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Land use at the margins of the Atibainha Reservoir, Cantareira Water System (SP): conflict with the current legislation

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Abstract – The management of hydrographic basins for water supply involves land use diagnose for environmental quality assessment and liabilities resulting from practices that can be harmful to water resources. The identification of different forms of land use in Permanent Preservation Areas (PPA), as defined in the New Brazilian Forest Code (Federal Law 12.651/12), is necessary for the assessment of expected impacts on water quality. The objective of this work is to comprehend territorial dynamics in the Atibainha Reservoir tributary basin, located in Nazaré Paulista and Piracaia (SP). GIS techniques were applied to define the PPA size on the margins of the reservoir, adopting widths of 100 meters for rural areas and 30 meters for urban areas. Remote sensing techniques were applied to map land cover through the automatic supervised classification. Land cover mapping showed the presence of 55.9% native forest, 29.3% undergrowth, 6.9% reforestation, 4.5% water and 3.4% of area built in the tributary basin. 98.5% of the total area of the reservoir (1596.24 km^2) corresponds to rural areas. The marginal Atibainha Reservoir PPA is composed of 58.9% native forest, 33.5% undergrowth, 5.7% built-up area and 1.9% reforestation. A growing urban development of homes and clubs around the dam is observed, affecting the PPA in varying alarming ways, which leads one to consider the urgent need of public policies for the Atibainha Reservoir.
Keywords: Atibainha Reservoir, Cantareira Water System, Permanent Preservation Area, New Brazilian Forest Code, Land Uses.

Resumo – O USO DA TERRA NAS MARGENS DA REPRESA ATIBAINHA, SISTEMA DE ÁGUA CANTAREIRA (SP): CONFLITOS COM A LEGISLAÇÃO AMBIENTAL VIGENTE. O gerenciamento de bacias hidrográficas de abastecimento implica na realização de diagnósticos de uso da terra para avaliação da qualidade ambiental e dos passivos resultantes de práticas danosas ao recurso hídrico. A identificação de diferentes formas de uso da terra que ocupam Áreas de Preservação Permanente, definidas no Novo Código Florestal Brasileiro (Lei Federal 12.651/12), é um levantamento necessário para a avaliação dos impactos esperados na qualidade da água. O objetivo deste trabalho é compreender a dinâmica territorial na bacia contribuinte do reservatório Atibainha, localizado em Nazaré Paulista e Piracaia (SP). Aplicaram-se técnicas de geoprocessamento para definir a faixa relativa à APP da margem do reservatório com 100 metros na zona rural e 30 metros na urbana. Técnicas de sensoriamento remoto foram aplicadas no mapeamento da cobertura da terra da bacia através da classificação automática supervisionada. A cobertura da terra demonstrou a presença de 55,9% de mata nativa, 29,3% de vegetação rasteira, 6,9% de reflorestamento, 4,5% de água e 3,4% de área edificada na bacia contribuinte. Da área total do reservatório (1.596,24 km^2), 98,5% encontra-se em zona rural. A APP marginal do reservatório Atibainha apresentou 58,9% de mata nativa, 33,5% de vegetação rasteira, 5,7% de área edificada e 1,9% de reflorestamento. Observa-se um crescente desenvolvimento urbano de residências e clubes ao redor da represa atingindo em inúmeras situações a APP de maneira preocupante, o que se leva a considerar a urgência de políticas públicas para o reservatório Atibainha.
Palavras-chave: Reservatório Atibainha, Sistema de Água Cantareira, Área de Preservação Permanente, Novo Código Florestal Brasileiro, Uso da terra.

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1 Introduction

Contamination of surface waters has taken place in an accelerated way in recent decades, due to the different forms of land use and anthropic occupation (Tundisi *et al*., 2006). Tundisi (2003) lists the major activities that cause negative impacts on inland aquatic systems and coastal waters in the Brazilian territory: deforestation, mining, urbanization, construction of roads, dams, canals and waterways, sewage discharge, discharge of industrial effluents and agricultural wastes, and solid waste disposal, among others.

As regards to urbanization, Tucci (2010) draws attention to the fact that global urbanization has depended on the socioeconomic development model adopted in the recent past. According to this author, it is estimated that in 2050 the world population, whose growth will mainly occur within metropolitan areas, will be 9 billion. Chart 1 presents a summary of the main environmental impacts of the urbanization process.

Chart 1. Main environmental impacts caused by urbanization (Braga & Carvalho, 2003).

Elements of physical environment	Main effects / processes
Soil	Permeability reduction Contamination Erosion
Relief	Mass movement Subsidence
Hydrography	Deregulation of the hydrological cycle Floods Pollution of water springs Contamination of aquifers
Air	Pollution (the main pollutants: SO_2, CO, particulate material)
Climate	Greenhouse effect Heat island effect Dehumidification
Vegetation	Deforestation Decreasing biodiversity Planting of inadequate species
Fauna	Decreasing biodiversity Proliferation of urban fauna Zoonoses
Man	Stress Urban diseases (infectious, degenerative, mental) Urban violence

Urban water services made available to the public by the competent bodies shall include, in an integrated manner, water supply, sewage treatment, urban drainage and solid waste disposal. According to Tucci (2010), these are the main components in order to have a sustainable urban environment, taking into account environmental conservation, public health and socioeconomic aspects of urban development.

In large urban centers or metropolitan areas, water comes from existing streams (water springs), underground aquifers and relatively often, neighboring basins. This is the case of the Metropolitan Region of São Paulo City – MRSP, composed of 39 municipalities with around 20 million inhabitants. In terms of reservoirs, it is supplied by eight water systems: Cantareira, Billings / Guarapiranga, Upper and Lower Cotia, Upper Tietê, Rio Claro, Rio Grande and Ribeira da Estiva, totalizing 22 reservoirs.

These artificial systems are not only major reservoirs for water supply, but are also areas where the people who live in MRSP perform important activities, such as tourism, recreation, fishing, and fish farming (Tundisi *et al*., 2006).

In terms of hydrographic basin, some of these producing systems are located in Water Source Protection Areas (WSPAs) (São Paulo, 1975, 1976), which were created in the 70's. The WSPAs only include a small part of the Cantareira System in its south part, and do not reach the Atibainha basin.

In order to protect the quantity and quality of water from these reservoirs and to meet the MRSP growing demand, the Piracicaba-Juqueri Mirim Environmental Protection Area (EPA) was instituted (São Paulo, 1987, 1991), which covers the major reservoirs of the Cantareira System, Jaguari/Jacareí, Cachoeira and Atibainha, and the Juqueri-Mirim River springs forming the Reservoir Paiva Castro in Mairiporã. Subsequently, the Cantareira System EPA was created (São Paulo, 1998) involving the municipalities of Mairiporã, Atibaia, Nazaré Paulista, Piracaia, Joanópolis, Vargem and Bragança Paulista. It is important to note that these EPAs lack regulation (Whately & Cunha, 2006). In other words, no Ecological-Economic Zoning was established for them. Figure 1 shows the location of the Atibainha basin in relation to the MRSP WSPAs and the Cantareira System EPA.

