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Land use capacity and environment services

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ABSTRACT

The increasing demand for food resulting from demographic growth has required more productive agropastoral practices. Consequently, new areas were selected for agropastoral production in an arbitrary way, disregarding land use capacity. This ends up in acceleration of degradation processes, mainly those related to water erosion. In this context, the system of land use capacity proposes the classification of maximum use allowed for land of a rural property or of a hydrographic sub-basin, in an attempt to make sustainable plans of use and management of natural resources. Concerning current use of land, the system indicates the sites where there are conflicts in use in relation to their use capacity. Thus, it is possible to propose measures to adapt land use to its use capacity. Therefore, in this study, the classes of land use capacity at the hydrographic sub-basin of Córrego Pedra Branca, in Alfenas, in the state of Minas Gerais, were evaluated. For that purpose, the following soil parameters were evaluated: effective depth, water permeability, texture, declivity, erosion class, base saturation, effective and potential cationic exchange capacity, and aluminum saturation. Soil analyses presented values of base saturation and of low capacity of effective and potential cationic exchange, which illustrate the low natural fertility of these soils, as well as aluminum saturation level harmful to most cultures. Thus, land use would be restricted to low impact, permanent crops, silvicultures, associated agrosilvipastoral system with conservationist management techniques, as, for example, direct seeding, soil correction and fertilization, and reforestation of permanent preservation areas

Key-words: Agroecology, Geotechnologies, Agroenvironmental Planning

Capacidade de uso das terras e serviços ambientais

RESUMO

A crescente demanda por alimentos devido ao crescimento demográfico tem exigido uma agropecuária mais produtiva. Novas áreas são destinadas à produção agropecuária de forma arbitrária, sem respeitar a capacidade de uso das terras. Neste contexto, o sistema de capacidade de uso das terras propõe a classificação do uso máximo permitido para terras de uma propriedade rural ou sub-bacia hidrográfica, buscando elaborar planos de uso e manejo sustentáveis de seus recursos naturais. Em relação ao uso atual das terras, o sistema indica os locais em que existe um conflito de uso em relação a sua capacidade de uso. Assim, é possível propor medidas para adequar o uso das terras com sua capacidade de uso. Nesta pesquisa, foram avaliadas as classes de capacidade de uso das terras da sub-bacia hidrográfica do Córrego Pedra Branca, Alfenas, Minas Gerais. Para tanto, foram avaliados os seguintes parâmetros do solo: profundidade efetiva, permeabilidade à água, textura, declividade, classe de erosão, saturação por bases, capacidade de troca catiônica efetiva e potencial, e saturação por alumínio. Ensaios analíticos do solo apresentaram valores de saturação por bases e de capacidade de troca catiônica efetiva e potencial baixos, que ilustram a baixa fertilidade natural desses solos em conjunto com índices de

saturação por alumínio, prejudiciais à maioria das culturas. A utilização do solo ficaria restrita a culturas permanentes de baixo impacto sobre o meio ambiente, silvicultura, sistema agrosilvipastoris aliados a técnicas de manejo conservacionistas, como plantio direto, correção do solo e adubação e reflorestamento das áreas de preservação permanente.

Palavras-chave: Agroecologia, Geotecnologias, Planejamento Agroambiental

Introdução

The increasing demand for food resulting from demographic growth has required more productive agropastoral practices. Consequently, new areas were selected in an arbitrary way for agropastoral production, disregarding land use capacity. This situation speeds up soil degradation processes, mainly those related to accelerated water erosion (Lepsch et al., 2015). In studies about soil losses related to water erosion, Ayer et al. (2015) evaluated soil loss susceptibility in the hydrographic sub-basin of Córrego Pedra Branca, Alfenas, in the state of Minas Gerais (MG). They detected losses of 23.86 Mg year⁻¹, with average losses of 8.40 Mg ha⁻¹ year⁻¹, and found that 34.80% of the sub-basin presented losses above soil loss tolerance limit (SLTL), which varied from 8.94 to 9.99 Mg ha⁻¹ year⁻¹.

The system of use capacity proposes a classification of the maximum use of land for a certain area and is relevant when planning conservationist management for rural properties and hydrographic basins. In relation to the current use of the soil, the system of use capacity may point out the sites in which the use is above capacity. With this in mind, it is possible to propose measures to adapt the use of the areas to their respective capacities and, thus, reduce degradation levels (Giboshi et al., 2006; Cunha e Pinton, 2012; Lepsch et al., 2015).

