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VARIATION OF WATER QUALITY ALONG A RIVER IN AGRICULTURAL WATERSHED WITH SUPPORT OF GEOGRAPHIC INFORMATION SYSTEMS AND MULTIVARIATE ANALYSIS

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KEYWORDS

geoprocessing, mapping land use and occupation, water quality.

ABSTRACT

This study demonstrates using remote sensing, geographic information systems and multivariate statistics to study water quality in an agricultural watershed. The monitoring of water quality in the watershed of Lontras's river in the southwestern region of the State of Paraná had been done in 2012 and 2013 with a multi-parameter probe in ten sites that were defined upstream and downstream watershed, during four different seasons. Mosaicked images were used from Google Earth, Digital Elevation Model and soil types of maps, defined as the explanatory variables. The definition of the areas of influence and multivariate statistical techniques, particularly the Redundancy Analysis (RDA), were used for the correlation between variables. In a spring area, located upstream watershed, the contribution on water quality variation has gotten smaller, when compared with the other monitoring sites. There was interference in water quality in downstream sites that has become greater due to the effects of diffuse pollution. The RDA enabled synthesizes the data variability structure and the relationship of multidimensional variables. These statistical techniques added to products resulting from the GIS contributed to a better understanding of the variation of water quality in the watershed.

INTRODUCTION

Changes is natural ecosystems caused by human actions have been diagnosed by environmental studies. To meet basic and cultural needs, as well as different consumption patterns, humans developed many different relationships with nature, and this interference has pressured natural resources in different levels.

The anthropic action has been changing the natural landscape and causing several consequences to the environment, and some of them irreversible. Among the most serious implications, we may highlight soil degradation through erosion, with subsequent water deterioration, due to the sediments contribution in water bodies, especially those to which pollutants are associated (Sari et al. 2013).

Several technologies have been used in studies of environmental planning and management, especially in river watersheds. By integrating data from different sources, the use of these tools has allowed generation of information that can be used in decision making, supporting management actions, especially in land management.

The techniques of remote sensing and geoprocessing can be applied in mapping the use and occupation of soil, providing support to work with systematic information and tools that provide detailed reconnaissance of the study area (Wrublack et al., 2013a). Spaceborne sensors and GIS techniques provide useful information such as land use and occupancy (Wrublack et al., 2013b), also watersheds delimitation, valuable for evaluation of environmental impacts and its source. The systematized information enables the integrated analysis of the study area, as well as processing large amounts of information through geographic information systems (Ferreira et al., 2011), therefore, becoming an essential tool, providing consistent information about the watershed

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and for driving strategies for management of natural resources.

The environmental monitoring at the watersheds spots seeks to analyze relevant aspects to characterize the changes that occur in the land use and occupation, making it possible to evaluate the effects of human activities on ecosystems (Bertossi et al., 2013). The main reason of monitoring the quality of water resources in a watershed lies in the fact that, from the information collected, we can infer about the environmental condition of the watershed as a whole.

The aim of this study was to introduce a thorough procedure to map the water quality and land use. This approach applies GIS techniques and multivariate statistics to evaluate the water quality through space and time, in an agricultural watershed.

MATERIAL AND METHOD

The study was conducted in the cities of Salto do Lontra and Nova Esperança do Sudoeste, in the State of Paraná – Brazil, where the Lontra's River watershed is located.

Based in existent data (Bazilio, 2012), the quality of water was analyzed in four distinct seasons: spring (September), summer (December), autumn (March) and winter (June), in the years of 2012 and 2013. We made four visits each year and made collections under conditions of rapid and stagnant waters, with ten repetitions at each monitoring spot, an amount of 5,600 measurements of water quality parameters. Physical parameters and chemical parameters were measured with Horiba multiparameter probe (U-50), a tool that provides a set of water quality parameters: hydrogen potential dissolved oxygen (mg L^{-1}), electrical conductivity (mS m^{-1}), turbidity (NTU), temperature (°C), oxidation reduction potential (mV), and total dissolved solids (g L^{-1}). The samples were collected in a period of rain lack without severe drought.

The sampling spots were geolocated on the upstream and downstream of the watershed (Figure 1). The Table 1 presents the monitoring spots respective identification as well as the main uses, and the impacts caused by the use.

