Climate Change Outlook and Adaptation
An International Journal
Vol. 1 No. 1 (2013), pp. 19-24
ISSN: 2220-4466 Online

Irrigation-Induced Soil Salinity Under Different Irrigation Systems – Assessment and Management: *Short Technical Note*

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ABSTRACT

The water requirement of crops is offset through irrigation using different irrigation systems. Regardless of any irrigation system, the improper irrigation practices (insufficient leaching, restricted drainage) accumulate salts in the root zone and beyond. However, the zone of salts accumulation is different in different irrigation systems, bed shapes and agriculture field. The most common irrigation systems are, flood, furrow, sprinkler, drip (surface and subsurface), and bubbler. Improper soil and water management in agricultural farms can disturb the salt balance in soils leading to develop soil salinization. Globally salinity costs about US$ 11 billion. Timely recognition of salinity symptoms in irrigated agriculture fields and use of appropriate soil and water management practices may save further soil degradation and costly reclamation efforts. Main causes of soil salinity are, poor land leveling, inefficient irrigation, poor drainage, shallow water table, soil compaction (use of heavy machinery), excessive leaching and insufficient drainage, improper cropping pattern and rotation, soil contamination (fertilizers and pesticides) etc..

Keywords *Soil salinity, irrigation systems, integrated reclamation approach, salt-affected soils*

INTRODUCTION

The irrigation method determines depth of irrigation, leaching, zones of salt accumulation, runoff, and uniformity of irrigation water application. The zone of salt accumulation depends on the methods of irrigation and bed shape. Before introducing irrigation methods and zone of salt accumulation, it is important to enlist various facts about salinity and plants, as well as salinity diagnostic symptoms.

Quick Facts – Salinity and Plants

1. Crop selection – one way to reduce salinity affects
2. Salts affect plant differently based on stages of plant growth
3. Matured plant is more tolerant to salt than seedling
4. Relative salt tolerance (field & forage crops > vegetable crops > fruits trees)

Salinity Diagnostics Symptoms

1. Surface white salt crust
2. Salt-stains on dry soil surface
3. Delayed/reduced germination
4. Reduced plant vigor
5. Change in leaf color
6. Foliar damage
7. Plants are either dead or dying
8. Water logging

In order to offset the crop water requirements various irrigation methods are in use worldwide, most common are described below.

Furrow irrigation system

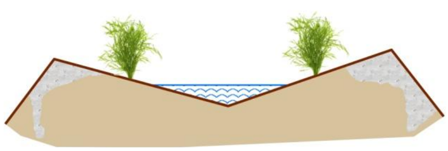
Soil salinity varies widely from the base of the furrows to the tops of the ridges. Figure 1 shows different patterns of salt accumulation in ridges between furrows. These patterns guide the best seed placement to minimize the salinity affects and to achieve the higher crop production. Seed placement at safe site is essential to avoid high salt concentration affects to plants.

Ploughing of furrow field will redistribute salinity to allow further cultivation in the area.

a) Salt accumulation in the center of the flat top bed. The bed is irrigated by both furrows.

b) Salt accumulation and safe zone for seeding

c) Salt accumulation and safe zone for seeding when alternate furrow is irrigated



d) Salt accumulation on sloping beds and safe zone for seeding

e) Salt accumulation on sloping bed, safe zone for seeding when the bed is irrigated by both furrows is evident

FIGURE 1 Salt-accumulation patterns in flat top and sloping beds. High and low salt concentration areas are evident

Figure 2 shows growth of barley crop when planted on the side of the ridges to avoid affect of salts,such a practice is also shown in Figure 1b & figure 3.

FIGURE 2 Barley grown on shoulder of bed. Salt accumulation in the bed top is evident.

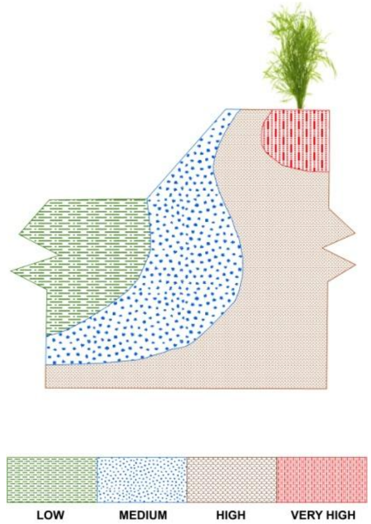
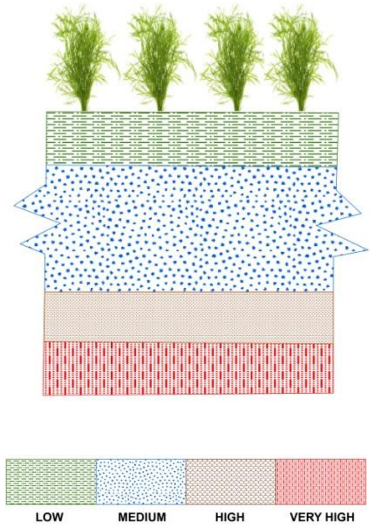


