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WATER QUALITY FOR SUPPLEMENTARY IRRIGATION IN THE QUEQUÉN SALADO RIVER BASIN (ARGENTINA)

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ABSTRACT

This paper focuses on the study of the water quality in the courses which compose the Quequén Salado river basin, Argentina, in order to determine their suitability for supplementary irrigation. Water samples were analysed to assess their salinity and sodium hazard.

The creeks from the hill sector have Very Good Quality Waters and the water of the middle basin courses can be used to irrigate the main crops in the area. The salinity values obtained in the main river are tolerated only by barley hay and some pastures.

Key words: Supplementary irrigation, water quality, basin, electrical conductivity, SAR.

RESUMEN

El presente trabajo está centrado en el estudio de la calidad de agua de los cursos que integran la cuenca hidrográfica del río Quequén Salado, Argentina, con el objeto de evaluar su empleo para riego suplementario. Se realizaron determinaciones de salinidad y sodicidad en muestras de agua tomadas en distintos tramos de los ríos y arroyos de la cuenca, así como en las lagunas más importantes, durante la primavera y el verano de los años 1998, 1999 y 2000. El estudio se cumplimentó con la caracterización química de los principales cursos. En base a los valores de conductividad eléctrica y RAS obtenidos, se cartografiaron aquellos sectores de la cuenca con calidades de riego similares. De acuerdo a estos resultados se establecieron los tipos de cultivo que podrían regarse teniendo en cuenta el grado de tolerancia de cada uno.

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Las aguas de los arroyos provenientes del sector de sierra son de muy buena calidad, y no presentan restricciones para casi ningún tipo de cultivos. Aunque de menor aptitud, los cursos de la cuenca media permiten el riego de los principales cultivos de la zona como el trigo, maíz, girasol, soja y sorgo, entre otros. El agua del río Quequén Salado presenta valores de salinidad sólo tolerados por la cebada y algunas pasturas. No obstante, no se recomienda su uso por su elevada sodisidad.

Entre los constituyentes secundarios se determinó el contenido de boro, ya que este elemento puede resultar muy tóxico para determinadas especies. No se encontraron concentraciones superiores al límite permisible de 1 mg/ l, pudiéndose mencionar máximos de 0.84 mg/ l en el río Quequén Salado y 0.76 mg/ l en uno de los afluentes principales.

INTRODUCTION

The Quequén Salado river basin is located in the south-east of the Province of Buenos Aires, Argentina (Fig. 1). Since last century this region has played a dominant role in the country's economy due to the great importance of its leading activities, farming and cattle rearing. Two contributing factors are its temperate climate and an annual mean rainfall of about 800 mm. Nevertheless, annual rains are extremely variable, with a maximum of 1330 mm in 1946 and a minimum of 277 mm in 1910.

According to the Thornthwaite & Mather categorization (1957), the climate of the basin oscillates between Dry Subhumid (C1) and Subhumid (C2) (Marini & Piccolo, 2000). Even though rainfalls in these kinds of climates help crops develop, they are sometimes untimely or insufficient to meet their needs at key moments of their growth. This occur because the annual precipitation distribution throughout the year does not always coincide with the crucial moments of development.

During the last decade, 1994 showed a decrease in precipitation which was even sharper in most of the province during 1995 and 1996, presenting values lower than 600 mm. This situation had a negative effect on the sowing and development of fine grain crops, and even coarse grain crops were affected since the process of ploughing was unfeasible. Due to this, supplementary irrigation is being used in some Buenos Aires farmland because of its beneficial effects on field crops and pastures.

According to a survey performed by Báez et al. (1996), this procedure is found in four south-western districts of the Province of Buenos Aires, and three of them are located in the Quequén Salado river basin: Tres Arroyos, Coronel Dorrego and Gonzáles Chaves (Fig. 1). The data gathered revealed that the area under supplementary irrigation is devoted mainly to maize (56%), wheat (26%), soya (13%) and the rest to sunflower and pastures.

However, this survey shows that most of the farmers who employ supplementary irrigation use groundwater. Only 14% have introduced surface waters as supplementary irrigation for field crops using water obtained from some of the different courses of the province. Nevertheless, data about surface water quality has always been very scanty. In the specific case of the Quequén Salado river basin, with exception of intermittent water sampling (Baez et al., 1996; the Dirección Provincial de Hidráulica — Buenos Aires, 1971 and 1976), the quality of surface waters has been largely ignored.

Due to the fact that supplementary irrigation plays an important role at times of drought, this paper aims at determining the quality of surface waters in the Quequén Salado river basin in order to establish their suitability for this practice. Several parameters can be used to determine irrigation water quality. However, the two main measurements to be regarded include salinity and sodium hazard.

METHOD

Water samples were taken at 29 sampling points during the spring and summer (from October to March) of 1998, 1999 and 2000. These seasons were chosen because temperatures are higher than during the rest of the year, and the concentrations of most parameters (e.g. Electrical Conductivity) increase. In addition, this is the period of time when waters are probably used for irrigation, because rain deficiencies occur around November for winter crops (e.g. wheat), and from late November to February for other cultivations (e.g. maize, sunflower and soya).

Before sampling for chemical analyses, 500 ml sample bottles were cleaned by soaking in detergent for 24 hs. All chemical analyses were done at least in duplicate and most samples were analysed within 48 hs. All water samples were analysed by the Instituto Nacional de Tecnología Agropecuaria (INTA), Hilario Ascasubi, Argentina.

The location of the sample sites are given in Fig. 1. Sampling points were selected to reflect water quality changes upstream, midstream and downstream of the major courses. In the minor creeks, just one or two sampling points were enough. Similar assessments were made in some lagoons and in the different kinds of soil in the basin both at surface level and at a depth of 40 cm. Owing to the fact that salinity and SAR parameters depend on rainfalls, samples were taken provided there had been no precipitation on previous days. When classifying the water quality of the different courses, the maximum value found was always considered.

