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5. Soil salinity

This chapter covers the factors that influence soil salinity, methods for assessing salinity in the soil, recommendations for how to monitor soil salinity over time and management of farming in salinity-affected areas.

Seawater inundation introduced salinity into areas where it had never before been a problem. As salts leached, surface salinity levels dropped faster than at depth. Rainfall soon leached salt from most sandy soils, but after seven months, clay soils inundated for one to three days after the tsunami had low to moderate salinity, and soils inundated for six days had higher salinity levels. In October 2005, 10 months after the tsunami, soil salinity was still a significant constraint to crop production during the dry season, with many farmers and extension workers reporting yield declines of around 50%. In January 2007 the salinity problem had substantially decreased except for low lying areas with poor drainage where salinity was still relatively high or fluctuated depending on the season.

Lack of familiarity with the salinity problem led to crops being planted in soil too saline for plant growth, or being watered with saline groundwater, leading to failed crops, wasted time, money and seed, and creating despondency among farmers already traumatised by the tsunami. Timely assessments of salinity help farmers avoid growing crops in saline areas and indicate when management practices are needed to alleviate salinity.

Factors affecting salinity levels

Length of time soil was inundated

The longer soil was inundated, the more chance there was of salts infiltrating the soil. Highest salinity levels occurred in areas where seawater stayed on the soil for weeks after the tsunami, allowing salts to penetrate the soil and attach to clay particles. Soil salinity assessments in eastern districts showed that the longer land was inundated after the tsunami the more saline the soils became. Land inundated for more than three days was usually too saline for most crops to yield well in the first year or so.

Soil texture

Generally sandy soils tended to be less saline because salts do not attach to sand particles so are easily leached through the soils. Peat soils also leach salt relatively quickly through surface drainage networks. Salts tend to attach to clay particles, so clay soils tended to be more saline for longer. In heavy clay alluvial soils around Bireuen on the east coast of Aceh, where rainfall is relatively low (~1600 mm/year), salinity persisted for some time, reducing yields.

The level of clay in soils is measured in texture tests. A handful of soil is mixed with water to form a small ball about 2cm in diameter and the ball is then pressed between fingers and thumb to form a ribbon. The longer the ribbon, the more clay is in the soil. Soil texture has a crucial role in salinity assessment and measurement.

Type of sediment

Sandy sediments leached salts easily while clay sediments held salts more tightly. The organic matter in peaty sediments tended to buffer the salts so they did not affect plant growth. However, the underlying soil type is more important for predicting soil salinity levels. If the soil underneath is sandy, leaching will occur; if it is clay the salts will tend to remain, even if the sediment is sandy.

Rainfall and availability of fresh water for leaching

Seawater is more likely to infiltrate dry soils than wet soils so when assessing soil salinity after seawater inundation it is useful to know how much moisture was in the soil beforehand. In Aceh, rainfall figures were not collected before the tsunami, so it was difficult to assess what soil moisture levels would have been when the tsunami hit, except where rice was growing. In Aceh, average rainfall on the west coast ranges from 2300-3300 mm/year compared with the east coast's 1365-1889 mm/year, so there is a likelihood of greater salinity on the east coast than the west coast.

Providing rainfall gauges in different locations and training in how to measure rainfall and record figures after a tsunami provides useful information that can be correlated against rates of leaching and crop growth.

Rice soils are compacted and clay-based to hold water, so do not leach easily, and need flushing to remove salt. If there is plenty of freshwater for irrigation and flushing, salinity levels are lower. Rain-fed paddy fields are more likely to be saline because the salts cannot be flushed away. In some areas the tsunami salinised well and ground water which meant crops irrigated with this water had additional salt added to the soil. Soil salinity reduces after each rice crop and wet season.

Drainage and circulation of water

Soil in the centre of the rice paddies tended to be more saline than the outer sections, because the centre section was often a drainage basin for the rest of the site and difficult to flush out. Through-flow of surface water is particularly important when establishing rice on tsunami-affected land.

Salinity assessment methods

Visual

Visual indicators of soil salinity (Figure 8) include patchy plant growth, bare soil, salt crystals on the soil surface, puffy dry soils and appearance of salt tolerant plant species. The level of soil salinity in soils affected by the tsunami varies widely. The type and vigour of plant growth can sometimes be a visual guide to the severity of soil salinity. Plant growth is often patchy in saline soils and the most salt-tolerant species may be the only plants that survive. Accumulation of salt crystals on the soil surface and puffy dry soils also indicate salinity. However if the soil has been cultivated there may be no visual indicators of the degree of soil salinity.

