

ASSESSING THE IMPACT OF SALINIZATION ON SOIL HEALTH WITHIN ROMANIA'S MACROREGION 4 (SOUTH-WEST OLTENIA AND WEST REGIONS)

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Abstract. Soil health constitutes the fundamental pillar of agro-ecosystem resilience and remains a critical prerequisite for global food security amid contemporary climate change. This study evaluates the impact of soil degradation through salinization within Romania's Macroregion 4, encompassing the South-West Oltenia and West development regions. It is an area characterized by extensive agricultural land and complex pedological diversity. The research focuses on the mechanisms of secondary salinization, using data sets compiled under the ADER 20.1.1./2023 project. An integrated methodology, combining classical soil analysis with Geographic Information Systems (GIS) techniques, was employed to identify vulnerable areas, such as the Socodor Plain in Arad County and the alluvial plains of the Danube and Jiu rivers. The findings highlight a direct correlation between suboptimal irrigation infrastructure management and the acceleration of secondary salinization via capillary rise – a phenomenon further exacerbated by recurring drought conditions. It was noticed that the elevation of the mineralized groundwater table to critical depths (below 2 meters) facilitates salt deposition within the fertile horizon, subsequently reducing the yield of primary crops. This study proposes a calibration of critical thresholds for key chemical indicators, specifically electrical conductivity (ECe) and the sodium adsorption ratio (SAR), providing a harmonized monitoring framework aligned with the objectives of the EU Soil Strategy for 2030. The analysis underscores the urgent need for a transition toward conservation agriculture and ecological restoration through shelterbelts to mitigate aridization. Ultimately, the study's conclusions provide decision-making support for prioritizing investments in drainage system rehabilitation and the implementation of no-till technologies, both essential for preserving national soil capital and adapting to increasing aridity in South-West and West Romania.

Keywords: soil health, soil salinization, secondary salinization, Macroregion 4

INTRODUCTION

Food security and the sustainability of terrestrial ecosystems rely fundamentally on the preservation of healthy soil resources, which are regarded as finite and non-renewable natural assets on a human timescale (Voicu et al., 2025). The salinization process represents one of the most severe forms of chemical degradation, recognized globally as a critical bottleneck for sustainable agricultural productivity. The Food and Agriculture Organization of the United Nations (FAO, 2021) estimates that over 20% of the world's irrigated land is affected by excessive salt accumulation - a direct threat to the security of food resources. In Romania, soil data indicate that approximately 614,000 hectares are currently affected by salinization, while other 600,000

hectares face an imminent risk of secondary salinization (DUMITRU et al., 2000; COTEȚ et al., 2010).

Macroregion 4 of Romania constitutes a vast and heterogeneous territorial unit, encompassing the South-West Oltenia Region (Dolj, Gorj, Mehedinți, Olt, and Vâlcea counties), and the West Region (Arad, Caraș-Severin, Hunedoara, and Timiș counties). This administrative configuration spans major landform units, ranging from the Western Plain (Banat and Crișana) and the Western Hills to the massifs of the South-Western Carpathians and the Getic Plateau. This geomorphological stratification leads to a complex, concentric distribution of soils, reflecting the interaction of pedogenetic factors across a significant altitudinal and climatic gradient (PATRICHE et al., 2023).

The configuration of the soil cover in Macroregion 4 follows the principles of horizontal zonality in the plains and vertical stratification in the mountainous regions, heavily influenced by parent material lithology, which ranges from loessoid deposits (in east) to alluvium and metamorphic rocks (in the west and north) (PATRICHE et al., 2023). According to the Romanian Soil Taxonomy System (FLOREA & MUNTEANU, 2012), Macroregion 4 exhibits a broad spectrum of soil classes and types, with distinct vulnerabilities to degradation processes. In the lowland areas, fertile soils of the Chernisols class predominate, alongside soils affected by gleying or vertic processes; and hilly and mountainous zones are characterized by the presence of Luvisols and Cambisols. While the Western region (e.g., the Socodor Plain in Arad County) faces salinization challenges linked to shallow mineralized groundwater and suboptimal water management (DRAGOI et al., 2022), the South-West region is marked by aggressive aridization and desertification, promoting salt accumulation in the floodplains of the Danube and Jiu rivers. The degradation of soil health through salinization is not an isolated phenomenon but emerges from a complex interplay between natural drivers, such as the excessive temperate-continental climate, and anthropogenic activities, particularly improper irrigation practices and deficiencies in drainage systems.