The legislation for Water Source Protection Areas was ultimately subject to alteration in view of the water sources of regional interest (São Paulo, 1997) with the mandatory preparation of specific laws for the Guarapiranga (São Paulo, 2006)

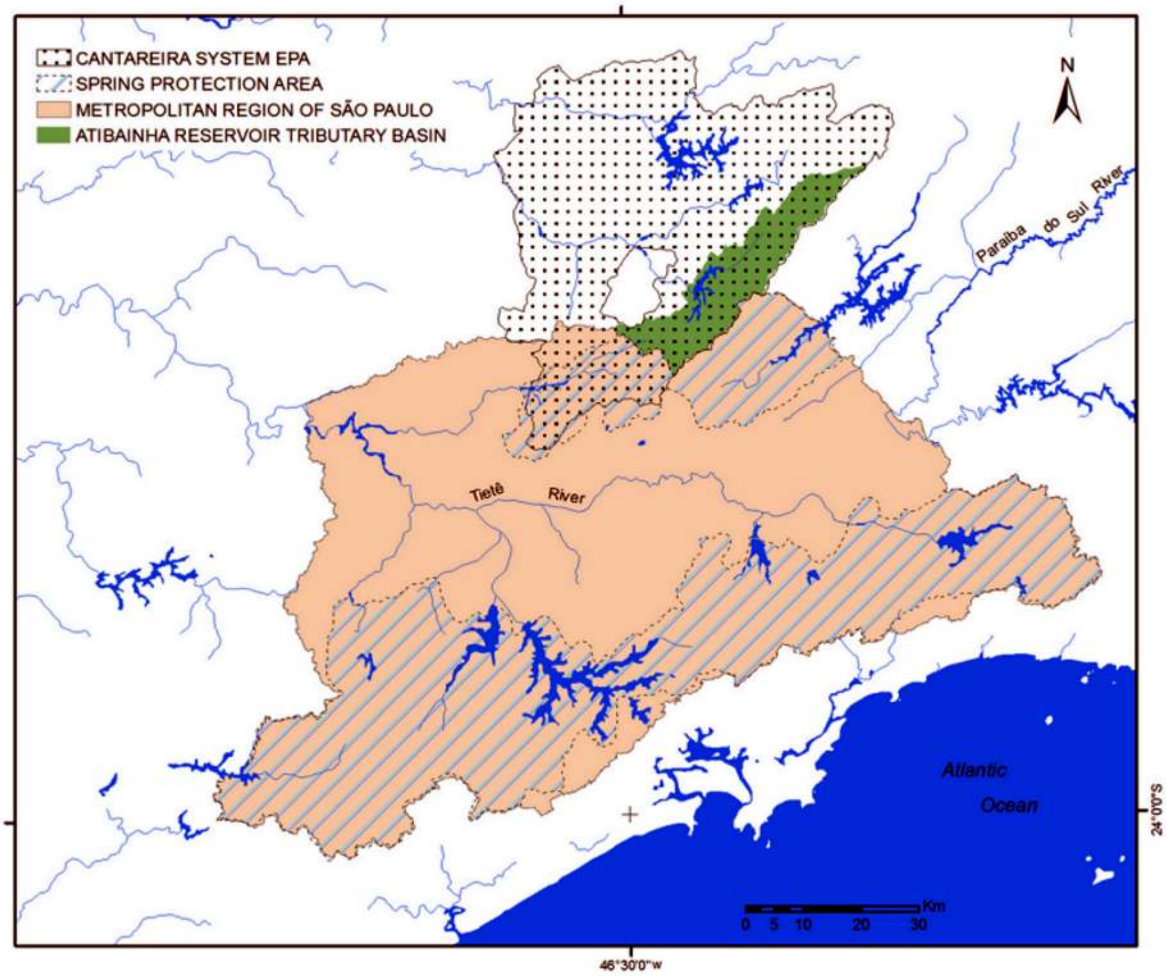

Figure 1. Location of the Atibainha basin in relation to the MRSP WSPAs and the Cantareira system EPA.

and Billings (São Paulo, 2009, 2010) water sources, but not for the Cantareira System.Although obvious precariousness exists in environmental control standards for land use regarding the Atibainha basin and great part of the Cantareira System, the Permanent Preservation Areas (PPAs), as established by the Brazilian Forest Code (Brasil, 2012a), aim to protect areas covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability and biodiversity, facilitating gene flow of fauna and flora, protecting soil, and ensuring the well-being of human populations. Note that water resources are the first to be related to PPAs.

The role of riparian forests for protection of water bodies as the hydrogeochemical changes is the subject of several studies that emphasize the importance of this dynamic component of the hydrological cycle (Likens, 1992; Paula Lima & Zakia, 2001; Tundisi & Matsumura-Tundisi, 2010). Skorupa (2003) points out that among the environmental benefits of maintaining riparian vegetation on the banks of watercourses and reservoirs, there is its role as a filter or buffer for the interface between agricultural areas and pastures with the aquatic environment, allowing control of soil erosion and water quality, and avoiding direct entrainment of sediment, nutrients and chemicals from higher parts of the terrain into the aquatic environment.

With respect to public water supply from artificial reservoirs, the Forest Code and the Law amending it (Brasil, 2012b) refer to the width definition of the PPAs surrounding areas as that one defined at the time of the PPAs environmental licensing. In this sense, the reservoirs rebuilt before the change in the legislation that enforced environmental licensing (CONAMA, 1986) (Brasil, 1981), as is the case of Atibainha, which started to be built in 1966 and opened in 1974, have no approved environmental licensing. Thus, it remains to consider the criteria of Resolution 302 (CONAMA, 2002) that establish a minimum of 100 m of width for rural areas and 30 m width for urban areas.

The Cantareira System is currently responsible for 61 % of the MRSP water supply; however, it proved to be extremely vulnerable to the biggest drought of the last 84 years, occurring from 2013 to 2014. This study aims at producing a diagnosis of the land use, especially the PPA related to the margins of the Atibainha reservoir, and thus to relevantly contribute to environmental planning and management of this major water supply system of unquestionable value.

The general objective of this work is to understand the territorial dynamics in the Atibainha basin and reservoir by observing the occupation process along the banks of the water bodies. Thus it is intended to demonstrate and measure the environmental and legal conflict caused by some form of improper land use in the reservoir PPA.

2 Area and methods

The total area of the Atibainha basin and reservoir is estimated to be 36,792 ha. It is located between parallels 22º 59'S and 23º19'S and meridians 46°05'W and 46°31'W, in the eastern portion of São Paulo State and close to Nazaré Paulista and Piracaia towns (Figure 2). The basin is adjacent to MRSP and located north-northeast of Water Resources Management Unit 5 (UMWR 05), including Piracicaba, Capivari and Jundiaí basins.

The basin is part of the Cantareira System, which supplies water to MRSP. The Atibainha basin is fully included in the Environmental Protected Area (EPA) of Cantareira System and EPA of Piracicaba-Juqueri Mirim, which are overlapping protected areas of sustainable use.

With an elongated shape, the basin extends for 51.5 km northeastwards-southwestwards, with an average width of about 8 km, being traversed in the east-west direction and in the central portion by the Dom Pedro I Highway. The urban center of Nazaré Paulista is located in the southwestern portion of the highway, in the vicinity of the reservoir dam.

The Atibainha Reservoir permanent preservation areas (PPA) as predicted by the Brazilian Forest Code (Brasil, 2012a) correspond to a marginal strip of land of variable width for urban (15 m) and rural (100 m) use, with a total estimated area of 1,596 ha, equivalent to ca. 4,3 % of the basin area.

