MIRÁBILE C.; MORÁBITO J.; FASCIOLO G.; LOUSTAUNAU H. The dynamics of soil salinity in crops irrigated with surface and surge flow methods. Acta Horticultura, ISHS, v. 646, p. 155-161, 2004.

THE DYNAMICS OF SOIL SALINITY IN CROPS IRRIGATED WITH SURFACE AND SURGE-FLOW METHODS

Carlos Mirábile[1], José Morábito[1-2], Graciela Fasciolo[1-2], Hugo Loustaunau[1]

[1] Instituto Nacional del Agua y del Ambiente-Centro Regional Andino
Belgrano (oeste) 210 (5500) Mendoza, Argentina
Telefax : 0261-428 8251. E-mail: jmorabito@ina.gov.ar
[2] Docentes e investigadores de la FCA – Universidad Nacional de Cuyo

ABSTRACT

This paper seeks to establish and analyze the dynamics of salts in the soil with crops irrigated with surge-flow and surface irrigation, and to determine whether the soil's final electrical conductivity (F EC) is associated or not to the irrigation method. In the case of surge-flow irrigation, water is applied intermittently.

The farms selected use both systems to irrigate the same crops (grapes, olive trees and vegetables) and are located in the cultivated areas of the Mendoza and Lower Tunuyán rivers.

The methodology consisted in selecting two furrows at random for each type of irrigation (surge-flow, surface), dividing them into three sectors (head, middle, tail), and taking soil samples from two layers (0-40 and 40-80 cm). The soil samples were taken at the beginning and end of each crop cycle. Electrical conductivity (EC) was determined at the laboratory using the saturated paste method and measured in micromhos/cm at 25ºC.

Tables have been prepared that show salt content variations with each type of irrigation for the whole profile and for each of the sampled layers.
A multiple regression model was applied on all the data obtained (384 samples). Final salinity (F EC) is a function of initial salinity (I EC) and of the type of irrigation (surge-flow, surface).

The best-fitting function is linear. The estimation of **β1** (initial salinity) is significantly different from 0 (zero) ($P = 0.0001$), whereas **β2** (type of irrigation) is not ($P = 0.376$). This is taken to mean that the soil's F EC is not related to the type of irrigation.

As **β1** is significantly smaller than 1, it is considered that both types of irrigation produce desalination.

The percent difference between F EC and I EC is not associated with the type of irrigation at the furrow's head, middle or tail. The changes in EC are not homogeneous within the farm.

INTRODUCTION

It is recognised that water resources in the Province of Mendoza, just as in all of Argentina's western region, are the main factor limiting agricultural expansion. This is becoming more and more serious due to the continuous increase in the demand for water for domestic and industrial uses.

Therefore, farmers have been forced to become much more efficient in their use of water and have adopted new irrigation systems that result in greater efficiency, as regards both the form and the timing of watering the crops. Surge-flow irrigation is one of them and, although not the most efficient, it is becoming very popular in Mendoza because of its cost-benefit ratio. With this system, first described by Stringhan and Keller in 1979 (Walker and Skogerboe, 1987), water is applied to the irrigation unit (furrow or basin) intermittently according to a pre-established program of flows and application times.

Surface irrigation systems (furrows, basins, etc.) are rather inefficient (usually, due to excess water) because of the way water is applied. In general, inefficiency is less than calculated since part of the excess water meets the leaching requirement, which is necessary to wash the salts brought by irrigation water.

The saline water balance prepared by Mirábile (1985) for the area irrigated by the Middle Tunuyán River (surface irrigation) showed that the water depths applied were greater than necessary and in excess of the leaching (desalination) requirements. However, in low land with high water tables there were salinity problems.

The adoption of new irrigation systems which apply water more efficiently poses the risk of soil salinization if the necessary surplus for leaching is not taken into account.

Several researchers, notably Castro (1996), have studied the dynamics of salinity with drip irrigation. After studying salt dynamics and other variables in different grape varieties irrigated with drip and surface irrigation, Castro demonstrated that there was an increase in soil salinity in drip-irrigated vineyards. Chambouleyron et al. (1997) reached similar conclusions after studying changes in salinity and soil nematodes in drip-irrigated crops. Those papers have generated critical discussions on the measures that should be taken to prevent the gradual salinization of the soil and its harmful consequences when irrigating with highly efficient methods.

