

High-resolution satellite image and GIS as a tool to analyze the socio-environmental conflicts: a study case in the Southeast of Brazil.

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Abstract: The discussion about environmental questions and sustainable development represented a change of paradigm in the relationship between man and nature. Since the 60's, the environmental issue has gained more notoriety in society debates. Agriculture is an important drive of land use changes and, when it is practiced in an unsustainably way, it can causes a lot of environmental problems that affected the society. The conflict emerges when a contradictory process of landscape changes, that is a phenomenon of social relations, emanated from the clash between different interests. Therefore, this paper will present a study case of conflict resulting from the mismatch between land use and environmental legislation that determine some areas as "permanent preservation areas" (PPA). The study was developed in a watershed at a mountainous region in the Southeast of Brazil, on Rio de Janeiro State. For this study was used remote sensing and GIS. A WorldView II image, from June 2010, was used to generate the land use map. GIS technologies emerged as important tools for manipulating and analyzing data and information necessary for this purpose. Therefore, it was possible to contribute with a technical support for the discussion of current environmental legislation in Brazil.

1. INTRODUCTION

The discussion about environmental questions and sustainable development represented a change of paradigm in the relationship between man and nature. Since the 60's, the environmental issue has gained more notoriety in society debates. Furthermore, changes in the consumption patterns and the increasing demand for natural resources, guided by the discourse of economic progress, have directed impacts on land use and land cover change, and those have enormous impact on the ecosystem services (Turetta et. al. 2010).

With the aim to order the land use and occupation in important areas for ecosystem preservation, the Brazilian legislation has created the permanent preservation areas (PPA - Forest Code, Law 4771, 1965) that are " areas covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability, biodiversity, gene flow of wild fauna and flora, soil protection and ensure the welfare of human populations". The permanent preservation areas are: Marginal strip protection, Slope, Springs and Boundaries of the tops of hills

Although the Brazilian law had been comprehensive, is not enough to order the occupation of the space. Specifically in the case of permanent preservation areas, this fact occurs because the law doesn't determine the limits of these areas previously. So the population doesn't know the limits occupied by these areas. Moreover, these facts difficult the fiscalization and conflicts emerge in reason of this situation. Because of that, initiatives to cooperate to solve these issues are useful for the government and society.

In relation of PPA delimitation, Oliveira (2002, *apud*, Nascimento et. al. 2005) underscores that the development of Geographic Information Systems (GIS) allowed the fast and

efficient processing of the data needed to characterize the landscape morphometric variables, which are of great importance for this kind of analysis.

Nascimento (*et. al.* 2005) corroborate with this idea and emphasis those methods that use Geographic Information Systems tools present advantages when compared to manual methods traditionally used, since the first has generated results less subjective, with more precision, and less time dispensed with its production.

The GIS techniques have been increasingly used in environmental planning, because it's efficient for diagnostics production. The results generated provide information for identifying and measuring the occurrence of land use conflicts in PPAs that are very useful for support the environmental monitoring, control and supervision. However, it is still necessary to invest in such studies, since the legislation does not define a scale parameter to map, which can imply in the distribution of spatial area of PPA (Cota and Moura, 2009).

The main aim of this study of conflicts from Pito Aceso watershed, located at a mountainous region in the Southeast of Brazil, on Bom Jardim city, on Rio de Janeiro State. So in this paper the main aim are map areas of conflicts resultant from the clash between different interests. In the study area, the conflicts originated from the clash between the interests from Brazilian government, who want maintain the permanent preservation areas, and the farmers, that want used this areas for maintenance yours activities.

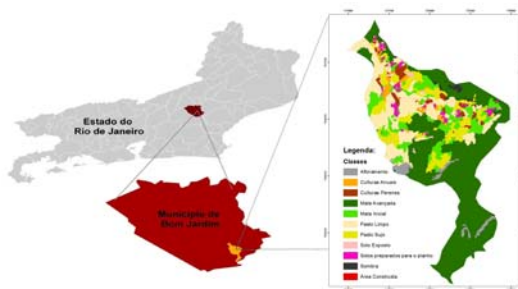
2. METHODS

2.1. Studs Area

The Pito Aceso watershed has an area of 498.15 hectares (Figure 1) and is essentially a rural area, located on the 4th

district of Barra Alegre, in the of Bom Jardim municipality, at a mountainous region of Rio de Janeiro State. The study area is located between the UTM coordinates 779774, 7537737 and 776950, 7533091 zone 23s. The municipality is located in the Serra do Mar, at Atlantic Forest biome. The altitude ranging from 620m and 1700m and the annual rainfall average, is 1400 mm. December is the wettest month and the months from July to August, are the driest. The climate is mesothermal, with temperatures well distributed throughout the year and with little or no water deficit (Mendes, 2006). It is located in a mountainous region, which is the morphological unit that is more susceptible to soil erosion. In the watershed area, as in other productive areas of the region, the agricultural practice is carried out along the slopes of narrow valleys. Due to its geomorphological characteristics, the intense rainfall and how the agriculture is practiced, the erosive processes are intense. For this reason, soil loss increases, and contributes to the conduction of pesticides and fertilizers into rivers, causing pollution and environmental contamination (Mendes, 2006)

Figure 1 –Pito Aceso watershed location.