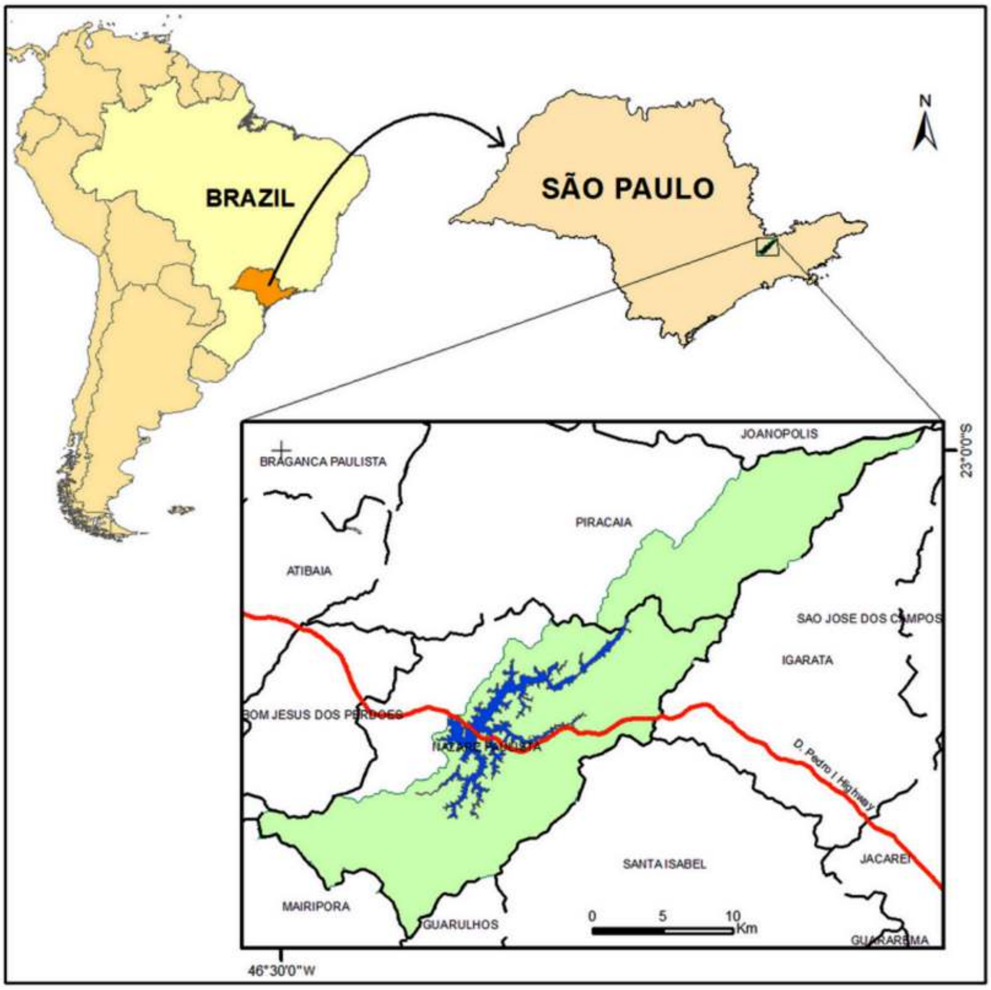

Figure 2. Location of the Atibainha Basin and Reservoir.

2.1 Geology

The area of the Atibainha Reservoir is part of the Southeastern Fold Region tectonic context (Hasui et al., 1978), more specifically related to the Ribeira Orogen and partly to the Brasília Orogen, which constitutes the Mantiqueira Province in southern Brazil (Almeida et al., 1977, 1981). It developed during the Neoproterozoic Brasiliano/Pan-African Orogeny (Brasiliano Cycle), which began ca. 880 Ma and ended ca. 480 Ma ago, resulting in the amalgamation of West Gondwana paleocontinent (Heilbron et al., 2004).

The Atibainha Basin it located in the central segment of the Mantiqueira Province, mostly in the Tectonic-Stratigraphic Terrain called Apiaí-São Roque Domain, with a smaller portion in the Apiaí-Guaxupé Domain. The predominant lithostratigraphic unit is the Serra Itaberaba Group, which is a Mesoproterozoic metavolcano-sedimentary sequence (1.4 Ga), characterized by metavolcanic rocks of tholeiitic affinity at the base that grade to andesitic and rhyolitic metavolcanic rocks and metatuffs and clast-chemical series of metapelites and immature metapsammites (Juliani, 1993; Juliani & Beljavskis, 1995). Metamorphism also reached the amphibolite facies, kyanite zone, and a São Roque's pre-schistosity.

The Neoproterozoic São Roque Group and the Varginha-Guaxupé Complex are the other lithostratigraphic units that occur in narrow bands. The São Roque Group is represented by meta-rhythmites and metabasic rocks, whereas the Varginha Complex-Guaxupé is composed of migmatitic orthogneisses and paragneisses. Abundant syn-orogenic, calc-alkaline and potassic granites predominantly of Neoproterozoic age also occur.

The tectonic compartmentation is marked by the NE-SW dextral, transcurrent Jundiuvira Fault, which separates the Serra do Itaberaba and São Roque Group, related to the Ribeira Orogeny, from the Varginha-Guaxupé Complex, in the Socorro Nappe terrain, located northwest of the Atibainha basin. The lithostratigraphic map of the Atibainha basin is shown in figure 3.

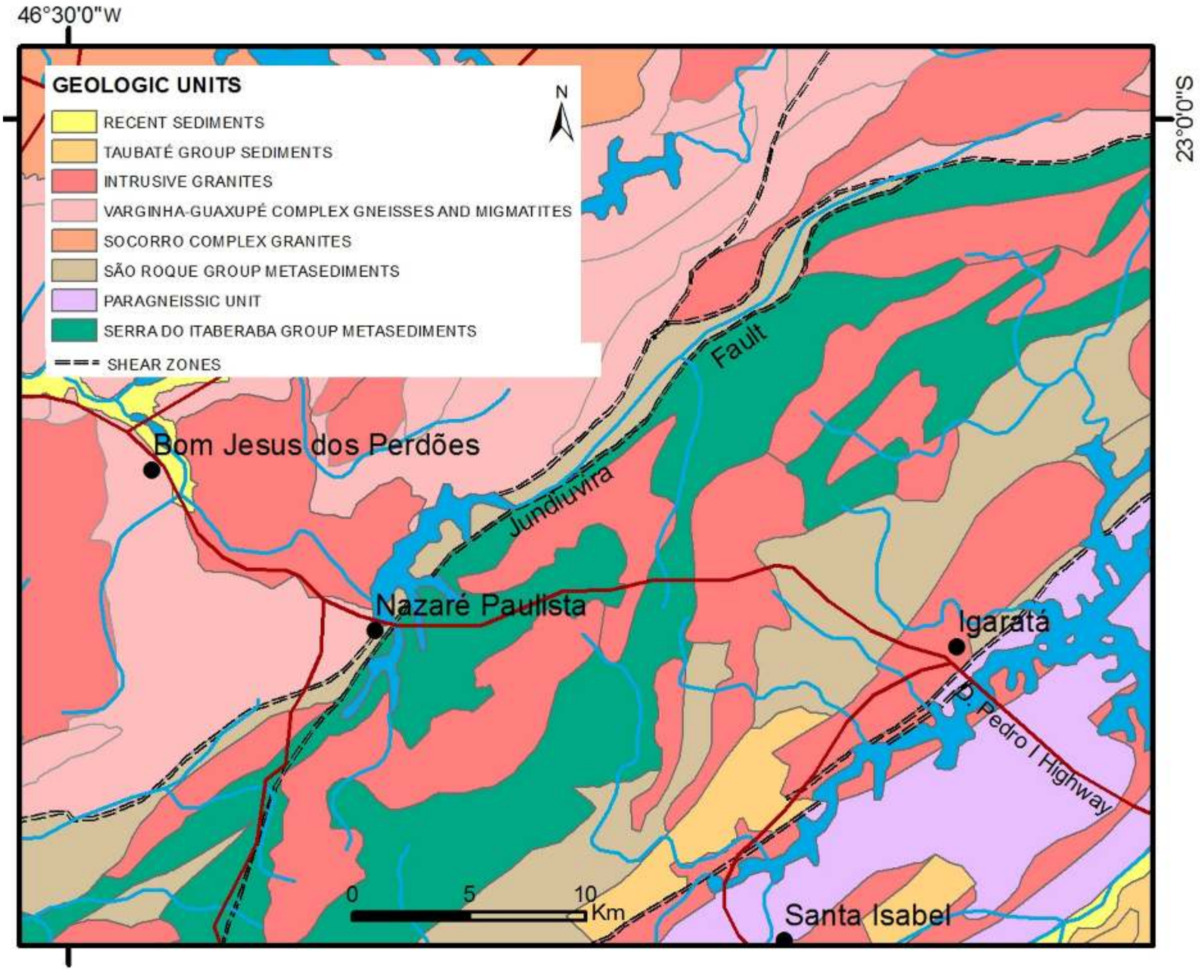

Figure 3. Lithostratigraphic map of the Atibainha Reservoir (modified from CPRM, 2006).