The system of use capacity indicates a better land use from the conservationist point of view. However, it is important to pay attention to the management practices adopted. Conservationist management practices are essential in establishing a socioeconomic and environmentally sustainable agriculture. Simple proceedings as, for example, the adoption of a rotating instead of continuous grazing system, and direct seeding could contribute to a significant reduction of erosion rates (Ayer et al., 2015; Olivetti et al., 2015).

Among soil conservation alternatives, agroecology is a process of production supported by environmental ecological aspects. Therefore, the use of agroecological concepts and practices favor management alternatives in agropastoral activities (Gliessman, 2000). These include the use of organic fertilizers including organic matter,

treated sewage sludge and/or the incorporation of biomass in direct seeding systems, which enable the maintenance of ecosystem services, offered freely by nature (Mendonça et al., 2006; Coelho et al., 2011; Macfadyen et al., 2012; Parron et al., 2015).

According to McGregor (1976), environment or ecosystem services are those offered by nature and may be in the form of products obtained from ecosystems which are referred to as provisioning services, as benefits resulting from the regulation of ecosystem processes, as non-material benefits, also referred to as cultural services and supporting services, necessary for the basic development of life.

Environment services are all the benefits that society obtains from ecosystems. For instance, we can mention the hydrological balance protection, prevention of landslides and erosion control promoted by established the native forest. Regarding agriculture, ecosystem services may lead to soil fertilization due to the accumulation of manure on the soil, decomposition of plants and animals, and microorganisms present in the soil and in plant roots, which contribute to the increase of organic matter present in the soil surface layer (Parron et al., 2015).

In the evaluation of land use capacity, geotechnologies enable handling a large amount of spatial data simultaneously in a faster and more reliable way. Geotechnologies are a set of powerful tools for the analysis and management of the territory, of broad application, with the possibility of being used in economic, social and environmental issues. With the availability of satellite imagery, it was possible to monitor spatial phenomena at different time intervals and at low cost (Lepsch et al., 2015; Olivetti et al., 2015).

By assessing the sustainability indicators at the public drinking water source in Oliveira - MG, Silva (2016) shows the feasibility of using the system of land use capacity as a technical and scientific support in decision making when sustainable management plans are in study for hydrographic basins. From the georeferenced databases, which presents information about relief, pedology, geology, hydrography, land use and socioeconomic factors he points out the importance of adopting the system of land use capacity when surveying the sustainability indicators.

According to Silva et al. (2013), the use of the geographic information system enables to sort out classes of soil and relief, besides determining the potential, actual and adapted soil use. At the sub-basin *das Posses* in Extrema – MG, in consequence of the low soil depth, steep slopes and high susceptibility to water erosion, the most recommended soil uses were native pasture, reforestation and environment conservation, evidencing the importance of sustainable management at the basin. 11% of *Das Posses* sub-basin area is behind use capacity, 12% is over use capacity, 58% is in balance, 18% are permanent preservation area and 1% is occupied by roads. In this case, land behind use capacity does not represent socioeconomic or environmental problem, provided conservationist management practices are followed.

Córrego da Pedra Branca hydrographic sub-basin is partially inserted in the urban area of Alfenas and it experiences intense urbanization since 1980. In 2015, urban areas occupied 21.62% of the sub-basin area. It is important to point out that urban expansion affects directly the sub-basin soil and water with pollution and contamination

because of inadequate disposal of effluents and solid residues. Currently, urban expansion and traditional agroforestry, disregarding Forest Code (Law number 12.651, May 25, 2012), exerts big pressure on ecosystem services (Ayer et al., 2015).

The aim of this study was to evaluate the evolution of adjustments to land use in the Hydrographic sub-basin of Córrego Pedra Branca, Alfenas, south of Minas Gerais, using multi-temporal satellite imagery from Landsats 5 and 8, based on the use capacity system (Lepsch et al., 2015). To propose conservationist plans of soil and water use and management, having in mind a sustainable agroforestry production and conservation of ecosystem services was also attempted.

Materials and methods

The study area comprises the Hydrographic sub-basin of Córrego Pedra Branca, which crosses Alfenas's urban area from South to North. The sub-basin occupies 2,642 ha between coordinates 21° 20' to 21° 00' S and 45° 55' to 46° 00' W, with altitudes of 780 and 920 m (Figure 1).