Surge-flow irrigation is a more efficient surface irrigation method by means of which water is applied intermittently. Therefore, it is of the utmost importance to understand its salt dynamics and to compare it with more traditional surface irrigation.

The farms selected for this study are located in the irrigated areas of the Mendoza and Lower Tunuyán rivers for two main reasons: the rivers' respective flows are fully allocated, and surge-flow irrigation is in widespread use in these areas. The productive model in both regions consists of vineyards, fruit and olive trees, and vegetables, with a total of 150,000 ha under irrigation.

This paper aims to ascertain the dynamics of soil salinity in crops irrigated with surface and surge-flow irrigation methods, to determine whether the Final Salinity (FEC) of the soil is related to the irrigation method.

MATERIALS AND METHODS

For this study 10 farms were selected which use both irrigation systems (surface and surge-flow) to irrigate the same crop. In practice, this means that there are some sectors or fields with surge-flow irrigation and others with surface irrigation. The crops are: grapes, peaches, apples, olives, and vegetables (garlic, onion, and tomato).

For the purpose of this assessment, we selected two non-contiguous furrows with surge-flow irrigation and two non-contiguous furrows with surface irrigation. Soil samples were taken at 25, 50, and 75% of their respective lengths (head, middle and tail of the furrow).

Samples were taken from two soil layers (0 – 40 cm and 40 – 80 cm) with a soil auger and were analyzed at the laboratory.

Samples from each farm were taken at the beginning and near the end of each crop's cycle.

For practical reasons, identification stakes were placed in each sampling point so as to ensure that the end-of-cycle samples were taken at exactly the same spot as the beginning-of-cycle samples.

Soil salinity was determined at the laboratory using the saturation extract method (saturated paste method) and expressed as electrical conductivity (EC) in μmhos/cm.

Laboratory results were then used to set up a database, which made it possible to perform various analyses and a statistical study.

In order to determine the relationship between the different variables under consideration – final electrical conductivity (F EC), initial electrical conductivity (I EC), and type of irrigation— a multiple regression analysis was run, where the response variable is F EC and the independent variables are I EC and **type of irrigation**, the latter being a dummy variable: 0;1 (Surge-flow: 0, Surface: 1). Farms were treated as single blocks because it was considered that irrigation management in each of them was homogeneous. The model adopted is expressed as:

$$\mathbf{F\ EC = \beta 0 + \beta 1\ \ I\ EC + \beta 2\ \ Irrigation}$$

$\beta 1$ estimates the change in F EC due to the increase of I EC in unit 1.

The following hypotheses were assessed:

- $\beta 1$ is different from 0; i.e., there is a relationship between F EC and I EC.

- $\beta 1$ is less than 1; i.e., there is soil desalination (because the slope of the straight line is less than 1).
- $\beta 2$ is different from 0; i.e., there is a relationship between F EC and type of irrigation.

If $\beta 2$ is significantly different from 0, it means that there is a difference in the F EC with both types of irrigation; otherwise, the type of irrigation must be eliminated from the regression model.

Three models were considered: linear, potential (log-log), and exponential (semi-log).

In order to analyze F EC and I EC at the three sampling points (head, middle, tail), the mean values of the percent difference were compared: **PD = ((F EC-I EC)/F EC) x 100.** Variance analysis was used for each point, farms being considered as single blocks and type of irrigation as treatment.

Analyses were performed on the complete soil profile (0 –80 cm) and also on each layer (0 – 40 and 40 –80 cm).

For each sampled point, the following hypothesis was assessed:

- There are differences between the mean **PD** of both irrigation types.

RESULTS

Table 1 shows mean percent salinity variations for both types of irrigation (complete profile and per layer) and for each sampled point. Mean percent salinity variation along the entire furrow is also shown.

