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# Analysis of Soil Salinization as an Environmental Issue in Latin America

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## ABSTRACT

A systematic review was conducted in this study with the aim of analyzing soil salinization in Latin America. Manuscripts published in the region over the past ten years in both English and Spanish that had undergone blind peer review in journals indexed in the databases of Copernicus Publications, Nature, Science Direct, Scielo, and Redalyc were taken into consideration. Soil salinity was discovered to be a growing environmental limitation in at least 9 of the 32 countries that make up the Latin American region. Secondary salinization spreads as a result of changes in land use brought on by the expansion of the agricultural frontier, poor irrigation management using low-quality water, and excessive use of chemical fertilizers, among other things.

**Keywords:** soil, Latin America, soil salinization.

## INTRODUCTION

The excessive accumulation of soluble salts on the surface of the soil is known as salinization, and it has a detrimental effect on agricultural productivity, biodiversity, and sustainable development. Soil salinization is one of the most significant environmental hazards in the world, leading to severe land degradation and desertification. Saline soils are primarily found in dry and semi-arid locations where evapotranspiration exceeds precipitation as well as in coastal regions as a result of seawater intrusion and coastal tidal floods (Periasamy & Ravi, 2020; Zhu et al., 2023).

Salinization of soil is a process that involves the evaporation of salt, the precipitation and dissolution of salt, the transport of salt, and the exchange of salt ions (Peng et al., 2023; J. Wang et al., 2023). Natural soil salinity, also known as primary soil salinity, is caused by the presence of salt in arid climates (Jat et al., 2023; Gopalakrishnan & Kumar, 2020). Secondary soil salinity is a term used to refer to soil that has been salinized as a result of direct human activity (Das et al., 2020; Khosravichenar et al., 2023). In the initial stages of salinity, soil organisms are adversely affected and the productivity of the soil is reduced (Pessoa et al., 2022; Vengosh, 2003). However, in the more advanced stages, vegetation and other soil organisms are destroyed, resulting in the transformation of fertile and productive land into land that is arid and deforested (Gao et al., 2021; Herrero & Castañeda, 2021).

The industrialization of the world, the unplanned urbanization of many countries, climate change and various types of land degradation are all contributing to a rapid decline in land availability for agriculture, particularly in developing nations (Bhuyan et al., 2023; Yang et al., 2023). Additionally, salt-affected soils account for nearly half of the irrigated land in the world, as reported by (Jia et al., 2023; 5. Mukhopadhyay et al., 2021). It has been estimated that over 800 million hectares of the world are affected by salinity, and this number is projected to rise; by 2050, it is estimated that more than half of arable land worldwide will be salinized (Ge et al., 2022; L. Wang et al., 2023).

It is estimated that the impact of soil salinization due to inadequate irrigation practices is responsible for the destruction of approximately 60 million hectares of irrigated land globally, representing 24% of the total irrigated land area. Salinization is the initial stage of environmental degradation caused by salinity, and is linked to the salinity of rivers and lakes (Negacz et al., 2022; Singh, 2021). Latin America is responsible for 14% of the degraded lands in the world. This region is characterized by a geological history, topographical features, climate and vegetation, which have resulted in a high diversity of soil types, with over 30 types of soils. Furthermore, Latin America is home to the largest concentration of megadiverse countries on the planet, with 6 of the 17 largest countries in the world being located in Latin America (Gardi et al., 2014). Therefore, the aim of this study was to conduct a systematic review of soil salinization in Latin America.

## METHODOLOGY

With the stated purpose in mind, the applied approach responds to a comprehensive assessment of studies on soil salinization that have been compiled in Latin America for the years 2013–2023 (administrative boundaries are shown throughout Fig. 1a). The environment of Latin America and the Caribbean is incredibly diverse, ranging from deserts and seasonally dry regions in the west to the massive rainforests of the Amazon basin, and from coastal lowlands with mangroves to the high mountain ranges and volcanoes of the Andes, in turn, this results in a very diverse spectrum of soils.

