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ENVIRONMENTAL ASSESSMENT FOR DEFINING NEW MANAGEMENT STRATEGIES FOR THE CONSERVATION OF SOIL AND WATER RESOURCES

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ABSTRACT The land use for agriculture and livestock activities in Brazil is marked by low technology and little knowledge about the environment support capacity. The results of this management way of the natural resources are the loss more than 90% of Atlantic Rainforest, erosion and loss of biodiversity. The site of research was in Capivara watershed, 22231 ha, that is inside of Botucatu city (Sao Paulo state – Brazil), inserted in Atlantic Forest biome and on the geologic formation called Basaltic Cuesta. The results of the research show that more than 40% of the basin is in conflict with land use according with the land use capacity and the Brazilian environmental legislation. Consequences of this inappropriate management are observed in the number of erosions, streams becoming wide and shallow, flood peaks shaking physical structure of the bridges, abandoned land by the farmers, and confinement of the wildlife in a few fragments of the native vegetation. Through the use of geographical information systems and remote sensing it was possible to define the current land use, a digital elevation model and spatial distribution of the different types of soils. This geographical information was the base to define the conservation areas of the watershed and the areas for agriculture and livestock through the investigation of the land use capacity. This method allowed a detailed evaluation of the conservation status of the watershed and the definition of the management zones according with the land use capacity and environmental legislation.

Keywords: Environmental legislation; planning units; riparian areas; watershed.

INTRODUCTION: The occupation of the land in Brazil and in the world is directly related with the population's demands for food production, urban and road systems expansion, exploitation of the minerals and fossil fuels, which over the generations past to the present, provides different levels of changes in the landscape. In some cases, especially in rural areas, the process of currently territories occupation can be considerably reorganized to enable the exploitation of soil, transformation of landscape and economic development with sustainability.

According with Piroli (2002), there is a urgent necessity for a planning for the land use and natural resources, because the form of occupation in the agricultural territories, disorderly and irresponsible, has taken the capacity of the land to the limit.

According with author, the situation of the agriculture in Brazil is alarming; however, by a planning on a regional scale, it is possible to adapt it.

In the context of the environmental planning, land and natural resources management, the use of computer technologies have been receiving special attention and importance by researchers, companies and public administrators. The geoprocessing is a discipline of the knowledge that uses geographic information processed and interpreted by mathematical techniques inside the computing environment (Piroli, 2002). This part of the science plays an important role for the areas of mapping, analysis of the natural resources, transportation, communication, energy, urban and rural planning (Câmara and Medeiros, 1998).

The tools for the geoprocessing are the Geographic Information Systems (GIS) that enable researches to perform complex analysis, integrating data from multiple sources and create a geo-referenced database (Rodrigues, 1990).

As a part of the data collection for the environment studies, Zimback (1997) considered that the soil survey identify units and establish geographical boundaries beyond their physical and chemical characteristics and systematize in thematic maps, which are widely used in the preparation of the land use capacity maps. Interpretations of the soil surveys are predictions of soil behavior, considering specific purposes and under certain environmental conditions (Pereira, 2002).

For Lepsch (1991), the adaptation of the land for different agricultural and forestry activities is related with the land use capacity, i.e., its adaptability for various purposes according its possibilities and limitations. The ability of the land is defined by comparison of its agricultural conditions with the levels required for soil fertility, water stress, erosion susceptibility and impediments to mechanization (Ramalho Filho and Beek, 1995).

The system of land use capacity represent qualitative groups of soil systematizing characteristics and properties to provide the possibility to establish its maximum capacity to use without risk of degradation or intensive erosion process; being the characteristic of the land, what can be measured and estimated, as a color of the soil, while the proprieties are the attributes relative to the behavior resulting from the interaction between the soil and environment, as a risk of erosion for example (Lepsch, 1991).