Total Salinity measurements —expressed in terms of Electrical Conductivity (EC)— were taken in creeks and rivers of the basin to determine irrigation water quality. Waters can be classified into different categories depending on their electrical conductivity value. The guidelines for irrigation water quality proposed by James et al. (1982) have been chosen in this research as they include a suitable number of five water categories. This enables a better quality differentiation since other classifications place some water courses with different ECs in the same category. The extreme values fluctuate between Excellent Waters (under 0.25 dS/m) and those Unsuitable for Irrigation (over 3 dS/m).

Sodicity was also measured and expressed as SAR (Sodium Absorption Ratio). As far as sodium hazard is concerned, Hergert & Knudson's four-category classification (1977) was applied to establish the different kinds of irrigation waters according to SAR values. They are ranked from Low Hazard Waters (SAR under 6) to Very High Hazard waters (SAR over 12). Another guideline by the same authors (1977) was chosen to classify the suitability of water for irrigation, relating EC and SAR values. It shows the potential hazard implicated in the use of waters for irrigation depending on the relation between both parameters. Thus, a certain water sample of up to 6 SAR value can be considered suitable, but salinity must be lower than 1.5 dS/m. Final categories are determined according to this kind of relationship.

The distribution of the major ions of water (anions and cations) helps to determine its chemical properties. The Radial Diagram method (Standards Methods, 1992) was chosen because it enables a quick identification of the chemical characterization of samples by simply observing the shape formed. This kind of graph was applied to the three main courses of the basin.

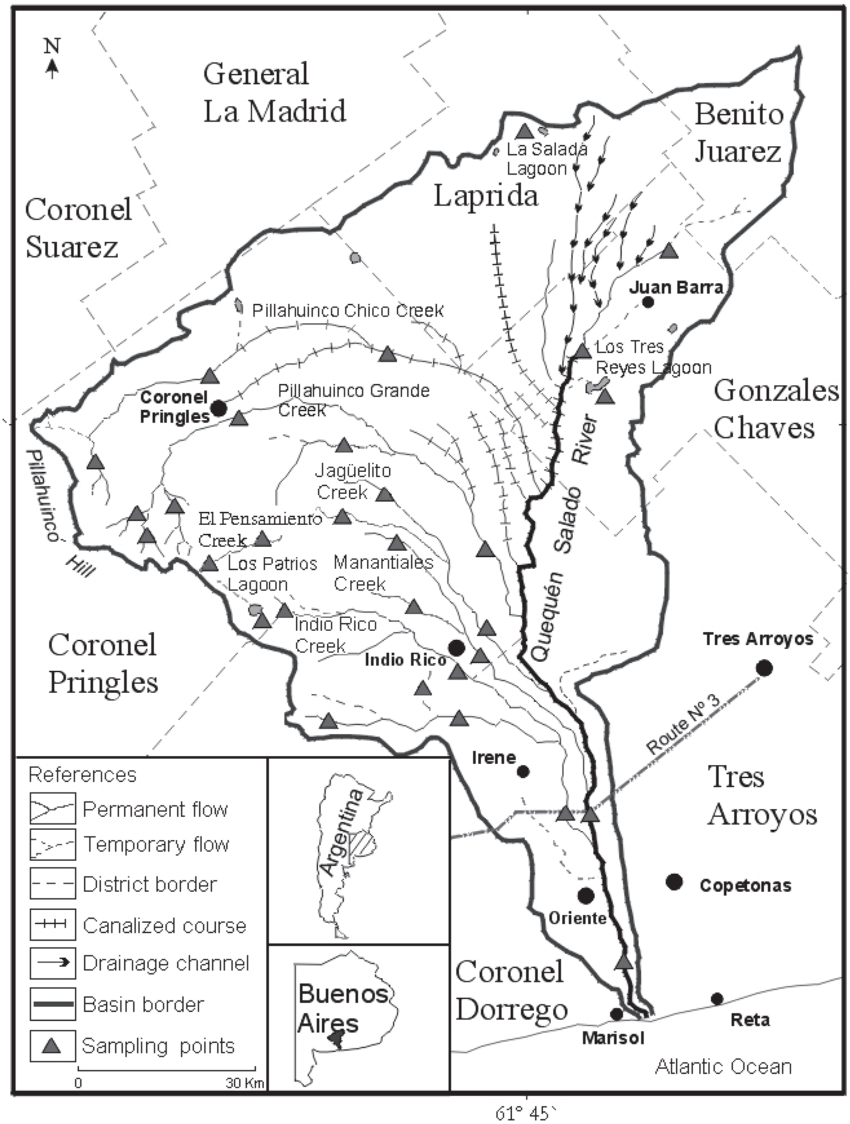

FIGURE 1: Quequén Salado river basin and sampling points.

FEATURES OF THE STUDY AREA

The Quequén Salado river basin is located in the southwest of the Province of Buenos Aires, Argentina, within a region known as the Humid Pampas. Since last century this zone has contributed greatly to the country's economy thanks to its two dominant activities: farming and cattle rearing. Its excellent edaphic characteristics have transformed it into the leading source of agricultural produce for Argentinean export. Two contributory factors are its temperate climate and an annual mean rainfall of 800 mm.