2.2 Geomorphology

The Atibainha Basin and Reservoir are located in the Atlantic Plateau, major relief unit in Southeastern Brazil that is inserted in the morphologic-climatic domain defined by Ab'Saber (1966) as Seas of Forested Hills.

The Atlantic Plateau was conceptualized by Ross & Moroz (1997) as the Atlantic Orogenic Belt Morphostructure, which admittedly is a major geomorphological compartment of Southeastern Brazil. In São Paulo State, it was subdivided into compartments that form a mosaic of morphologically uneven surfaces or levels due to a complex history involving tectonic activity associated with cycles of flattening, starting in the Cretaceous (Wealdenian reactivation) and extended to the Cenozoic with the South American Platform slow uplift associated with the mobilization of tectonic plates.

The Atlantic Orogenic Belt Morphostructure defines the macro-unit relief as plateaus and mountains named Eastern-Southeastern Atlantic (Figure 4), with the Atibainha Basin specifically located in the Serra da Mantiqueira compartment (Ross & Moroz, 1997), whose landforms are formed by hills and elongated hills, shows a dense dendritic drainage network strongly affected by major structural directions, located at altitudes between 900 and 1,400 m, predominantly capped by soil and lithic cambic Neosoils (Ross, 2006). In the watershed, the highest elevations are found south (1,438 m) and north (1,482 m) of the Itaberaba Peak, whereas the lowest surface corresponds to the water reservoir level (approximate altitude of 790 m).

The Mantiqueira Plateau relief units are characterized by its very dissected shapes, incised valleys, very high drainage density and very steep slopes. Ross & Moroz (1997) describe it as of very high potential fragility, subject to intense erosion and high probability of occurrence of mass movements.

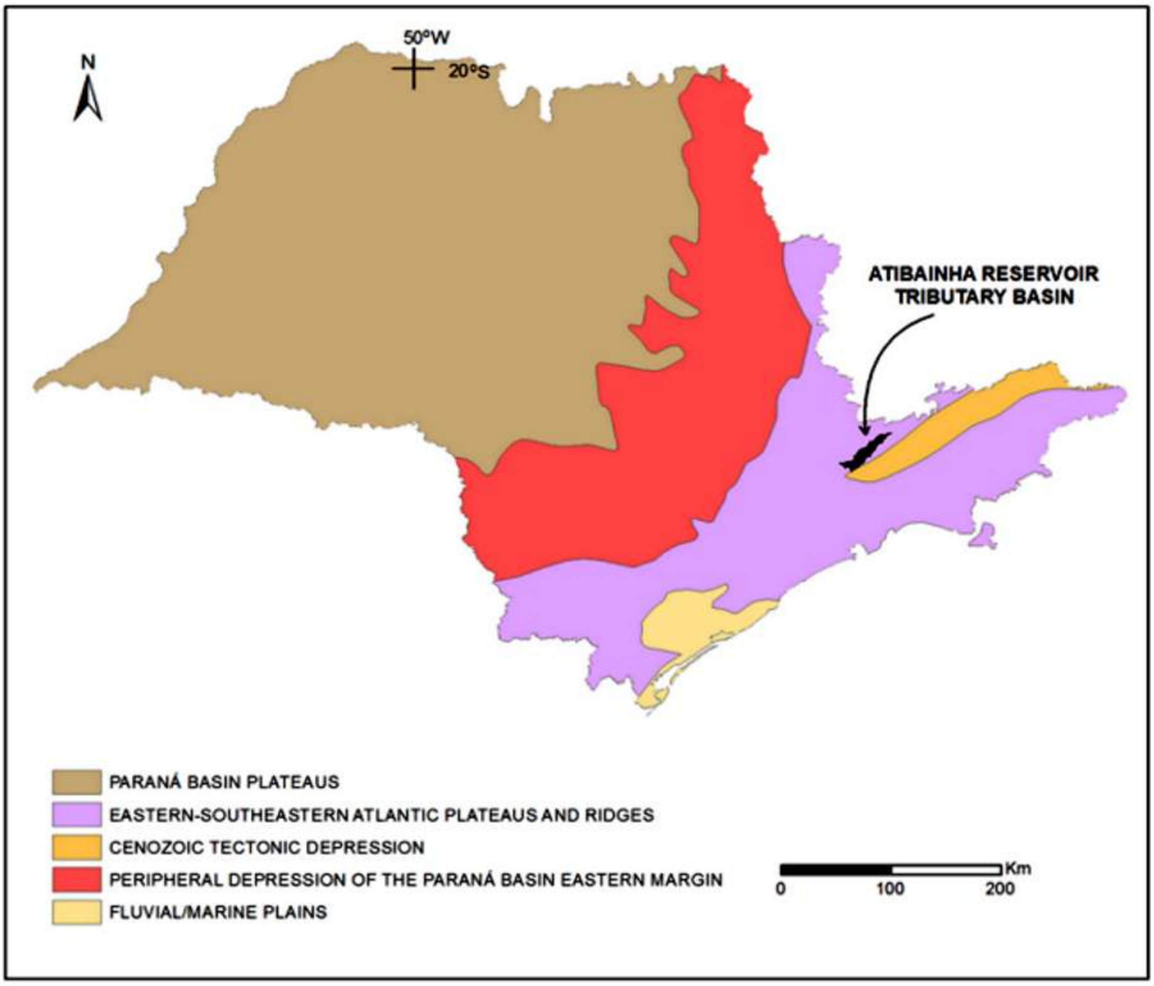

Figure 4. Location of the Atibainha Basin in the São Paulo State relief macro-compartmentalization (modified from Ross, 2006).

2.3 Climatic aspects

The climate in the Atibainha Basin region is strongly influenced by the Atlantic Ocean, conferring to it a significant rainfall distribution. Climatological data presented by Alvares et al. (2013) for the Nazaré Paulista municipality point to an average annual rainfall exceeding 1,436 mm, the average temperature of the coldest month (July) equaling 14.1 ºC and of the hottest month reaching 21 ºC. Also based on these authors and on Koppen's classification, the basin lies in the Subtropical Humid Zone, influenced by the oceanic climate, with no dry season and temperate summer (Cfb). Figure 5 shows the Climatic Zoning of São Paulo State and the location of the Atibainha Basin.

Especially due to climatic characteristics, the predominant biome in the region is the Atlantic Forest, with typical dense rain-forest vegetation type (IF, 2005). The basin is inserted in the Atlantic Forest Biosphere Reserve (AFBR) and the Green Belt Biosphere of the City of São Paulo Reserve (GBBR). The rainfall pattern and abundant forest cover confer significant water availability for the basin.