Figure 1. Study area with soils mapping units. LVd1: Dystrophic Red Latosol in flat relief; LVd2: Dystrophic Red Latosol in gently wavy relief; LVd3 Dystrophic Red Latosol in wavy relief; UFS: Undifferentiated Floodplain soils. Source: Adapted from Ayer et al. (2015).

The sub-basin belongs to the Rio Grande Hydrographic Basin and it is a tributary of the Furnas Hydroelectric Power Plant (FHPP) dam, which is of strategic importance in supplying energy and water to the southeastern region of Brazil (Ayer et al., 2015). Climate, as per Köppen classification, is Mesothermal, Tropical (CwB) (Sparovek et al., 2007), with mean yearly precipitation of 1,500 mm.

Figure 1 also illustrates the digital soil map resulting from overlapping Minas Gerais Soil Map (FEAM, 2010) and the relief unities obtained from the slope map of the digital elevation model "Shuttle Radar Topography Mission" (Embrapa, 2006). Four soil unities were mapped: Dystrophic red latosol in flat area (LVd1), in gently wavy area (LVd2), and in wavy area (LVd3), and undifferentiated floodplain soils (UFS). Each soil unity occupies respectively, 1.5%, 33.8%, 56.5%, and 8.3% of the sub-basin area.

Polymetamorphic, pre-Cambrian granulite gneisses and charnockitic form the geological substratum. Slopes and hills form the relief (Hasui, 2010).

Soil samples were collected from the surface layer of 0-0.2 m, from October 2012 through April 2013. Four samples for each main use were collected in each soil unity. For each sample, the sum of exchange bases, potential and effective cationic exchange capacity, aluminum saturation and bases saturation indices, and organic matter content were obtained. Physical attributes analyzed were texture and soil permeability to water. From the results, limiting factors regarding soil intrinsic properties, such as low natural fertility, low potential and effective cationic exchange capacities, and low organic matter content were defined.

Conservationist survey and harmonious balance of land use involve collecting environmental and socioeconomic data to help in the classification of land use capacity. Conservationist survey data were organized by means of symbols and conventional notetaking, displayed in a specific organization known as obligatory formula by Lepsch et al. (2015). Such formula considers soil effective depth, texture, permeability to water, declivity, apparent erosion, specific limiting factors for use in agriculture, and actual soil use. From this formula, use capacity classes are defined (Silva et al., 2013).

Land use mapping and temporal classification were carried out with bands 5 (middle infrared), 4 (near infrared), and 2 (green)

of the Landsat-5 sensor Thematic Mapper-TM, corresponding to orbit/site 291/74 of May 5, 1986, August 7, 1996, and of September 14, 2006, and of Landsat-8 sensor Operational Imager – OLI of March 14, 2015. Landsat-5 and Landsat-8 imagery have spatial resolution of 30 m and each image covers 185 Km². Radiometric resolution is of 8 bits, which makes separation of objects with similar spectral behavior difficult. However, field work allowed correcting areas with questionable classification. Imagery from Landsat-5 and Landsat-8 sensors were freely obtained from Instituto Nacional de Pesquisas Espaciais – INPE. As satellite Landsat-5 was landed in 2011, imagery from satellite Landsat-8 was used in 2015.

Images classification was based on the following parameters: Image color, texture and roughness. The adopted classification was visual, due to small dimensions of the study area and by the higher precision that this classification offers. This and the other procedures that involve the use of geographic information systems (GIS) were made using the ArcGIS 10.2 software. Coordinates system of cartographic products was the UTM zone 23° K and the Datum WGS-84.

According to the Brazilian Forestry Code (Brasil, 2012), consolidated use areas are those in Permanent Preservation Areas (PPA) which, in 2008, had already been occupied with traditional cultures for at least 10 years. Thus, the percentage of cultivated area in such situation in imagery from Landsat 5-TM of March 26, 1998, and May 30, 2008 were quantified. Those areas were delimited in GIS and their uses characterized.

Land use adjustment was carried out by comparing maps of land use with those of land use capacity, which enable the definition of areas with land use over natural capacity. Areas with use over capacity were calculated by GIS. Assessment of land use adjustment was carried out on the same dates as those of land use mapping.

