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ANALYSIS OF EROSION, SALINIZATION, AND SOIL DEGRADATION PROCESSES IN SOUTHEASTERN ROMANIA: A PEDOLOGICAL PERSPECTIVE ON VULNERABILITY

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Abstract

The Southeastern region of Romania 35,762 km^2, encompassing the Bărăgan Plain and Dobrogea Plateau, represents the national epicenter for land degradation, placing 40% of the country's agricultural area at risk of desertification (Demeter, 2004). This analysis investigates the vulnerability of the region's fertile Chernozems and Luvisols, developed predominantly on erodible loess, to major degradation processes. Physical degradation is dominated by erosion: pluvial erosion on the fragmented Dobrogea Plateau strips the fertile A horizon, severely reducing the soil's usable water capacity and intensifying aridity (Dumitru, et al. 2009), while eolian erosion threatens the exposed plains of Bărăgan. The critical lack of conservation measures, with only 4.55% adoption of anti-erosion contracts (Demeter, 2004), exacerbates these losses. Chemical degradation, primarily salinization and sodicization, is equally severe. Sodicization, driven by the capillary rise of mineralized groundwater, causes exchangeable sodium to disperse clay colloids. This process irreversibly destroys soil structure, drastically lowering hydraulic conductivity and rendering extensive areas (614,000 ha nationally) economically marginal (MESP, 1997). Secondary processes, including severe compaction and depletion of organic matter, act synergistically to hasten the structural collapse and amplify susceptibility to climatic drought stress (Dumitru et al., 2009). The acceleration of degradation, with affected areas having at least doubled in the last 25 years, indicates that the persistence of conventional agricultural strategies is pushing the region towards an economically irreversible state. Protecting the pedological integrity requires the urgent implementation of non-conventional tillage and intensive monitoring of key quality indicators.

***Key words**: erosion, salization, soil degradation*

INTRODUCTION

The South-Eastern (SE) region of Romania, comprising major landforms units such as the Bărăgan Plain, the Danube Floodplain, and the Dobrogea Plateau, represents an extensive geographyical area, covering 35.762 km^2. From a pedological perspective, this region is considered an epicenter of land degradation and desertification risk at the national level, alongside the southern Romanian Plain and southern Moldova. Nationally, approximately 7 million hectares, including 40% of the agricultural area, are located in zones with desertification risk (Kivinen, 1980).

The pedological landscape of the region is dominated by fertile soils, primarily Chernozems and Luvisols. Chernozems, with a clearly differentiated profile and accumulation of calcium-saturated humus, exhibit high fertility, favouring intensive agricultural activity (FAO-UNESCO,1988). Luvisols, characterized by the presence of an argic (Bt) horizon formed by clay illuviation, are found on old substrata and under different drainage conditions (Motoc et al., 1975). A determining geopedological factor is the thick loess layer covering a large part of the landforms (Nedelcu et al., 1965). This parent rock, being easily erodible, makes the integrity of the soil profile directly dependent on the stability of the loess mantle, amplifying the vulnerability of soils to erosion once the protective vegetation layer is compromised.

In the context of anthropogenic pressures and climate change, the high fertility of Chernozems and Luvisols attracts intense agricultural use. However, the presence of the argic horizon in Luvisols, which is rich in clay (Motoc et al., 1975), makes them extremely sensitive to structural degradation, especially compaction and crust formation under the action of heavy agricultural machinery. This situation generates an intrinsic vulnerability, where high agricultural potential undermines the long-term sustainability of the edaphic ecosystem.

1. SOIL DEGRADATION THROUGH EROSIONAL PROCESSES

Erosion represents the main physical threat to soils in Southeastern Romania, affecting approximately 6.4 million hectares nationally, of which 3.6 million are arable lands (Demeter, 2004). In the SE region, erosion acts as a powerful factor in amplifying aridity and drought.

1.1. Water erosion - is significant in areas with fragmented topography, especially in the Dobrogea Plateau. The process is supported by local morphometric characteristics, such as elevation differences of 100-160 m and intense fragmentation (1-2 km^2). These conditions, combined with loess-covered slopes, favor the rapid formation of rill erosion, gullies, and landslides (Kivinen, 1980).

Practices that are not sustainable, such as intensive tillage, lack of crop rotation, and deforestation, represent the main anthropogenic pressures that accelerate severe erosion on slopes (Demeter, 2004). The resulting degradation through water erosion in Dobrogea is not just a physical loss of soil; it directly amplifies arid conditions (Dumitru et al., 2009). By removing the A horizon (rich in organic matter and nutrients), the soil depth decreases, diminishing its capacity to retain available water (Available Water Capacity), (MESP, 1997). This hydric reduction accelerates surface runoff and intensifies water stress, establishing a negative feedback loop that increases local aridization.

1.2. Eolian (wind) erosion - is predominant in the wide and exposed plain sectors, characterized by sandy soils (Psamosols) and loess deposits, including the Bărăgan Plain and certain parts of Dobrogea (Dumitru et al., 2009).

