Learning about soil salinization

To start

Soil is an important component that hosts and supports a wide variety of natural ecosystems and managed agroecosystems. Soil is essential not only for the conservation of vegetation and animals, but also for the subsistence of human populations, as most of the food we consume daily depends on the soil. Unfortunately, today the soil faces many problems that put its health and that of agricultural systems at risk.[1]

One of these serious problems is soil salinization, a phenomenon that occurs when soil accumulates water-soluble salts excessively. On our planet there are more than 833 million hectares of soils affected by salinity; about 8.7% of the Earth's surface. These areas that have been expanding in recent years, can be found in naturally arid or semi-arid environments in continents such as Africa and Asia, but also in some areas of Latin America.[2]

Other recent figures show that between 20% and 50% of cultivated soils on all continents are being drastically affected by salinity. This means that around 1.5 billion people around the world have difficulty growing food because of the severe degradation of the soil. But what impacts does salinization have on soil? How does this silent enemy affect ecosystems and human well-being? How could we solve this? These and other questions we will try to solve in this booklet.

"Halt soil salinization, boost soil productivity"

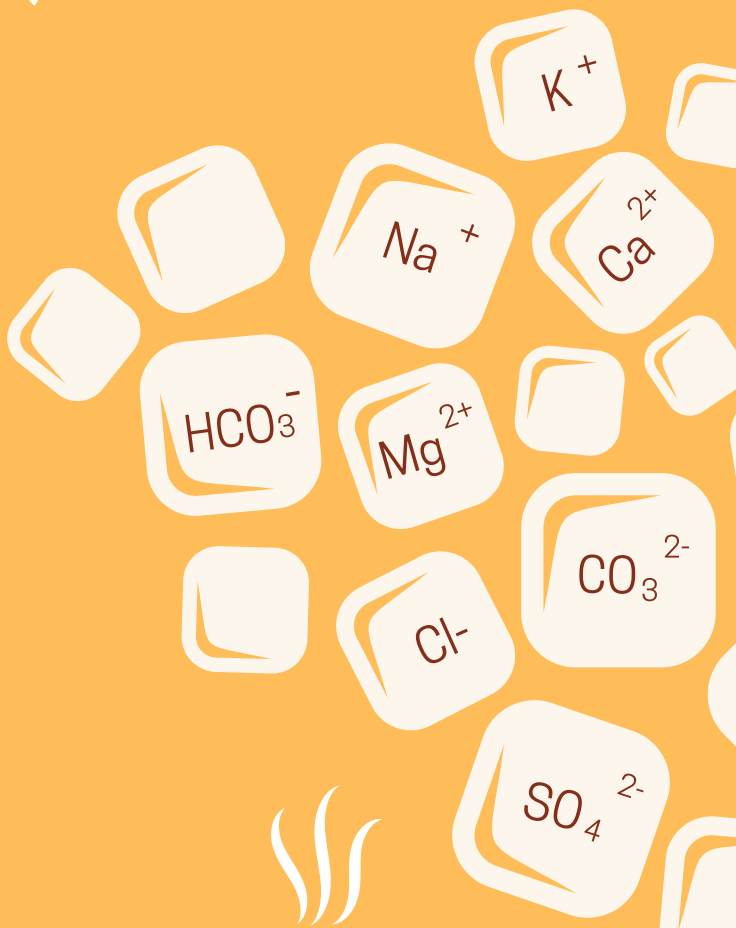
1 Wall, Nielsen and Six (2015)
2 FAO (2020)

Primary and secondary salinization [3]

Soil salinization occurs when there is a gradual increase, gain, or accumulation of soluble salts in the soil. These salts are potassium, magnesium, calcium, chlorides, sulphates, carbonates, bicarbonates and sodium. When it comes to the increase in the percentage of sodium there is talk of **sodification** of the soil.

Primary or natural salinization involves the accumulation of salt due to a high salt content in the soil itself or in groundwater. Secondary salinization is caused when people mishandle the soil.

Discover:
What salt does each symbol correspond to?