From the above characteristics and the cartographic documents with the indication of areas with inadequate use, measures were proposed to improve local agropastoral productivity, having in mind socioeconomic and environmental sustainability.

Results and discussion

Analytical results defined soil properties (Table 1). Variables considered were the sum of exchange bases, potential and effective cationic exchange capacity, bases saturation and aluminum saturation indices, and organic matter content.

Table 1 comprises sampled sites, which are organized by mapping unities, followed by the average value of each unity.

Land potential (T) and effective (t) cationic exchange capacity indicates the quantity of negative charges the soil has, and, therefore, the quantity of cations that may be adsorbed. Low T and t values mean that the soil is more vulnerable to loss of nutrients by lixiviation. Thus, important cations for soil fertility as, for example, Ca, K and Mg are easily carried away by rain or irrigation water, contributing to eutrophication of rivers. Consequently, it is recommended to correct soil in the area with organic matter and intermittent lime application. Such measures will improve soil fertility and reduce contamination of surface and underground waters resources. Chemical fertilization of plantations will also have costs reduced (Ronquim, 2010).

Except for the LVd3 native forest unit, every sampled soil presented values below 50% for bases saturation index (V), indicating its dystrophic feature (Table 1). Low indices of bases saturation and of organic matter turn natural fertility at the sub-basin a limiting factor for annual crops, which demand large quantities of nutrients and of organic matter. This reinforces the necessity of use of management techniques that fix nutrients and organic matter in the soils. Fast growing plants, with roots that fix hydrogen are recommended for such process, as, for example, leguminous plants and banana trees. These may be used in consortium and or in rotation with more traditional cultures such as coffee, corn, among other species. On the other hand, besides protecting the soil from rain erosion, direct seeding would allow a larger incorporation of biomass with the increase of organic matter contents and fertility (Ronquim 2010).

Table 1. Chemical analyses of soil samples from the hydrographic sub-basin of Córrego Pedra Branca

	UTM Coordinate	SB ¹	t ²	T ³	V ⁴	m ⁵	OM ⁶
Sample	m	-----	cmol _c dm ⁻³ -----	-----	% -----	-----	Dag/kg ⁻²
P1LVd1	403739 W - 7635367 E	3.09	3.19	7.61	40.67	3.13	2.87
P2LVd1	403858 W - 7633285 E	0.56	1.26	6.86	8.11	55.56	2,61
P3LVd1	402868 W - 7628945 E	2.11	3.51	14.39	14.65	39.89	2.74
PMN LVd1	403465 W - 7635296 E	1.06	1.46	8.10	13.14	27.40	3.70
M LVd1	--	1.71	2.36	9.24	19.14	31.50	2.98
P1LVd2	402473 W - 76383655 E	0.55	1.65	8.42	6.49	3.13	1.87
P2LVd2	4043930 W - 76357181 E	1.88	2.38	9.75	19.30	55.56	2.87
P3LVd2	403192 W - 7631066 E	1.51	2.11	7.15	21.09	39.89	2.11
PMN LVd2	403002 W - 7628587 E	1.57	2.67	10.37	15.11	27.40	2.23
M LVd2	--	1.38	2.20	8.92	15.50	31.50	2.27
P1LVd3	403770 W - 7638147 E	0.57	0.97	5.09	11.23	41.24	2.48
P2LVd3	403691 W - 7637329 E	0.68	0.96	4.72	14.34	30.61	1.64
P3LVd3	402473 W - 76303359 E	1.20	1.70	6.25	19.24	29.41	2.11
PMN LVd3	403725 W - 7637757 E	4.79	4.89	8.41	56.95	2.04	2.63
M LVd3	--	1.81	2.13	6.12	25.44	25.83	2.21
P1UFS	403123 W - 7638084 E	1.11	3.21	18.24	6.10	65.42	5.43
P2UFS	402729 W - 7636930 E	0.62	1.92	9.42	6.56	67.71	3.14
PMN UFS	402224 W - 7629289 E	0.46	1.76	9.26	5.01	73.86	2.48
M UFS	--	0.73	2.30	12.31	5.89	69.00	3.68

¹SB: sum of exchange bases; ²t: effective cationic Exchange capacity; ³T: potential cationic Exchange capacity;

⁴V: base saturation index; ⁵m: aluminum saturation index; ⁶OM: organic matter. P: sample spot; M: sample sites mean for each soil class; LVd1: Dystrophic Red Latosol in flat relief; LVd2: Dystrophic Red Latosol in gently wavy relief; LVd3 Dystrophic Red Latosol in wavy relief; UFS: Undifferentiated Floodplain soils.

