OCCUPATION EVOLUTION ON PEQUENO RIVER WATERSHED – SÃO JOSÉ DOS PINHAIS - PR OVER 30 YEARS

Richardson Guenther SCHECHI, Maciel Paulino BATISTA,
Rita de Cássia BIANCHI, Rafael Zoboli GUIMARÃES, Nivaldo Eduardo RIZZI

Engineering Department and Forestry Technology Forest, Federal University of Paraná, Curitiba, Paraná, Brazil
*E-mail: engricardson@gmail.com

ABSTRACT: This study demonstrates the dynamics of land use in the Pequeno River watershed, São José dos Pinhais, PR. Within the watershed is an area of urban and industrial expansion in the metropolitan region of Curitiba. Using techniques of remote sensing and geographic information systems, land use mapping was completed for 1986, 1996 and 2007 years with the objective to identify the occupation dynamics on this watershed. The maps were generated by digital classification of Landsat 5 images. A growth of 19.98% was observed in the urban class and a 14.10% reduction in the swamp class.
Keywords: Land use, Geographic Information System.

EVOLUÇÃO DA OCUPAÇÃO DA BACIA HIDROGRÁFICA DO RIO PEQUENO - SÃO JOSÉ DOS PINHAIS – PR AO LONGO DE 30 ANOS

RESUMO: *O presente trabalho demonstra a dinâmica do uso do solo da bacia hidrográfica do rio Pequeno, São José dos Pinhais – PR que é uma área de crescente expansão urbana e industrial da região metropolitana de Curitiba. Através de técnicas de geoprocessamento e sistemas de informações geográficas foi realizado o mapeamento de uso do solo para os anos de 1986, 1996 e 2007 com o objetivo de identificar a dinâmica de ocupação desta bacia hidrográfica. Os mapas foram gerados por meio da classificação de imagens digitais Landsat 5. Foi observado um crescimento de 19,98% na classe urbano e uma redução de 14,10 % na classe várzea.*
Palavras-chave: *Uso do solo, sistema de informações geográficas.*

1. INTRODUCTION

As water uses are increasing today, it is necessary to understand the factors of how to sustainably manage this resource. In the past, hydrological studies in watersheds were generally developed based primarily on the need to understand the processes controlling water movement, the impacts related to land use change, water resources quality and water availability (WHITEHEADE; ROBINSON, 1993). Lang; Blachke (2009) reported the importance of updated data on land use needed for planning and decision making regarding natural resources utilization, especially when it is necessary to facilitate the diagnosis of a particular area current status or region.

The study of land use is important because often rural areas have conflicting about it. In this context, an important aspect to be analyzed is the study of the land use dynamics in a watershed. In certain points of the catchment basin there are areas that are capable of providing water flow to these points and are influenced by topography (FLORENZANO, 2008). The most expressive legal instrument to regulate land use in Brazil is the Forest Code established by Federal Law n° 4.771/65 and CONAMA Resolution N° 303/02, both are responsible for establishing the concept of Permanent Preservation Areas (APPs). Even though riparian zones occupy only a small percentage of the basin area, they are extremely important components in ecosystems understanding (CHECCHIA, 2003).

Because of its proximity to watercourses, the riparian zones present intense hydrological activity (GUIMARÃES, 2000) and perform their hydrological function by generating direct runoff, maintaining water quantity and quality, nutrient cycling and sustaining the aquatic ecosystem (LIMA, 2008). These zones are regions where the terrain tends to be flat and the soils are shallow and influenced by the watercourses and groundwater which results in water storage conditions generally close to saturation and therefore have relatively low infiltration capacity which is further reduced during the intense rainfall events (GUIMARÃES, 2000).

The study of the interactions between slope, soils and land use in the watershed can be assessed using geoprocessing because it is possible to store and manage the data quickly and accurately, as well as allow the identification of priority areas to environmental degradation and evaluation of management strategies before they are implemented (PINTO et al. 2005). The Pequeno River watershed, due to its location, is greatly impacted by residential and agricultural development. In addition to development, the watershed has been under a

continuous process of environmental degradation caused by agricultural activities, automobile traffic, recreation, and other activities. Because of this degradation, it is possible that the minimum environmental protection condition may be lost (SANTOS; BERTOTTI, 2009).