Table 1: Mean percent salinity variation according to type of irrigation, sampled point and layer

Surge-flow irrigation –Complete profile

Depth	**Farms**								
0 – 0.80 m	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
Head	6,1	-19,0	-50,0	61,8	-17,0	44,1	145,4	-20,0	**18,9**
Middle	25,0	-30,0	-31,5	81,8	-34,7	18,9	-75,2	-57,1	**-12,8**
Tail	28,0	-26,0	-29,0	0,1	-6,8	-11,0	-75,0	-19,4	**-17,4**
Mean	**19.7**	**-25,0**	**-37,0**	**47,9**	**-19,5**	**17,3**	**-1,6**	**-32,2**	**-7,2**

Surface irrigation –Complete profile

Depth 0 – 0.80 m	Farms								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
Head	37,0	-24,0	-27,0	4,6	-30,9	N/d	-29,7	valor	**-11,7**
Middle	21,0	-41,0	7,0	7,7	-12,8	N/d	72,5	44,8	**14,2**
Tail	-5,6	-43,5	-20,5	-1,0	-38,0	N/d	140,2	99,4	**18,7**
Mean	**17,5**	**-36,2**	**-13,5**	**3,8**	**-27,2**	**N/d**	**61,0**	**72,1**	**11,1**

Surge-flow irrigation –Layer

Sector	Farms								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
Head 0,00 - 0,40	6,5	-10	-33,5	4,8	-66,2	79,3	195,9	-67,2	**13,7**
0,40 - 0,80	6	-27,5	-66,5	118,8	32,1	8,9	94,9	27,2	**24,2**
Middle 0,00 - 0,40	22,5	-41,5	-14,5	29,3	-44,4	-31,4	-67,1	-61,8	**-26,1**
0,40 - 0,80	27,5	-18	-48,5	134,3	-24,9	69,2	-83,3	-52,5	**0,5**
Tail 0,00 - 0,40	45,5	-36,5	-21,5	-23,4	-56,9	-47,2	-83,3	-18,1	**-30,2**
0,40 - 0,80	10,5	-16	-36	23,7	43,2	25,3	-66,8	-20,7	**-4,6**

Surface irrigation --Layer

Sector	Farms								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
Head 0,00 - 0,40	57	-18	-26	-8,3	-64,9	N/d	-16,4	110,9	**4,9**
0,40 - 0,80	18	-29,5	-27,2	17,5	3,0	N/d	-42,9		**-10,2**
Middle 0,00 - 0,40	18,5	-52	6,5	-50,5	-39,1	N/d	45,5	85,6	**2,1**
0,40 - 0,80	24,5	-30	7,5	65,9	13,4	N/d	99,4	4,0	**26,4**
Tail 0,00 - 0,40	9,5	-51,5	-10	-28,1	-64,4	N/d	195,0	10,4	**8,7**
0,40 - 0,80	-20,5	-35,5	-31	26,1	-11,6	N/d	85,5	188,5	**28,8**

The best-fit multiple regression model is the linear model, from which the following equation is obtained

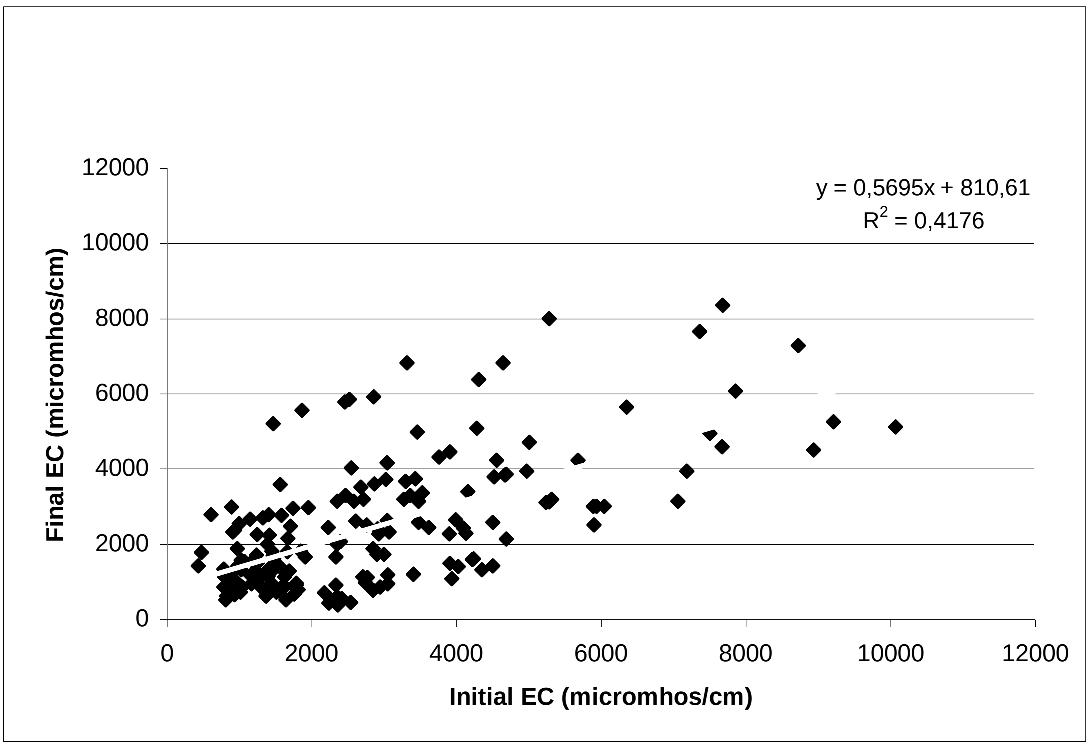
F EC = 810.6 + 0.560 I EC – 167.02 Irrigation (1)

