Management of saline water for irrigation of conventional and non-conventional crops

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Why saline water resource?

There is not enough fresh water:

It is less than one percent of the world’s water reserve: the rest is SALINE or FROZEN as ICE

The largest reserves on land are ground waters
they are the equivalent of 200 years of rainfall
but more than half are saline: particularly in the arid regions
where they are needed most for irrigation
Salinity impact on crops

- Toxicity of certain ions.
- Nutritional imbalance.
- Reduced growth and transpiration.
### Table 1. Classification of saline water (adapted from Rhoades *et al.* 1992)

<table>
<thead>
<tr>
<th>Water class</th>
<th>Electrical Conductivity dS/m</th>
<th>Salt Concentration mg/l</th>
<th>Typ of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-saline</td>
<td>&lt; 0.7</td>
<td>&lt; 500</td>
<td>Drinking and irrigation water</td>
</tr>
<tr>
<td>Slightly saline</td>
<td>0.7 - 2.0</td>
<td>500 - 1500</td>
<td>Irrigation water</td>
</tr>
<tr>
<td>Moderately saline</td>
<td>2.0 - 10.0</td>
<td>1500 - 7000</td>
<td>Primary drainage water and groundwater</td>
</tr>
<tr>
<td>Highly saline</td>
<td>10.0 - 25.0</td>
<td>7000 - 15000</td>
<td>Secondary drainage water and groundwater</td>
</tr>
<tr>
<td>Very highly saline</td>
<td>25.0 - 45.0</td>
<td>15000 - 35000</td>
<td>Very saline groundwater</td>
</tr>
<tr>
<td>Brine</td>
<td>&gt; 45.0</td>
<td>&gt; 35000</td>
<td>Seawater</td>
</tr>
</tbody>
</table>
Management Practices for Saline Water

The irrigation water management

The Crop and soil management

Accurate estimates of Crop water requirement

Management of waters with different salinities
Management Practices for Saline Water

Selection of crops or crop variety that produces satisfactory yields.

Irrigation method that maintains relatively high level of soil moisture.
WATER MANAGEMENT

Irrigation: System, efficiency, strategies to use different quality waters (blending, alternating, cycling, etc.)

Leaching: When & How?

Drainage: system, leaching requirement, controlling water table, etc.
Irrigation System

Drip irrigation especially the subsurface is best suited. Seasonal leaching is required.

Sprinkler can cause leaf burn in sensitive crops

Furrow: planting location is important
Furrow irrigation
Sprinkler Irrigation
Today we use 30% less water to grow a crop than we did 25 years ago.
Surface & Sub Surface drip irrigation

Surface drip irrigation in potatoes

Subsurface drip irrigation in potatoes
Drip System
Low Tech – low cost drip irrigation system
Figure 2.1 Implementation of PRD irrigation set up: A) PRD: at any time water was withheld from one side; B) control: vines received water on both sides.
Improving Irrigation Efficiency and productivity-PRD

Saving water by irrigating half of the root zone, the PRD method
Food security requires production of more crop per water drop. Water saving through irrigation with drip subsurface irrigation system and PRD technique (only one half of the vertical root zone is irrigated at a time then alternate irrigation with the dry half). Saving in water is significant ~ 40% which means 40% more food can be produced.
The field versus laboratory salinity

The $E_{Ce}$ measured in the laboratory using saturated paste extract, does not represent the salinity of the field.

Salinity of the field is associated with a current soil moisture. Both salinity and soil moisture should be measured at the same time.

Models produced soil salinity are associated with a twin value of soil moisture. Model’s users often make mistakes by comparing the soil salinity of the model with the laboratory salinity measured of the saturated paste extract.

Keep in mind that plants grow between the wilting soil moisture content and close to saturated soil moisture content. In that range, salinity goes from low at saturation to high at wilting point.
Improving Irrigation Efficiency - Precision Irrigation

Spectrum SMEC300 and Watch Dog data logger

Sensors and suction cups deployment sketch. In the upper part is sketched the RDI treatment, in the bottom part the PRD plots.
Improving Irrigation Efficiency - Precision Irrigation

Soil water salinity trends measured by SMEC 300 sensors under drip irrigation, RDI & PRD
College Field Top Transect in Sheepdrove Farm 21-04-2006. “Transect based” for irrigation performance check and better estimate of SMD to accurately calculate the irrigation requirement.