The EU Soil Strategy for 2030 mandates the achievement of good soil health for all soils by 2050. This requires harmonized monitoring and the definition of measurable critical thresholds for indicators such as electrical conductivity (EC_e) and the sodium adsorption ratio (SAR) (ONTEL et al., 2023; YU et al., 2025). Developed within the framework of the ADER 20.1.1./2023 project, the present study aims to evaluate the impact of the salinization process on soil health within Macroregion 4. It provides the necessary scientific foundation for calibrating national monitoring systems and prioritizing remediation measures through phosphogypsum amendments and conservation agriculture technologies.

MATERIAL AND METHODS

The evaluation of the salinization process required an integrated approach, combining GIS spatial data with in-situ soil analyses. The methodology was based on multi-criteria analysis within a GIS environment, using a comprehensive set of cartographic resources: the Soil Map of Romania (1:200,000 scale); the Map of Salt-Affected Soils and Soils Susceptible to Salinization in Romania (1:1,000,000 scale) (FLOREA, 2007); the Groundwater Map (1:1,000,000 scale); the Landform Map (1:200,000 scale); and the Climatic Map (1:500,000 scale). Additionally, topographic maps at a 1:25,000 scale were integrated as georeferenced images.

The soil health indicators selected for calibration included electrical conductivity (EC_e), the sodium adsorption ratio (SAR), soil pH, groundwater depth, and groundwater mineralization. The calibration of these thresholds was performed by correlating GIS spatial data with laboratory analytical results and crop tolerance levels (VOICU et al., 2025).

RESULTS AND DISCUSSIONS

Salinization is a chemical degradation process characterized by the excessive accumulation of soluble salts, primarily chlorides, sulfates, and carbonates, within the topsoil. This phenomenon exerts a direct toxic impact on vegetation and leads to the irreversible degradation of soil structure. In Macroregion 4, this process is identified as a medium-to-high priority issue, predominantly localized in areas with deficient natural drainage across the Western Plain (Banat), as well as within the floodplains and low-lying terraces of the Danube and Jiu rivers.

A fundamental distinction between primary (natural) and secondary (anthropogenic) salinization is essential for developing effective management strategies. Primary salinization is characteristic of areas where mineralized groundwater occurs at shallow depths, facilitating spontaneous salt crust formation, while the secondary salinization results from suboptimal irrigation water management, which inadvertently triggers salt accumulation in previously non-saline soils.

The secondary salinization process within Macroregion 4 follows a precise hydrological mechanism, characterized by the following stages:

- ✓ irrigation water input: the application of large water volumes, frequently characterized by high salt content, within irrigation schemes lacking functional drainage networks;
- ✓ water table elevation: excess irrigation water infiltrates the profile, causing the mineralized groundwater table to rise into the active root zone, often reaching critical depths of less than 2 meters;
- ✓ capillary rise and evapotranspiration: under the influence of a temperate-continental climate with high summer temperatures, mineralized water is drawn upward through the soil capillaries toward the surface. Upon evaporation, the dissolved solutes are deposited within the A horizon;
- ✓ concentration and precipitation: during prolonged drought periods, salt concentration increases significantly, surpassing the tolerance thresholds of most conventional agricultural crops.

Sodicization (or alkalization) is a frequently associated process, occurring when sodium ions (Na^+) occupy a significant proportion of the exchange complex, exceeding 13–15% of the cation exchange capacity. This condition triggers clay dispersion, the disintegration of soil aggregates, and the formation of a dense surface crust. Identifying areas affected by salinization requires the use of rigorous chemical indicators (Table 1), calibrated to reflect the severity of the degradation process. The most critical parameters for this assessment are the electrical conductivity of the saturation extract (ECe) and the sodium adsorption ratio (SAR) (FLOREA, 1994; IORDACHE et al., 2024).

The effective monitoring of salinization processes within Macroregion 4 relies upon rigorous quantitative parameters. The calibration of these indicators is essential for differentiating between transient seasonal fluctuations and permanent structural degradation.

