Characterization of Rio do Salto micro-basin, district of Cascavel – PR

Andreia A. Ferreira Silva[1], Elisandro Pires Frigo[1], Mauricio Guy de Andrade[1], Roberson R. Parizotto[1] and Vanderley de Oliveira[1]

[1]Universidade do Oeste do Paraná – UNIOESTE, Master Degree in Energy on Agriculture. 2069 Universitária Street, 2069, Zip code: 85.819-130. Cascavel - PR, Brazil. Telephone number: 45-3220-3155.

profandreiabio@seed.pr.gov.br, epfrigo@gmail.com, mauricio.agro@hotmail.com, rrparizotto@fag.edu.br, vanderley_olivei@uol.com.br

Abstract: The discussion of the physical and functional characteristics of watersheds is intended to provide knowledge of the various factors that determine the nature of the discharge of a river. The aim was to study the physical features of the Rio do Salto basin, located between the districts of Rio do Salto, and Centenario, Santo Domingo, in western Paraná. The results indicate that the physical characterization of the Rio do Salto watershed points to a more elongated form, being proved by the coefficient of compactness and form factor. This indicates strong structural control of drainage. The appearance of the basin with non-compact value of Kc = 1,24 indicates less prone to flooding. The form factor FF = 0,52 confirms this fact, indicating lower chances of high peak floods in the basin under study. About the order of Rio do Salto watershed, it is considered as Sixth, indicating that the drainage basin is of considerable ramification. Morphometric data and rainfall, along with information generated in the GIS such as location of the basin area and vegetation are valuable tools for further management of water resources of Rio do Salto.

Key words: water resources, compactness index, slope

Introduction

The water is known as a public asset and represents a human right and it is essential for life. By following this principle it is possible to establish a water management policy, prioritizing its preservation, quality and quantity. It is evident the necessity of a rational and conscientious use of the water resources to assure the survival of the planet, also for the future generations (SEMA, 2010).

Water resources are destined for multiple ways of use, being indispensable in a large spectrum of human activities, within which it can be highlighted the public and industrial supply, agricultural irrigation, electrical power production and leisure and recreational activities, as well as the preservation of aquatic life. Human activities, without exception, need water resources to be performed (Freitas, 2010).

According to Cristofoletti (2002), a watershed constitutes an open system, complex and organized, composed by components that establish an interactive relation, intermediating information about the surroundings and using them to adapt their internal structural as consequence of these interactions. Lima (1989) states that every watershed has a dynamical equilibrium even when they do not suffer anthropic actions, because they receive energy through climatic agents and lose it due to the water runoff.

A watershed is necessarily defined by a water divisor which separates it from the adjacent basins. The water divisor follows the peak line of the topographic formations around the watershed and crosses the water curse only on the exit section. The discussion of the physical and functional characteristics of the watersheds has the purpose of providing knowledge of the various factors that determine the nature of the discharge of a river (Porto *et al*., 1999). Furthermore, according to referred author, the importance of this knowledge lies on the fact that by the evaluation of the parameters which affects this flow, a comparison amongst the watersheds can be made, knowing better the past phenomena and performing extrapolations.

Each watershed interconnects to another of superior hierarchical order, constituting the last one in a sub-basin. For this reason, these terms are relative, because the watersheds relate by hierarchical order inside a particular hydric network. The subdivision has relevant importance for the watersheds study because it allows the identification of natural resources degradation spots, the nature of environmental degradation processes and the impairment level of the sustained production that exists. (Souza and Fernandes, 2006).

Pires (2003) enhances that the environmental approach, as perspective of the health sustainability of the ecosystems and the economy, defining strategies of protection and recovering of the systems responsible for the maintenance of ecological services, is an important parameter for planning and manage development processes. The ecological integrity of the ecosystems is extremely important and for it to happen, the application of methodological approaches that contribute to the decision making regarding the public strategies and more appropriate management to maintain the capability of natural resources is necessary.

Being a natural system, the watershed allows the analysis and comprehension of the natural elements behavior that are inter-related. From the choice of a watershed as analytical category it is possible to understand the natural dynamic operation of a particular environment. Inside the studies of physical geography, the watershed being considered a system allows the comprehension of geomorphology, geology, hydrology, weather and vegetation of a particular area, as well as checking how these elements behave and relate, originating processes and forms of landscape.