64 electrode ERT transect at 0.5m spacing crossing 3 distinct vegetation types – winter cereal (foreground), ‘beetle-belt’ (centre),
COSMOS soil moisture sensors “Area based”

- Large scale: 300 m radius of sensitivity
- Non-invasive, completely passive
- Uses background fast neutrons generated by Cosmic rays, which are scattered (slowed) by H atoms.
- Gives more representative soil moisture based on area not on a single point. More accurate SMD to better estimate irrigation water requirement.
Strategies for using waters of different qualities

Network Dilution: different waters are blended in the supply network.

Soil dilution: Altering good and poor quality according to the availability and crop needs. Switching according to the critical stage of the growth.

Cyclic management.
Mixing waters with different salinities

Surface drip irrigation system:

- Two different pools for saline and non-saline water
- Lateral lines with self-compensating drippers (4 L h⁻¹), along the rows at a distance of 0.30 m
Example of sequential saline drainage water reuse

1. Drainage water from field salt tolerant crops irrigates salt tolerant plants
2. Drainage water from trees irrigates halophytes
3. Drainage water from halophytes evaporates in solar evaporator
Example of sequential saline drainage water reuse

Regional drainage water reuse plan

Salt-sensitive trees and crops

Salt-tolerant trees and crops

Salt removal

Halophytes

Salt-resistant tree species

Solar pond evaporator

Water volume
Salt concentration
LEACHING

When? Only when salt concentration exceeds plant tolerance limit.

How:
By unavoidable irrigation inefficiency

Occasional rain

Apply seasonally (recommended)

Apply after each irrigation (not recommended)
CROP MANAGEMENT

Selection of tolerant / suitable varieties.

Apply low salinity at the most sensitive growth stage and higher salinity at other stages.
sensitive crop

crop stage

sowing - seedling - veget. development - flowering - fruit setting - ripening

fresh water + 15% initial leaching

no irrigation

soil salinity

Prof. Atef Hamdy,
CIHEAM-Mediterranean Agronomic Institute of Bari
conventional classification of crop tolerance

threshold value

yield unacceptable for most crops

E_{Ce}, dS/m

relative crop yield, %

sensitive, moderately sensitive, moderately tolerant, tolerant

Prof. Atef Hamdy,
CIHEAM-Mediterranean Agronomic Institute of Bari
Use of saline water on conventional crop
Chickpea, Syria
Tomatoes of high quality with high sugar content were obtained when using saline water for irrigation in field experiment in Egypt.

Use of saline water resources on conventional crops
Use of saline water for conventional crop

Cherry tomato - Malaga, Spain
50% yield reduction ($\pi_{50}$ value) in chickpea, lentil, and faba bean occurred at salinity levels of 4.2 dS m$^{-1}$, 4.4 dS m$^{-1}$, and 5.2 dS m$^{-1}$, respectively. These results suggest that faba bean can withstand relatively high levels of irrigation water salinity, followed by lentil and chickpea.
Use of saline water resources

Barley production with high salinity

Evaluation of salinity tolerance and yield of 280 barley genotypes at 15 dS/m (12g/L)

Pearl millet production under medium-high salinity

Evaluation of salinity tolerance and yield of 42 pearl millet genotypes at 5, 10 and 15 dS/m
Halophyte grasses *Sporobolus virginicus* and *Distichlis spicata* successfully adapted to intensive irrigated production using highly saline water (up to 30 dS/m or 24 g/L).

Halophyte shrub *Atriplex* using very highly saline water (up to 30 dS/m) at ICBA HQ and on a demonstration site in Oman.

