

EVALUATION OF SALINE-SODIC ALLUVIAL SOIL IN THE STÂNCUȚA AREA AND IMPLICATIONS FOR CROP TECHNOLOGY

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Abstract. This study presents an integrated pedological and agrochemical assessment of a mollic saline–sodic alluvial soil identified on an agricultural area of 8.24 ha located in the Stâncuța Administrative Territory, Brăila County, Romania. The main objective was to evaluate land productive potential under saline–sodic conditions and to translate soil diagnostic results into practical, risk-based crop technology recommendations, adapted to local edaphic constraints. Field investigations and soil sampling were carried out in March 2025, in accordance with the national methodology for pedological studies, and included detailed soil profile description and standardized laboratory agrochemical analyses. The results indicate the presence of significant edaphic limitations, primarily related to salinity and sodicity, fine-textured soil horizons, deficient drainage, and a high degree of soil compaction. These cumulative constraints led to the classification of the investigated land into quality class IV for arable use, corresponding to a natural land suitability rating (NN = 37), equivalent to a low land capability level under international land suitability frameworks. From an agrochemical perspective, the soil exhibits a neutral to slightly alkaline reaction, a medium nitrogen supply, good to very good available phosphorus content, and excessive potassium levels, indicating an unbalanced nutrient status that requires carefully adjusted fertilization strategies. Based on the pedo-agrochemical diagnosis, integrated technological recommendations were developed, focusing on soil amelioration and sustainable agricultural use rather than yield maximization. These include the application of chemical amendments to mitigate sodicity effects, incorporation of organic matter to improve soil structure, adaptation of tillage systems to reduce compaction, and differentiated fertilization according to nutrient availability. In addition, the adoption of appropriate crop rotations and salt-tolerant crop species is recommended as a key measure for yield stabilization under class IV land conditions. The study highlights the importance of integrating pedological evaluation, land suitability assessment, and agronomic decision-making to support sustainable agricultural use of saline–sodic soils.

Keywords: saline–sodic soils; soil fertility; land quality assessment; crop technology; soil management

INTRODUCTION

Saline and sodic soils are of major importance for agriculture due to their extensive global distribution and their direct impact on food security. Large areas of agricultural land worldwide are affected by salinization and sodication processes, particularly in arid and semi-arid regions and in alluvial plains characterized by deficient natural drainage. Under such conditions, soil productive potential is significantly reduced, posing serious constraints on sustainable agricultural development (QADIR et al., 2014; RENGASAMY, 2010).

From an agronomic perspective, saline and sodic soils impose severe limitations on seed germination, root system development, and the uptake of water and nutrients. Elevated

concentrations of soluble salts generate osmotic stress and ionic imbalance in plants, while excessive exchangeable sodium adversely affects soil structural stability, leading to clay dispersion, compaction, reduced permeability, and poor aeration (SUMNER, 1993). In the absence of appropriate amelioration measures and adapted crop technologies, the agricultural use of these soils becomes inefficient and environmentally unsustainable.

Nevertheless, saline and sodic soils represent an important agricultural resource in regions where alternative high-quality soils are limited. The application of suitable soil management strategies—such as chemical amendments, drainage improvement, differentiated fertilization, and the cultivation of salt-tolerant crops—allows these lands to be integrated into agricultural production systems and contributes to the stabilization of yields under restrictive edaphic conditions (DUMITRU et al., 2011; QADIR et al., 2014). In this context, pedological and agrochemical evaluation acquires strategic relevance by providing the scientific basis for the development of crop technologies adapted to local soil constraints (TEACI et al., 1985; ICPA, 2014). Integrated use of gypsum and organic/bio-organic amendments is widely reported as an effective strategy to improve chemical and physical constraints in salt-affected soils (BELLO et al., 2021).

Within the framework of sustainable agriculture, saline and sodic soils assume a strategic role, particularly in regions facing increasing pressure on high-quality agricultural land resources. Sustainable agriculture does not imply the abandonment of salt-affected soils, but rather the adaptation of agricultural technologies to existing edaphic conditions and the rational use of degraded lands (QADIR et al., 2014). Practices such as crop rotation, increased organic matter inputs, and reduced mechanical disturbance contribute to preserving soil structure and maintaining chemical and biological balance (DUMITRU et al., 2011; RENGASAMY, 2010).

