The impact of soil salinity on our food security

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Soil is a vital resource for feeding the burgeoning global population, expected to reach over 9.8 billion people in 2050 (United Nations, 2020), and is a controlling variable of the hydrological processes of the planet, supplying products and services fundamental to maintaining life and prosperity. Presence of excess salts in the soil make it saline, and pose a significant threat to farm productivity, environmental health and financial welfare. Salt accumulation in the root zone or soil surface results in loss of soil fertility and alters the soil properties, thus harmfully impacting the soil's environmental functions and its ability to support plant growth. For instance, it restricts water intake and the soil-water capacity limit, which causes surface runoff and erosion, leading to soil degradation, worldwide. Based on the FAO/UNESCO soil map of the world, the total area of saline soils is 397 million hectares (Mha) which is approximately 3.1% of the world's land area (FAO, 2005). Moreover, future projections of climate change and human population growth suggest that the extent of saline soils will grow accordingly.

Saline soil includes saline, alkaline and saline-alkaline soils characterized as elevated salt concentrations, elevated pH and high sodium concentrations, respectively. Saline soils have EC (of the saturated paste extract) values of >4 dS/m, ESP <15 and pH values <8.5, while alkaline soils have the corresponding values as less than 4 dS/m (EC), more than 15 (ESP) and more than 8.5 (pH) (Table 1). The high pH level in alkaline soils is mainly the result of high carbonate concentrations.

Soil salinization prompts the change or even disturbance of the characteristic natural biochemical and erosional properties. Therefore, elevated salinization levels would result in the loss of the available soil resources, affecting agricultural development and ecological well-being. If left unattended, this condition could develop into a socio-economic and human health problem in the long run.

Table 1: Classification of salt effected soils.

TABLE 1 Classification of salt-affected soils

	Soil property		
Classification	EC (dS/m)	ESP	pH
Saline soils	>4	<15	<8.5
Alkaline soils	<4	>15	>8.5
Saline–alkaline soils	>4	>4	>8.5

There are two major causes of soil salinity: natural (primary salinization), and human-made (secondary salinization). The occurrence of parent materials and physical or chemical weathering of minerals and seawater intrusion is the leading natural cause of soil salinization. Utilization of low-quality water for crop irrigation because of prolonged dry spells, in conjunction with heavy chemical fertilizers is the principal human-made practice bringing about soil salinization. The human-made salinization conditions are aggravated under poor drainage settings. Irrigated areas are more susceptible to land degradation, and over 14 km2 of fertile areas are lost per day due to soil salinization.

Over 23% of overall farmland is assessed to be saline. Information and mapping of soil salinity at temporal and spatial scales are vital for the water system and seepage management.

Impact of salinity on plant yield

Raised soluble salts such as sodium and chloride in soils are a significant risk to agriculture globally, predominantly in dry areas. In these areas, salts are inclined to build up in the soil profile because of elevated evaporative conditions that raise the osmotic stress and negatively influence soil water availability to plants. A surplus of salt in the rootzone relates to a decreased capacity to extract water. Salts alter the water's osmotic potential and restrict water movement through the root. Therefore, plant development, transpiration and productivity are diminished when soil salinity reaches the threshold. If saline environments endure, the limited quantity of salt that penetrates a plant alongside water builds up in due course and becomes toxic. These effects cause asymmetrical plant development and plant wilting. Moreover, high Na in the soil may also influence soil water correlations, bringing about the scattering of soil colloids that change the water and air movement, decreasing infiltration rate, promoting waterlogging and possibly causing anoxic situations in the rootzone. In any event, even in limited quantities, soluble salts lessen yields for some crops.

Table 2: water salinity classification

Salinity class	Salinity level (dS/m)	Effect on plant yield
Non-saline	<2	Insignificant
Slight saline	2–4	Affects only sensitive plants
Moderate saline	4–8	Affects many plants
High saline	8–16	Affects all plants except salt-tolerant ones
Very high saline	>16	Affects almost all plants except some highly tolerant ones

Different plants vary in their response to saline conditions, also within the same species (Table 3). The two main mechanisms of salinity impact on plants are the osmotic and toxicity effects. The osmotic effect occurs when salt concentrations outside the root membrane exceeds the in-root concentration, which limits the plants' ability to extract water from the soil, which in turn leads to wilting. On the other side, some of the water extraction by the plant is an active action by specific water channels in the root cells. This active water extraction along with active ion extraction pumps on the root cells, increases the total ion concentration within the plant tissues. Plants have different methods to adapt to increasing ion concentrations, by storing the excess ions in specific cells or flushing the salts through the water vascular to the leaf tips. This is why in many cases the effect of salt can be seen by burnt leaf tips.

