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Land use evolution and effects on the degradation of Permanent Preserved Areas of Piedade River Watershed (1985-2011), MG, Brazil

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Abstract

The current state of environmental degradation has mobilized society and led researchers and public administration to propose mechanisms for the protection of natural resources. Environmental studies have focused on increasing the diagnosis of watersheds, identifying the strengths and weaknesses of the study area, later to establish the planning and management guidelines to be followed. In Minas Gerais, after publication of the State Policy on Water Resources – Law n°. 13.199/1999, the Minas Gerais Institute of Water Management has proposed the division of the state in units of Planning and Management of Water Resources having the parameter by of geographical division of watersheds. Not only for the assessment of water resources, the watershed has also been adopted as a planning unit for different environmental studies such as physical and biotic diagnosis, landscape analysis, use and occupancy of soil surveys, landscape ecology surveys, among several others. In this perspective, because of its relevance to the mesoregion of Triângulo Mineiro, it was adopted as the unit of study the Piedade River Watershed - PRW, an area of approximately 1746,89 Km2. The main objective was to assess the modification of the landscape arising from human occupation in the period from 1985 through 2011, verifying its reflection on environmental conditions in the basin under discussion, especially in the fragmentation of native vegetation along it and the Permanent Preservation Areas (PPA). In order to achieve the objective of this research, we used the available studies on this subject, consolidating the theoretical framework and defining the work methodology that basically consisted of technical visits to the Piedade river watershed; mapping of land use and land cover for the years 1985, 1995, 2005 and 2011, qualitative and quantitative definition of Permanent Preservation Areas according to Federal Law. 4.771/1965 (Forestry Code), delineation of remnants of native vegetation. The study of PRW, among other figures, showed development of the use and occupancy between 1985 and 2011. From this it was possible to notice that in 1985 the rate of native cover was 28.87% of the basin, however, between the years 1985 and 1995 there was a reduction of native vegetation to 35%, reaching only 17.73 % of the basin in 2011, this percentage being computed areas with native vegetation in areas of permanent preservation. Analyzing the data obtained in this work, in a general sense, it is concluded that the sheer existence of an environmental law protecting natural resources, has not been able to minimize the negative effects of human occupancy on the protected areas. It is evident the urgent need for diagnoses and integrated studies that can be translated into tools of land management on the basis of environmental planning.

Keywords: Watershed; Permanent Preservation Areas; Piedade River; Analysis of the landscape

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1. Introduction

The hydrographic basin and its components as rivers, sources, springs and lakes are considered in Brazilian laws a basic unit for environmental planning and represent a geographical space where environmental conservation activities should be implemented to preserve hydric resources, associated with preservation the dynamics of landscape and landforms (Ambers et al, 2006; Church, 2002; Leonardi et al, 2010; Rodrigues, 2002; Pena et al, 2010).

Located in Minas Gerais state, the Piedade River Watershed (PRW) is located in a landscape with a high intensity of non-planned human occupation. These actions should consider the need for preservation of native vegetation and production of water for economic activities as well as for the maintenance of ecological functions.

The conservation of water sources, its rational usage, the guarantee to access, allied to the concerns about the environmental impacts caused by the current pattern of the land use and land cover are important aspects in the hydrographic basins management in the environmental preservation, as well as in the solution of conflicts related to the water access (Stoate et al, 2011; Myers et al, 2000; Zacharias et al, 2003)

Human actions as the expansion of economic activities and also the population growth creates problems to the water access, as conflicts to water exploitation which occurs in the study area, caused by increase of demand and decrease of water production due to over exploration. (Gücker et al, 2009; McDowell and Moll, 1992; Rodrigues, 2002).

Some rural activities, as irrigation, coffee processing, maintenance of farms, hydroelectric power generation consume high amounts of water, and this changes the hydrological flows and available amount of water. (Allan et al, 1997; Allan, 2004; Bramley and Roth, 2002).Also other rural activities could pollute the superficial water as raising chickens and pigs in farms, which produce a high content of organic waste which contaminate the water sources, or the excessive usage of pesticides.

In the Piedade River Watershed (PRW), the amount of economic activities which are installed in the territory creates a situation of conflict to the water consumption. Such activities require more water continuously, higher than the hydrographic basin can offer.

In another direction, environmental legislation has tended to indicate a reduction in the availability of water, favoring the maintenance of ecological functions of the basin.