In Romania, saline and sodic soils are mainly distributed in the Danube Plain, the Bărăgan Plain, and the floodplains of major rivers. These areas are characterized by fine-textured alluvial deposits, flat or slightly sloping relief, and shallow groundwater levels—conditions that favor the accumulation of soluble salts and exchangeable sodium within the soil profile (FLOREA, 2012; DUMITRU et al., 2011). Identifying salt types and their distribution is important for selecting appropriate management measures in salt-affected agricultural systems, especially under drainage limitations (OMAR et al., 2024).

The Lower Danube Plain represents one of the most affected pedogeographical units, where relatively low precipitation, high temperatures during the growing season, and mineralized groundwater intensify salinization and sodication processes, particularly in poorly drained floodplain areas (FLOREA, 2012). The effects of salinity and sodicity on agricultural production are reflected in yield reduction and production instability. While salinity induces osmotic stress and disrupts plant physiological processes, sodicity leads to soil structural degradation, reduced permeability, and increased compaction, thereby limiting root development and fertilizer efficiency (SUMNER, 1993; RENGASAMY, 2010). These constraints require the adaptation of crop technologies and the careful selection of salt-tolerant crop species or varieties (QADIR et al., 2014; TEACI et al., 1985).

In Brăila County, crop selection must be strictly correlated with the degree of soil salinization and sodication, the hydrological regime, and local climatic conditions. Barley (*Hordeum vulgare* L.) and wheat (*Triticum aestivum* L.) show relatively good adaptability to slightly saline soils, whereas maize (*Zea mays* L.) and sunflower (*Helianthus annuus* L.) exhibit moderate tolerance, associated with increased production risk in dry years.

Salt-sensitive crops, such as grain legumes and potato, are severely restricted on non-ameliorated saline–sodic soils (TEACI et al., 1985; DUMITRU et al., 2011).

Under these conditions, integrated pedological and agrochemical evaluation is essential for identifying productive limitations, classifying land into quality classes, and substantiating appropriate technological interventions (TEACI et al., 1985; ICPA, 2014).

The aim of this study is to conduct an integrated pedological and agrochemical assessment of a mollic saline–sodic alluvial soil located in the Stăncuța area, Brăila County, Romania, in order to determine its actual productive potential and the main edaphic limitations. These constraints are expressed through a natural land suitability rating (NN = 37), corresponding to quality class IV for arable use. Based on this diagnosis, the study proposes adapted crop technology recommendations aimed at sustainable agricultural use and the reduction of production risks.

MATERIAL AND METHODS

Study areal

The study area is located in the eastern part of Brăila County, within the administrative territory of Stăncuța commune, belonging to the Lower Danube Plain, one of the most important physico-geographical units of Romania, characterized by extensive agricultural land and pronounced fluvial influence (FLOREA, 2012). The investigated agricultural area covers 8.24 ha and is situated outside the built-up area of Stăncuța locality, close to the Danube floodplain, a region known for the presence of alluvial soils affected by restrictive hydro-pedological factors (DUMITRU et al., 2011; OSPA Brăila, 2025).

From a geomorphological perspective, the area belongs to the Danube floodplain, with local influences from the flood plain of the Călmățui River. The relief is of alluvial accumulation type, characterized by flat or very gently sloping surfaces, typical of embanked floodplain areas (FLOREA, 2012). This geomorphological setting favors water stagnation, poor natural drainage, and the occurrence of gleying and salinization processes, especially in fine-textured soils (CANARACHE, 1990).

Climatic and hydrological conditions.

The Stăncuța area is characterized by an excessive continental climate, specific to eastern Romania, with very hot summers, cold winters, and high thermal variability (FLOREA, 2012). The mean annual air temperature is approximately 11 °C, while mean annual precipitation is relatively low, ranging between 450 and 460 mm, with an uneven seasonal distribution (OSPA Brăila, 2025). The frequent moisture deficit, particularly during the vegetation period, represents a favorable factor for groundwater capillary rise and subsequent salt accumulation within the soil profile (RENGASAMY, 2010).

From a hydrological standpoint, the investigated territory is bordered by the Danube River to the east and the Călmățui River to the west. Although these watercourses are currently embanked, their influence persists through groundwater dynamics. The groundwater table is situated at depths between 2.01 and 3.00 m, and its elevated mineralization constitutes a major factor in triggering soil salinization and sodication processes (DUMITRU et al., 2011; OSPA Brăila, 2025).

