ISSN 1808-3765

WATER SALINITY USED FOR IRRIGATION IN THE MARINS STREAM WATERSHED, BRAZIL

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1 ABSTRACT

Water quality is vital to human activities and irrigation is an activity that uses an accentuated volume of this natural resource. An alternative is the use of water with a salinity level that does not cause damage to plants and the environment. This study aimed to assess the salinity of water used for irrigation of vegetables in Ribeirão dos Marins watershed. The water electrical conductivity, Sodium Adsorption Ratio (SAR) and the Exchangeable Sodium Percentage were obtained using the AquaChem program. Water samples used were collected in 2005, and chemical and physical parameters were assessed. Results showed that region three presented risk to salinization, but overall it is possible to conclude that salinity of the water basin has low risk of salinity.

Keywords: soil, water quality, vegetables

LUCAS, A.A.T.; FOLEGATTI, M.V.; DUARTE, S.N.; LUCAS, S.C. de O. SALINIDADE DA ÁGUA USADA PARA IRRIGAÇÃO NA BACIA HIDROGRÁFICA DO RIBEIRÃO DOS MARINS, BRASIL

2 RESUMO

A qualidade da água é vital para as atividades humanas e a irrigação é uma atividade que utiliza um volume acentuado deste recurso natural. Uma alternativa é a utilização de águas salobras, mas com um nível de salinidade que não cause danos às plantas e ao ambiente. Este estudo teve como objetivo avaliar a salinidade da água utilizada para irrigação de hortaliças na bacia do córrego Marins. A condutividade elétrica da água, a Razão de Adsorção de Sódio (RAS) e a porcentagem de sódio trocável foram obtidos usando o programa AquaChem. As amostras de água utilizadas foram coletadas em 2005, quando foram avaliados os parâmetros químicos e físicos. Os resultados mostraram que em apenas uma região existe risco de salinização; mas no geral, é possível concluir que a salinidade da água da bacia é de baixo risco.

Palavras-chave: solo, qualidade da água, hortaliças

Recebido em 11/06/2013 e aprovado para publicação em 12/01/2016

3 INTRODUCTION

The water is one of the most important natural resources to maintain ecosystems. However, with the increase of demand in relation to availability it is possible to observe large water quality degradation. On the other hand, the concerning with the environmental preservation, especially with the aquatic ecosystems raises among the society water users sectors. The sector that causes more concerning to society is the agricultural sectors, throughout water using in irrigated agricultural to produce food (LUCAS, 2007).

This scenario has been led searching to solve the water consumption problem by human activities. The irrigation has been contributed to the salinity of water use to produce vegetables. Several authors have been studying the effect of irrigation water quality or the use of the salinity water in soil and crops, as Souto et al. (2015), Santos et al. (2014), Silva et al. (2014), Sousa et al. (2014), Gomes et al. (2011) and Amorim et al. (2010).

Brazilian conditions present in some places, especially in semiarid region, problems with soil salinization. However, Marins stream watershed, tributary of the Piracicaba River Basin, although is not located in a semiarid region, belongs to São Paulo State, the most developed economy, industrial and agricultural area of the country (FERRAZ, MARTINELLI, VICTÓRIA, 2001).

This area of the São Paulo State is characterized by the non-uniform soil occupation with the major population concentrated in urban center. The economic activities are heterogeneity dominated by agriculture and industry. Marins stream watershed is a typical example of this pattern of soil use. The economic activities are related with agriculture, especially sugar cane, vegetables crops, cattle for milk and meat, lamb, goat and horses (AGRICULTURE AND SUPPLY AGENCY - SEMA, 2003) and one of the most important environment problems is related to the water quantity and quality, because the Piracicaba River basin is one of the most degraded in the country.

According to the SEMA (2003) vegetable producers use water for irrigation from Marins stream and tributaries in their crops, which includes 58% of the producers. When are included producers that use water from reservoir or lakes the percentage increase to 88.2. It is important to report that many producers use more than one water source for irrigation. Based in the water sources for irrigation it is easy to note high potential to vegetable yield contamination of a considerably part of gardens (CASAGRANDE, 2005).

