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Agricultural exploitation impact on the quality of natural waters in the trout-breeding region of the Mantiqueira ecological corridor

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ABSTRACT. Seasonal assessment of water quality was undertaken in an agricultural cattle-raising and trout-breeding region. Seventeen sites were sampled in ten municipalities close to the Papagaio and Ibitipoca State Parks in Minas Gerais, Brazil. Landsat 5 satellite images and Spotmap mosaic images with resolution of 2.5 m were employed to correlate classes of land use and topographic characteristics with the environmental contamination index of the water bodies at these sites. Results show a change in hydric classification of three sites evaluated. During the rainy season, sites 3, 7 and 17 were classified as class 3 according to CONAMA regulations, whereas the other sites were classified as class 2. During the dry season, sites 10 and 11 belonged to class 3 and the others to class 2. Literature and analysis of images and visits on the area showed that the principles of sustainable farming were not being followed in the region. Current research may be a tool for planning the preservation of natural resources. Results indicate there is a need for specific planning for fish farming and agriculture in the region for its sustainable economic exploitation.

Keywords: water classification, water contamination, monitoring, geo-referencing.

Impacto da exploração agropecuária na qualidade de águas naturais em região de truticultura no corredor ecológico da Mantiqueira

RESUMO. Realizou-se a avaliação sazonal da qualidade da água, em região de truticultura e agropecuária, por amostragem, em 17 pontos, dez municípios, em torno dos parques estaduais do Papagaio e do Ibitipoca em Minas Gerais, Brasil. Usando imagens gratuitas Landsat 5 e imagens de mosaico Spotmap, resolução de 2,5 m, correlacionando as classes de uso da terra e características topográficas com o índice de contaminação ambiental dos corpos d'água nesses pontos. Os resultados mostram alteração da classificação hídrica de três dos pontos avaliados. Na época das chuvas, os pontos 3, 7 e 17 foram classificados como classe 3, de acordo com as normas do Conama (Conselho Nacional do Meio Ambiente), enquanto os outros pontos foram 2. Durante a estação seca, os pontos 10 e 11 eram de classe 3 e os outros como classe 2. A revisão de literatura, com a análise das imagens e visitas na área, mostrou que os princípios da agricultura sustentável não estão sendo seguidos na área. Este trabalho serve como ferramenta para o planejamento para preservação dos recursos naturais. Os resultados indicam que há a necessidade de um planejamento específico para a criação de peixes e agropecuária na região, permitindo assim sua exploração sustentável.

Palavras-chave: classificação hídrica, contaminação da água, monitoramento, georreferenciamento.

Introduction

Anthropic activities in areas with well-defined natural limits (water basins) may be detected in the region's water resources (EPA, 2013). The strategic location of the Mantiqueira Ecological Corridor, straddling the borders of the States of Rio de Janeiro, São Paulo and Minas Gerais, Brazil, places it under high economic pressure. This is particularly relevant for trout farming, an important activity in the area under analysis, which requires plenty clean running water which is available only in mountainous regions.

Therefore, water quality is considered a main factor in fish farming (ASSAD; BURSZTYN, 2000; TAVARES; SANTEIRO, 2013). The drawbacks to growth of trout farming in the southeast region of Brazil are limited physical space with the necessary characteristics, relatively high costs for the setting up of the entrepreneurship, the need for sanitary regularization for its registration on the Federal Inspection System (SIF) and the bureaucratic hurdles of environmental legalization, which stimulate informality. In this context, agricultural activity as a rule plays an important role in

environmental contamination, with high degradation potential, mainly when exercised in areas that need special conservation care.

The main pressures on the environment in the ecological corridor under analysis are associated with traditional land use and management practices, such as extensive grazing and burning of primary vegetation for planting crops in protected areas, especially on steep slopes. The resulting loss of the natural plant coverage aggravates erosion, prevents the soil from performing its role of filtering the residues derived from crop growing and stock raising activities, and contaminates water resources coupled to the hampering of the production system.

Environmental aspects are a particular concern to dairy farmers since their productivity depends on the integrity of the soil/water/plant/animal system and the proper treatment of environmental issues is therefore necessary for sustainable exploitation, coupled to the preservation of the landscape´s geographical features.

Current research assessed through satellite images the relationship between water quality and soil/water/plant/animal use for fish farming, specifically trout farming. Evaluation was based on data obtained as part of the project called 'System for monitoring natural water quality, agricultural exploitation and preservation of water resources: community participation of family dairy farmers and quilombolas, carried out by the Embrapa Dairy Cattle (Embrapa Gado de Leite). The aim of this investigation is specifically the assessment of water quality in the region of the Mantiqueira Ecological Corridor and its influence on trout farming, based on the classification of water bodies and examination of satellite images.

