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Annual rainfall intensity on the upper course of Pirapó River-PR: a comparison between two methodological proposals

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ABSTRACT

This research aims at assessing the rainfall intensity and its correlation with water resource management, as well as the recurrent impacts on the upper course of Pirapó River basin. For carrying out this study, data related to the rainfall from 1980 to 2014, and from 2009 to 2013 were obtained. The information was collected in the weather stations of Apucarana, which belongs to both, the Agronomic Institute of Paraná (IAPAR) and the Meteorological System of Paraná (SIMEPAR), as well as in the station of Maringá, which belongs to the National Institute of Meteorology (INMET). These data were analyzed on an annual scale. The descriptive statistics was applied to the rainfall data of the two municipalities by using the following parameters: mean, standard deviation and coefficient of variation, in addition to the standard year technique proposed by Monteiro (1976). The Manual of Meteorological Observations (INMET, 1999) and Reichardt's proposal (1990) were used as methodology for classifying the rainfall intensity. It was concluded that although Apucarana and Maringá have similar climatic characteristics and are located in the upper course of Pirapó river basin, they show significant differences related to the precipitation variability. Regarding the intensity classification, it was seen that the light intensity class predominates in relation to the moderate and heavy classes. Considering the heavy intensity class, there was a significant difference in the number of occurrences between the two weather stations. Concerning the intensity classification proposed by Reichardt (1990), it was seen that the number of occurrences of light rains was lower than that of the moderate and heavy ones, which are higher in the classification proposed by INMET (1999).

Keywords: Rainfall intensity, water resource management, INMET (1999), Reichardt (1990), Pirapó River.

Intensidade pluviométrica anual no alto curso do rio Pirapó-PR: uma comparação entre duas propostas metodológicas

RESUMO

A presente pesquisa objetiva estudar a intensidade pluviométrica e sua correlação com a gestão dos recursos hídricos, bem como os impactos a ela recorrentes no alto curso da bacia hidrográfica do rio Pirapó. Para realização da pesquisa foram obtidos dados de precipitação pluviométrica no período de 1980 a 2014 e dados de precipitação pluviográfica de 2009 a 2013; as informações foram coletadas nas estações meteorológicas de Apucarana, que pertence ao Instituto Agrônomo do Paraná (IAPAR) e ao Sistema Meteorológico do Paraná (SIMEPAR), e de Maringá, que pertence à rede do Instituto Nacional de Meteorologia (INMET). Esses dados foram analisados na escala anual. Foi aplicada a estatística descritiva para os dados de chuva dos dois municípios, utilizando-se os parâmetros: média, desvio padrão e coeficiente de variação e o emprego da técnica de anos-padrão proposto por Monteiro (1976). Para a classificação da intensidade pluviométrica, foram utilizados como metodologia o Manual de Observações Meteorológicas (INMET, 1999) e a proposta de Reichardt (1990). Concluiu-se que embora Apucarana e Maringá apresentem características climáticas semelhantes e estejam situadas no alto curso da bacia do rio Pirapó, demonstraram diferenças significativas quanto à variabilidade da precipitação. Em referência a classificação da intensidade, percebeu-se que a classe de intensidade fraca predomina em relação às classes moderada e forte. Para a classe de intensidade forte houve significativa diferença quanto ao número de ocorrências entre as duas estações meteorológicas. Com relação à classificação de intensidade proposta por Reichardt (1990), observou-se que o número de ocorrências de chuvas fracas foi inferiores às intensidades moderada e forte, sendo estas superiores na classificação proposta pelo INMET (1999).

Palavras-chave: Intensidade pluviométrica, gestão de recursos hídricos, INMET (1999), Reichardt (1990), Rio Pirapó.

Introduction

Human life and culture are intimately linked to climatic events. It is the atmospheric processes that influence events in other parts of the environment, whether in the maintenance of life, in the hydrological regime and even in the rock weathering and soil formation, in addition to their relation with the dynamics of society.

Among the climatic elements, precipitation stands out as being essential for life maintenance and also as an important factor for agricultural activities. Brazil has a close dependence on climatic elements, mainly on precipitation, since much of its economy is focused on agriculture, with regard to irrigation and use for rural supply, besides the energy production from hydroelectric plants, supply for the several economy sectors, and the activities related to the urban environment.