As seen in Figure 1b, soils from arid regions make up roughly 16% of South America. Entisols of alluvial fans, piedmonts, and floodplains make up the majority of Entisol areas in Argentina and Bolivia, while shallow soils over marine deposits predominate in Chile and Peru; the arid region's alfisols are confined to northeastern Brazil; on the tropical Caribbean coast of Colombia and Venezuela, in western Argentina, as well as in the cold Altiplano and Patagonia, aridisols predominate, saline soils are widespread in the southern part of the continent, and soils affected by sodium are frequent in the semi-arid regions of Argentina, Bolivia, and Paraguay (Dregne, 1976). The northern part of the Mollisol area is situated in the forests and savannahs of the Gran Chaco, while the southern part is located in the western extension of the Argentine pampa grasslands.

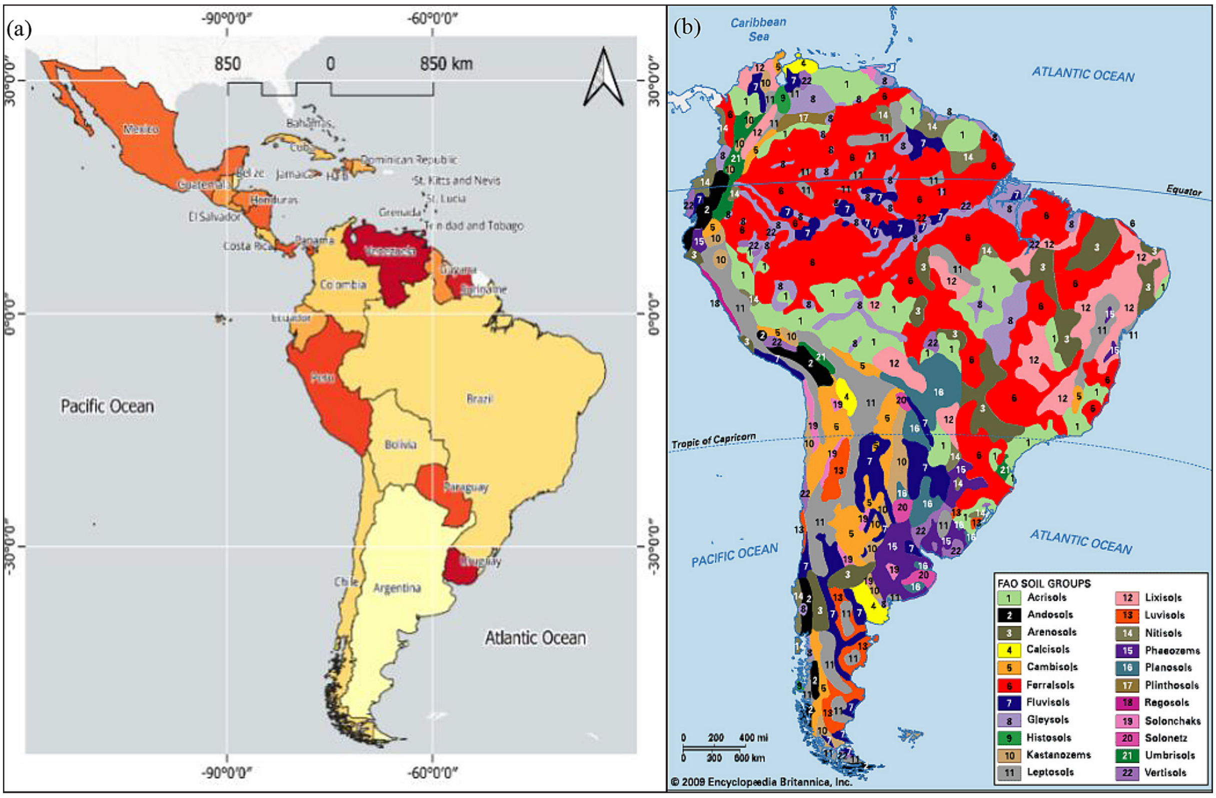


**Figure 1.** (a) administrative boundaries of Latin America; (b) Soils of South America, according to FAO groups. Retrieved from: https://cdn.britannica.com/44/127444-004-0AC60573/Distribution-soil-groups-South-American-Food-and.jpg

### Definition of inclusion and exclusion criteria

The proposal from Ahn & Kang (2018) was modified to define the criteria for the research's development. The following factors were taken into account for the inclusion criterion: articles written in English and Spanish that have been published in the past ten years in the region of Latin America and that have undergone blind peer review in journals indexed in the databases of: Copernicus Publications, Nature, Science Direct, Scielo, and Redalyc; Keywords like "soil salinization", "increased soil salinity," and "soil salinity consequences" were used during the search.