Low concentration of aluminum is beneficial to native forests in areas with neuter pH, and Al₂O₃ contributes to maintain tropical soil structure due to its flocculation activity. However, at high concentrations it is harmful to almost all

crops. Al concentrations above 20.0% (Table 1) are considered high; therefore, a limiting factor for the satisfactory development of crops (Ronquim, 2010). Soil texture varied from clayey to medium, with a predominance of medium grains. Soils with

medium texture present homogeneous granulometry among the different grains that compound them. This texture naturally favors infiltration; however, due to anthropic process, this feature favor compaction and soil erosion (Ayer et al., 2015).

At the sub-basin (Table 2), soils are deep, well developed and well drained, except for small

areas where rocks emerge upstream. Sub-basin latosols present low natural potential to erosion. However, due to the absence of conservationist management in agropastoral activities, these become more and more susceptible to water erosion, a result from soil compaction.

Table 2. General and specific limiting factors of studied soils from the hydrographic sub-basin of Córrego Pedra Branca, Alfenas, MG.

Soils ¹	Limiting Factors ²					Especific
	Effective depth	Texture	Soil water permeability	Relief	Water erosion	
LVd1	Moderate	Medium	Fast	Flat	Laminar	Dystrophic alic
LVd2	Moderate	Medium	Fast	Gently Wavy	Laminar	Dystrophic alic
LVd3	Shallow	Medium	Fast	Wavy	Laminar	Dystrophic alic, rocky, pebbles and gravel.

¹Soils: LVd1: Dystrophic Red Latosol in flat relief; LVd2: Dystrophic Red Latosol in gently wavy relief; LVd3 Dystrophic Red Latosol in wavy relief; ²General and specific Limiting Factors adapted from Lepsch et al. (2015).

In order to improve soil quality in the area, it is necessary primarily to stop degradation processes associated to soil conventional management, which use plowing, harrowing and, sometimes, scarification, and compaction as a consequence of mechanization, and, besides this, to adopt measures to increase organic matter contents. Pacini et al. (2003) research compares soil quality in three classes of agropastoral enterprises: organic systems, integrated systems and conventional systems. Organic systems are classified as monocultures with organic management techniques. Integrated systems, by the consortium of different crops and native forest. Conventional systems are characterized by intensive use of soil and abusive use of chemical fertilizers and pesticides. The results obtained by researchers show that, from the soil maintenance and fertility points of view, the most indicated systems are the integrated and the organic. Dale and Polasky (2007) showed the effects of agropastoral practices on soil and found out that conservationist management techniques, especially the production of organic fertilizer (agropastoral residues), besides increasing productivity in agriculture, add value to the product in the market. On the other hand, authors point out that the use of conventional agropastoral practices increase erosion rates and

negatively affect ecosystem services processed by the soil.

In relation to classes of land use capacity, four classes of land use capacity were identified at the Córrego da Pedra Branca Latosols: Classes IV, V, VI and VII, whose spatial distribution are illustrated in Figure 2. Land use capacity are in accordance with Lepsch et al. (2015) definitions.

Class IV is indicated for occasional temporary cultures, limited permanent cultures and rotation cultures with pasture, forests and wild fauna and flora protection areas. Lands in this class demand complex conservationist management practices, due to soil frailty very susceptible to erosion in very steep areas, and that, therefore, must be monitored. Thus, the use of permanent cultures in consortium with native species, direct seeding and in contour lines is recommended.

Class V is indicated for pasture, agroforestry systems and wildlife preservation. Soils may be indicated for pasture and permanent cultures when low fertility is corrected with the use of organic matter and direct seeding. As erosion in this class may be severe due to relief characteristics, soil should not be exposed to bad weather and seeding must be direct and in contour lines.

Class VI presents severe limitations to agriculture. Therefore, it is recommended with though restrictions, with risks of rill and laminar erosion. This class is recommended for native or cultivated forests, for refuge of wild fauna and flora. In the study area, the soil of this class is not much relevant from the agricultural point of view. This way, they are indicated for agroforestry projects, for recreation and wildlife watching.

