6TH INTERNATIONAL CONFERENCE ON FLOOD MANAGEMENT
September 2014 - São Paulo - Brazil

EVALUATION OF THE CONTRIBUTION OF RIPARIAN VEGETATION IN REDUCING SURFACE FLOW AND WATER QUALITY IN URBAN WATERSHED

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ABSTRACT: The urban planning focused on environmental issues is a challenge for large urban centers and is becoming increasingly a trend of public planners. Currently, is possible to notice in Brazil that cities are growing without an efficient urban and environmental model of planning, areas considered at risk are being occupied indiscriminately, laws of land use being disobeyed, including river banks, resulting in degradation of riparian vegetation. This kind of vegetation is associated with the water bodies, forming long corridors that have functions as: erosion control, water filtration, flood control, increased biodiversity and contribute to the landscape harmony. With perceptive evaluation of orthophotos obtained in this work it was possible to evaluate the gradual development of riparian vegetation over twenty-five years at a stretch that belongs to the Belém River Basin in Curitiba-PR - BR, this is an urbanized watershed. Concluded that the method used by the riparian vegetation caused a considerable effect on some water quality parameters, as well as collaborating with the containment of floods. Increased water quality and benefits in relation to drainage would be maximized if the riparian vegetation extended along the basin, characterized as an important environmental service and reducing the impact of heavy rainfall in urban areas. Payment for Environmental Services - PES can be seen as an incentive to maintain riparian basins not only in rural but also in urban watersheds, where the impacts of a full cause major damage due to population density.

Key Words: Riparian Vegetation, Water Quality, Surface Flow, Urban Rivers, Payment for Environmental Services.

1. INTRODUCTION

The urban population in Brazil is has been experiencing a strong growth since 1960, when the rural area was changed by city and in just a decade the urban population rose to total of 55,9%. The southern region also recorded a large increase in urban areas and in 2010, according to IBGE (2012), about 84.9% of people lived in cities.

These data indicate the rapid population growth in urban centers and show the need for urban planning in order to prevent illegal occupation and environmental damage. According to MOTA (2011), any transformation from a rural to an urban environment will always result in environmental changes, leaving the man to minimize the degree of this impact.

Currently, is possible to notice that the cities in Brazil are growing without an efficient urban and environmental model of planning, areas considered at risk are being occupied indiscriminately, disobeying laws of land use, including river banks, resulting in degradation of riparian vegetation. This situation results in a low quality of life for the population for the population which does not have access to basic sanitation resources, understood as access to minimum conditions as drinking water, sewage system, solid waste management and drainage. Another consequence is the degradation of basic mechanisms for the quality of human life, such as water and vegetation resources, impacts that are no longer regarded local but extending, adding to other affected areas. Accordingly, Mota (2011, p.19) "*the metropolization process has generated a deficit of growth of public services. This has led to degradation of quality of life, social pressure, increased environmental cost, high prices of inputs for development*".

Among all the natural resources, water resources are more easily impacted by man, where the degree of change can be seen clearly. In urban centers, this feature is influenced by impermeable areas that alter the dynamics of runoff and pollution maximized in underdeveloped or developing countries, where the network of sewage collection is small or nonexistent, and most often has problems of leakage in the pipes. There is also the issue of illegal connections in the gallery of storm drainage, which throw the raw sewage into water environment, and solid wastes that are dumped in rivers where there are no frequent collections of wast.

The lack of investment in urban planning results in deforestation and illegal occupation of vegetation margins. The Figure 1 portrays the occupation of the bank of the Belém River with the occurrence of suppression of riparian vegetation.