The occurrence of salinization and sodication phenomena in the Stăncuța area is the result of the combined action of climatic, geomorphological, and hydrogeological factors. Flat relief, deficient drainage, and shallow groundwater levels promote upward salt transport by capillary movement, particularly under conditions of intense evapotranspiration (SUMNER, 1993; RENGASAMY, 2010). The alluvial nature of the parent material, associated with fine

textures and low permeability, further contributes to salt accumulation and soil structural degradation, thereby limiting soil fertility and agricultural land use efficiency (DUMITRU et al., 2011; QADIR et al., 2014).

Pedological investigations and soil sampling.

Field investigations and soil sampling were conducted in March 2025, ensuring a representative pedological and agrochemical characterization under the prevailing land-use and climatic conditions. At the time of the survey, the investigated land had not been tilled or cultivated for more than five years, representing an uncultivated agricultural area with minimal recent anthropogenic disturbance. The research was carried out in accordance with the Methodology for the Elaboration of Pedological Studies (MESP) applied in Romania, which provides an integrated framework for soil classification, fertility assessment, and land suitability evaluation under natural conditions (TEACI et al., 1985; ICPA, 2014). This methodology is particularly suitable for saline-sodic soil assessment, as it integrates morphological, physical, and chemical indicators with climatic and groundwater factors, allowing a comprehensive evaluation of edaphic constraints affecting agricultural productivity. Pedological mapping was performed at a scale appropriate to the investigated surface, based on detailed field observations and analysis of soil unit distribution, following national soil survey standards (ICPA, 2014). A single soil mapping unit was identified, occupying the entire study area (8.24 ha), which allowed a uniform and detailed characterization of soil properties (OSPA Brăila, 2025). A representative soil profile was opened and described in the field according to standard pedological criteria. The morphological description included the sequence of genetic horizons, soil color, texture, structure, consistency, degree of compaction, presence of carbonates, soluble salts, hydromorphic features, and humus type (FLOREA, 2012; ICPA, 2014). These observations formed the basis for soil taxonomic classification within the Romanian Soil Taxonomy System (FLOREA and MUNTEANU, 2012). Soil samples were collected by genetic horizons directly from the soil profile, following standard procedures for pedological and agrochemical sampling (ICPA, 2014). Samples were properly labeled, preserved, and transported to the laboratory for further analyses. The surface mollic horizon (Am) had a field-defined thickness of 0–19 cm (field morphology), whereas agrochemical indicators were interpreted for the standardized arable layer (0–20 cm) used in routine soil fertility assessment.

Laboratory analyses and land suitability assessment.

Agrochemical analyses were performed using standardized laboratory methods. Soil reaction (pH) was determined potentiometrically, total nitrogen content by the Kjeldahl method, available phosphorus by the Egner–Riehm method, and exchangeable potassium by ammonium acetate extraction (LĂCĂTUȘU and KOVACS, 1998; Jurcă, 2008). Soil salinity and sodicity were evaluated through the determination of soluble salt content and exchangeable sodium, while cation exchange capacity was used to assess nutrient retention potential (SUMNER, 1993; DUMITRU et al., 2011).

Soil fertility assessment was based on the interpretation of agrochemical results using nationally established threshold values. Humus content, nitrogen, phosphorus, and potassium supply, together with soil reaction, texture, and degree of compaction, were considered essential criteria for evaluating soil productive capacity (TEACI et al., 1985; LĂCĂTUȘU and KOVACS, 1998).

Natural land suitability for arable use was assessed according to the MESP methodology through the cumulative evaluation of soil, relief, climatic, and groundwater factors (TEACI et al., 1985; ICPA, 2014). The natural land suitability rating was calculated as

the arithmetic mean of the suitability scores obtained for the main agricultural crops. Based on this value, the investigated land was classified into the corresponding quality class, highlighting both productivity level and major edaphic limitations (OSPA Brăila, 2025).

RESULTS AND DISCUSSION

Pedological classification of the soil and the results of the natural land suitability assessment are summarized in Table 1, providing the basis for interpreting the productive potential and the main edaphic limitations of the investigated land.