This basin has an area of 9,801 km^2 (Marini, 2002) and shows a predominantly north-southward orientation. The topography corresponds to a plain region flanked at the northwest by the Pillahuincó Hill (Fig. 1), which is the oriental part of the Austral Hills of Buenos Aires The headwaters of the different courses are both on this hill and on a plain area. As a result, the basin is highly heterogeneous featuring sectors with different dynamics. The dominant soil belongs to the M*ollisols* order (INTA, 1994 —similar to *Chernozem* soils—FAO / UNESCO, 1987)

The upper basin courses flow through a wide plain with very flat gradients, ranking from 3.3 to 0.81 per thousand. This leads to serious problems of water circulation which have led to the construction of numerous drainage canals. The majority of the canals flow into the Quequén Salado river down the low slopes of the plain. In addition to the existing flat gradients, there are also very low infiltration indices. The soil in this sector is silty clayey, poorly drained, and is classified as *Argialbol* suborder (INTA, 1994 —similar to *Luvic Phaeozems* soils—FAO / UNESCO, 1987). These factors have contributed to the formation of numerous permanent lagoons, such as La Salada, Los Tres Reyes, Los Patrios, etc. (Fig. 1). The rest of the soils are classified as *Acuic*, suborder *Argiudoll* (*Luvic Phaeozems* soils — FAO / UNESCO, 1987), poorly drained, usually found in plainer areas.

The soil of the sides of the hill known as *Chernozem*, regarded as the optimum soil for agriculture as it is deep, rich in organic matter, retains moisture, and has an ideal crumb structure. Surface drainage is largely controlled by the south-eastward direction of the slopes of the region. Even though their gradients are low (between 1.66 and 7.5 per thousand), they are clearly higher than those of the upper basin, and this fact has helped to develop a better — integrated drainage system.

The main course flows on the eastern side of the basin and receives the waters of most of its affluents on its right bank. The main affluent is the Pillahuincó Grande Creek and the second most important tributary is the Indio Rico Creek. Other affluents are the creeks Pillahuincó Chico, Jagüelito and Manantiales (Fig. 1).

Farming predominates over cattle rearing, except in the upper basin where the soil is clayey. Agriculture has increased in recent years and in some districts, such as Tres Arroyos and Coronel Pringles (Fig. 1), 80 % of the area is under cultivation. Some sectors present two sowing cycles for fine and coarse grain crops. Whereas wheat bread is the main crop in all the districts — followed by other winter crops such as barley, oats and wheat durum, sunflower, maize, sorghum and soya are amongst the summer crops. In addition, 10 % of the soil is devoted to pastures such as alfalfa, gramineae and wheat grass. Cattle rearing is a first — rate activity mostly carried out as part of mixed farming.

Ovines and bovines are the leading cattle, followed by horses and pigs in small percentages. Several cities are located in this area such as Coronel Pringles, Laprida, Oriente, Indio Rico and Marisol (Fig. 1).

RESULTS AND ANALYSES

1. Salinity

Salinity refers to the total soluble salt content and is generally expressed either in TDS (Total Dissolved Solids) or —as in this study— as Electrical Conductivity (EC). An increase in salinity affects crop growth and will result in yield reductions, since the energy normally used in its development will be diverted to the extraction of pure water from the saline water absorbed by its roots.

According to the EC guidelines proposed by James et al. (1982), the hydrographic basin presents five kinds of water (Fig. 2). Generally, EC downstream is higher than

TABLE 1: Maximum EC and SAR values registered in each water course and in the main lagoons of the Quequén Salado river basin.

Water Course	EC (dS/m)	SAR	Sampling Site Location
Quequén Salado river	7.88	37.8	60º 36 ’ W - 38º 36 ’ S
Indio Rico creek	2.46	9.7	60º 39 ’ W - 38º 36 ’ S
Indio Rico Main Affluent	1.58	5.2	60º 48 ’ W - 38º 28 ’ S
Indio Rico Minor Affluent	1.97	8.8	60º 50 ’ W - 38º 26 ’ S
Pillahuincó Grande Creek	0.97	4.2	60º 55 ’ W - 38º 03 ’ S
Pillahuincó Grande minor Affluents	0.24	0.6	61º 29 ’ W - 38º 10 ’ S
Pillahuincó Chico Creek	0.78	2.3	60º 57 ’ W - 37º 55 ’ S
El Pensamiento Creek	0.37	0.6	61º 15 ’ W - 38º 12 ’ S
Jagüelito Creek	1.51	6.8	60º 51 ’ W - 38º 17 ’ S
Jagüelito Affluent	0.80	5.0	60º 56 ’ W - 38º 10 ’ S
Manantiales Creek	1.96	8.7	60º 53 ’ W - 38º 18 ’ S
Los Patrios Lagoon	2.77	14.8	61º 15 ’ W - 38º 18 ’ S
Los Tres Reyes Lagoon	1.46	6.8	60º 37 ’ W - 37º 56 ’ S
La Salada Lagoon	3.19	19.1	60º 42 ’ W - 37º 32 ’ S

midstream or upstream. The minor affluents which flow into the Pillahuincó Grande and Pillahuincó Chico creeks have Excellent water quality with an EC below 0.24 dS/m. This condition worsens gradually as these courses flow away from the hill region. Thus, both courses show values ranging from 0.30 to 0.61 dS/m near Coronel Pringles (Fig. 2), and change their quality from Excellent to Good. Likewise, another creek which begins on the Pillahuincó Hill, El Pensamiento (Fig. 1), presents Excellent quality waters only at its