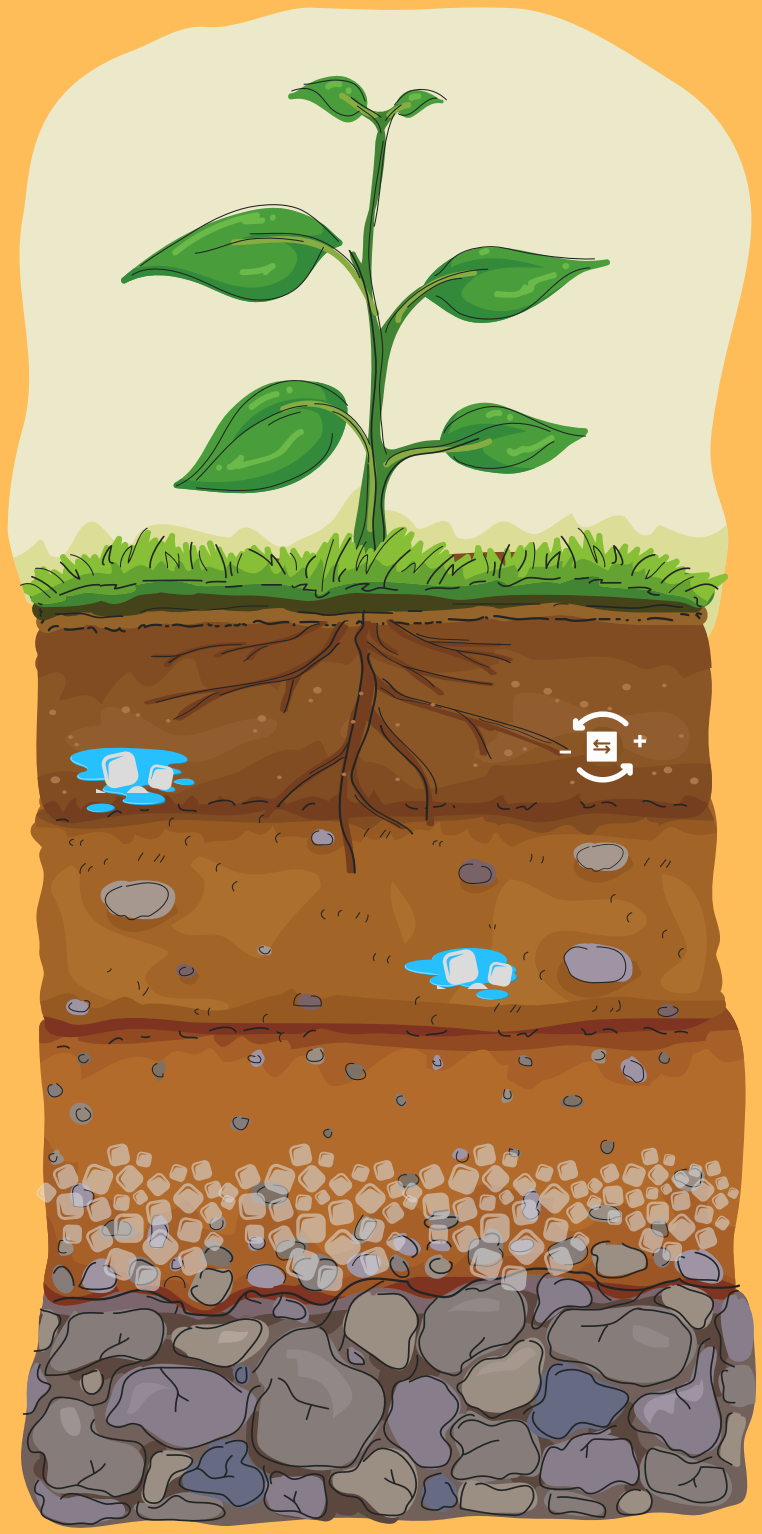
3 Singh (2021)

State of salts in soil[4]

Salts can be found in different states in the soil:

- Precipitated in the form of crystals
- Dissolved in soil water
- Retained in plant uptake change complex

Find the three states of salts in the ground



These three states are highly variable and depend on various factors such as climate, seasons, rainfall, evapotranspiration, land use and management. During the dry season, the number of dissolved salts decreases, while during the wet season, the number of precipitated and retained salts decreases. The balance of these three states depends on the structure of the soil, its fertility and health.