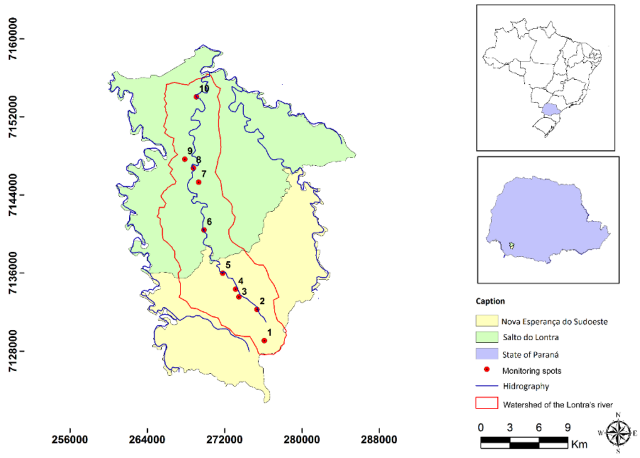


FIGURE 1. Spatialization of the ten spots of water quality monitoring in the watershed of Lontras's river. Datum WGS-84, coordinates UTM zone 22 S.

TABLE 1. Identification of spots of water quality monitoring in the watershed of Lontra's river and the main impacts in the area.

Spot	Characterization of monitoring points and impacts
1	Headwaters of the Lontra's river region where the springs meet.
2	Area with uncharacteristic riparian vegetation and presence of a chicken farm 50 m from the monitored point. Near the left bank is found a swine farm.
3	Bridge to exit/enter the city, houses on the border of the left bank with the presence of domestic animals. Waste arising from the activities in machine and wood shop near the river in which sediments enter.
4	Monitoring under bridge located in rural areas.
5	Rio Gavião Bridge (asphalt), river springs of Rio das Lontras.
6	Booth banks with absence of APP[1] and large presence of sediment.
7	Rio dos Porcos Bridge (urban area), area with uncharacteristic riparian woods, presence of houses near the banks.
8	Altered APP because of houses on the right bank (slum) and grazing areas on the left bank of the river.
9	Division between urban and rural areas, partly preserved margins, agricultural areas on the right bank of the river.
10	The riverbanks are unprotected due to the presence of grazing.

[1] Translator's note: APP – Permanent Preservation Area.

For the Lontra's river watershed land use and occupancy characterization, a visual classification was performed using Google Satellite Lauer through the OpenLayers Plugin for QGIS (Kalberer & Walker; 2017), to obtain a very detailed thematic map of the considered classes. The watershed environmental characterization included the steps of surveying (in loco) the main impacts on the monitoring points, as well as the sampling the water for quality parameters analysis, and subsequently integrated with the land use and occupancy map, and with the, slope classes extracted from the Aster Global Digital Elevation Model (Aster GDEM) (USGS, 2015), and the soil types map (ITCG, 2015).

Assuming that the water quality in the watershed is impaired by a diffuse source of pollution (not allowing to determine the exact location of the source), it was necessary the use the Thiessen Polygons technique to determine the influence of the contaminating agents around each sampling spots. Being indicated when there is no uniform distribution of spots (Pearson, 2007; Wrublack et al., 2013a). The polygons were created based on the ten sampling spots within the watershed.

To define the areas of influence in the monitored spots, we used the ArcGIS 10 software. By tracing straight lines that connected the closest spots between themselves, with the layout of the gutters of these lines, which consist of perpendicular medium lines, defining the regions of influence of each spot. Using the method of Thiessen polygons over the spots located to study water quality in the watershed, we improved the recognition of each parameter's behavior, through the generation of thematic maps of each polygon.

Conducting environmental studies, especially environmental variables monitoring, generates many response variables. The analysis of large databases can be interpreted with the help of multivariate statistical techniques. Thus, we highlighted the use of sorting methods as a collective term for multivariate statistical techniques to group sample spots along the axis, based on the characteristics of these sites (Ter Braak, 1986).

Among the methods of direct ordination, there is the use of Principal Component Analysis (PCA) and Factor Analysis (FA), in which the ordination axes are interpreted subsequently, in terms of possible explanatory variables. The PCA and the FA were applied to water quality parameters, collected in four distinct seasons and in ten monitoring spots in the watershed (amounts downstream). This multivariate statistical analysis applied to the data set obtained aimed at synthesizing/simplifying original information, reducing the contribution of less significant variables, improving the interpretation of a set of variables, stated as correlated.

