Land use and water quality in two sub-basins

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Abstract**—** *The study evaluated the effects of land use and occupation in water quality in two sub-basins located in the State of Paraná, Brazil. The first sub-basin has 69.8% of native vegetation (natural) and the other has 54.1% of the land cultivated (anthropic). Samples were collected from April to December 2015, analyzing the following parameters: dissolved oxygen, temperature, electrical conductivity, pH, total dissolved solids, turbidity, color, biochemical oxygen demand, total nitrogen, total phosphorus and fecal coliforms. The natural sub-basin presented, significantly, better water quality. Total phosphorus, biochemical oxygen demand and fecal coliforms exceeded the legal limits on the anthropic sub-basin. At this sub-basin correlation was found between cumulative rainfall of five days with turbidity and fecal coliforms, two days cumulative rainfall and total nitrogen, as well as between air and water temperature, affecting the dissolved oxygen, pH, electrical conductivity and fecal coliforms. In the natural sub-basin correlation was found between cumulative rainfall of two days and turbidity, total dissolved solids and electrical conductivity.*

Keywords* — *agriculture, native vegetation, watershed.

I. INTRODUCTION

Water is a fundamental substance and its peculiarities are important indicators of environmental quality because, during its course, it acquires characteristics derived from the environment.

The characteristics of a watershed have an important influence on water quality, such as landscape and spatial configuration (Bateni *et al*, 2013) as well as land use (Kamjunke *et al*, 2013; Wang *et al*, 2014; Meneses *et al*, 2015; Valle Junior *et al*, 2015; Durło *et al*, 2016). The watershed is the territorial unit chosen for the study and management of water resources, where the systemic view is fundamental for understanding the relative phenomena.

The removal of natural vegetation to give place to human activities affects the quantity and quality of water, since the vegetation influences the hydrological cycle, the water availability and the biogeochemical cycles. Importance has been directed to riparian vegetation that acts as a "filter", retaining substances and sediments that can be carried to water bodies (Sweeney and Newbold, 2014).

Despite the economic benefits provided by changes in land use, there is, simultaneously, a decrease in the ability of the environment to sustain human activities (Foley *et al*, 2005). In this context, public supply sources must receive special attention for their social and economic importance.

The objective of this study was to analyze the water quality in two sub-basins, with different land uses, which are part of the São João watershed - PR, used as the supply source for the city of Carambeí – PR, in southern Brazil.

II. MATERIAL AND METHOD

The São João watershed has 145 km^2 and the length of the main course is 39 km, located in the transition of Paraná first and second plateau (Fig. 1). The river is classified as class II (Paraná, 1991) and is tributary of the right bank of the Pitangui river, which belongs to the Tibagi watershed. According to the Köppen classification, the region belongs to the Cfb climate type.

The region is located in the Atlantic Rain Forest Biome in the Mixed Ombrophilous Forest (MOF), comprising the sub-formations of Montane MOF and Alluvial MOF in the general matrix of subtropical grasslands, and occasionally, cerrado (savannah type) fragments.

Twenty-one sub-basis were studied and they were delimited based on topographic map, sheet MI 2824-4 / IBGE (2001). The land use map was elaborated based on RapidEye satellite image visual interpretation, classifying: native forest (MOF), reforestation (exotic), dry and wet grasslands, agriculture, bracatinga forest (*Mimosa scabrela*), buildings for poultry and swine husbandry and other human use. To represent the native vegetation, forest, grasslands and bracatinga units were defined and mapped. The GIS component were performed with QGis® 2.6.1 software (2014).