Figure 1: Urbanized Belém river bank

A watershed is all land that contributes water to a stream, river or lake. Activities on the land impact the quality and quantity of that water. For example, urban land use disrupts the flow regime, diminishes water quality, and alters stream channels (Snyder 2003). This was proven by most stream research and monitoring work (BOHN and KERSHNER, 2001; FISRWG, 1998; MCDONNELL and PICKET, 1990; MILTNER, 2004; RANDOLPH, 2004; RILEY, 1998; SWEET, 2003). Stream health is negatively correlated with the amount of urban land use in the surrounding watershed (MILTNER *et al,* 2004). The effects of land use impacts can be manifold.

The riparian is a vegetation that forms naturally on the banks of springs, rivers, streams and lakes (RIZZO, 2007). This vegetation type is always associated with water bodies forming long corridors which may be tens of meters long and suffer variations in floristic composition. It can be denominated in several ways such as lowland forest, gallery forest, riparian forest, riparian forest or riverine forest. This kind of vegetation provides many environmental functions such as erosion control on the banks of watercourses avoiding siltation of water sources that comes fron sediments of the higher parts of the watershed, filtration processes of fertilizers or chemicals that flows through soil and roots and they contribute to biodiversity producing fruits and seeds, which are used as shelter for wildlife. Besides, riparian vegetation reduces the process of erosion by protecting the soil from heavy rains, also collaborating with the improvement of water quality, aquatic life and harmony to the landscape of urban centers.

According to Davide *et al* (2000), riparian vegetation is able to retain about 80% of phosphorus and 89% of nitrogen runoff from the entire area of the basin, varying depending on the state of preservation of the riparian.

The riparian areas are also considered of saturation, have direct participation in the runoff process in the catchment area, mainly by surface and subsurface runoff due to high infiltration capacity. During periods of low rainfall only saturated zones, which are located on the banks of water bodies, participate in this process, besides the rising rivers (FREIXÊDAS, 2007). During rain these areas expand and contribute to the generation of direct runoff, influencing hydrological functions such as flood peaks, flow, thermal balance and nutrient cycling (LIMA; ZAKIA, 2000).

Moreover, the riparian zone is an ecosystem that provides an environmental service of great importance: the maintenance of water resources in the aspects of quality and quantity is essential to ensure the availability of water for multiple uses (LIMA; ZAKIA, 2000).

In 2009, the bill No.5487 was sent to the National Congress whit the purpose of establishing a National Policy for Environmental Services, called the National Program of Environmental Services and the goal of establishing control and funding of this process. This design is considered the most complete Bill. According to RECH e ALTMANN (2009, p.93):

> From this appreciation expressed through its own national policy, the government and society will be able to devise strategies for preserving and restoring the environment. Conceive the environment as a provider of environmental services and considers it as part of the economic, productive, social and cultural process rather than as a supplier of raw materials and waste receiver.

In this context, the main objective of this work was to verify the influence of riparian vegetation on water quality of the Belém river and the contribution to the damping of surface drainage through the analysis of orthophotos, statistical surveys of a historical series of monitoring specific points regarding no water quality and perceptive theoretical analysis of authors in relation to aspects of drainage.

2. METODOLOGY

The research is classified as exploratory and uses case studies and the literature as methods. According to Gil (2008, p. 43), “exploratory research has as main purpose to develop, clarify and modify concepts and ideas in order to formulate more precise hypotheses or searchable problems for further studies”.

The area chosen to conduct the study was the Pontifical Catholic University of Paraná (PUCPR), located in the Belém River Watershed (Figure 2), As the university is located next to the river bank, we were allowed quick and easy access to the banks of the stretch surrounding the campus. The institutional importance of the university has also been taken into consideration as well as the recovery project conceived and implemented by the university.