Figure 7: Visual indicators of soil salinity include patchy growth, bare soil and the emergence of salt tolerant plants

Laboratory

Laboratories commonly assess soil salinity by measuring the electrical conductivity (EC) of water extracts of soil samples. EC is commonly expressed in units of deciSiemens per meter (dS/m). The value of soil EC increases with increasing salinity. Different laboratories may use different ratios of soil to water, e.g. saturated paste (ECe), a 1:2 soil to water ratio, or a 1:5 ratio. Care must be taken when interpreting laboratory data because the different ratios of soil to water will give different laboratory results even though the soil salinity is the same.

> **How do you measure soil salinity?**
>
> International Rice Research Institute
>
> http://www.knowledgebank.irri.org/tsunamiAndRice/How_Do_You_Measure_Soil_Salinity_.htm

Soils with an ECe greater than 4 dS/m are classed as saline because the growth of many crops is reduced at this level of salinity.

Field

You can measure soil salinity in the field by mixing dried crushed soil with five parts of rainwater, shaking, settling and then measuring the water with a portable/field salinity meter.

> **How to texture soils and test for salinity**
>
> http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/168866/texture-salinity.pdf

Electromagnetic field measurement (EM38)

In the field soil EC can be assessed indirectly using electromagnetic induction (EM) methods such as the EM38 instrument shown in Fig.2. The EM38 measures the average EC of the soil *in-situ* to a depth of approximately 1 m in the field. EM38 measurements increase with increasing soil salinity, clay content and moisture content. They can provide a guide to level of salinity for different texture classes of soils and can be used to guide soil sampling for laboratory analysis.

> **Rapid assessment of soil salinity in tsunami-affected areas**
>
> Experiences from Nanggore Aceh Darussalam province, Indonesia
>
> http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/168813/assess-salinity-tsunami-areas.pdf

Training is needed in interpreting EM38 results as these depend on soil texture, so using raw figures as the basis for salinity action can be misleading. Soil tests show high correlation between EM38 readings and soil EC 1:5 analyses of 0-0.4m soil samples, which indicate that the EM38 surveys are a fast and accurate method of determining soil salinity levels in the field.

Protocols for using an EM38 to monitor soil salinity over time

EM38 surveys were very useful in rapid assessment of salinity in Aceh, but need strict protocols to ensure that readings are reliable.

- Take GPS readings to allow operators to return to the same sites for follow up surveys.
- Ensure that EM 38 operators do not wear footwear containing metal as the metal affects the electromagnetic radiation readings.
- Measure the depth of water above the soil surface in flooded sides. EMh is very sensitive to height above ground whereas the EMv is less sensitive so EM operators need to note the depth of water on flooded sites to enable interpretation of EM results.

- Determine the random error of EM38 readings by taking one reading across a full transect and repeating it four times, and then calculating the standard errors of the means. Do this under three different conditions as shown below: dry soil surface, saturated soil surface and standing water (flooded). This exercise only needs to be done once to allow better interpretation of the site survey data over time.

Figure 8: The EM38 being used in the field

- Do spot EM38 checks in areas with low growth or yield potential to diagnose salinity-related crop losses.

- If a site has transect locations with very different EM38 readings, these need to be treated separately. This will build up the data set, and enable interpretation of EM survey results over time, particularly in relation to movement of salt through the profiles. The ideal time to do this is at the end of the wet season at the end of harvest.

- Increased EM38 values during wet season could be due to increased soil water content, which needs to be taken into account when interpreting data.

- If the site has variable growth across it then the degree of crop losses should be assessed in relation to the soil monitoring area.

- Due to the need for interpretation of EM38 readings, all EM38 data needs to be managed through project leaders so that only interpreted data is available.

Figure 9: Random error is determined by using the EM38 in three different conditions; dry soil surface (left), saturated and flooded (right)

Salinity monitoring

Monitoring is needed to assess how quickly soils recover from seawater inundation and regain their productive capacity. After the Aceh tsunami, salinity monitoring enabled the ACIAR projects to assess:

- the impact of the tsunami on crops and yields
- movement of salt through the profile
- the rate of return to pre-tsunami conditions.

Site selection

Sites selected for monitoring had all been inundated by seawater, covered a range of soil types, and were located in the different agricultural areas of the province. Background information is needed for each site to make sense of monitoring results. Questions asked about each site included:

- How long did tsunami water cover the site?
- What type of sediment was left behind?
- How deep was the sediment?
- How was the sediment treated?
- Was topsoil eroded and, if so, to what depth?
- Is the site now affected by tidal water?
- Is there good drainage at the site?
- Is the site dryland or irrigated?
- Is fresh irrigation water available?
- Are there problems with irrigation or drainage at the site?