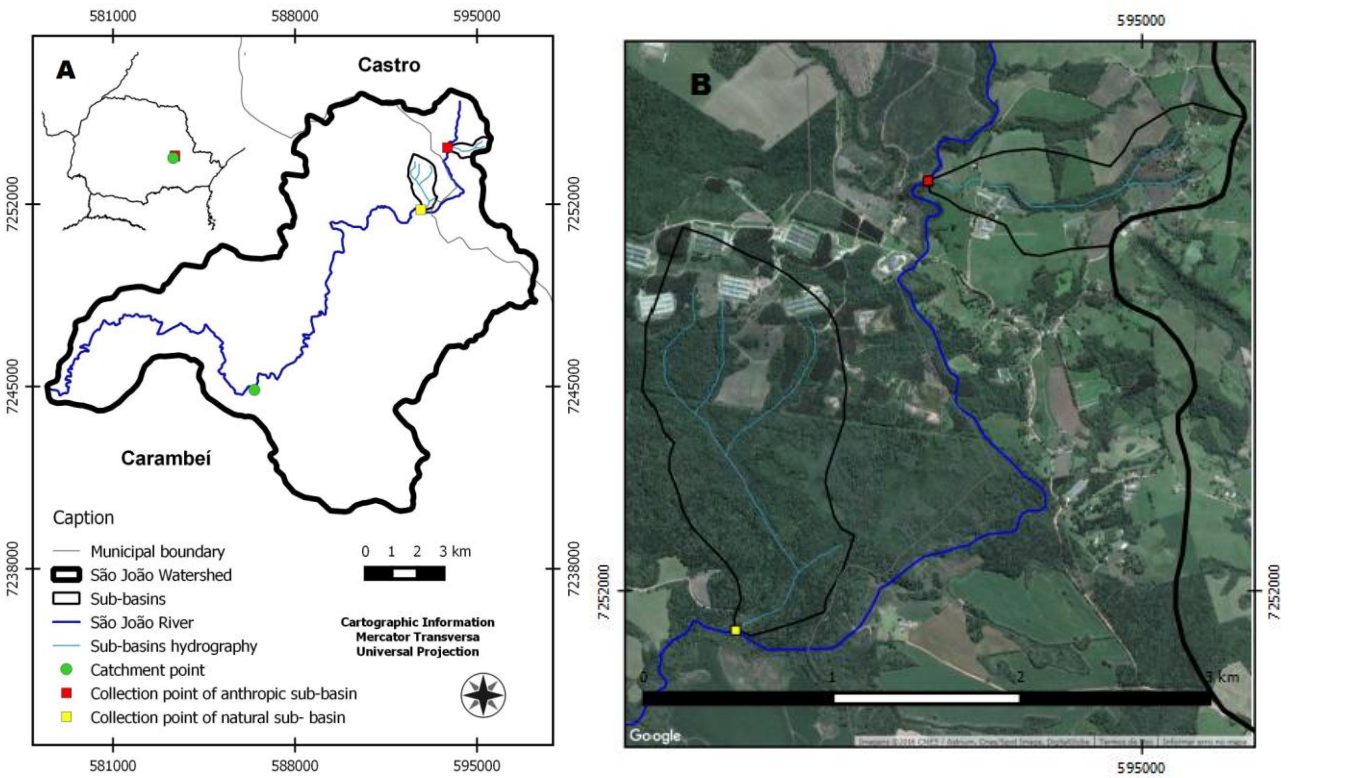

FIGURE 1. LOCATION OF THE SÃO JOÃO WATERSHED (A) AND SUB-BASINS STUDIED (B)

The collection points are located at the UTM coordinates: 592.860,28 m E and 7.251.793,18 m S for the natural sub-basin, and 593.909,4 m E and 7.254.172,43 m S for the anthropic sub-basin (22J, SAD 69). The water samples were collected monthly, from April to December 2015. With YSI 556 MPS® multiparameter probe it was *in situ*, analyzed, dissolved oxygen (DO), temperature, electrical conductivity (EC), pH and total dissolved solids (TDS). The parameters turbidity, color, biochemical oxygen demand (BOD), total nitrogen (TN), total phosphorus (TP) and fecal coliforms (FC) were analyzed at the Water Resources Laboratory (LRH) of the State University of Ponta Grossa (UEPG). Hach® turbidimeter was used for turbidity evaluation and DM-Color Digimed® colorimeter for color analysis. For the bacteriological examination Colilert® substrate and Quanti Tray/2000® Idexx card were used. For BOD, VelpScientifica® equipment was used. For the TN and TP DRB-200 reactor and DR-5000 Hach®, spectrophotometer were used for digestion and reading the analysis.

The meteorological data were obtained from the Maracanã Agrometeorological Station in Castro - Brazil (UTM coordinates 609554,0844 x and 7246980,6670 y, WGS84 - 22J) (ABC Foundation, Agricultural Research and Development).

In the evaluation, descriptive analysis, analysis of variance and Pearson correlation were performed. The variables were tested for homogeneity of variance and normality. When these values were not observed, the values were transformed: Ln for TDS and EC, square root for FC and 1/x for TP, color and turbidity. For such software Sisvar 5.6 was used (Ferreira, 2011). The design was completely randomized blocks. The two sub-basins were considered as treatments and the date of collection as blocks (nine dates). The replicates ranged from three to twenty per variable.