In Paraná state, the water resources state policy was instituted by the Law n^{o} 12.726, from November 26th, 1999 and its principles are the adoption of watersheds as planning unit, the multiple uses, recognition of water as a finite and vulnerable asset, recognition of the economic value of water and decentralized and participative management. Still according to the water resources state policy, the watersheds nominated as being one hydrographic region limited by a water divisor and, based on this principle, Paraná state was divided into 16 watersheds, instituted by the Resolution nº 024/2006/SEMA, as follow: Litorânea, Iguaçu, Ribeira, Itararé, Cinzas, Tibagi, Ivaí, Paranapanema 1, Paranapanema 2, Paranapanema 3, Paranapanema 4, Pirapó, Paraná 1, Paraná 2, Paraná 3 and Piquiri (SEMA, 2010).

Therefore, the aim was to study the physical features of Rio do Salto watershed, located between the districts of the Rio do Salto, and Centenario, Santo Domingo, in Western Paraná.

Material and Methods

Rio do Salto micro-basin, as displayed on Figure 1, is located in Cascavel city – PR. The city is located 491,00 km from Curitiba, capital city of Paraná, geographically located in Western Paraná. The cities that border it geographically are: Toledo in Northeast, Cafelândia in East, Céu Azul in West and Lindoeste in North (IPARDES, 2012).

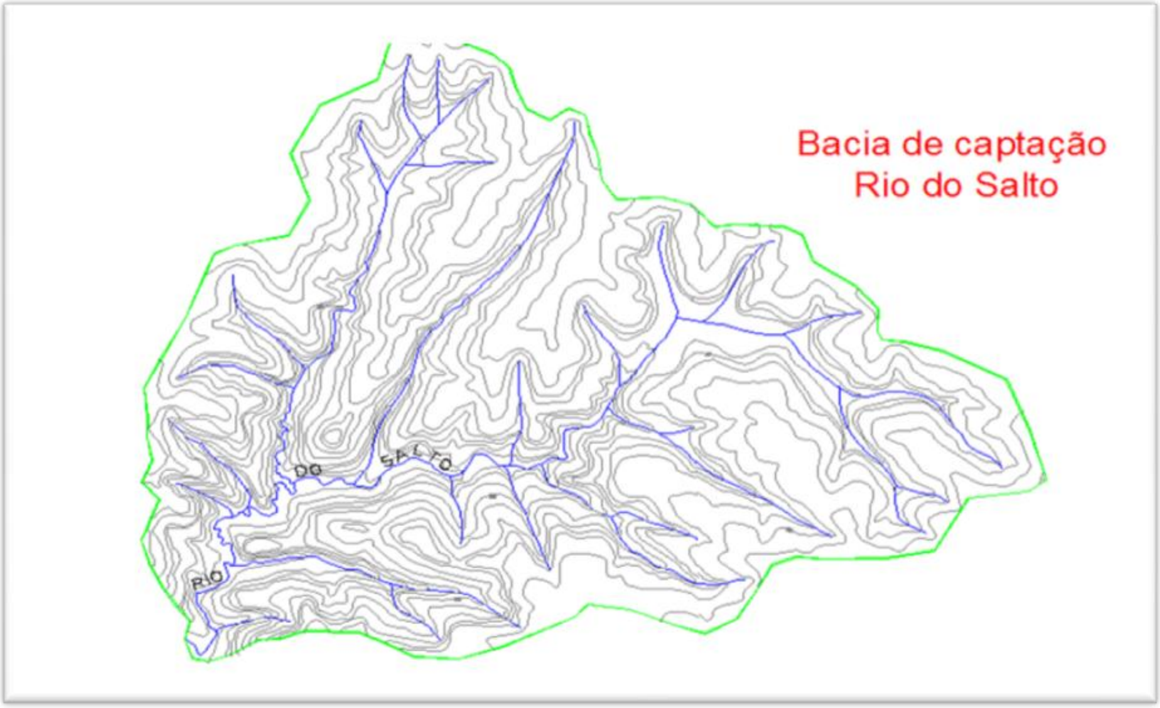

Figure 1 – Rio do Salto catchment basin. AutoCAD (2012).