The irrigation water quality can vary significantly according to the type and amount of dissolved salts. Usually, the salts are found in relatively small quantities, but significant, and have their origin in the dissolution of rocks weathering and soils, including the slow dissolution of limestone, gypsum and other minerals. In addition to being carried by the irrigation water and deposited in the soil, where they accumulate as the water evaporates or is consumed by cultures (AYERS e WESTCOT, 1999). The total concentration of salts from irrigation water can be expressed in relation to its electrical conductivity (BERNARDO, 1995). The main parameters considered important for irrigation are Na, Ca, Mg, Fe, Cl contents, EC_w, and pH value

Lucas et al. (2010) working at the Marins stream watershed report that water quality used for irrigation did not meet the requirements presented by Brazilian Agency, which establishes standards to water quality used to vegetables irrigation. The authors observed that iron, nitrate and phosphorus were above the established limit.

However, the damage that the water quality used for irrigation in the Marins stream watershed related to soil salinization was not presented yet. So, the objective of this work was to evaluate the water quality used for irrigation in Marins stream watershed according to the salinity damage.

4 MATERIAL AND METHODS

4.1 the study area

The Marins stream watershed (Figure 1) is entirely located in Piracicaba district between UTM coordinates 7,471,450 m and 7,486,995 m N and 218,044 m and 225,545 m E, zone 23, with an area of 5,844 hectares.

The climate is mesotermic, in other words humid subtropical, the winter is dry with the dryer month less than 30 mm of rain and the hotter month with temperature higher than 22º C, while the colder month is above 18º C. Annual average precipitation is about 1300 mm, concentrated during the summer. In geomorphological terms, the watershed is located in sedimentary terrains that form the Peripheral Depression of São Paulo State.

The intensive agricultural production in the watershed has caused environmental damage, as well as the presence of a landfill that served to the community of Piracicaba, worsening the situation of water resources in the watershed.

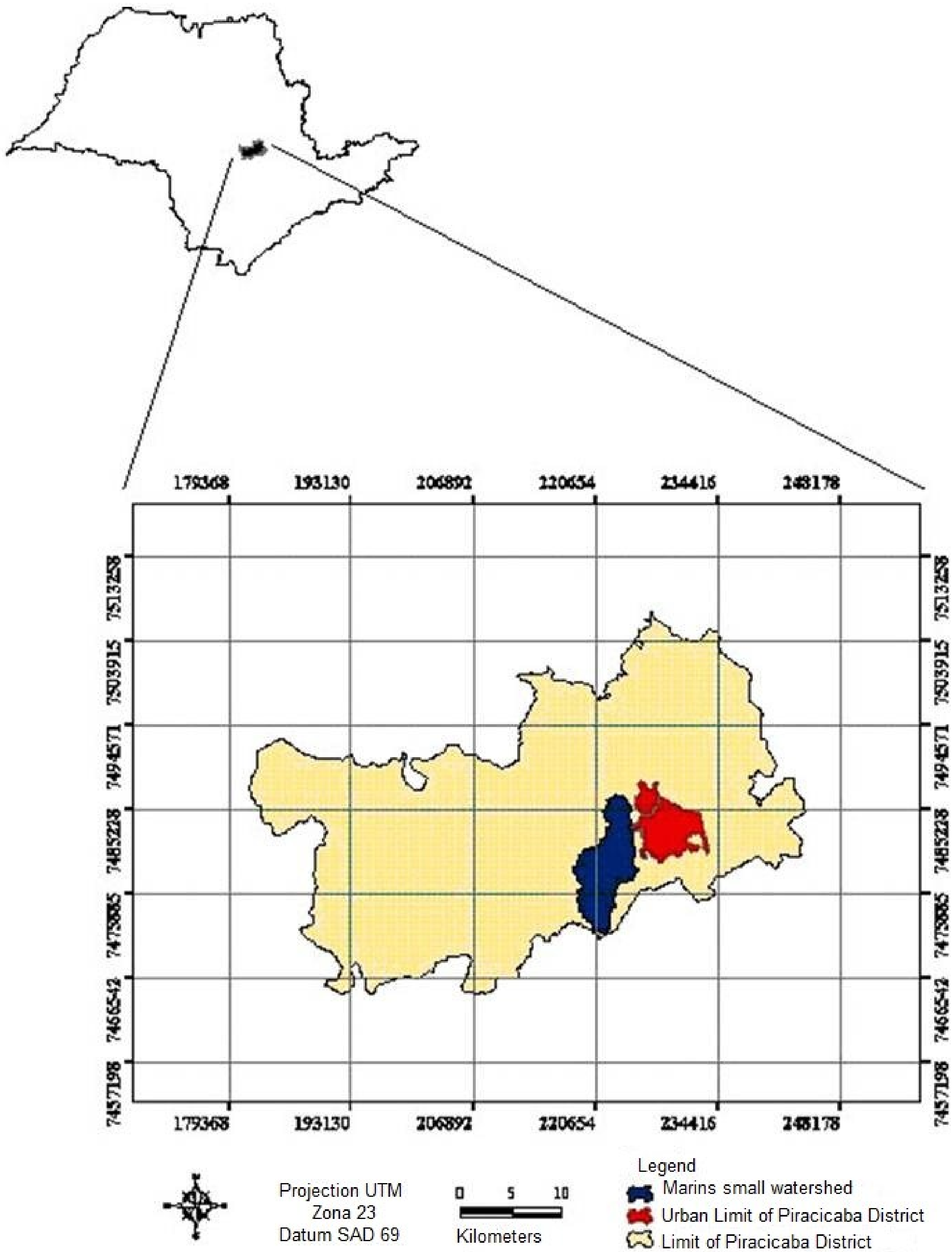
The Table 1 shows values relative to the drainage network and dimensional properties of the watershed described by Casagrande (2005).