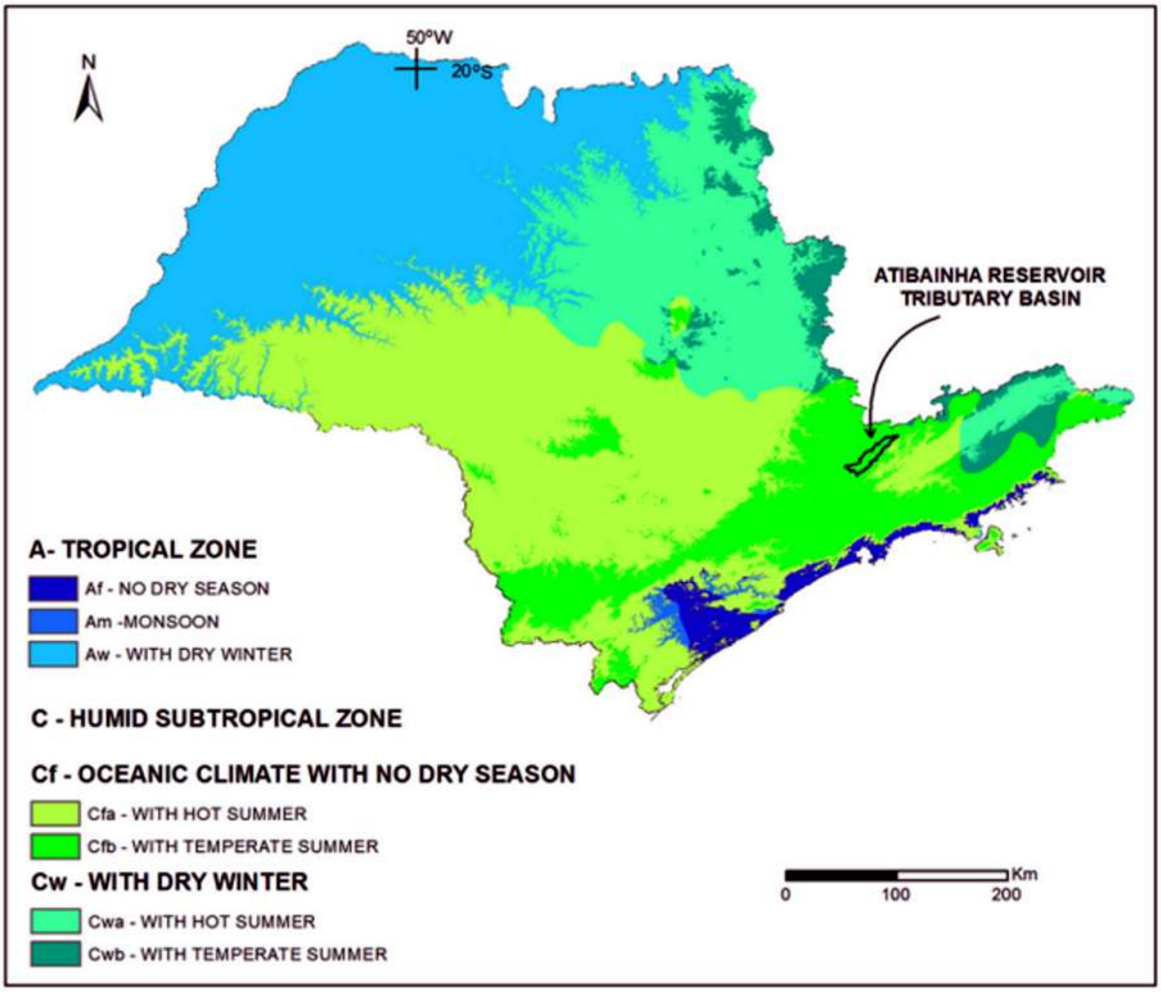

Figure 5. The location of the Atibainha Basin in the São Paulo State Climate Zoning map (modified after Alvares *et al.*, 2013).

2.4 Methods

The methodology was oriented to allow the understanding of the land use process in the tributary basin of the Atibainha Reservoir and especially in the permanent preservation area (PPA) marginal to the reservoir lake. Thus, we sought to measure the problem of improper occupation of this PPA.

The observation, data collection and analysis were performed in two ways. The first step was an automatic land cover mapping by digital processing of a Landsat 5 image at a regional scale covering the entire tributary basin of the reservoir and using the SPRING software (Camara *et al.*, 1996). The second analysis consisted of a land use inventory by photo-interpretation of a high resolution spatial database accessed by Google Earth (Google Earth, 2013).

2.4.1 Land cover mapping at the basin scale

The identification of different types of land cover was done by interpreting a colored composition 432 (RGB) image whose utilized resolution was 30 m. The tributary basin of the Atibainha Reservoir was linked to the IBGE topographic base using an ArcGIS application that was superimposed on the color image.

The recognition of the types of coverage was made possible by clearly differentiating the reflectance of different targets in the multispectral bands of the Landsat TM sensor, aided by knowledge of field ("ground truth"). The classes of land cover are shown in chart 2.

The process of automatic classification, supervised in this case, was conducted by the maximum likelihood method and the per pixel classification technique, which uses the spectral information of each pixel individually to find homogeneous regions. With this method, the training areas including sets of samples were obtained for each class.

After processing, it was necessary to analyze the samples of each class of land cover to check the quality of these based on confusion matrices. According Shandley & Franklin (1996), the acceptable range of accuracy for thematic maps is 80-95 %. In this way, samples in the confusion matrix with accuracy below 80 % were discarded so that the results thus obtained were considered acceptable. Land cover mapping was completed with the generation of a thematic image.

Chart 2. Compositions of land cover classes.

Class	Composition
Built-up area / Exposed soil	Areas of intensive use, structured by buildings and road system. Included in this category are cities, towns, highways, and various instruments that in some cases can be found isolated from urban areas.
Reforestation	Planting or formation of massive exotic species (*Eucalyptus*).
Native forest	Arboreal formation in this research includes areas of dense rain forest only.
Undergrowth	Locations specially designed for grassland (pasture), subordinate cultivated land (agriculture).
Water	Includes classes of indoor water as naturally closed, still water bodies (regulated natural lakes) and artificial reservoirs (artificial water impoundments constructed for irrigation or water supply).

2.4.2 Occupation register for the Atibainha Reservoir PPA

Different marginal widths were adopted to analyse the PPA Reservoir, which are 100 m for rural areas, and 30 m for urban areas, taking as basis the Federal Law 12.651/12 (Brasil, 2012a) and considering valid the criteria in § 4 of Article 3 of CONAMA Resolution Number 302/02 (CONAMA, 2002). Information about the location of rural and urban areas at the margins of the tributary basin was obtained from Land Use Map (IPT, 2006), which covers almost the entire perimeter of the Atibainha Reservoir. The demarcation of different bands of PPA was generated in GIS environment using generation-of-bands (buffer) operations from the perimeter of the reservoir.

Browsing Google Earth images of the Atibainha reservoir neighboring areas helped identify the existing types of marginal occupation. The measurement tools were used to check the distance of the water body to selected markers. From the coordinates collected for each point marked directly on Google Earth images, a GIS register was generated.

The detailed observation of the types of marginal occupation was possible thanks to the high spatial resolution (1:10.000) of the 2013 Google Earth images as follows illustrated in figure 6.

