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# EFFECT OF SOIL USE ON THE QUALITY OF WATER RESOURCE IN WATERSHED USING MULTIVARIATE STATISTICAL ANALYSIS

**MARCELO ZANATA[1]; TERESA CRISTINA TARLÉ PISSARRA[2]; ANTONIO SERGIO FERRAUDO[3]; MAURICIO RANZINI[4] E SERGIO CAMPOS[5]**

[1] Pesquisador Científico, Instituto Florestal de São Paulo, Batatais-SP, marcel_zanata@hotmail.com
[2] Profa. Doutora, Faculdade de Ciências Agrárias e Veterinárias –UNESP, Jaboticabal, SP, teresap@fcav.unesp.br
[3] Prof. Doutor, Faculdade de Ciências Agrárias e Veterinárias –UNESP, Jaboticabal, SP, fsajago@gmail.com
[4] Pesquisador Científico, Instituto Florestal de São Paulo, Batatais-SP, ranzini@ig.com.br
[5] Prof. Titular, Faculdade de Ciências Agronômicas–UNESP, Botucatu, SP, seca@fca.unesp.br

## 1 ABSTRACT

Changes in soil use in protected areas modify the landscape, and therefore, monitoring water quality in headwaters is essential to improve the population health and control water pollution. The objective of this study was to determine environmental changes as a result of soil use, evaluating physical and chemical characteristics of the water of the drainage network in watersheds. The study was conducted to determine the effects of soil use in watersheds with first order streams, related with management practices of water quality, according to the strategic importance for the supplying source. Watersheds are predominantly covered by sugar cane, reforested with Pinus and native forest. Temperature (TºC), pH, electrical conductivity (EC) and total dissolved solids (TDS) were the parameters determined in the headwaters. Dissolved oxygen (DO) and turbidity (T) were obtained in the lab. The majority of variables and factors were explained by changes in soil use associated with management practices. Two factors resulting from the multivariate analysis showed direct correlation with SDT, CE and pH variables, which shows surface runoff with possible water nitrification of a watershed planted with sugarcane. The second factor showed direct correlation between TCº and T variables, while both were negatively correlated with DO, which shows the seasonality effect on one of the watersheds reforested with Pinus. The results highlight management practices in conservation and maintenance planning of forested areas surrounding headwaters as indicators for higher quality of natural water.

**Keywords:** Pinus, sugar cane, nitrification, seasonal variation

**ZANATA, M.; PISSARRA, T. C. T.; FERRAUDO, A. S.; RANZINI, M.; CAMPOS, S. EFEITO DO USO DO SOLO NA QUALIDADE DO RECURSO HÍDRICO UTILIZANDO ANÁLISE ESTATÍSTICA MULTIVARIADA**

## 2 RESUMO

Mudanças no uso do solo ao longo das áreas protegidas modificam a paisagem, assim o monitoramento da qualidade das águas das nascentes torna-se essencial para melhorar a saúde da população e controlar a poluição dessas águas. O objetivo deste trabalho foi determinar alterações ambientais devido ao uso do solo, avaliando características físicas e químicas da água da rede de drenagem de microbacias. O trabalho foi realizado para estudar os efeitos do uso do solo em microbacias de primeira ordem, relacionado com práticas de gestão da

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qualidade da água, de acordo com a importância estratégica para a fonte de abastecimento; as microbacias são predominantemente ocupadas com cana de açúcar, reflorestadas com Pinus e com mata nativa. Os parâmetros, de temperatura (T), pH, condutividade elétrica (CE) e sólidos dissolvidos totais (SDT) foram determinados nas águas das nascentes. O oxigênio dissolvido (OD) e a turbidez (t) foram obtidos em laboratório. As variáveis e os fatores foram explicados por mudanças decorrentes do uso do solo associados às práticas de gestão. Dois fatores resultantes da análise multivariada, mostraram correlação direta com as variáveis SDT, CE e pH, evidenciando o escoamento superficial com possível nitrificação da água de uma microbacia plantada com cana de açúcar. O segundo fator mostrou correlação direta entre as variáveis T e t enquanto ambos estavam negativamente correlacionada com OD, mostrando o efeito da sazonalidade sobre uma das microbacias reflorestadas com *Pinus*. Os resultados destacam as práticas de gestão no planejamento da conservação e a manutenção de áreas florestais ao redor das nascentes, como indicadores para melhor qualidade da água natural.

**Palavras-chave:** *Pinus*, cana de açúcar, nitrificação, sazonalidade.

## 3 INTRODUCTION

Soil use changes in the surroundings of protected areas modify the landscape, and the monitoring of water quality on headwaters has been essential to a better population health and to control the water pollution. The watershed is a fundamental geomorphological region of the Earth's surface, considered by geomorphologists and hydrologists as the main physiographic unit of the land, since its characteristics govern all surface and subsurface water flow (ZANATA, 2009).

