SOIL SALINITY AND IRRIGATION WATER QUALITY

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Abstract
Soil salinity is a factor that must be taken into account to characterize the conditions of plants development. In this context, the research presented in this work reveal a number of issues regarding: the conceptual of dryland salinity (causes, impact, remedial actions and crop salt tolerance), irrigation water quality and its influence on the regime of saline soils, such as the irrigation systems supplied from the Siret and Buzau rivers.
Dryland salinity occurs where removal or loss of native vegetation, and its replacement with crops and pastures that have shallower roots. This results in more water reaching the groundwater system. The groundwater rises to near the surface in low-lying areas. It carries dissolved salts from the soil and bedrock material through which it travels. As saline groundwater comes close to the soil surface (within 2m), salt enters the plant root zone. Even where the groundwater does not bring much salt with it, the water logging of the plant root zone alone can damage or kill vegetation.
The sustainable use of a water resources for the irrigation of agricultural land requires no adverse effects of the applied water in the soil environment. From the perspective of soil chemistry, all irrigation waters are mixed electrolyte solutions. Their chemical composition, which reflects their source and post withdrawal treatment, my not be compatible with the suite of compounds and weathering processes that exist in the soils to which they are applied. Adding to this the salt-concentrating effects of evaporation, crop extraction of water, and fertilizer amendments, one readily sees possibility that irrigated soils can become saline or sodic without careful management.
The chemical proprieties of irrigation water that must be identified and controlled to maintain the water suitable for agricultural use are termed irrigation water quality criteria. The numerical interpretation of the water quality criteria to achieve goals in irrigation water quality management leads to water quality standards. These two distinct aspects of irrigation water quality are determined in the first case by the results of field and laboratory research and in second by research data combined with the collective experience of extension scientists, farm advisers, and growers.
The three principal water quality-related problems in irrigated agriculture are: salinity hazard, sodicity hazard and toxicity hazard. Supplementing the volume of water in the soil by irrigation can lead to changes in the soil salinity, making it saline or alkaline if management is inadequate. Therefore, control of irrigation water quality, especially in arid areas, is a mandatory requirement.

Keywords: soil salinity, water resources, irrigations

1. IRRIGATION WATER QUALITY

The sustainable use of a water resources for the irrigation of agricultural land requires that the there be not adverse effects of the applied water in the soil environment. From the perspective of soil chemistry, all irrigation waters are mixed electrolyte solutions. Their chemical composition, which reflects their source and post withdrawal treatment, my not be compatible with the suite of compounds and weathering processes that exist in the soils to which they are applied. Adding to this the salt-concentrating effects of evaporation, crop extraction of water, and fertilizer amendments, one readily sees possibility that irrigated soils can become saline or sodic without careful management.

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The three principal water quality-related problems in irrigated agriculture are: salinity hazard, sodicity hazard and toxicity hazard. Irrigation water quality standards to control salinity hazard are listed in Table 1.

Table 1 Irrigation water quality standards to control soil salinity and sodicity hazards [1]
(Adapted from Ayers, R.S., and D.W. Wescot, 1985)

Water quality	Restriction on water use		
	None	Slight to moderate	Severe
Salinity hazard EC_w (dS m^{-1})	< 0.75	0.75 – 3.0	> 3.0
Sodicity hazard SAR_{pw} range ($mol^{1/2}$ $m^{-3/2}$)	EC_w (dS m^{-1})		
0 - 3	> 0.7	0.7 – 0.2	< 0.2
3 - 6	> 1.2	1.2 – 0.3	< 0.3
6 - 12	> 1.9	1.9 – 0.5	< 0.5
12 - 20	> 2.9	2.9 – 1.3	< 1.3

They are designated preferentially by three classes of conductivity (EC_W), measured in decisiemens per meter. These classes correspond approximately to groupings of agricultural crops into sensitive, relatively sensitive and relatively tolerant categories respectively [2]. Thus, for example, sensitive crops require EC_W < 0.75 dS m^{-1}, and only relatively tolerant crops can withstand EC_W > 3 dS m^{-1} without significant yield reduction. The three EC_W ranges in Table 1 are equivalent to the ionic strength ranges: I < 11 mol m^{-3}, 11 < I < 44 mol m^{-3}, I > 44 mol m^{-3}.

The definition of a saline soil refers to the conductivity of the soil saturation extract (EC_e), no that of applied water. Even though EC_W is recommended to be < 3 dS m^{-1}, the validity of this restriction depends of knowing the relationship between EC_W and EC_e in the root zone. This relationship continues to be the subject of much research in the chemistry of soil salinity, because many complicated factors enter into it, even in the absence of external effects from rainwater and shallow groundwater. As a rule of thumb, the steady-state value of EC_e that results from irrigation with water of conductivity EC_W is estimated from a knowledge of the leaching fraction (LF) of the applied water. The leaching fraction is defined by the equation:

$$LF = \frac{volume\ of\ water\ leached\ below\ root\ zone}{volume\ of\ water\ applied} \quad (1)$$

Typically, LF is in the range 0.05 to 0.20, meaning that 5% to 20%, of the water applied leaches below the root zone whereas 80% to 95% is used in evapotranspiration. With the value of LF known, the average value of EC_e in the root zone is estimated as

$$EC_e = X(LF)EC_W \quad (2)$$

Where X(LF) is a function with a dependence on LF that has been worked out on the basis of experience with typical irrigated, cropped soils. The function X(LF) is given in numerical form in Table 2. As an example of its use, if water with EC_W = 1.2 dS m^{-1} is applied and LF = 0.25, then EC_e is predicted to be 1.44 dS m^{-1}, on average, in the root zone. Note that LF > 0.3 results in EC_e < EC_W, and that LF ≤0.1 will produce a saline soil if water with EC_W > 2 dS m^{-1} is applied.