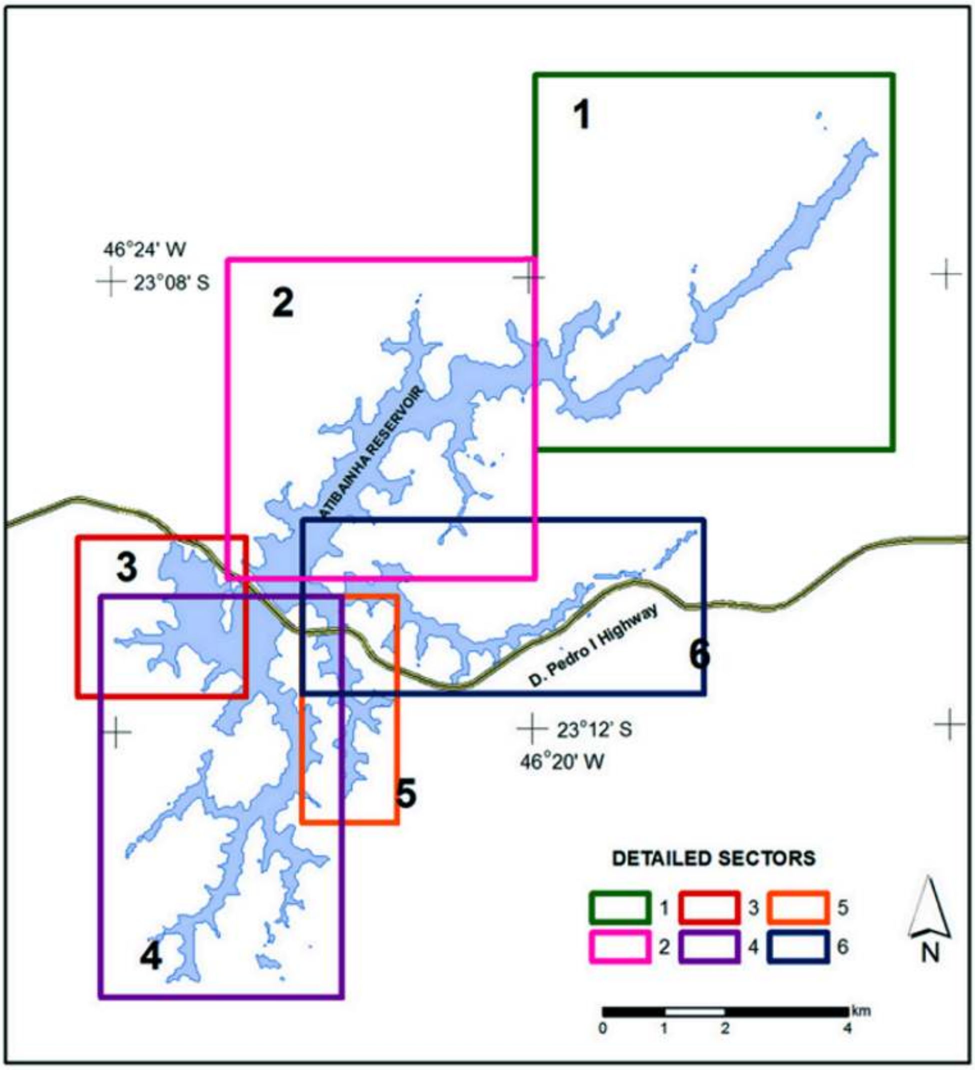

Figure 6. Separation of the study area into sectors for the identification of the different types of marginal occupation in the Atibainha Reservoir PPA.

3 Results

The results were organized into three sections: general data collected by means of mapping, analysis of the tributary basin land cover, and register of the occupation of the Atibainha Reservoir PPA.

3.1 General data compilation

A noticed aspect when mapping the Atibainha Reservoir and its tributary basin is the presence of the D. Pedro I Highway, which crosses it from east to west. The result is that ca. 60 % of the basin lies north of the highway, along with 75 % of the reservoir and the corresponding marginal PPA.

The overall results generated by measuring the areas and perim on the 1:50,000 scale contour map are given in table 1.

Table 1. Areas and perim of the Atibainha reservoir tributary basin.

PARAMETER	SIZE
Total area of the Atibainha Reservoir tributary basin	36.792 ha
Total area of the Atibainha Reservoir	2.009 ha
Total perimeter of the Atibainha Reservoir	173.686 m
Atibainha Reservoir perimeter in the rural area (95.3% of the total)	165.555 m
Atibainha Reservoir perimeter in the urban area (4.7% of the total)	8.131 m
Total area corresponding to the Atibainha Reservoir PPA	1.596 ha
Area considering a 100 m-wide reservoir PPA (98.5% of the total)	1.571 ha
Area considering a 30 m-wide reservoir PPA (1.5% of the total)	1.596 ha

3.2 Analysis of the tributary basin land cover

The land cover mapping (Figure 7) revealed the predominance of vegetation (90 % of the basin area), which corresponds to a widespread rural landscape throughout the reservoir tributary basin. Table 2 shows the results obtained with mapping and quantification of the basin land cover.

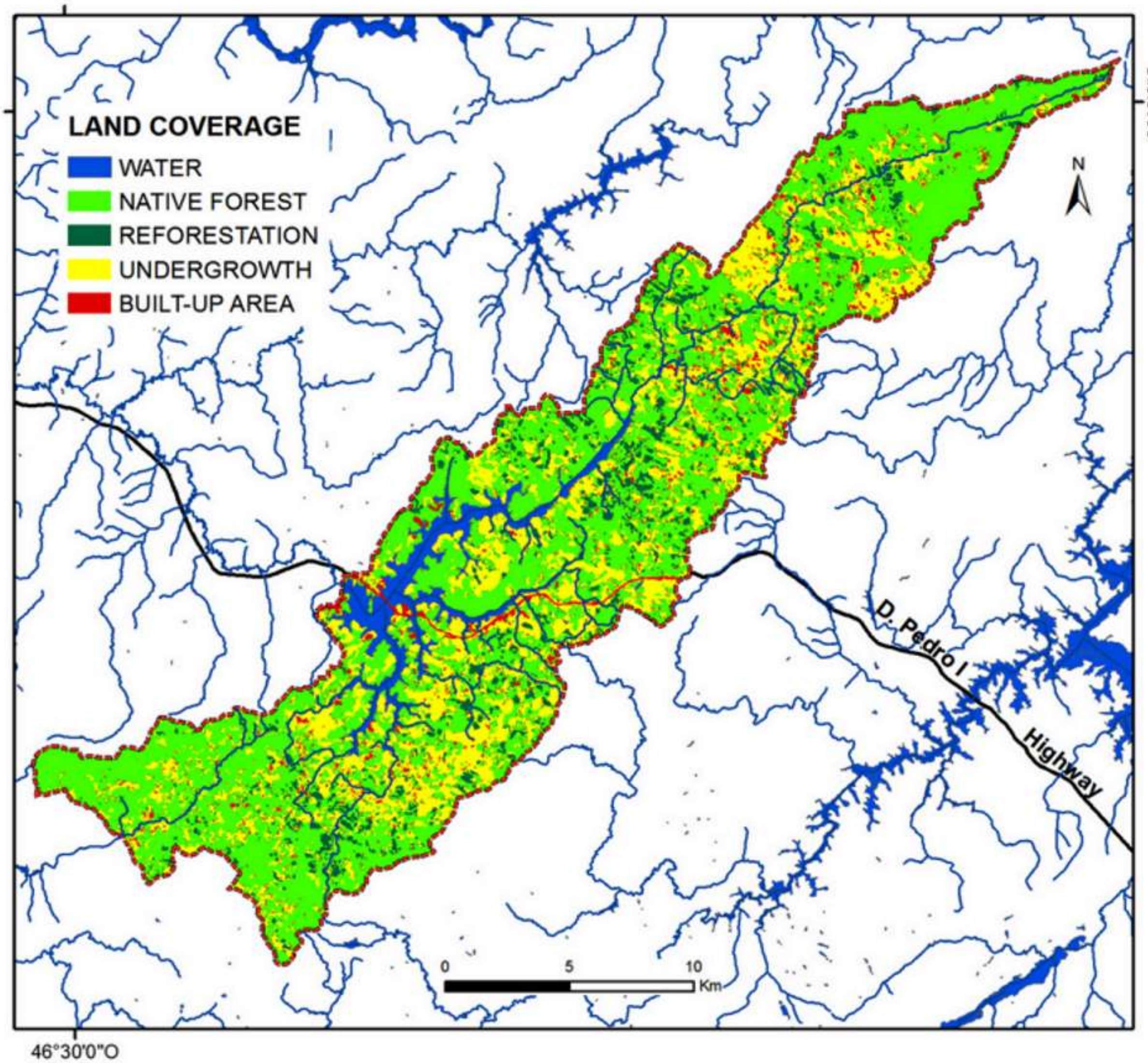

Figure 7. Land Cover Map of the Atibainha Basin (based on Landsat imagery dated August 24, 2010).

Table 2. Details of the Atibainha reservoir tributary basin land cover based on a LANDSAT image of August 24, 2010.

Type of land cover	Absolute area (ha)	Relative area (%)
Native forest	20.567	56
Undergrowth	10.780	29
Reforestation	2.538	7
Water	1.655	4.5
Built-up area	1.251	3.5

The native forest predominates in the basin, forming differentiated, continuous or fragmented domains with varying dimensions. This type of cover is concentrated in the northern and southern regions of the basin. It is worth mentioning that significantly preserved areas with native plants occur in the segment close to the D. Pedro I Highway.

In general, it can be noted that the types of cover considered anthropogenic, including, undergrowth, reforestation and built-up areas, are usually scattered, sometimes clustered in certain regions.

