	0.0	179.0
July	53.35	392.8	0.0	100.00	0.00	53.4	0.0	392.8
Aug.	52.56	-49.5	-49.5	60.98	-39.02	42.1	10.4	0.0
Sep.	40.22	210.2	0.0	100.00	39.02	40.2	0.0	171.2
Oct.	79.14	91.9	0.0	100.00	0.00	79.1	0.0	91.9
Nov.	77.24	62.3	0.0	100.00	0.00	77.2	0.0	62.3
Dec.	80.40	10.2	0.0	100,00	0.00	80.4	0.0	10.2
Total	782.68	1668.8	-	1161	0.00	772.2	10.4	1679.3

Basic data: IAPAR (2005)

those which consider the impact of extreme events (drought) in water availability.

In figure 6 and in Table 4 it is presented the water balance of the year 1983, year which presented highest rainfall level and which, with exception of the month August, which had monthly rainfall inferior to the usual average, the other months had superior index. In this, it was verified that only the month of August had deficiency, the others presented water excess.

In Figure 7 it can be seen the water balance estimated to the average on the period from 1963 to

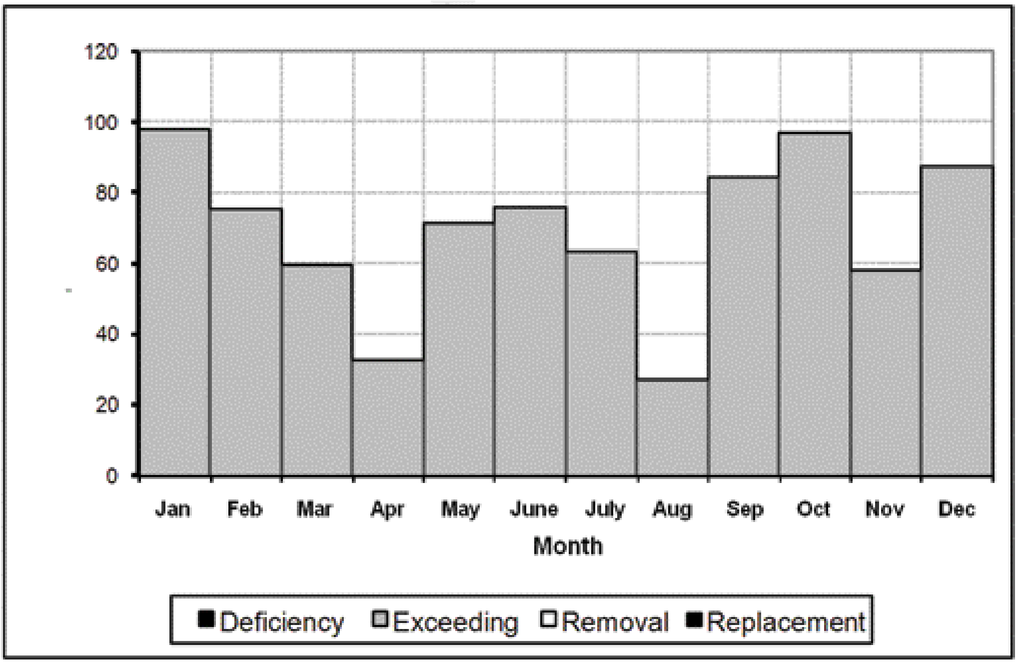

Figure 7. Water balance of the monthly average from 1963 to 2004

Table 5. Water balance of the monthly average on the period from 1963 to 2004

MONTH	ETP (mm)	P-ETP (mm)	NEG-AC (mm)	ARM (mm)	ALT (mm)	ETR (mm)	DEF (mm)	EXC (mm)
Jan.	81.08	97.8	0.0	100.00	0.00	81.1	0.0	97.8
Feb.	75.90	75.4	0.0	100.00	0.00	75.9	0.0	75.4
Mar.	81.38	59.7	0.0	100.00	0.00	81.4	0.0	59.7
Apr.	66.99	32.5	0.0	100.00	0.00	67.0	0.0	32.5
May	53.19	71.3	0.0	100.00	0.00	53.2	0.0	71.3
June	44.81	75.7	0.0	100.00	0.00	44.8	0.0	75.7
July	45.40	63.5	0.0	100.00	0.00	45.4	0.0	63.5
Aug.	52.91	27.1	0.0	100.00	0.00	52.9	0.0	27.1
Sep.	55.96	84.5	0.0	100.00	0.00	56.0	0.0	84.5
Oct.	66.57	96.8	0.0	100.00	0.00	66.6	0.0	96.8
Nov.	70.53	58.2	0.0	100.00	0.00	70.5	0.0	58.2
Dec.	76.90	87.2	0.0	100.00	0.00	76.9	0.0	87.2
Total	771.63	829.8	-	1200	0.00	771.6	0.0	829.8
Average	64.30	69.1	-	100.0	-	64.3	0.0	69.1

Basic data: IAPAR (2005)

2004. In this, it may be observed significant water exceeding in soil. In Table 5, it is presented data from the water balance to the mean rainfall data and temperature from 1963 to 2004.

Conclusions and final considerations

In the classification of the standard-year only the years 1983 and 1968 were categorized in normal tending to rainy and in normal tending to dry, since they presented coefficient of annual rainfall variation of 16.4% and -19.7%, respectively. The other years were classified as normal.

The water balance of the years which presented highest and lowest rainfall incidence allowed to conclude that in Fernandes Pinheiro, South-center region of the state of Paraná, the existence of a period during the year with water scarcity (deficit) is normal, since the water availability is conditioned by the regularity and not by the rainfall amount.

The period less rainy is winter, and the rainiest is summer. The month of August is the driest, with an average of approximately 80 mm, followed by the month of April with 99.5 mm of average. The rainiest months are January, December and October with average of 179, 164 and 163 mm, respectively.

Finally, it was verified that despite the low variation in the amount of annual rainfall in the municipality of Fernandes Pinheiro, South-center region of the state of Paraná, it was found significant index of variation.

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