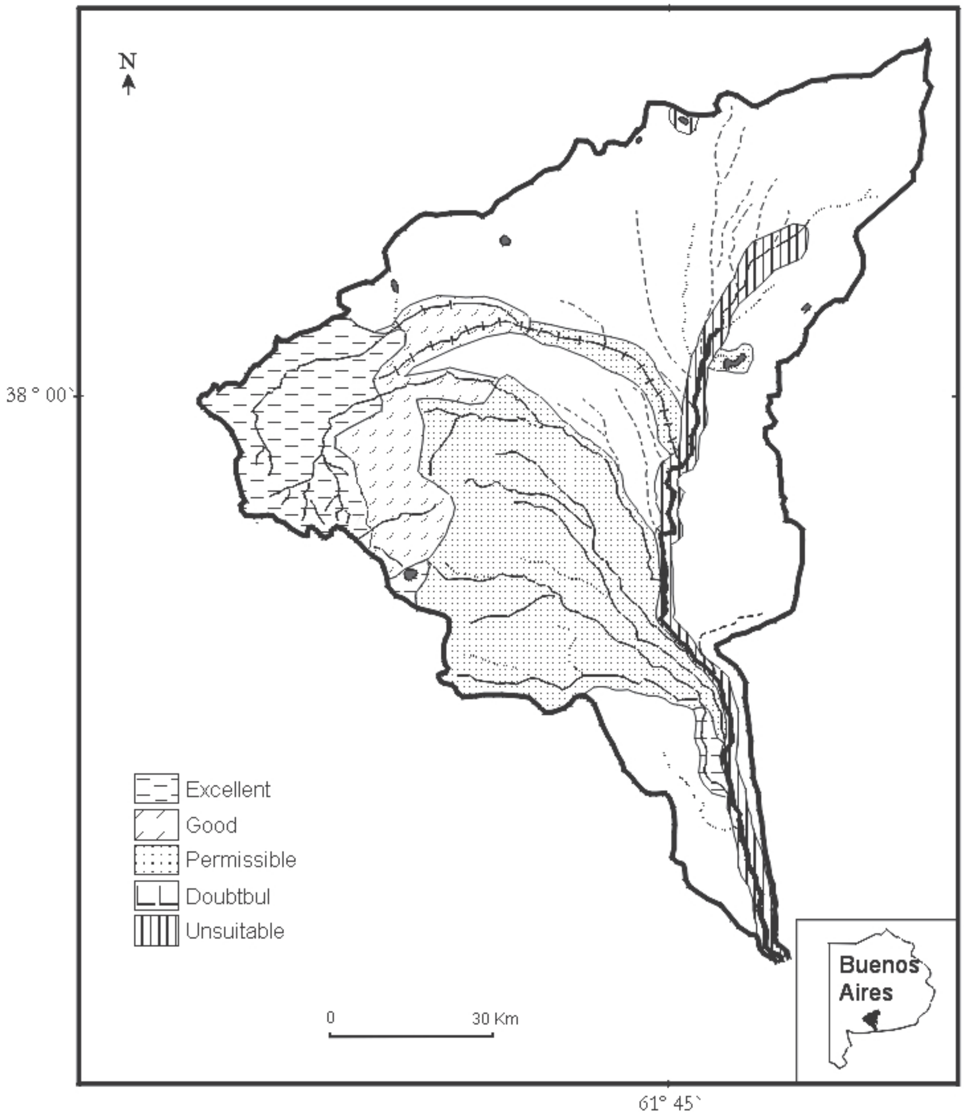

FIGURE 2: Irrigation Water Quality based on the Electrical Conductivity values (according to the James et al. Guidelines, 1982).

headwater. EC values increase in the middle and lower reaches of this course, with a maximum of 0.37 dS/m (Table 1).

The courses whose headwater is located at the piedmont of the hill area such as the Indio Rico, Manantiales and Jagüelito creeks and their affluents (Fig. 1) feature lower quality waters. All these creeks present Permissible water quality (Fig. 2). The maximum values registered upstream of the Jagüelito creek and its affluent (0.80 dS/m) increase downstream, reaching 1.51 dS/m. The waters of the lower reaches of the creeks Pillahuincó Chico and Pillahuincó Grande are also Permissible (0.97 dS/m, Table 1). This occurs because EC values in a water course usually increase as it flows across the terrain. This situation also applies to downstream Indio Rico creek once it meets its main affluent. Although the EC does not increase significantly, the quality in this reach can be defined as Doubtful (2.46 dS/m). Maximum values are close to this water category —though Permissible— were also registered in a minor affluent of the Indio Rico creek (1.97 dS/m, Table 1).

Unlike the rest of the streams, the main river presents high EC values along its course (Fig. 2). Very high EC values have been detected both at its upper, middle and lower reaches. The maximum values registered are 7.52 dS/m at Estancia El Micheo (close to Juan Barra, Fig. 1) and 7.88 dS/m at the National Route 3 crossroads. Accordingly, its water quality makes it hardly recommendable for irrigation. Two factors contribute to this situation: First, the saline soils in the upper basin area has had an influence on the water courses that flow across them. The EC values found were 5.59 dS/m on the soil surface, and even higher at a depth of 40 cm (8.65 dS/m). Second, there is another factor that affects water quality: the difficult drainage presented by the upper basin sector associated with the flat gradients. This condition gives rise to two processes: 1) groundwater remains underground for a long time, gradually absorbing the dissolved salts from the abundant volcanic ash present in the aquifer sediments, 2) the shallow aquafer enables the ascent of groundwater to the surface and its subsequent evaporation, so that the soils absorb the salts formerly dissolved in the sediments. Thus, using the James et al. Guidelines for Irrigation Water Quality (1982), the class for the Quequén Salado river is Unsuitable (Fig. 2)

Lagoons present variable EC values with a generally low irrigation quality (Fig. 2). The largest one, called Los Tres Reyes (Fig. 1), is one of the few to possess Permissible waters. Its highest registered EC was 1.46 dS/m (Table 1). The rest have low irrigation quality, such as Los Patrios lagoon (at the headwaters of the Indio Rico creek), whose irrigation quality is Doubtful (maximum of 2.77 dS/m). Nevertheless, the high salinity shown by the Los Patrios lagoon does not affect the creek because it only communicates with this water course during the overflows. Higher EC values have been found in the upper basin lagoons, such as La Salada (Fig. 2), which are Unsuitable for irrigation.