2.2. Satellite images processed

A WorldView II image, from June 2010, was used to generate the land use map (Figure 2). Before start the classification image process, it was necessary to perform the digital orthorectification. The processes of images georeferencing and the orthorectification were performed by ENVI software version 4.5.

The classification procedures were processed in Definiens Developer software version 7.0. For the image segmentation and classification was used the same parameters showed in Prado *et al.* (2009). The land use classes were adapted from the Technical Manual for Land Use (IBGE, 1999). The following classes will be used in detailed map: Outcrop; Built Area; Culture Annual; Perennial Crops; Forest in advanced stage; Forest in early stage; Pasture; Dirty Pasture; Bare Soil e Shadow (Appendix I)

A fieldwork was realized in May 2011, to give more consistency for de mapping and take out the doubts concerning the visual interpretation of the image. The points were georeferenced and were also photographed. Subsequently, this information was used for adjustments on the map. A post classification was processed in in ARCGIS 10.0 (ESRI, 2010) and after that, it was calculated the area of each land use class.

For the delimitations of PPA were used digital data sets already available in the collection of EMBRAPA SOIL regarding Pito Aceso watershed. The data were worked in

ArcGis 10.0, which were delineated preservation areas and subsequently generated a map with all PPA.

The delimitation of Permanent Preservation Areas (PPA) was the big challenge of this work, because there is no methodology that could be applied in this work, especially regarding the delimitation of the mountain top areas and ridge line (Appendix-II).

To perform the mountain top areas and ridge line were used shapes of contours and hydrography of the study area in ArcGis 10.0. The mountain top areas were defined from the upper to the third part of the slope and the polygons were drawn manually. The option for a manual delimitation was because the automatic delimitation generates misleading generalizations.

The preservation permanent areas of marginal strip protection and springs were made automatically, using the buffer tool at ArcGis 10.0. The demarcation of the buffer for marginal strip protection was 30 meters, because the channels in Pito Aceso watershed do not have over 10 meters wide. The delimitation of areas with 45 degree or 100% slope or more was made from the shape of slope.

After finalized the delimitation of each preservation area, it was necessary to make the union of each area, followed by dissolution (dissolving) of the overlapping areas. This procedure was required to know the real size of the areas, which must be preserved inside the watershed.

The delimitation of areas of permanent preservation was based on criteria established by the Brazilian Forest Code (Law 4.771/65) and CONAMA Resolution 303/2002, namely:

- Marginal strip protection 30 meters wide, which was made from the channels of the river system, the course water with less than ten meters wide;
- The springs were delimitation around from radius of 50 meters;
- Delimitation of areas with slope equal to or greater than the 45-degree tilt or 100%;

For to understand the conflicts in the study area was necessary known the point of view of the population in the watershed. For this purpose, it was applied a questionnaire to a few groups of people, who represented the interests of the area. The questionnaire had four questions and asked about the maintenance of agriculture and permanent preservation area

-Boundaries of the tops of hills were considered the upper third, whose difference between the maximum elevation and the base is over 50 meters. Definition of ridge lines set of peaks at a distance equal to or less than 500 meters, which are a common area, that the maximum distance from the common area is one thousand meters, and the upper third of the lower peak is to determine the upper third of the whole. For analysis purposes, the area's top line of hills and ridge lines were combined in a single mode PPA: Top of the Mountains and Ridge Lines.

The mapping of conflict use areas or inadequate use aims to make a cartographic representation of the conflicts that arise from the clash between the interests of farmers of the basin area and the Brazilian state, which determines through the Forest Code and the Resolution CONAMA (No. 302/2002, No. 303/2002, No. 396/2006, No. 425/2010) areas that should be preserved. This mapping is the result of overlapping of land use map and the PPA map, after that were demarcated areas where the human activities and permanent preservation areas converged this areas were qualifying and quantifying these areas.

