

URBAN PLANNING BASED ON WATERSHEDS: FROM THEORETICAL DEBATE TO MUNICIPAL MANAGEMENT

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Introduction

The incorporation of environmental variables into urban planning has promoted the inclusion of alternatives for managing and evaluating land use and occupation; highlighted among these is management by river basin. As emphasized by Bevilacqua (2012), adopting the hydrographic basin as a territorial planning unit implies recognizing that anthropic actions and resulting degradation takes place according to these spatial demarcations.

In Brazil, Code 9,433/97 created the National System of Water Resources (SNRH), formalizing participatory watershed management through an institutional model centered on regional decision-making bodies (watershed committees) where federal, state, and local authorities participate alongside civil society organizations and users of water resources. Operationalization of the system is the responsibility of the water agencies, which act as executive secretaries for the committees, and potential conflicts between contiguous watersheds are resolved by the National Water Resources Council, where the federal government has the highest authorityⁱ.

According to Cardoso (1994), from the late 1970s a new theoretical and political conjuncture arose which was partly founded on criticism of the ideals focused on nationalism and developmentalism, which had been espoused since 1964. At the same time, the modernization achieved during the previous period expanded trade union movements and social movements, creating demands for responsibility related to the benefits incurred by state action. This emphasis on social issues began to dominate the urban discussion. This author indicates the new standard that is adopted for interpreting the urban problem, where “the discussion is no longer creating the ideal city, but efficiently managing the existing city, eliminating the pockets of ‘distortion’ deriving from the ‘dysfunctions’ of economic growth” (CARDOSO, 1994, p. 85).

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Within this context, legal planning instruments have been established in anticipation of correcting these dysfunctions and, at the same time, meeting new social demands. The three laws guiding urban policy in this period were Complementary Code 14 of 1973, which created the metropolitan regions and established the rules for metropolitan planning, Code 6766 of 1979, which addressed land division for urban purposes, and Code 6803 of 1980, which established the basic guidelines for industrial zoning in critical areas for pollution.

From the 1980s, society organized itself around the idea of urban reform, and in 1983 Bill 775 was generated, proposing the regulation of urban devices to support urban policies at the federal, state, and municipal levels. This project originated in the National Council for Urban Development (CNDU), which is linked to the Ministry of the Interior. The discussion of urban reform took shape, featured significantly in the drafting of the 1988 Constitution, and continued to be organized over the next few years, resulting in Code 10,257/2001.

The 1988 Federal Constitution established regulations for urban development in Chapter II on urban policy, which established that the federal sphere was responsible for providing general urban policy guidelines “to be executed by the municipal authority”, in addition to establishing guidelines for urban development including housing, basic sanitation, and urban transport.

The City Statute, approved in 2001 under Code 10,257, regulated articles 182 and 183 of the Federal Constitution and established the general guidelines for urban policy. Approval of this law granted new powers to the municipalities in order to more fully carry out the social functions of the city and of urban property.

The main changes brought about by the City Statute were obligatory popular participation in the planning process, reaffirmation of the mandatory nature of the master plan (which was already expressed in the Constitution), and the extent of planning for the entire municipal territory and not just urban areas, which had previously been the case.

Article 2 of the City Statute established general guidelines for urban policy with the introduction of the concepts of environmental sustainability, democratic management, and the establishment of special standards for land regularization and regularization of areas occupied by the low-income population.

Returning to the watershed, the principles guiding these new concepts can be summarized as follows:

The watershed is an appropriate spatial scale for evaluating the impacts current urban occupation and new urbanization projects have on hydrological processes and diffuse pollution loads;
New ventures cannot aggravate or compromise the functions of pre-existing drainage systems, and should take into account overall urban land use planning, including future urban projects;
Rainwater runoff systems should have multiple and complementary objectives, combining control of floods and diffuse pollution with the creation of green areas, recreational spaces and sports practices whenever possible;

Environmental protection and, in particular, the value of bodies of water in the urban context must be made compatible with the functional goals of runoff control and reducing risks to health (MCIDADES, 2004).