The accumulation of salts in the root zone has adverse effects on plant growth, not only due to the low osmotic potential of the soil solution resulting in decreased availability of water to plants, but also due to the ion imbalance and ion toxicity.

Table 3: Sensitivity and tolerance level of some key crops

TABLE 3 Sensitivity and tolerance level of some key plants

Sensitive (up to 2 dS/m)	Moderately tolerant (up to 6 dS/m)	Highly tolerant (up to 10 dS/m)
• Blackberry	• Guava	• Spinach
• Tangerine	• Sunflower	• Barley
• Cherries	• Pineapple	• Date palm
• Deciduous orchard	• Maize	• Sugar beet
	• Onion	• Asparagus
• Pummelo	• Carrot	• Bermuda
• Boysenberry	• Fig	• Rye
• Avocado	• Olive	• Swiss chard
• Lemon	• Cucumber	• Cotton
• Grapefruit	• Pomegranate	• Kenaf
• Lime	• Rice	• Rapeseed
• Apple	• Oats	• Triticale
• Orange	• Grape	• Wheat, durum
• Almond	• Alfalfa	• Wheat, semi-dwarf
• Peach	• Tomato	
• Apricot	• Potato	• Wheatgrass
• Prune	• Flax	
• Pear	• Sudangrass	
• Beans	• Rye-grass	
• Peas	• Harding grass	
• Plum	• Coconut	
• Sugarcane	• Wild rye	
• Red clover		

Soil salinity and organic carbon content

Salinity affects microorganisms mainly by decreasing osmotic potential, which reduces their activity and alters the composition of the microbial community. These changes have implications for soil organic matter decomposition. Recent studies projected the loss of soil organic carbon (SOC) from saline soils across the globe due to a reduction of plant growth and reduction in microbial activity which will reduce the SOC inputs and increase the emission of the remaining carbon from these soils. This research suggests that saline soils can lose up to 17% of their SOC stock, which can reach up to 3.99 tons h^{-1}.

Projected soil salinity in drylands up to the year 2100

While we know the dispersion of salty soils around the globe today, there is a need to know what will happen in the near and far future to plan and act accordingly. To this end, a research group has developed several models to predict the global changes in saline soil distribution according to a few possible scenarios. The models, based on the output of Global Circulation Models (GCMs) were applied to new input predictor data to estimate the annual soil salinity level for each grid-cell (0.5° spatial resolution) of the global soil base map of the drylands between 1904 and 2100.

Figure 1 shows the spatial distribution of the projected change in primary soil ECe in the mid-term (2031–2060), relative to the reference period (1961–1990).

According to our long-term predictions based on all multi-model ensembles, the dryland areas of South America, southern Australia, Mexico, south-west United States, and South Africa are generally at the highest risk of increased soil salinity, compared to the reference period. The threat of climate-induced soil salinity is also projected to increase in the drylands of Spain, Morocco, and northern Algeria.

In a wider perspective, given the current and projected climate change and land use, it seems that mostly the southern hemisphere will be subject to increasing land area under saline conditions. In some regions in the northern hemisphere, the total area under saline conditions seems to decrease over time, given the projected conditions (Fig. 2).