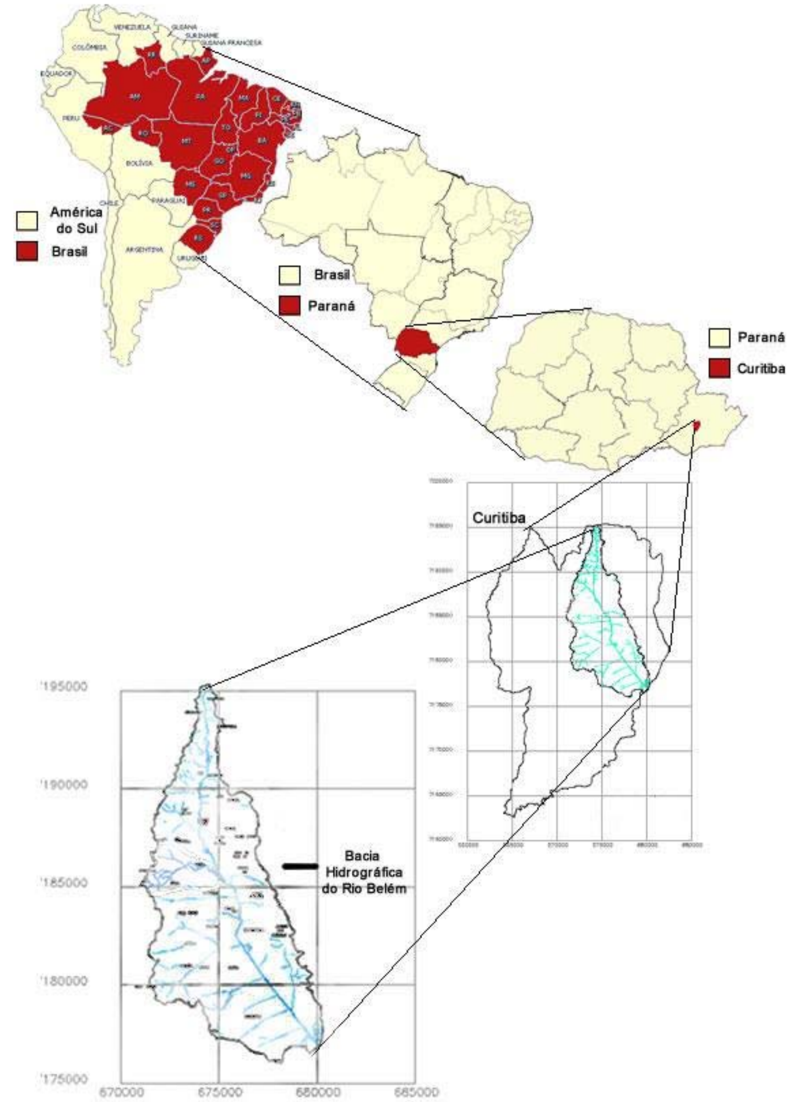


Figure 2: Belém River's watershed localization

Data collection was divided into three stages. The first step was to obtain the time series through consultation with the Water Institute of Paraná (IAP) where the data of all collections made in chronological order was available, from 1983 to 2011, at the point PUC Prado Velho, including parameters that comprise the Index of Water Quality. The second step was to search for images (orthophotos) of historic occupation of the study area (PUCPR) and the status of riparian vegetation found in the database of the IAP. The third step was to compare the theoretical aspects presented by some scholars regarding what would be the appropriate banks of a river (natural) and anthropic banks of a river (artificial).

For purposes of understanding the result, the images were classified according to the perception of the development of riparian vegetation. The vegetation was defined and classified proportionally, considering the continuity and density. The possible ratings are: low, medium low, medium, medium high and high.

Figure 3 references points where the water was collected to generate the time series (Point PUC - Prado Velho) and provides insight into the development of riparian vegetation and urbanization in the region dating back to the year 2009/2010.

Figure 3: Point of collect – PUC – Prado Velho

The PUCPR, the institution that houses the study area, is located on the banks of the Belém River and conducts environmental education projects for the recovery of the river through volunteer work of students of institutions and public. These projects include the revitalization of riparian vegetation by planting native trees and joint efforts for river cleaning, aiming at the removal of solid waste. In addition, the project titled "My River, My Life" organized by the International Federation of Catholic Universities with support from the Araucaria Foundation offers workshops and debates about the topic. Figure 4 is from the year 2012 and shows the evolution of native vegetation recovered on the banks of the stretch.