In the state of Paraná, the agency responsible for management of water resources (the Paraná Water Instituteⁱⁱ) and the State Public Ministry have begun to require municipalities to prepare municipal water resource management plans in order to reconcile two objectives: [I] quality and control of water use (legislated by watershed plans) and [II] the use and occupation of municipal land (legislated by the Municipal Master Plans).

The overlap between these goals, transformed into a municipal management instrument, is the challenge of these plans, so that watershed management can act as an instrument to monitor land use and occupation, based on environmental and man-made indicators allowing assessment of the situation in the watershed.

This poses a series of challenges to public managers, to develop a system that consistently marks public performance. In this context, the first challenge involves the diagnostic stage, where the current panorama of territorial demarcation is analyzed in detail with regard to watershed quality, hydrological balance, and distribution of anthropic activities and their resulting effects. A key question emerges: how to properly evaluate the watershed areas on the municipal scale?

In keeping with this question, this article presents a project undertaken together with the municipality of Rio Negro in the state of Paraná, where an analytic instrument was built, adapting to the assessment variables which are required for this function (a restricted capacity, as a rule) for small municipalities to collect and handle environmental data. Therefore, the ultimate objective was to demonstrate the feasibility of implementing a system to monitor the use and occupation of municipal land, using watersheds as the basic unit of planning.

This article is structured in three parts, namely: the first, in which the methodology is described, the second, in which the indicators obtained for the pilot study in the municipality of Rio Negro are presented, and the third, which presents conclusions about the study evaluating the quality of the watersheds.

Watershed as a planning unit: methodology for diagnosis

The diagnostic for municipal water resources, drawn from the systematization of available information and environmental quality assessment, was built to generate the necessary instruments for formulating environmental monitoring indicators for the municipality's urban and rural areas.

The watershed was adopted as a planning unit, a fundamental delimitation for creating plans and projects to conserve or preserve water (CASTRO, 2005). Cunha and Guerra (2003) corroborate this, stating that adoption of the watershed as a planning unit allows environmental and anthropic issues to be integrated in an appropriate territorial demarcation, helping to overcome a departmentalist visionⁱⁱⁱ which continues to persist in public management.

To understand the watershed as a territorial unit, the classic concept that only defines drainage and its connections as the network cannot be adopted. Instead, it is necessary to understand it as a space composed of a set of physical, biological, social, and political elements which interact with each other, modifying the entire system. For Santos (2004, p. 85), every event in a watershed, natural or anthropic, “affects the dynamics of this system, in the amount of watercourses and their quality. Measuring some of these variables allows the sum of these events to be interpreted, at least partially”.

Recognizing the watershed as a system implies accepting that everything which happens within it directly or indirectly impacts the rivers and water quality, consequently affecting all the other elements that comprise this system (CASTRO, 2005). In this way, the diagnostic will only be consistent when analysis of the isolated parts is added to analysis of interrelationships, fully encompassing the holistic analysis of the basin.

The adopted methodology is based on the combination of quantitative and qualitative data, using the sum of both to obtain the current scenario of the watershed. As shown by Dorney (1989), this scenario can indicate appropriate and inappropriate uses of the land and its resources. According to this author, the result of this step also allows trends to be identified, permitting the simulation of future scenarios and predictions of possible corrections for negative trends. In this way, the definition of the desired scenario directs the policies and management guidelines for a given basin.

In order to construction the diagnostic, the natural and man-made elements that impact water quality were identified. Von Sperling (1996) briefly described the influence each of these aspects has on the quality of water resources:

- Environmental Aspects: even with the watershed preserved in its natural condition, water quality is mainly affected by runoff and infiltration into the soil as a result of atmospheric precipitation. The impact on the quality of this water is directly related to the contact runoff, infiltrated water, and percolated water have with particles and substances in the soil;
- Anthropic Aspects: man-made interference generates impacts on water quality both in the form of concentrated releases of effluents (generation of domestic or industrial waste), and in the dispersed form of surface runoff (diffuse load). Therefore, the way in which people use and occupy the land has a direct impact on water quality.

The common characteristic of these variables, according to this concept, is the impact on the water balance^{iv} in the watershed, with direct effects on the ecosystems that depend on it. This choice requires a careful selection process, because as Martínez warns (2004), the failure of a particular diagnostic method and environmental monitoring often results from selecting a very large number of variables.