The land use in disagreement with its respective capacity associated with few knowledge and indifference about the characteristics and ecological functions of certain landscape elements, such as replacement of riparian forests by pasture or planting areas, cause serious damages to the quality of water resources and to the regime of floods and droughts in the basin. Still, (Ramalho Filho and Beek, 1995) call attention to the implementation of agricultural crops in regions near to spring water, which are grown with fertilizers and pesticides that can contaminate water bodies including reservoirs supply for human.

The process of expanding the management zones for agriculture and livestock caused over the decades a large-scale replacement of natural vegetation in modified landscapes. In this context, the forests which have important role for the water quality, minimization of erosion, regulation of sediments and working as filters retaining pollutants before to enter into the streams (Hamilton et. al, 2008); they are dramatically reduced to fragments in the Atlantic Forest ecosystem (Rodrigues and Gandolfi, 2007). According to Pinto et al. (2009), this ecosystem was traditionally supplier of agricultural products and today, it's the host of largest industrial occupation, sugar cane and the major urban centers, with most of this ecosystem has been destroyed over a number of

developmental cycles resulting in severe consequences, mainly by the high fragmentation of habitat.

In perspective of watershed management is important to remember about the role of riparian areas. The native vegetation inside the riparian areas protect water bodies against wave action in coastal mangroves, streambanks and lakes. This occurs because the roots of shrubs, the roots of trees and forest understorey stabilize banks against erosion (Hamilton et. al, 2008).

The riparian area is a vital element between land use and the watershed river system. Its functions go beyond just the protection against river banks erosion and silting, but the vegetation along the riparian area more forest understorey, intercept large quantities of pollutants and sediments from agriculture as it moves towards flowing water from upslope areas outside the riparian areas and reduce the speed of runoff improving well rate of water infiltration into the soil and better regulation of basin flood (Hamilton et. al, 2008).

By the importance of the riparian areas, the Brazilian Federal Government in 1965, while creating the Brazilian Forest Code, Law 4.771, determined the riparian areas such as Permanent Preservation Area (APP – in Portuguese). According to the Forest Code, the APP zone must be finding in all watercourses and spring water in a buffer at least 30 meters to each side of its banks and 50 meters of radius to preserve the springs. Moreover, in southeastern Brazil, the private rural lands must to keep an area of Legal Reserve (RL – in Portuguese) of 20% of the property with native vegetation, in purpose to maintain habitat for wildlife, corridors of biodiversity and preservation of flora.

The knowledge about the socioeconomic and environmental characteristics is the basic information for evaluating the potential of the land use, knowledge necessary to define areas for sustainable use and areas just for conservation of the natural resources and biodiversity. To know the environmental characteristics by the preliminary study associated with scientific knowledge is fundamental in the decision make process to choose the better management way for the land, to recovery degraded land and reforestation (Isernhagen et al., 2009). For these authors, the study and recognition of the area that will be worked by the environmental assessment, lead us to the environmental adequacy plan that consists in actions such as conservation, management and recovery of the environment.

By the fragmentation state of the native vegetation in the most basins in Sao Paulo State, the conflicting uses for agriculture and livestock related with the land use capacity, the process of erosion accelerated in some regions, the non-compliance and disrespect of the Forest Code, the fragility of the soils from the Basaltic Cuesta in Capivara watershed, significant wildlife hosted in this basin and for to be habitat for species of mammals at risk of extinction, especially the *Puma concolor* (Cougar) and by the reason of Capivara watershed can be a potential water source, the research was conducted in order to evaluate the use and conservation of the watershed and develop maps of suitability for riparian areas restoration and sustainable use of soil.

METHODS: This work was carried out in the Capivara watershed, located in Botucatu city (SP – Brazil), between the plane coordinates 758.000, 7486.000 and 779.645, 7456.286 with a total area of 22.231 ha (Figure 1).