The literature on climatic research shows that precipitation is one of the most important meteorological variables and one of the most assessed elements in Brazil and worldwide. There are several studies on the variability, spatial distribution, as well as on their relationship with agriculture and urban spaces in several regions of Brazil. However, the studies that characterize the intensity are still scarce, especially when regarding the river basins.

It is seen that there are extensive researches related to heavy rains in the urban environment. However, the heavy rains have a significant influence in river basin areas, since they can cause soil degradation, besides generating problems related to floods, crop losses, destruction of infrastructure, and risk of landslides, which contributes to significant socio-environmental losses.

Sant'Anna Neto (2000) points out that although intense precipitation events have significant impacts, they are due to the dynamic character itself of natural phenomena, particularly those originating in the atmosphere. In general, it is possible to see that in the scientific community the definition of what constitutes an event of intense precipitation is far from being uniform.

There are different methodologies and interpretations for assessing the intense precipitation events, and most of them are results of statistical techniques that also involve other areas of knowledge, such as engineering, agronomy, meteorology, among others. However,

it is seen that the use of different intensity values is not only focused on environmental studies, but also provides a basis for making decisions related to planning and minimizing the impacts generated by these events.

Given the relevance of knowledge on the subject, this research aims at assessing the rainfall intensity and its correlation with water resource management, as well as the recurrent impacts on the upper course of Pirapó River basin. This study was carried out by applying the methodology of the Manual of Meteorological Observations (INMET, 1999) and the proposal by Reichardt (1990), based on the investigation of the intense events from the daily analysis scale.

Material and methods

The water basin of Pirapó River (Figure 1) is located in the northern region of Paraná state. It covers a total area of 5,098.10 km², between the latitudes of 22°30' and 23°30' South, and longitudes of 51°15' and 52°15' West. Pirapó River is an important tributary of the left bank of Paranapanema River, part of Paraná River. It is born in the municipality of Apucarana, about 1,000 meters above sea level, and flows northwards, covering a length of 168 km up to its mouth in Paranapanema River, about 300 meters above sea level in the municipality of Jardim Olinda (SEMA, 2010).

According to the classification proposed by Köppen (1948), the mesothermal humid subtropical climate (Cfa) is predominant in the region where these municipalities are located. Therefore, there is rainfall concentration in the summer months, without a well defined dry season. The mean annual rainfall varies between 1,400 and 1,600 mm and the mean annual temperature is 22°C (Caviglione et al., 2000).

However, when applying the Köppen (1918) climatic classification system, Terassi and Silveira (2013) concluded that the Pirapó basin shows mostly the Ama typology, characterized by having a tropical climate with dry winter, with a temperature above 18°C in the coldest month; and above 22°C in the hottest month, besides a precipitation concentration during the summer months; on the other hand the Cfa typology extends in areas with altimetry above 650 meters in such a basin.

Figure 1 – Location of the weather stations in Apucarana and Maringá in Pirapó River basin - PR

For characterizing the rainfall in the upper course of Pirapó River basin, monthly rainfall precipitation was used from 1980 to 2014 at Apucarana station (code 02351008) that belongs to both, the Agronomic Institute of Paraná (IAPAR) and to the Meteorological System of Paraná (SIMEPAR), which is located at 23°30'00" south latitude, and 51°32'00" west longitude, at a sea level of 746 meters; and Maringá station (code 83767) that belongs to the National Institute of Meteorology (INMET), located at 23°25'00" south latitude and 51°57'00" west longitude, at a sea level of 542 meters. The weather stations were selected based on a preliminary analysis that considered the quality of the data available (continuous sequence), thus, filling out the failures was not necessary.

After obtaining the rainfall data from the historical series of the two weather stations, the statistical treatment was carried out by using the Excel 2010 spreadsheet, through which the mean, standard deviation and coefficient of variation were calculated. Therefore, the mean values for each station were verified, based on the annual analysis scale.

Knowing that precipitation is a rather variable climatic element concerning time and space, and that the characterization of its rainfall pattern is fundamental for planning several socioeconomic activities, the methodology

proposed by Monteiro (1976) was applied for the historical series from 1980 to 2014 on the annual scale.

For analyzing the rainfall intensity, daily precipitation data of the conventional weather stations in Apucarana and Maringá were used from 2009 to 2013. The rainfall data from the automatic weather station in Apucarana were counted by using a rain gauge similar to a dumpster, that is, the 'Tipping Bucket' model 5600-0425-2 by Sutron.