Figure 4: Riparian vegetation and urbanization in 2012 – PUCPR

With the use of orthophotos of IPPUC (Institute for Research and Urban Planning of Curitiba) the absence of riparian vegetation around the river in the area of the University in prior periods and the evolution of the urbanization process in the region was observed. Figure 5 (date 1969) explains the situation of the vegetation at that time.

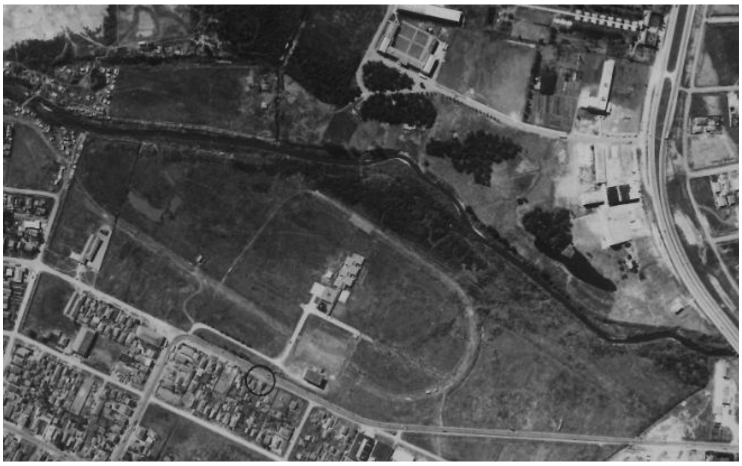


Figure 5: Riparian vegetation and urbanization in 1969 – PUCPR

3. RESULTS

3.1 Perceptive analysis of orthophotos in relation to ideal theoretical profiles

For this research, it has been considered that natural conditions are those defined by the watershed characteristics in its natural state. Some of them stand out: basin geometry, relief/slope, soil type, vegetation cover, precipitation type, drainage capacity and density (TUCCI, 2001). The artificial conditions are those provoked by men's actions, such as: urbanization, hydraulics structures, deforestation, reforestation and agricultural use of the land. Therefore, the various processes, the human and natural ones, are intimately related to the hydrologic dynamic of the rivers.

Figure 6 presents a schematic profile of what would theoretically be an ideal model of occupation of a river margin and perfect working of the involved cycles in basins under natural conditions. Figure 7 shows a schematic profile of a river with urbanized margins, mainly demonstrating the influence of this model land use/land cover in the dynamics of water supply and storage in the underground level and the relation to floods, caused by soil sealing, with the increasing of run-off (artificial conditions).

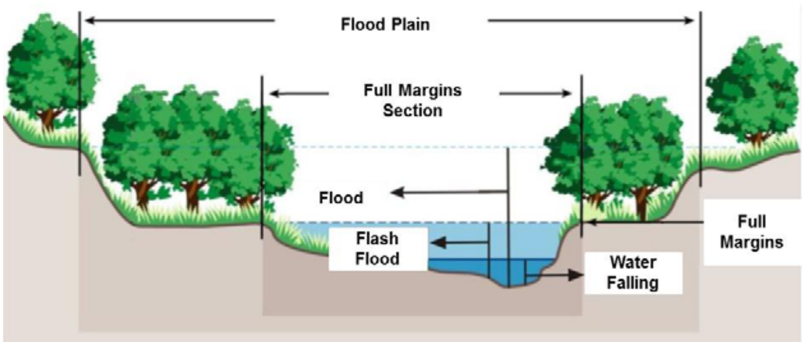


Figure 6: Ideal margins of a river (natural)

