Environmental Assessment: Land Use and Conservation of Natural Resources

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Abstract: A considerable number of studies to evaluate the land use capacity and conservation of natural resources from integration methods for spatial data have shown the importance of integrated knowledge about the biophysical environment to enable land use planning coherent with the natural potential of the ecosystems. The purpose of the research was defined conservation areas and areas for agriculture and livestock, by investigating the land use capacity through the use of geographical information system and remote sensing. The results of the research show that more than 40% of the Capivara watershed is under conflict over land use based on land use capacity and Brazilian environmental law. Consequences of this inappropriate manner of management are observed in the number of erosions, streams becoming wide and shallow, flood peaks and the confinement of wildlife to a few fragments of native vegetation.

Key words: Environmental law, planning units, riparian zones, land use capacity, geographical information system.

1. Introduction

The occupation of land in the world, including Brazil, is directly related to the population's demands for food production, to urban and road system expansion and to exploitation of minerals and fossil fuels, which over the generations has brought about different scales of changes in the landscape. In some cases, especially in rural areas, the current process of territory occupation can be considerably reorganized to enable the exploitation of the soil, transformation of the landscape and economic development with sustainability.

The need for planning in the use of land and natural resources is urgent, because the disorderly and irresponsible occupation in the agricultural territories has pushed the capacity of the land to the limit. For that author, the situation of agriculture in Brazil is

alarming; however, by means of planning on a regional scale, it is possible to achieve favorable adaptations [1].

In the context of environmental planning and the management of land and natural resources, the use of computer technologies have become a special priority of researchers, companies and public administrators. Geoprocessing is a discipline that uses geographic information processed and interpreted by mathematical techniques inside the computing environment [1]. This field of science plays an important role in mapping areas, natural resource analysis, transportation, communication, energy and urban and rural planning [2].

The tools for geoprocessing are the Geographic Information Systems (GIS) that enable researchers to perform complex analysis, by integrating data from multiple sources, and create a geo-referenced database [3].

As a part of the data collection for environment studies, the soil survey should identify units and

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establish geographical boundaries beyond their physical and chemical characteristics and be systematized in thematic maps, which are widely used in the preparation of land-use-capacity maps [4]. Interpretations of soil surveys are predictions of soil behavior in the context of specific purposes and certain environmental conditions [5].

The adaptation of land for different agricultural and forestry activities is related to the land use capacity, i.e., its adaptability for various purposes given its possibilities and limitations [6]. The capacity of a land parcel is defined by comparing its agricultural conditions with the levels required for soil fertility, water stress, erosion susceptibility and impediments to mechanization [7].

The land use capacity system represents qualitative groups of soil systematizing characteristics and properties to enable the establishment of its maximum capacity for use without risk of degradation or intensive erosion process; the land characteristic is what can be measured and estimated as a soil color, while the proprieties are the attributes relative to the behavior resulting from the interaction between the soil and environment, such as a risk of erosion for example [6].

The land use in disagreement with its respective capacity associated with lack of knowledge and indifference about the characteristics and ecological functions of certain landscape elements, such as replacement of riparian forests by pasture or planting areas, causes serious damage to the quality of water resources and to the regime of floods and droughts in the basin. The implementation of agricultural crops in regions near spring water, which are grown with fertilizers and pesticides that can contaminate water bodies including reservoir supplies for humans [8].

Over the decades the process of expanding the management zones for agriculture and livestock has caused a large-scale replacement of natural vegetation in modified landscapes. In this context, the forests—which perform an important role in water

quality, erosion minimization, sediment regulation and filtration of pollutants before they can enter into the streams [9]—have been dramatically reduced to mere fragments in the Atlantic Forest ecosystem [10]. This ecosystem was traditionally the supplier of agricultural products whereas today, it hosts the largest occupation of industry, sugarcane and major urban centers [11]. Most of this ecosystem has been destroyed over a number of developmental cycles resulting in severe consequences, especially high fragmentation of habitat.

From the perspective of watershed management it is important to keep in mind the role of riparian areas. The native vegetation inside the riparian areas protects water bodies against wave action in coastal mangroves, streambanks and lakes. This occurs because shrub roots, tree roots and forest understorey stabilize banks against erosion [9].

The riparian area is a vital element between land use and the watershed river system. Its functions go beyond just protection against the erosion and silting of river banks, given that the vegetation along the riparian area, especially forest understorey, intercepts large quantities of pollutants and sediments from agriculture as they move towards flowing water from upslope areas outside the riparian areas and reduce the speed of runoff, which improves the well rate of water infiltration into the soil and provides better regulation of basin flood [9].

Due to the importance of the riparian areas, the Brazilian Federal Government in 1965, while creating the Brazilian Forest Code, Law 4.771 [12], determined the riparian areas such as the Permanent Preservation Area (APP-in Portuguese). According to the Forest Code, the APP zone must be found in all watercourses and spring water in a buffer of at least 30 meters to each side of its banks and a radius of 50 meters to preserve the springs. Moreover, in southeastern Brazil, the private rural lands must set aside a native vegetation area of Legal Reserve (RL-in Portuguese) of at least 20% of the property in order to

maintain habitat for wildlife, corridors of biodiversity and preservation of flora.