Soil use change monitoring of watershed aims to characterize relevant aspects that allow diagnosing the environment and to evaluate the effects of human activities about ecosystems (BU et al., 2014; PINTO, MELLO e ÁVILA, 2013; QUEIROZ et al., 2010). The superior quality of water resources is reflected in other characteristics of the aquatic environment. Leaching nutrients and herbicide concentrations can be a problem with increased volume of water in the drainage system and decreases with drought, suggesting the need to adopt fertilizer management practices for reducing or minimizing it (HERMOSÍN et al., 2013; RASIAH, ARMOUR, 2013; ANDRADE et al., 2007).

Exploratory multivariate analysis is a technique that analyzes interrelated multiple variables, projecting the original relevant information into two-dimensional planes. Multivariate analysis of water quality parameters specifies the regions that affected the most the quality of water resources (SONG et al., 2011), water quality characterization (ENTRY, 2012), and where water deterioration occurred due to agricultural activities (COLETTI et al., 2010), thus, contributing to the monitoring of water and its availability. The likelihood and magnitude of human activities' effects will increase as humans continue to modify the landscape, rendering necessary empirical studies to provide evidence of these transformations and a multidisciplinary understanding of these effects on the natural communities/ecosystems (BLITZER et al., 2012).

Several authors have used multivariate statistics to identify processes, (MORA-LEYVA et al., 2007; HERMOSIN et al., 2013) report that the principal component analysis is very useful in environmental studies for identifying patterns and diffuse contamination sources, where ecological processes that incorporate the main variability of the measurements can be identified by factor analysis technique that allows the association of a set of variables to be explained in terms of a limited number of new variables.

The Prata River, a major tributary of the Sapucai River, supplies water for the urban area of Batatais, São Paulo State, Brazil. This tributary belongs to the Paraná River basin, which, after joining the Paraguay River empties into the Atlantic Ocean, at the border of Uruguay and Argentina (ZANATA e PISSARRA, 2012). The soil uses were defined by the aggressive exploitation of natural resources during the agricultural expansion of São Paulo State (ZANATA, 2009), and soil use intensification transformed the landscape into a mosaic of native areas and those submitted to human interventions (SUGIHARA et al., 2012).

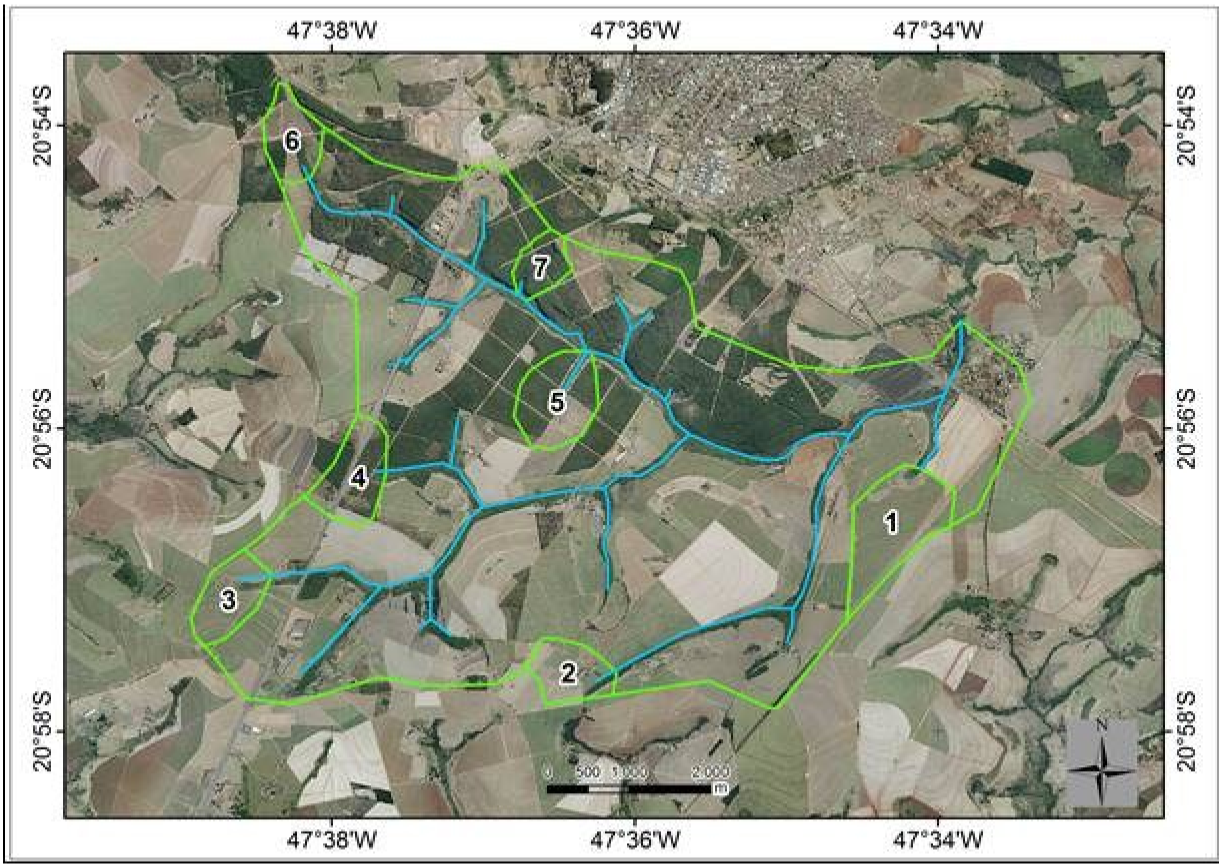
The objective of this work was to determine the environmental changes caused by soil uses, evaluating water physical and chemical characteristics from the drainage network in watersheds.