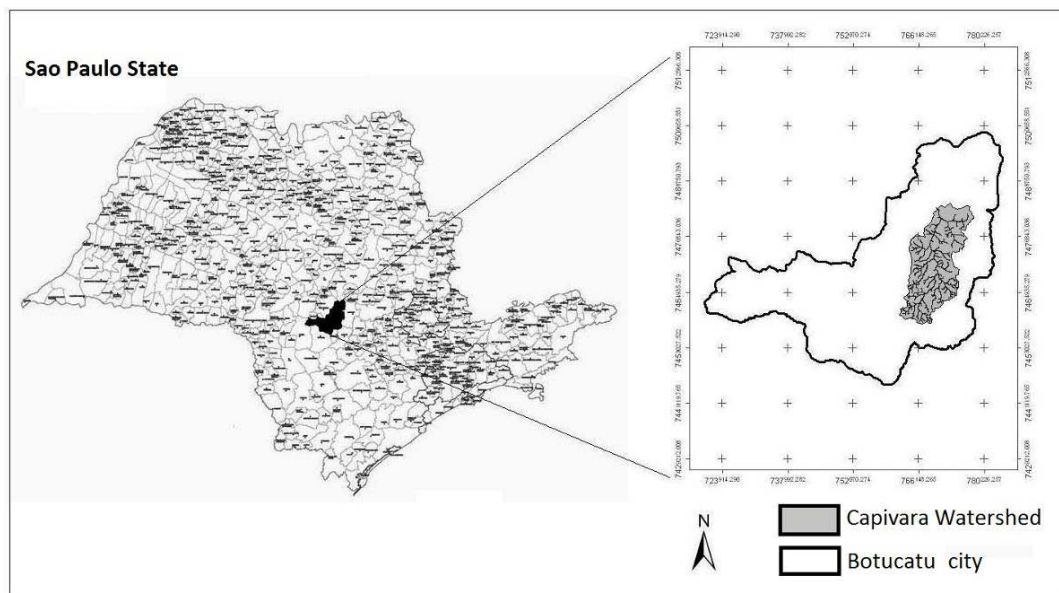


Figure 1. Location of the Capivara watershed in the state of Sao Paulo.

The study area is inserted in the region of geologic formation called Basaltic Cuesta, characterized for three distinct geological units: 1. Reverse of the Cuesta (beginning of plateaus Occidental) with altitudes between 700 and 950 m; 2. The Front of the Cuesta (sandstone-basaltic scarp); and 3. Peripheral Depression with altitudes between 400 and 600 m (Jorge, 2000).

The relief of Cuesta is a striking feature of the region, resulted of the continuous action of erosion on the ground that formed rocky platforms that stand in the smooth valleys around then. The asymmetrical relief is constituted by an alternating succession of layers with different hardness against abrasion and that it incline in one direction, forming a smooth slope in the Reverse and one abrupt or steep slope in the Front of the Cuesta (Carrega, 2006).

The predominant climate in Botucatu town according to system of Köppen is the Cfa - rainy temperate climate and the predominant direction of wind is Southeast.

The natural vegetation of the basin consists of three types: Semideciduous seasonal forest, especially in the area called the Front of the Cuesta, Brazilian Cerrado both Reversal of the Cuesta as the Peripheral Depression, and Riparian vegetation along the water bodies (Carrega, 2006). Ecotone areas are also found in the transition from semideciduous seasonal forest with Brazilian Cerrado (Jorge, 2000).

In a survey of fauna developed for Alves (2009), in fragments of native vegetation in the Capivara watershed, 20 species of mammals has been found. Amongst these, three between the species are in Brazilian list at the risk of extinction. They are: *Myrmecophaga tridactyla* (Tamanduá-bandeira), *Leopardus pardalis* (Ocelot), *Puma concolor* (Cougar). For the researcher, the study area is indicative of the need to carry out programs for the conservation of medium and large mammals.

The data about land use and contour lines of region were obtained from the Direct Plan of Botucatu town developed in 2005. The map of land use was updated in November 2009 for this study (Figure 2), where the following distribution of land use was found: 0.21% dams (29 ha); 26.5% native vegetation (5896 ha); 44.8% pasture (9880 ha); 0.5%

erosion (116 ha); 3.5% citrus (797 ha); 4% annual culture (900 ha); 0.05% coffee (13 ha); 17.6% eucalyptus (3922 ha) and 3% building (670 ha).