2. Sodicity

Calcium, magnesium and sodium are the most important chemical elements found in water in the form of salts. There are others, such as iron, manganese, boron, nitrates, etc, which contribute very little to salinity. Sodium is the most important component as far as soil structure and water permeability are concerned. However, the content of this element

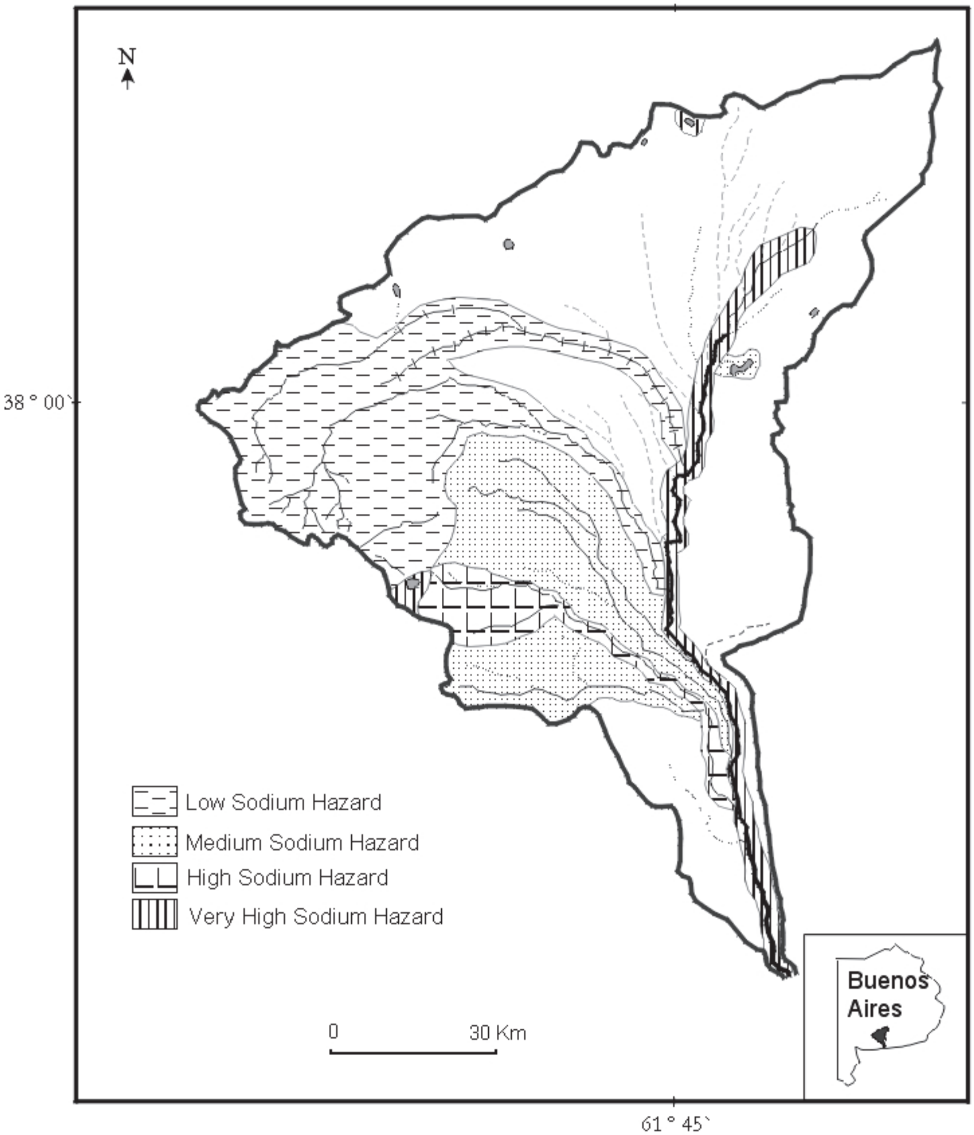

FIGURE 3: Sodium Hazard of irrigation water based on SAR values (According to the Hergest & Knudsen Guidelines, 1977).

alone does not supply enough information about water quality and its effects on the soil. Calcium and magnesium in large enough quantities will counter the effect of the sodium and help maintain good soil properties. Waters with a high sodium content may be of good quality provided the calcium and magnesium contents are also significant. Thus, the ratio of sodium to calcium and magnesium usually expressed as SAR (Sodium Adsorption Ratio) enables the classification of waters into different kinds.

In general, the arrangement of the SAR values registered in the different courses is similar to that of the salinity measures (Fig. 3). Unlike these parameters, the SAR values do not present any important variation along the course of the creeks. This is clearly seen in the Indio Rico creek since the 9.7 SAR maximum value registered in the area close to the National Route 3 (Fig. 1) is slightly higher than that registered upstream. The Pillahuincó Grande and Pillahuincó Chico creeks shows maximum SAR value of 4.2 and 2.3 downstream (Table 1). According to Hergert & Knudsen (1977), both courses and their hill affluents fall into the Low Sodium Hazard category (Fig. 3). In fact, the hill sector features very low SAR values with a maximum of only 0.7 in the headwaters of the Pillahuincó Chico creek and in a minor affluent of the Pillahuincó Grande creek. This is related to the very good quality of the soils in this area, whose SAR values found range between 0.3 and 3.1. Based on the James et al. Soils Guidelines (1982) they are considered Normal.

Conditions are different in the middle basin of the Quequén Salado river. All waters present a Medium or a High Sodium Hazard (Fig. 3). Such is the case of the Jagüelito and Manantiales creeks, the latter having a maximum SAR of 8.7 downstream. These conditions get even worse along the Indio Rico creek which features a High Sodium Hazard. However, its main affluent does not exceed the Medium Hazard limit (SAR 9).