Within this context, the present study suggests the use of Geographic Information Systems (GIS) to analyze the dynamics of land use in the Pequeno River watershed, using Landsat 5 TM images taken for three different scenarios, 1986, 1996 and 2007.

2. MATERIAL AND METHODS
2.1. Characterization of the study area

The study area contains the Pequeno River watershed (Figure 1), belonging to the Upper Iguaçu basin. Its source is located in a region known as the Watersprings Mountains (in the western portion of the Sea Mountain Range top) which crosses to the north of São José dos Pinhais to the east of Curitiba in Paraná state. It is bordered to the north by the Itaquí River watershed and the Miringuava river watershed to the south. To the east, it is bordered by the steep section of the Sea Mountain Range and to the west by the Iguaçu River. The main drainage of the watershed moves from the east to the west. In its southwestern portion, near the urban area of São José dos Pinhais, it presents the major focus of urban expansion in the metropolitan region of Curitiba. About 57% of the basin watershed is considered an environmental protection area (Pequeno River's State APA), entirely in São José dos Pinhais and part of the water resource plan of the Upper Iguaçu basin (SANTOS; BERTOTTI, 2009).

This watershed is an important water source for public, industrial and agricultural uses, covering an area of 134 km². The watershed areas chosen to study are taken due to their variety of features, from high regions, which are typically located within the springs that create creeks and streams, steep areas where water flows faster, and lowland areas where it is often possible to observe the consequences of inadequate management done at higher altitudes (PIROLI, 2002).

2.2. Methodology

The goal of the satellite image analysis is the identification and spatial location of different land use types that occur in the Pequeno River sub-watersheds in each observed period. The typologies adopted for vegetation classification were based on recommendations of Brazilian Institute of Geography and Statistics - IBGE (Table 1). Multispectral Landsat 5 - TM images , orbit point 220/78 taken in 4/1986, 6/1996 and 8/2007, that cover the study area, obtained through the National Institute for Space Research - INPE.

The Environment for Visualizing Images - ENVI 4.5, was the software used for processing the images. First the images were georeferenced using the geometric correction method where control points on the ground are selected (easily identifiable features in both cartographic base and satellite image). These points are located in the spectral image and through polynomial cohesions, the images distortions and displacements are significantly decreased.
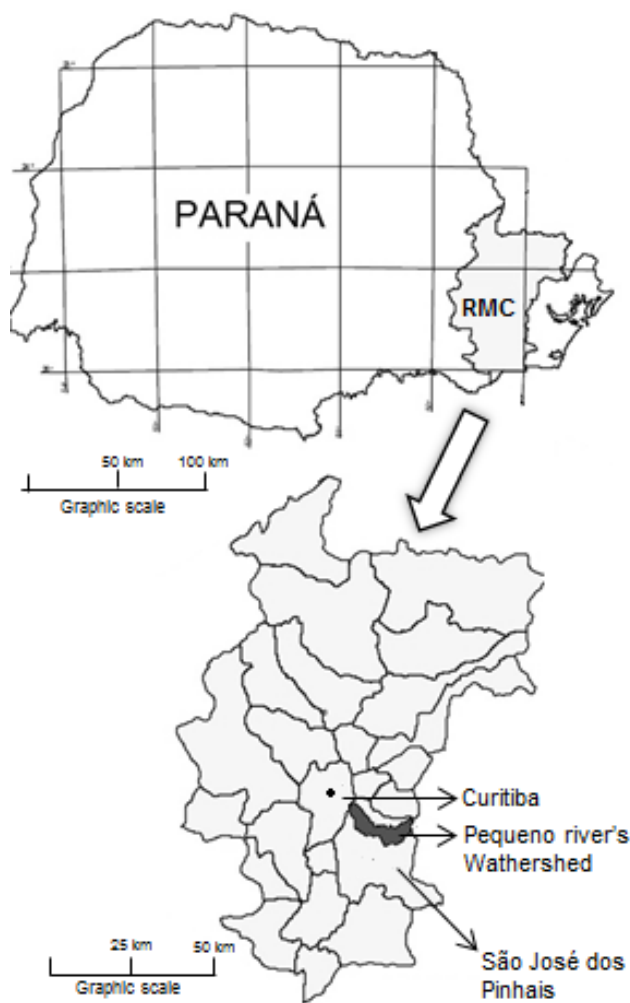

Figure 1. Location of the Pequeno River Watershed.
Source: SANTOS; BERTOTTI, 2009.