In order to present a perspective that suits the outcomes of this issue in the real environment, studies that concentrate on laboratory experiments were omitted. To prevent producing mistakes in the results provided, publications with references but no blind peer review were also disregarded (Félix et al., 2023; Heyn et al., 2019).

## SALINIZATION OF THE SOIL IN LATIN AMERICA

In general, research on the extent and distribution of soils affected by salinity are out-of-date and imprecise (Pla, 2021). This is due to the huge heterogeneity of Latin America, which includes nations with a variety of natural resource and economic availability. Latin America is third globally in terms of surface area with soils impacted by salt, according to information presented at the World Symposium on Soils impacted by Salt, sponsored by the Food and Agriculture Organization of the United Nations (Lavado, 2021).

Table 1 provides a complete summary of the most important findings on soil salinization by nation. Several countries are left out of this picture because the necessary investigations have not yet been conducted, according to what has been reported to date.

**Table 1**. Estimates of soil salinization in Latin America, organized by nation

| Country | Impact | Reference |
|---|---|---|
| Cuba | More than 1,000,000 hectares of land between salinized and saline conditions, or around 15% of the nation's agricultural land. | (Lavado, 2021; O'Farrill et al., 2018) |
| | Salinity in Solonchaks, as well as potential or actual salinity in Gleysols, Vertisols, and Fluvisols, as also in some Cambisols and Ferralsols | (Gardi et al., 2014) |
| Dominican Republic | Salinity and sodicity have an impact on about 80,000 hectares, mostly in the eastern region of the nation. | (Pla & Gómez, 2019) |
| Colombia | Salinity rises in direct proportion to wastewater transit and drainage of water containing high levels of pesticides and fertilizers. | (Echeverri et al., 2016) |
| Venezuela | By using large quantities of chemical fertilizers and pesticides, salinization of soils is assessed in monoculture systems. | (Pastor et al., 2015) |
| | Around 90,000 irrigated hectares are thought to be impacted by varied salt and sodicity levels. | (Lavado, 2021) |
| Brazil | The relationship between agricultural management and desertification is strongly influenced by salinization. | (Coelho & Dos Santos, 2020; Lavado, 2021) |
| | There is proof that at least 25–30% of the irrigated land has been affected by salinization processes. | (Lavado, 2021) |
| Ecuador | Due to the usage of salty water, which results in the buildup of salts, soils used for rice crops are salinized. | (Cobos et al., 2021) |
| Peru | Intense salinization brought on by the expansion of irrigation water volume (Gallito Ciego dam). | (Gamboa et al., 2021) |
| | Salinization issues were discovered in around 300,000 irrigated hectares, with 150,000 hectares having severe salinity levels. Soil salinity is a problem that affects over 40% of the Peruvian coast's entire agricultural area. | (Lavado, 2021) |
| Mexico | Chemical damage (7%), caused by excessive fertilizer use and irrigation of crops with low-quality water, causes varying degrees of salt in the soil. | (Gardi et al., 2014) |
| | Salinity or sodicity has affected between 70,000 and 140,000 hectares. | (Lavado, 2021) |
| Argentina | Maximum salinization was observed in tree plantations near the water table, indicating that groundwater uptake and solute exclusion by tree roots may be the major salinization mechanism. | (Nosetto et al., 2013) |
| | 423,000 hectares are impacted by salinity or sodicity to variable degrees, ranging from 11% in the north to 36% in irrigated areas in the south. | (Lavado, 2021) |

Soil salinity, as outlined in Table 1, is an increasing environmental limitation observed in many locations throughout Latin America. Highly saline soils support naturally adapted plants in non-irrigated dry and semi-arid locations; yet, saline soils are also present in irrigated places where intensive agriculture is conducted. It has also been linked to recent agricultural growth, which has resulted in substantial forest destruction (Taleisnik & Lavado, 2021).

According to research conducted in Mexico, the causes of salinization of agricultural soils in crop plots near Lake Texcoco (northeast of the country) are: poor irrigation management, use of low-quality water for irrigation, and excessive use of chemical fertilizers (Santoyo et al., 2021). On the other hand, it has been demonstrated that changes in land use, different forest species, and silvicultural management cause changes in the magnitude of salts accumulated in soil; however, these differences are reversible and do not have such a large impact on agricultural or forestry crops (Milione et al., 2020). It has also been linked to recent agricultural growth, which has resulted in substantial forest destruction (Taleisnik & Lavado, 2021).