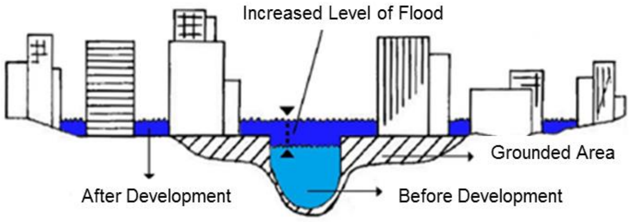


Figure 7: Men-altered margins of a river (artificial)

Through the interpretation of the Figures 8 to 12 it is possible to observe in a chronological way the evolution of the urbanization process and of the suppression or insertion of riparian woods in the study area during the period of 1980 to 2008 The quality of the figures varies from one orthophoto to the others, as well as the precision. For this reason the assessment can only be done in a perceptive way.

Figure 8: Riparian woods and urbanization PUCPR - 1980

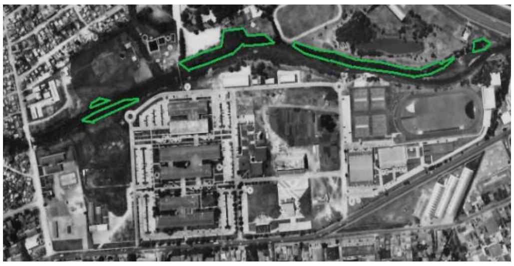


Figure 9: Riparian woods and urbanization PUCPR – 1985

Figure 10: Riparian woods and urbanization PUCPR - 1990

Figure 11: Riparian woods and urbanization PUCPR – 2000

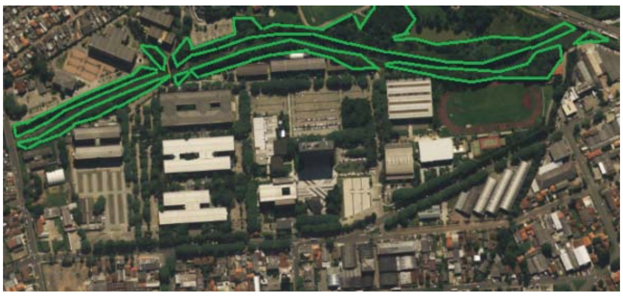


Figure 12: Riparian woods and urbanization PUCPR – 2008

Trying to obtain a model of classification that doesn't benefit the analyzed moments, has been taken into account it uniformity of vegetation through the section and bulk density of vegetal masses. The following classification was adopted: Inexistent, Low, Medium-Low (ML), Medium, Medium-High (MH) and High. It is emphasized that the classifications don't refer to the ideal model, as demonstrated in Figure 6, which works only as an aiming object, but to the changing scenario of the assessed region in a perceptive way by the authors.

In figure 8, of the year 1980, it is possible to notice the discontinuity of the riparian woods through the section of the Belem River, being presented in small, isolated portions. In a perceptive way it can be classified as LOW.

In Figure 9, of the year 1985, it is possible to notice the riparian woods in a more continuous shape through the section of the Belem River. In a perceptive way it can be classified as MEDIUM-LOW.

In Figure 10, of the year 1990, a significant increase of the riparian woods has occurred, initiating an increase of the vegetation density of the margins of the section of Belem River. In a perceptive way it can be classified as MEDIUM.

In Figure 11, of the year 2000, the interactions come from the campus construction were already finished. The riparian woods show a good capability of recovery.

In Figure 12, of the year 2008, it is possible to notice a bigger uniformity of the vegetation through the section as well as the increased density of vegetation. In a perceptive way the vegetation can be classified as HIGH.

In Table 1 it is essential to understand the evolution of the riparian woods growth, assessed in a perceptive way year-to-year.

NUMBER	ORTHOPHOTO	EVALUATION
1	1980-1985	LOW
2	1985-1990	MEDIUM-LOW
3	1990-2000	MEDIUM
4	2000-2005	MEDIUM-HIGH
5	AFTER 2005	HIGH

Table 1: Evolution of the riparian woods.