This device is automatic and registers the accumulated precipitation in a defined period of 15 minutes, thus, the data were obtained in digital format. Therefore, only the rainfall data at the weather station of Maringá were obtained. This station is located at the headquarter campus of the State University of Maringá, which has records in graphics (rain gauges) from Lambrecht pluviograph, siphon model - 831 in the years selected for the analysis. According to Varejão-Silva (1973), the manual pluviograph enables to record rainfall in a detailed way, because the graph defines the height in millimeters (mm), the duration and intensity of precipitation per hour. In the pluviograph operating mechanism, the water from the capacity area is drawn into a cylindrical vessel, provided with a very light float; as the water is being accumulated, the float is rising inside the cylinder. The float movement is transmitted to the

pen recorder, which prints it on the diagram: the rain gauge. When the water in the vessel reaches its maximum level, a siphon is put into operation, emptying it, which makes the pen to return to the zero level of the rain gauge scale.

The pluviograph, in addition to indicating the total precipitation dropped in a given time interval, also has the advantage of informing the initial and final instants of each precipitation and, thus, their respective duration; this enables to calculate the intensity of the precipitations with a reasonable degree of safety and prevent errors due to evaporation, since the registration is made during the precipitation (Varejão-Silva, 2006).

After accessing the rainfall data of the weather stations, the spreadsheets and rain gauges were analyzed, and the day when the precipitation occurred, the time, the duration and its respective intensity were typed and later classified on the annual scale.

Classification of rainfall intensity

Two methodologies were used to classify the rainfall intensity in this scale of analysis. The first one refers to the technique described in the Manual of Meteorological Observations of the National Institute of Meteorology (1999), which classifies precipitation in:

Invisible drizzle: precipitation consisting of such small droplets that they seem to float in the air, and when they reach the ground they do not moisten it completely.

Light drizzle: precipitation of a maximum of 0.3 mm per hour, and visibility over 1,000 meters.

Moderate drizzle: precipitation from 0.3 to 0.5 mm per hour and visibility between 500 to 1,000 meters.

Heavy drizzle: precipitation of 0.5 mm per hour and visibility of less than 500 meters. When rainfall exceeds 1,0 mm per hour, it is considered as rain.

Invisible rain: precipitation whose quantity cannot be measured in the pluviographs, since it is not accumulated or because an active evaporation in this gauge causes it to disappear. Only the onset occurrence of the phenomenon should be informed.

Light rain: precipitation from 1,1 mm to 5,0 mm per hour, or a maximum of 0,8 mm in 10 minutes. Raindrops are well highlighted; the drops on roofs are light; puddles of water appear slowly; the dry surfaces take about two minutes to be moistened; drizzles of water run into the gutters of the streets.

Moderate rain: Precipitation from 5,1 mm to 60,0 mm per hour or a maximum of 6,0 mm in 10 minutes. The raindrops are rather identified and when they meet hard surfaces they provoke sprinklings; the water drainage into the roof downspouts ranges from one third to more than half of its capacity; the rain falling down the roofs causes a noise similar to a simple crackle or even to a drum beat.

Heavy rain: precipitation above 60,0 mm per hour, or up to 10,0 mm in 10 minutes. The rain falls torrentially and all other characteristics are more pronounced than those indicated for moderate rain.

The second methodology used to classify the rainfall intensity was proposed by Reichardt (1990) who considers:

Light rain: the precipitation of up to 2,5 mm per hour (maximum 0.25 mm in 6 minutes) is considered to be invisible. It consists of isolated drops, easily identifiable; no splash on floors, roofs or other dry surfaces. Drops or small fillets fall from the roofs or downspouts. When the precipitation is uniform, that is, droplets of diameter less than 0,5 mm and very numerous, it is called 'drizzle'.

Moderate rain: the precipitation varies between 2,5 to 7,5 mm per hour (0,25 to 0,75 mm in 6 minutes). It is characterized by hardly seen isolated drops; it is possible to see small splashes on flat surfaces and a relatively rapid formation of water puddles.

Heavy rain: the precipitation is over 7,5 mm per hour (more than 0,75 mm for 6 minutes). The rain seems to fall on tables, and it is not possible to identify isolated drops; large splashes are seen, which rather rise from flat surfaces. There is rapid formation of water puddles and visibility is impaired.