The negative effects on the yield and quality of crops also result in social and economic costs, which immediately affect the communities established in these environments and, obviously, society as a whole (Ramos et al., 2023; Taleisnik & Lavado, 2021). These impacts are related to the susceptibility of plants in general, and crops specifically, to these conditions. A lower expression of salt accumulation processes can therefore go hand in hand with the proper selection of the species and adequate management of cutting shifts, plantation densities, thinning, and hedging. At the same time, it has been reported that understanding the dominant plant species and management are key factors to take into account, due to their rapid impact on the salt flows of the system (Milione et al., 2020).

The aridity index, soil texture, and fertilization techniques are the most significant factors, followed by the drainage system and water level depth, according to the results of the model used by Echeverri (2022) to assess soil vulnerability to salinization. Salinization of Colombian soils is caused by low irrigation water application efficiency, poor fertilization methods, clay soil textures, and a lack of subsurface drainage systems (Echeverri et al., 2016).

## SOIL SALINIZATION AND CLIMATE CHANGE

The changing temperature regime has caused major alterations in the precipitation pattern over the last 150 to 200 years, resulting in notable variability in natural vegetation, soil properties and land use practices, soil temperature, the composition of soil gases, the biological parameters of the soil, the character of the litter horizon, the intensity of cryoturbation phenomena, the salt content, and the organic matter content of the soil, among others (Okur & Örçen, 2020).

Hassani et al. (2021) advise that the expected hydrological repercussions of climate change may result in physical, biological, biochemical, and chemical degradation of soils, and that this is one of the major dangers to soil stability, fertility, and biodiversity. Soil salinity is a major and growing concern in a warmer world; simulations suggest that by the end of the twenty-first century, dry areas of South America and Mexico are at risk of greater soil salinity due to climate change, compared to the reference period (1961–1990). In general, altering climatic conditions caused by global warming and growing aridity would contribute to the salinization of hydromorphic soils; arid regions are especially vulnerable to desertification and soil salinization (Okur & Örçen, 2020).

Climate change has a wide range of negative environmental effects on soil salinity and groundwater. As a result, climate-smart salinity management strategies may give alternative avenues to relieve salinity and its environmental consequences. Applying biochar could reduce $CH_4$ emissions from salt-affected soils by 28% to 68%, whereas applying manure could reduce N2O emissions by around 50% (Nguyen et al., 2020).

## FUTURE OUTLOOK ON SOIL SALINIZATION IN LATIN AMERICA

There is an obvious and pressing need to estimate the extent of salinity-affected soils, their expansion, and their potential to support agriculture and forestry without further land degradation. If these areas are to be cultivated, they must be managed with care through innovative management, new kinds of agriculture, and the utilization of novel genetic resources (Taleisnik & Lavado, 2021). These concerns apply to all continents, as well as the three major Latin American countries of Mexico, Argentina, and Brazil. These are the mainstays of global cattle and sugar production, also soybeans, corn, and a variety of other agricultural items.

The challenges created by this problem have inspired research efforts to overcome them. As a result, it is deemed critical to simulate the state of soil resources worldwide with increasing detail in order to analyze and respond to global and local concerns such as soil salinization (Armas et al., 2023; Mujica et al., 2019). Rodriguez et al. (2019) discovered that it is possible to use halophilic bacteria isolated from saline environments as a possible alternative for the rehabilitation of salinized soils in Colombia, with a direct effect of halophilic bacteria on the decrease in the electrical conductivity of the soil, going from 5.2 to 3.0 ds/m.

## CONCLUSIONS

The findings of this study provide scientific evidence that soil salinization has become an environmental issue in 9 of the 32 countries that comprise the Latin American region. Because the availability of adequate cropland is impacted, agricultural development (food production) and, as a result, the region's sustainability and food sovereignty are jeopardized. As a result, the impact of salinity on soils is an issue with a growing trend that must be addressed in each nation's policy formulation, allowing the consolidation of viable long-term alternatives with environmentally rational and socioeconomically viable mitigation approaches for recovery. of salinized soils capable of adapting to the biophysical and socioeconomic conditions of Latin America's diverse communities.

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