The time available to design and implement an indicator is always limited. Therefore, there needs to be a minimum consensus on the

most important variables and their behavior, grouping them to avoid excessive details, with a level of interrelationships that would impede a bird's-eye view of the phenomenon. [...] Global experience seems to show that it is more functional to start from a prior conceptual framework that the group considers acceptable, which addresses a sufficient but not excessive level of variables; this framework is then adapted, modified, and simplified (MARTÍNEZ, 2004, p. 262-263).

Therefore, starting from extensive bibliographical research and a survey of the information available from federal, state, and municipal agencies, we chose the qualitative variables with the greatest impact on the watersheds, which were validated together with the municipal technical team to confirm the feasibility of collection (Table 1).

Table 1– Selected quantitative variables with the greatest impact on the water balance within watersheds

	Topics		Selected Variables
Natural Environment	Physical	Water	<ul style="list-style-type: none"> ▪ Water Quality ▪ Use of Water Resources
		Soil	<ul style="list-style-type: none"> ▪ Excessive Impermeability ▪ Inappropriate Land Management
		Air	<ul style="list-style-type: none"> ▪ Excessive Pollutant Emissions
	Biological	Fauna	<ul style="list-style-type: none"> ▪ Alteration of Habitats
		Forest	<ul style="list-style-type: none"> ▪ Forest suppression ▪ Level of Preservation of Riparian Forests
Anthropic Environment	Urban	Land Use and Occupation	<ul style="list-style-type: none"> ▪ Generation of solid waste with inappropriate disposal ▪ Generation of sewage with inappropriate disposal ▪ Generation of industrial effluents with inappropriate disposal ▪ Occupation of unfit areas (valley bottoms, slopes, and wetlands)
	Rural	Agricultural Activity	<ul style="list-style-type: none"> ▪ Generation of waste with inappropriate disposal ▪ Indiscriminate use of agrochemicals with inappropriate disposal

Source: the authors.

For the quantitative assessment of each micro-basin, the land was classified according to the specific types of land use, namely: remnants of native vegetation, wetlands, reforestation, urban centers, and other anthropic uses.

We used LandSat 5 satellite images, which were provided by the National Institute for Space Research (INPE). With a 16-day revisit time and 30m resolution, processing of the data collected made it possible to obtain up-to-date images, avoiding any delays between the available data and the current situation. Additionally, free access was an extremely important criterion in choosing the type of image, since it allows public ma-

nagers to update diagnostics according to the frequency desired, without incurring costs to acquire updated imagery”.

The outlines of the typologies described above were demarcated on the satellite image with RGB composition in the 2/1/3 bands, at a 1:50,000 scale, determined on the basis of the definition of the image used. The percentage and the type of coverage in areas of permanent preservation (APPs) were also calculated, permitting the need for restoration in degraded areas to be assessed, as well as identification of APPs transformed into grazing areas or invasion by exotic species. To this end, in addition to the LandSat image, vectorial data related to hydrography, political divisions, and contours were also required, and were provided by the municipality of Rio Negro.

Pilot study: municipality of Rio Negro, Paraná

The municipality of Rio Negro is located in the south of the state of Paraná in southern Brazil; it is 604.14 km² in size and has 31,274 inhabitants (IBGE, 2012). Its urban occupation is characterized by the conurbation it shares with the municipality of Mafra in the state of Santa Catarina; together, this urban agglomeration has about 80,000 inhabitants. The administrative boundary between the two cities is the Rio Negro river.

In 2006, the municipality of Rio Negro revised its master plan for urban development (PDDU) in order to comply with the City Statute (Federal Code 10,257/2001). Since the ratification of the City Statute, the municipal master plan has become an instrument for strengthening implementation of municipal policies to protect water resources, as it defines the guidelines for use and occupation of municipal land for the ten years following its approval.

In this way, the preparation of the municipal plan for water resources management in Rio Negro was mainly aimed at integrating and creating compatibility between the master plan’s urban development policies and the guidelines of national and state water resource policies in order to introduce a system to monitor, preserve, and conserve water resources into the municipal arena.