3.2 Water Quality Diagnoses

For the diagnostic raising of the influence of the riparian woods in water quality, the data from the IAP – Environmental Institute of Parana State – were used. The historical series embraces the period of 1980 to 2008, which reflects the necessary time to assess the improvement of water quality in the study area with riparian woods, after revealing the sections through projects or joint efforts and without riparian woods due to deforestation of the area by urbanization.

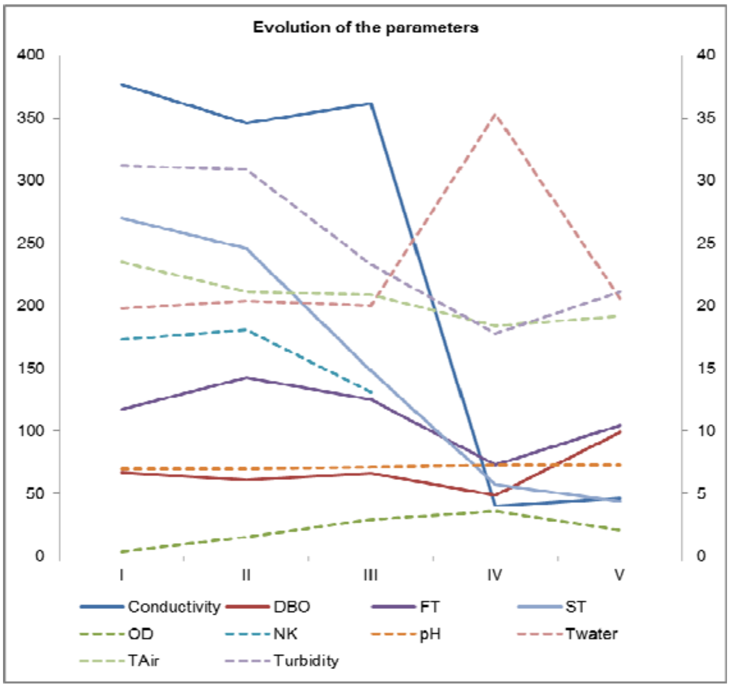
The historical series was divided in periods of I to V, and for different parameters, for better visualization and tabling the data. The parameters of water quality considered for the research were: Conductivity (Cond), Biochemi cal Demand of Oxygen (DBO), Chemical Demand of Oxygen (DQO), Total Phosphors (FT), Kjeldah Nitrogen (NK), Dissolved Oxygen (OD), Hydrogenionic Potential (pH), Total Solids (ST), Water temperature (TAgua), Air temperature (Tar) and Turbidity. They were treated and grouped.

The process of collecting is susceptible to the occurrence of error by various factors. When using a historical series, it is important to verify the consistence of obtained information to avoid altered results. This way, the values of CF and CT were unconsidered for having few records. The monitored registers and the occurrence of the values of OD, DBO and DQO which have shown results out of the pattern were considered as “chemical impossibility” and were also not used for the mean calculus, avoiding result alteration. Table 2 presents the synthesis of the data grouped by period and parameter and relates classification of water quality by period.

P	Classification	Cond	DBO	FT	NK	OD	pH	ST	TWater	TAir	Turbidity
Unity	-		mg/L			mg/L	-	mg/L	ºC	ºC	UT
I	LOW	376,8	66,8	117,2	17,3	0,4	7,0	269,8	19,8	23,5	31,2
II	ML	345,7	60,8	142,4	18,1	1,5	7,0	245,7	20,4	21,1	30,9
III	MEDIUM	361,6	66,5	125,1	13,1	2,9	7,1	148,0	20,0	20,9	23,3
IV	MH	40,4	48,9	73,1		3,6	7,3	56,9	35,3	18,4	17,8
V	HIGH	46,0	99,01	104,5		2,1	7,3	43,5	20,6	19,2	21,1

Table 2: Data synthesis

For a better visualization of the evolution of the analyzed parameters, the Graph 1 was built, where the x-axis represents the period of analysis (from I to V) and the y-axis the values obtained in the analysis. The continuous lines correspond to the values left (0 to 400) and the dashed lines to the values right (0 to 40).