The data on the socioeconomic and environmental characteristics constitute 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 ascertain the environmental characteristics by the preliminary study associated with scientific knowledge is fundamental in the decision-making process to choose the best manner to manage the land, to recover degraded land and achieve reforestation [13]. For these authors, the study and recognition of the area that will be subjected to the environmental assessment lead us to the environmental adequacy plan that consists of actions including conservation, management and recovery of the environment.

Given the fragmented state of the native vegetation in most basins in Sao Paulo state, the conflicting uses for agriculture and livestock related to the land use capacity, the accelerated erosion process in some regions, the non-compliance and disrespect of the Forest Code, the fragility of the soils from the Basaltic Cuesta in the Capivara watershed, the significant

wildlife hosted in this basin, its status as a habitat for mammal species at risk of extinction, especially the *Puma concolor* (Cougar) and the potential of the Capivara watershed as a water source, the present study was conducted in order to evaluate the use and conservation of the watershed and develop maps of suitability for restoration of riparian areas and sustainable use of soil.

2. Materials and Methods

2.1 Study Area

This work was carried out in the Capivara watershed, located in the town of Botucatu (SP-Brazil), between the plane coordinates 758,000, 7,486,000 and 779,645, 7,456,286 with a total area of 22,231 ha (Fig. 1).

The study area is within the region of a geological formation called Basaltic Cuesta, characterized by three distinct geological units: (1) Reverse side of the Cuesta (beginning of western plateaus) with altitudes between 700 and 950 m (in relation to the sea level); (2) Front of the Cuesta (sandstone-basaltic scarp); and (3) Depression of Cuesta with altitudes between 400 and 600 m (in relation to sea level) [14].

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

The Cuesta relief, a striking feature of the region, results from the continuous action of erosion on the ground which formed the rocky platforms now standing in the smooth valleys. The asymmetrical relief is constituted by an alternating succession of layers with different resistances against abrasion and unidirectional inclination to form a smooth slope in the Reverse side and one abrupt or steep slope in the Front of the Cuesta [15].

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

The natural vegetation of the basin consists of three types: Semideciduous seasonal forest, especially in the Front / Face area of the Cuesta, Brazilian Cerrado both on the Reverse side of the Cuesta and the Peripheral Depression, and Riparian vegetation along the water bodies [15]. Ecotone areas are also found in the transition from semideciduous seasonal forest to Brazilian Cerrado [14].

In a survey of fauna developed in fragments of native vegetation of the Capivara watershed, 20 species of mammals had been found. Amongst these, the following three are on the Brazilian list of species at risk of extinction: *Myrmecophaga tridactyla* (Tamanduá-bandeira), *Leopardus pardalis* (Ocelot) and *Puma concolor* (Cougar) [16]. For the researcher, the study area is indicative of the need to carry out programs for the conservation of medium-size and large mammals.

2.2 Methods

The data on the land use and contour lines of the region were obtained from the Direct Plan of the town of Botucatu developed in 2005. The land-use map, which was updated in November 2009 for this study (Fig. 2) shows the following distribution of uses: 0.21% dams (29 ha); 26.5% native vegetation (5,896 ha); 44.8% pasture (9,880 ha); 0.5% erosion (116 ha); 3.5% citrus (797 ha); 4% annual crop (900 ha); 0.05% coffee (13 ha); 17.6% eucalyptus (3,922 ha) and 3%

buildings (670 ha).

The soil map was obtained from a soil survey according to the Brazilian soil system [17]. On scale of 1:50.000, the following soils were determined: Oxisol (*Latossolo Vermelho distrófico*—LVd), Oxisol (*Latossolo Vermelho distroférrico*—LVdf), Oxisol (*Latossolo Vermelho-Amarelo distrófico*—LVAd1), Entisol (*Neossolo Quartizarênico órtico*—RQotípico), Inceptisol (*Gleissolo Háplico distrófico*—GXbd), Ultisol (*Argissolo Vermelho—Amarelo distrófico*—PVAd1), Alfisol (*Nitossolo Vermelho distroférrico*—NVdf) and Neosol (*Neossolo Litólico eutrófico*—RLe) (Fig. 3).

The digital elevation model was processed by the triangulation of the contour line map from the Direct Plan of the town of Botucatu. Surface modeling was accomplished by the interpolation method called Triangulated Irregular Network. From this form a raster surface model is generated so that the valleys and tops of hills are shaped according to the trends of the closest data.

The digital elevation model is reclassified as a 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 Lepsch [6].

The study of the land use capacity was based on the methodology proposal by Lepsch [6], through superimposing the soil map on the map of slope classes.

2.3 Data Analysis

This evaluation is categorized into groups, classes, subclasses and units of use capacity. The groups are characterized by intensity of use, the classes by the level of limitation for use, the subclasses by the type of limitation while the units are characterized by specific conditions that affect the use or the management of the land. Fig. 4 presents the definition of each group and its respective classes.

Fig. 2 Land use map of Capivara watershed from 2009.

Fig. 3 Soil map of Capivara watershed.

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.