The soil map was obtained from soil survey conducted by Piroli (2002) according to Brazilian soil system (Embrapa, 2006). On scale of 1:50.000, the following soils were determined: Oxisol Red dystrophic (LVd), Oxisol Red dystroferric (LVdf), Oxisol Red-Yellow dystrophic (LVAd1), Neosol Quartzarenic orthic dystrophic (RQotípico), Gleysol haplic (GXbd), Ultisol Red-Yellow dystrophic (PVA1), Nitossol Red distroferric (NVdf) and Litholic Neosol eutrofic (RLe) (Figure 3).

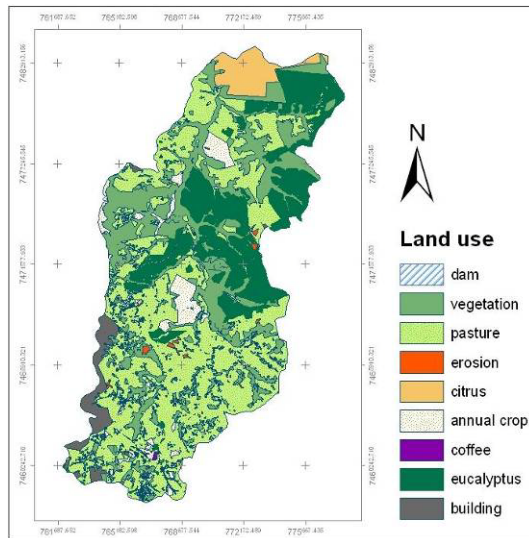


Figure 2. Land use map of Capivara watershed at 2009.

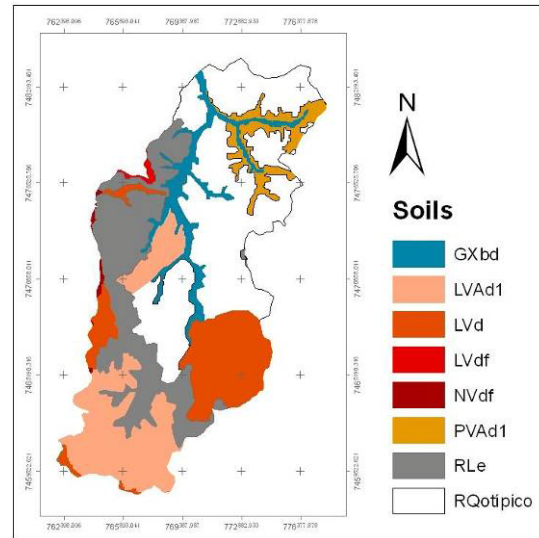


Figure 3. Soil map of Capivara watershed by Piroli (2002).

The digital elevation model was processed by the triangulation of the contour line map from Direct Plan of Botucatu city. For the modeling of the surface was used the method of interpolation called Triangulated Irregular Network. Thus is generating a raster model of surface where the tops of the hills and depressions are shaped in accordance with the trends of nearer data.

The digital elevation model is reclassified in percentage to produce the slope class map which is reclassified into seven categories: 0-3%; 3-6%; 6-12%; 12-20%; 20-40%; and above 40%, according to França (1963) and Lepsch (1991).

The study of the land use capacity was done based on methodology proposal for Lepsch (1991), by the overlay of the soil map with the slope classes map. This evaluation is categorized in groups, classes, subclasses and units of use capacity. The groups are characterized by the types of the intensity use on land, the classes by the level of limitation to use, the subclasses for the type of limitation and the units are characterized to specific conditions that affect the use or the management of the land. Figure 4 presents the definition of each group and its respective classes.