## 4 MATERIALS AND METHODS

The Prata watershed is located between 20°53'35" and 20°57'54" S and 47°31'45" and 47°33'21" W, and 880 m average altitude, in Batatais, São Paulo State, Brazil (ZANATA, 2009). According to the Köppen Climate Classification system, simplified and used for São Paulo State (CEPAGRI, 2012), the study area is classified as warm subtropical with dry winters (Cwa). Average temperature is higher than 22ºC in the hottest rainy month and below 18ºC in the cold and dry winter. The average annual rainfall in the region is between 1,100 and 1,700 mm.

The watersheds with first order streams were selected according to their strategic importance for water supply and distribution in the study area. Figure 1 shows a satellite image obtained by Google Earth®. The uses of soil define two groups of watersheds: the ones predominately planted with sugarcane (1, 2 and 3) and the ones reforested with *Pinus* (4, 5 and 7), and a watershed 6, that is mainly occupied with native vegetation.

**Figure 1.** Watersheds with first order streams (1 to 7) in Prata watershed, Batatais, SP, Brazil. Available in: <www.googleearth.com.br>. Accessed on: November, 20, 2012. No scale.




In each watershed, surface water was sampled at five different points (repetitions) from the headwaters near the headwaters, monthly for one year. On-site observations of agricultural activity, fauna, flora and aspects related to watercourses were recorded during each sampling. The measurements of temperature (T), pH, electrical conductivity (EC) and total dissolved solids (TDS) were analyzed at the headwaters, calibrated during the first measurements of each collection, and the headwaters waters were collected in plastic container (500 ml) for the determination of turbidity (t) and dissolved oxygen (DO) in the laboratory, according to APHA (2005).

The factors are extracted using the principal components method, and it is a linear combination of the original variables that aggregates the largest possible variation contained in the samples. The second factor is the second linear function of the original variables, containing the remaining variability, and so on. The factors are independent of each other, dimensionless and standardized variables (normal distribution, mean=0, variance=1). The coefficients of the linear functions define the factors that serve and interpret their meaning, using the sign and the relative value of the coefficients as an indication of the weight of each variable. The effect of physicochemical variables of watershed water, sampling monthly, and their interaction were tested using analysis of variance (ANOVA), the factors were tested by the general linear model (GLM) and the Fisher test at 5% significance ($p<0.05$). The Eigenvalues (F1 and F2) resulting from the factor analysis, and the Fischer test results ($\alpha$ = 5%) the better of the Prata watershed, for the surface water variables.

## 5 RESULTS AND DISCUSSION

Table 1 presents the results of the factor analysis performed on the water quality data, along with their respective ANOVA and the mean of multiple comparisons test.

The first two factors accounted for 65.09% of the variability contained in the original variables. The greatest variation possible in the sample is aggregated by the first factor (45.73%), with higher weight for TDS, EC and pH variables, evidenced in the watershed 3 (sugarcane), in the months of February and March. The second greatest variation is aggregated by the second factor (19.36%), with higher weight for DO, T and t variables, evidenced in the watershed 4 (*Pinus*), in the same months of February and March.