FIGURE 3 Relative salt accumulation zones under furrow irrigation system

Sprinkler irrigation system

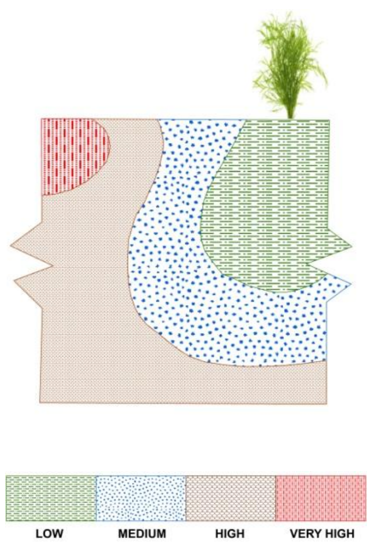
Sprinkler irrigation (SI) uniformly distributes water; however, high wind can distort water distribution. Sprinkler irrigation leaches the salts evenly. The lateral salt distribution is relatively uniform. The salts build up is in deeper layers (figure 4a), which can be drained to avoid water table built up. Highly saline water can cause foliar damage (necrosis-salt injury). The SI is highly effective in leaching salts at surface and providing conducive soil environment for seed germination and initial stage of plant growth.



a) Relative salt accumulation zones under sprinkler irrigation system

Drip irrigation system (Trickle irrigation)

Drip irrigation delivers water near to plants roots through closely spaced tubes and emitters. The flow rate of emitters can be controlled to make frequent and controlled irrigation. The water and salt flow from emitter to the boundary of wetting zone (figure 4b). Salts concentrate through evaporation and plant uptakes. Salt accumulation is on the boundaries of wetted soil volume, lowest being under the immediate vicinity of water source, highest being at surface, and center of two emitters and boundary of wetted soil volume.

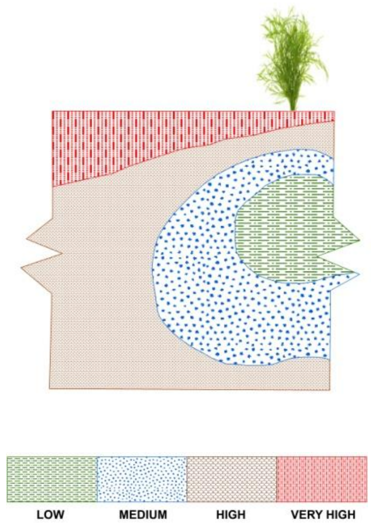


b) Relative salt accumulation zones under drip irrigation system

Sub-surface irrigation (SSI)

In sub-surface irrigation, the soil above water source has no means of water to leach salts. This causes salts to accumulate at surface due to capillary rise and evaporation (figure 4c). Salt-accumulation is faster when saline/ brackish water is used, and when the soils are fine textured.

Only rainfall and/or switch over from subsurface to sprinkler irrigation can leach salts, otherwise salts will accumulate to toxic levels.



c) Relative salt accumulation zones under sub-surface irrigation system

FIGURE 4 Relative salt accumulation zones under different irrigation systems: sprinkler system (a); drip irrigation system (b); sub-surface irrigation system (c).

Border and Basin irrigation system

Water flows downward uniformly in border and basin irrigation, when there is no high water table. Under such circumstances surface accumulation of salts is unlikely. The salt accumulates in deeper layers based on wetted zone.

Salt-Affected Soils

The soils may be rich in soluble salts (saline), exchangeable sodium (sodic) or combination of both (saline-sodic). Based on the soil salinity (electrical conductivity of extract from saturated paste-ECe) and soil sodicity (exchangeable sodium percentage-ESP) levels, soils can be classified (table 1) into three categories (saline, saline-sodic, sodic). pHs is not criteria for the classification, however, it indicates soils alkalinity and acidity status.

TABLE 1 Classification of salt-affected soils

Salt-affected Soil Classification	[1]ECe (dS m^{-1})	ESP
Saline	≥ 4	< 15
Saline-sodic	≥ 4	≥ 15
Sodic	< 4	≥ 15

[1] ECe is measure of electric current passing through solution extracted from saturated soil sample; ESP = Is percent contribution of exchangeable Na to soils cation-exchange-capacity (CEC)

Soil Salinity and Sodicity Management–Integrated Approach

There is no single or combination of techniques globally available to reclaim all types of salt-affected soils. The diagnostics of the problem (salinity, sodicity and their levels) dictates to formulate an integrated approach, which is site specific and may be applicable in areas where similar soils and environmental conditions may prevail (figure 3). For instance, salts can be leached through irrigation, water logging can be managed through drainage, soil sodicity can be reclaimed through the addition of gypsum followed by leaching of salts, dense and hard layers can be shattered through deep ploughing and sub-soiling. Where salinity is increasing as a problem on an irrigated farm, it may be necessary to select crop varieties or production systems that have a greater tolerance to salts. In extreme cases where regardless of significant efforts salinity problem cannot be avoided, such as, areas near the sea where continuous sea water intrusion is the main cause of salts build up, under such specific conditions, it is wise to take this area out of agriculture production and address the negative environmental impacts. The use of mulches improves water conservation and keeps the salts diluted, green manuring improves soil structure and add nitrogen to soil, salt scrapping reduces surface salt temporarily and build up again if salt source is not properly addressed, optimum levels of plant nutrients (N, P, K, Fe, Cu, Mn, Zn etc) in soil keeps the soil fertile, use of organic (composts /biofertilizers) and inorganic amendments improves soils physical health (tilth) for crop production. For an effective reclamation of salt-affected soils, problem diagnostics bases integrated approach is pre-requisite.