Table 1. Land use classes for the 1986, 1996, 2007 years.

Classes of Use	Description
Forest	Mixed Ombrophilous Forest and Dense Ombrophilous Forest in advanced second succession stage
Shrubland	Mixed Ombrophilous Forest and Dense Ombrophilous Forest in intermediate second succession stage
Marsh	Mixed Ombrophilous Forest and Dense Alluvial and Alluvial influenced Primary Formations
Reforestion	Reforestation with exotic species
Grassland	Natural fields (grassland) and created by man (pasture)
Urban	Residential, commercial and industrial urban areas
Agriculture	Crops and cattle ranching

Subsequently, a supervised classification was carried out using the same software, which consisted on selecting training samples, these samples were representative of each attribute or terrain feature (in this case , types of land use) and represented the average behavior of classes that would be automatically mapped. The use of this classification tool is based on the pixel identification contained in the samples to identify which pixel of the image is most similar statistically.

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The criteria used for defining the classes were based mainly on the specific land use characteristics related to the hydrological cycle. So due to the fact that Araucaria Forest and Tropical Rainforest and certain stages of plant succession, are easily distinguishable in the field, but with some difficulty in multispectral images, they were grouped in the same class once that their hydrological processes are similar.

The classification algorithm used was the Maximum Likelihood (Jensen, 2009), which assumes a condition where the pixels contained in the training samples are in a normal distribution. This algorithm compares the radiation intensity vector of each pixel to the mean vector of each class training samples. After the image classification, the result was homogenized by using a filtering tool. After that, the result was exported in SHP (shapefile) format and maps were created using ArcGIS

9.3. To validate the data obtained by orbital sensors it was required to visit the watershed area. The verification process showed that the image classification was consistent with the features observed in the field.

3. RESULTS AND DISCUSSION

Urban watersheds are very complex because they are composed by a variety of features. In other words, there are several land use classes, vegetation covers, and urbanization elements (MORAES et al, 2012). The evolution of land uses in the watershed for the 1986, 1996, 2007 years was established. The Pequeno River watershed land uses were obtained by classifying satellite images and its classes were defined according to Table 1.

The spatial distribution of the land use values are shown in Table 2, the graph in Figure 2 and illustrated in Figures 3, 4 and 5.

Table 2. Land use in 1986, 1996, 2007 years, expansion and retraction of classes between 1986 and 2007.

| Classes	Year							
	1986		1996		2007		1986-2007	
	Área (Km²)	%	Área (Km²)	%	Área (Km²)	%	Área (Km²)	%
Forest	36.40	27.90	51.07	39.15	40.5	31.05	4.10	3.15
Reforestation	0.21	0.16	0.37	0.29	0.78	0.60	0.57	0.44
Capoeira	5.80	4.45	17.34	13.29	7.19	5.51	1.39	1.07
Fields	57.49	44.07	27.24	20.88	41.84	32.07	-15.65	-12.00
Agriculture	2.99	2.29	8.80	6.75	4.9	3.76	1.91	1.46
Lowland	20.97	16.08	8.31	6.37	2.58	1.98	-18.39	-14.10
Urban	6.59	5.05	17.32	13.28	32.66	25.04	26.07	19.98
Total	130.45	100.00	130.45	100.00	130.45	100.00		
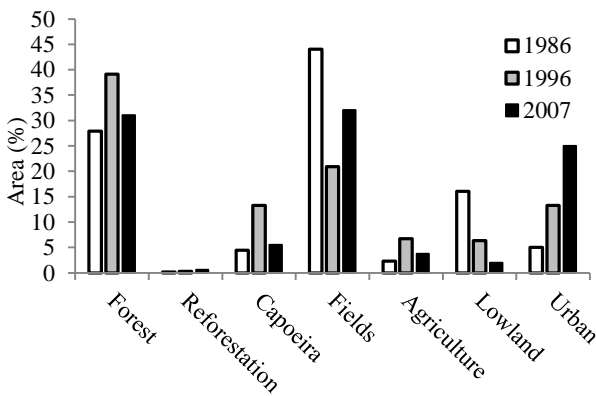
Figure 2. Land uses in 1986, 1996, 2007 years.