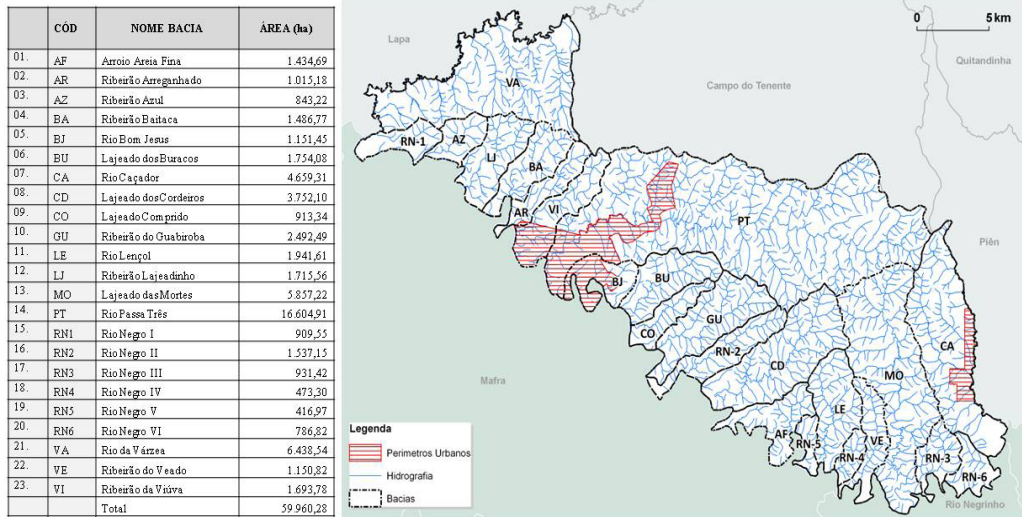
Starting from the proposed methodology, the information collected was systematically organized according to the municipality’s hydrographic network, which was divided into 23 micro-basins. One of these belongs to the Várzea River watershed, while the rest pertain to the Rio Negro basin.

The Rio Negro is the most important river in the municipality, as 96% of municipal water courses are part of its drainage basin and it supplies water to the central district. The headwaters of the Rio Negro are found in the Serra do Mar range near the Atlantic Ocean. The river runs from east to west, and is approximately 300 km long. The river suffers environmental impacts before it passes through the city, because of the lack or precarious nature of basic sanitation in the urban areas upstream. However, because the urban nuclei that exist within the basin are scattered, “this distribution favors the processes of dilution and processes self-purification of water courses” (SDS, 2006).

The river has had two major floods: one in 1983 and another in 1992. With regard to water quality, the Environmental Institute of Paraná (IAP) classified it as class 02, in other words, its water can be consumed as long as it is properly treated.

Another highlight is the Passa Três River, a tributary of the Rio Negro, which flows for approximately 30 km within the municipality and has strategic importance, since it is considered a future public water source to supply the central district of the city. Its watershed is contained entirely within the municipality, which allows the quality of its water to be maintained through municipal preservation policies. The figure below lists the twenty-three municipal watershed basins, along with their area.

Figure 1 – Municipal Watershed Basins



Source: the authors

The systematization of collection of data related to the micro-basins followed a cataloging standard, providing the initial data to create a municipal geographic information system (SIG) and allowing monitoring of water resources^{vi} (Figure 3).