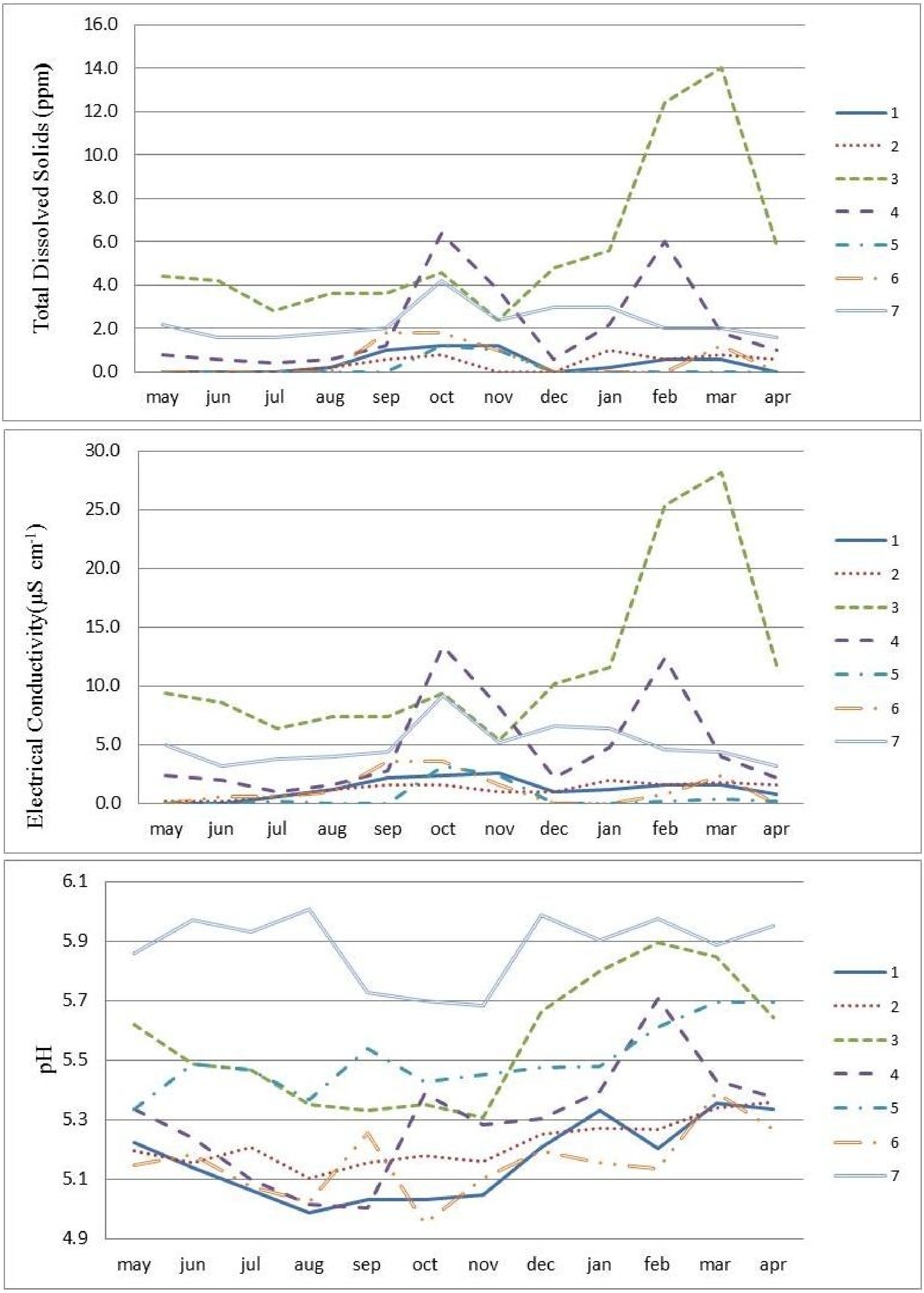
The ANOVA of the model (watershed, Month, and watershed*Month) of the process explained the F1 (Table 1) indicating a significant effects in watershed, but no time (month) or interaction effect. F1 factor shows a positive correlation of a group of variables (TDS, EC and pH), which indicate that the higher the ionic concentration (TDS=0.95) cause more ability to conduct electrical current (EC=0.95) for water at the collected point, and the higher the pH of the headwaters surface water (pH=0.73), corresponding also researches of Bu et al. (2014) e Queiroz et al. (2010). February and March are noteworthy for the highest changes in TDS and EC (Figure 2). Therefore, it appears that the anthropogenic activities during the rainy months of the summer season (October to March) may have altered the TDS and EC values of the water of the three watershed planted with sugarcane (Table 1 and Figure 2), through agricultural inputs (lime, fertilizers and pesticides), similar to Hermosín et al. (2013) e Pinto, Mello e Ávila, 2013. According Sabará (1999), in the rainy season the electrical conductivity and alkalinity were higher in streams in agricultural areas, probably due to the increased concentration of basic cations in the water for agricultural streams and input of organic acids in forest streams, due to rain. Thus, as a result of components input (TDS) in the watershed system, there was an increase of EC at the three sampling point in the watershed. In the summer period, the pH also rises in the three point in watershed (Figure 2), showing that runoff during the rainy season introduced particles that increase alkalinity and reduce acidity of headwaters surface water.