- What crops were grown and what were the yields before the tsunami?
- What is the cropping history and yields since the tsunami?
- Are they any other special characteristics of the site?

Monitoring criteria

The ACIAR project team monitored 21 sites every three months for:

- soil salinity
- soil texture (salt movement differs in clay and sandy soils)
- depth of water above ground at flooded sites (this is important when interpreting EM38 salinity readings)
- soil nutrients (N,P,K, organic matter)
- soil pH
- surface and well water salinity and pH
- crop performance in the ground (leaf appearance, grain/fruit appearance, potential yield and yield).

Soil sampling protocols

The Aceh projects adopted the following protocols for sampling.

- Take one soil profile at each site to at least 60cm, with samples from 0-20, 20-40, and 40-60cm levels. Submit the samples to the soil laboratory for analysis.
- Sample well waters at soil and crop assessment sites whenever possible. Record the sample depth and field EC. Submit well water samples to lab for EC and pH. Note water colour, particularly indicators of soluble iron after storage (oily surface and yellowing).
- Monitor EC at selected points in the trial area without bulking samples, because soil EC is spatially variable. Sampling points could be based on visual indicators of plant growth (e.g. poor, medium and good growth).
- Take plant tissue samples where crop nutrition or soil fertility problems are indicated.
- Clarify who will do what with respect to sampling, soil and plant sample analysis, data analysis and interpretation, and synthesis of monitoring.

Record keeping

Keep records of soil and water measurements at trial sites to develop a site history of salt movement. This will help build a database of post-tsunami soils recovery. Take field notes in a dedicated field diary during EM38 survey and keep it on file for future reference.

Communication

One way to communicate soil salinity results to a range of audiences is to categorise survey sites in terms of salinity levels and post-tsunami crop losses as shown in the table below. A matrix could be prepared for sites in a given crop or season, or at specified time periods since the tsunami. Where salinity is low and losses high, this suggests losses are not related to salinity.

Post tsunami crop losses

Soil salinity ECe[1] dS/m	ECe range dS/m	High crop losses (>50%)	Moderate crop losses (50-15%)	Low crop losses (<15%)
High	>8	Sites: x, y,		
Moderate	4-6	Sites: a	Sites: z	
Low	2-4	Sites: j, k, l,		Sites: b, c,

[1] ECe refers to actual soil salinity. EC 1:5 and EM38 readings can be converted to ECe.

Salinity management

The ACIAR projects developed several strategies to help advisors and farmers deal with salinity.

Leaching and flushing

Aceh's naturally high rainfall encouraged leaching of salts down through the soil profile, especially in sandy soils. Leaching can be encouraged by preventing tidal water entering fields, raising crop beds to improve drainage, and mulching beds to prevent soil drying out and bringing salts to the surface.

> A guide to reducing the effects of salinity on crops
>
> http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/168816/reduce-salinity-tsunami-areas.pdf

Flushing fields with irrigation water and natural rainfall is possible once drainage and irrigation channels are cleared of sediment and a through flow of water is available. It may be necessary to use pumps to remove saline water in low lying areas.

In Aceh, salt in all rice soils was close to the ground surface because the soils were already flooded, and the compacted, puddled soils prevented the salt leaching down through the soil. Where farmers had access to irrigation water, this surface salt was easily flushed away and rice crops appeared unaffected by the tsunami seven months later, even where tsunami deposits were present.

Figure 10: Irrigation water (right) helps to dilute and flush salts from rice paddies

Rice growing

> **Salt tolerant rice varieties**
>
> Indian Agricultural Research Institute
>
> http://www.iari.res.in/tsunami/salt.html
>
> International Rice Research Institute
>
> http://www.knowledgebank.irri.org/tsunamiAndRice/Do_Rice_Varieties_Vary_in_Tolerance_to_Salt_.htm

The use of water in rice growing helped to leach salts from the soil profile, reducing the salinity for the following crop. At Triang Gadeng, Pidie district, rice in one bunded field failed although the crops in bunded fields on either side grew normally. The only difference in management was that the failed crop had not received any irrigation water before planting. The farmer had waited for the wet season rain after sowing. The farmers with good crops started growing them before the wet season by pumping irrigation water onto their fields. EM readings indicated that this irrigation had leached surface salts; whilst salts had remained in the non-irrigated bund.

Raised beds

Raised crop beds allow water to drain quickly from the soil, taking any salt with it. This is a useful technique in high rainfall areas, but not so useful in dry periods when the water demand is high.

Calcium

Adding calcium to saline soils replaces sodium on the cation exchange, effectively leaching the sodium from the soil. Calcium is commonly added in the form of gypsum, but where gypsum is unavailable poultry manure can be used as it is high in calcium.

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