Table 2 The factor X(LF) in Eq. 2 (Ayers, R.S. and D.W. Wescot, 1985) [1]

LF	X(LF)	LF	X(LF)
0.05	3.2	0.30	1.0
0.10	2.1	0.40	0.9
0.15	1.6	0.50	0.8
0.20	1.3	0.60	0.7
0.25	1.2	0.70	0.6

2. Causes of Dryland Salinity

Dryland salinity occurs where removal or loss of native vegetation, and its replacement with crops and pastures that have shallower roots. This results in more water reaching the groundwater system. The groundwater rises to near the surface in low-lying areas. It carries dissolved salts from the soil and bedrock material through which it travels. As saline groundwater comes close to the soil surface (within 2m), salt enters the plant root zone. Even where the groundwater does not bring much salt with it, the water logging of the plant root zone alone can damage or kill vegetation.

3. Crop Salt Tolerance

Crop salt tolerance also needs to be taken into account when assessing the suitability of water and soil for irrigation [3,4,5,6]. The salt content of the soil water in the crop's root zone,

referred to as the average root zone salinity (EC_{se}), is important in assessing which crops are suitable for growing in particular soils.
The average EC_{se} can be calculated using the measured EC_i of irrigation water [8]. This requires estimation of the average root zone leaching fraction (LF) of the soil under irrigation, i.e. the proportion of applied water moving below the root zone. This is shown in figure 1.

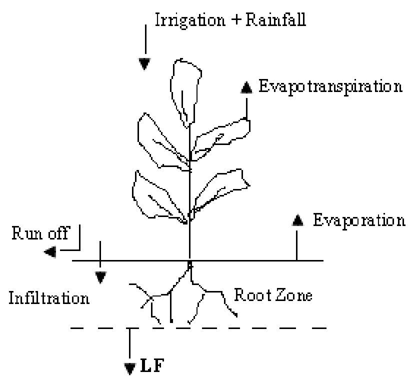

Fig. 1 Diagram of the leaching fraction (LF) concept

Average root zone leaching fraction, for four soil types, are listed in table 3.

Table 3 Soil type and average root zone leaching fraction

Soil type	Average root zone leaching fraction (LF)
Sand	0.6
Loam	0.33
Light clay	0.33
Heavy clay	0.2

Average root zone salinity (EC_{se}) can then be calculated using the following equation:

$$EC_{se} = \frac{EC_i}{2.2 \times LF} \qquad (3)$$

where: EC_{se} is average root zone salinity (dS/m); EC_i – electrical conductivity of irrigation water (dS/m); LF - average root zone leaching fraction.
The calculated EC_{se} can then compared against the EC_{se} values in table 4 to asses the general level of salinity tolerance required of the preferred crop in the particular irrigation situation.
Common crop and pasture species are listed in table 5 in order of salt tolerance determined by average root zone salinity at the threshold level causing yield reduction.

Table 4 Soil and water salinity criteria based on plant salt tolerance groupings [1

Plants salt tolerance grouping	Water or soil salinity rating	Average root zone salinity EC_{se} (dS/m)
Sensitive crops	Very low	< 0.95
Moderately sensitive crops	Low	0.95 – 1.9
Moderately tolerant crops	Medium	1.9 – 4.5
Tolerant crops	High	4.5 – 7.7
Very tolerant crops	Very high	7.7 – 12.2
Generally too saline	Extreme	> 12.2

Electrical conductivity of irrigation water at the threshold level for a range of soil types is also shown and can be used as a general guide for selecting suitable cropsfor the particular irrigation situation.

4. Case – study

The water of Siret River and Buzau River, used as water sources for eastern Romania irrigation systems [7] has the electrical conductivity (EC_i) presented in Table 7. The averages root zone salinity (EC_{se}) has calculated with equation (1) from sand, loam, light clay and heavy clay.

5. Remedial Actions

Remedial actions can be preventative and aimed at eventually stopping further loss of resource (land and/or water) to salinity, or ameliorative and attempt to reclaim the resource. Preventative measures aim to stabilize the depth to the water table, while for amelioration there must be a lowering of the water table [7,8,9,10].
The remediation strategies can be split into two broad themes - (I) an agronomic approach and (II) an engineering approach. The agronomic approach relies on reducing the amount of recharge to a level commensurate with, or less than, the discharge (a causal approach). Engineering solutions rely on the ability to cost effectively remove salt from the zone of interest and dispose of, or store, in a minimal impact way (a symptomatic approach.)