This type of erosion, facilitated by wind action on uncovered areas, leads to the physical loss of the upper fertile layer and generates an additional source of dust. The indirect consequences are negative, affecting the foliage of vegetation and water surfaces (MMAP, 2019). The specific steppe climate of Dobrogea, along with temperature variations, contributes to shaping the land through selective erosion, separating isolated heights (inselbergs) composed of more resistant rocks (Richards, 1954). The magnitude of hydric and eolian erosion processes contrasts with the adopted combat measures. The percentage of agricultural lands under management contracts for the prevention of soil erosion was only 4.55% within the NRDP 2014-2020 (Demeter, 2004), indicating an insufficient response to the magnitude of the threat.

2. SALINIZATION AND SODICIZATION: HYDROPEDOLOGICAL MECHANISMS

Salinization and sodicization represent critical chemical degradation processes that act as intensifying factors for dryness and aridity in affected areas. Nationally, saline soils (Salsodisols) cover 614,000 hectares in 29 counties. In the SE, the most affected areas include the northeastern Romanian Plain (Bărăgan), low terraces, and poorly drained plains, characterized by the presence of soils such as Meadow Gleysols (Lacoviștele) (Dumitru et al., 2009).

2.1. Salsodization mechanisms. Salsodisols are soils whose fertility is strongly affected by three major factors: a high content of soluble salts in the soil profile, the presence of exchangeable sodium in the soil's colloidal complex (sodicization), and the proximity of the mineralized phreatic level to the surface (MESP, 1997).

The fundamental mechanism of salsodization is the capillary rise of mineralized groundwater, followed by rapid evaporation at the surface, a process accelerated by the arid climate. The accumulation of salts (salinization) increases osmotic stress for plants. However, the most destructive form of degradation is sodicization, where exchangeable sodium causes the dispersion of clay colloids. This dispersion destroys the soil structure, leading to a drastic reduction in saturated hydraulic conductivity and impermeabilization of the profile (MESP, 1997).

2.2. Key pedochemical Indicators. The evaluation and monitoring of salsodization are carried out based on specific pedochemical and hydrological indicators, used in national (ICPA) and international methodologies (e.g., Richards limits, 1954, adapted in Guide No. 69) (MESP, 1997).

The table 1 below details the essential parameters for characterizing the state of salinity and sodicity.

Table 1. essential parameters for characterizing the state of salinity and sodicity

Pedological indicator	Measured parameter	Regional pedological significance	Critical state (Interpretive)
Electrical Conductivity (EC)	Total Concentration of Soluble Salts (dS)	Direct indicator of salinity, contributes to osmotic stress.	EC > 4 dS (Saline Soil)
Exchangeable Sodium (Na)	Percentage of sodium adsorbed on the colloidal complex	Causes clay dispersion (sodicization), destroying the structure.	High value in the colloidal complex
Saturated Hydraulic Conductivity	Water infiltration rate through the profile	Low in sodic/compacted soils, increasing surface runoff.	Values below 5% (requires measurement)
Depth of the Water Table	Level of mineralized groundwater	Determines capillary rise of salts to the surface.	Mineralized Water Table, Shallow Depth

Sodicization represents a structural physical threat far more severe than simple salinization. While salinity can sometimes be corrected by washing (if drainage allows), exchangeable sodium irreversibly destroys the clay complex, turning the soil into a hard and impermeable mass upon drying. Consequently, severely affected lands (approximately 4,280 ha nationally) are often considered non-ameliorable from an economic efficiency perspective, with the exception of specialized crops like rice. The threat of intensification and expansion of salinization is considered highly probable, necessitating a periodic review of risk zones (MESP, 1997).

3. SECONDARY DEGRADATION PROCESSES. In addition to erosion and salinization, Southeastern Romania faces a series of secondary degradation processes that, although physical or chemical at their base, converge towards the destruction of soil structure, aggravating vulnerability.

3.1. Soil compaction and crust formation. Compaction is an extensive phenomenon, affecting large areas in Bărăgan and Dobrogea, especially heavy-textured, clay-rich soils, such as Luvisols and Chernozems (Dumitru, 2009). Compaction, exacerbated by the use of heavy machinery and tillage under inadequate moisture conditions, has negative consequences on soil hydrology. It reduces water infiltration, increases the risk of moisture excess and, implicitly, intensifies surface runoff and erosion (MMAP, 2019).

Compaction and crust formation are cited as processes that amplify aridization and desertification in the southern plain region Dumitru, 2009).

3.2. Depletion of Organic Matter (O.M.) The loss of organic matter is a severe threat resulting from intensive conventional agriculture. This degradation leads to the depletion of soil nutrients and, crucially, to the deterioration of structural stability (Motoc, 1975). Organic matter acts as a cement for soil aggregates. Its reduction amplifies the soil's susceptibility to erosion, compaction, and crust formation, thus contributing to the expansion of areas classified into lower quality classes.