3.RESULTS

The Pito Aceso watershed has a landscape configuration as a mosaic with diversity of uses. The land use cover map reflects this plurality. The watershed presented the Forest in advanced stage as a matrix of landscape. This class represented more than 40 % and is concentrated in the areas with steep slope (Table 1)

The class Forest in early stage occupies an area of 11,07 % of the total area of the watershed. This class corresponds the areas that are in fallow or have been abandoned and are no longer in use for agriculture. The results indicate a high level of preservation in the watershed area. This fact is very important, specially in areas with steep slope, since the vegetation acts like a natural protection for soil and reduce the erosion process (Guerra, 1994).

The permanent preservation areas were delimited according to the Brazilian Forest Code (Law 4.771/65) and CONAMA Resolution 303/2002. Afterwards we observed the permanent preservation areas have a total area of 271.77 hectares (ha), which corresponds to 54.56% of the total area of the watershed, which is 498.10 ha. The sum of all areas of PPAs initially indicated an area of 330.20 ha. However, it was subtracted the overlaps among the PPAs, and the real area was calculated in 271.77 ha.

The table 2 shows that the category of PPAs "Boundaries of the tops of hills" has the major representation of the watershed area – 40, 98%. The preservation of these areas is essential for maintenance of slopes

Table 1: Land use classes area at Pito Aceso Watershed.

Uses	Year 2010 (%)
Outcrop	3,3
Built Area	0,7
Culture Annual	9,4
Perennial Crops	4,2
Forest in advanced stage	45,1
Forest in early stage	11,7
Pasture	15,3
Dirty Pasture	8,2
Bare Soil	1,5
Shadow	0,7

Table 2: Area (ha) and percentage of each PPA

Unit	Area hectares	Area ratio of the PPA and Basin area (%)
Watershed	498,10	100,00
PPA: slope equal to or greater than the 45-degree tilt or 100%;	23,82	4,78
PPA: Spring	21,78	4,37
PPA: Marginal strip protection	80,46	16,15

Unit	Area hectares	Area ratio of the PPA and Basin area (%)
PPA: Boundaries of the tops of hills	204,14	40,98
Total PPA dissolve	271,77	54,56

The PPA "Marginal strip protection" occupies an area corresponding to 16.18% of the total watershed area. The main objective of this PPA is to preserve the riparian forests, since they are responsible for maintaining the hydrological balance.

A overlay with the land use and land cover and the PPAs maps was made to check areas with land use conflicts. 63.93% of the areas of PPAs have their uses in accordance with the law, indicating that the area presents a high state of preservation.

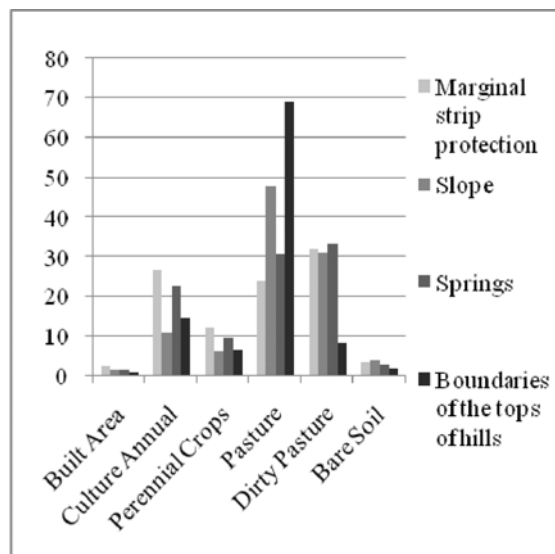
It was considered as conflict, the areas which the uses of any type were contraries with the law. Accordingly, it is observed that 29.48% of the area of PPA have mismatch between the use and regulation (Table 3). The remaining 6.60% represent areas related to classes shadow or outcrop.

Table 3: Percentage of areas of PPA that may or may not have a conflict of use

Conflicts	Accordance with the law	Disregarded	
Marginal strip protection	50,16	49,48	0,36
slope	3,57	49,20	47,23
springs	60,01	38,25	1,74
Boundaries of the tops of hills	17,96	74,08	7,96
Total	29,48	63,92	6,60

The PPA "springs" presented the major incompatibility of use –60.00%. The pasture areas (pasture and dirty pasture) were the most contributed to this inadequacy, because together, these classes represent over than 63.00% of the total area of conflict of use (Figure 2).

Figure 2 - Percentage of conflict for each use in different forms of PPA (2010)



Source: Table prepared by the author.

The PPAs "Boundaries of the tops of hills" and "slope" had an inadequate occupation of 17.96% and 3.57% respectively. These low levels, which means less conflict than in other PPA, is due to the high steepness of the terrain that naturally ends up hindering the process of occupation of the slopes. About the APP "Boundaries of the tops of hills", the classes related to pasture (Dirty Pasture and Pasture) were the main responsible for the discrepancy between the legislation and use, since the two classes together account for 77.07% of the inadequacy of land use of this type of PPA. The permanent preservation areas related to the slope exceeding 45 ° or 100% also presented the same behavior.