Table 5 Tolerance of plants to salinity in irrigation (field crops) [1]

Scientific name	EC_{se} average root zone salinity threshold for yield reduction (dS/m)	EC_i threshold for yield reduction for crops growing in (dS/m)		
		Sand	Loam	Clay
Sorghum almun	8.3	11.6	6.6	3.9
Hordeum vulgare	8.0	12.6	7.2	4.2
Gossypium hirsutum	7.7	12.1	6.9	4.0
Beta vulgaris	7.0	11.0	6.3	3.7
Sorghum bicolor	6.8	9.4	5.3	3.1
Carthamus tinctorius	6.5	8.2	4.7	2.7
Triticum aestivum	6.0	9.4	5.3	3.1
Triticum turgidum	5.7	9.6	5.5	3.2
Helianthus annual app.	5.5	7.5	4.3	2.5
Avena sativa	5.0	7.0	4.0	2.3
Glycine max	5.0	7.0	4.0	2.3
Arachis hypogala	3.2	4.4	2.5	1.5
Oryza sativa	3.0	4.8	2.7	1.6
Vigna unguiculata var. Caloona	2.0	3.7	2.1	1.2
Zea mays	1.7	3.2	1.8	1.1
Vinum usitatissimum	1.7	3.2	1.8	1.1
Saccharum officinarum	1.7	4.3	2.5	1.4
Vigna uncuiculata	1.6	3.4	2.0	1.1
Macroptilium lathyroides	0.8	2.7	1.5	0.9

Table 7 The averages of EC_i and EC_{se}

River	EC_i (dS/m)	EC_{se} (dS/m)			
		sand	laom	light clay	heavy clay
Siret	1.30	0.98	1.79	1.79	2,95
Buzau	2.03	1.53	2.79	2.79	4,61
Plants salt tolerance grouping		Moderately sensitive crops	Moderately tolerant crops	Moderately tolerant crops	Moderately tolerant crops

Agronomic solutions include:

a) Revegetation with woody perennials

Trees and shrubs on recharge areas can reduce recharge, maintain or lower water tables and thus prevent or ameliorate salinity. However, unless there is (i) an economic value (or an economic value can be assigned by society, for instance, in terms of carbon sequestration) in the trees or shrubs themselves and (ii) a recognition of the spatial extent of the recharge zone and the magnitude of the reduction in the absolute amount of recharge, implementation on a broad scale is unlikely.

With plantings closer to, or on, discharge areas, the range of species is limited to those that are salt tolerant and, with the exception of halophytes, their longevity is questionable.

b) Perennial pastures

Perennial pastures, such as lucerne, can control water table rise. The advantage of perennial pastures is that potentially they can be grown on large areas. The current economics of the animal industries predicate against widespread adoption. In high rainfall areas the effectiveness of this treatment is dubious.

c) Phase cropping

With the prospect of a significant proportion of cropping land being lost to salt (as high as 30% in some regions) the use of deep rooted perennials as part of a longer cropping rotation offers some opportunity for water table control.

d) Productive use of saline land

Salt tolerant shrubs (eg *Atriplex*) and grasses (eg *Puccinellia, Agropyron*) can grow well on saline land. They have been shown to lower water tables in situ and the limited leaching this allows permits the invasion or establishment of less salt tolerant species. The resulting species mix can be a productive fodder source. However, this type of treatment is only localized in terms of the extent of its applicability.

Engineering options include: drainage, aquifer pumping. Drainage (with drains to 1.5-2 m) and aquifer pumping can be effective at controlling water tables. The area of effect away from the drains or pump depends on the transmissive properties of the aquifer. Disposal of the effluent can present legal and environmental problems.

Integrated approach include catchments water management

Rarely will a single treatment be sufficient or applicable, even within small catchments. In most cases the water balance of a catchments can only be manipulated by invoking a treatment or treatments appropriate to the land unit, its underlying hydrology and the major land use, and with due recognition of potential off-site impacts.

Technically salinity is reversible, with massive re-vegetation, drainage and pumping. However, in practice, and recognizing the need for farmers to continue to make a dollar, we contend that it is only reversible on a local scale. In large catchments the time constants for reversal are very long (hundreds of years) and there needs to be acceptance that what is now saline will remain saline. Thus the aim must be to reduce the rate of spread and learn to live with salinity by getting production from the saline land and the saline water - salt land agronomy.

2. CONCLUSIONS

A detailed knowing of the soil salinity, of the quality of irrigation water and the of the salinity tolerance in plants is a very important component of management of irrigated lands.

Dryland salinity has many environmental, economic and social impacts. The remediation strategies can be split into two broad themes: an agronomic approach and an engineering approach.

Supplementing the volume of water in the soil by irrigation can lead to changes in the soil salinity, making it saline or alkaline if management is inadequate. Therefore, control of irrigation water quality, especially in arid areas, is a mandatory requirement.

Where there is uncertainty regarding the effect of irrigation water quality on soil structure stability or crop salt tolerance, it is recommended that soil samples from the surface and subsoil of representative profiles of the soil under irrigation be submitted for laboratory analysis.

3. REFERENCES

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