The results were compared against the values established by the CONAMA Resolution nº 357 for class II freshwater rivers (Brasil, 2005).

The values of precipitation, mean, maximum and minimum temperature were used for correlation analysis with water quality parameters. Cumulative precipitation values of two and five days prior to sampling were used, and for the temperature values of the mean of the collection day and the mean of two previous days, for the mean, maximum and minimum temperatures.

III. RESULTS AND DISCUSSION

From the sub-basins studied, one was selected to represent natural land use, with a 69.8% area covered by native vegetation (forest 51.5% + bracatinga 18.3%) and another representing anthropic use, with 54.1% of area covered by agriculture (Fig.1).

Both sub-basins are shaped by second-order rivers and the hydrographic network pattern is dendritic (Strahler, 1952). The main course length of the natural sub-basin is 2.3 km and the anthropic is 1.6 km. The soil types that occur in the São João watershed are Histosol, Cambisol and Nitosol.

The hypsometric and topographic gradient maps were elaborated from ASTER GDEM/NASA (2011) image, demonstrating that the natural sub-basin presents altitudes ranging from 1.018 to 1.162 m and the anthropic sub-basin between 1.066 m and 1.163 M. The relief of the natural sub-basin ranges from undulating (3-8%) to rolling (8-20%) and in the northern part is steep (20-45%) to very steep (> 45%). The anthropic sub-basin presents relief ranging from flat (0-3%) to rolling (8-20%).

Land use and cover are presented in Table 1. At the head of the natural sub-basin there are buildings for livestock production located very close to the springs, within Permanent Preservation Areas (PPA). In the midst of native vegetation there are forest plantations based on exotic species (*Eucalyptus spp and Pinus spp*) and native (*Mimosa scabrela*), and this river is intersected by a vicinal road. The sample collection point was located few meters before the mouth into São João river. In this place the water body presents 15 cm of depth, 2 m of width and a sandy bed.

TABLE 1
USE AND RELATIVE LAND USE IN THE NATURAL AND ANTHROPOGENIC SUB-BASINS

Classes of land use and occupation	Sub-basins			
	Natural		Anthropic	
	%	Area (ha)	%	Area (ha)
Agriculture	0.0	0.0	54.1	37.3
Bracantiga (*Mimosa spp*) forest	18.3	29.6	0.0	0.0
Grassland	0.0	0.0	1.4	0.9
Livestock buildings	5.3	8.6	6.2	4.3
Native forest	51.5	83.6	26.5	18.3
Reforestation	29.4	40.5	0.0	0.0
Other farm buildings and houses	0.0	0.0	11.8	8.2
Total	100	162.3	100	69.0

At the head of the anthropic sub-basin there are buildings for human use near the springs and inside the PPA. The riparian vegetation accompanies most of the hydrography, except in the lower part where it was clear-cut. On the left bank of the main river there are livestock buildings near the water body, also inside the PPA. A vicinal road cuts the watershed lower portion. At the sample collection point the river bed is rocky, the water depth is 15 cm and the width of the channel is 1.5 m.

The minimum DO value for the anthropic sub-basin was 4.4 mg L^{-1} and for the natural sub-basin 6.6 mg L^{-1} (Table 2). The anthropic sub-basin presented lower values, most of these measurements presented high DO concentrations due to a small waterfall located some meters before the collection point and to the rocky substratum, resulting in turbulence and replenishing water with oxygen (Von Sperling, 1996).

In the natural sub-basin there was variation in temperature from 10.5 °C to 17.4 °C and in the anthropic sub-basin from 14.2 °C to 20.1 °C (Table 2). These values are low due to the climate of the region (Cfb) and the altitude (± 1000 m).

The anthropic sub-basin presented greater variability for most of the parameters (Table 2), which is directly related to the predominant type of land use (Table 1). The BOD and FC showed great variation in the two sub-basins (Table 2).

