How salty is your soil? Measuring water and soil salinity

Farmers who suspect salinity or simply want to test the salinity of their soil, can collect a soil sample from the top 20 cm and determine the electric conductivity (EC). Electric conductivity is an indirect measure of the amount of salts in a soil solution. These salts (Na^+, K^+, Mg^{2+}, NH_4^+, Ca^{2+}, SO_4^{2-}, NO_3^- HCO_3^- and $B(OH)_4$) add to the value of EC (see table 3.1). EC is therefore an important indicator of soil health. This chapter explains how to do the appropriate measurements to learn more about the soil or water salinity.

EC measurement

If you want to measure the EC often, you can buy a simple EC meter. Even the cheap ones will deliver a fair indication, although not necessarily 100% precise. The method of sampling and sample preparation is simple, as is shown in these videos:

- *Method of sampling*
- *Saturated paste method*
- *1:2 method*

A laboratory can measure EC making use of the so called saturated paste methodology or by following the 1:2 method by mixing 15 mL of air dried and sieved soil with 30 mL fresh water. Both methods are commonly used, but 1:2 is easier to use as it can be difficult to determine when a soil is water saturated.

When you receive your results, check the units. You will get the numbers in dS/m (deci siemens per meter) or in µS/cm (micro siemens per meter). To convert from µS/cm to dS/m, simply divide the values by 1000 ((µS/cm)/1000 = dS/m).

Table 3.1 EC values from both methods and the level of salinity of your soil

Classification/method	Saturated paste method	1:2 method
	EC (dS/m)	
No salinity	0-2	
Low salinity	2-4	<1
Moderate salinity	4-8	1-2
High salinity	8-16	2-3
Very high salinity	> 16	> 3

Many of the salt ions are essential to maintain healthy plant growth and a healthy soil ecosystem. But, if the concentration of these salt ions becomes too high, your crop yields and nutrient availability will decrease. The activity of soil microorganisms can be reduced which influences key soil processes including the emission of greenhouse gases such as nitrogen oxides (N_2O) and methane (CH_4). Excess salts hinder plant growth by affecting the soil-water balance (see figure 3.1).

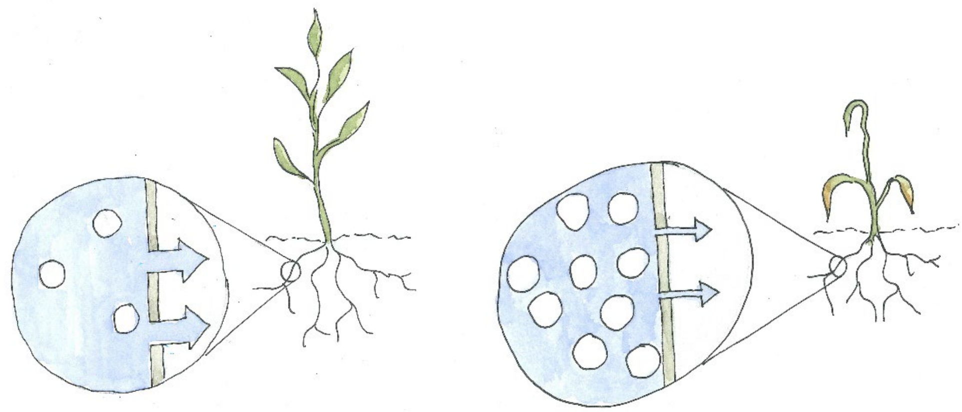

Figure 3.1. Illustration of how increased concentrations of dissolved ion (white bubbles) in soil water reduces water uptake by plant roots.

Higher salt concentrations in soil increase the osmotic potential of the soil water and reduce the soil water potential. In practise, this means that it will be difficult for plants and organisms such as earthworms to absorb soil water even if the soil is wet. This is known as physiological drought. It causes plants to wilt and appear stunted in saline soils. Some of the salt ions such as chlorine (Cl) and boron (B) can even have direct toxic effects.

Accumulation

Salinisation is defined as the accumulation of water-soluble salts in soils or soil horizons (Na^+, K^+, Mg^{2+}, NH_4^+, Ca^{2+}, SO_4^{2-}, NO_3^- HCO_3^- and $B(OH)_4$).
A major distinction is made between addition of salt through precipitation – which only leads to an accumulation in arid climates – and salt addition via groundwater. The latter is observed in coastal regions both in arid and humid climates. Soils at the coast may also be affected by salinisation due to sea water flooding. Finally, fertilisation, irrigation and use of road salts can lead to artificial salinisation.

Occurrence

Salinisation in arid soils occurs if the ratio of precipitation to evaporation is less than about 0.75, meaning much higher evaporation than precipitation. This is because all water contains some salts (dissolved ions). Since salts cannot evaporate, they are left behind and accumulate on the topsoil crust when water is evaporated during drought. In humid climates, any salt accumulated by road salting, an episode of sea salt drift over land (aerosols) near the coast or irrigation will in most cases rapidly leach out of the topsoil during normal rainfall.