Considering that the amount and intensity of rainfall vary within a day, from day to day, month to month and year to year, the use of these methodologies is justified by the fact that understanding the rainfall intensity provides subsidies to knowledge on its structure and dynamics, which may contribute to the solution of problems generated by rainfall impacts. It is worth mentioning that although the methodology of the Manual of Meteorological Observations (INMET, 1999) also classifies the drizzle, only the light, moderate and heavy intensity classes will be used in this study in order to standardize it with the methodology proposed by Reichardt (1990).

For classifying the intense rains of the station of Maringá, the calculation was limited to

the period of time in which the precipitations occurred in the graph. The time of 10 minutes was set to classify the light, moderate and heavy precipitation intensities, as proposed by the Manual of Meteorological Observations (INMET, 1999).

After analyzing the rainfall events in the rain gauge, the descriptive statistics was used for all the data obtained. Therefore, a simple arithmetic equation was applied in a spreadsheet, considering the interval of 10 minutes between the precipitation peak and the time that it took to be reached; equation (1).

$$PI = P * 10 / T_p \quad (1)$$

Where: PI = precipitation intensity;

P = precipitation peak (mm);

T_p = period of time until reaching the precipitation peak, and

10 = interval in minutes.

Since the precipitation data for the station in Apucarana was in a total cumulative time of 15 minutes, the rainfall intensity classification was based on the same arithmetic equation used for Maringá, but changing the period of time of precipitation, that is, it was taken into account the fact that the peaks of rain occurred only in the period of time of 15 minutes, and not in a variable time, according to the rainfall record in the rain gauge at Maringá station. Thus, the following equation (2) was used:

$$PI = P * 10 / 15 \quad (2)$$

Where PI = precipitation intensity;

P = cumulative total precipitation (mm);

15 = time recorded, and

10 = interval in minutes.

The calculation to obtain the intensity proposed by Reichardt (1990) followed the same criterion of the previous classification, that is, a simple arithmetic equation in a spreadsheet was used. According to this methodology, a 6-minute interval between the precipitation peak and the time it took to be reached was considered, equation (3).

$$PI = P * 6 / T_p \quad (3)$$

Where PI = precipitation intensity;

P = precipitation peak (mm);

T_p = period of time until reaching the precipitation peak;

6 = interval in minutes.

After classifying the rainfall intensity, the results obtained in both methodologies were analyzed, and represented graphically in the annual scale.

Results and discussion

Figures 2A and 2B show the annual rainfall distribution in the areas assessed. It can be seen that in Apucarana (Figure 2A) with a historical mean of 1,608.1 mm, the precipitation was higher in 1980, 1983, 1997, 1998, 2009 and 2013, when the annual totals were higher than 2,000 mm. The years of 1985, 1988, 2005, 2006 and 2008 showed the lowest total annual rainfall values during the historical series with 1,187.2 mm, 1,295.0 mm, 1,271.0 mm, 1,561 mm and 1,279.4 mm, respectively.

When analyzing the rainfall in Maringá (Figure 2B) with an annual mean of 1,654 mm throughout the historical series, it is seen that only 1983, 1997 and 2009 had annual totals above 2,000 mm. However, it is possible to notice that there are no years with precipitation of less than 1,250 mm, with emphasis in 1988 and 2012, when the lowest values were seen; 1,280.6 mm and 1,329.0 mm, respectively.

The results obtained by Baldo et al. (2012) show the variability of annual precipitation for the area of Pirapó River basin, both for the mean rainfall above of 1,600 mm and for the years of precipitation above 2000 mm. According to the authors, the years when the highest mean values of rainfall in the basin were recorded were 1980, 1983, 1997, 1998 and 2009. On the other hand, the years when the lowest annual means were recorded were 1978, 1984, 1985 and 1988. However, Terassi et al. (2014) stated that the difference in precipitation distribution is due to the fact that it is located in a climatic transition area.

Berezuk and Sant'Anna Neto (2006) state that rainfall variation may be characteristic of regional atmospheric phenomena, such as the action of the South Atlantic Convergence Zone (SACZ), Frontal Systems and Instability Lines in the region.