The Rio do Salto micro-basin characterization was performed by contouring the watershed area by its topographic divisors (points of maximum quota between watersheds). The physical features of the watersheds were analyzed, mentioned by Porto *et al*., (1999), following the physical factors: soil use; soil type; area; form; watershed slope; drainage density and watershed flow. In the city, the predominant soil is Eutroferric Red Latosol, characterized as clayey to very clayey, which facilitates the managing and mechanization. The region presents a slightly wavy relief, predominantly, benefiting farming activities because that soil facilitates mechanization. The rest of the soil are classified as wavy and strongly wavy provide forms at levels and sub-tabular hills. The smoothed landforms, the soil with high fertility and the weather with well distributed rainfall allow the agricultural activities performance in a broad and intense way in the city, on which the largest part of the soil use is destined to agricultural activities, with well distributed areas of forest.

The type of use, the soil occupation (agricultural and urban) and the soil conservation system in the city avoid the degradation. According to Porto *et al*., (1999), one of the most important physiographic factors that affect the drainage is the soil use or the coverage of the land. The predominant weather of the region is mesothermal humid subtropical, whose characteristics are predominance of hot summers and frequent frost, with tendency of rain concentration during the summer months, without defined dry season (Koppen classification).

The annual average temperature of the hottest months is higher than 22ºC and in the coldest months, the temperature is lower than 18ºC, with annual average temperature of 21ºC and the relative humidity of the air with an average of 60% (Paraná Cidade, 2012). The average monthly precipitation of the region from April 2011 to March 2012, according to IAPAR (2012), was 130 mm, with a total precipitation of 1.560 mm.

Rio do Salto micro-basin encompass an area of 107,7 km². The area was obtained by using the AutoCAD software. According to Porto *et al*., (1999), big watersheds usually are pear-shaped or fan-shaped, while small watersheds, like Rio do Salto, present multiple possible shapes due to the geological structure of the land.

For this work it was used tools from Geographical Information System (GIS) SPRING 4.3.3, produced by the National Institute of Spatial Researches (translated from the Portuguese and stands for *Instituto Nacional de Pesquisas Espaciais* - INPE).

To determinate the watershed form, it was considered the coefficient of compactness (Kc) which relates the watershed form with one circle, constituting the relation between the perimeter of a circle with the same area as the watershed, and it was determinate by the equation:

$$Kc = 0{,}28 \cdot \frac{P}{\sqrt{A}}$$

On which *P* is the watershed perimeter (Km), *A* is the watershed area (Km^2) and *Kc* is the coefficient of compactness (non-dimensional).

The form factor is the ratio between the average width and the axial length of the watershed. It indicates the tendency of the watershed to flood and it is evaluated considering the value obtained from the ratio between length and width, which as close as the result is to number 1, higher is the tendency to suffer with flooding.

$$FF = \frac{B}{L}$$, where:

L = watershed length;

B = average width = $\frac{1}{n} \cdot \sum_{1}^{n} Bi$

Another parameter used was the Index of Conformation (Fc), which is defined as the relation between area and axial length of the watershed; the closest the result is to number 1, more the watershed presents a squared form and for this reason higher are the chances of flood peaks.

$$Fc = \frac{A}{L^2}$$

On which *A*, corresponds to the watershed area and *L* to the axial length.

To calculate the drainage density, it was used the equation (Costa & Lança, 2001):

$$Dd = \frac{L}{A}$$

Where:
Dd is the drainage density (Km.Km$^{2\ -1}$),
L is the total length of every channel (Km)
A: Drainage area (Km^2).

The watercourse slope was calculated using the following equations:

$$S_1 = \frac{\Delta H}{\mathbf{L}}$$

Where: ΔH = **variation of the quota between two extreme points and** *L* = length in plant of the river

$$S_2 = \frac{2 \, . A_{bp}}{L^2}$$

Where A_{bp} = area below the profile; L = length in plant of the river

$$S_3 = \left(\frac{L}{\sum_1^n \frac{L_1}{\sqrt{Ii}}}\right)^2$$

Where *L* is the length in plant of the river, *Li* is the horizontal length of each one of the *n* stretches and *li* is the slope of each one of the *n* stretches (*li=Hi/Li*).

