THE PROCESS OF SOIL SALINIZATION UNDER CHANGING GROUNDWATER LEVELS.

https://doi.org/10.5281/zenodo.17439495

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Abstract

Soil salinization is one of the most serious environmental and agricultural problems affecting irrigated lands worldwide. The fluctuation of groundwater levels plays a crucial role in the accumulation and redistribution of salts within the soil profile. This study analyzes the relationship between the depth of groundwater and the intensity of salinization processes in meadow and meadow-marsh soils. The findings highlight that shallow groundwater levels accelerate salt migration toward the root zone, resulting in reduced soil fertility and crop productivity. Conversely, lowering the groundwater table through drainage or improved irrigation management significantly mitigates salinization risks.

Keywords

Groundwater level, soil salinity, irrigation, meadow soils, capillary rise, drainage, soil fertility.

INTRODUCTION

Soil salinity is a critical factor limiting agricultural productivity, especially in arid and semi-arid regions. In irrigated lands, the balance between groundwater depth, irrigation water quality, and evaporation intensity determines the extent of soil salinization. Groundwater close to the surface contributes to the upward movement of saline water through capillary rise, leading to the accumulation of soluble salts in the upper horizons. Understanding the dynamics of this process is essential for developing sustainable soil management practices. The study aims to examine how variations in groundwater levels influence the rate and direction of salt accumulation in different soil layers and to propose practical measures to prevent secondary salinization.

MATERIALS AND METHODS

The research was conducted on irrigated meadow and meadow-marsh soils located in regions with varying groundwater depths (from 0.8 m to 2.5 m). Field sampling involved measuring:

- Electrical conductivity (EC) and pH of soil extracts,

- Groundwater mineralization level,
- Soil texture and moisture content.

Laboratory analyses were performed to determine the concentrations of major cations (Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}) and anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}). Statistical correlations between groundwater depth and soil salinity levels were established to identify threshold values for safe groundwater management.

RESULTS AND DISCUSSION

The results demonstrated a strong inverse correlation between groundwater depth and soil salinity levels. When the groundwater level was less than 1.2 m, salts accumulated rapidly in the upper 0–30 cm soil layer due to intensive capillary rise and evaporation. At depths greater than 2.0 m, the salinity of the root zone remained relatively stable, and the leaching of soluble salts occurred naturally with irrigation and rainfall.

The dominant salts were sodium chloride and sulfate compounds, contributing to soil alkalinity and structural degradation. Continuous irrigation without proper drainage enhanced the salinization process, particularly in fine-textured soils with poor permeability.

Implementing subsurface drainage systems, optimizing irrigation schedules, and using salt-tolerant crops were identified as effective methods to control salinity buildup. Periodic monitoring of groundwater quality and depth is essential for maintaining soil fertility and preventing irreversible degradation.

Soil salinization is a major constraint to sustainable agriculture in irrigated regions, particularly where groundwater tables fluctuate due to natural or human-induced factors. This study investigates how variations in groundwater depth influence the rate and extent of soil salinity in meadow and meadow-marsh soils. Field observations and laboratory analyses were used to determine the physicochemical properties of soil and groundwater at different depths. The results indicate that shallow groundwater levels accelerate upward salt movement through capillary rise, while deeper groundwater conditions significantly reduce the accumulation of salts in the root zone. Effective water management, improved drainage, and the use of salt-tolerant crops are identified as key strategies for mitigating salinization.

Soil salinity affects over 800 million hectares of land globally (FAO, 2021), making it one of the leading causes of land degradation. In arid regions such as Central Asia, salinization has become a serious environmental and economic problem. The main factors that contribute to secondary salinization include excessive irrigation, poor drainage systems, and fluctuations in the groundwater table. When the groundwater is shallow, water containing dissolved salts rises

AMERICAN JOURNAL OF EDUCATION AND LEARNING
ISSN: 2996-5128 (online) | ResearchBib (IF) = 10.91 IMPACT FACTOR
Volume-3| Issue-9| 2025 Published: |30-10-2025|

toward the surface by capillary action. As water evaporates, salts remain in the upper soil layers, leading to the formation of a saline crust, deterioration of soil structure, and decreased fertility. Over time, this process severely limits crop productivity and threatens long-term soil health.