Table 1. Dimensional properties of Marins small watershed.

Dimensional Properties	Dimension
Perimeter	43.3 km
Drainage area	58.4 km^2
Longer length	15.4 km
largest width	7.4 km
Length of the main channel	22.3 km
Length of the drainage network	188.1 km
Drainage density	3.20 $km.km^{-2}$

Source: Casagrande (2005)

Figure1. Marins small watershed location in State of São Paulo – Brazil.



Source: Casagrande (2005)

The Figure 2 presents the drainage network localization and the locals where water samples were collected to analyze, during the period from February to December of 2005. Points sampling were selected according to the tributaries of Marins stream and the localization of properties that produce vegetables, beside others soil uses and occupations of house field, landfill, potteries and access facilities.

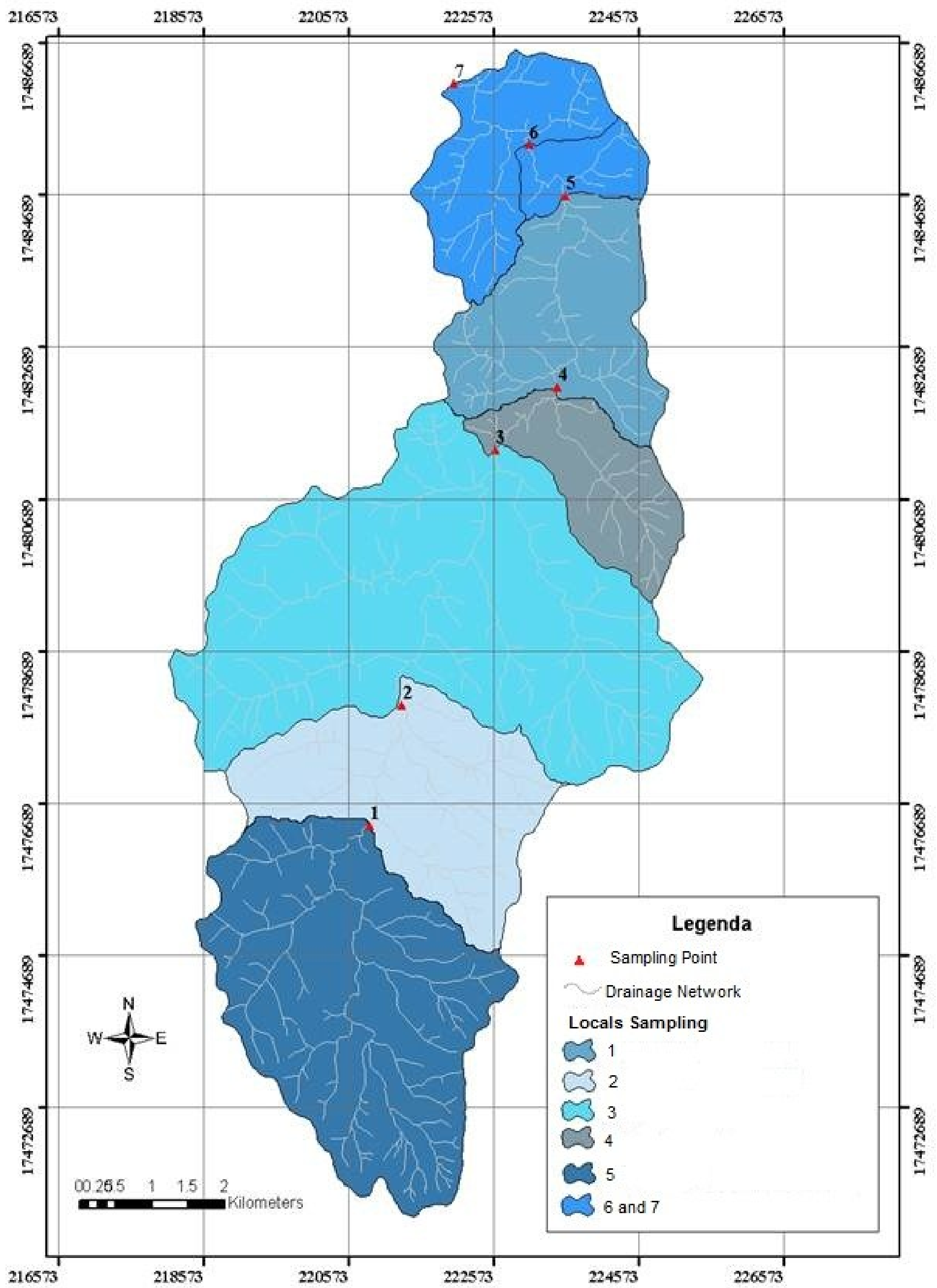
Water samples obtained in these places were submitted to analysis of chemical and physical parameters and then were used in AquaChem (CALMBACH, 1997) software, which both numerical model and graphical geochemistry data set are in aqueous medium. Thereby, electric conductivity results were extracted. Sodium Adsorption Ratio (SAR) and the Exchangeable Sodium Rate (ESR) results were also obtained by AquaChem (CALMBACH, 1997) which uses the following equations (1 and 2). The results were submitted to Tukey test (p>0.05) statistical analysis.