In the North-Sea region, the natural groundwater salinisation occurs in areas influenced by the ocean; brackish water (<1% salt content) occurs at estuaries typically where rivers are meeting the ocean in a bay or a fjord. Also some are exposed to open salty sea water (3.5% salt content). Such soils are typically low tidal flats, often not surrounded by dykes. In some places tidal water or rising sea levels from storm events can flood far into rivers or break in and overflow low-lying land. This can cause short or long term salinisation effects, depending on precipitation (rain) and soil types.

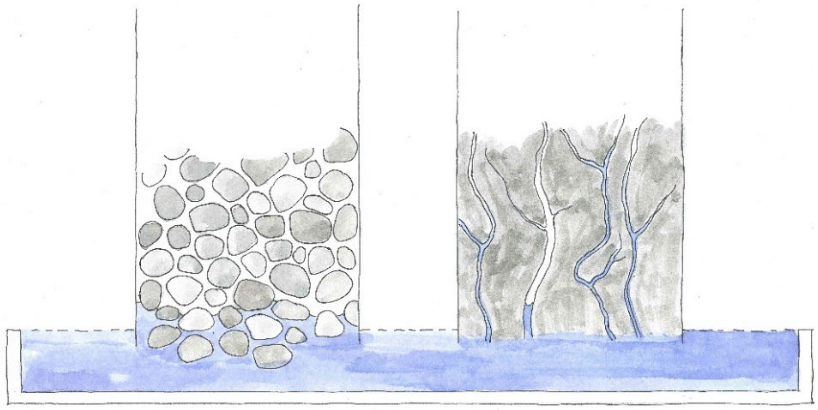

Figure 3.2. Illustration of how soil texture affects capillary forces in a column of sandy soil (left) and a clay rich soil (right). The thin cracks and pores in the clay soil provide better capillarity.

Soil type

The soil profiles capacity in lifting water from deeper layers, such as from (salty) ground water, is controlled by the capillary forces. The capillary forces are stronger when the diameter of pores in the soil are small (Figure 3.2). Since capillary forces are stronger in smaller pores than in larger pores, saline ground water can be lifted much higher in the profile of clay-rich soil than in that of sandy soil types. The effect can easily be seen if you place the edge of a paper sheet in water: you will notice how water is lifted well above the water surface without the aid of any external forces.

The water infiltration capacity of a soil is an important quality to transport excess water, and salt, from the topsoil to deeper layers. A good soil for crop cultivation contains a combination of small and large pores. The small cracks or pores store the water and dissolved nutrients and make them available for plants long after rainfall. The larger pores effectively transport excess water down to deeper layers (ground water), preventing water saturation and generation of anoxic conditions in the topsoil layers.

Water infiltration is high in sandy soils, and such soils are drought sensitive but also less sensitive to salinisation. That is because accumulated salts will easily be leached out by rainwater. On the opposite side the water infiltration is low in clay-rich soil but also in organic soils (> 20-30% organic material). In such soils, accumulated salts remain in the root zone for a much longer time.

Soil structure

Salinity can also result in more permanent degradation of the soil structure. Soil colloids, particularly clay minerals, are generally negatively charged. These negative charges are balanced by positively charged elements such as Na+, K+, Mg2+, Ca2+. The general charge is indicated by a single or double + sign in figure 3.3. Because Ca and Mg have two positive charges, they can hold clay particles together in a loose and favourable structure called aggregates (figure 3.3 right-hand side).