**Table 1.** Surface water variables at the Prata watershed, Batatais-SP.

| Factors | F1 | F2 |
|---|---|---|
| T | 0.02 | 0.63 |
| pH | 0.73 | 0.07 |
| EC | 0.95 | 0.11 |
| TDS | 0.95 | 0.11 |
| DO | -0.13 | -0.82 |
| T | 0.35 | 0.56 |
| Eigenvalues | 2.74 | 1.16 |
| % | 45.73 | 19.36 |
| Factor Interpretation (Processes) | Solids runoff (ionic particles) with increasing pH and EC | Seasonality, periods of drought and cold, versus heat and rain |
| Analysis of variance [a] | | |
| Watershed | *** | *** |
| Month | Ns | *** |
| Watershed * Month | ns | *** |
| Watershed averages [b] | | |
| 1 | ____e | ab_ |
| 2 | ___de | _b_ |
| 3 | a____ | ab_ |
| 4 | __c__ | a__ |
| 5 | __cd_ | __c |
| 6 | ___de | __c |
| 7 | _b___ | ab_ |
| Monthly Averages [b] | | |
| January | ab | ab____ |
| February | a_ | a_____ |
| March | a_ | a_____ |
| April | ab | ab____ |
| May | ab | ____e_ |
| June | _b | ___d__ |
| July | ab | _____f |
| August | _b | ___d__ |
| September | _b | _bc___ |
| October | ab | ab____ |
| November | _b | __c___ |
| December | _b | __c___ |

[a] Significance levels: *$P$=0.05, **$P$=0.01, ***$P$=0.001 and ns=not significant. [b] Multiple comparisons averages: values of the letters in the columns are non-significant at 5%, where a>b>. . .

**Figure 2.** Surface water variables of the Prata watershed, Batatais-SP, over time (months) for the first factor (F1 = runoff).



This can be due to the agricultural practices as related by Entry (2012) e Colleti et al. (2010). EC and TDS values in the four watershed follow the same pattern in February, showing that runoff also affects headwaters waters of this watershed, which is reforested with *Pinus*. The high value observed in October (Figure 2) is due to the dry season peak, when little water was present during data collection. The same pH increase in the hot, rainy summer occurs at the four watershed (Figure 2).

The ANOVA of the model of the process explained by F2 factor (Table 1) indicates a significant effect in watershed, month, and their interaction. F2 factor shows a negative correlation between dissolved oxygen (DO=-0.82) and a group of variables (T=0.63, t=0.56) indicating that the higher the T and t values, the lower the DO concentration in the water. The second factor has a significant cross effect, the temperature graph separates the collected year in two seasons; the hot and rainy summer (October to March) and the cold and dry winter (April to September), showing the seasonality of the data (Figure 3). Fisher test for F2 factor (T, t and DO) highlights the four watersheds, which is reforested with *Pinus*. In the dry and cold winter (lower TºC) the oxygen remains, but in the rainy and warm summer (higher T) DO rates decrease (Figure 3), showing these variables to be inversely related. Seven watersheds stand out in October (Figure 3) because of the highest turbidity and lowest DO values, probably due to water shortage at the sampling points. Four watersheds showed similarly, but with lower values. The highest T value for three watersheds occurs in February and the lowest DO value in March (Figure 3), the same time of water change of the F1 factor (rainy season). The multivariate analyses related the environmental condition as runoff and seasonality, in according with research done by Mora-Levya et al. (2007) and Hermosin et al. (2013).

Cicco e Arcova (1999) evaluated the factors that influence water quality in watersheds with Atlantic forest, livestock and agriculture, and concluded that the watersheds with agriculture had turbidity values higher than those recorded in the forested watersheds. According Sperling (1996), the water temperature can affect the delay or acceleration of the biological activity in oxygen absorption and precipitation of the compounds.

The chart of the averages for the different uses, sugarcane, *Pinus* and native vegetation (Figures 4 and 5), shows differences between watersheds with different soil uses. The mean T value for watersheds with sugarcane is superior to other uses (Figure 5), and presents the highest TDS and EC values in February and March (Figure 4). Reforestation with *Pinus* has (on average) the highest pH values of headwaters surface water (Figure 4), followed by watersheds occupied with sugarcane and native vegetation. The average of the variable t for watersheds with *Pinus* is higher in October (Figure 5), just like TDS and EC (Figure 4). The control (native vegetation) has the lowest pH (more acidic water) and T (colder water) with TDS, EC and t peaking in September (Figures 4 and 5). Also was observed, like Guzman et al. (2012) and Ng Kee Kwong et al. (2002), that a service road facilitated rainwater runoff from an area with sugarcane towards the area headwaters of three watershed, a saturated and unprotected riparian area, where the transported inputs altered the water of the drainage network. The electrical conductivity of the water may change due to the input of fertilizers and pesticides that end up increasing the ionic concentrations of watercourses and causing ionic imbalance (QUEIROZ et al., 2010).

**Figure 3.** Surface water variables of the Prata watershed, Batatais-SP, over time (months) for the second factor (F2 = seasonality).