with $R^2 = 0.413$; the estimation of $\beta 1$ is different from 0 –significant value-($P < 0.0001$) I while the estimation of $\beta 2$ is not significant ($P = 0.376$). As there is no difference between surface and surge-flow irrigation, it may be removed from equation (1):

F EC = 810.6 + 0.569 I EC (2)

R^2 is 0.418 (Prob > F = 0.0001); i.e., almost 42% of F EC is accounted for by the Initial EC. On average, when I EC increases by 1000 μmhos, F EC rises by 569 (see Figure 1).

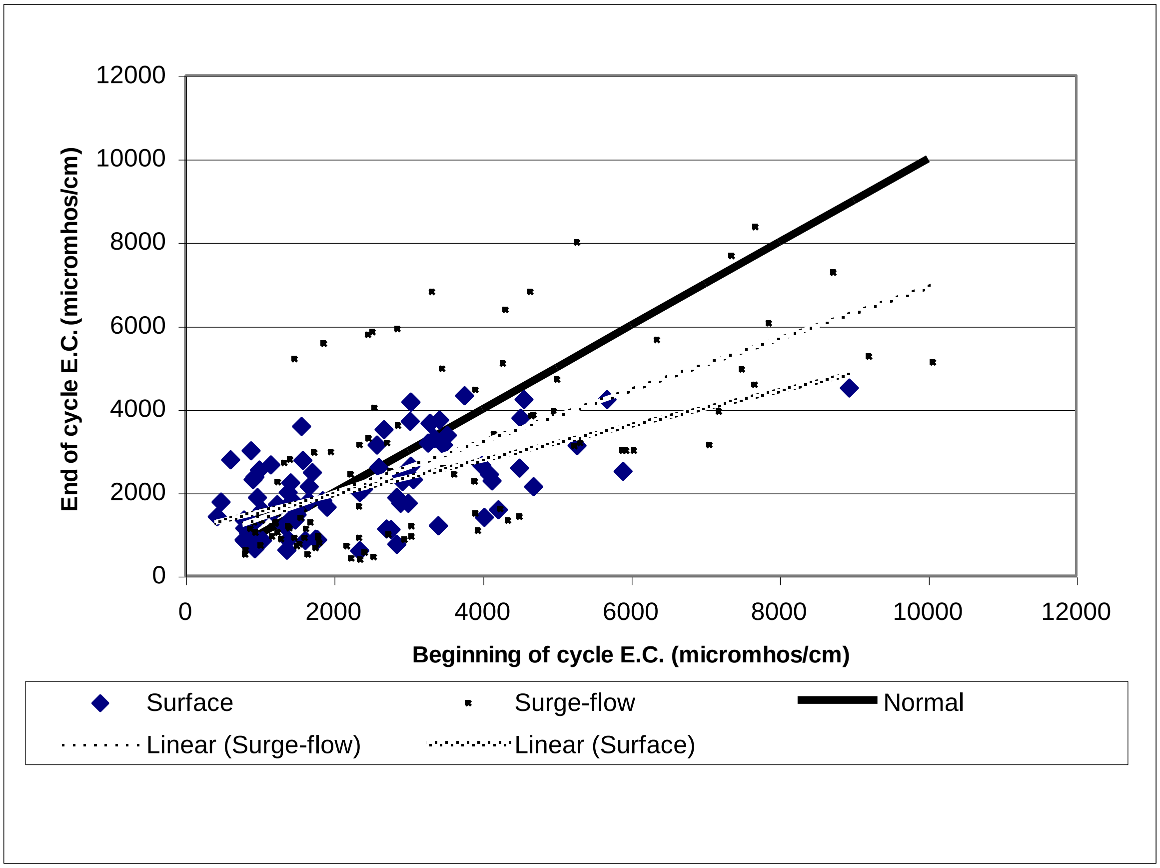
Figure 1. Relationship between initial and final electrical conductivity with surge-flow and surface irrigation