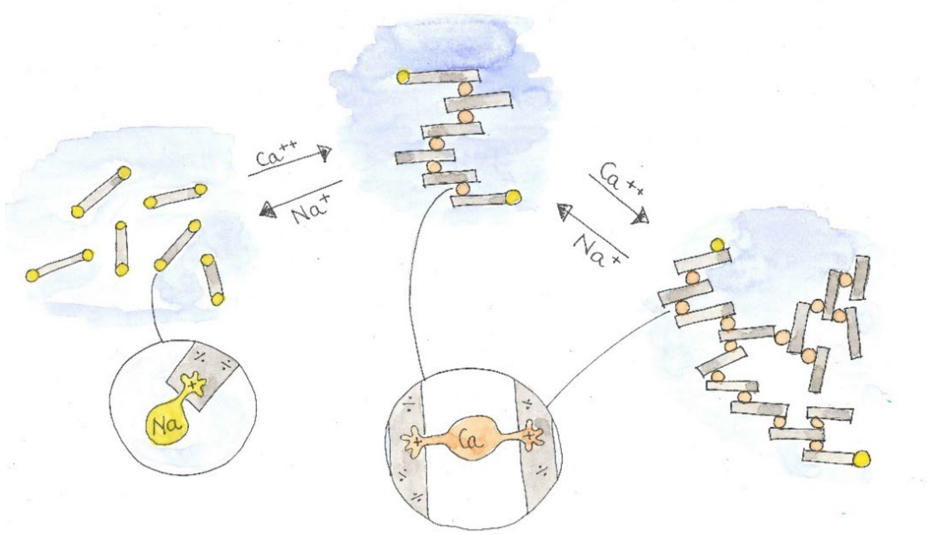

Figure 3.3. Importance of divalent cat-ions, such as Ca^{2+}, for flocculating clay particles (binding them together) forming stable soil aggregates and a good soil structure. The displacement of Ca^{2+} by Na^+ is illustrated on the left side, leading to dispersal of soil clay particles (falling apart) and poor soil structure development (also seen in figure 3.4b)

Although not shown in the figure, these described processes occur with the aid of decomposed organic structures from plant roots and other dead organic material. These aggregates provide the ideal combination of small and large pores. But if salt water is either flushed over land or lifted from groundwater, these aggregates can break down, and the ideal soil structure will be damaged (figure 3.3, left side). This happens because Na^+ is the dominating ion in saline water and Na^+ has only one positive charge. That means that an extreme increase of Na^+ in comparison to the other divalent salts, displaces these other salts (*de facto* Ca^{2+} and Mg^{2+}) by taking their place on the clay particle surfaces. The result is a collapse of the soil structure, changing a well aggregated soil into a dense soil with low or no water infiltration capacity (figure 3.4). This limits the space where plant roots can explore the soil, the volume for water and nutrients, and it will increase the risk of water saturation, the risk of soil erosion and the production of the very potent climate gasses CH_4 and N_2O.

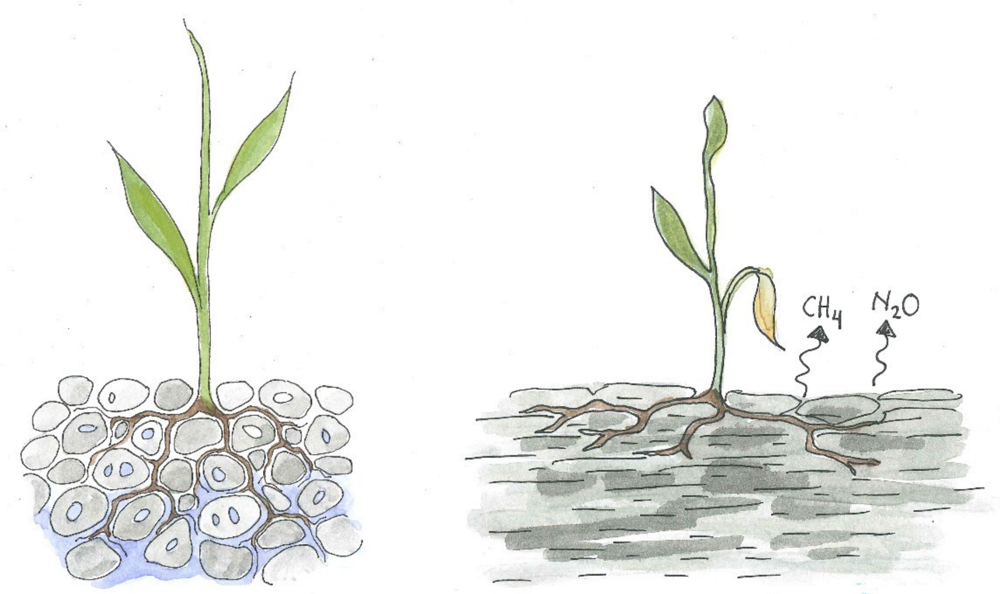

Figure 3.4. On the left-hand side, a well aggregated soil composed of larger pores providing vertical leaching of excess surface soil, and smaller pores retaining plant available water in micropores and aggregates. The right-hand side shows a collapsed clay soil with a poor and dense structure. The latter may result in anaerobic conditions (no oxygen) with increased risk of CH_4 and N_2O emissions.

Irrigation

So, what does this mean for a crop produce? Can you irrigate your soil using salt or brackish water in periods of lasting drought? Table 3.2 summarises your alternatives.

Table 3.2. Summary of saline irrigation options for sandy and clayey soils.

Dominating soil type	Soil salinity	Irrigation water	
		Fresh	Salt/brackish
Sandy	Yes	Good possibilities	Good possibilities
	No	Conventional agriculture	Good possibilities
Clayey	Yes	Tricky	Not recommended
	No	Conventional agriculture	Not recommended

If you have a sandy soil, you can irrigate your soil with brackish water if your crop tolerates episodes of salinity. However, if your soil is clay or organic, it is not recommended to do so.