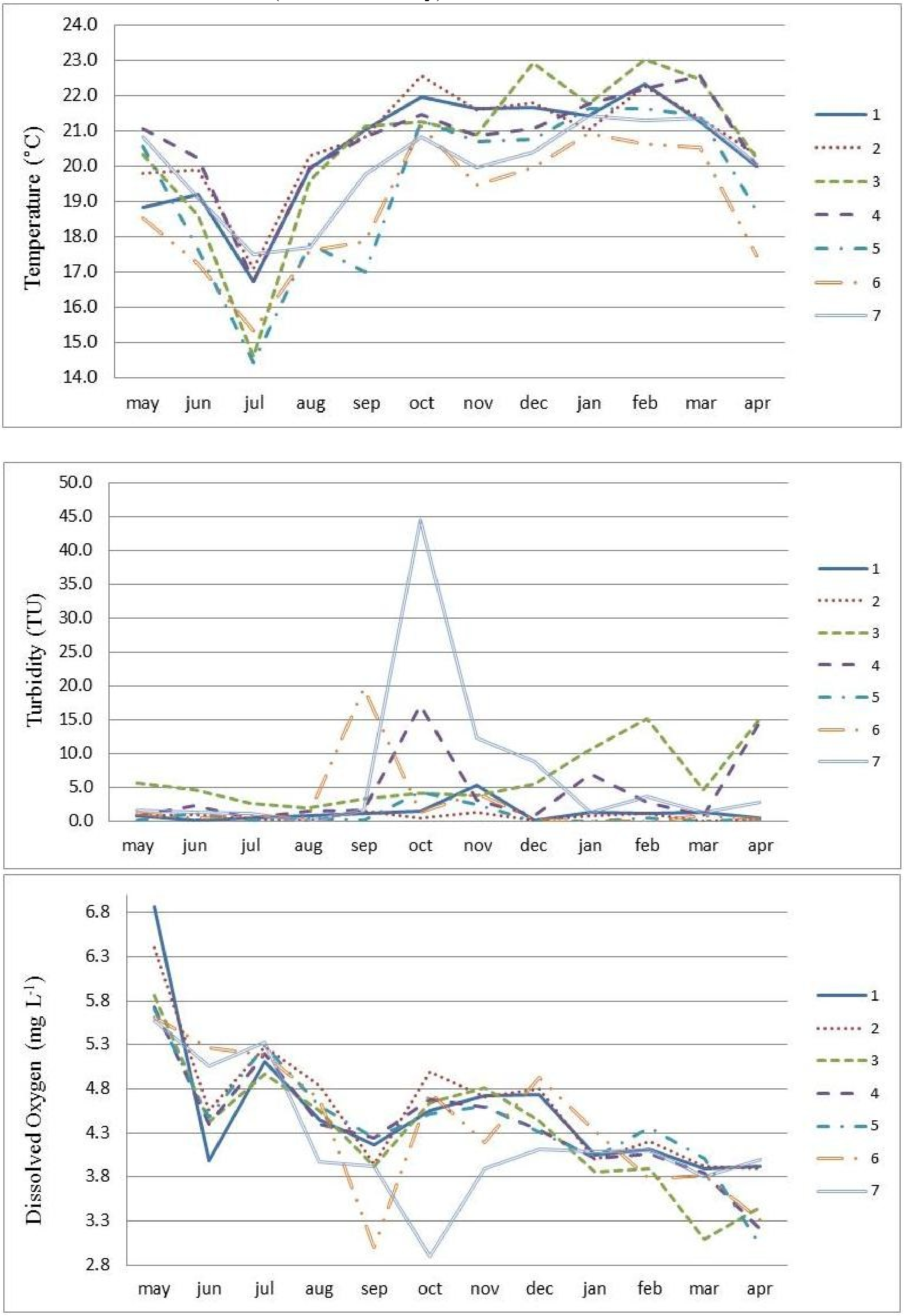


**Figure 4.** Plots of the observed data for each application and the control, for each variable and over time (months) for the first factor (F1 = runoff).