The municipalities most affected by this growth were Piraquara, Campo Largo, Araucaria and São José dos Pinhais, where the latter contains the Pequeno River watershed. The large population concentration around urban centers, especially since the 1980s, gave birth to the phenomenon of the metropolis in Brazil (AMARAL, 2002).

The great growth of the RMC occurred mostly by intensive marketing management. Curitiba was nationally promoted as a city with a good life quality, being promoted as a developed country capital and also called a social capital. However, with the large population growth and high real estate prices in Curitiba, population expansion occurred in the metropolitan region (AMARAL, 2002). The regions with the highest growth in São José dos Pinhais during this period were from Afonso Pena neighborhood district and the northern

region, near BR 277 Highway, where the Pequeno river flows.

It is possible to verify in Table 2 and Figure 4 the classes of land use in the Pequeno River watershed in 1986, where more than half of its area was covered by Grassland (44.07%), followed by Forest (27.90%) and Shrubland (4.45%). Marsh areas covered 16.08% of the watershed, which includes wetlands and very wet soils. Agriculture areas where present in only 2.29% of the area. Reforestation areas were also small, representing just 0.16% of the area. Finally, the class use defined as Urban occupied a total of 6.69 %.

During the 1990s the city of São José dos Pinhais were under an intense industrial growth due to the installation of the Renault factory in Brazil, located in the boundaries of the Pequeno River watershed. In the same period the Afonso Pena airport's construction was completed, elevating its status to an international airport.

As we can see in Table 2 and Figure 3, ten years later, in 1996, the land use classes consisted in 39.15% of Forest, 20.88% of Grassland, 13.29% of Shrubland 13.28%, of Urban, 6.75% of Agriculture, 6.37% of Marsh and 0.29% of Reforestation. According to Lima (2008), in São José dos Pinhais, during the 90s, the number of occupations in the preserved areas grew 34.93% in just five years.