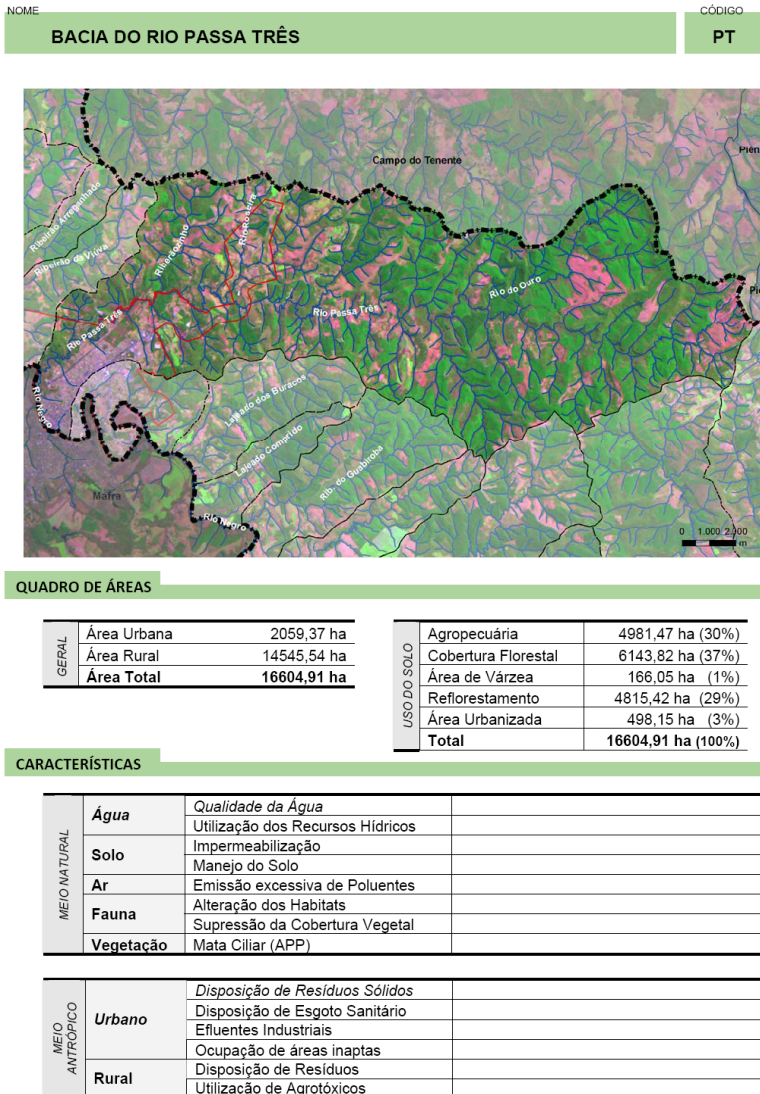
Systematized organization of the results

Although the systematized organization of the data by micro-basin provides detailed and individual characteristics for each one, it does not provide an understanding of the whole. As stressed by Van Bellen (2006), the aggregation and use of composite indexes are fundamental to creating diagnostics and comparisons between the main trends involved in environmental policies.

One of the goals in synthesizing the data collected was to relate the values obtained in the charts for each of the micro-basins, grouping them according to the similarity between them for each variable. Afterward, the classification was made in ascending order by variable analyzed (percentage of APP preserved, for example), which allowed the identification of trends and the most critical situations within the land area studied.

As an example of the findings using the classification of the basins according to the percentage of native vegetation present, Basins AR, BU, LE, RN-4, VE, and VI stand out^{vii}, with between 45% and 56% of their land exhibiting forest cover.