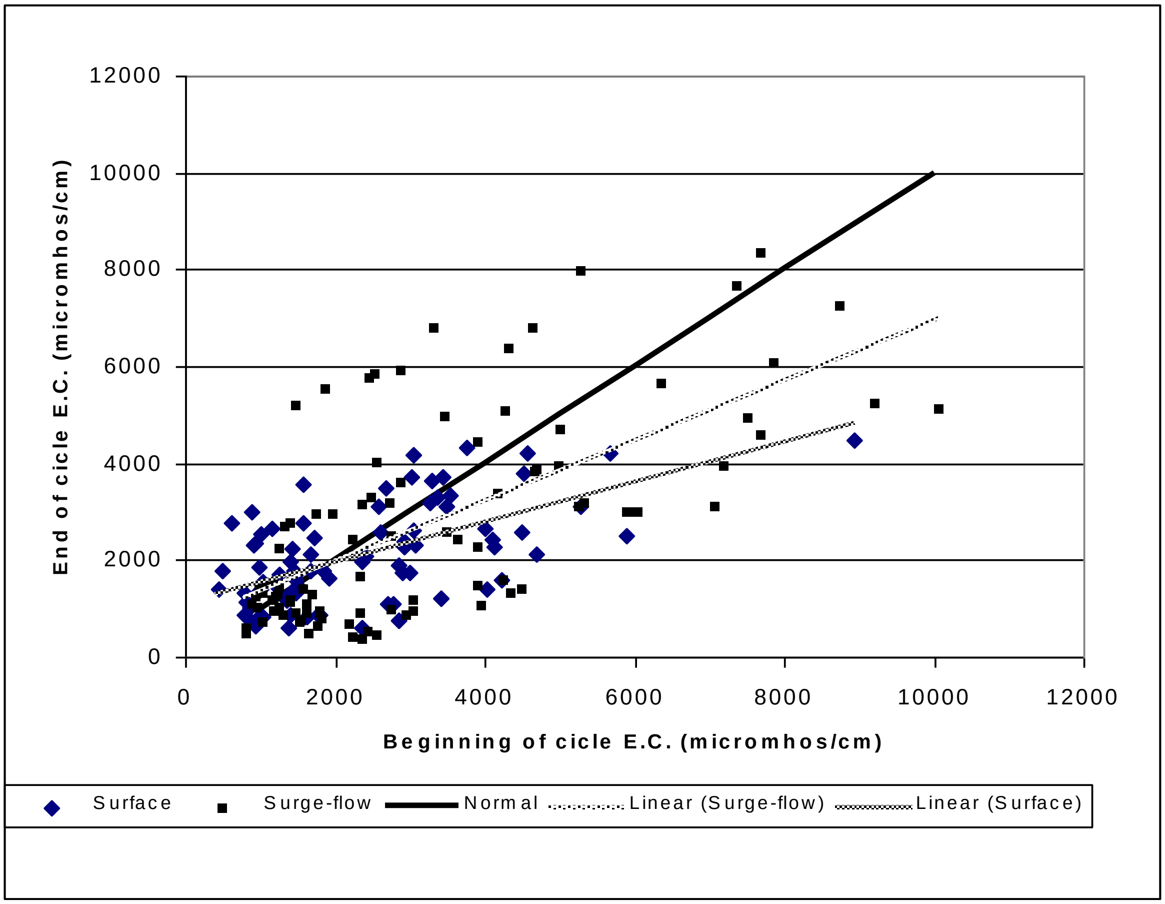


In equation (1), $\beta 1$ is significantly lower than 1, which indicates that both types of irrigation produce soil desalination (see Figure 2).