The SAR values found along the Quequén Salado river present Very High Sodium Hazard (Fig. 3). For instance, there are SAR maximum values of 25.7 under the bridge located on the National Route 3 (Fig. 1) and of 37.8 11 km away from its mouth (Table 1). The very high SAR values could be due to the characteristics of the soil. Specifically, soil samples collected close to the headwaters of the river and a few kilometers downstream present maximum SAR values ranking from 17.9 on the surface to 21.54 at a depth of 40 cm. These soils are classified as Saline – Sodic according to the James et al. Soils Guidelines (1982).

The lagoons show high SAR values (Fig. 3). Only the Los Tres Reyes lagoon presents acceptable rates (with a maximum of 6.8) and a Medium Sodium Hazard. The remaining lagoons, such as Los Patrios and La Salada (the last in the upper basin), exceed 12 (Table 1). According to the Hergert & Knudsen Guidelines (1977), these lagoons are classified as Very High Sodium Hazard.

3. COMPLEMENTARY ANALYSES: CHEMICAL QUALITY OF THE MAJOR COURSES

The two main courses of the basin in terms of their chemical properties are presented in figure 4 by means of a Radial Diagram (Standard Methods, 1992). As to the main river and the Indio Rico creek, the diagram does not show a prevailing direction which indicates that the content of anions and cations is balanced. The diagram corresponding to the Quequén Salado river waters shows that the ionic composition is $SO_4^{=}$ - Cl^- - Na^+, though with a significant bicarbonate content. The proportion of choride is important in this course and represents a Severe Hazard (Tanji, 1990), making the nitrogen and phosphorous absorption difficult. The proportion of sulphates presents a Moderate Hazard according to James et al. (1982). The considerable magnitude of this anion is related to the presence of gypsum beds along the river. In the case of the Indio Rico creek waters, their ionic composition is HCO_3^-- Cl^- (Fig. 4). The radial diagram corresponding to the Pillahuincó Grande waters shows a non significant ionic concentration. Nevertheless, they can be classified as Slightly Bicarbonate (Fig. 4).

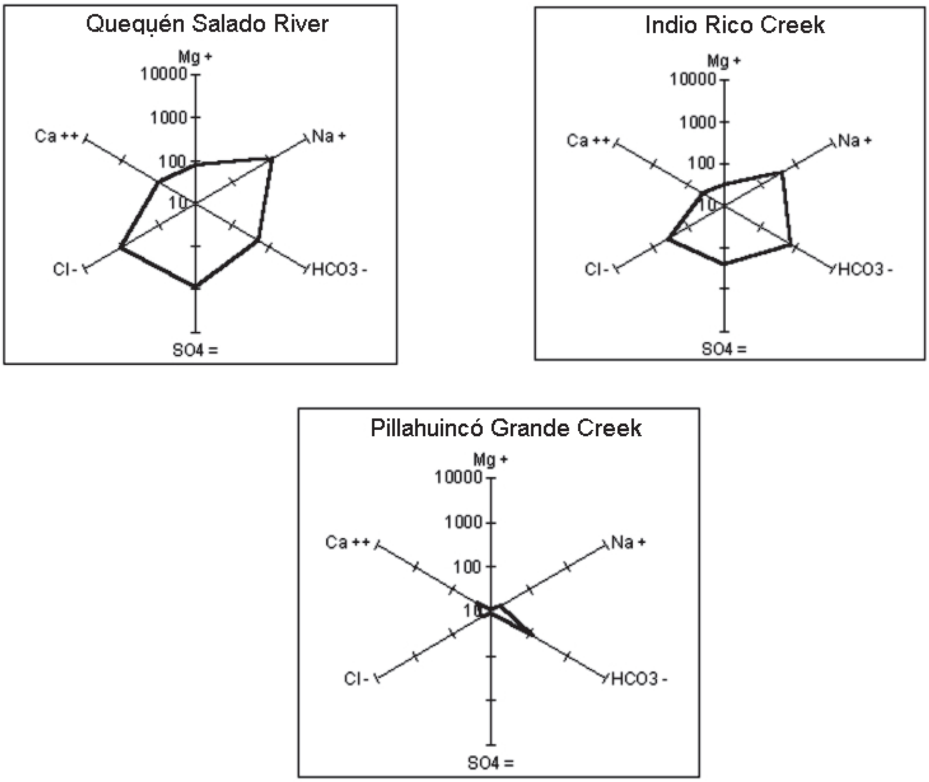

FIGURE 4: Radial Diagram for the Quequén Salado river and the Indio Rico and Pillahuincó Grande creeks.

In addition to those diagrams, a comparative graph showing the anionic concentration was designed to include all the data obtained by the analyses performed in July 1971 and 1976 by the Dirección Provincial de Hidráulica (Buenos Aires, Argentina) and in July 2000 (Fig. 5). According to the results, the predominant anions in decreasing order are $Cl^- > SO_4^= > HCO_3^-$ for the Quequén Salado river while they are inverted for the Indio Rico creek ($HCO_3^- > Cl^- > SO_4^=$ (Fig. 5).

Bearing in mind its potentially toxic effect on certain species, the boron content was also assessed. Most authors agree that concentrations under 1 mg/ l do not represent hazard to crops (e.g. CCME, 1987; Mc. Farland, 1998, etc.). None of the values registered for this secondary constituent exceed the limit and the maximum values recorded are 0.84 mg/ l in the Quequén Salado river and 0.76 mg/ l in the Indio Rico creek.