Group	Class	Description
A - land that may be used with annual crops, perennial and/or reforestation and wildlife	I	Cultivable lands, apparently without problems for conservation
	II	Cultivable lands, with simple problems for conservation
	III	Cultivable lands, with complex problems for conservation
	IV	Cultivable lands only occasionally or to a limited extent, with serious conservation problems
B – unsuitable land for intensive cultivation, but also adapted for pasture and/or eucalyptus and/or wildlife, but cultivated in some special cases of crops with protective soil practices	V	Adapted land for pasture and/or reforestation, without requirement for conservation practices, cultivated only in very special cases
	VI	Adapted lands only for pasture and/or eucalyptus with simple problems of conservation, cultivated only in special cases of some permanent crops with protective soil practices
	VII	Adapted lands only for pasture or eucalyptus, with complex problems of conservation
C	VIII	Inadequate land for annual crops, perennial crops, pasture or eucalyptus, but appropriate for protection of the biodiversity, recreation and storage of water

Figure 4. Presentation of the Groups and Classes of the Land Use Capacity.

According to this system of classification, the classes are categorized into subclasses: **s** – soil restriction; **e** – susceptible to erosion; **a** – restriction of water excess into the soil; **c** – climate.

RESULTS AND DISCUSSION: Established the zone of APP, was made the overlay between the APP zone (30 m of buffer for the both sides the banks and 50 m of radius to preserve the springs) with the land use map, and then identified how much of the Permanent Preservation Area is not in accordance with the Brazilian Forest Code. To Isernhagen et al. (2009), this information consists in a first and important thematic map (Figure 5), which is the adequacy of land use according to Brazilian environmental legislation. The areas identified in the APP zone without native vegetation cover are considered areas of conflict land use and therefore must be recovered with native vegetation. The total area for permanent preservation in the Capivara watershed, 36% (783 ha) are not cover with native vegetation, therefore are in conflict.

The failure of the Code is explained, partly, because in Brazil there is an inefficient supervision activity executed by government agencies in all the private rural lands, deforestation of the riparian areas to increase productive areas and also the lack of extension actives aimed for land users to the adoption of management practices for the responsible use of natural resource and to promote the conservation of vegetation in riparian areas.