3.3. Soil Subsidence. A specific, although localized, degradation process is the subsidence of peat soils (Histosols) in the impounded and drained enclosures of the Danube Floodplain and Delta. This phenomenon is caused by the loss of water (maturation) from organic material, followed by the reduction of soil volume (Motoc, 1975).

The analysis of secondary processes indicates that erosion, compaction, loss of organic matter, and sodicization represent distinct mechanisms but converge towards a unified result: the collapse of soil structure (porosity and aggregation). This structural destruction, largely anthropogenically induced, degrades hydraulic and nutritional properties, accelerating the transition of Chernozems and Luvisols towards a state of advanced degradation. Regionally, the areas affected by these phenomena have at least doubled in the last 25 years (Dumitru, 2009) highlighting a critical acceleration trend of degradation.

4. ASSESSMENT OF REGIONAL PEDOLOGICAL VULNERABILITY

4.1. Methodological framework and vulnerability typology. The assessment of pedological vulnerability at the national level is based on methodologies developed by the Institute for Research and Development for Pedology and Agrochemistry (ICPA), which allow for pedological mapping and the elaboration of thematic risk maps. These methodologies aim to evaluate vulnerability to erosion, moisture excess, salinity and sodicity, as well as drought stress and physical/chemical contamination.

Integrated management: An effective approach cannot treat problems in isolation. For example, increasing organic matter content is an essential common target, it improves aggregate stability (combating erosion), reduces bulk density (combating compaction) and improves infiltration (helping to wash away salts).

Adaptive calibration: Thresholds for compaction should be flexible (adapted to texture), while the erosion and salinization threshold provides a strict limit for soil health (Table 2).

Table 2. Main degradation process

The degradation process	Calibrated indicator	Regional priority (macroregions)	Key management measures
Erosion	Annual loss (>5 t/ha/year)	All macroregions (especially 1, 2, 4)	Soil conservation, contour works, increasing organic matter content, forest curtains (anti-wind in SE).
Compaction	Bulk density (1.40−1.80 g/cm3)	Macroregion 3 and 2	Traffic control, scarification (subsoiling), avoiding carrying out

The degradation process	Calibrated indicator	Regional priority (macroregions)	Key management measures
			works on wet soil.
Salinization	Electrical Conductivity (>4 dS/m)	Macroregion 2 and 3 (Romanian Plain)	Salt washing (drainage), chemical amendments (gypsum), choosing tolerant crops.

Regional policies: Interventions and allocation of funds (e.g. agri-environment subsidies) should be targeted as a priority to macro-regions where the risk is highest and where the specific type of degradation is prevalent.

4.2. Climatic Vulnerability and Desertification. Pedological vulnerability is amplified by climatic trends. Projections indicate that an average temperature increase of 3°C by the end of the 21st century could extend the phenomenon of desertification to over 30% of the country's surface. Soil degradation and desertification are the result of the complex and long-term interaction between natural factors (climate, soil, landforms) and anthropogenic factors (socio-economic) (Dumitru et al,. 2009).

Currently, degradation processes do not act in isolation, but synergistically with climatic factors (drought, high temperatures) to intensify the risk. For example, compaction and depletion of organic matter reduce the soil's capacity to retain water, making it more susceptible to drought stress induced by climatic factors (Dumitru et al,. 2009).

CONCLUSIONS

The pedological analysis of the Southeastern region of Romania reveals that the edaphic landscape, defined by Chernozems and Luvisols developed on loess, is in a critical balance under the arid climatic regime and intensive anthropogenic pressure.

The most significant pedological vulnerabilities are determined by two major categories of processes, acting synergistically:

Physical and Hydric Degradation: Erosion by water on the Dobrogea plateaus and by wind in Bărăgan) and compaction are feedback mechanisms that intensify regional aridity by deteriorating the soil's hydric capacity (Dumitru et al., 2009).

Chemical and Irreducible Structural Degradation: Sodicization (part of salinization) and the loss of organic matter cause the irreversible destruction of the soil structure. Sodicization, through clay dispersion and drastic reduction of hydraulic conductivity, transforms fertile soils into lower quality classes, with high or prohibitive amelioration costs (MESP, 1997).

The acceleration of degradation, with affected areas at least doubling in recent decades, is an indicator of the significant gap between the scientific identification of risk and the practical implementation of conservation measures. The low adoption rate of conservation agriculture (4.55% of agricultural land) (Demeter, 2004), suggests that the persistence of conventional strategies, which favor structural collapse, accelerates the region's transition towards an economically irreversible state of desertification.

It is imperative that future research focuses on quantifying the rate of change of key quality indicators (especially organic matter, EC, and Na), in parallel with the strategic promotion of non-conventional tillage systems, to protect the remaining structural integrity of the Chernozems and Luvisols in Southeastern Romania.

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