The PCA was applied to the water quality variables to reduce the number of variables under study and thus, improve the interpretation by built linear combinations. Thus, the information contained in the original variables was replaced by information contained in the main uncorrelated components. In this technique, the variables are analyzed simultaneously, not being defined as dependent or independent. We applied the Factor Analysis (FA) to the output of the Principal Component Analysis with the main goal of further reducing the variability of the data from the PCA. This analysis aims to describe the original variability of the random vector in terms of fewer random variables (factors) that are related to the original vector through a linear model. Part of this variability is attributed to common factors, and the rest of the variability is assigned to the variables that have not been included in the model or attributed to random error.

Multivariate statistics techniques with direct ordering are based on Euclidean distance calculations and assume linear relationships between the explanatory variables and response. Among the techniques of direct ordering, we highlighted the use of Redundancy Analysis – RDA, being recommended for the ordination of water quality parameters in accordance with environmental variables, represented by metric data. In the RDA, the goal is to simultaneously correlate different dependent variables (response variables) with several independent metric variables (predictors or explanatory variables). Thus, the RDA aims at identifying an optimal structure for each group of variables that maximizes the relationship between the dependent (such as parameters of water quality) and independent variable groups (such as categories of land use and occupation).

To assess the relationship between two sets of data, the Redundancy Analysis (RDA) was applied to the data of water quality, which were the first group of variables, stated as dependent and target of direct interest, and the second group of variables comprised the categories of land use and occupancy in the watershed, which supposedly influence the variables of the first group. In this sense, the main objectives for the application of this technique were justified in determining which dependent variables, or the combinations thereof were more influenced, and estimate the effects of those explanatory (independent) variables that influenced the most in the variables of interest (dependent).

RESULTS AND DISCUSSION

The results of the water quality monitoring in the Lontras river watershed is shown in Table 2, and also the water use restrictions, according to the regulation for class 1 freshwater (BRASIL, 2005).

TABLE 2. Values of water quality variables in the watershed of Lontras's river.

Variable	Minimum	Maximum	Average	Standard deviation	Limit / Restriction
Temperature	12.89	27.46	20.69	4.04	Not defined
pH *	5.09	**10.76**	7.42	1.36	6,0 to 9,0
ORP *	176.12	**578.42**	284.17	74.75	100 to 500 (mV)
EC *	**0.04**	**0.13**	0.08	0.02	5 to 150 $mS^{-1}m$
Turbidity *	0.00	**72.04**	11.46	15.41	Up to 40 UNT
DO *	**4.93**	14.30	8.53	2.62	Not less than 6 mg/L O_2
TDS	0.03	0.59	0.06	0.09	Less than 500 mg/L

Note: * minimum or maximum values that showed restriction to the water quality in Class 1 (CONAMA 357/2005).

The water quality standards helped identify the water conditions in the monitoring spots. We observed that some of the parameters present restriction, based on the standards set for class 1 fresh water. Based on this information we tried to investigate weather was a correlation between the land use and occupancy and the changes in water quality parameters.

Visual classification was applied covering the study area to determinate land use classes and its distribution on the watershed. The land use and occupancy map is shown in Figure 2, followed by the sampling spots location and the watershed's divisions, determined by Thiessen Polygons technique. The percentage that each class occupies in each watershed division is presented in Table 3.

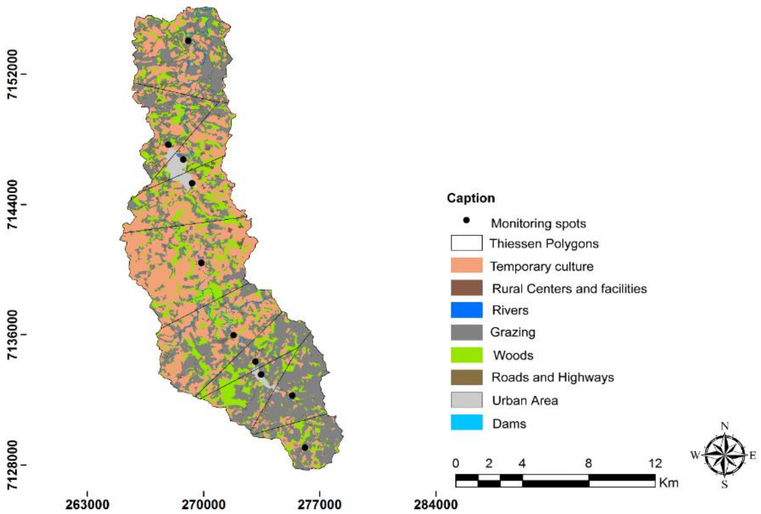


FIGURE 2. Characterization of the use and occupation of land in the watershed of Lontras's river, with a highlight to the water quality monitoring spots and definition of areas of influence, obtained by the Thiessen polygons technique. Datum WGS-84, UTM 22S coordinates.