Material and methods

Sixteen communities were selected in nine municipalities in the State of Minas Gerais (Lima Duarte, Santana do Garambéu, Santa Rita de Ibitipoca, Pedro Teixeira, Olaria, Ibertioga, Carvalhos, Bocaina de Minas and Alagoa), where milk production is the main activity on small farms, generating jobs and income, plus the Quilombola Colônia do Paiol in the municipality of Bias Fortes.

Water bodies in the studied area were classified according to parameters by CONAMA Resolution 357 (BRASIL, 2005) by using free Landsat 5 satellite images and Spotmap mosaic images, resolution 2.5 m (in the latter case acquired with project's funds). All the municipalities in the study area are located in the southeastern region of the State of Minas Gerais, distributed within the upper Rio Grande and Paraíba do Sul river basins.

Seventeen young people were selected from the communities involved. They were trained as environmental water quality monitoring agents on the premises of Embrapa Dairy Cattle, by the project team on the proper choice of sampling sites, the use of geo-referencing (GPS) equipment and the use of the following kits to measure water quality parameters in rivers and streams: Ecokit® to measure pH, turbidity, hardness, temperature and concentrations of dissolved oxygen, phosphate, ammonia, iron and chloride; the Cardkit® to measure nitrate and nitrite concentration; the Tecnobac® kit for analysis of fecal and total coliforms and *Salmonella*, according to method described by Hermes et al. (2004), enabling classification of the water bodies according to CONAMA Resolution 357 (BRASIL, 2005).

The collection sites were selected by the trainees through the technical support of the local offices of the Technical Assistance and Rural Extension of Minas Gerais (Emater). Each trainee was responsible for the analysis of a determined site located in the participating communities near fish-farming properties. Sampling sites were located in 16 communities using the criteria easy access and belonging to the rural portion of the water body. So that results with the Ecokit® could be validated, the project team visited all the sampled sites and measured the temperature, dissolved oxygen and pH with a Hanna model HI 9298 multiparameter water quality meter. During these visits, the geographic coordinates of each sampling site were determined with Garmin Etrex Legend HCx GPS device.

A land use map was prepared with ArcGis® 9.3 software from Landsat 5 satellite images, obtained at no charge from the National Space Research Institute (INPE, 2012), corresponding to the orbits/point 217/75 and 218/75, and Spotmap mosaic images, with 2.5 m resolution, acquired with funds from the project entitled 'System for monitoring natural water quality, agricultural exploitation and preservation of water resources: community participation of family dairy farmers and quilombolas', run by Embrapa Dairy Cattle. Mapping facilitated the study of each of the criteria for image analysis, such as shadow, farmed and urban areas, hydrography and vegetation, and

correlated them to the environmental contamination/pollution index.

For the expeditious identification of land use, supervised classification by the maximum likelihood method was used. Categories comprised urban area/exposed soil/bare area (areas with or without structures where plant coverage has been totally removed), agricultural area (composed mainly of herbaceous or bushy vegetation, notably natural or planted pastures), forest (dense forest formations, secondary forests and seasonal or semideciduous forest fragments), water (rivers, streams or lakes) and others (shadows and clouds). According to this technique, each pixel was automatically associated with a class according to the statistical similarity obtained in each spectral signature, generating a thematic map with the classes specified above.

The digital elevation model (DEM) was employed, with the necessary refinements, to cross-reference the data on the land use classification with the results of water sample analyses and the natural drainage system in the region.

Due to the final scale of map (1:250.000), the use of SRTM data was sufficient to satisfy the requirements for the analysis of the region´s hydrological characteristics.

Results and discussion

Figure 1 shows the distribution of land use and ground coverage classes. Forests and agricultural areas stand out among the classes, underscoring the potential for farming degradation within the region.