The research findings reveal distinct degradation patterns across the analyzed geographical units, highlighting a critical vulnerability to secondary salinization in the Western and South-Western Plains. In the Socodor area (Arad County), a representative site for secondary salinization, monitoring has demonstrated that process intensity is strongly correlated with extreme drought events, which accelerate the capillary rise of salts from a groundwater table situated at depths of less than 2 meters. It was noticed that the $\text{ECe} > 4 \text{ dS/m}$ threshold is frequently exceeded within the fertile horizon when the water table rises above the 2-meter mark;

at this stage, capillary forces transport dissolved solutes to the surface, resulting in a decrease of maize crop yields by over 10%. In Dolj County, the salinization process is closely associated with the aggressive desertification of the "Oltenia Sahara". Correlated analysis indicated that the loss of organic matter (falling below the critical threshold of 2.5%) diminishes structural stability, thereby facilitating salt accumulation at the surface under the influence of intense evapotranspiration (PALTINEANU et al., 2025). Regarding sodicization, the SAR > 13 threshold was validated as a reliable indicator of soil aggregate disintegration and the formation of impermeable surface crusts, a phenomenon observed particularly in the clay-rich soils of Timiș County (MARIN, 2025).

Table 1

Chemical indicators used for identification of salinization process

Degradation Indicator	Critical threshold (Risk)	Biogeochemical impact	Pedological implications	Intervention measures
Electrical Conductivity (ECe)	> 4 dS/m	Increased osmotic pressure; inhibition of water uptake; significant decrease of biomass and crop yield	Decrease of the yield for salt-sensitive crops	Salt leaching (lixiviation) using high-quality water combined with efficient drainage systems
Sodium Adsorption Ratio (SAR)	> 13	Colloid dispersion; decreased soil permeability; root asphyxiation; surface crust formation	Clay dispersion and structural collapse of the soil matrix	Application of gypsum amendments (CaSO ₄ 2H ₂ O) to facilitate sodium-calcium exchange
Groundwater depth	< 2 m	Promotes continuous capillary rise of solutes into the upper horizons during summer periods	High risk of salinization via capillary action	Lowering the groundwater table through horizontal or vertical drainage infrastructure
Groundwater mineralization	> 1,5 g/l	Acts as a permanent source of salts for topsoil	Continuous influx of solutes into the soil profile	Water quality monitoring and limiting the phreatic supply to the root zone

Through multi-criteria analysis in GIS environment, by overlaying and weighting the data from the utilized maps, a complex map of secondary salinization on agricultural lands was generated. The surface areas occupied by lands affected by secondary salinization were calculated and are presented in Table 2 and Figure 1.

About 10% of the study area is affected by strong salinization-sodicization processes, and 5.6% is affected by moderate salinization-sodicization processes the sodicization processes, being predominant. The first category is characterized by a predominantly fine texture and groundwater table at 1-3 m, water mineralization ranging between 2-5 g/l; while the second one is characterized by fine and medium texture, groundwater at 1-3 m, water mineralization ranging from 1 to 5g/l.

Approximately 37.7% of the study is occupied by unaffected soils, but susceptible to salinization, with predominantly medium texture and groundwater at 2-5 m, water mineralization 1-2 g/l, while about 46.7% of the surface is occupied by soils unaffected by salinization processes, groundwater above 5 m.

Table 2

Distribution of lands affected by salinization processes within Romania’s Macroregion 4 (South-West Oltenia and West Regions)

Type of degradation/salinization	Area	
	ha	%
Soils strong affected by salinization/sodicization processes	106004.63	10.0
Soils moderate affected by salinization/sodicization processes	50999.17	4.8
Soils affected by salinization and/or sever risk of salinization	8439.10	0.8
Soils non-affected by salinization		
with risk of salinization	400428.21	37.7
without risk of salinization	496505.01	46.7
	1062376.12	100.0

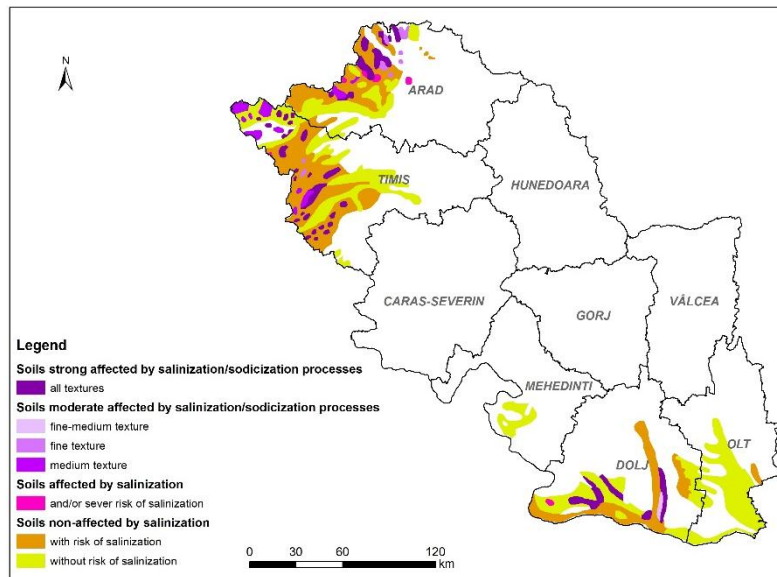


Figure 1. Representative areas for land degradation through salinization in Romania’s Macroregion 4 (South-West and West)