Class VII presents limitations associated to low soil fertility and to relief, being inadequate for crops and are of restrict use for extensive cattle raising in grazing rotating system. These areas are also indicated for agroforestry systems or for preservation of fauna and of flora. However, this is the class that best represents the sub-basin and has an important role in the urban and rural development of the municipality.

Figure 2. Classes of land use capacity. Specific limiting factors: s5= low bases saturation (V) – indicative of soil natural fertility, the higher the value of V, the higher the content of calcium, magnesium and potassium; s6= high aluminum saturation – indicative of aluminum content at levels harmful to plants; s7= low cationic exchange – indicative of low adsorption of positive charges in the soil, such as Ca, K and Mg ions.

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For the area occupied by class VII it is suggested an investment in management practices that may reduce the limiting factors related to low soil fertility and to restrictions imposed by the relief. They represent sites recommended for conservationist management practices including green fertilization, direct seeding and consortium planting with native species. Regarding terrace farming method, with filled in and leveled ground and contour lines, which contributes to the reduction of erosion rates, it may be used without restriction for agricultural development.

Due to the proximity to the urban area, sewage water sludge from the treatment station cannot be used in the process of soil correction by direct incorporation of organic matter, in compliance with Resoluções n°. 375 and 380 from CONAMA (Brasil, 2006).

Land uses, from 1986 to 2015, are presented in Table 3 and, based on satellite images, were classified in: coffee, sugar cane, eucalyptus, native forest, corn, urban area and pastures. In this time interval, we highlight the reduction of areas planted with coffee from 8.80 to 4.00%. Sugar cane

area was reduced from 5.60 to 0.14%. Sugar cane area reduction was due to relief features that disfavor mechanization. Pasture areas decreased from 53.70 to 44.40%. Corn, which occupied 6.00% of the area in 1986, was not identified in 2015.

The area with eucalyptus grew from 0.20 to 6.40% in the same time interval. Such increase is corroborated in eucalyptus culture from 2006 to 2011, which, in Brazil, increased from 3.7 to 4.9 million of hectares and, in Minas Gerais, from 1.2 to 1.4 million of hectares as a result of paper export, of consumption in construction industry and of energy production as charcoal (ABRAF, 2012).

The areas with native and in succession stage forests increased from 9.00 to 11.00% from 1986 to 2015. Such increase probably results from changes in environmental legislation, as for instance the Forest Code (Brasil, 2012), which defines the permanent preservation areas – PPA, at rivers edges, with a minimum width band of 30 m and a 50 m radius around water springs. In order to comply with legal requirements, the legal reserve area, which is of 20% for the Mata Atlântica biome, it will be necessary to increase the native forest area in the sub-basin in 9%. Bare soil areas increase from 1.00 to 4.94% from 1986 to 2015, is due, mainly, to urban expansion.

The urban area expanded from 7.70 to 21.62% into the sub-basin from 1986 to 2015. Such expansion occupied part of the Córrego da Pedra Branca floodplain and of native forest and pasture areas. Presently, expansion has occupied PPA areas, threatening ecosystem services.

Table 3. Land use at the hydrographic sub-basin of Córrego Pedra Branca in hectares (ha) and in percentage (%) in the years 1986, 1996, 2006 and 2015.

Land Use	1986		1996		2006		2015	
	ha	%	ha	%	ha	%	ha	%
Coffee	231	8.80	100	3.75	47	1.80	105	4.00
Sugar Cane	147	5.60	29	1.09	8	0.30	4	0.14
Eucaliptus	6	0.20	36	1.37	0	0.00	169	6.40
Native Forest	237	9.00	277	10.50	277	10.50	290	11.00
Corn	158	6.00	86	3.23	92	3.50	0	0.00
Bare Soil	27	1.00	50	1.90	18	0.70	130	4.94
Urban Area	203	7.70	319	12.10	467	17.70	571	21.62
Floodplain	212	8.00	211	8.00	198	7.50	198	7.50
Pastare	1449	53.70	1534	58.06	1532	58.00	1173	44.40

ha: hectares

In 2015, illegal uses were observed inside the PPA if forest code is taken into consideration. Results show that 60% of PPA are in accordance

with legislation. However, the remaining 40% are illegally occupied for different purposes, as for example, coffee, eucalyptus, pasture and bare soil.