$$SAR = \frac{Na^{+}}{\left(\frac{Ca^{2+} + Mg^{2+}}{2}\right)^{\frac{1}{2}}} \tag{1}$$

$$ESR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}} \tag{2}$$

Where:
Na^{+} - Sodium concentration, $mmol_c\ L^{-1}$;
Ca^{2+} - Calcium concentration, $mmol_c\ L^{-1}$; and
Mg^{2+} - Magnesium concentration, $mmol_c\ L^{-1}$.

Figure 2. Map of drainage network Marins stream watershed and sampling point locations.



Source: Lucas (2007)

5 RESULTS AND DISCUSSION

5.1 irrigation water quality

The sample points exhibited values compatible for use in irrigated agriculture, but the maximum electrical conductivity, according to the classification found in Ayers e Westcot (1999), showed a light degree use restriction. The problems caused by poor water quality used for irrigation are damaging equipment performance, as well as damaging to plants and the environment, such as nutrient availability or/and increasing the concentration of salts in the rooting zone (BELIZÁRIO et al., 2014; MUNIZ, 2014; SILVA el al, 2013).

In general locals one (P1) and two (P2) presented the lowers values, which local sampling belonging to upper Marins watershed, while locals from three (P3) to seven presented higher values because they suffer influence of the use and occupation of the soil (Table 2).

Table 2. Tukey statistical test results of medium values of electric conductive water, ratio of adsorption sodium and exchangeable sodium ratio.