TABLE 3. Mapping of the use and occupation of land in the watershed of Lontras's river.

Spot	Dams	Rivers	Urban area	Rural Roads	Woods	Grazing	Temporary	Rural centers/ facilities	Total area (%)
P1	0.03	0.06	0.00	0.16	4.14	**6.84**	3.71	0.22	15.16
P2	0.02	0.02	0.21	0.15	2.60	**3.05**	1.80	0.17	8.03
P3	0.02	0.02	0.70	0.10	**1.62**	1.25	1.61	0.22	5.53
P4	0.03	0.00	0.47	0.22	3.67	1.81	**3.74**	0.51	10.44
P5	0.05	0.02	0.00	0.36	5.80	3.29	**9.52**	0.53	19.55
P6	0.08	0.04	0.00	0.22	4.49	5.09	**5.27**	0.37	15.56
P7	0.01	0.00	0.06	0.04	2.16	**3.02**	0.60	0.08	5.97
P8	0.01	0.00	0.35	0.04	2.26	**2.69**	0.46	0.08	5.90
P9	0.01	0.00	0.05	0.08	1.70	**5.74**	0.46	0.10	8.14
P10	0.01	0.00	0.00	0.06	1.71	**3.25**	0.63	0.05	5.71

According to the mapping the Lontras river watershed size is 18,091.16 hectares. We found that the predominant class is grazing lands, followed by areas with woods and areas of temporary crops. Considering the Thiessen polygons, six of them have most of their area occupied by grazing lands, while other three have the highest intended occupancy of crops (temporary culture), and the polygon relative to the sampling spot 3, defined as the municipality entry/exit is mostly covered by woods. According to this classification the land use is predominantly agricultural (Wrublack et al., 2013a).

The agricultural and livestock activities are prevalent in the watershed, especially being represented by areas with grassland and seasonal crops occupying the highest area percentage. The perennial crops are mainly orchards and pasture. The main seasonal crops correspond to soybean, corn, tobacco and horticulture; corn and soybeans, deserve special attention in the agro-ecosystems context as they represent a serious threat to ecosystems due to inadequate practices of soil management, contributing to increased risks of soil loss due to erosion, also the inappropriate use of fertilizers and pesticides (Santos et al., 2010) constituting the nonpoint sources of pollution, been the main source of diffuse pollution caused by nutrients such as nitrogen and phosphorus.

The intensive exploitation of natural resources, linked to the emission of urban and industrial effluents, agricultural and forestry activities, have been contributing to the imbalance of terrestrial and aquatic ecosystems by changing the quality and quantity of water (Lucas et al., 2010). Monitoring the watershed points enables to point out diffuse problems, making it easier to identify outbreaks of natural resources deterioration, also the environmental degradation processes already installed, and the degree of involvement of the existing production; moreover, the territorial area has been considered ideal for the integrated management of natural resources (Alves Sobrinho et al., 2010).

Aiming to identifying the types of soils found in the watershed, we elaborated thematic maps, and resulting from this mapping (Figure 3) we quantified the areas of each soil type, as shown in Table 4.

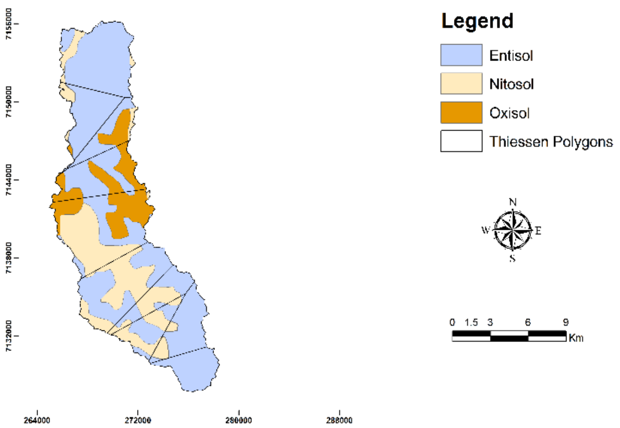


FIGURE 3. Classification of soils in the watershed of Lontras's river/PR.