Illegal use of the soil associated with little presence of native forest in floodplains and in PPA areas increase production of sediments which cause silting of the floodplain and of Córrego Pedra Branca waterpath, thus hampering local water availability and hydrological balance, and contributing for the sediment accumulation in the Furnas Hydroelectric Plant Dam.

In relation to the adjustment of land use, the multi-temporal mapping of the land use and of the classes of use capacity of the soil in the hydrographic sub-basin of Córrego Pedra Branca allowed the identification of areas with land use above natural capacity and without conservationist management. In these cases, soils in general undergo more degradation, with loss of nutrients and of organic matter, due to intensification of eroding processes (Lepsch et al., 2015). In a study about water erosion of Latosols in the hydrographic basin of Córrego Pedra Branca, Ayer et al. (2015) made a map of soil loss and found that 34% of the sub-basin area present losses above SLT limits.

Soil loss between 10 and 25 Mg ha⁻¹ year⁻¹ occur in sites with conventional management, mainly eucalyptus, corn, sugar cane and pastures. The last represents approximately 50% of the sub-basin area. Losses between 25 and 100 Mg ha⁻¹ year⁻¹ are also in sites with conventional management of eucalyptus, sugar cane, pastures and coffee. Such data show that even in the class of correct capacity use, the absence of conservationist management leads to severe soil loss and degradation (Ayer et al., 2015).

The increase of inadequate areas vary in accordance with the planted culture. The system of use capacity established a maximum land use limit. When the adopted crop surpasses the limits established by the system of land use capacity, the area is defined as inadequate, and, in this case, the degradation processes tend to increase. However, the degradation level vary in accordance with management practices adopted in farming. Therefore, in order to reduce soil degradation, it is necessary to respect land use capacity in association with the best conservationist management techniques, considering the intrinsic aspects of soil, geology, relief, climate and legislation.

Figure 3 presents multi-temporal maps of soil use from 1986, 1996, 2006 and 2015, pointing out areas in conflict with the class of land use capacity. However, the adapted areas increased from 78.80 to 91.60% from 1986 to 2006, and, then decreased to 79.30% in 2015.

Latosols are clearly predominant in the sub-basin and present low natural fertility and low content of organic matter (Table 1). However, in the area where use is legal though inadequate, it is recommended the adoption of conservationist management practices and organic and/or chemical fertilization of the soil in order to improve productivity (Rigby and Cáceres, 2001). Currently, eucalyptus (Figure 3) is planted without conservationist management techniques, which accelerates the degradation processes, in areas adapted to the development of consortium plantations and reforestation. The same is observed in almost all temporary cultures in the study area.

Erosion rates vary depending on factors inherent to soil and environment. The factors are soil erodibility, rain erosivity, topography, and soils management (Mello et al., 2007).

Soil erodibility points out vulnerability or susceptibility to erosion, that is, a soil with high erodibility will suffer more erosion than one with low erodibility under the same conditions. Declivity in association with erodibility have large influence on soil loss (Silva et al., 1999; Silva et al., 2009). This is observed in the area by means of soil loss above SLT limit for LVd3, which contributes with 87% of total erosion, where declivity in association with use and Latosols erodibility were critical in deepening erosion (Ayer et al., 2015).

In the study area, it was observed that the uses that most contribute to erosion were pasture areas and eucalyptus plantations, which were responsible for 51.30% and 21.80%, respectively, of total erosion. It is important to point out that pasture areas occupy 45% of the area and area degraded due to the absence of conservationist management practices, which contribute for the loss of soils quality and for the decrease of pastoral productivity.

When simulating conservationist management techniques for agropastoral activities at the hydrographic sub-basin, Ayer et al. (2015) found out that total contribution of erosion in pasture plots and eucalyptus plantations decreases to 8.50% and 0.20%, respectively. This illustrates the potential and advantages of agro ecological conservationist management techniques, as illustrated by Freitas et al. (2012).

The evaluation of soil use at the PPA shows the absence of areas with consolidate use, in accordance with the Forest Code (Brasil, 2012). Cultures established in PPA areas before 1998 were not identified in 2006 and in 2008. Cultures after 1998 were replaced with different ones and, even

coffee, a permanent crop, was not identified for a period of over 10 years. Such areas, as per the forest code, are illegally occupied and should be recovered as permanent preservation areas.