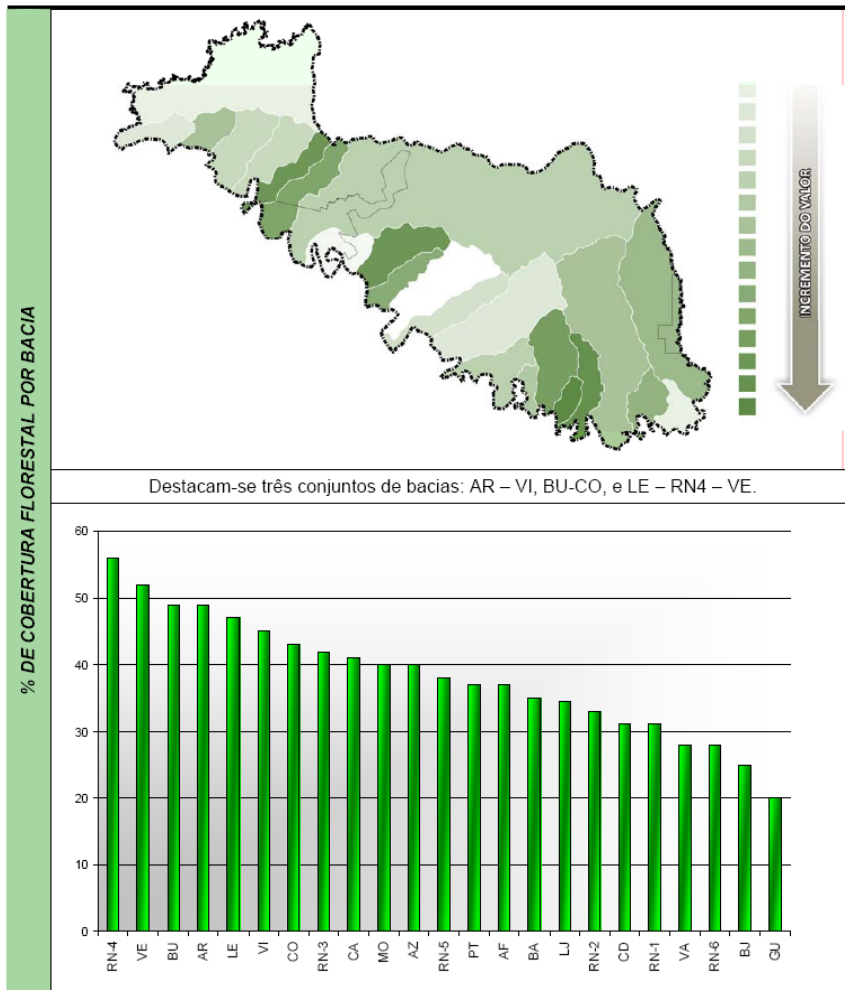
Figure 2 – Model for Systematizing the Data, using charts



Source: the authors

Through aggregation, the data collected by micro-basin were classified into distinct categories, according to the identification of patterns of land use and conservation of areas of permanent preservation.

Figure 3 – Classification of the Basins According to Percentage of Native Vegetation.