4 Pickering (1985)

Main Causes of soil salinization [5]

The soil can be salinized and/or sodified due to natural factors such as the material of the mother rock that is under the ground or in a nearby area, the topography, the climate, the wind and the type of vegetation. But also by the infiltration of groundwater into areas below sea level. In addition, there are some human activities that accelerate soil salinization:

- Excess soil irrigation with poorly drained irrigation systems or brackish water irrigation from saline aquifers, sewage or industrial by-products
- Deep or conventional soil tillage
- Deforestation or loss of vegetation cover
- Excessive groundwater abstraction in coastal areas
- Overuse of fertilizers and other chemical inputs
- Overexploitation of land for agricultural activities

Note in the illustration the inappropriate practices that cause soil salinization

5 Okur and Örçen (2020)

Environmental impacts of soil salinization [6]

Soils with high content of soluble salts and/or high amounts of sodium ions, have difficulties in the exchange of water and nutrients with the roots of plants. Consequently, most plants that are not tolerant to salt die, as well as most animals that live in the soil, being replaced by other plants and animals that adapt to these conditions. In this way, the soil degrades rapidly, losing structure and fertility; thus the ecosystems are transformed into arid and desert zones, an issue that increases global warming.

6 Teh and Koh (2016)

Soil salinization and food production

The amount of world agricultural land destroyed by salt accumulation each year is estimated to be 10 million ha.[7] Agricultural soils affected by salt accumulation have little capacity to produce food profitably. Salts make deeper layers of soil more impermeable, which increases compaction and decreases water infiltration. This type of saline and sodium soils are more exposed to water and wind erosion, thus progressively losing nutrients and fertility until their degradation, which causes the soil to be unsuitable for agriculture. Most crops fail to tolerate high levels of salt, saline stress causes nutritional imbalance, as well as reduced growth and development of plants, so they end up dying from toxicity. These processes drastically affect food production, putting food security in rural and urban communities at risk.[8]

7 Pimentel *et al.*, (2004)
8 Piedra and Cepero (2013)

Socio-economic impacts of soil salinization[9]

Generally, when the soils of agricultural farms undergo salinization and/or sodification, farmers increase the use of chemical fertilizers. This affects the economy of peasant families who, without land or money, are forced to abandon the fields and productive activities. As a result, rural communities migrate to urban areas in search of new livelihoods, leading to land encroachment and urban sprawl. This situation has serious consequences for the well-being of communities as food shortages, hunger and poverty increase.

9 Salvati and Ferrara (2015)

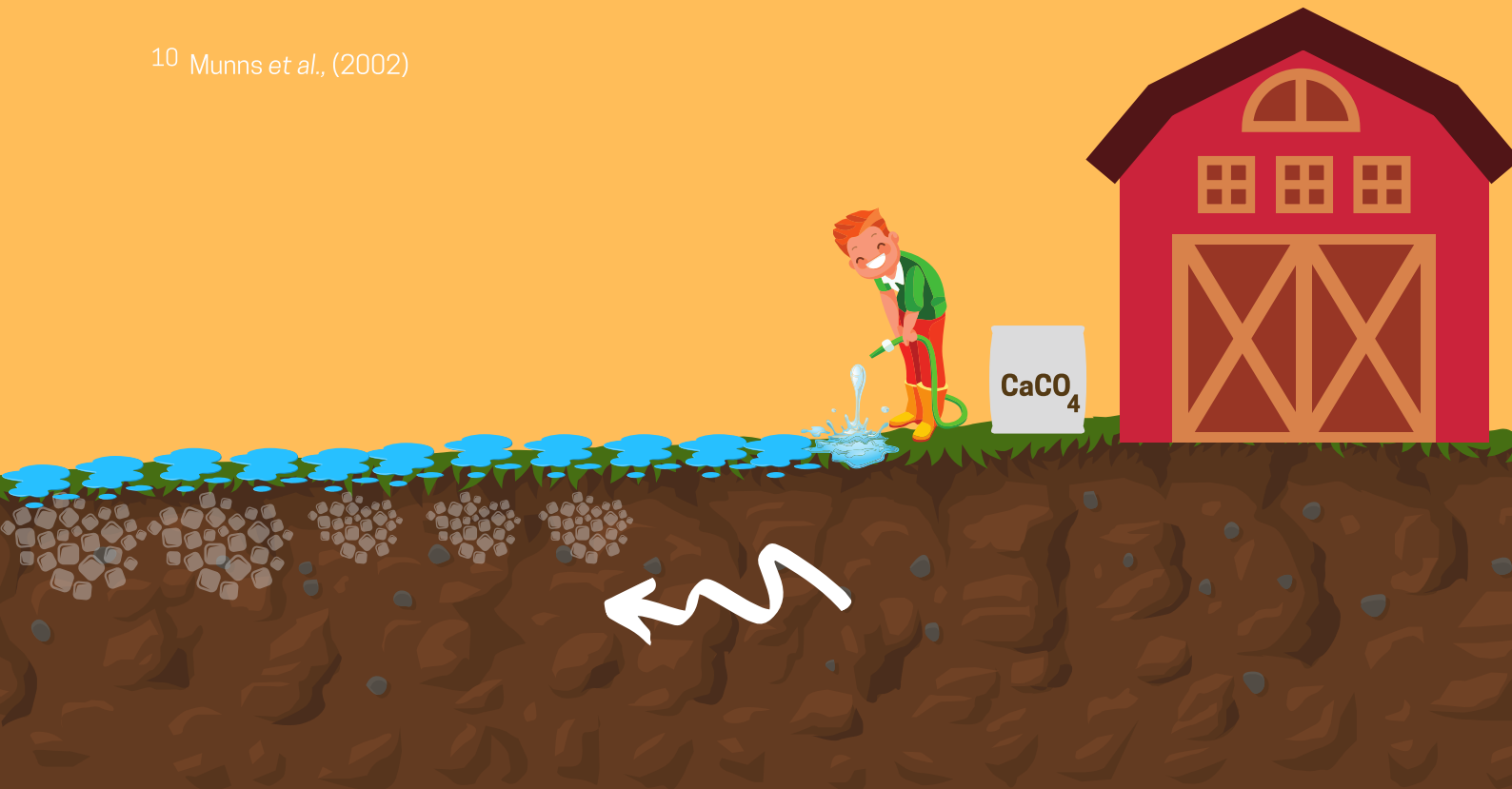
Sustainable Management of salt-affected soils