The PPA map shows that areas predicted in the forest code are not thoroughly observed on the edges of Córrego Pedra Branca. Currently, 60% of the PPA are in accordance with legislation and 40% are not. They are used for pasture areas, urban areas, and coffee and eucalyptus plantations. Studies carried out by Silva et al. (2013) at the sub-basin of Posses, in Extrema, MG, presents 11% of its lands with use below capacity, 12% with use above capacity, 58% within the correct classification, 18% as PPA and 1% as roads.

PPA, according to Brasil (2012), have the ecological role of protecting native forest from erosion, avoiding sedimentation of water bodies, promoting geologic stability and giving support to the development of biodiversity. Ecosystem services offered by forest fragments in PPA are essential to keep environment ecologically balanced, and, therefore, should be recovered as per pertinent legislation. According to McGregor

(1976) and Ricketts et al. (2008), pollination services are responsible for up to 70% of world agricultural productivity. In the region, it is necessary a minimum of 25% of native forest for the maintenance of ecosystem services, as, for instance, insect pollination (Raniero, 2013).

In 2015, the study area had 11% of native forest (Table 3), far behind the minimum limit of 20% required by the Legal Reserve (Brasil, 2012) and the minimum of 25% of native forest for the offer of pollination ecosystem services. However, in accordance with the SOS Mata Atlântica and INPE (2012), Alfenas-MG municipality presents less than 7% of native forests. Thus, though the study area presents native vegetal cover larger than that of the municipality, it does not grant ecosystem and environment services since, for that, fragments should have a minimum area of 50 ha (SOS Mata Atlântica and INPE, 2012).

This situation is worsened by the use of agrochemical products that affect pollinators and may have a negative effect on the average agropastoral productivity of the region (Londres, 2011).

Figure 3. Temporal evolution maps showing adaptation of land use at the hydrographic sub-basin of Córrego Pedra Branca, Alfenas – Minas Gerais: A) 1986; B) 1996; C) 2006 e D) 2015.

Studies by Townsend, Begon and Harper (2006) showed that the shape of fragments affects the quality of native forests. Deforestation of fragments leads to the increase of border effect causing negative effect on biodiversity, species dispersion, genetic diversity and on the ecosystem services offered by fragments such as temperature attenuation, soils and water preservation, with the possibility of causing native species extinction and of favoring the dispersion of exotic species. In 2015, it was observed 290 ha (Table 3) of native forest at the sub-basin. However, these are mainly sparse, small fragments with no connectivity, which hampers the offer of environment and ecosystem services and the agropastoral activity. PPA recovery would contribute to the reduction of forest fragmentation, favoring species genetic flow and increasing quality and quantity of ecosystem services offered by nature, mainly those related to soil and water preservation.

Ecosystem services may be classified as: 1) regulating, when it regulates climate, diseases and water, erosion and pollination; 2) provisioning, when it offers food, fresh water, wood, fibers, biochemical and genetic resources; and, 3) cultural, when it offers recreation, leisure, scenic beauty, education, place feeling, besides supporting services as soil formation, nutrients cycling and primary production, among other benefits. However, the current use configuration in the study area severely compromises those ecosystem services. Therefore, agroecology is a profitable alternative to reach a sustainable agropastoral activity since it conciliates economic development, soil, water and biodiversity preservation, and also contributes to the effectiveness of ecosystem services.

Conclusions

1. Soils from the hydrographic sub-basin of Córrego Pedra Branca present low contents of organic matter and low natural fertility, besides being susceptible to water erosion. Thus, these soils are indicated for permanent crops, pasture and preservation of fauna, flora, soils and waters.

2. The adoption of conservationist management techniques could increase agropastoral productivity. Direct seeding techniques and in contour lines, green fertilization, crops rotation, establishment of agroforestry systems and rotation grazing system could reduce negative agropastoral impacts.

3. Data show that agroecology is a real possibility for the improvement of biodiversity, by increasing the number of wild fruit species and

natural attraction of fauna, promoting the development of ecosystem services and the ecological balance, besides preserving soil and water.

4. Landscape fragmentation associated with the absence of management in agropastoral activities hamper the offer of environment and ecosystem services and increase the degradation process, mainly those related to soil loss due to water erosion. Thus, the application of the land use capacity system is an alternative to improve the quality of environment services, provided it conciliates agropastoral production with conservationist management.

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