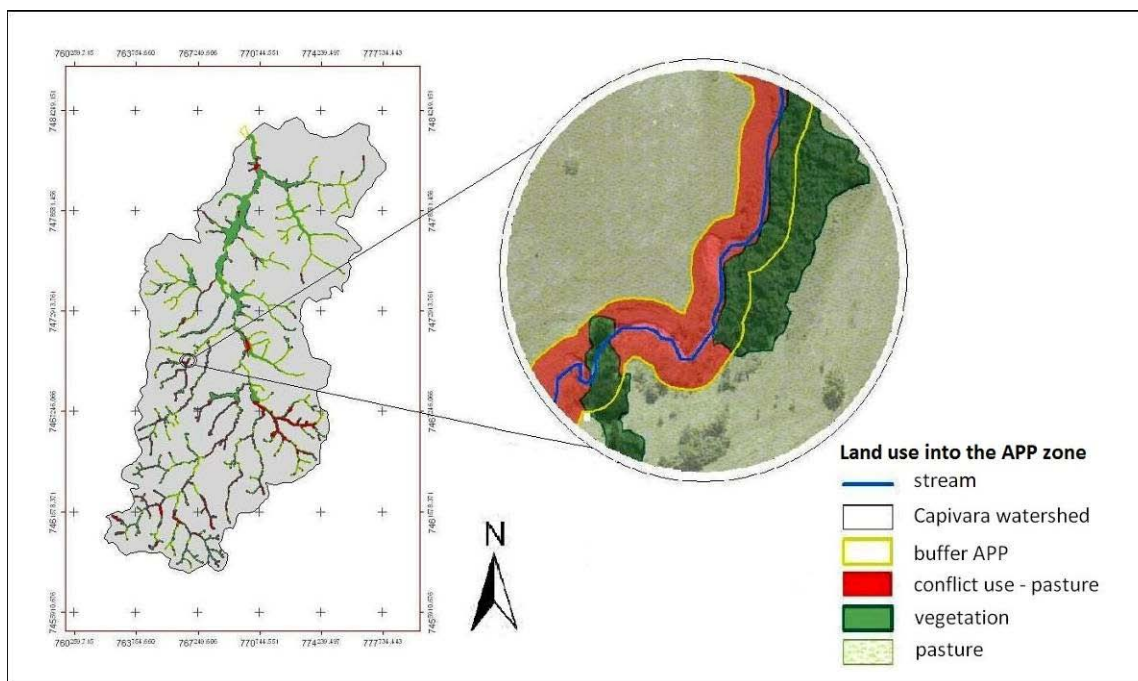


Figure 5. Identification map of APP zone in the Capivara watershed. Red areas correspond to the conflict of land use, therefore must be recovered – 738 ha.

The fragments of native vegetation, for its importance to maintaining biodiversity, soil and hydrological properties, it was excluded from the study of ability of land use. These fragments, by a specific study to each private rural land in the Capivara watershed may be registered as a Legal Reserve can be exploited commercially after a technical specific study for the management plan, paid by the respective landowners and approved by Sao Paulo State Environmental Agency.

With the identification of APP zone and fragments of native vegetation, these were defined as conservation areas, accounting 30% (6680) of the total area of the watershed.

After defined the conservation areas, the study focused on analysis in the potential lands for economic exploration by agricultural and livestock activities using the methodology of land use capacity. This method of classification proposed by Lepsch (1991) is based on the permanent limitation of land directly related with the possibility for intensity of use, which is a factor that expresses the level of mobilization needed to the management of soil, which causes more or smaller exposure to risk of erosion or loss of productivity.

Thus, the areas with potential for agricultural and livestock use, were identified following the classes: IIs; IIIs,e; IVe; IVs,e; Va; Ve; VIIe, corresponding in the total of the basin: 31% (6984 ha), 20% (4386 ha), 2.7% (622 ha), 8.5% (1911 ha), 2.3% (473 ha), 3% (702 ha), 2% (433 ha), 0.5% (30 ha) respectively.

The lands of the classes III and IV belong to the group A. This group consist of the flat lands or smooth undulate with low fertility and require special practices of soil conservation. In these lands, the use is predominantly for grazing and eucalyptus. What was observed in the field is that the system of overgrazing has led to the formation of erosion, therefore the abandonment of land and gradual loss of fertility; however, in the eucalyptus areas was observed the better conservation of soil and the absence of erosion.

Compared the subclasses **s**; **e** and **s,e** was observed that in the subclasses **e** and **s,e** the number of erosion is most than the other subclass because it's has higher susceptibility to erosion.

Group B, represented by fragile lands, with limitations to intensive cultivation, requires special systems of management for the conservation land. The class Va has flat lands limited by water excess into the soil because it's present low capacity of drainage. These lands are vulnerable to flooding and can be used for eucalyptus and pasture, but for pasture just in specific seasons of the year. This class is occupied by eucalyptus and pasture and not present advanced erosion process. Classes VIe and VIIe are characterized by steep slopes some times more than 40%, severe runoff and also severe restrictions of mechanization. For these classes, eucalyptus is the best way for the conservation of the soil and land use. However was observed in these classes the prevalence use for grazing and consequent accelerated process of erosion and siltation of watercourses.

By the study of land use capacity and the definition of the priority areas for conservation, it was possible to accomplish the zoning of Capivara watershed in units for economic use and units for conservation (Figure 6). The definition of the basin in specific units of the landscape was called as Ecological and Economic Zoning (ZEE – in Portuguese).