During the 90's it brought to the attention that there were irregular occupations, due to the expansion of the urban area to areas without planning or infrastructure, resulting in a slums increase (AMARAL, 2002). These concerns were due to the fact that urban expansion occurred mostly on areas for public water supply.
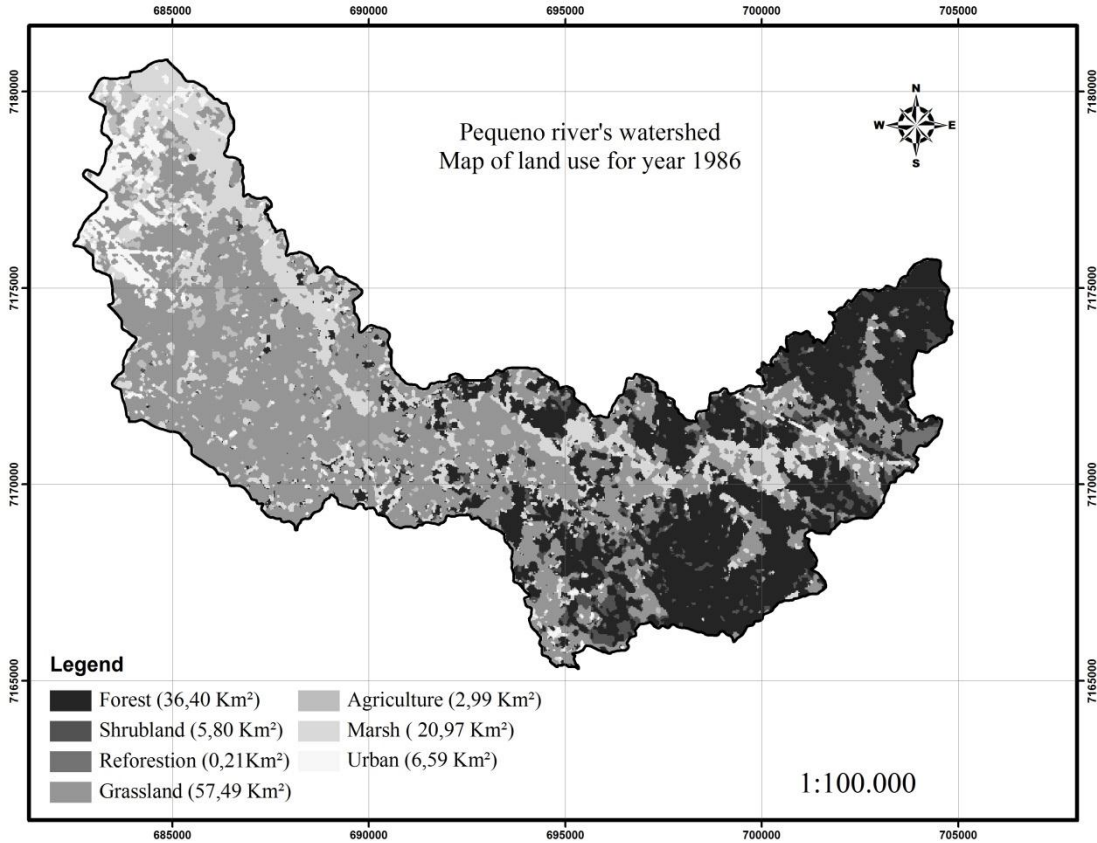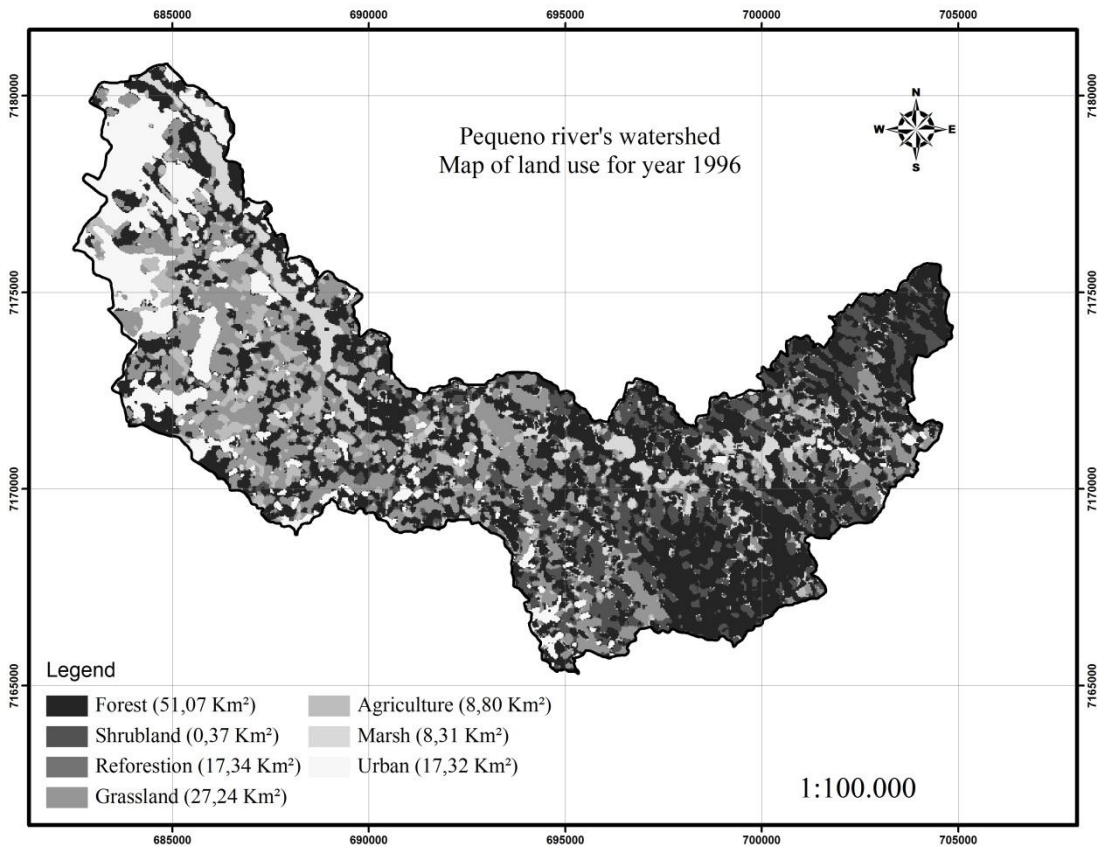
Figure 3. Land use map for 1986.
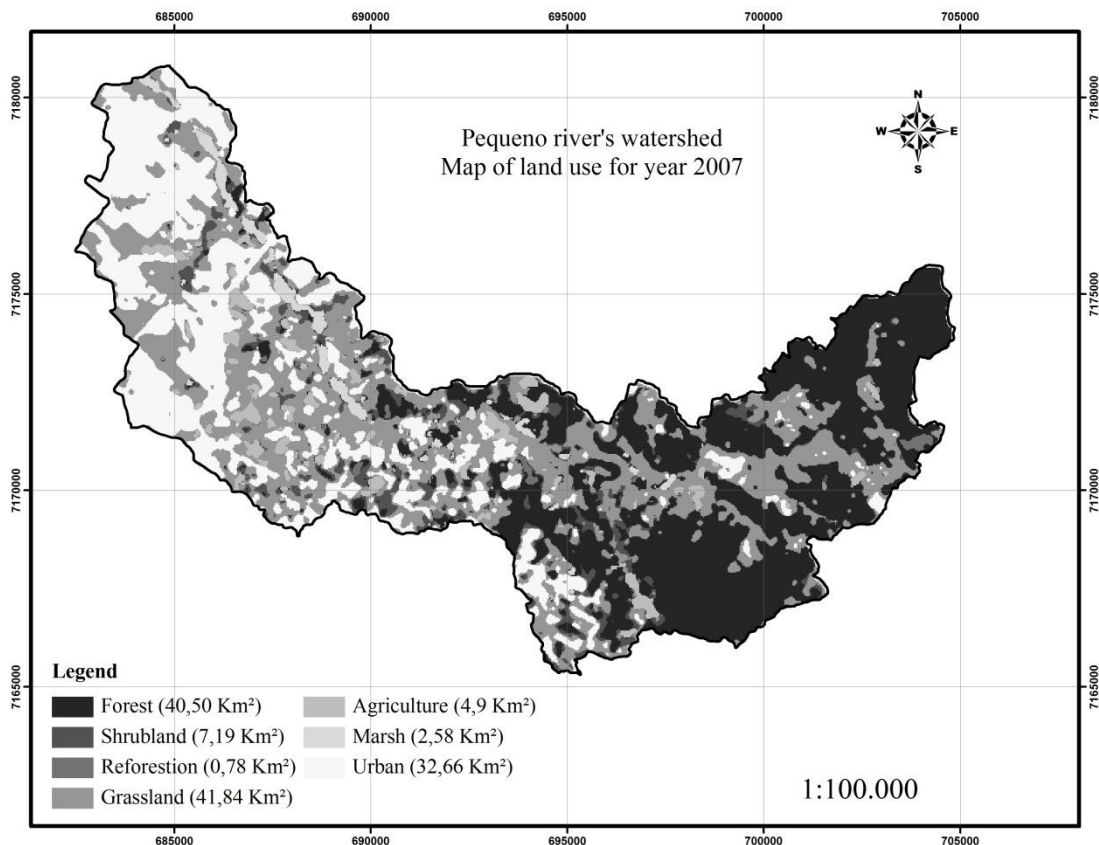
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Figure 4. Land use map for 1996.