The land use in the basin follows the pattern of Brazilian central area occupation which started in the 18th century, but only after the creation of Brasilia city, Brazilian new capital, in the 1960 decade, started the growth of occupation in an accelerate rate. So for the past 50 years the region has changed completely, from a highly conserved natural landscape to a high technology agricultural area. The fragmentation of native vegetation (Cerrado Savannah) increased rapidly and the result was a landscape cleared of vegetation and replaced by agriculture and pasture. The effects of these quick changes have reflected on high rates of soil erosion, decrease on water production, extinction of fauna and flora species and decrease of biodiversity and geodiversity, as observed in others regions of the world. (Lord and Norton, 1990; Riitters et al, 2000; Li et al, 2010; Abdullah and Nakagoshi, 2007; Fensham and Fairfax, 2003)

As Brazilian laws define, all sources of water, river banks and border of natural and artificial lakes and as well as lagoons, are considered Permanent Preserved Area (PPA), a new concept created in federal laws and regulated by resolutions since 1965. Their purpose is to conserve and preserve native vegetation cover in order to the maintenance of ecosystems and landscapes. (Leonardi et al, 2010; Patriota, 2009).The main objective of this paper is evaluate the process of landscape changes and land use evolution between the 1985/2011 period and analyse the effect of this process in the environmental conditions of the basin, with focus in the vegetation fragmentation and the impacts of environmental laws through the time.

So, the evaluation level of degradation of the Permanent Preserved Areas as response to these changes in land uses were also compared with the changes of regulation in these laws through the time.

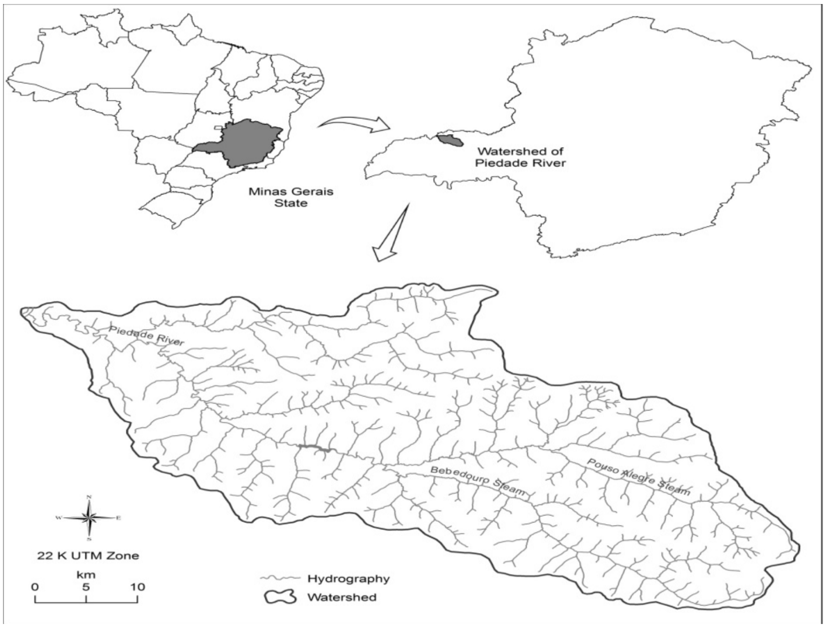
2. Study Area

The PRW is an important drainage area located in the left side of the low course of the Paranaiba River Basin, Triângulo Mineiro region in the central uplands of Brazil, and comprises 1,746.9 km2.

The PRW has a set of rivers and creeks that flow in the gentle surface of the plateau of Parana Sedimentary Basin. The river flows about 120 km until it reaches its mouth at the Paranaiba River.

The study area is located in the west part of Minas Gerais State between 18°29'S a 18°53'S of latitude and 48°34'O a 49°14'O of longitude, comprising areas of the counties Araporã, Tupaciguara, Monte Alegre de Minas, Canápolis and Centralina.

Figure 1.



The climate classification of the basin is Cw, half-humid tropical type, with average temperature of 23°C, with two well defined seasons, dry from May to October and wet from November to April, and presents annual pluviometric average between 1300 and 1700mm. (Vrieling et al, 2007).The rain distribution during the year causes an intercalation of periods from deficit to excess of soil moisture. Table 1.