FIGURE 3 Integrated soil reclamation approach

Salt Tolerance of Plants

Salt tolerance is the plant's capacity to endure the salts effects in the medium of root growth (Ayers and Westcote 1994; Maas 1990). Plant can withstand to a certain level of salts without adverse effects (threshold salinity). Truly, the plant salt tolerance is not exact value, but depends on, salts and types of salts (NaCl-halite is more toxic thant Na_2SO_4-thenardinte), soil conditions, the stage of plant growth and variety, and environmental and edaphic factors etc.. (Table 2). But remember soil salinity is a layered feature in soil profile and not uniform throughout. Plant salt tolerance ratings are defined by the boundaries as described by Francois & Maas (1978, 1985).

TABLE 1 Plant salt tolerance (Ayres and Westcote 1994); MS (Moderately sensitive); MT (Moderately tolerant); T (Tolerant)

Common name	Botanical name	[1]Threshold ECe (dS m^{-1})	[2]Slope % per (dS m^{-1})	Rating
Field Crops				
Safflower	Carthamus tinctorius	5.3		MT
Sunflower	Halianthus annuus	4.8	5.0	MS
Sorghum	Sorghum bicolor	6.8	16.0	MT
Wheat	Triticum aestivum	6.0	7.1	MT
Wheat	Triticum turgidum	5.9	3.0	T
Triticale	X Triticosecale	6.1	2.5	T
Sugarbeet	Beta vulgaris	7.0	5.9	T
Cowpeae	Vigna unguiculata	4.9	12.0	MT
Guar	Cyamopsis tetragonoloba	8.8	17.0	T
Forages				
Alalfa	Medicao sativa	2.0	7.3	MS
Barley	Hordeum vulgare	6.0	7.1	MT
Bermuda grass	Cynodon dactylon	6.9	6.4	T
Clover berseem	Trifolium alexandrinum	1.5	5.7	MS
Corn	Zea Mays	1.8	7.4	MS
Wheat	Triticum durum	2.1	2.5	MT
Wheat	Triticum aestivum	4.5	2.6	MT
Sesbania	Sesbania exaltata	2.3	7.0	MS
Vegetables				
Bean	Phaseolus vulgaris	1.0	19.0	S
Broccoli	Brassica oleracea (Botrytis Group)	2.8	9.2	MS
Cabbage	Brassica oleracea (Capitata Group)	1.8	9.7	MS
Carrot	Daucus carota	1.0	14.0	S
Celery	Apium graveolens	1.8	6.2	MS
Cucumber	Cucumis sativus	2.5	13.0	MS
Eggplant	Solanum Melongena esculantum	1.1	6.9	MS
Lettuce	Lactusa sativa	1.3	13.0	MS
Pepper	Capsicum annum	1.5	14.0	MS
Radish	Raphanus sativus	1.2	13.0	MS
Spinach	Spinacia oleracea	2.0	7.6	MS
Tomato	Lycopersicon lycopersicum	2.5	9.9	MS
Potato	Solanum tuberosum	1.7	12.0	MS
Asparagus	Asparagus officinalis	4.1	2.0	T
Fruits				
Data palm	Phoenix dactylifera	4.0	3.6	T
Orange	Citrus sinensis	1.7	16.0	S
Grapefruit	Citrus paradise	1.8	16.0	S
Peach	Prunus persica	1.7	21.0	S
Almond	Prunus duclis	1.5	19.0	S
Apricot	Prusus armeniaca	1.6	24.0	S
Grape	Vitis vinifera	1.5	9.6	MS
Guava	Psidium guajava	4.7	9.8	MT
Plum	Prunus domestica	2.6	31.0	MS

[1]Threshold salinity level where affect of salinity is negligible,
[2]Percent change of yield per unit of salinity above threshold

CONCLUSIONS

Modern irrigation systems save significant quantity of irrigation water; however, the salt accumulation zones are different for each irrigation system. Therefore it is essential to adopt suitable practices for placing seeds in relatively the lowest salinity zone. During the next cropping season special measures may be taken to avoid the effect of residual salts on seed germination. There is no single method to reclaim all types of salt-affected soils; therefore, site specific diagnostics based (salinity, sodicity, in depth soil features based) integrated approach (including physical, chemical, hydrological, and biological methods) of soil reclamation is to be adopted for better results.

ACKNOWLEDGEMENTS

I highly acknowledge the assistance of Richard Sulit GIS expert at the Dubai based International Center for Biosaline Agriculture to prepare the diagrams showing relative salt accumulation zones under different irrigation systems.

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