Local Sampling	ECW	Local Sampling	SAR	Local Sampling	ESR
P4	680.7a	P4	2.20a	P4	0.81a
P5	412.0ab	P5	1.79ab	P5	0.76ab
P6	359.5b	P7	1.36bc	P3	0.65abc
P3	356.5b	P3	1.30bc	P7	0.58abc
P7	343.4b	P6	1.28bc	P6	0.54abc
P2	234.8b	P2	0.80c	P2	0.43bc
P1	232.0b	P1	0.69c	P1	0.31c

It appears that the waters of Marins stream watershed classified into C1and C2, with exceptions of section 3 in August and December, have low to medium risk of salinity according to the classification proposed by USDA, presented by Bernardo (1995).

According to the classification of saline waters presented by Ayers e Westcot (1999) the waters of Marins stream watershed used for irrigation were classified as no degree of restriction on use, except Section 3 which showed mild to moderate degree of restriction use during the months from June to August, the dry season, and November and December, the wet season. This highlights the care that must be observed indifferent of the classification and guidelines for water quality, both for use in irrigation and for other uses. On the other hand, because of the sub-humid climate and the fact that the soil conditions vary from one place to another, these imply that limits should be established based under Brazilian conditions.

Table 3. Values of electric conductivity, sodium adsorption ratio, sodium risk, classification of water and risk of salinization of the soil (AYERS e WESTCOT, 1999).

Local sampling	ECw □S.cm^{-1}	SAR	ESR	Classification	Risk of salinization	Guideline	Local sampling	ECw □S.cm^{-1}	SAR	ESR	Classification	Risk of salinization	Guidelines
P1							P3						
1	230	0.84	0.39	C1	low	none	1	330	1.23	0.56	C2	medium	none
2	170	0.49	0.27	C1	low	none	2	280	1.09	0.55	C2	medium	none
3	170	1.39	0.65	C1	low	none	3	310	1.34	0.62	C2	medium	none
4	190	0.65	0.32	C1	low	none	4	650	2.43	0.95	C2	medium	none
5	180	0.64	0.30	C1	low	none	5	750	3.52	1.19	Limit C2 – C3	medium/high	slight /moderate
6	170	0.76	0.39	C1	low	none	6	740	4.28	1.65	C2	medium	slight /moderate
7	384	0.42	0.13	C2	medium	none	7	1859	1.83	0.50	C3	high	slight /moderate
8	285	0.42	0.13	C2	medium	none	8	558	1.82	0.50	C2	medium	none
9	254	0.56	0.23	C2	medium	none	9	216	2.30	0.79	C1	low	none
10	287	0.73	0.40	C2	medium	none	10	1114	2.82	1.19	C3	high	slight/moderate
11	249	1.14	0.80	C1	low	none	11	1543			C3	high	slight /moderate

P2							P4						
1	250	0.76	0.35	Limit	low/medium	none	1	600	2.68	1.10	C2	medium	none
2	190	1.26	1.13	C1 – C2	low	none	2	590	2.56	1.13	C2	medium	none
3	220	1.08	0.51	C1	low	none	3	500	3.40	1.38	C2	medium	none
4	250	0.69	0.31	C1	low/medium	none	4	330	1.17	0.55	C2	medium	none
5	190	0.64	0.29	Limit	low	none	5	320	1.51	0.65	C2	medium	none
6	170	0.77	0.38	C1 – C2	low	none	6	290	1.33	0.60	C2	medium	none
7	339	0.66	0.28	C1	medium	none	7	517	1.11	0.44	C2	medium	none
8	257	0.65	0.28	C1	medium	none	8	368	1.11	0.44	C2	medium	none
9	221	0.70	0.32	C2	low	none	9	242	1.28	0.58	C1	medium	none
10	261	0.81	0.42	C2	medium	none	10	363	1.50	0.80	C2	medium	none
11	253	4.80	2.24	C1	medium	none	11	267			C2	medium	none
				C2									
				C2									

P5							P6						
1	350	1.26	0.52	C2	medium	none	1	350	1.18	0.49	C2	medium	none
2	330	1.30	0.68	C2	medium	none	2	310	1.04	0.49	C2	medium	none
3	340	1.30	0.57	C2	medium	none	3	350	1.63	0.71	C2	medium	none
4	370	1.16	0.49	C2	medium	none	4	360	1.33	0.57	C2	medium	none
5	320	1.58	0.69	C2	medium	none	5	320	1.18	0.51	C2	medium	none
6	330	1.42	0.67	C2	medium	none	6	320	1.50	0.68	C2	medium	none
7	516	1.18	0.44	C2	medium	none	7	539	1.19	0.43	C2	medium	none
8	395	1.18	0.44	C2	medium	none	8	437	1.19	0.43	C2	medium	none
9	222	1.31	1.31	C1	low	none	9	220	1.31	0.52	C1	low	none
10	392	1.44	1.44	C2	medium	none	10	389	1.51	0.69	C2	medium	none
11	272	0.44	0.10	C2	medium	none	11	283			C2	medium	none