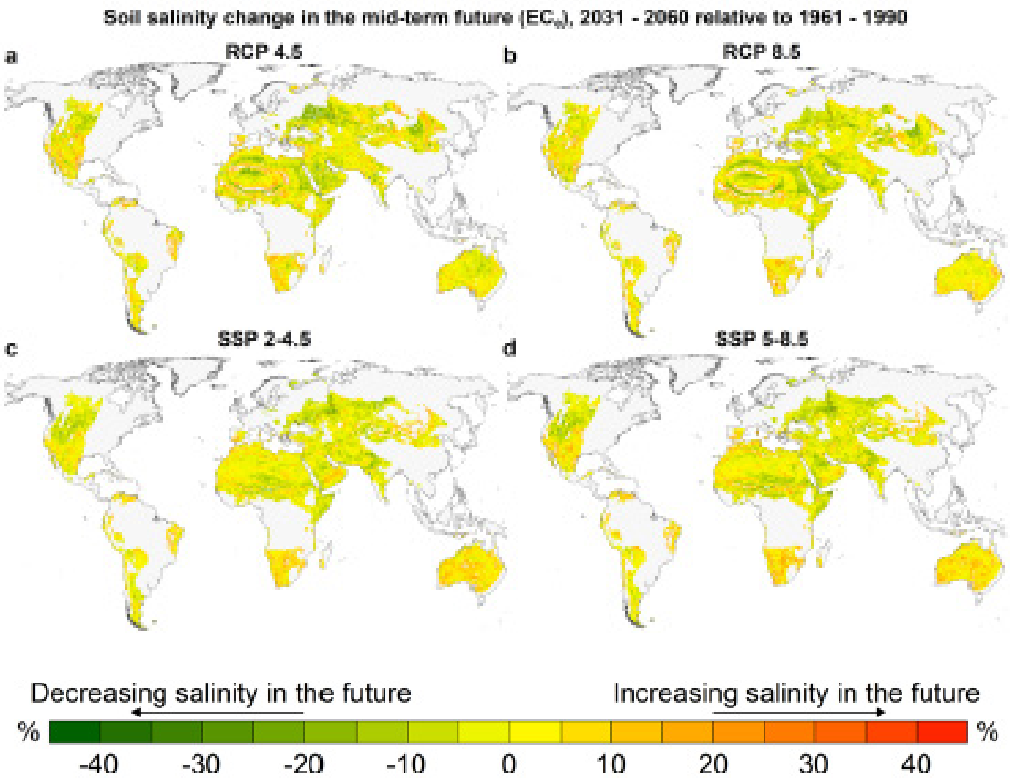

Fig. 1: Spatial distribution of the change in primary soil ECe projected by the multi-model

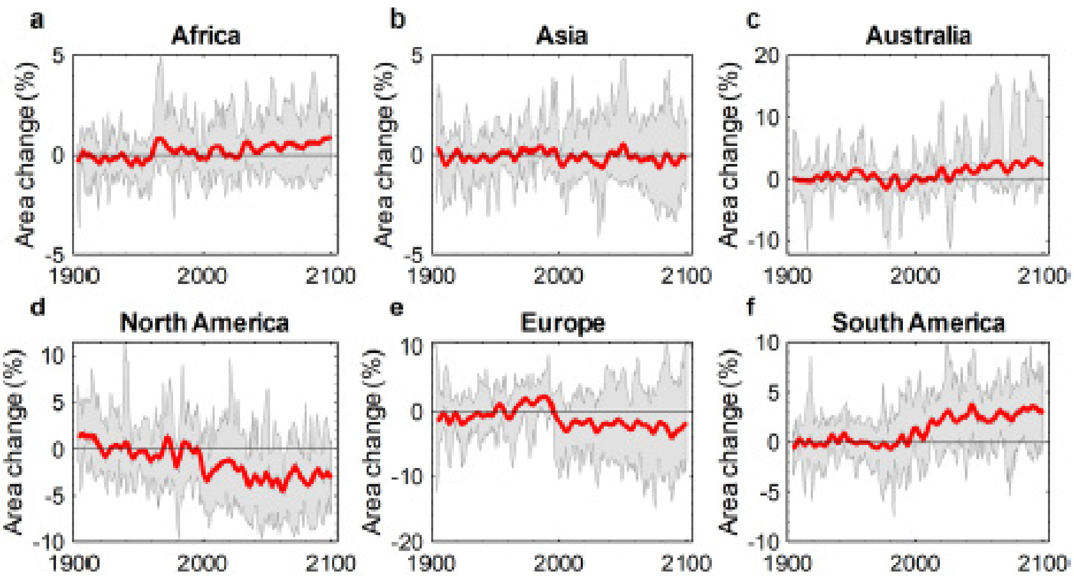

Fig. 2: Continental-level predicted annual change in the total area of soils with an ECe ≥ 2 dS m−1 relative to the 20th century average (1904–1999)

Looking forward, the future looks salty. The recent studies show various trends in salt accumulation across the globe where some gain and some lose. Those trends threat the capacity of agriculture to supply the future food demand for the rapidly increasing population. In addition, as a result of climate changes, water availability and soil degradation, the main cropping areas of today might not be as fertile tomorrow, while other areas would be the main global food suppliers. That would affect the entire global political and economic map as we know it today.

Sources

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