Table 1 - Mean Monthly Precipitation for hydro meteorological stations inside or close to the Piedade River basin (1975-2010).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Monte Alegre de Minas	280,3	197,8	180,9	83,1	36,0	15,5	11,6	12,8	46,7	136,5	199,8	257,3	1458,3
Tupaciguara	280,7	183,7	192,9	74,1	32,1	13,6	7,6	12,8	47,4	94,1	201,2	291,3	1431,5
Avantiguara	304,0	199,6	185,2	92,9	37,3	14,9	7,2	17,5	49,3	124,0	198,3	277,0	1507,0
Xapetuba	284,8	202,9	200,9	78,2	38,2	19,7	7,6	20,0	46,5	109,0	204,7	288,3	1500,9
Fazenda Cachoeira	227,0	173,8	176,5	73,5	32,9	13,8	8,2	14,2	41,4	109,7	166,8	265,8	1303,7
Brilhante	339,4	209,2	207,8	67,5	33,9	14,7	6,7	13,6	56,0	94,9	198,1	329,4	1571,2
Average	286,0	194,5	190,7	78,2	35,1	15,4	8,1	15,2	47,9	111,4	194,8	284,8	1462,1

Source: ANA (Hidroweb), 2011.

The landscape of the study area is a flat plateau associated to the Parana Sedimentary Basin, where gentle hills with slopes ranging from 0° a 5° occupy 93.1% of the total area of the basin. In some areas, especially near the valley bottom carved on basaltic rocks, slope reach values of 20°. (Rodrigues, 2002).

Natural vegetation in the basin is mainly composed by the Savannah Biome, which comprises 2/3 of the total area and is located above the altitude of 500 m. The Brazilian savannah is a rich phytoecological biome, with a high diversity of phytophysiognomies and has a particular feature, the veredas, which are humid soils near the river sources where a typical palm tree (*Mauritia flexuosa*) and graminea vegetation occurs. (Marris, 2005). Below the 500 m of altitude, in the lowermost course of the river occurs the rain forest Biome (Mata Atlântica). There are no urban areas located inside the basin, which confers a rural landscape to the basin.

The Brazilian economic development after the 1960 decade was based in the assumption of occupation of the central territory, because concentration of population in the coastal areas of the South and Southeast regions allied to the general development of the country, created the necessity of increases of agriculture, and so the new frontiers of agriculture moved from the coastal to central areas, in special over the savannah biome between 1960 and 1970. (Marris, 2005)

In Minas Gerais state the effects of these governmental actions were felt, in special in the Triângulo Mineiro region, which was progressively converted first to the charcoal production exploiting the native vegetation and afterwards with the introduction of agriculture and pasture areas facilitated by flat characteristics of the landscapes, drainage systems with conditions of irrigation of crops and new technologies of soil corrections. (Cabral et al, 2010; Costa and Pires, 2010; Gücker et al, 2009; Nepstad et al, 1997)

3. Materials and Methods

The maps of land use and cover were elaborated with use of four TM Landsat 5 satellite images with 30 meters resolution acquired in: 01 of August 1985; 13 of August 1995; 23 of July 2005 and 06 of June 2011. These images were processed in ArcGIS 9.3.1 software. The accuracy and precision of the maps were done with field works, using a navigation GPS in Geographic Coordinates with horizontal datum WGS84.

The land use maps were done using the digital processing of images with supervised classification, which is used when a good knowledge to the study area is prior to the image processing, both the number of sampling points and for the chosen number of classes for mapping. (Costa et al,1996; Leonardi et al, 2010; Chander and Markham, 2003;Rodrigues et al, 2012; Rodrigues and Silva, 2012; Vrieling et al, 2008).

The analysis of legal conformity of land uses was done using the federal laws and resolutions that explain what a Permanent Preservation Area (PPA) according to the evolution of the concept through time. So, a series of buffers were used to extract the land use inside the PPA areas, showing areas which are in accordance to the law and the ones which are of illegal usage. Figure 2. These illegal usages were considered in this study as degraded land (Fig. 2).

So, the PPA's maps were done according to the parameters of each law or resolution: Federal Law 4.771/1965 Forest Code (Brasil, 2011a) to the 1985 map, Federal Law 7.803/1989 (Brasil, 2011b) for the 1995, 2005 and 2011 maps. The CONAMA Resolutions 302/2002 (Brasil, 2002a) and 303/2002 (Brasil2002b) were used in special cases, as artificial lakes construction. These parameters pointed in laws and resolutions are summarized in Table 2.