TABLE 2
MAXIMUM, MINIMUM, MEDIAN AND COEFFICIENT OF VARIATION OF THE DEPENDENT VARIABLES FOR SUB-BASINS WITH NATURAL AND ANTHROPIC USE

Parameters*	Natural sub-basin				Anthropic sub-basin			
	Maximum	Minimum	Median	Coefficient of variation (%)	Maximum	Minimum	Median	Coefficient of variation (%)
DO (mg L^{-1})	9.1	6.6	7.2	11.92	7.9	4.4	6.3	16.14
Temperature (ºC)	17.4	10.5	15.4	14.97	20.1	14.2	18.8	12.33
pH	8.0	6.4	7.3	9.68	7.4	6.5	7.0	5.95
Color (Pt-Co)	3.4	1.4	1.9	31.85	210.0	5.5	38.1	118.07
Turbidity (NTU)	4.5	1.9	2.7	32.82	81.1	3.4	9.6	107.84
TDS (mg L^{-1})	26.9	20	25.6	11.74	77.5	40.1	58.1	24.02
EC (µS cm^{-1})	33.9	25.6	31.1	11.45	108.0	52.1	76.0	25.4
TP (mg L^{-1})	0.6	0.3	0.4	28.27	2.5	0.6	1.9	38.96
TN (mg L^{-1})	2.7	0.6	1.3	90.23	5.5	0.4	1.6	92.29
BOD (mg L^{-1})	24.8	0.0	5.2	105.79	29.3	5.2	16.5	80.6
FC (MPN)	866.4	54.6	193.5	96.04	2419.6	235.9	1553.1	60.16

Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electric Conductivity (EC), Total Phosphorus (TP), Total Nitrogen (TN), Biochemical Oxygen Demand (BOD), Fecal Coliforms (FC)

According to analysis of variance all parameters presented significant differences between sub-basins (Table 3). In both sub-basins, the DO was above the minimum established by the Brazilian legislation. The natural sub-basin presented higher average than that of the anthropic sub-basin, with values of 7.5 mg L^{-1} and 6.2 mg L^{-1}, respectively. The relationship between the amount of native vegetation and DO concentration tends to be positive (Sweeney and Newbold, 2014).

TABLE 3
ANALYSIS OF VARIANCE AND COEFFICIENT OF VARIATION OF THE VARIABLES FOR SUB-BASINS WITH NATURAL AND ANTHROPIC USE, AND WATER QUALITY STANDARDS ESTABLISHED BY CONAMA RESOLUTION Nº 357 (BRASIL, 2005)

Parameters*	Natural sub-basin mean	Anthropic sub-basin mean	Coefficient of variation (%)	p-value	CONAMA (Brasil, 2005)
DO (mg L^{-1})	7.5	6.2	5.7	<0,00001	> 5
Temperature (ºC)	15.0	17.8	3.2	<0,00001	-
pH	7.3	6.9	6.0	<0,00001	6,0 - 9,0
Color (Pt-Co)	2.1	68.1	19.3	<0,00001	-
Turbidity (NTU)	3.0	26.5	23.7	<0,00001	< 100
TDS (mg L^{-1})	24.1	56.6	5.1	<0,00001	< 500
EC (µS cm^{-1})	29.9	76.1	4.4	<0,00001	-
TP (mg L^{-1})	0.4	1.7	28.2	<0,00001	< 0,1
TN (mg L^{-1})	1.1	2.1	38.9	<0,0011	-
BOD (mg L^{-1})	8.0	18.2	55.4	<0,0001	< 5
FC (MPN)	308.6	1451.9	39.4	<0,00001	< 1.000

Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electric Conductivity (EC), Total Phosphorus (TP), Total Nitrogen (TN), Biochemical Oxygen Demand (BOD), Fecal Coliforms (FC)

The anthropic sub-basin has 27.9% of native vegetation cover and in many places does not present riparian vegetation. In water bodies where the riparian forest is non-existent the water temperature tends to be higher (mean water temperature of 17.8 °C in the anthropic sub-basin and 15.0 °C in the natural sub-basin), showing an inverse relation with DO and decreasing its concentration in water (Table 3).

The pH in both sub-basins was close to neutrality in accordance with the legislation (Table 3). The color and turbidity presented higher averages for the anthropic sub-basin, 68.1 Pt-Co and 26.5 NTU respectively, in relation to the natural sub-basin, 2.1 Pt-Co and 3.0 NTU respectively, where the CONAMA Resolution nº 357 establishes a maximum value of 100 NTU for turbidity (Table 3). The results are directly related to the amount of vegetation in the sub-basins, where less vegetation allows the carrying of a greater amount of sediments (Sweeney and Newbold, 2014).