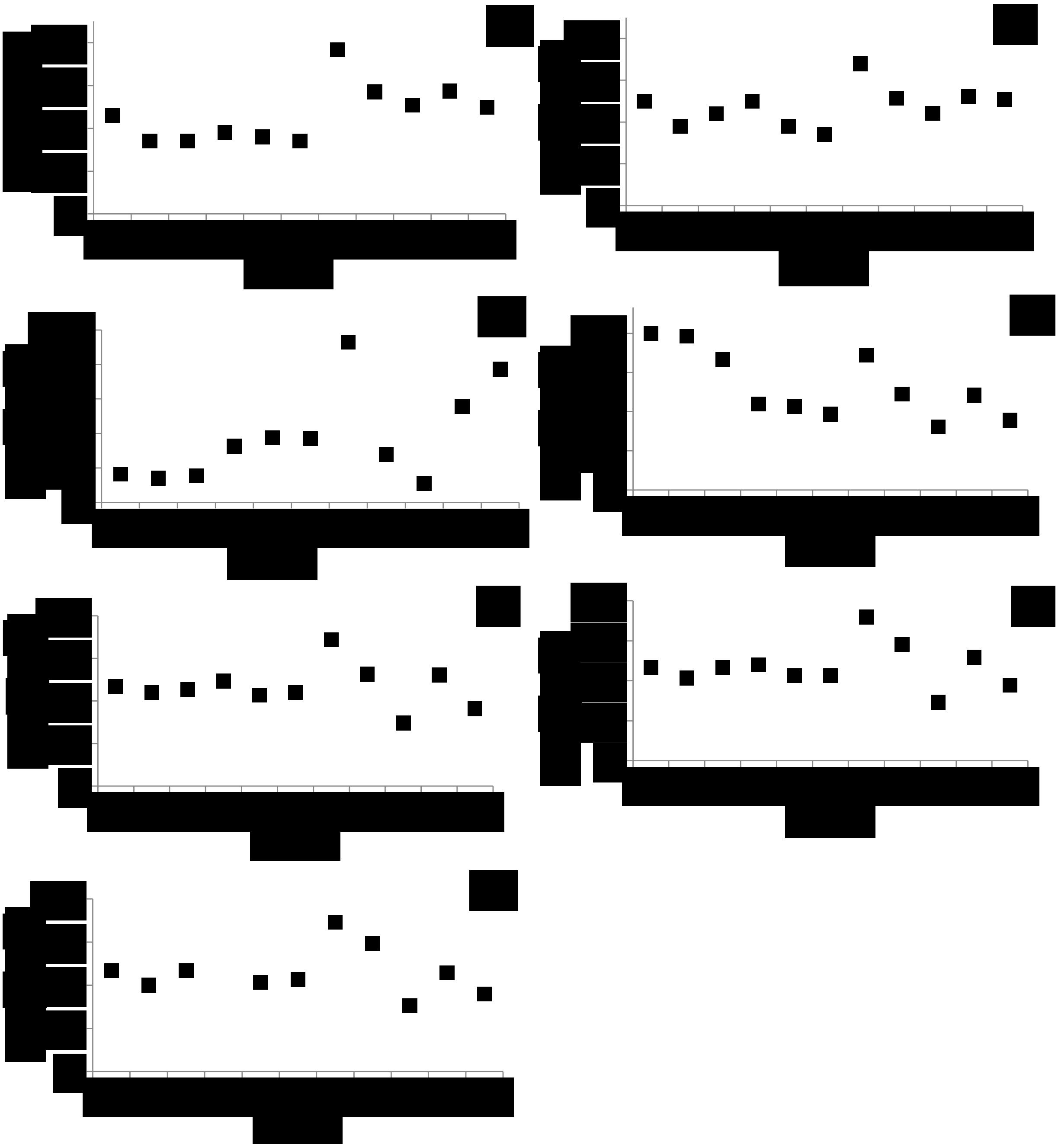
Local sampling	ECw □S.cm^{-1}	SAR	ESR	Classification	Risk of salinization	Guideline
P7						
1	350	1.22	0.50	C2	medium	none
2	300	0.75	0.36	C2	medium	none
3	350	1.90	0.80	C2	medium	none
4	310	1.61	0.71	C2	medium	none
5	320	1.39	0.63	C2	medium	none
6	519	1.24	0.47	C2	medium	none
7	444	1.24	0.47	C2	medium	none
8	229	1.31	0.52	C1	low	none
9	343	1.54	0.72	C2	medium	none
10	269			C2	medium	none