According to Climanálise (2009), the incursion of frontal systems associated with other systems, such as the low level jets and the SACZ in the south region, provoked a cumulative of 334 mm in Maringá only in October, 2009, being the climatology for this period equal to 162,4 mm. The same was seen in 2013, when only on October 4th there was a record of 84,4 mm of rain (Climanálise, 2013).

Troppmair (1990) points out that in the state of Paraná, during the winter, polar masses with low temperatures and low humidity dominate. During the summer, the influence of the tropical marine masses predominates, which form north and northeast streams, and when accompanied by lines of instability originate high precipitations.

According to Reboita et al. (2009), the rainfall variability in this region is associated not only with frontal systems, but also with mesoscale convective complexes, cyclonic systems at medium levels and atmospheric blocks, as well as local circulation systems (breezes).

When comparing the two municipalities, it is seen that both Apucarana and Maringá showed 19 years along the series with annual rainfall values above the annual mean of 1,608.1 mm and 1,654 mm, respectively. Coincidentally, the years of 1980, 1983, 1997, 2009 and 2013 revealed high annual rainfall totals. Nevertheless, Apucarana showed two years (1980 and 2013) more, with precipitation above 2,000 mm. On the other hand, it showed three years (1985, 2005 and 2006) with

lower rainfall than the two years with less precipitation in Maringá (1988 and 2012), which indicates a greater annual variability in Apucarana.

The study by Anjos et al. (2001) revealed that the years of 1982, 1983, 1997 and 1998 were characterized by the occurrence of the El Niño phenomenon, which showed markedly high annual rainfall. The years of 1985, 1988, 1994 and 1999 were diagnosed as La Niña years, in which the rainfall values and the number of rainy days were rather below the average.

In relation to the mean rainfall, the results found are similar to those by Terassi (2012), which verified that the mean rainfall in the upper course of Pirapó river basin was over 1,660.0 mm. This value was also similar to that found by Ribeiro (1987) who showed the variation of 1,700.0 mm of rainfall for the same sector of the basin.

Figure 2- Distribution of the annual rainfall in Apucarana (A) and Maringá (B) from 1980 to 2014.

Table 1 shows the standard years in the annual scale for Apucarana and Maringá, respectively. The annual pattern of Apucarana shows that there was a predominance of years with 'normal' pattern throughout the series, totaling 19 occurrences, followed by 7 years with the pattern referred to as 'dry-tend', 6 years of 'rain-tend', and only 3 years with a 'rain' pattern. In relation to Maringá, there are 19 occurrences of 'normal' pattern, 9 'dry-tend', 5 'rain-tend' and 2 years with 'rain' pattern. There were no 'dry' pattern occurrences for the two municipalities; however, the data previously presented show that Apucarana has a slight tendency to have rainier periods than Maringá. Andrade (2009) found that the rainfall indices that occur in Maringá based on the standard year analysis always indicate a lower rainfall when compared with Apucarana.

It can be seen that both municipalities had the same 'rain' pattern in 1983, just as in 1985, 1988, 1991, 1994; and 2005 presented the same 'dry' pattern and a large number of years with 'normal' pattern, such as in 1981, 1992, 2002 and 2013 for both cities.

In relation to the coefficient of variation, it is worth mentioning that the highest values above the average in Apucarana are represented by 1980, 1983 and 1998, with 32.7%, 33.7% and 31.5%, respectively; on the other hand, the highest values of coefficient below the average were identified in 1985 with -29.9%, 2005 with -25.8% and 2006 with -27.1%. In Maringá, in 1983 and 2009, the coefficients of variation were 34.3% and 33.8% higher than the average, whereas 1988 and 2012 were identified with a greater variation below the average, that is, -29.0% and -21.9%, respectively.

Based on these values, it is considered that in the annual scale, the variability of the coefficient of variation is similar for the two municipalities, however it is seen that Apucarana shows higher negative and positive values of coefficient of variation in relation to Maringá. Similar results were also found by Souza et al. (2002), who consider that the area assessed does not have a great rainfall variation, since the mean values are approximate.

Table 1 – Standard year for Apucarana and Maringá during the historical series assessed.