Figure 2

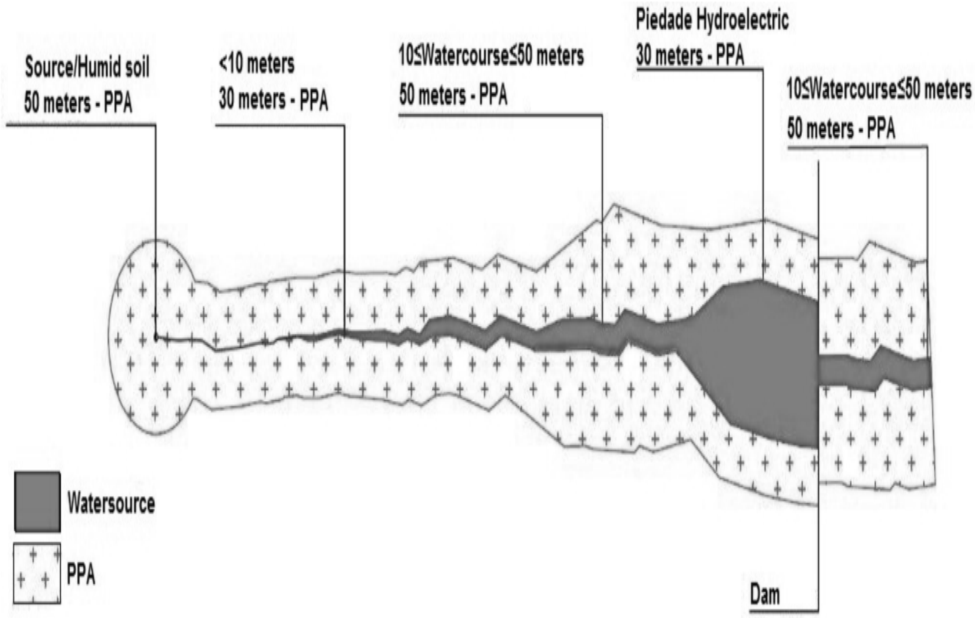


Table 2 - APP length parameters pointed in environmental laws since 1965 to 2002

Permanent Preservation Areas - PPA	Through rivers or water course		Throughout natural and artificial reservoirs		Sources / humid areas / veredas	Mesas, buttes borders	Maps
	Water course length	APP length					
Law 4.771/1965	< 10m 10 to 200m >200	5m ½ length of water course 100m	N.D.		N.D.	N.D.	APP –1985
Law 7.511/1986	<10m 10 to 50m 50 to 100m 100 to 200m >200m	30m 50m 100m 150m = Water course length	N.D.		N.D.	N.D.	--------
Law 7.803/1989	<10m 10 to 50m 50 to 200m 200 to 600m >600m	30m 50m 100m 200m 500m	N.D.		50m	100m	APP –1995, 2005 and 2011
CONAMA Resolution 302/2002	N.A.	N.A.	AU[1] AR[2] until 10ha[3] until 20ha[4]	30m 100m 15m 15m	N.A.	N.A.	Not used
CONAMA Resolution 303/2002	<10m 10 to 50m 50 to 200m 200 to 600m >600m	30m 50m 100m 200m 500m	AU[1] AR[2] AR until 20ha[5]	30m 100m 50m	50m	100m	Not used

Another analysis was done with the intention to compare the effects of law and resolution in the degradation states of the APPs through the time. So a new map was created with the overlap of the APP buffer for the 2011 law over the land use map done with TM LANDSAT 5 image from 1985. The comparison between this map with the 2011 image could show us if the implementation of law created an increase or no in the amount of preserved lands in APPs.

4. Results and Discussion

4.1. Analysis of land uses and land cover evolution through time

The land use data for the PRW were done to the period from 1985 to 2011 and show a common pattern to the set of basins in the central Brazilian uplands, in which the native vegetation was cleared and gradually replaced by agriculture and pasture.

In the 1750 km2 of the basin, 1985 Land Use map shows that 28,87% of the total area was occupied by Native vegetation, 39,89% occupied by pastures, 31,04% by agriculture, 0,18% by exotic forests (pines) and 0,03% by water bodies. The evolution of the land cover is presented in Table 3.