Undergrowth is the predominant anthropogenic cover in the basin. It mostly corresponds to anthropogenic fields formed by pastures where cattle breeding can occur. This type of cover also includes small crops. A cluster of this anthropic field type is found south of the D. Pedro I Highway. Reforestation is another significant kind of anthropogenic cover. It corresponds especially to Eucalyptus plantations.

The built-up area, including land with exposed soil, represents areas occupied by buildings intended especially for residential, sport and recreational purposes. The buildings may occur isolated or concentrated. One can notice a concentration of built-up areas along the D. Pedro I Highway and near the center of Nazaré Paulista. The overlap of PPA information and land cover mapping resulted in the data presented in table 3.

Table 3. Types of land cover found in the Atibainha Reservoir PPA (Mesquita, 2013).

Type of land cover	Absolute area (ha)	Relative area (%)
Native forest	19.2	58.9
Undergrowth	10.9	33.5
Reforestation	1.9	5.7
Water	0.6	1.7
Built-up area	0.06	0.2

The results demonstrated that about 59 % of the reservoir marginal PPA is covered by native forest and nearly 2 % by commercial reforestation, and the remaining non-forested 39 % corresponds to a more intense anthropogenic use.

3.3 Register of the reservoir PPA occupation

The register of the Atibainha Reservoir marginal PPA occupation resulted in the recognition of a total of 155 occurrences, characterized by a more or less intense use of different types of landforms in punctual, grouped or continuous patterns.

The PPA occupation is represented by various types of land use including agriculture, borrow pits, anthropic fields, areas occupied by isolated or grouped farmsteads, recreation centers, boathouses, forested areas and bare soil. Based on EMPLASA (2005) and field work, these types of land use are described as follows:

Agriculture: corresponds to cultivation areas, mainly vegetables (horticulture), corn and fodder, planted continuously on the same land (Figure 8a).

Borrow pits: mining areas in the form of excavations, and removal of material for use in landfills. It occurs at an apparently abandoned land which occurrence of soil erosion is flagrant (Figure 8b).

Anthropic field: corresponds to those areas characterized mainly by the presence of grass forming a continuous cover for pasture and cattle breeding. It occurs over large areas and is continually maintained on the same plots (Figure 8c).

Farmstead: Isolated terrains that correspond to isolated farmsteads, used for leisure or residential purpose, and headquarters that are especially located along the back roads. It is a set of smaller properties with some regularity on the ground, and is identified by the presence of lawns, gardens and small orchards, ponds, woods, sports courts and swimming pools. Mainly small- and medium sized constructions (Figure 8d).

Grouped farmsteads: correspond to subdivisions and condominiums of farmsteads (Figure 8e).

Recreation Centers: area occupied by establishments, spaces and facilities intended for sport and leisure activities, especially boating (Figure 8f).

Boathouses: area occupied by installations in the form of sheds, intended for the accommodation and maintenance of boats (Figure 8g).

Silviculture: homogeneous tree plantations, predominance of *Eucalyptus* planted continuously in the land. It can be found in various stages of development, from soil prepared for planting to the cutting phase (Figure 8h).

Bare soil: corresponds to areas that underwent earthworks, with soil exposed by the removal of the vegetation and soil excavation (Figure 8i).

The Figure 9 shows the result of membership through sectoral map 6 which can be seen in Figure 6.

4 Discussion

The perimeter of the Atibainha Reservoir in rural areas corresponds to ca. 95 % of the total, and therefore the 100 m wide PPA represents 98.5 % of the PPA total perimeter. The land cover mapping based on the 2010 Landsat image showed that ca. 59 % of the Atibainha Reservoir PPA is covered by natural forest. This coincides with Antunes (2009) results, although this author used aerial photographs for measurements. This allows us to consider, on one hand, that it is likely that the PPA deforestation is not advancing, *i.e.* it has stabilized, and, on the other hand, that the methodology based on satellite imagery can be a fast and feasible way of monitoring PPA. This result differs from that by Ditt (2008) and Martins *et al.* (2007), who showed that the Atibainha Reservoir PPA is devoid of ca. 50 % natural cover.

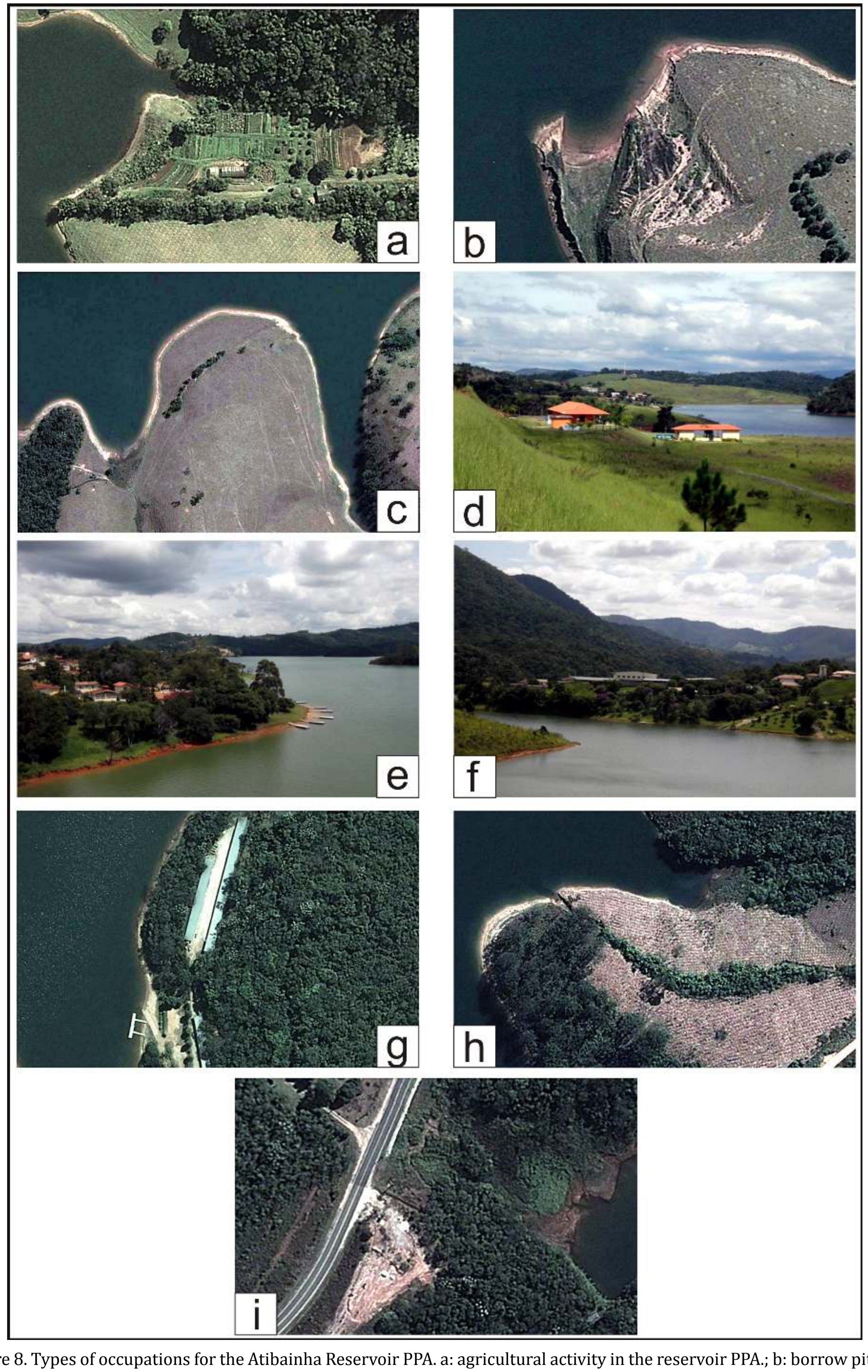

Figure 8. Types of occupations for the Atibainha Reservoir PPA. a: agricultural activity in the reservoir PPA.; b: borrow pit in the reservoir PPA; c: anthropogenic field in the Reservoir PPA; d: Example of an isolated farmstead in the Reservoir PPA; e: Example of a farmstead condominium in the reservoir PPA; f: Example of a recreation center in the reservoir PPA; g: Example of a boat-house in the reservoir PPA; h: Example of silviculture in the reservoir PPA; i: Example of bare soil in the reservoir PPA. Sources: images “a”, “b”, “c”, “g”, “h” & “i”: Google Earth (2013); photos “d”, “e” & “f” - Mesquita, (2013).