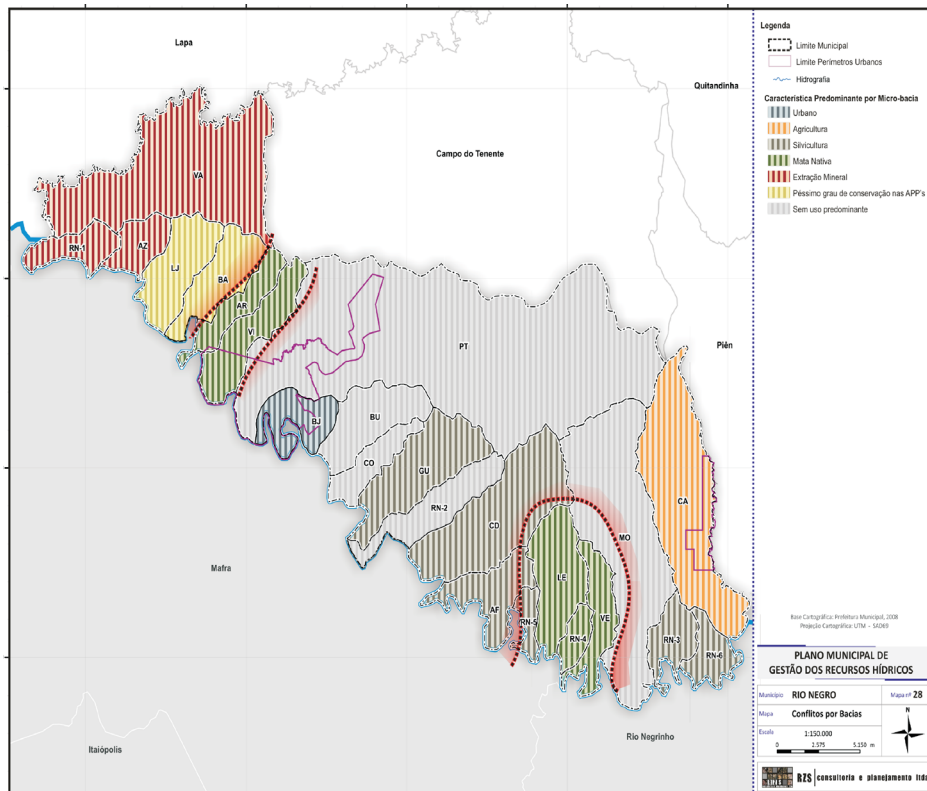
Source: the authors

The twenty-three micro-basins were divided into four distinct categories: (1) Basins with a large percentage of land occupied by forestry activities, and showing the advance of these activities on APPs; (2) Basins where areas destined for other uses stand out, such as urban occupation, agricultural activities, and mineral exploitation; (3) Basins containing a large percentage of native forests, including those where APPs were highly conserved; (4) Basins with less than 50% of native forest preserved in APPs, where problems conserving this resource are seen. Those basins that are not included in any of the groups mentioned do not have a predominant characteristic, and instead feature a mix of uses within their land.

This classification allowed us to identify the main conflicts in the municipal land by micro-basin. The group of basins that featured a large percentage of forest cover in their land (LE + RN4 + VE) is located between two major groups ([FFA + CD + RN4] and [RN3 + RN6]), which in turn are characterized by intensive forestry activities. The advance of this activity in these areas can reduce native forest, impacting fauna, flora, and the quality of water resources in the region. The group [AR + VI] stands out for its high percentage of forest cover. Located in the western area of the urban perimeter, this group includes the buffer zone for the São Luiz Tolosa eco-tourism park^{viii}.

It is also evident that the group of basins located in the northwest of the city (VA + RN-1 + AZ) is characterized by sand extraction activities on the banks of the watercourses. Adjacent to this set of basins, the group [BA + LJ] is characterized by a low degree of conservation of APPs, with less than 50% of native forest. Also worth highlighting is basin VI of the Rio Negro (RN-6), which not only features reforestation activities in a large portion of its area, but also has APPs in very poor states of conservation; 54% of these areas do not have native forest. The spatialization of conflicts by basin can be seen in the figure below.

Figure 4 – Classification of Municipal Micro-Basins According to Predominant Characteristics



Source: the authors

Final considerations

Based on the analysis of the results obtained, it was possible to make some recommendations to the municipality which are basically structured along two lines of action: (I) operational, aimed at recovering areas that are currently undergoing degradation, and (II) institutional, aimed at regulating water resource management by the municipality. The proposed regulations sought to integrate and create complements between land use (municipal sphere) and water management (state and federal spheres).

Continuous monitoring of land use and occupation involves a geographic data system by river basin, which allows both municipal water quality control and the establishment of flexible urban parameters that guide land use and occupation by establishing the appropriate urban density for each basin. From a viewpoint of rural activities, it is similarly possible to define guidelines for occupation and to propose the creation of biodiversity corridors by integrating existing preservation areas. In this way, urbanistic control and environmental control become connected through the watersheds, which are understood as municipal management units, complying with relevant legislation and creating more sustainable urban environments.

The key role of public managers in this whole process should be emphasized. Implementing the environmental monitoring system is a nod toward a positive outlook related to the transformation of public managers, who guide their activities according to the precepts of sustainable development, recognizing the interdependence of departmentalized services and the inevitability of integration.

Overcoming the disciplinary barrier requires a transdisciplinary environmental model, which is very similar to the construction of environmental knowledge proposed by Henrique Leff (2001). For this author, it is not possible to respond to the complexity of environmental problems and consequently seek sustainable development without transforming the systems of knowledge (sciences), values (wisdom), and behaviors generated by current social rationality. To this end, it is necessary to pass from social awareness of environmental problems to the production of new knowledge (LEFF, 2001).

However, such a cultural shift is not undertaken instantaneously, nor does it occur in a fully explicit manner. In this context, the words of Santos (2002, p. 168) are relevant; when dealing with the process of awareness, this author states that “the individual discovery is already a considerable step forward, even though it may seem a painful to the person who bears it, to the extent that resistance surrounds this new way of thinking”. The key, as Miller recalls (2007), is to recognize that most changes are the result of individual actions, and individuals acting together to promote them.

Notes

- i The model that inspired SNRH was established in France in 1964, organizing the country into six large river basins. Within each basin, a water agency and a committee were created; this committee was composed of representatives of the “collectivités territoriales”, representatives of the users and the government.
- ii Previously, the Superintendent of Water Resources and Environmental Development (SUDERHSA).