Table 3 - Evolution of the land use and land cover between 1985 and 2011 of BHRP

	1985		1995		2005		2011	
Classes	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
Watercourse	54,59	0,03	91,25	0,05	76,17	0,04	292,43	0,17
Native vegetation	50.429,66	28,87	32.336,19	18,51	32.595,21	18,66	30.977,11	17,73
Exotic forest	314,55	0,18	23,34	0,01	154,06	0,09	839,68	0,48
Pasture	69.674,84	39,89	91.094,94	52,15	76.913,35	44,03	89.819,33	51,42
Agriculture	54.215,62	31,04	51.143,62	29,28	64.950,54	37,18	52.760,77	30,20
Total	174.689,26	100,00	174.689,33	100,00	174.689,33	100,00	174.689,33	100,00

The analysis show that after 27 years the situation has changed to a new level, and the native vegetation covers only 17,73% of the watershed. The decrease of natural area was replaced by pasture and exotic forest, 51,42% and 0,48% respectively. Agricultural areas still almost the same value (30,20%), but a huge change occurs in production, with substitution of fruits (bananas and oranges) by sugar cane. The water bodies increase due to a dam construction and creation of an artificial lake.

The environmental conditions of the basin, mainly the flat relief and deep soil, provide a good condition of production, and 93,10% of the basin have slopes below 5%, in which modern production technologies can be applied.

The fragmentation of landscape is one of the huge problems observed in field trips in PRW. The native vegetation of Cerrado (Brazilian Savannah) was cut and replaced by pasture and agriculture through years and a mosaic of small areas located over the territory conforms a landscape in which a mesofauna has small possibilities of survival due to habitat restrictions. Also the fragmentation creates problems to the genetic exchanges between populations of fauna and some flora species.

The decrease of native vegetation observed in Table 3 could be summed to the Figure 3 to understand the effects of fragmentation. The period 1985/1995 presents a reduction of 50% in the medium size of fragments, showing that the process of clearing the native vegetation was in movement, because at the same time the numbers of fragments rises from 1411 to 1848.

This trend has a change in the 1995/2011 period when the number of fragments reduces and the medium size growth. The spatialization of fragments in Land Cover map (Figure 4) also indicates that some landform conditions influence the places where the fragments occur, which are the ones the economic activities are not allowed to take place (PPAs) or where environmental conditions are prohibitive (high inclination of slopes, outcrop rocks, humid soils).

Figure 3

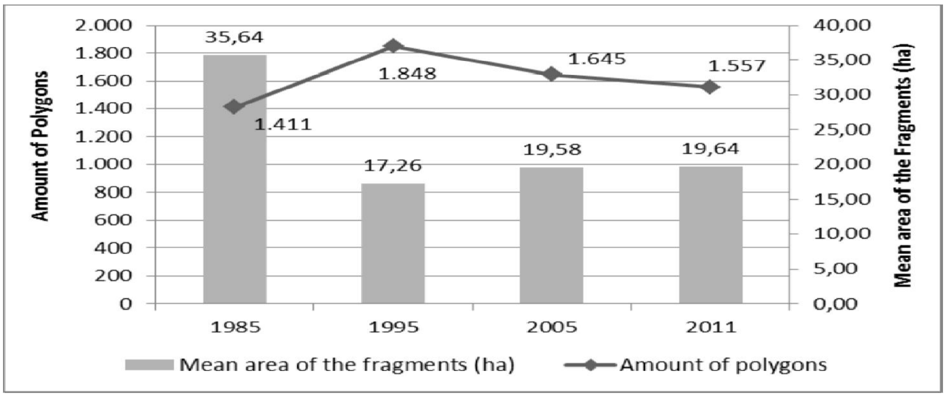
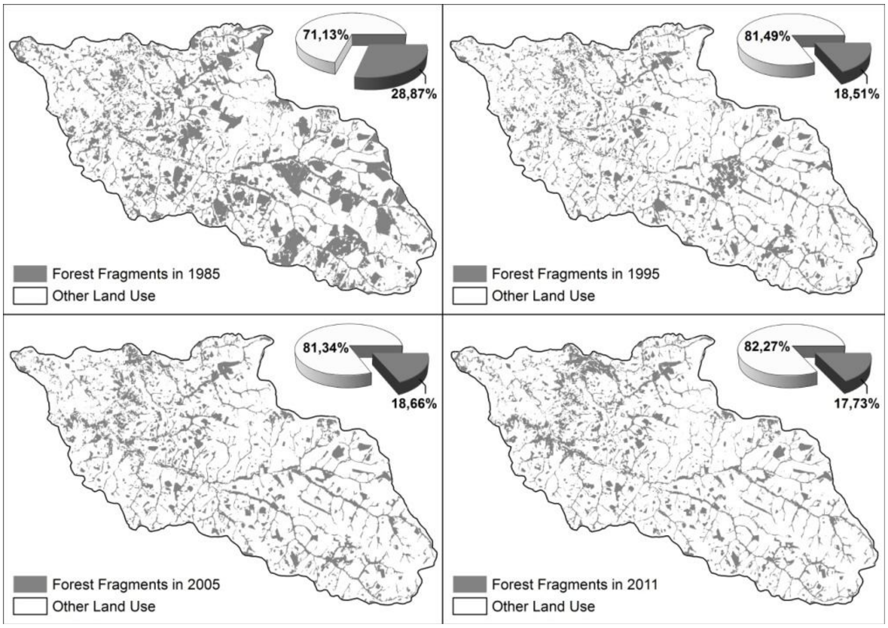