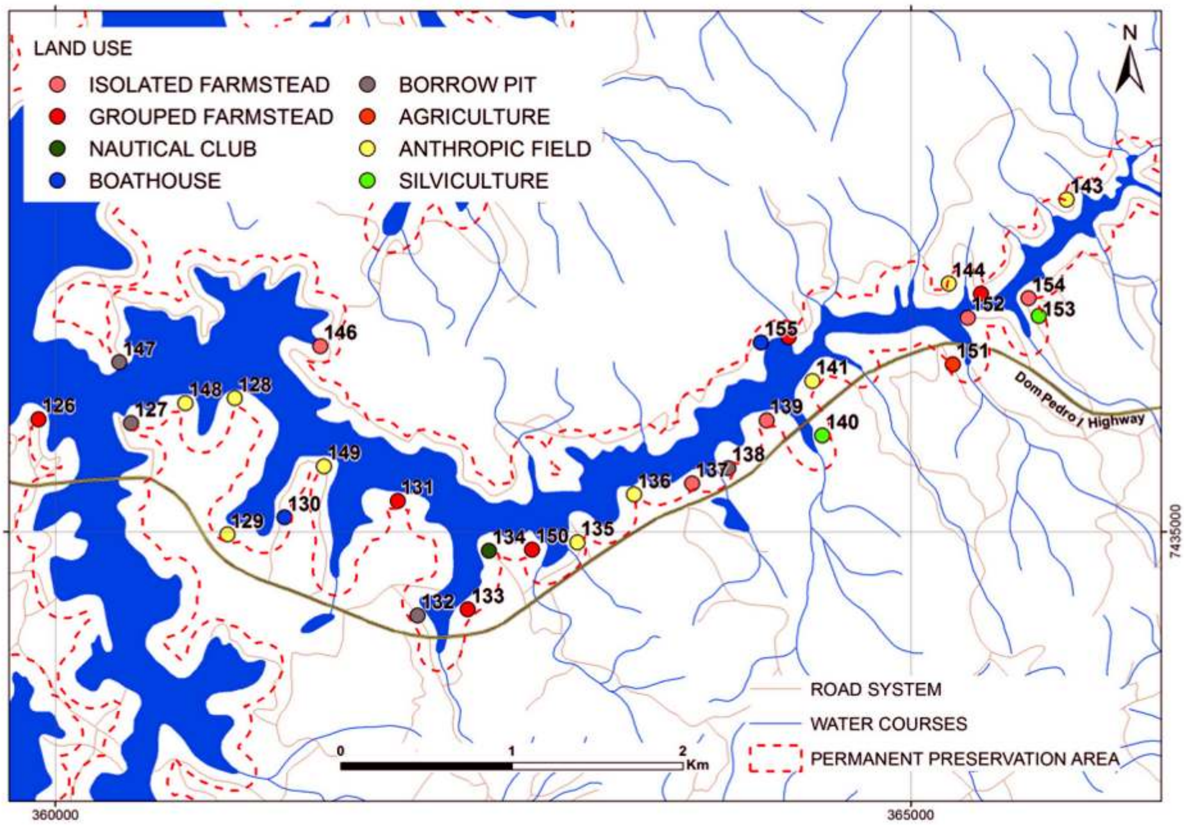

Figure 9. Occupation of the Atibainha Reservoir PPA – register for Sector 6.

The number of Reservoir PPA occupation types by Registration sector was made by visual recognition assisted by Google Earth (Google Earth, 2013) and is presented in table 4.

The analysis of the data allows us to observe a large number of urban occupation types corresponding to isolated farmsteads and grouped farmsteads. Together they correspond to 68 records (43.9 % of the occurrences) that reflect the presence of hundreds of buildings that are fully or partially built. Sector 2 has the highest concentration of grouped farmsteads.

The anthropic field type is especially used for pasture. There are 51 records (32.9 % of occurrences). Silviculture has 13 records (8.4 % of all occurrences). This activity usually covers large areas, sometimes also involves PPA extensions. There are 5 recreation centers and 7 boathouses in PPA. Associating recreation centers with boat garages we have 7.7% of the total occurrences. Also the number of borrow pits is high, with seven occurrences.

By evaluating the record of occurrences by sector, it can be seen that sector 4 is especially

Table 4. Number of PPA occupation types by mapping sector.

Type of use	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Total
Agriculture	0	0	0	1	1	1	3
Borrow pits	3	0	0	0	0	4	7
Anthropic fields	5	3	8	20	6	9	51
Isolated farmsteads	6	6	0	4	5	5	26
Grouped farmsteads	8	13	0	9	6	6	42
Recreation Centers	0	0	1	5	0	1	7
Boathouses	1	0	0	0	2	2	5
Silviculture	3	1	0	4	3	2	13
Bare Soil	0	0	0	1	0	0	1
TOTAL	26	23	9	44	23	30	155

problematic as the number of situations account for 28.4 % of cases of PPA occupation. It also features the largest variety of use types, besides borrow pits and boathouses.

Sector 2 has proved to be particularly problematic because of the existence of grouped farmsteads, which are also fairly frequent in sectors 4 and 1. Sectors 6 and 1 proved to be especially problematic due to the presence of borrow pits.

The built-up area observed in land cover mapping clearly expresses the existence of an alarming urban dynamics in progress, which has consequences when it comes to public water supply. The amount of 3.4 % of built-up areas is quite close to 3.58 % reported by CPLA and IG (2013), although measuring is based on SPOT images.

5 Final considerations

The occupation register for the Atibainha Reservoir PPA reveals a growing urban development of residential and recreation centers around the reservoir, reaching in numerous situations the countryside.

This growing urban development is preoccupying, since urban use implies the abrupt change of the natural processes, such as runoff, infiltration and groundwater recharge, the microclimate and biotic conditions, precisely in the transition area between the aquatic and terrestrial environment, which is the reservoir margins. As product of urban use the formation of punctual pollution sources and diffuse pollution foci is expected, the latter aggravated by increased runoff on impermeable surfaces. Water pollution is the result of the generation of sewage and wastewater from areas with solid waste generation process, which are carried by perennial or intermittent water bodies to the reservoir.

The geoenvironmental characteristics demonstrate a fragile biotope in face of human interventions, a basin where runoff conditions prevail instead of rainwater infiltration in the soil, as a function of the crystalline rock basement, shallow soils and very steep slopes.

All these features allow us to consider the urgency of public policies to protect the Atibainha Reservoir margins, according to EPA regulations, either through control measures or environmental restoration. There are vast areas free of buildings that can be immediate object of forest restoration.

The Cantareira System EPA regulation should be guided by the vocation and multiple uses of water resources as established by the National Water Resources Policy (Brasil, 1997), in particular regarding the possibility of coexistence of public supply, sports and leisure, for purposes of compatibility between these uses and environmental preservation and quality of water supply.

Installation of the APA Management Council and the establishment of Management Plans, Development and Environmental Protection of the Cantareira System by specific laws are objective measures to be taken immediately.

It is up to any Plan to carry out a proper diagnosis of the current situation of the basin and the correct sizing of environmental liabilities to be recovered. It should also seek to reconcile with current legislation and governmental programs in progress. Therefore it is expected that a Plan established by law shall clearly define structural and non-structural measures that effectively guarantee the quality and quantity of water for public supply in the present day and in the future.

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