Washing soil [10]

Soil salinity and sodicity are problems too difficult to overcome, requiring salt washing from the root zone. However, in addition to being slow and expensive, the process requires large quantities of quality water and effective soil drainage. It is not always easy to obtain enough quality water, because the possible water sources next to the soils to be treated may already themselves be highly saline.

In case the sodic soils, the reclamation involves substituting sodium in the soil with calcium ions, through applying large quantities of gypsum. Gypsum, when slowly mixed with water, releases calcium ions, which replace sodium ions from the soil into the downward moving water. Sulfuric acid and elemental sulfur can also be used as alternatives to gypsum.

[10] Munns *et al.*, (2002)



Sustainable Management of salt-affected soils

Correct fertilization

Crop fertilization is one of the sources of salinization of soils. To reduce this negative impact, the fertilizer characteristics and the method of fertilizer application. Excessive nutrient applications must be avoided, and high-purity, chloride-free, low-saline fertilizers should be selected. The application of fertilizers through irrigation water (fertigation) can reduce soil salinization and mitigate salt stress effects because it improves the efficiency of fertilizer use, increases nutrient availability and timing of application, and the concentration of fertilizers are easily controlled.[11]

Humic substances and biofertilizers can ameliorate the deleterious effects of salt stress by increasing root growth, improving uptake, thus inducing salt tolerance.[12]

[11] Machado and Serralheiro (2017)

[12] Ouni *et al.*, (2014)

Sustainable Management of salt-affected soils

Efficient irrigation and drainage

Irrigation method, irrigation scheduling and artificial drainage can prevent and mitigate the effects of soil and water salinity. For better salinity management is advisable to use irrigation methods such as surface drip irrigation and subsurface drip irrigation. An appropriate irrigation scheduling with these methods can also reduce the effects of salinity by continuously maintaining moist soil around plant roots and providing steady washing of salt to the edge of the wetted zone. If soil drainage is poor and the water table is shallow, it is recommended an artificial drainage system must be installed.[13]

In addition, to ensure long-term land use with irrigated vegetable crops, it is necessary to do a maintenance leaching. The volume of water applied with irrigation must include a water amount that drains down the root zone, which is in addition to the amount required for normal irrigation.[14]

[13] Malash *et al.*, (2008)
[14] Letey *et al.*, (2011)