TABLE 4. Types of soils in the watershed of Lontras's river with emphasis on areas of influence and monitoring spots.

Soil/ha	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Oxisol	-	-	-	-	-	6.58	4.83	2.09	0.14	-
Entisol	**5.65**	**6.66**	2.88	**3.14**	**8.59**	4.99	**5.76**	**3.09**	**7.14**	**13.68**
Nitosol	-	1.15	**2.98**	2.76	7.07	**8.23**	0.01	0.42	0.76	1.38

The types of soils present in the watershed of Lontra's River were identified as Entisol, Nitosol and Oxisol. The Entisol class encompasses soil formed by mineral material, not hydromorphic, or by thinnest organic material, with low-intensity of pedogenetic processes (EMBRAPA, 2013). The area occupied by the Entisol is the largest of all soil types in the watershed, with 61.58%. The second largest area is from soil formed by Nitosol, in which\ this soil type is formed by mineral material, with clay or loamy textures, accounting for 24.76% of the watershed area. The third category is Oxisol, with an occupation of 13.64%. Oxisol include the types of soils consisting of mineral material, with an advanced weathering stage, very evolved as a result of intense transformations of the parent material (EMBRAPA, 2013).

The soil type recognition is essential to understand physical and chemical processes that occur in a watershed. Environment changes directly influence agricultural practices which may include reduction of water holding capacity, aeration, soil resistance to root penetration as well can change soil aggregates stability and hydraulic conductivity (Bono et al., 2012).

The turbidity indicates sediments and pollutants found into the water bodies mainly derived by superficial runoff. Considering the terrain slope one of the main causes of soil erosion, a map of slope gradient (Figure 4) was obtained through the Digital Elevation Model (DEM), and the slope classes were classified according to the Table 5.

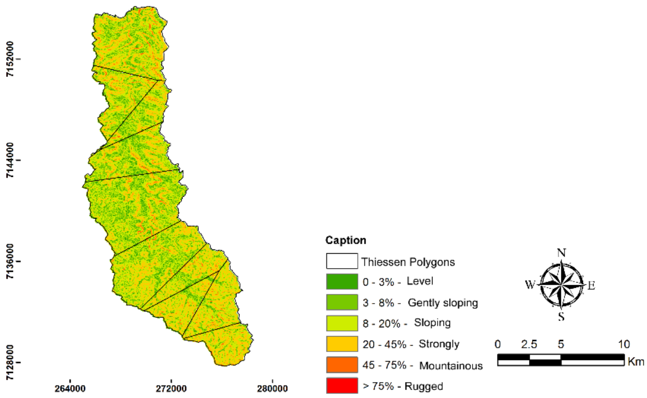


FIGURE 4. Slope classes in the watershed of Lontras's river/PR.

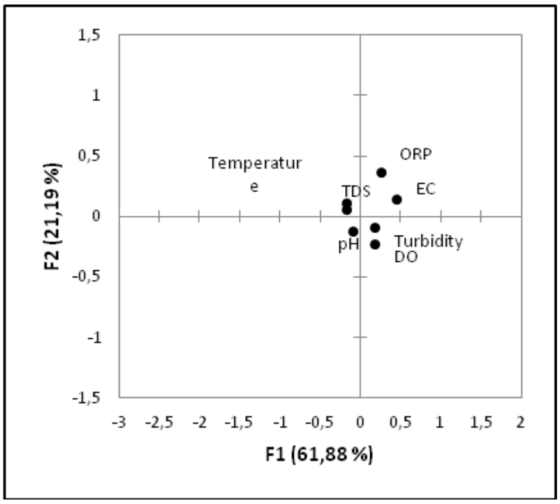
TABLE 5. Class of the slope and its respective areas, especially in watershed monitoring spots of watershed of Lontras's river/PR.