- iii Contrary to the disciplinary vision which is specific to the division of scientific specializations in the 19th century, environmental problems brought with them the construction of a paradigm of complexity, showing the limitations of the previously established model in dealing with social and environmental demands (FLORIANI, 2004; LEFF, 2001).
- iv This is defined as the circulation of water in its various states on Earth, through its transfer mechanisms such as precipitation, runoff, infiltration, evaporation, and transpiration.
- v Corroborating this position, Martínez (2004, p. 253), stresses the “importance of appropriate and true [environmental] data for decisions [...]. Methodical and stable production of environmental and ecological information and knowledge does not only result in benefits, but also in investment and operating costs”.
- vi In the words of Van Bellen (2006, p. 42), “the most desirable indicators are those that summarize or otherwise simplify the relevant information, making certain phenomena that occur in reality become more apparent, something that is particularly important in environmental management”.
- vii These codes are presented in Figure 1.
- viii This is a 54 ha full-protection conservation unit created by city ordinance 061/05 in 2005 to preserve a significant fragment of a forest with Araucari

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URBAN PLANNING BASED ON WATERSHEDS: FROM THEORETICAL DEBATE TO MUNICIPAL MANAGEMENT

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Resumo: Os debates a cerca da conservação e preservação dos recursos hídricos tem se tornado recorrente nos estudos urbanos, visando a compatibilização do desenvolvimento urbano com a manutenção da qualidade e controle do uso da água. Estes objetivos, transformados em instrumental de gestão municipal, se traduzem nos Planos Municipais de Recursos Hídricos (PMRH), que passaram a ser desenvolvidos no Paraná desde 2008. Impõe-se assim aos gestores públicos uma série de desafios a fim de desenvolver uma sistemática que balize com consistência a atuação pública. Neste artigo procura-se apresentar a experiência do PMRH do Município de Rio Negro (PR), onde foi desenvolvido um instrumental analítico próprio, adequando-se as variáveis de avaliação necessárias à capacidade – via de regra, restrita – de municípios de pequeno porte em coletar e tratar dados ambientais. Tem-se por objetivo fim demonstrar a viabilidade de implementação de uma sistemática de monitoramento municipal tendo a bacia hidrográfica como unidade de planejamento.

Palavras-chave: Bacia hidrográfica;, Indicadores ambientais, Gestão ambiental.

Abstract: Debates related to the conservation and preservation of water resources has become recurrent in urban studies, focusing on an urban development compatible with maintaining the quality and control of water use. The overlap of these goals, transformed into an instrument of municipal management is the challenge of Municipal Plans for Water Resources (PMRH), which started to be developed in the state of Paraná since 2008. In this context, public managers face a series of challenges in order to develop a system that consistently balize public actions. This papers seeks to present the experience of PMRH in Rio Negro (PR), in which we developed an analytical instrument, adapting the evaluation variables required to the restricted capacity of municipalities in collect and process environmental data. The final objective is to demonstrate the feasibility of implementing a municipal systematic monitoring, with watershed as a planning unit.

Key-words: Wwatershed;, Eenvironmental indicators;, Eenvironmental management.

Resumen: Debates relacionados con la conservación y preservación de los recursos hídricos se ha tornado recurrente en los estudios urbanos, centrándose en un desarrollo urbano compatible con el mantenimiento de la calidad y el control del uso del agua. La superposición de estos objetivos es el reto de los Planes Municipales de Recursos Hídricos (PMRH), desarrollados en el estado de Paraná desde 2008. En este contexto, los gestores públicos se enfrentan a una serie de desafíos con el fin de desarrollar un sistema que Balize constantemente las acciones públicas. Este artículo pretende presentar la experiencia de PMRH en Río Negro (PR), en el que se desarrolló un instrumento analítico, adaptándose las variables de evaluación necesarios a la capacidad limitada de los municipios de recopilar y procesar datos ambientales. El objetivo final es demostrar la viabilidad de la implementación de un monitoreo sistemático municipal, con la cuenca como unidad de planificación.

Palabras clave: cuencas, indicadores ambientales, gestión del medio ambiente.