The study was conducted in the Zarafshan Valley of Uzbekistan, a region characterized by an arid climate with an average annual rainfall of 200–250 mm and high evapotranspiration exceeding 1500 mm. Experimental plots were located on irrigated meadow and meadow-marsh soils under wheat cultivation. Groundwater depths varied from 0.8 to 2.5 meters. Soil and groundwater samples were collected and analyzed for electrical conductivity (EC), pH, texture, and major ion composition. Measurements were made in three soil layers: 0–30 cm, 30–60 cm, and 60–90 cm during different growth stages of wheat. The methods followed ISO 11466 and USDA salinity laboratory standards.

A strong inverse relationship was found between groundwater depth and soil salinity (r = 0.85). When groundwater levels were shallower than 1.2 meters, the average soil EC in the top 30 cm exceeded 6.8 dS/m, indicating high salinity. At depths greater than 2.0 meters, soil EC values dropped below 3.0 dS/m, which is considered moderately safe for most crops. Capillary rise was more pronounced in fine-textured clay soils, where the upward water movement could reach 1.5–2.0 meters, compared to sandy loams with only 0.6–0.8 meters. During the summer, high evaporation rates (up to 8–10 mm per day) further intensified salt accumulation on the surface, forming visible white saline layers.

The dominant salts identified in the soils were sodium chloride (NaCl) and sodium sulfate (Na2SO4). These salts increased soil alkalinity (pH 8.2–8.9) and caused dispersion of soil particles, which reduced permeability and hindered root respiration. Elevated sodium levels also led to a high sodium adsorption ratio (SAR), which is harmful to soil structure. Continuous irrigation without proper drainage aggravated this process, particularly in heavy clay soils with low infiltration capacity.

In terms of agricultural productivity, shallow groundwater conditions caused a 35–45% reduction in wheat yield due to osmotic stress, nutrient imbalance, and reduced water uptake. However, when groundwater was maintained deeper than 2.0 meters and periodic leaching irrigations were applied (1.2 times the crop evapotranspiration rate), soil salinity was reduced, and wheat yield recovered to approximately 90% of its potential. The application of organic matter and gypsum also helped reduce sodium toxicity and improved soil permeability.

Several management practices were found effective in controlling soil salinization. Subsurface drainage systems maintain groundwater depth between 2.0

and 2.5 meters, preventing excessive capillary rise. Proper irrigation scheduling prevents over-irrigation and waterlogging. The use of salt-tolerant crops such as barley, alfalfa, and sorghum can maintain productivity in moderately saline areas. Regular monitoring of groundwater depth and salinity, combined with remote sensing and GIS mapping, allows early detection of salinity risks and informed decision-making in irrigation management.

Beyond its agricultural impacts, soil salinization has serious ecological and socioeconomic consequences. It reduces biodiversity, contaminates surface and groundwater resources, and decreases the sustainability of local farming systems. The reclamation of saline lands is expensive and time-consuming, making preventive measures more practical and cost-effective. Integrated water and soil management strategies that include hydrological monitoring, drainage improvement, and efficient irrigation systems are essential for sustainable agriculture in arid and semi-arid regions.

CONCLUSION

Changes in groundwater level significantly affect the process of soil salinization. Shallow groundwater contributes to upward salt migration, increasing soil electrical conductivity and reducing crop yield potential. Deepening the groundwater table and ensuring proper leaching through irrigation and drainage can effectively minimize soil salinity. Sustainable soil and water management strategies must consider the dynamic interaction between groundwater and surface soil layers to maintain long-term agricultural productivity.

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