Use of saline water resources
Saline water and non conventional salt tolerant crops

The drought and salinity tolerant crops, Quinoa and Amaranth

Bolivia (pictured) and Peru produce more than half of the world's 70,000 tonnes of quinoa.
Turkey quinoa
Italy, Quinoa and Amaranth Experiments
MOROCCO EXPERIMENT: QUINOA, SWEET CORN AND CHICKPEA

Dry matter and yield calibration-validation

Quinoa
A surge of interest in quinoa is offering new opportunities to British growers, with Shropshire providing the unlikely heart of UK quinoa production.

http://www.britishquinoa.co.uk/
### Use of non conventional water resources

<table>
<thead>
<tr>
<th>Country</th>
<th>Cultivated Crops</th>
<th>Salinity conditions</th>
<th>Yield (ton/ha)</th>
<th>EC iw dS/m</th>
<th>Actual yield (ton/ha)</th>
<th>Actual Relative yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>Amaranth</td>
<td></td>
<td></td>
<td>22</td>
<td>2.7</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Quinoa</td>
<td></td>
<td></td>
<td>22</td>
<td>3</td>
<td>97</td>
</tr>
<tr>
<td>Turkey</td>
<td>Quinoa</td>
<td></td>
<td></td>
<td>30</td>
<td>2.5</td>
<td>83</td>
</tr>
<tr>
<td>Denmark</td>
<td>Quinoa</td>
<td></td>
<td></td>
<td>40</td>
<td>1.66</td>
<td>68</td>
</tr>
</tbody>
</table>

SWUP-MED Project
Land Management Practices

Land preparation to ensure uniform distribution of irrigation water, infiltration and better salinity control. Subsoiling, chiselling, and ploughing to break up compaction and improves water infiltration.

Special treatments such as tillage (deep ploughing), adding and mixing sand with soil layer, addition of organic matter, gypsum, green manure to improve permeability.
Accurate estimate of crop water requirement has impact on Salinity

Why accurate estimate of Crop water requirement has impact?

Adding more saline water = adding more salts
  = more leaching of nutrients & fertilizers
  = decreasing soil and groundwater qualities
  = decreasing water productivity and WUE
  = Irrigating less area
Crop Water Requirement Calculation versus Measurements

The future will see more accurate estimation of irrigation requirements that is based on new technologies such as sensors for soil moisture deficit in the root zone, and actual evapotranspiration, Eta using Eddy Covariance and Scintillometers instead of the current estimations that is based on potential evapotranspiration. The latter is based on metrological data, i.e. meeting the atmospheric not soil or plant needs.

The potential Evapotranspiration, Etp over estimates the irrigation requirements. Current research indicates that the actual evapotranspiration, Eta is significantly lower than the Potential Evapotranspiration.

These modern technologies for measuring the Eta is expected to play an important role in the future in estimating the crop irrigation requirement.
Field Instrumentation

COSMOS  Scintillometer  Eddy Covariance

www.water4crops.org
Comparison between actual evapotranspiration measured by Eddy Covariance and by the Scintillometer versus the reference evapotranspiration calculated by Penman-Monteith equation.
Using the field scale models for salinity management

Agricultural water management models are already in use and able to predict soil salinity at a certain soil moisture content over the time (e.g. SALTMed model, Ragab 2015).

Salinity is a slow process and models are useful for long term predictions.

These models once validated, they can be used to: predict soil salinity and yield, long term impact of using saline water on yield and soil productivity, accurate estimation of the leaching requirement, establishing more dynamic yield-salinity response function that accounts for soil and irrigation water salinity combined.
SALT MED Model: A systems approach to a sustainable increase in irrigated vegetable crop production in salinity prone areas of the Mediterranean region.

Free download at: https://www.icid.org/wg_crop.html
On Line e-course & CEH organized course - SALTMED

The model can be downloaded at:
https://www.icid.org/wg_crop.html

There is a course on agricultural water management and SALTMED model at:
https://www.ceh.ac.uk/training/water-land-and-crop-management

How to install the model:
https://www.youtube.com/watch?v=Rt-V87jlg3w

YouTube all parts of the online course are at:
https://www.youtube.com/watch?v=JRMeUFzuBYU
Evolution of soil moisture, salinity profiles & yield
Non-conventional way to use the models

Using the model to predict missing parameters and difficult-to-measure parameters (i.e. Pi 50, Kcb, Kc, Photosynthesis efficiency, etc.),

Using the model to predict Climate change impact (CO2, Radiation, rainfall, temperature, etc.)

Using the model for experimental design such as the best crop rotation, tillage level, fertilizer management and scheduling.

Using the model to estimate the crop water requirement and time to irrigate (scheduling).

Using the model to design a program for data collection.
We have degraded an area of land the size of the United States and Canada combined.
Thank You!