Phytoremediation of salt to directly and indirectly to recover land and revenue

Erick A Carlson
Outline

- **Introduce the Salt Problem**: too much salt = high blood pressure, osmotic stress, soil disturbance, water quality, etc.
- **Propose Plant Based Solutions**: attack causes of saline levels
- **Discuss Several Cases Studies**: recovering Ag productivity and direct phytoremediation

**KEY Info to look for:**

- *Why* are high levels of salt bad for plants?
- What are potential *sources* of salt?
- A *method* for treating high salinity (i.e. what to plant and where).
Salt “pollution”

- Causes/Sources
  - Natural weathering of **salty parent material** (ancient seafloors)
  - Irrigation with **saline groundwater**
  - Clean irrigation water traveling through saline parent material/soils
  - High water tables from plant cover changes
**Problems**

- **Osmotic stress**
  - Osmotic strength of soil is increased under saline conditions, i.e. soil holds water more tightly.

- **Internal plant toxicity**
  - Chlorine (Cl) is a micro nutrient, but in high levels can “burn” the tissues of plants from the inside out.

**Results**

- Reduced crop yields
- Damage to soil permeability

<table>
<thead>
<tr>
<th>Relative yield decrease</th>
<th>0%</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field crops</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>8.0</td>
<td>10.0</td>
<td>13.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Sugarbeets*</td>
<td>7.0</td>
<td>8.7</td>
<td>11.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>6.0</td>
<td>7.4</td>
<td>9.5</td>
<td>13.0</td>
</tr>
<tr>
<td><strong>Forages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tall wheatgrass</td>
<td>7.5</td>
<td>9.9</td>
<td>13.3</td>
<td>19.4</td>
</tr>
<tr>
<td>Wheatgrass</td>
<td>7.5</td>
<td>9.0</td>
<td>11.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Crested wheatgrass</td>
<td>3.5</td>
<td>6.0</td>
<td>9.8</td>
<td>16.0</td>
</tr>
<tr>
<td><strong>Vegetables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td>2.8</td>
<td>3.9</td>
<td>5.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Cucumber</td>
<td>2.5</td>
<td>3.3</td>
<td>4.4</td>
<td>6.3</td>
</tr>
<tr>
<td>Cantaloupe</td>
<td>2.2</td>
<td>3.6</td>
<td>5.7</td>
<td>9.1</td>
</tr>
</tbody>
</table>
**Solutions**
- Flush root zone in winter/pre sowing to aid in germination (susceptible life stage)
- Reduce groundwater recharge
- Plant salt tolerant crops or buffer species

<table>
<thead>
<tr>
<th>Percent Salt Reduction</th>
<th>Amount of Water Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%</td>
<td>6 inches</td>
</tr>
<tr>
<td>80%</td>
<td>12 inches</td>
</tr>
<tr>
<td>90%</td>
<td>24 inches</td>
</tr>
</tbody>
</table>

Salt “pollution”
List of Case Studies

• **Recovery of Agricultural Productivity**
  • Bartle (2006) Australia
  • Bennett and Virtue (2004) Australia

• **Direct Phytoremediation**
  • Banuelos and Lin (2005), Freeman and Banuelos (2011) - California
Recovery of Agricultural Productivity: Non-Food Crops in Western Australia

Bartle (2006)

PROBLEM

• Previously stable salts in deep strata are flushed to the surface through increased deep infiltration through irrigation.

• Shift from deep rooted woody species to shallow rooted annual species has allowed the water tables to rise.

• Salts move upward as water tables rise.

• These can then move laterally, come to the surface, or enter river/stream channels

• 5 million hectares negatively affected (almost the size of West Virginia)

• Slim profit margins of pasture, food and fiber crops make them susceptible to base level reductions in harvest.
SOLUTION

- Perennial, deep rooted crops to lower water tables.
- Present species in area not economically viable (would be water stressed or have no market value).
- Use previously present NATIVE mallee eucalyptus tree
- Not a large component of bioenergy, not “energy rich”, but if it can produce in marginal areas…
- 3 products:
  - eucalyptus oil
  - activated carbon (charcoal)
  - biomass generated electricity
Recovery of Agricultural Productivity: Perennial Grasses vs. Weed Introduction
Bennett and Virtue (2004)

PROBLEM

- High water tables and salinity.
- Lowland salinity control vs. upland weed introduction
- Soil acidification from nitrate leaching.
- Positive feedback loop.
  - 1\textsuperscript{st} annual crops allow water table to rise
  - 2\textsuperscript{nd} salinity builds up and begins to “poison” crops
  - 3\textsuperscript{rd} fewer and less vigorous plants growing
  - 4\textsuperscript{th} water table rises further because of reduced evapotranspiration
Recovery of Agricultural Productivity:
Perennial Grasses vs. Weed Introduction
Bennett and Virtue (2004)

SOLUTION/CONSIDERATION

• Lucerne shown to lower water table 3m in first year!
  • Even after removal of lucerne, WT stays low.

• Legumes like lucerne use nitrates at a high rate and are perennial so they use nitrates when annual crops are not in the field.

• Total area affected by salinity likely much greater than the influence of any single weed species

• Potential hybridization with native species; also considered in US.

• Use of introduced species to solve problem and provide economic benefit.
  • Currently World Trade Organization use of “sanitary and phytosanitary” measures do not include potential benefits of introductions, very restrictive
  • Weeds to control other weeds
Direct Phytoremediation: 
Salinity Considerations in Selenium Management – California
Banuelos and Lin (2005), Freeman and Banuelos (2011)

- **Location**: San Luis Drain (Central California)
- **Pollutant**: Selenium
- **Salt Problem**: Lowers biomass of phytoremediation species, making it ineffective
- **Salt Solution**: Amend soils to lower salinity levels and increase biomass of salt tolerant species (cordgrass, canola, fescue, salado grass) that can also take up Selenium
Bioaccumulation is the process by which pollutants, such as selenium, are concentrated in organisms through the food chain. In the context of the San Francisco Bay and the Sacramento River, this process is illustrated through a diagram showing the movement of selenium inputs through different ecosystems, including birds, fish, clams, and particulates. The map highlights the source of the pollutant, the San Luis Drain, and its impact on the ecosystem. The concentration of selenium in the food web is also shown, with guidelines for exposure levels in different organisms.
Conclusion

- Salt is rough on plants via water gathering and internal toxicity
- Potential sources of salt are: (#1) **GIVE 1 SOURCE**
- Much of the work with salinity has been on recovering agricultural resource (per the case studies)
- What is (#2a) **1 PLANT CHARACTERISTIC** that is beneficial for phytoremediation of saline soils and (2b) **WHERE ON THE LANDSCAPE** would it be advantageous to plant these?
Work Cited


8. Fillery, I; Poulter, R; Zhu, C; Rippey, J; Godwin, C; Smettem, K. 2001. Sustainable management of soil, water and nutrients in high and medium rainfall zone of Western Australia. Western Australia Soil Acidity Research and Development Update, Perth.