Table 1

Location	Stăncuța administrative unit, Brăila County
Investigated area	8.24 ha
Soil group	Protisols
Soil type / subtype	Mollic saline-sodic alluvial soil
Parent material	Alluvial deposits
Groundwater depth	2.01–3.00 m
Natural land suitability rating (NN)	37
Quality class (arable use)	Class IV
Agricultural use	Conditionally suitable

The data presented in Table 1 confirm that the investigated area is occupied by a mollic saline-sodic alluvial soil classified as quality class IV for arable use. The natural land suitability rating (NN = 37) indicates the presence of significant edaphic constraints that limit the inherent productive potential of the soil without excluding agricultural use. It should be noted that the investigated land had not been tilled or cultivated for more than five years; therefore, the pedological and agrochemical properties largely reflect natural pedogenetic processes, with minimal recent anthropogenic influence.

To assess soil fertility status and the main agrochemical indicators in the arable layer, the analytical results obtained at plot level (0–20 cm) are presented in Table 2.

Table 2

Indicator	Range / value	Assessment
pH	6.45–7.31	Neutral to slightly alkaline
Humus (%)	3.59–3.90	Low to moderate
Total nitrogen (%)	0.191–0.249	Moderate supply
Nitrogen index (IN)	2.49–3.63	Medium
Available phosphorus (P _{AL} , ppm)	71–139	Good to very good
Exchangeable potassium (K _{AL} , ppm)	600–783	Excessive
Cation exchange capacity (cmol(+)/kg)	88.6–100.2	Very high

Note: 0–20 cm represents the standardized agrochemical sampling/interpretation depth.

The results show an unbalanced agrochemical status, characterized by a moderate nitrogen supply combined with high to very high levels of available phosphorus and excessive exchangeable potassium. Nitrogen availability represents a relative limiting factor for crop growth, while phosphorus and potassium accumulation reflects both the very high cation exchange capacity of the soil and the legacy of previous fertilization practices. Similar nutrient patterns have been reported for saline-sodic soils with high buffering capacity, where excessive K and P accumulation coexists with limited N availability (RENGASAMY, 2010; CORWIN and SCUDIERI, 2019).

The neutral to slightly alkaline soil reaction, together with high cation exchange capacity, provides good nutrient retention potential. However, under saline-sodic conditions, these characteristics may also promote nutritional imbalances and reduced micronutrient availability, justifying the need for differentiated and rational fertilization strategies adapted to the reduced productive potential of quality class IV land (SUMNER, 1993; QADIR et al., 2014).

Vertical variation of soil reaction and nutrient distribution within the soil profile is presented in Table 3.

Table 3

Vertical distribution of soil reaction and nutrients

Horizon (cm)	pH	Humus (%)	Nitrogen (%)	P_AL (ppm)	K_AL (ppm)
0–19 (Am)	6.58	4.16	0.249	~100	680
19–53 (C1)	7.60	2.70	0.191	28	191
53–77 (C2k)	8.27	-	-	-	-
77–150 (C3kscac)	7.91	-	-	-	-

Note: The Am horizon thickness in the described profile was 0–19 cm (field morphology). Agrochemical reporting follows the standardized 0–20 cm depth.

Marked vertical differentiation of chemical properties is evident within the soil profile. The surface horizon (Am) shows near-neutral reaction and higher humus and nitrogen contents, reflecting biological activity and organic matter inputs. With increasing depth, a pronounced alkalization trend is observed, accompanied by a sharp decline in nutrient content. This zonation is typical of alluvial soils influenced by mineralized groundwater and contributes significantly to the reduction of effective root zone depth and nutrient availability (RENGASAMY, 2010).

Textural characteristics and their physical implications are summarized in Table 4.

Table 4

Soil texture and physical implications

Horizon (cm)	Texture	Total clay (%)	Implications
0–19 (Am)	CL	~46.5	Reduced permeability
19–53 (C1)	CL	~57.1	High compaction tendency
53–77 (C2k)	CL	~52.0	Poor drainage
77–150 (C3kscac)	SiCL	~63.7	High risk of densification

Fine textures dominate throughout the soil profile, resulting in reduced permeability, high susceptibility to compaction, and poor aeration conditions. These physical limitations restrict root penetration and amplify the negative effects of sodicity on soil structure, a behavior commonly reported for saline–sodic alluvial soils in floodplain environments (SUMNER, 1993; DUMITRU et al., 2011).

The vertical distribution of salinization and sodication processes is shown in Table 5.