		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Area (%)
1	0 to 3%	0.93	0.50	0.41	0.85	1.63	0.99	0.29	0.27	0.31	0.15	6.33
2	3 to 8%	2.84	1.56	1.21	2.51	5.12	3.28	0.90	0.82	0.87	0.52	19.63
3	8 to 20%	**6.26**	**3.52**	**2.48**	**4.58**	**9.24**	**7.43**	**2.58**	**2.45**	3.22	2.03	43.78
4	20 to 45%	4.58	2.30	1.43	2.51	3.56	3.85	2.06	2.25	**3.29**	**2.83**	28.65
5	45 to 75%	0.44	0.15	0.07	0.15	0.26	0.11	0.08	0.07	0.13	0.14	1.60
6	> 75%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01

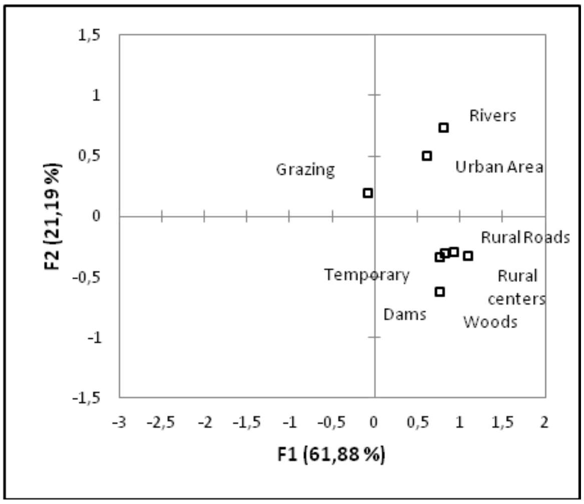
Note: (1) Level; (2) Gently sloping; (3) Moderately sloping; (4) Sloping; (5) Strongly sloping; (6) Mountainous and rugged.

The Lontra's river watershed has a large predominance of land in moderately sloping relief (13-20%) followed by the sloping relief (20-45%). Approximately 43.78% of the watershed has moderately sloping. Areas with sloping relief represent approximately 28.65% of the area, while the areas with gently sloping relief are 19.63% of the relief on this slope class and a percentage of approximately 6.33% of areas of level relief. The lower part of the study area, was assigned to strongly sloping relief; and mountainous and rugged correspond to the percentage of 1.60% and 0.01% respectively in these slope classes. The development of morphology maps and classification of soils have been the basis for decision-making processes, particularly in agriculture, which can be used in combination with other factors (Alexandre & Marques da Silva, 2009).

The investigation of the supposed relationship between the dependent variables, defined by the water quality parameters and the independent variables (UCS, soil types, MDT and monitoring points in the watershed) were obtained through the direct ordering method by the Redundancy Analysis based on multiple linear regressions. The results of the orderings have been validated by the permutation test (Anderson & Ter Braak, 2003), by testing the null hypothesis in which the response variables represented by the water quality parameters are not linearly correlated to the explanatory variables of soil use and occupation; soil type; slope class and monitoring spots at a level of 5% (p value 0.209). Whereas the F1 and F2 factors explained 83.07% of the variability, we considered these two factors for the interpretation of ordination analysis in the X and Y axes, represented by the explanatory and response variables. The ordination diagrams of the first two axes of the Redundancy Analysis, obtained for the ordination of the seven dependent variables (water quality parameters) and the twenty-seven explanatory variables (eight categories of soil use and occupation; three soil types; six slope classes and ten monitoring spots) are shown in Figure 5 (a to e).



(a)



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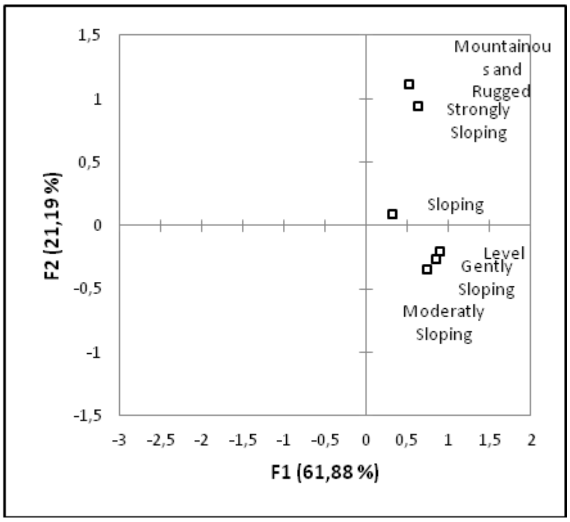