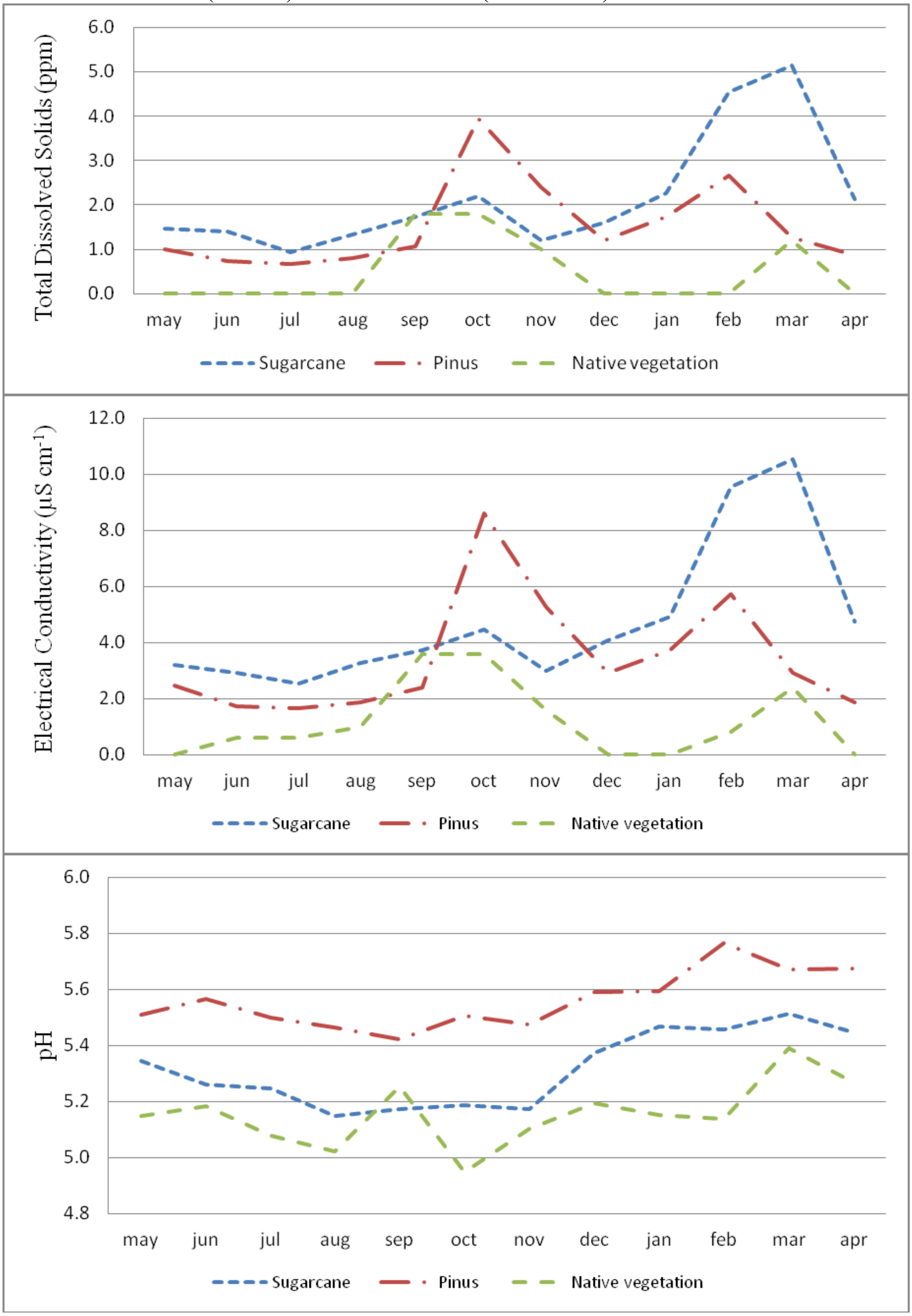
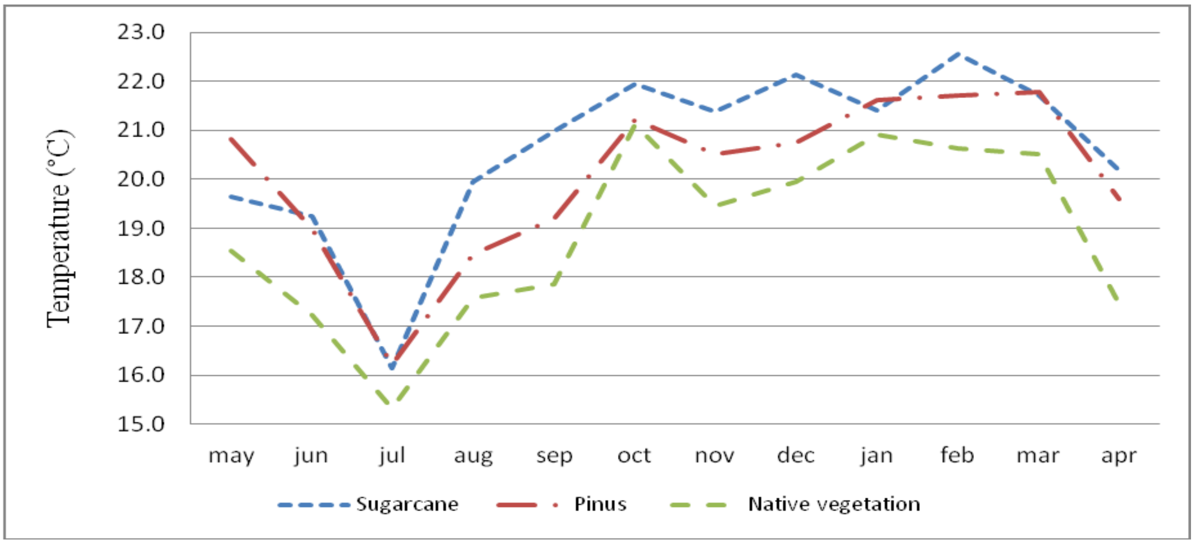
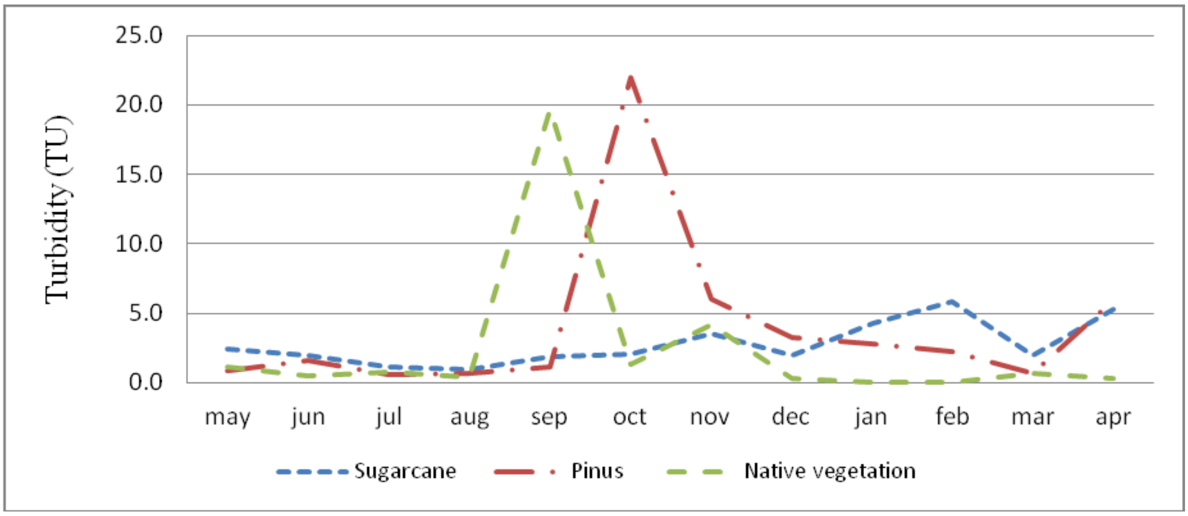
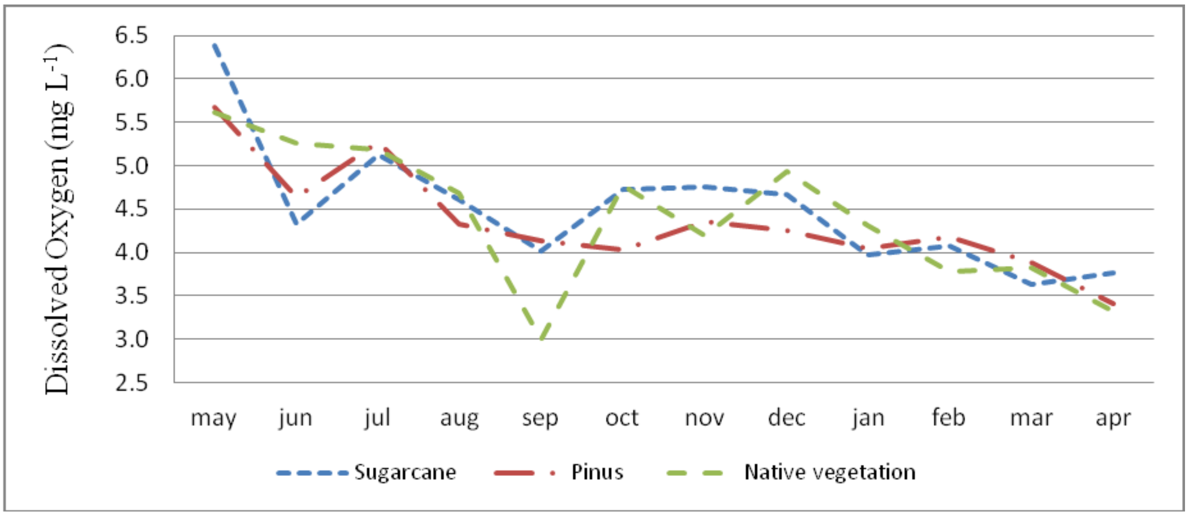


**Figure 5.** Plots of the observed data for each application and the control, for each variable and over time (months) for the second factor (F2 = seasonality).



A watershed is an open system, since the flow of matter and energy is dynamic and highly dependent on soil management. In the areas of deployment of production systems, management practices are directly related to the quality of water resources. Thus, the impact of agricultural practices on ecosystems is a consequence of the discrepancies between management and soil and water conservation. Donadio, Galbiatti e Paula (2005), Pinto, Mello e Ávila (2013) found that the presence of remnant riparian vegetation assists in protecting these water resources, something that is not verified here, at the headwaters of three watershed (sugarcane). The adoption of agricultural management practices (Masters et al., 2013), which minimize herbicide transport as the rain flows, is a priority for the Australian sugarcane industry, especially in the coastal basins that drain into the world heritage site of the great barrier reef.

## 6 CONCLUSIONS

The physicochemical characteristics of the drainage network water show a change of the environmental system, which is caused by different soil uses of watershed, depending on management type and presence of riparian vegetation. Factor analysis indicated a correlation between water physicochemical parameters, the importance of runoff and water erosion processes, and how seasonality reflects throughout the year, thus demonstrating that the environmental system changed due to soil uses of the studied watersheds.

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