Apucarana		Maringá	
Year	Coefficient of Variation (%)	Year	Coefficient of Variation (%)
1980	35,3	1980	16,9
1981	-7,6	1981	-7,5
1982	18,5	1982	8,3
1983	37,8	1983	36,6
1984	-2,3	1984	-15,8
1985	-28,6	1985	-20,2
1986	0,7	1986	-2,1
1987	15,1	1987	3,7
1988	-23,8	1988	-27,6
1989	20,6	1989	4,1
1990	25,7	1990	21,3
1991	-19,7	1991	-17,5
1992	16,4	1992	4,7
1993	0,0	1993	-3,0
1994	-14,8	1994	-17,2
1995	-7,9	1995	-5,0
1996	-8,5	1996	-7,6
1997	20,1	1997	24,5
1998	33,2	1998	26,8
1999	-13,6	1999	-16,7
2000	4,7	2000	13,5
2001	0,8	2001	2,7
2002	-3,9	2002	4,8
2003	-14,4	2003	-10,6
2004	-8,5	2004	7,7
2005	-25,0	2005	-19,4
2006	-25,7	2006	-11,4

2007	-8,7	2007	-6,3
2008	-8,1	2008	-1,2
2009	23,0	2009	33,6
2010	-4,1	2010	-19,8
2011	-4,8	2011	-1,0
2012	-11,8	2012	-20,2
2013	27,5	2013	14,9
2014	15,5	2014	21,6

Standard year classification		Ocorrências			
		Apucarana		Maringá	
		Num.	%	Num.	%
Dry	0	0,0	0	0,0
Dry-tend	5	14,3	9	25,7
	Normal	18	51,4	19	54,3
Rain-tend	9	25,7	5	14,3
Rain	3	8,6	2	5,7
Mean rainfall (mm)		1.608,1		1.654	

Figures 3 and 4 show the number of occurrences of light, moderate and heavy rainfall from 2009 to 2013 according to the methodology by INMET (1999). Figure 3 specifies the values recorded in Apucarana, showing that the total of light rain stands out in relation to moderate and heavy rains during the years assessed in the present study. The years 2011 and 2013 are in evidence due to the occurrence of 1,198 and 1,232 of light rains, 247 and 345 of moderate rains, 19 and 37 heavy rains, respectively. In 2010 there were 1,073 light rains, 331 moderate rains and 15 heavy rains. In 2009 there were 931 light rains, 350 moderate rains and 20 heavy rains, whereas in 2012 there were 963 light rains, 278 moderate rains and 17 heavy rains.

The prevalence of the light intensity class in relation to the moderate and heavy ones was also verified by Leite et al. (2011) for the municipality of Ponta Grossa-PR. According to the authors, the light rains were more frequent during nine months of the year (29.45%) and the heavy rains with the lowest frequency (1.18%).

Lima et al. (2012) analyzed the number of days and rainfall intensity in Caçu-GO basin from January to June 2012 by using hourly precipitation data through rain gauges and the methodology proposed by the Manual of Meteorological Observations (INMET, 1999). The analysis showed that there is a great spatial variability in the area assessed, with light rains occurring more frequently in the basin (356 hours), followed by moderate rains (178 hours) and heavy rains (8 hours). The results found by these authors are in accordance with those found in Pirapó River basin, since according to the methodology by INMET (1999) it is possible to verify remarkable

differences in the number of events among the three intensity classes analyzed.

Silva and Clarke (2004), when working with the rainfall intensity in São Francisco River basin, showed that the light rains were predominant in relation to the moderate and strong intensity classes in the low river course, where the altimetric dimensions are smaller. However, this result shows a divergence in relation to the high course of Pirapó River, since the light rains were higher, mainly in Apucarana, which has an altitude of 746 meters, that is, the highest sector assessed in the present study.

Figure 4 shows the classes of rainfall intensity for Maringá. An increase in the number of occurrence of the three intensity classes is seen in relation to Apucarana, except in 2012 for the light and moderate intensity classes. The years 2009 and 2011 showed a higher number of light rains with 1,104 and 1,143, whereas moderate rains totaled 514 and 312, and the heavy ones 84 and 57, respectively. In 2010, there were 1,041 light rains, 373 moderate rains and 37 heavy rains, in contrast with 2012, whose values showed the occurrence of 842 light rains, 277 moderate rains and 41 heavy rains. Finally, in 2013 there were 1,063 light rains, 349 moderate rains and 63 heavy rains.