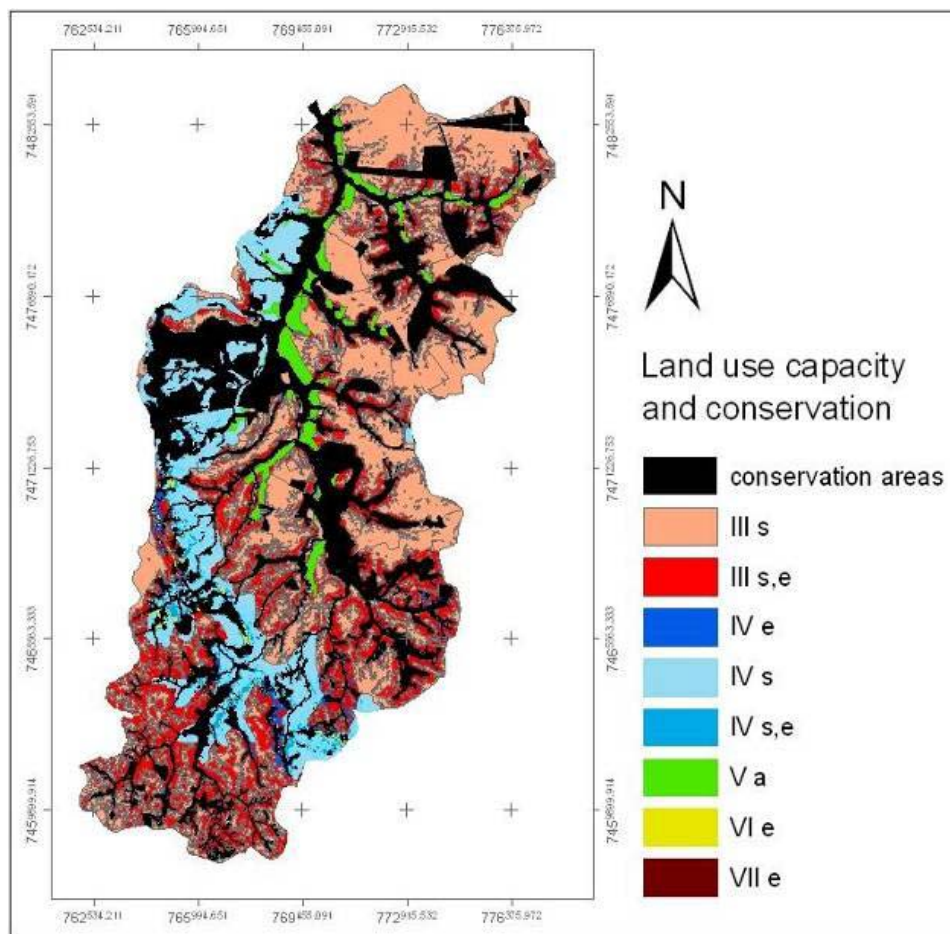


Figure 6. Ecological and Economic Zoning of Capivara watershed

CONCLUSION: Finally the ZEE provided an environment assessment about the physical and biotic features becoming an special instrument to planning that provides guidelines to reflect into the different decisions makers, they are public managers, landowners and others direct users of the land. The system of planning by ZEE will be more effective because the investments and efforts, both government and private initiative can be applied in accordance with peculiarities of the areas, which now are treated as planning units.

The study in level of watershed it made possible to understand that the Capivara watershed is different if compared with others similar basins in the same region. It not yet received on a large scale the cultivations of orange and sugar cane. This cultivations has been demonstrating by studies, to be serious responsible for the loss of the soil quality, deforestation of the forest fragments, riparian areas and contamination of the water resources. However, in this basin is possible to understand that the land use without any rational management action, in over the decades has been promoting mainly overgrazing by cattle, erosions and siltation of the all watercourses. This situation is leading the Capivara watershed to face high levels of flood which promote economic and environmental damages.

Even with all the efforts applied by government agencies, institutions of research and private initiative, for environmental recovery and the conservation of native vegetations remnant in Brazil, the environmental degradation process is occurring. Thus, it's clear to figure out that an important part of sustainable development process hadn't been achieve yet; which is the largest participation of universities and research institutions in extensions educations programs aimed to the land users, the effective commitment of the government agencies in the enforcement, compliance the Brazilian environmental legislation, the responsible and careful use of all private rural lands and the commitment of the citizens to demand sustainable products.

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