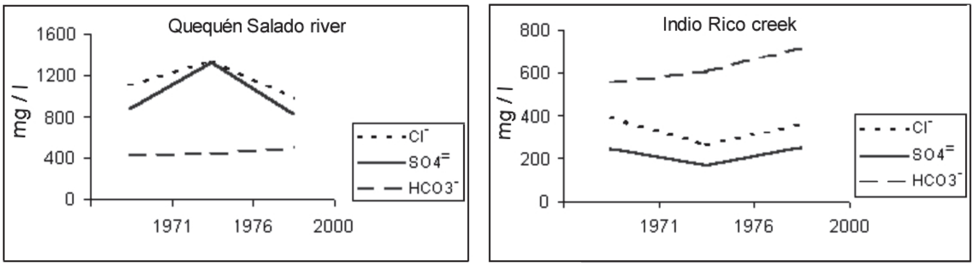

FIGURE 5: Comparative anionic concentration analyses (mg/ l) performed in July 1971 and 1976 (Dirección Provincial de Hidráulica, Buenos Aires) and 2000.

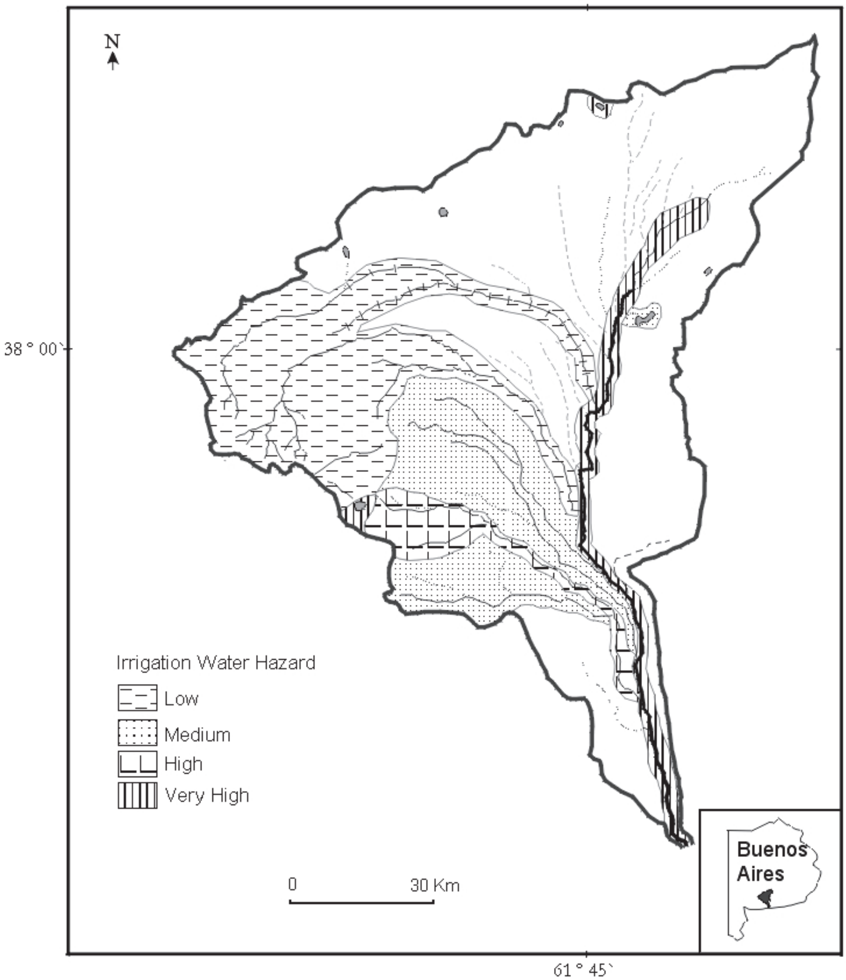

FIGURE 6: Irrigation Water Hazard based on EC x SAR relationship, according to the Hergest & Knudsen Guidelines, 1977.

4. CLASSIFICATION OF THE WATER OF THE BASIN FOR IRRIGATION

Based on another Hergert & Knudsen Guideline which relates EC and SAR (1977), the Quequén Salado river basin courses were mapped according to the irrigation water hazard (Fig. 6). The Pillahuincó Grande and Pillahuincó Chico creeks and their minor affluents present Low Hazard along their courses. The difference between them and the piedmont creeks such as the Manantiales and the Jagüelito is significant. Even though the EC values of these courses makes them Permissible for irrigation, SAR values are higher than in the streams originated in the Pillahuincó Hill. Thus, some problems of permeability connected with SARs above 6 may appear in the soils. Difficulties are greater in the Indio Rico creek, which presents High Hazard. As far as the main river is concerned, its water quality exceeds the limits of both EC and SAR (Fig. 6). Even if chemical amendments are added, the use of the Quequén Salado waters may cause severe problems in the physical structure of the soil. This is true for most of the basin lagoons.

5. WATER QUALITY INFLUENCE UPON THE MAIN CROPS IN THE AREA

Apart from requiring the best management conditions, any crop will increase its potential yield if it has enough water. Supplementary irrigation is an option to supply the missing water at critical times for cultivation. However, the effects of the irrigation water quality will vary depending on the different plants and crops. The salinity tolerance limit of the main field crops and forage crops ranges from Very Tolerant —such as for wheat grass— to the most sensitive like white clover (*Trifolium repens*). In many cases waters with an EC slightly higher than the tolerance limit can be used, although the potential yield will decrease.

Like EC and SAR, salinity tolerance can be measured by using international guidelines, such as Ayers & Wescot's (1989). However, the Argentinian INTA (1999) has established different tolerance rates for the various crops in the province of Buenos Aires. Since this area is more humid, the highest tolerated EC levels are higher than those suggested by methods like the first one mentioned above. While —for example— alfalfa and maize tolerate a maximum EC of 1.1 dS/m (without yield reduction) according to Ayers & Wescot (1989), the INTA has established a 3 dS/m tolerance limit for both crops.