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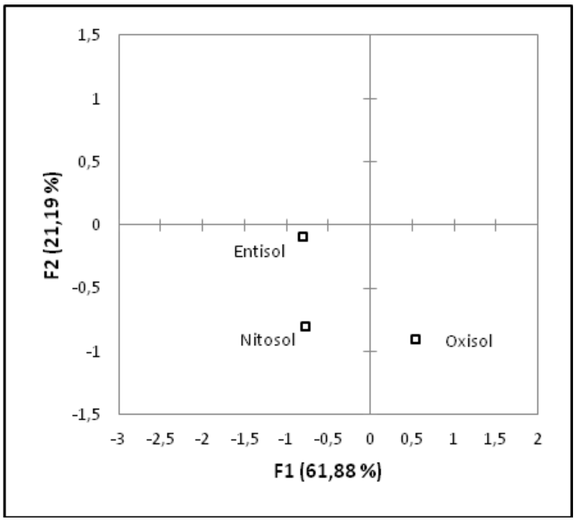

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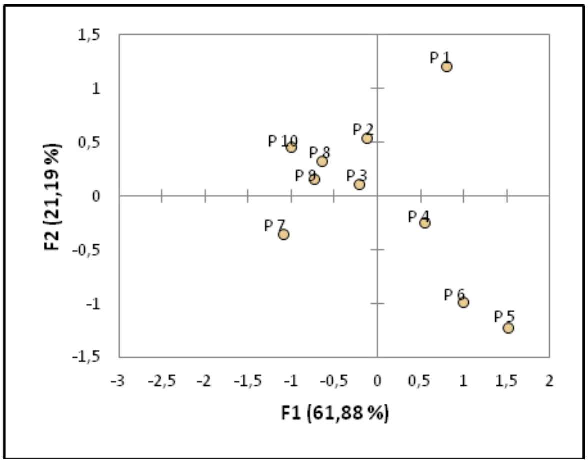

(e)

FIGURE 5. Result Analysis Redundancy (RDA) with regional expansion (a) parameters of water quality; (b) land and soil use categories; (c) slope classes; (d) types of soils (e) monitoring spots in the watershed of Lontra's river.

The resulting ranking of the RDA revealed a positive correlation to the variables (dependent) EC and ORP indicating that there is a dependence on the rivers and urban areas, mountainous and rugged, strongly sloping and sloping (notably, the categories with the highest slope) in spot 1, situated in headwaters of the Rio das Lontras. The parameters of temperature and total dissolved solids have dependence on grazing areas, in spots 2 and 3 (contribution of pig manure and waste from mechanical activities) and spots 8, 9 and 10 (slum, bridge over urban area and exit of the city). The hydrogen potential showed it has a dependence on the categories of entisol and nitosol, in spot 7 (Porcos river). The parameters of turbidity and dissolved oxygen have shown dependence with the areas of oxisol and the categories of level relief, gently sloping and moderately sloping (0-30% slope) in a special way, the categories of lower slope. The categories of soil use and occupation (rural roads, rural centers/facilities, woods, dams and temporary crops) are dependent on each other because, according to the ordering of the RDA diagram, they denote a correlation.

In the watershed, we identified two dominant soil types, areas with Entisol (61.59%) revealing soils in the process of formation and Nitosol (24.76%) derives from rock weathering, which comprise soils of great agricultural importance, contributes to the enhancement of the effects of erosion and water pollution, especially agrochemicals through runoff, in contrast, areas with Oxisol (13.62%) with soils in intense weathering and very advanced evolutionary processes. Soils under discussion present erosion risks if they are in corrugated reliefs, as is the case of the watershed, in which the relief predominates, in the categories, from moderately undulating to undulating (> 72%). Thus, it contributes to the potentialization of the effects of erosion and water pollution, especially agrochemicals, by surface runoff.

CONCLUSIONS

Geotechnologies represented in this study by remote sensing, geoprocessing techniques and geographic information systems enabled execution of complex analysis, composing database from different sources, demonstrating its potential to mapping land use and occupation and carry out variation studies of water quality in a watershed that is agricultural.

Water quality parameters identification in monitoring points, spatiality distributed in the Lontra's River watershed / PR, as well as the characterization of anthropic activities (land use, slope and soil type) allowed the area acknowledgment.

Influence areas near monitoring points were determined by using Thiessen polygon method, as well as multivariate statistics have made possible infer which explanatory variables were the most influential water quality parameters. In headwater areas, located upstream of the watershed the contribution was smaller compared to other monitoring points. Points located downstream, were identified that water quality interference has become evident, probably because of diffuse pollution along the watercourse.