CONCLUSIONS

The study highlights the efficacy of an integrated approach, combining GIS spatial modeling with calibrated field data, for the identification and monitoring of secondary salinization at a regional scale. This methodology allows a high degree of precision in mapping vulnerable areas and distinguishing between transient conditions and permanent soil degradation.

The integrated assessment demonstrates that salinization represents a major threat to soil health within Romania’s Macroregion 4 (South-West and West). The biogeochemical impact translates into a drastic reduction in soil fertility and agricultural yields, leading to immediate structural interventions. Sustainable management must prioritize the restoration of drainage

systems to control salinity levels and the adoption of conservation agriculture practices within the affected areas to ensure long-term soil resilience.

In order to prevent the extension of affected areas, proper agricultural recommendations have to be enforced (application of gypsum amendments; urgent rehabilitation of drainage networks; selection of salt-tolerant crops; promotion of no-till technologies; expansion of forest shelterbelts).

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BIBLIOGRAPHY

- COTEȚ, V., DUMITRU, M., FLOREA, N., 2010 – Cercetări privind ameliorarea solurilor sărăturate din Câmpia Brăilei, Editura Sitech, Craiova, Romania.
- DRAGOI, D.S., LUCA, D., MIHUT, C., DUMA-COPCEA A., 2022 – Studies on the sustainable use of soils from the location of Gelu, Research Journal of Agricultural Science, 54(4), 26-31.
- DUMITRU, M., DUMITRU, S., MOCANU, V., 2000 – Soil degradation processes and their impact on environment in Romania, Soil Science Society of Romania.
- FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO), 2021 – The state of the world's land and water resources for food and agriculture – systems at breaking point (SOLAW 2021). Rome, Italy.
- FLOREA N., 1994, Indicatori referitori la solurile sărăturate, Mediul înconjurător, 5(1), 35-48.
- FLOREA, N., MUNTEANU, I. (coordonatori), 2012 – Sistemul Român de Taxonomie a Solurilor (SRTS), Ed. Sitech, Craiova, Romania.
- IORDACHE, M., MAZARE, R., BORZA, I., 2024 – Using the bulk density and particle size composition of soil as sustainability indicators, Scientific Papers. Series A. Agronomy, LXVII(2), 37-43.
- MARIN, N., 2025 – Soil Health Assessment under the Conditions of Practicing the Conservative Farming System, Romanian Agricultural Research, 42, 294-298.
- ONTEL, I., CHEVAL, S., 2023 – Assessing the Recent Trends of Land Degradation and Desertification in Romania, Remote Sensing, 15(19), 4842.
- PALTINEANU C., DOMNARIU H., MOCANU V., DUMITRU S., 2025 – Assessing soils' health by using soil organic carbon (SOC) content, SOC/clay ratio and mean SOC reference values: a case study on Romanian mineral soils, Journal of Agricultural Science, Volume 163, Issue 3, DOI10.1017/S0021859625000280, pp. 307-319.
- PATRICHE, C.V., ROȘCA, B., PÎRNĂU R.G., VASILINIUC, I., 2023 - Spatial modelling of topsoil properties in Romania using geostatistical methods and machine learning, PLoS One. 2023 Aug 23;18(8):e0289286. doi: 10.1371/journal.pone.0289286. PMID: 37611038; PMCID: PMC10446225.
- VOICU, V., DUMITRU, S., MOCANU, V., SURUGIU E., FUDULU I.D., 2025 – Identification of secondary salinization areas on agricultural lands, Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, 55(1), 433-436.
- YU, X., BEN-GAL, A., SCUDIERO, E., KISEKKA, I., RENGASAMY, P., YAO, R., 2025 – Soil and water management to prevent salinization under changing climate conditions, Agricultural Water Management, Volume 322, 2025, 110002, ISSN 0378-3774, <https://doi.org/10.1016/j.agwat.2025.110002>.
- ***, 2021 – EU soil strategy for 2030, <https://op.europa.eu/ro/publication-detail/-/publication/13fda7ad-5450-11ec-91ac-01aa75ed71a1>