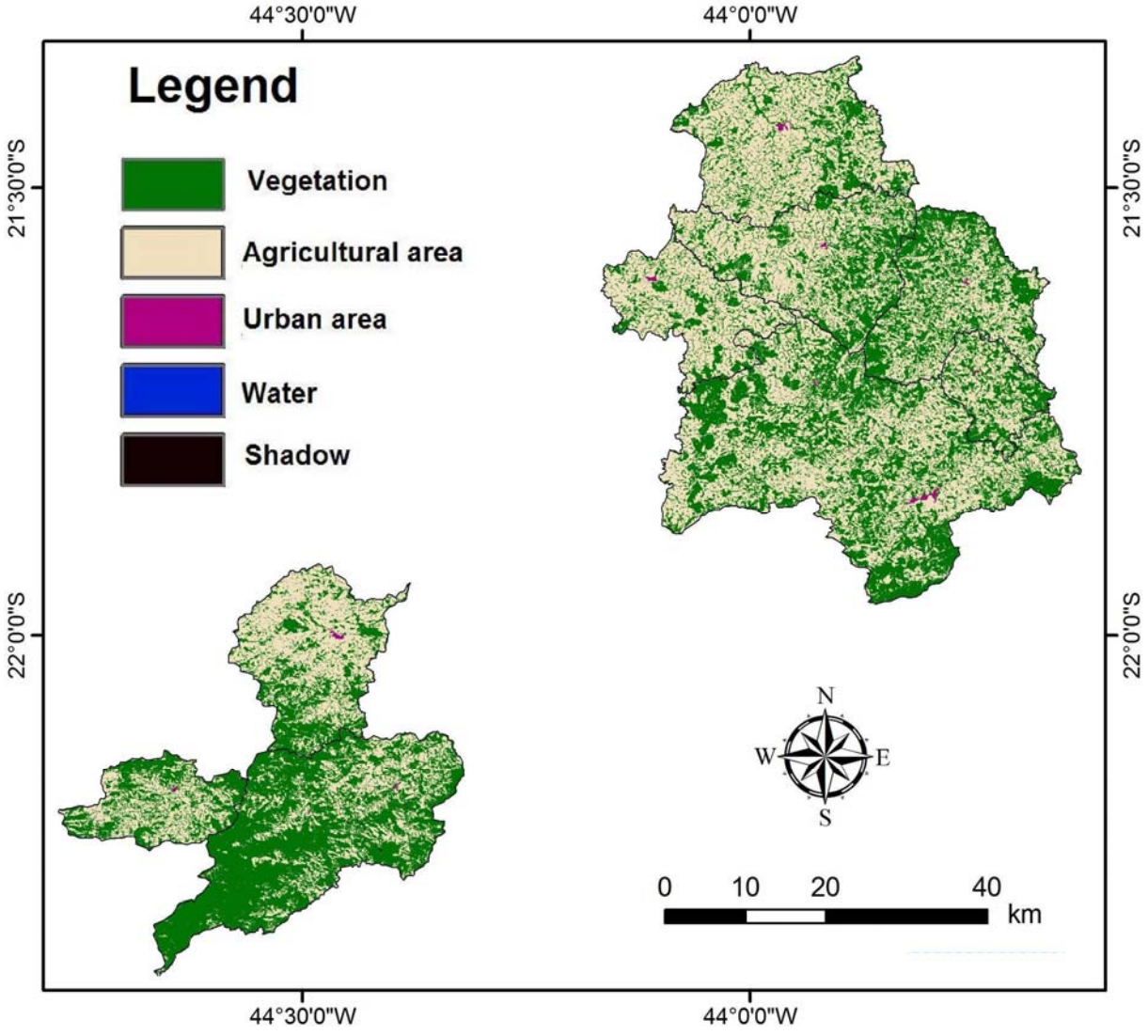

Figure 1. Land use and ground coverage in the study area.

Riparian areas were covered and stable, with high infiltration capacity and water storage in the soil. The time of traversal of the bed of the water source was consequently increased. Areas with such occupations tended to reduce runoff, an effect already evidenced by Silva et al. (2005) when they reported that complete soil coverage prevented breakdown caused by the impact of raindrops and the formation of surface sealing, favoring water infiltration into the soil and runoff decrease. Agricultural areas were characterized by lower water infiltration in the soil´s hydraulic conductivity and by higher resistance to penetration with regard to natural vegetation (ZIGOMAR; ALVES, 2003).

Although represented by small areas (Figure 1), inhabited areas (the urban area) were characterized by reduced permeability of the soil, or by sealing and/or compression in the case of populated areas or by changing of the physical properties such as compression in cropped areas. According to Gomes et al. (2007), it was expected that the dynamic use and land cover affected the variability of some soil physical properties especially those characterized by management of density and organic material. Change in the physical attributes of these areas was primarily characterized by the reduction of their infiltration capacity and water storage which increased runoff and by reducing their contribution to groundwater flow, an important factor in water availability during the dry season.

Cropped areas without proper management became major potential sources of sediment, already observed by Gomes et al. (2007) in maize crops located in a recharged area. Leys et al. (2010) also reported that conventional tillage by plowing and disking was characterized by an almost complete absence of coverage, low surface roughness, a larger number of particles readily available for transport and a greater susceptibility of soil to erosion.