The data about the soil use were obtained using Google Earth as base and Geographic Information System – GIS (translated from the Portuguese and stands for *Sistema de Informação Geográfica* (SIG) – SPRING 4.3.3.)

Results and Discussion

Applying the river classification, according to Christofoletti (1974, 1980), it can be verified that Rio do Salto micro-basin is classified as third order, which reflects in a watershed with low ramification level. This feature is closely related to the orientation element, because the watershed has basically two main axes and the ramification is not well orientated.

It is allowed to measure that the referred watershed presented a drainage density of 0,8370 Km Km$^{2\text{-}1}$. It is possible to assure that this micro-basin presents a relatively poor drainage, or mild drainage, considering that there is no high rate of nourishment runoff, therefore the soils of this watershed are more fertile than the soils from other watersheds with the same size.

The review of the physical characteristics calculated for Rio do Salto/PR micro-basin is presented on Table 1.

Table 1 – Physical characteristics of Rio Salto, PR micro-basin

Physical Characteristics	**Results**
Drainage area	107,70 Km².
Perimeter	46,09 Km
Form Factor (FF)	0,52.
Compactness Index (Kc)	1,24
Conformation Index (Fc)	0,22
Watercourse Density	0,3157 cursos d’água.Km$^{2\ -1}$
Drainage Density	0,8370 Km.Km$^{2\ -1}$

The micro-basin under study presents a more elongated shape and, for this reason the index of compactness and the form factor correspond to 1,24 and 0,52, as it can be observed on Table 01 previously presented. The evaluation of these parameters allows to assume that the coefficient of compactness relatively close to the unit and the form factor smaller that the unit are indicatives of a micro-basin with less time of concentration, more possibilities of intense rain and more likely to flood.

Andrade *et al*. (2008), verified on the Rio Manso watershed, located in Mato Grosso state, that the drainage area of the watershed was 10.793,109 km^2 and its perimeter was 532,66 km. According to the morphometric results, it can be stated that the Rio Manso/MT watershed is less susceptible to flood under normal precipitation conditions, in other words, excluding events of abnormal intensities due to the fact that its coefficient of compactness presents a value that is distant from the unit (1,43) and, while its form factor shows a low value (0.21).

The density of Rio do Salto watercourse is 0,3157 watercourse.$Km^{2\ -1}$ and this value is considered low according to the specialized literature. On the other hand, the sinuosity is one of the factors that control the drainage on the channel, its equal value compared to the unit shows that the river follows exactly the thalweg line, presenting low level of sinuosity.

The data for the calculation of the watercourse slope are presented on Table 2.

Table 2 - Longitudinal profile of Rio do Salto

Quotas (m)	Distance (m)	Distance (L) Km	Accumulated Distance (Km)	Slope/ segment li (20/Distance)	Si (√li)	Li	Li/Si
800	101	0,101	0,101	50,1980	0,44499	0,101	0,23
780	992	0,992	1,093	0,0202	0,14199	0,992	6,99
760	1775	1,775	2,868	0,0113	0,10615	1,775	16,72
740	4315	4,315	7,183	0,0046	0,06808	4,315	63,38
720	480	0,48	7,663	0,0417	0,20412	0,48	2,35
700	612	0,612	8,275	0,0327	0,18078	0,612	3,39
680	865	0,865	9,14	0,0231	0,15206	0,865	5,69
660	1007	1,007	10,147	0,0199	0,14093	1,007	7,15
640	3548	3,548	13,695	0,0056	0,07508	3,548	47,26
620	6088	6,088	19,783	0,0033	0,05732	6,088	106,22
600	2317	2,317	22,1	0,0086	0,09291	2,317	24,94
Total	22100	22,1	22,1			22,1	284,30

By the difference between the extreme quotas, an approximately slope value can be obtained; this factor might influence directly the speed of the drainage. Regarding to Rio do Salto micro-basin, the values found were 0,00905 $m.m^{-1}$; S_2 = 0.00739 $m.m^{-1}$ and $S_{3\ =}$ 0,00604 m.m^{-1}. Figure 2 shows information about the hypsometric curve regarding to the analyzed micro-basin.