Figure 5. Land use map for 2007.

In the 2000s, the municipality growth was mainly driven by the installation of the Audi/Volkswagen factory and its industrial suppliers of auto components. The factory and its suppliers were located near the springs in the watershed and caused concern regarding the water availability and quality in the RMC. The city's agriculture is characterized by family farms and agricultural products such as vegetables, grapes (wine), pork, fish and cattle (AMARAL, 2002). In 2007 the Pequeno river's watershed was occupied by 31.05% of Forest, 32.07 % of Grassland, 25.04% of Urban, 5.51% of Shrubland, 3.76 % of Agriculture, 1.98 % of Marsh and 0.60% Reforestation (Table 2). In the Pequeno River watershed there is a disordered spatial distribution of urban areas, with spots spread throughout the watershed, as shown in Figure 5.

When evaluating the difference in the percentage of areas in each soil class in 1986 and 2007, as described in Table 2 and illustrated in Figure 6, it is possible to notice that the urban class showed the greatest variation with a growth of 19.98% which would correspond to an area increase of 26.07 km^2. The following classes were forest, agriculture and shrubland increasing their areas in 4.10 km^2 (3.15%); 1.91 km^2 (1.46%) and 1.39 km^2 (1.07%), respectively. The class marsh showed the highest decrease with a reduction of 18.39 km^2 (14.10%) in its area, followed by grassland with a reduction of 15.65 km^2 (12%). This dynamic land use shows how the watershed is vulnerable, and it is happens mainly because of urban settlement and agricultural activities in areas of environmental fragility, presenting disorderly occupation trends (SOARES, 2011). Moraes et al. (2012) found that the increasing urbanization, where soils become waterproofed, causes the first occurrences of flooding.

Also Leite (2012) noted that the intensification of land use in the springs vicinity directly affects water availability in a river basin.
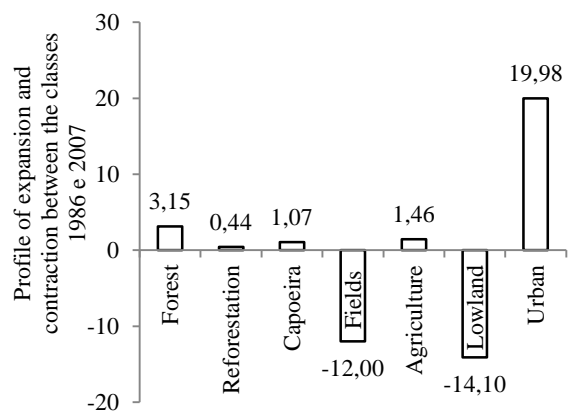
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Figure 6. Expansion and retraction of classes of land use between 1986 and 2007.

Analyzing the three decades covered by this study it was possible to notice that occurre an increased on the amount of soil sealing due to the growth on the watershed urban area. This urban growth was the leading cause for waterproofing the soil it also modified the forest cover capacity to protect the soil.

Most of the changes in the land use structure, such as changes in natural land uses classes into manmade classes, were generated because of the Curitiba metropolitan region's growth policies. The occurred reductions in the classes of high-capacity storage for the

average were mostly related to deforestation and the increase of grassland and shrubland classes.

The territorial expansion of the Curitiba metropolitan region is inevitable it is due to population growth and migration to the region. Therefore, the raising need for infrastructure, goods and services by the society makes indisputable the development of socioeconomic activities. All activities related to municipality growth modify the hydrological conditions of the region, directly affecting the watershed potential water storage capacity.

This study provides information that can assist in planning the territorial growth of Pequeno River watershed. This information should be used for watershed management as well as consulting other environmental fragility's studies.

4. CONCLUSION

The ArcGIS 9.3 and Envi 4.5 software were efficient in generating supervised use maps and land use, however, field visits is necessary to confirm the information obtained.

The use of low-resolution digital images, such as Landsat 5 is appropriate for this type of mapping, is an accessible and economically viable technology.
The thematic mapping allowed us to assess the changes in the land use in Pequeno river watershed, São José dos Pinhais, PR. Also, clearly demonstrate the possible replacement of lowland areas by urban areas occurred between 1986 and 2007.

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