Based on the questionnaire, the people who were interviewed consider possible continues their activities and protect the PPA. For them, the preservation is very important and the government have to create legal mechanisms for maintain the agriculture and the preservation policy

4. Conclusions

At Pito Aceso watershed, the conflict is the result of the clash between environmental issues and the land use. In this context, environmental management can be presented as an important instrument for measurement this type of conflict. The tools related to geotechnology presented as an important instrument for surveying and mapping of the land use conflict in, land cover and areas of permanent preservation, as well as a great efficiency in processing spatial data and integration. However, to have a real sense of conflict it was necessary to have knowledge of the perception of the main actors of the study area.

The results show high conservation of forest remnants in the watershed area that reflected on the proportion of PPA. For this reason 69.58% of PPA areas are consistent with the legislation standards. Indeed, it is observed that 23.99% PPA area presents inconsistency between the land use and the legislation. The PPA called "area surrounds the springs" presented the major incompatibility of use, i.e. 41.83% of the total area had some type of misuse.

Related to the multitakeholder interview, it was highlighted that is very important the PPA preservation, as well as the maintenance of agricultural practices. This study addressed that the landscape planning are strategic for a sustainable use. GIS technologies emerged as important tools for manipulating and analyzing data and information necessary for this purpose. Therefore, it was possible to contribute with a technical support for the discussion of current environmental legislation in Brazil.

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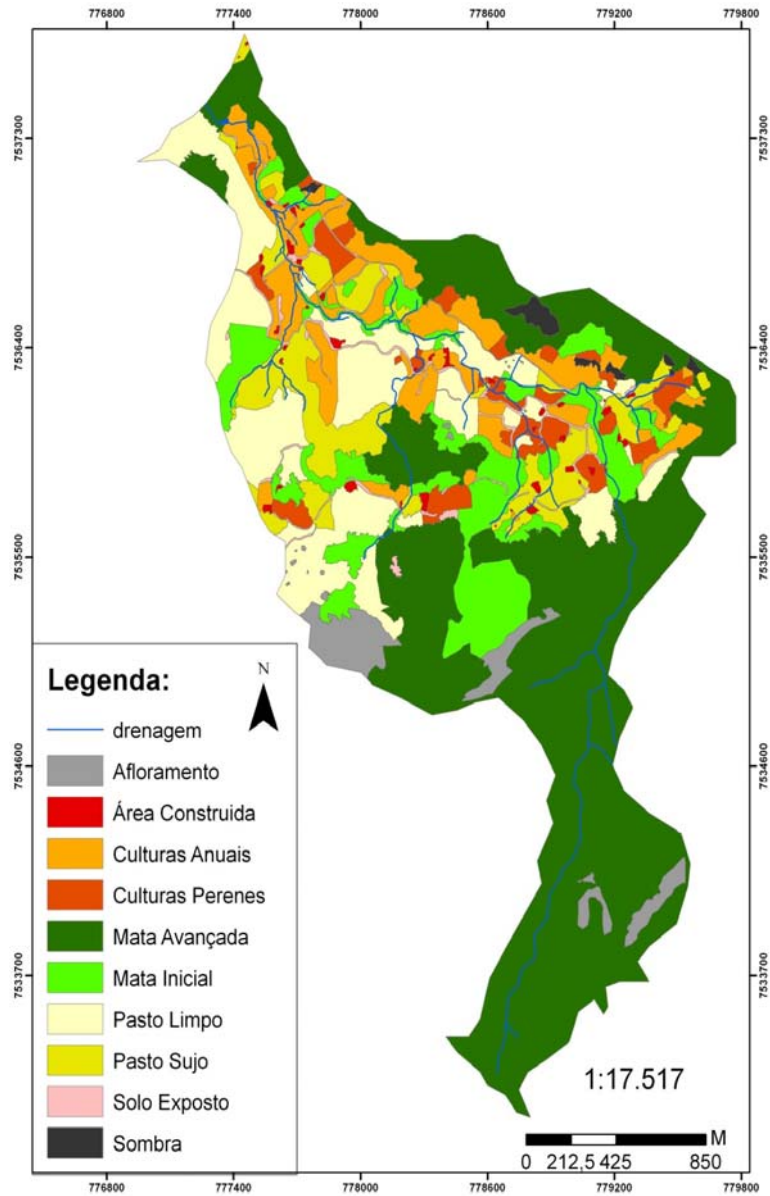
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Appendix-I

Figure 3: Map of Land use classes of watershed of Pito Aceso



Appendix-II

Figure 4: Map permanent preservation area of watershed of Pito Aceso