Alves (2014) carried out an analysis on the intense precipitation in Maringá in 1988, 1999 and 2009. By using the classification proposed by the Manual of Meteorological Observations (INMET, 1999), the author concluded that the light and heavy rains occurred in smaller amounts in relation to the moderate rains in 1988 and 1999. It should be emphasized that in 2009 there was the highest occurrence of moderate and heavy precipitations in relation to the other two years studied.

Deffune et al. (1995), when using the same methodology to assess rainfall concentration and intensity in Maringá from 1976 to 1994, emphasized that the highest intensities are for moderate rains with a mean annual value of 57 days of occurrence, and heavy rains with 16.3 days during the year.

It is possible to notice that the research on precipitation intensity points to a great extent not only for verifying the intensity classes, but mainly the impacts generated by the intense events. The studies by Sanches et al. (2014) showed that the occurrence of extreme rainfall events in the upper Uruguayan state of Rio Grande do Sul causes negative impacts. According to the authors, the

occurrence of rain events of over 250 mm/24 hours compromised the physical structure of viaducts, spillways and dams, due to the increase in the flow of the main rivers of the region, in addition to the concentrated surface runoff. Larentis et al. (2008) found that in the Taquari-Antas-RS river basin, intense precipitation events determined the wash up of pollutants into the drainage area of the basin.

Studies by Rufino (1986), Spohr et al. (2009), Eltz et al. (2011), Sampaio et al. (2011) and Eltz et al. (2013) indicate that in addition to erosion, knowledge on intensity favors better management of water resources, planning and recovery of the eroded areas by rain and surface runoff.

Figure 3 – Annual light, moderate and heavy intensity classes for Apucarana, from 2009 to 2013, according to the methodology by INMET (1999).

Figure 4 - Annual light, moderate and heavy intensity classes for Maringá, from 2009 to 2013, according to the methodology by INMET (1999).

Reichardt's (1990) proposal found higher values of the moderate intensity classes in 2010, 2011 and 2012; and the values related to the heavy intensity class were seen in all the years assessed, as shown in Figures 5 and 6. This is due to the fact that the values adopted for rainfall classification are lower than the values considered by INMET (1999). When analyzing the rainfall intensity in Apucarana (Figure 5), it is seen that, according to the annual scale throughout the period assessed, there were events of light rains superior to the moderate and heavy ones. In 2009, there were 694 light rains, 323 moderate rains and 240 heavy rains. In 2010 there were 861 light rains, 355 moderate rains and 211 heavy rains, whereas in 2011 the light rains totaled 978 and the moderate and heavy rains were quantified at 275 and 173, respectively.

It can be seen that in 2012 the proportion of light, moderate and heavy rains was 762, 293 and 197, whereas in 2013, the light rains accounted for 1,008 events, the moderate rains 343 and the heavy rains 263. It should be emphasized that the light rains were higher than the moderate and heavy intensity classes throughout the years assessed, mainly in 2011 and 2013, which showed 'normal' and 'rain-tend' pattern in Apucarana.

Dantas et al. (2014) used daily rainfall data from 108 stations located in the Una River basin in

the state of Pernambuco (PE). These authors analyzed the intense precipitation events that occurred in August 2000, February 2004 and June 2010, in order to monitor and predict floods in the upper, middle and low Una. They evidenced that in the upper Una, light rains occurred for the three flood events mentioned; on the other hand, in middle Una, extreme and severe rains predominated for the event of August, 2000, and moderate rains in February, 2004 and June, 2010. Concerning the low Una, moderate rains characterized the events of August, 2000 and February, 2004, whereas extreme and severe rains were significant for the event in June, 2010.

In Maringá (Figure 6), it can be seen that the number of occurrences of heavy rains is much more significant than that found in Apucarana, however the highest values of this intensity class occurred in 2009 and 2013. Another characteristic observed is that the values referring to the moderate intensity class decreased from 2009 to 2013, in addition to the differences being less evident among the number of occurrences of moderate and heavy rains.

In relation to the light rains, it is worth mentioning that only in 2009 there was a higher value than that of the same year in Apucarana. In Maringá, in 2009, there were 852 events of light

rain, 484 moderate rains and 385 heavy rains, whereas in 2010 the events related to the light, moderate and heavy intensity classes decreased to 735, 445 and 263, respectively. Considering 2011 it is seen that the values were the following: 851 light rains, 413 moderate rains, and 248 heavy rains; in 2012 there was the lowest rain value of the three intensity classes, totaling 586 light rains, 348 moderate rains and 226 heavy rains. Finally, in 2013 there were 787 occurrences of light rains, 371 moderate rains, and 318 heavy rains (Figure 6).