The ordination diagram generated by Redundancy Analysis enabled the identification of anthropic activities on water quality parameters, mainly when compared to points located upstream and downstream of Lontras's River watershed.

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REFERENCES

Alexandre C, Marques da Silva JR (2009) Influência da morfologia do terreno nas características do solo em terrenos agrícolas do Alentejo – aplicação de classificações geomorfométricas. Revista de Ciências Agrárias 32(1):407-422.

Alves Sobrinho T, Oliveira PTS, Rodrigues DBB, Ayres FM (2010) Delimitação automática de bacias hidrográficas utilizando dados SRTM. Engenharia Agrícola 30:46-57.

Anderson MJ, Ter Braak CJF (2003) Permutation tests for multi-factorial analysis of variance. Journal of statistical computation and simulation 73:85-113.

Bazilio S (2012) Variabilidade espaço temporal da comunidade de macroinvertebrados Bentônicos na microbacia do rio Lontra na região sudoeste do estado do Paraná. Tese Doutorado, Cascavel, Universidade Estadual do Oeste do Paraná.

Bono JAM, Macedo MC, Tormena CA, Nanni MR, Gomes EP, Müller MM (2012) Infiltração de água no solo em um Latossolo Vermelho da Região Sudoeste dos Cerrados com diferentes sistemas de uso e manejo. Revista Brasileira de Ciência do Solo 36:1845-1853.

BRASIL. Conselho Nacional do Meio Ambiente. CONAMA. Resolução no. 357, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. Available: http://www.mma.gov.br/port/conama/legiabre.cfm?codlegi=459. Accessed: Aug 21, 2017.

Bertossi APA, Cecilio RA, Neves MA, Garcia GO (2013) Qualidade da água em microbacias hidrográficas com diferentes coberturas do solo no sul do Espírito Santo. Revista Árvore 37:107-117.

EMBRAPA (2013) Sistema brasileiro de classificação de solos. Brasília, Embrapa. 353p.

Ferreira E, Toledo JH, Dantas AAA, Pereira RM (2011) Cadastral maps of irrigated áreas by Center pivots in the state of Minas Gerais, using CBERS-2B/CCD satellite imaging. Revista Brasileira de Engenharia Agrícola 31(4):771-780.

ITCG - Instituto de Terras, Cartografia e Geciências (2015) Produtos cartográficos/dados e informações geoespaciais temáticos/Solos. Available: www.itcg.pr.gov.br. Accessed: Sep 25, 2017.

Kalberer, P., Walker, M. QGIS OpenLayers Plugin. Sourcepole AG. Available: https://github.com/sourcepole/qgis-openlayers-plugin. Accessed: Aug 20, 2017.

Lucas AAT, Folegatti MV, Duarte SN (2010) Qualidade da água em uma microbacia hidrográfica do Rio Piracicaba, SP. Revista Brasileira de Engenharia Agrícola e Ambiental 14:937-943.

Pearson JA (2007) Comparative Business Site-Location Feasibility Analysis using Geographic Information Systems and the Gravity Model. Winona, Saint Mary's University of Minnesota Central Services Press, p1-10. (Papers in Resource Analysis, 9)

Santos EHM, Griebeler NP, Oliveira LFC (2010) Relação entre uso do solo e comportamento hidrológico na Bacia Hidrográfica do Ribeirão João Leite. Revista Brasileira de Engenharia Agrícola e Ambiental 14:826-834.

Sari V, Poleto C, Castro NMR (2013) Caracterização dos processos hidrossedimentológicos em bacias rurais e urbanas. Revista Enciclopédia Biosfera 9:596-624.

Ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology:1167-1179.

USGS. Use for a changin world. Digital Elevation/SRTM. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM). Available: earthexplorer.usgs.gov. Accessed: Sep 23, 2015.

Wrublack SC, Mercante E, Vilas Boas MA (2013a) Mapping of use and occupation of the soil and irrigation water quality in the city of Salto do Lontra-Paraná, Brazil. Revista Engenharia Agrícola 34(5):1024-1037.

Wrublack SC, Mercante E, Vilas Boas MA, Piana PA (2013b) Influence of use and land occupation on the water quality with the application of multivariate statistical techniques. Journal of Food, Agriculture & Environment 11:2131-2135.