Sustainable Management of salt-affected soils

Genetic improvement

Salinity tolerance is a desirable attribute of plants that are sought in laboratories through genetic improvement. This is achieved by the selection and recombination of species to obtain such a character. The success of these processes depends on the availability and extent of genetic variability within the species concerned. Genetic improvement becomes a tool that offers an increase both in the recovery of underutilized areas, and in yields in those areas where salinity is a limiting factor of agricultural production. To do this, many scientists are working to obtain varieties resistant to salinized soils. Among these, the incorporation of genes from tolerant wild parents, the domestication of wild halophiles and the identification of traits related to high tolerance are of particular interest. The intention is to produce these varieties in laboratories and then share them with farmers to improve productivity in the field. [15]

[15] González *et al.*, (2000)

To Finish

So far we have learned a little about the salinization and sodification of soils, a complex problem that is increasing the desertification of large agricultural and non-agricultural areas in different parts of the world. Undoubtedly, as soil salinization increases, so do environmental, social, and economic impacts. Therefore, this issue should interest us all because it affects not only the biodiversity of our ecosystems, but also the sustainable production of food. We must understand as humanity that we depend heavily on the soil to eat daily and that the quality of the soil conditions the quantity and availability of food in our dishes.

Fortunately, there are already some technical solutions for sustainable soil management, which must be socialized with people in the countryside to be implemented. However, less costly solutions need to be sought to halt soil salinization and increase soil productivity. It is important that we continue to learn about the soil a wonderful ecosystem that offers multiple environmental services, but that currently suffers serious degradation problems.

References

1. Wall, D. H., Nielsen, U. N., and Six, J. (2015). Soil biodiversity and human health. Nature, 528(7580), 69-76.
2. Food and Agriculture Organization of the United Nations (FAO) (2020). Global Map of Salt-affected Soils (GSASmap).
3. Singh, A. (2021). Soil salinization management for sustainable development: A review. Journal of Environmental Management, 277, 111383.
4. Pickering, W. F. (1985). The mobility of soluble fluoride in soils. Environmental Pollution Series B, Chemical and Physical, 9(4), 281-308.
5. Okur, B., and Örçen, N. (2020). Soil salinization and climate change. In: Vara, P.M., and Pietrzykowski, M. (eds.) Climate change and soil interactions. Elsevier, pp. 331-350.
6. Teh, S. Y., and Koh, H. L. (2016). Climate change and soil salinization: impact on agriculture, water and food security. International Journal of Agriculture, Forestry and Plantation, 2, 1-9.
7. Piedra, A. L., and Cepero, M. C. G. (2013). La salinidad como problema en la agricultura: la mejora vegetal una solución inmediata. Cultivos tropicales, 34(4), 31-42.
8. Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E., and Nandaopal, S. (2004). Water Resources: Agricultural and Environmental Issues. BioScience, 54, 909–918.
9. Salvati, L., and Ferrara, C. (2015). The local-scale impact of soil salinization on the socioeconomic context: An exploratory analysis in Italy. Catena, 127, 312-322.
10. Munns, R., Husain, S., Rivelli, A.R., Richard, A.J., Condon, A.G., Megan, P.L., Evans, S.L., Schachtman, D.P., and Hare, R.A. (2002). Avenues for increasing salt tolerance of crops, and the role of physiologically based selection traits. Plant Soil, 247, 93–105.
11. Machado, R. M. A., and Serralheiro, R. P. (2017). Soil salinity: effect on vegetable crop growth. Management practices to prevent and mitigate soil salinization. Horticulturae, 3(2), 30.
12. Ouni, Y., Ghnaya, T., Montemurro, F., Abdelly, C., and Lakhdar, A. (2014). The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. Int. J. Agron. Plant Prod., 8, 353–374.
13. Malash, N.M., Flowers, T.J., and Ragab, R. (2008). Effect of irrigation methods, management and salinity of irrigation water on tomato yield, soil moisture and salinity distribution. Irrig. Sci., 26, 313–323.
14. Letey, J., Hoffman, G.J., Hopmans, J.W., Grattan, S.R., Suarez, D., Corwin, D.L., Oster, J.D., Wu, L., Amrhein, C. (2011). Evaluation of soil salinity leaching requirement guidelines. Agric. Water Manag., 98, 502–506.
15. González, L. M., Zamora, A., and Céspedes, N. (2000). Análisis de la tolerancia a la salinidad en variedades de Vigna unguiculata (L) sobre la base de caracteres agronómicos, la acumulación de iones y el contenido de proteína. Cultivos Tropicales, 21(1), 47-52.

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