The mean for TDS in the anthropic sub-basin (56.6 mg L^{-1}) was higher than the natural sub-basin (24.1 mg L^{-1}), lower than that established by legislation (Table 3). The EC mean was higher for the anthropic sub-basin. This difference must be related to the vegetation cover, since the sediment transport containing soluble ions to the water increases the value of these parameters (Lima *et al*, 2015).

The TP presented averages of 0.4 mg L^{-1} and 1.7 mg L^{-1} for the anthropic and natural sub-basins, respectively, values higher than those define by the legislation (Table 3). Mean TN of 1.1 mg L^{-1} for the natural sub-basin and 2.1 mg L^{-1} for the anthropic sub-basin, are considered high. Even with greater presence of vegetation in the natural sub-basin, there are animal confinements that generate a large amount of manure and the relief at the headwaters ranges from steep to very steep. In the anthropic sub-basin these values were expected. It is largely occupied by intensive farming and high use of chemical fertilizers, pesticides and animal manure.

The BOD means for the natural and anthropic sub-basins presented values of 8.0 mg L^{-1} and 18.2 mg L^{-1}, respectively, higher than those stipulated by the legislation (Table 3). In the stabilization of organic matter the DO is consumed in the microorganisms metabolic processes, reducing its availability (Von Sperling, 1996). The high BOD of the anthropic sub-basin indicates the presence of a greater amount of organic matter, compromising the DO in this sub-basin.

The FC had mean of 308.6 MPN in the natural sub-basin and 1.451.9 MPN in the anthropic sub-basin, a parameter that should not exceed 1.000. The highest mean for the anthropic sub-basin is due to the lack of regular riparian vegetation and in the natural sub-basin may be related to the presence of livestock farming.

The turbidity presented a negative correlation with the accumulated precipitation of five days in the two sub-basins (Table 4). The water transparency decreased after rainfall, with higher turbidity in the early stages of precipitation. In the natural sub-basin the correlation is associated with a higher percentage of native vegetation.

TABLE 4
PEARSON CORRELATION ANALYSIS BETWEEN DEPENDENT VARIABLES AND ACCUMULATED PRECIPITATION FOR TWO AND FIVE DAYS PRIOR TO COLLECTION

Parameters*	Two days precipitation		Five days precipitation	
	Natural	Anthropic	Natural	Anthropic
DO (mg L^{-1})	-0.35	-0.35	-0.44	-0.27
Temperat. (ºC)	0.2	0.38	0.33	0.45
pH	-0.26	-0.32	-0.28	-0.29
Color (Pt-Co)	-0.42	-0.33	-0.49	-0.52
Turbidity (NTU)	-0.41	-0.37	-0.7	-0.71
TDS (mg L^{-1})	-0.57	0.47	-0.88	0.49
EC (µS cm^{-1})	-0.48	0.51	-0.74	0.52
TP (mg L^{-1})	0.28	-0.33	0.33	-0.6
TN (mg L^{-1})	0.25	0.66	-0.02	0.63
BOD (mg L^{-1})	-0.31	-0.15	-0.41	-0.23
FC (MPN)	-0.15	0.38	-0.34	0.67

Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electric Conductivity (EC), Total Phosphorus (TP), Total Nitrogen (TN), Biochemical Oxygen Demand (BOD), Fecal Coliforms (FC)

Although the positive correlation between TN and accumulated precipitation of two days in the anthropic sub-basin is not strong (Table 4), it was observed that after rain events there was foam on the water surface, strong odor of manure and sludge in the river bed. It can be concluded that the runoff from the agricultural area and the lack of riparian vegetation contributes to the transportation of nutrients to the water.

The TDS and EC in the natural sub-basin showed a negative correlation with the accumulated rainfall of five days (Table 4), reflecting the importance of vegetation in the river bank stability and sediment retention (Sweeney and Newbold, 2014).

In the anthropic sub-basin there was a positive correlation between accumulated rainfall of five days and FC (Table 4), being related to the farms, the use of manure fertilization and lack of riparian vegetation. Positive correlations between these indicators and precipitation of one and three days prior to collection have already been reported (Liang *et al*, 2013).

Observing the correlations between air temperature and DO (Table 5), the inverse relationship between these variables is evident, showing strong and negative correlation for the anthropic sub-basin. The lack of riparian vegetation exposes the river to higher solar radiation, increasing the water temperature and decreasing the solubility of the DO (Tables 2 and 3). In the natural sub-basin, correlations (Table 5) reinforce that the presence of vegetation promotes water shading, decreasing temperature and increasing DO concentration (Tables 2 and 3).