Graph 1: Evolution of the parameters

It was possible to verify that the conductivity indicates a significant improvement of water quality and that the total solids show a decreasing of suspended solids during the last two periods, where the vegetation was considered medium and high, with values from 50.00 mg/L and 48.00 mg/L, respectively.

The DBO had a little decreasing on concentration, with a small oscillation during the implementation of the riparian woods, still classified as MEDIUM. The DQO highly varied, showing itself inert to the gradual development of vegetation. This result may be characteristic of high rates of organic material coming from the throwing of effluents beyond the capacity of assimilation of plants and river.

There was a reduction of the turbidity from the mean vegetation, decreasing in IV period, followed by the increasing in the end of the series, with values from 23.00 mg/L, 18.00 mg/L and 21.00 mg/L. It is possible to observe that OD has high interaction between riparian woods and water body, representing the process of vegetal evolution. It is possible to notice the increase of dissolved oxygen with the increase of vegetal cover.

The increase of was observed of the concentration of phosphorus, even with the development of the riparian woods, this variation of the concentration rate indicates the occurrence of oxidation, from the decomposition process of organic material. As for Kjedal nitrogen, the data is incomplete due to the lack of records, and errors found in the historical series, however it is possible to observe a decrease of concentration, one cannot say that this decreasing is derived only from riparian woods.

In the variation of the pH parameter, it is possible to notice a pattern of neutrality of the water. In this section the parameter is consistent with other surveys in urban rivers.

4. FINAL CONSIDERATIONS

With a perceptive evaluation of obtained orthophotos, it was possible to evaluate the gradual development of riparian woods along the section of Belem River. The data obtained from monitoring points was essential to characterize the water quality of the section, the object of study.

The development of a method for classification of the quality of riparian woods was one of the key points for obtaining results in this study, comparing the classification of riparian woods with the average concentration of each parameter.

It concludes that with the method used, the riparian vegetation caused a considerable effect on some specific parameters such as conductivity, total solids, turbidity and dissolved oxygen. The results made it possible to identify the function of biorretention, being possible to classify the existing riparian woods as a Best Practice Management - BMP, considered the most effective actions to control pollution. It is important to note that when observing the graphs of DBO and DQO, the influence of pollution diffuse in Belem River can be noticed, indicating contributions of effluents far above the carrying capacity that the vegetation provides in the section of PUCPR.

In this situation, it is suggested to establish stricter control systems for clandestine domestic sewage discharge *in natura* present in the storm sewer and the industrial effluents must receive the same stringent control in the treatment processes before released in water bodies.

The ability of biorretention and increased water quality would be maximized if the riparian woods extended over long sections of urban watersheds, as linear parks or ecological corridors also helping in harmonious landscape of large urban centers.

The importance of riparian woods in urban rivers must be highlighted, when considering flood containment. They reduce runoff and flood containment, attenuating high flows when the water rises above the river channel and is attenuated by vegetation. The larger the area of riparian vegetation, the greater the ability to reduce runoff and mitigate floods will be, highlighting the need to preserve existing forests and encourage the reestablishment of those which are degraded .

The PES (Payment for Environmental Services) can be seen as an incentive to maintain riparian basins not only in rural but also in urban watersheds. The PUC - PR projects developed for the recovery of riparian vegetation in the section of Belem River where the campus is located. This type of action could be the object of study in applying the PES mechanism in urban basins, besides serving as encouragement and advertisement for this action to occur in other institutions or even be part of new urban planning projects.

Finally, it is important to stress the need to increase the number of monitoring points in the section of Belem River, the calibration of the measurement equipment parameters and to clearly organize the results as a way to get quality trends and scenarios for water in the study area, so that it is possible to propose improvements with regard to water quality.

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