Fig. 4 Presentation of the groups and classes of land use capacity.

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

3. Results and Discussion

The Permanent Preservation Area was established by overlaying the APP zone (30 m of buffer for both banks and 50 m of radius to preserve the springs) on the land use map, and then identifying how much of the Permanent Preservation Area is not in accordance with the Brazilian Forest Code. To Isernhagen et al. [13], this information consists of an important primary thematic map (Fig. 5), which presents the adequacy of land use according to Brazilian environmental law. The areas identified in the APP zone without native vegetation cover are considered areas of land use conflict and therefore must be recovered with native vegetation. The total area for permanent preservation in the Capivara watershed,

36% (783 ha), is not covered with native vegetation and is thus in conflict.

The failure of the Code is explained partly by the fact that in Brazil the supervisory activity executed by government agencies is inefficient in relation to all the private rural lands, deforestation of the riparian areas to increase productive areas and also the lack of extension activities aimed at stimulating land users to adopt management practices to use natural resources responsibly and to promote the conservation of vegetation in riparian areas.

Given their importance for maintaining biodiversity, soil and hydrological properties, fragments of native vegetation were excluded from the study of land use capacity. These fragments, by a specific study for each private rural land in the Capivara watershed, may be registered as a Legal Reserve that can be exploited commercially after a specific technical study for the management plan funded by the respective landowners and approved by the Sao Paulo State Environmental Agency.

Fig. 5 Identification map of APP zone in the Capivara watershed: red areas correspond to areas of land use conflict and, therefore, must be recovered 738 ha.

Once the APP zone and fragments of native vegetation were identified, they were defined as conservation areas, accounting for 30% (6,680) of the total watershed area.

After defining the conservation areas, the study focused on analysis of the potential lands for economic exploration by agricultural and livestock activities using the methodology of land use capacity. This classification method is based on the permanent limitation of land and focused on its possibilities and limitations in direct relation to the use intensity, a factor that expresses the level of mobilization needed to manage the soil, which causes greater or smaller exposure to risk of erosion or loss of productivity.

Thus, the areas with potential for agricultural and livestock use were identified according to the following classes: IIs; IIIs,e; IVe; IVs,e; Va; Ve; VIIe, corresponding to the following respective total percentages in the basin: 31% (6,984 ha), 20% (4,386 ha), 2.7% (622 ha), 8.5% (1,911 ha), 2.3% (473 ha), 3% (702 ha), 2% (433 ha) and 0.5% (30 ha).

The lands of the classes III and IV belong to group

A, which consists of the lands that are flat or possess smooth undulations with low fertility and require special practices of soil conservation. These lands are used predominantly for grazing and eucalyptus. What was observed in the field is that the system of overgrazing has led to the formation of erosion and, therefore, the abandonment of land and gradual loss of fertility; however, in the eucalyptus areas, better soil conservation and the absence of erosion were observed. By comparing the subclasses s; e; s,e it was revealed that the subclasses e and s,e presented more numerous instances of erosion than the other subclasses due to their higher susceptibility to erosion.

Group B, represented by fragile lands with limitations on intensive cultivation, requires special systems of land conservation management. The class Va has flat lands limited by excess water in the soil due to low drainage capacity. These lands are vulnerable to flooding and can be used for eucalyptus and, only in specific seasons of the year, pasture. This class is occupied by eucalyptus and pasture and does not present an advanced erosion process. Classes VIe

and VIIe are characterized by steep slopes, of more than 40% in some cases, severe runoff and also severe restrictions on mechanization. For these classes, eucalyptus is the best means for soil conservation and land use. However, grazing was the prevalent use among these classes which presented, consequently, an accelerated process of erosion and siltation of watercourses.

By studying the land use capacity and defining the priority areas for conservation, it was possible to accomplish the zoning of Capivara watershed in units for economic use and units for conservation (Fig. 6). The definition of the basin in specific landscape units was denominated Environmental and Economic Zoning.

4. Conclusion

Finally the Environmental and Economic Zoning provided an environmental assessment of the physical and biotic features which functions as a special instrument for planning that provides guidelines to the different decisions makers who include public

managers, landowners and other direct users of the land. The system of planning by Environmental and Economic Zoning will be more effective because the investments and efforts by both governmental and private initiative can be applied in accordance with the peculiarities of the areas, which now are treated as planning units.

In this basin of the present study, it is possible to understand that the land use without any rational management action, over the decades, has been promoting mainly cattle overgrazing, erosions and siltation of the all watercourses. This situation is leading the Capivara watershed to face high levels of flooding which promote economic and environmental damage.

Despite all the efforts applied by government agencies, research institutions and private initiative to promote environmental recovery and the conservation of the remaining native vegetations in Brazil, the environment continues to degrade. Thus, it is also clear that an important component in the process of sustainable development was not achieved, namely a

Fig. 6 Environmental and Economic Zoning of Capivara watershed.

greater participation of universities and research institutions in educational extension programs aimed at the land users, the effective commitment of government agencies to the enforcement of and compliance with Brazilian environmental law, the responsible and careful use of all private rural lands and the commitment of the citizens to demand sustainable products.

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