In Figure 3 it can be seen the variation of electrical conductivity, from point 1 to point 7, throughout the period from February to December of 2005. The point 3 showed high values in August and December, ranking in Class 3 water (USDA classification), indicating that the concentration of salts in water used for irrigation has potential for soil salinization in the absence of an appropriate irrigation management and lack of periodic monitoring. However, to correct interpretation of water quality for irrigation from the analyzed parameters should be related to its effects on soil, crop and irrigation management (BERNARDO, 1995). On the other hand, in small farms, there is no irrigation management and less concern about the quality of water used to irrigate crops and the effects that it causes to the environment. Although the annual precipitation in the Piracicaba region cooperates to the not occurrence of salts accumulation in the watershed soil, except when the cultivation is carried out in a protected environment, some cases in properties that the watershed can occur.

Second Richards (1954) a water classified as quality C2 (salinity between 250 and 750 □.cm^{-1}) can be used whenever the soil has a moderate degree of drainage; while a water Class C3 (salinity between 750 and 2250 □.cm^{-1}) cannot be used in soils with deficient drainage.

Marins stream watershed irrigation is used to produce the following vegetables: beets, carrots, chives, parsley, lettuce, endive, cabbage, cauliflower, radish, okra, chicory, arugula, cabbage, and other vegetables, which have different levels of tolerance to salt concentration. Thus, according to the table of crop tolerance shown by Ayers e Westcot (1999), the vegetables growth in Marins stream watershed has moderately tolerance: beets and zucchini; moderately sensitive: lettuce, eggplant, broccoli, cabbage, cauliflower, radish, cabbage and sensitive: carrot. Therefore, it is important to verify the use of irrigation water and producers should do the section of the vegetable varieties.

Figure 3. Variation of the electric conductivity in Marins stream watershed from point 1 to point 7 along one year.



Vanzela (2004) studied the water quality for irrigation in the Three Bars watershed in Marinópolis district, São Paulo State, and found that ECw ranged from 89.0 to 961.0 $\mu S.cm^{-1}$, and in one of sampling point 25% of the samples had values with high risk of salinization according to USDA classification. Brito et al. (2005) noted that the surface sources showed no risk of salinization in the river basin Salitre, Bahia State, with only 35% of the samples being classified as C3 and C4. However, 75 and 78% of the samples of groundwater salinization presented serious risks of being classified as C3 and C4.

A comparison for the values found in the Marins watershed is difficult, because the spatial variability among basins is great and there are differences in the climate and in the geology of the regions, factors that influences water quality. There is also scarcity of water quality data for irrigation in the state of São Paulo, only CETESB makes an annual report on the quality of waters of the State.

A diagnostic study of environmental and temporal analysis of the suitability of the use and land cover in Marins stream watershed was conducted by Casagrande (2005). The author concluded based on the survey and analysis of water resources that the basin is being degraded. For him this author, potential sources for contamination of soil, ground water and water bodies were compromising the quality of water used for vegetables irrigation.

6 CONCLUSION

The water quality in Marins stream watershed, considering the salinity problem, represents low risk to soil. However, the results indicate that some care must be taken into consideration, because of the reduction of water quality in the river. Salinization problems may occur especially in the area of point 3. In general, water quality in the basin can still be used to irrigate vegetables, but producers must observe the particular tolerance of cultivated species and make monitoring of water used in irrigation as well as constant chemical and physical soil analysis.

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