Based only on surface water quality, figure 7 shows which crops can be irrigated in the basin. There are three clearly defined areas:

1. *Very Good Quality Waters*: The creeks Pillahuincó Grande and Pillahuincó Chico as well as their different affluents. In this sector almost every crop —even slightly tolerant crops like white and red clover (*Trifolium pratense*)— can be irrigated.
2. *Good Quality Waters:* This is the case of the courses of the middle basin. Although its waters are inferior in quality, they are permissible for most of the predominant crops, such as maize, wheat, sunflower, soya, sorghum, and forage crops such as alfalfa and trefoil big.
3. *Poor Quality Waters:* The Quequén Salado river waters can be used for just a few very salinity tolerant crops. Such is the case with wheat grass (*Agropyron elongatum*),

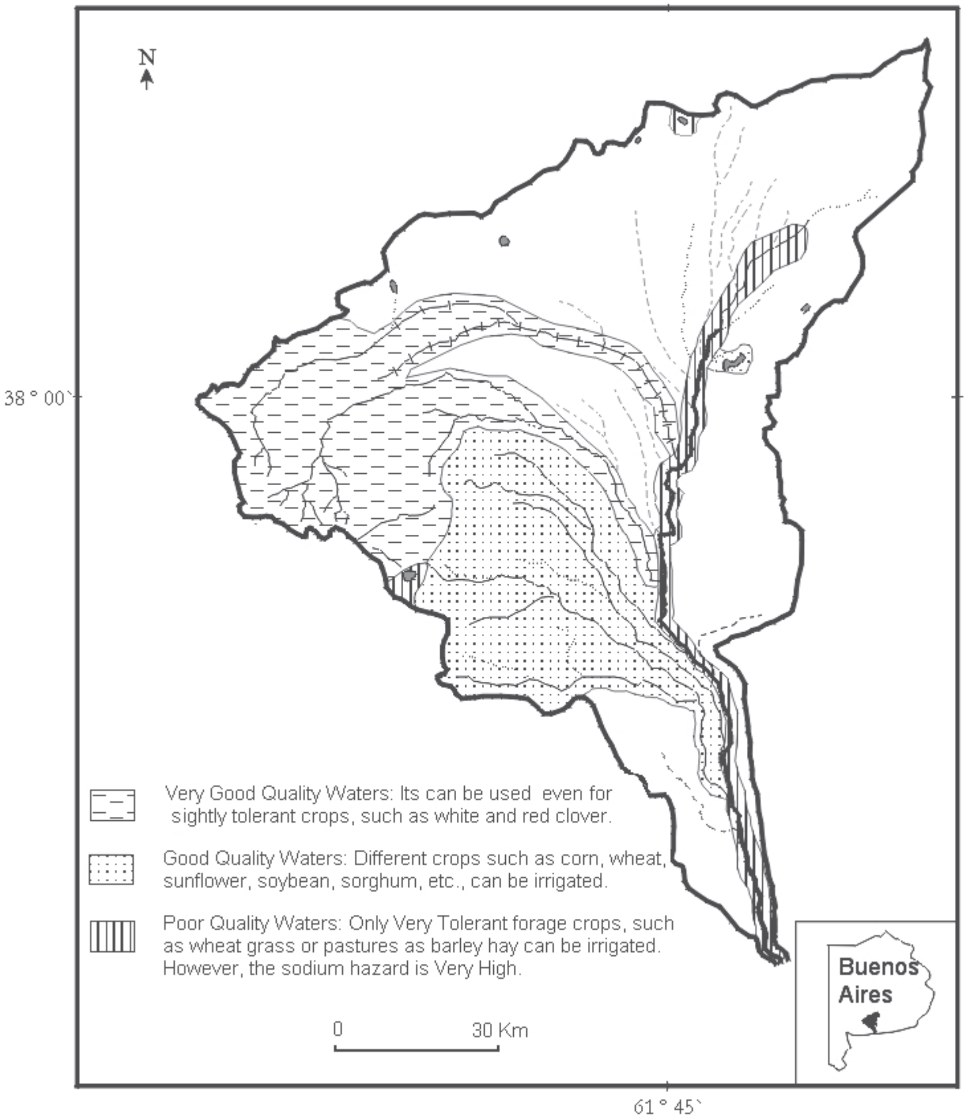

FIGURE 7: Recommended crops according to the Irrigation Water Quality (INTA Guidelines, Argentina, 1999).

which was successfully planted in the upper basin and other tolerant pastures like barley hay — though the expected yield reduction is ranked from 10 % to 25 %.

Add to the yield reduction of the crops, high concentrations of salt in the soil can result in a physiological drought condition. Continued use of waters having a high SAR leads to a breakdown in the physical structure of the soil (Ayers & Wescot, 1989).

CONCLUSIONS

Supplementary irrigation provides a specific solution during drought in order to avoid yield reduction of some crops. The use of surface waters for irrigation is proposed as a valid alternative in the short-term. This is due to the fact that in humid areas —with irregular rainfalls— this system is not required throughout the year.

Most courses are permissible for all types of cultivation, specially the Pillahuincó Grande and Pillahuincó Chico creeks, which have Very Good Water Quality. However, the waters of these courses should be used only during drought periods to supplement below normal rainfall. The use of the Quequén Salado river waters is recommended only for a few highly salinity-tolerant crops. However, their high SAR should be decreased to a safe value to avoid soil problems which would limit crop yields. Some management practices at the required rate, such as the addition of water amendments (e.g. calcium sulfate) metered into the water may be necessary. Moreover, owing to the high SAR present in this river the use of its waters would lead to a breakdown in the physical structure of the soil.

The Quequén Salado river waters may be used by the cattle. Water is the most important nutrient for livestock, and according to the salinity values, this water is classified as Satisfactory (CCME, 1987). However, it may cause temporary diarrhea or refusal at first by animals not accustomed to it.

In view of the importance supplementary irrigation is gaining in this leading farming area, further research is deemed necessary. As regards the quality of both river and creek waters, similar investigations should be undertaken in other basins in the country. Last but not least —considering its present extended use— a thorough research into groundwater quality should be pursued to complete this study.

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