The correlations between water and atmospheric temperature (Table 5) shows seasonal influence (Silva *et al*, 2015). The higher temperatures in the anthropic sub-basin (Tables 2 and 3) tend to catalyze chemical and biological reactions, increasing the activity of the organisms that release CO_2, forming carbonic acid and hydrogen ions that lower the water pH (Esteves, 1988), justifying the observed correlations (Table 5).

TABLE 5
PEARSON CORRELATION BETWEEN THE DEPENDENT VARIABLES AND THE MAXIMUM, MINIMUM AND MEAN TEMPERATURE ON THE DAY OF COLLECTION AND TWO DAYS PRIOR TO COLLECTION

Parameters*	Maximum temperature				Minimum temperature				Mean temperature			
	of the day		Two days		Of the day		Two days		Of the day		Two days	
	Ant.	Nat.	Ant.	Nat.	Ant.	Nat.	Ant.	Nat.	Ant.	Nat.	Ant.	Nat.
DO (mg L^{-1})	0.67	0.81	0.54	0.8	0.84	0.68	0.75	0.52	0.83	0.92	0.8	0.9
Temperature (ºC)	00.63	00.69	00.5	00.54	000.89	00.88	00.7	00.76	00.8	00.85	00.76	00.78
pH	-0.36	-0.66	-0.36	-0.67	-0.45	-0.48	-0.48	-0.45	-0.52	-0.72	-0.52	-0.78
Color (Pt-Co)	-0.27	-0.56	-0.18	-0.39	-0.69	-0.65	-0.87	-0.72	-0.55	-0.63	-0.5	-0.64
Turbidity (NTU)	00.29	-0.39	00.51	-0.17	-0.43	-0.41	-0.67	-0.53	00.01	-0.37	00.2	-0.37
TDS (mg L^{-1})	00.03	00.3	00.36	00.17	-0.18	00.32	-0.55	00.59	00.04	00.39	00.11	00.34
EC (µS cm^{-1})	00.33	00.41	00.6	00.27	00.2	00.53	-0.25	00.74	00.4	00.56	00.46	00.48
TP (mg L^{-1})	-0.23	-0.46	-0.38	-0.31	-0.48	-0.43	-0.07	-0.51	-0.46	-0.46	-0.44	-0.48
TN (mg L^{-1})	00.45	00.38	00.53	00.28	00.27	00.22	00.14	00.45	00.52	00.39	00.47	00.34
BOD (mg L^{-1})	-0.33	-0.21	-0.09	-0.06	-0.08	-0.05	-0.47	-0.33	-0.16	-0.11	-0.21	-0.16
FC (MPN)	-0.5	00.35	-0.38	00.12	00.18	00.53	00.03	00.74	-0.17	00.42	-0.31	00.39

Anthropic (Ant.), Natural (Nat.), Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Electric Conductivity (EC), Total Phosphorus (TP), Total Nitrogen (TN), Biochemical Oxygen Demand (BOD), Fecal Coliforms (FC)

Turbidity interferes with the penetration of light into water (Von Sperling, 1996) as well as color, demonstrating consistency in the correlations found (Table 5).

The EC of water is dependent on its temperature, increasing 2% at each ºC (Esteves, 1988). In this sense, the positive correlation in the anthropic sub-basin is justified (Table 5). The higher water temperatures found for the anthropic sub-basin (Tables 2 and 3) tend to promote bacteria proliferation, with higher concentrations of FC (Table 2), explaining the correlation found (Table 5) (Liang *et al*, 2013).

Concerning the water quality, the land use has shown to be relevant, observed in the difference of the parameters between the sub-basins, which agrees with Mori *et al* (2015), and the greater compliance with legislation for the natural sub-basin.

IV. CONCLUSION

The natural sub-basin presented better water quality than the anthropic sub-basin. Upstream farms and the lack of Permanent Preservation Area in springs contribute to fecal contamination and high values of total phosphorus, total nitrogen and biochemical oxygen demand in the natural sub-basin. The predominant use of agriculture, the absence of riparian vegetation and the use of synthetic and natural fertilizers degrade water quality in the anthropic sub-basin. Precipitation and atmospheric temperature tended to influence the analyzed parameters.

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