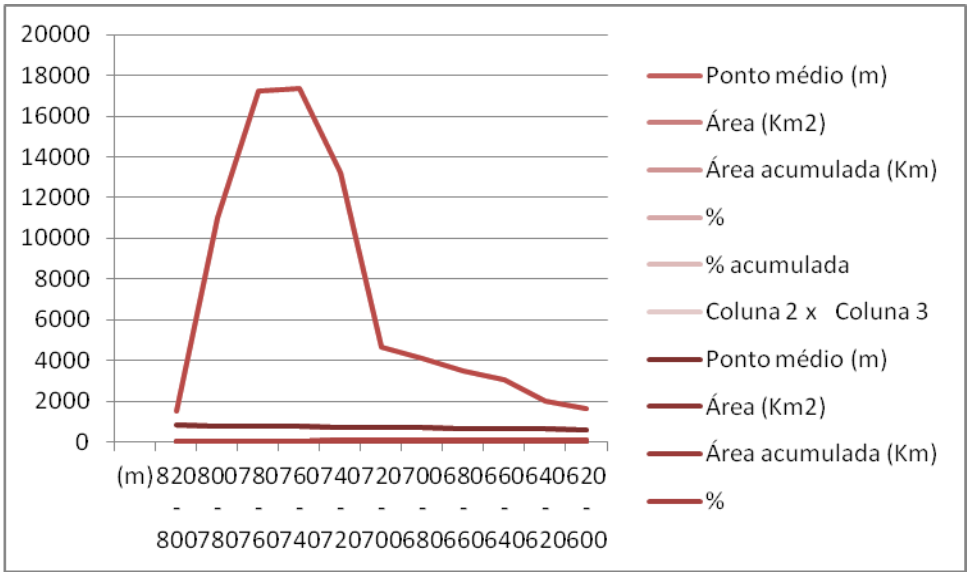

Figura 2 – Hypsometric Curve of Rio do Salto micro-basin
Average point
Área
Accumulated area
Column 2

Using Google Earth and Geographic Information System – GIS (translated from the Portuguese and stands for *Sistema de Informação Geográfica* (SIG) – SPRING 4.3.3.), the following data about soil use were obtained, as displayed on Table 4.

Table 4 – Use and occupation of Rio do Salto/PR micro-basin soil

Soil use data	**Results**	
	Ha	%
Agricultural Areas (farming or pasture)	51,3377	47,67
Urban Areas	0,5130	0,48
Forest	55,8493	51,85

Regarding to the surface conditions, amongst the factors that most influence the superficial runoff, it can be mentioned: soil type, topography, drainage network and hydraulic buildings that exists in the watershed. Table 5 presents values associated to the superficial runoff, using Picking formula (Freitas, 1984).

Table 5 – Values associated to the superficial runoff of Rio do Salto/PR micro-basin.

Values	**Results**
Runoff coefficient	0,4972
Concentration time	186, 68 minutos
Maximum intensity	31, 24 $mm.h^{-1}$
Maximum flow (runoff)	4, 6468 $m^3.s^{-1}$

Conclusion

In order to better describe the Rio do Salto/PR micro-basin, the characteristics that were found must be considered as a whole. The comparison of the obtained results indicates that the physical characterization of the Rio do Salto/PR micro-basin points to a watershed that presents a more elongated shape, which could be proved by the index of circularity, coefficient of compactness and form factor. This denotes a strong natural drainage control. The non-compacted aspect of the micro-basin with the value Kc= 1,24 indicates less propensity to flood when compared to a circular watershed (Kc=1). The form factor FF= 0,52 reassure this fact, indicating less chances of flood peaks in the studied watershed. Regarding to the order of the watershed, Rio do Salto/PR micro-basin is in the third order, indicating that the drainage system of the watershed is of low ramification. The morphometric and rainfall data, along with the information provided by GIS, such as watershed localization and vegetation are valuable tools for further management of water resources of Rio do Salto micro-basin.

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