Figure 4



This data also indicate that the fragments are not the same through time, because some of them appear after the implementation of legislation (Forest Code or Environmental Impacts Analyses Report) and others are cleared and transformed into production lands.

4.2. Landscape analysis: native vegetation cover and Preserved Areas

The native vegetation is considered as an indicator of equilibrium of environment, because its presence indicates that the ecological functions and dynamic of landscape are controlled by natural laws at the surface of the terrain. The native vegetation occurs, for instance, when equilibrium exists between local climate, the soil and hydrological functions in the watershed.

The Brazilian laws indicate that in all spaces in the territory where a hydric resource occurs should be protected, and define it as Permanent Preserved Areas. So sources, channels, humid soil, lakes, lagoons should be protected from productive activities. Also all farms should have 20% of its total area maintained in natural conditions and these territories couldn’t be on the same areas as of PPAs. In fact, the regulation indicates that almost 30% to 35% of all private or public lands should be preserved and natural vegetation remain intact.

The evaluation of land uses and land cover of the PRW in 2011 shows us that only 17,73% of the total area is covered by native vegetation, so almost 50% of the area that should be under protection has been eliminated and replaced by economic activity (pasture and agriculture). To attend the minimum of PPA determined by the Forest Code, Law 4715/65, at least 3960,76 ha should be converted from pasture and agriculture to recovered areas of natural vegetation.

Besides the already observed value of protected areas under the official regulations, another observation done about the land use and land cover of the basin is the fragmentation of the native vegetation. The number of fragments of savannah vegetation observed is high while the small size of fragments and the sparse distribution cooperates to the low connectivity of vegetation remnants.

The preserved fragments are located in specific sectors of the basin, as the scarps where the slopes presents values above 20%, near the valley Piedade River and its tributaries, where humid soils occur, and all watershed areas where agriculture and pasture have no good conditions to be installed. Thus, some of the fragments located in the valley bottom could offer conditions of connectivity to fauna and flora, and also to preserved areas, with larger dimensions, which could occur in the landscape.

The PPAs were mapped to the years of 1985, 1995, 2005 e 2011 using the parameters of the law in force in the years mapped. The law that was used in 1985 determines a width from 5 meters of preserved area for channels with less than 10 meters width. For channels between 10 and 200 meters the width of preserved area is 50% of the river width. In the PRW almost all channels are narrow, and the small tributaries ranging until 10 meters of length determine a PPA of 5 meters each side on the basin and almost all are this class. Only the lowermost course of Piedade River has more than 10 meters of width, and the PPAs for these section are 50% of the river width of each side. The total area preserved using these law parameters were mapped and comprises 1.401,37ha in 1985.

The federal law has changed in 1986 and the PPAs maps for the years of 1995, 2005 and 2011 represent the preserved area using the parameters stated by this law.

Thus, channels with less than 10 meters of width determines a preserved area of 30 meters width along each side of the channel and for rivers between 10 and 50 meters width, the preserved area comprises 50 meters at each side. For these maps a total area preserved is about 23000ha (Table 4).