By superimposing the scatter diagrams with the trend lines corresponding to each type of irrigation, and including a normal straight line (45º) which corresponds to a soil where Initial and Final EC are equal, it may be observed that both trend lines are below the normal straight line; however, as the surface irrigation line deviates towards axis (x) more than the normal line, it represents a stronger tendency to desalination (Figure 2).

Figure 2. Comparative assessment of soil salinity with surge-flow and surface irrigation during the 1999-2001 period





From the analysis of the trend lines by layer or sampling depth (0 – 40 and 40 – 80 cm) for each type of irrigation, it may be observed that with both types of irrigation desalination is always greater in the upper layer.

Variance analysis of percent differences (PD) shows that the differences between the mean values of the percent change by irrigation type (treatment) are not significant at the head, middle or tail of the furrow.

a) PD at head. There are no significant differences ($P = 0.7103$). This confirms the regression result for $\beta 2$.
b) PD at the middle. There are no significant differences ($P = 0.1625$)
c) PD at the tail. There are no significant differences ($P = 0.088$)

No significant statistical differences have been found when analyzing variations in salinity in each site (head, middle, tail) for each sampled layer.

On the other hand, no significant differences have been found between the mean values of percent differences of the farms (blocks). Thus, the hypothesis of on-farm homogeneous irrigation management is rejected.

CONCLUSIONS

A statistical analysis shows that type of irrigation (surge-flow and surface) has no impact on final soil salinity.

The soil's final electrical conductivity is related to the initial electrical conductivity. The 42% variation in the F EC is explained by changes in I EC.

The estimation of $\beta 1$ obtained from the multiple regression analysis shows that both irrigation methods produce desalination since when initial EC rises by one unit, final EC increases only by 0.57.

Trend lines show that desalination is greater with surface irrigation (which is less efficient), and that with both irrigation methods it is greater in the upper layer of the soil's profile.

There is a logical explanation for this. Both types of irrigation are, in fact, surface runoff, and water application losses cause desalination with both of them (although less with surge-flow irrigation because of its higher efficiency). Field-measured application efficiencies (Romay and Morábito, 2000) were 19% (surface irrigation) and 42% (surge-flow irrigation), and deep percolation losses were 52 and 39%, respectively.

It is only logical that the desalination tendency with both types of irrigation be more marked in the upper layer of the root zone: as irrigation water flows down the upper layer, it washes down salts and, therefore, the leaching efficiency diminishes in the lower layer.

The percent difference between Final EC and Initial EC is not related to the type of irrigation, as shown in the measurements made at the head, middle and tail of the furrows.

Changes in final electrical conductivity within the farms are not homogeneous.

REFERENCES

Chambouleyron J., Morábito J. , Zuleta J. ,Salatino S., y Fornero L, 1985, Eficiencia de Uso del Agua en Cultivos de Mendoza. Incyth – Cra, Mendoza – Argentina.

Chambouleyron J., Rearte E., 1996, Desempeño del Riego Presurizado en la Evolución de la Salinidad y los Nemátodos del Suelo, Actas del seminario nacional de riego presurizado, Mendoza - Argentina

Castro T.,1996, Evaluación de Sistemas de Riego Localizado en Uva de Mesa, Actas del seminario nacional de riego presurizado, Mendoza – Argentina.

Mirábile C 1985), Mapa y Balance Salino del Área Regada por el Río Tunuyán Medio, Conicet - Incyth, Actas del XII Congreso Nacional del Agua. Mendoza - Argentina.

Mirábile C. 1987, Balansal. Modelo de Balance Hídrico Salino de Suelos Regados. Incyth - Cra.

Romay C, Morábito J., 1999, Evaluación Técnico Económica de Riego por Pulso. UNCuyo-Secyt., Actas del XVIII Congreso Nacional del Agua, Santiago del Estero - Argentina

Walker W., Skogerboe G., 1987, Surface Irrigation, Theory and Practice, (Utah State University), Prentice Hall INC, 386, New Jersey, USA..