When relating the rainfall intensity to the impacts occurred in the city of Recife-PE, Souza et al. (2012) found that the moderate rains were more constant from March to August. In addition, the authors reported that the impacts generated by this intensity class were flooding points in the city.

Zanella (2006) showed the impacts caused by the events of intense rainfall over 60 mm/24 hours in the city of Curitiba. Among the main problems reported it is worth mentioning flood in riversides and streets, material losses, lack of energy, water and telephone, traffic problems, structure damage in buildings and health related issues, such as leptospirosis.

According to Zanella and Olímpio (2014), the structure and organization of cities are important indicators for solving problems related to the occurrence of intense events, especially if they are concentrated in river basin areas. The authors emphasize that frequent floods and landslides from heavy rains have serious social and environmental impacts, as they may increase the number of deaths, injuries, and homelessness, as well as

economic losses and the proliferation of diseases. It should be emphasized that knowledge on the rainfall intensity and the frequency it occurs are important tools to minimize the problems pointed out by the authors.

The results obtained from the perspective of two methodologies for classifying rainfall, together with information on the organization and structure of the cities, show that both the occurrence of intense concentrated rains and the regularity of light and moderate intensity rains may generate negative impacts.

It can be seen that when applying the methodology by INMET (1999), the year of 2013 stood out by the greater number of occurrences of light rains in both municipalities. In comparison to Apucarana, Maringá had higher values in all the intensity classes during the period assessed. The values related to the light intensity class were higher in Apucarana according to the proposal by Reichardt (1990), mainly in 2013; however Maringá was noticeable for revealing higher values of moderate and heavy rains in relation to Apucarana.

It should also be emphasized that there was a reduction in the number of occurrences of the light intensity class in Reichardt's (1990) proposal. On the other hand, the occurrence of moderate and heavy classes increased in both municipalities. This characteristic is due to the use of the different time intervals of both methodologies, as well as to the intensity values stipulated.

Figure 5 – Annual light, moderate and heavy classes in Apucarana from 2009 to 2013, according to Reichardt's methodology (1990).

Figure 6 - Annual light, moderate and heavy classes in Maringá from 2009 to 2013, according to Reichardt's methodology (1990).

Final considerations

The results obtained enabled to understand and analyze the rainfall intensity and variability for the annual scale. In relation to the rainfall means of the historical series from 1980 to 2014, it is concluded that Apucarana and Maringá, in spite of having similar climatic characteristics and being

located in the upper course of Pirapó river basin, they showed significant differences in precipitation variability.

These differences and similarities were also found in the analysis that refers to the rainfall pattern, since both municipalities showed a higher number of years with 'normal' pattern. However, in relation to the 'dry-tend pattern Maringá stood

out, whereas the ‘rain-tend’ pattern was higher in Apucarana throughout the series.

According to the analysis scale and the methodologies applied in the present study, the assessment of the rainfall intensity from 2009 to 2013 revealed significant results. It was seen that in Apucarana and Maringá, the values of light rains were higher than the moderate and heavy intensity classes according to INMET (1999). However, when applying Reichardt’s proposal (1990) there was a reduction in the number of occurrences of the light intensity class; and the number of moderate and heavy classes occurrence was approximated.

The application of the different methodologies favors a more accurate analysis regarding the impacts that the rains may cause both in the cities and in the field. According to INMET (1999) methodology, a large amount of rain is required for the occurrence of impacts. Such a methodology can be applied in urban space. However, Reichardt’s proposal (1990) shows that lower precipitation values may also contribute to the occurrence of impacts, mainly surface runoff in arable areas.

It could be seen that not only the events of heavy rains are responsible for the occurrence of negative impacts. Considering the urban environment, impacts are more visible in a short term due to soil sealing and the commitment of the drainage rainwater channels.

Therefore, Reichardt’s proposal (1990) enabled to show such processes in a more detailed way. This proposal is more suitable for agricultural and environmental purposes because it stipulates intensity values lower than those by INMET methodology, since the occurrence of heavy rains are much smaller than the moderate and light ones according to the methodology by INMET (1999).

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