Table 4 - Condition of PPAs through time - Years 1985, 1995, 2005 e 2011

	1985		1995		2005		2011	
Classes	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)
PPA preserved	1.023,80	73,06	11.482,74	49,93	12.488,15	54,27	11.557,70	50,49
PPA degraded	377,57	26,94	11.515,09	50,07	10.521,92	45,73	11.335,31	49,51
Total	1.401,37	100,00	22.997,83	100,00	23.010,07	100,00	22.893,01	100,00

One new situation was created for the 2011 APP map, because an artificial reservoir was built to provide water to a small Hydroelectric Power Station. The law determines that margins of artificial lakes should be protected with the same parameters of natural lakes, and so, for this case the preserved area comprises 100 meters along the lake margin, but an arrangement created by the Environmental Impact

Report requires that the preserved area should be 30 meters along the lake margin. In this case a decrease of the protected area was created by the artificialization of the environment.

The APPs according to the law, are sectors of the basin in which the native vegetation should have been preserved. Thus, through the analysis of a time span between 1985/2011, presumed that the preservation of the area will increase through time until 100% of the area stay under native vegetation cover. The analysis of PRW Land Cover Maps presents a distinct reality. In this analysis the concept of Preserved Area means that the PPA has native vegetation, that could be mapped by satellite images and degraded areas, concept represented by areas of the PPA mapped as pasture, agriculture and others uses.

For the 1985 Land Cover map a total of 1.401,37 ha of preserved area corresponds to 0,80% of the total basin area, in which 73% is covered by native vegetation and 27% is covered by agriculture or pasture systems.

Changes in the legislation in 1986 have created new parameters to define preserved areas, and so the total area of PPAs in the PRW rose from 1401,37ha to approximately 23.000 ha, a 1543% of increase in preserved areas.

In this case, also sources, humid soils and mesas and buttes borders are considered preservation areas. This increase in PPA parameters and consequent rise of total area protected, should create a better situation on the environment through time, as it can be seen in the maps, when one compares the 1985/2011 data and finds that the total preserved area of PPA has decreased from 73,06% to 50,49% (Table 5).

Table 5 - Comparison between permanent preservation areas in the year 1985 using the *buffer* of 2011

	2011		Image - 1985 / Legislation - 2011	
Classes	Area (ha)	(%)	Area (ha)	(%)
PPA preserved	11.557,70	50,49	12.775,98	55,46
PPA degraded	11.335,31	49,51	10.258,78	44,54
Total	22.893,01	100,00	23.034,76	100,00

In the opposite direction of the increase of PPAs, the Land Cover maps of 1995, 2005 and 2011, show at least 50% of the PPA is not preserved and is occupied by pastures and agriculture.

The comparison between maps 2005 and 2011, shows a decrease of 3,78% of preserved areas or an increase of 930,45ha of degraded lands, in areas under protection of laws, even in times like now, when concerns about the legislation and environment grows in our society.

The researched data show that real preservation of PPA in 2011 reaches only 50,49% of total area. Thus, it is assumed that 49,51% of the PPA is under degradation, so 11.335 ha of the total PPAs should be recovered and are actually a environmental passive in the watershed.

5. Conclusion

The PRW, as others hydrographic basins located in the Brazilian Central Uplands, shows a high percentage of occupation of lands by economic activities, especially by the increase of pasture and agriculture, that increased and changed through time as observed on data from maps of Land Use and Land Cover from 1985, 1995, 2005 and 2011. This evolution of occupation created a situation of high fragmentation of the native vegetation and a disconnection between similar environments within the basin.

The Brazilian Environmental legislation created in 1965 proposes a new category of preservation applied to national level called Permanent Preservation Area, which protects river margins, summit of mountains, sources of water, borders of flat surfaces and some other special features. This legislation evolves through time and the parameters of preservation have been changed to a high level of protection of these landscape features. The analysis of evolution of land uses and land cover of PRW shows that law was not capable to change the status of degradation and amount of preserved areas inside the hydrographic basin.

The evolution of occupation follows mainly of the interests of economic stakeholders and legislations are not obeyed. The evolution of preservation parameters of vegetation do not result in a better quality environment according to data provided by the Maps of Land Use and Land Cover, that show the amount of native vegetation fragments which comprises a total area minor of which are delimited by the legislation.

The result of this situation, observed in field trips and in meetings of the Piedade River Basin Authority, is that nowadays the requisition to water consumption is higher than the capability of production and exploitation on the hydrographic basin, and so a conflict about water exploration between stakeholders occurs.

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