In the case of coliforms, agricultural areas tended towards an increase in coliform quantity (Tables 1 and 2), possibly due to manure and garbage thrown into the watercourses. The breeding of pigs, poultry and dairy cattle without manure treatment worsened the situation. Similar results were obtained by Sauvé et al. (2012) when they investigated high biological contamination in sites close to urban agglomerations and to places with a lot of garbage (plastic, cans and packages of pesticides).

The preservation or degradation of environmental quality, more specifically the water resources at these sites, were due to natural conditions such as runoff, soil infiltration and the use and occupation of the watershed. Human activities, such as the production of domestic or industrial wastes in the form of diffuse pollution and the application of pesticides in the soil, contributed towards the introduction of compounds in the water negatively affecting its quality (PATOINE et al., 2012). The high fecal coliform counts indicated contamination by feces and consequently the presence of pathogenic microorganisms (SILVA; ARAÚJO, 2003). When related to the images generated, the presence of fecal coliforms (Tables 1 and 2) showed that certain sites (3, 7 and 17, for instance) were classified as class 2 in the dry season and as class 3 in the rainy season, according to the CONAMA system. These classifications took into consideration all water quality parameters and were mainly determined by increasing counts of fecal coliform bacteria. In the dry season, with the reduction of the volume of water sources and wastewater discharges with biodegradable organic compounds, nutrients and bacteria were mainly observed with the increase in the number of fecal coliforms.

Sites 10, 11 and 15 were classified as class 3 and others as class 2 during the dry season (Table 1). During the rainy season, sites 3, 7, 10, 11, 15 and 17 were classified as class 3 according to the CONAMA Resolution, and the other analyzed sites as class 2. (Table 2). The load of fecal coliform increased in class 3 sites during the rainy season. The positive correlation might be related to the use and occupation of the other sub-basins in which runoff due to rainfall led this diffuse pollution load to the river. Sites still classified as class 2 during the dry and rainy seasons had sub-basins predominantly occupied by preserved forest areas.

Table 1. Mean rates of water analyses and classification by sites during the dry season (April 2010 to August 2010).

Parameters/Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fecal Coliform Count (CFU100 mL^{-1})	465	943	435	210	640	330	840	480	648	1.120	37.420	599.5	326	493	1.260	840	645
Total Colony Forming Units (CFU100 mL^{-1})	1.335	1.621	29.760	780	1.403	840	18.180	1.320	5.425	3.280	8.653	40.860	16.437	8.355	15.360	4.846	1415
Salmonella (CFU 100 mL^{-1})	0	0	0	0	500	90	270	253	0	0	0	0	0	0	210	177	720
Classification	2	2	2	2	2	2	2	2	2	3	3	2	2	2	3	2	2

Table 2. Mean rates of water analyses and classification by sites during the rainy season (October 2009 to March 2010).

Parameters/Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fecal Coliform Count (CFU 100 mL^{-1})	744	1.000	379.8	312	480	375	1.065	580	3.445	1.020	465	610	532	820	1.460	480	700
Total Colony Forming Units (CFU 100 mL^{-1})	1.370	1.660	537.6	1.008	760	900	17.220	1.560	4.725	2.232	5.187	10.563	14.322	3.747	13.120	1.170	1.566
Salmonella (CFU 100 mL^{-1})	0	360	0	120	0	450	60	343.3	0	0	0	0	0	1,060	286.6	90	633.3
Classification	2	2	3	2	2	2	3	2	2	3	3	2	2	2	3	2	3

Results indicated small variations between the presence or absence of *Salmonella* at the sites that underwent alteration, due to the diffusion of contamination with a greater dispersion into the water body, hindering the quantification and characterization of the pollution sources (SOTTORIVA; GARCIAS, 2011). According to Souza et al. (2011), during rainy periods, the presence of bacteria such as Salmonella was more significant due to a higher tendency of these bacteria to remain in all types of soil when the ground was more waterlogged.

Bacteria do not occur in trout but are introduced during handling or by contact with water contaminated by human feces or feces from stock-raising facilities carried away by runoff and turning the water inadequate for trout farming during rainy periods (BARTOLOMEU et al., 2011). When compared with results of maps produced with the classification of the water body, the absence of or deficiency in plant coverage indicated that the environmental degradation of certain points worsened water quality (PEREIRA-SILVA et al., 2011).

Conclusion

Alterations in hydric classification of sites analyzed during the dry and rainy seasons reflect diffused pollution and inadequate management of the soil/water/plants in the region studied.

These results provide information for local policymakers to plan actions in water basins for the preservation of water and other natural resources and assure sustainability of fish farming.

The continuous existence of pollution sources may render unfeasible fish farming activities in the long run, leading to decline or disappearance of one of the region's traditional activities.

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