Table 5

Salinization and sodication within the soil profile

Horizon (cm)	Salinity type	Intensity	Na/T (%)	Assessment
0–53	-	Non-saline	<1	Non-alkaline
53–77	Chloride	Weak	~1.3	Non-alkaline
77–150	sulphate	Moderate	~7.0	Slightly sodic

The arable layer is currently non-saline and non-alkaline, whereas salinization and sodication intensify in deeper horizons, where moderate sulphatic salinization and incipient sodicity occur. This pattern reflects upward salt movement driven by capillary rise from shallow, mineralized groundwater and represents a latent risk for soil degradation under intensive agricultural use. Comparable vertical salinity patterns have been reported for saline–sodic alluvial soils with deficient drainage in both Eastern Europe and semi-arid regions (RENGASAMY, 2010; CORWIN and SCUDIERI, 2019; QADIR et al., 2014).

An integrated synthesis of pedological, agrochemical, and land suitability data is presented in Table 6.

Table 6

Integrated diagnostic synthesis

Component	Conclusion
Nutrient status	Unbalanced (high P and K, moderate N)
Physical properties	Unfavorable (fine texture, compaction)
Pedogenetic processes	Subsoil salinization and sodication
Productive potential	Low (NN = 37)
Agricultural status	Conditionally usable

The cumulative effect of unfavorable physical properties, nutrient imbalance, and active salinization–sodication processes confirms the low productive potential of the investigated land. In this context, the natural land suitability rating applied within the Romanian assessment system is conceptually equivalent to international approaches such as land suitability evaluation or land capability classification, expressing the degree of land adequacy for agricultural use under natural conditions (TEACI et al., 1985; ICPA, 2014).

Crop suitability, production risk, and recommended technological measures under NN = 37 conditions are synthesized in Table 7.

Adaptation of crop structure to class IV land must be accompanied by corresponding technological adjustments. Salt- and compaction-tolerant crops such as barley, sorghum, and perennial grasses show greater production stability, whereas salt-sensitive crops, including potato and grain legumes, exhibit very high production risk and are not recommended on non-ameliorated soils. To operationalize these recommendations, crop choice should be combined with periodic monitoring of key indicators related to salinity–sodicity and physical degradation (e.g., EC/soluble salts, exchangeable sodium, and compaction-related parameters), especially after dry years or major changes in management (CORWIN and SCUDIERI, 2019; RENGASAMY, 2010). This is essential because sodicity-driven structural instability and reduced infiltration can amplify yield variability and constrain root exploration even when the topsoil appears only weakly affected (SUMNER, 1993; RENGASAMY, 2010). A phased implementation is advisable, prioritizing tolerant crops and conservative practices in the first years, while applying targeted amendments and organic matter inputs to improve structural stability and reduce production variability (QADIR et al., 2014; SHABBIR et al., 2019). Such adaptive management supports sustainable use of class IV land and aligns land suitability interpretation with agronomic decision-making frameworks (TEACI et al., 1985; ICPA, 2014).

The distinctive contribution of this study lies in the integration of pedological and agrochemical evaluation with natural land suitability rating and crop-specific production risk analysis, enabling a direct link between actual edaphic potential and applied technological decisions. This integrated approach goes beyond descriptive assessments and provides a practical framework for sustainable agricultural land use on saline–sodic alluvial soils.

Moreover, the proposed integrated framework can serve as a decision-support tool for land managers by prioritizing stability and sustainability over short-term yield maximization. Such an approach is particularly relevant for saline–sodic alluvial soils, where inappropriate crop selection and intensive technologies may accelerate soil degradation and increase production risk. Therefore, the results emphasize the need for site-specific land evaluation as a prerequisite for adaptive and responsible agricultural management.

Table 7

Crop suitability, production risk, and technological recommendations under NN = 37 (quality class IV)

Crop (scientific name)	Recommendation (NN = 37)	Production risk level	Recommended technological measures
Barley (<i>Hordeum vulgare</i> L.)	Highly recommended	Low risk – tolerant to slight salinity and compaction	Gypsum amendment in sodic zones; balanced N–P fertilization; minimum tillage to prevent compaction
Wheat (<i>Triticum aestivum</i> L.)	Conditionally recommended	Moderate risk – sensitive to drought and sodicity	Localized amendment application; split nitrogen fertilization; moderate loosening; maintenance of crop residues
Maize (<i>Zea mays</i> L.)	Limited recommendation	High risk – sensitive to saline and water stress	Organic matter incorporation; phosphorus-oriented fertilization; periodic deep loosening
Sunflower (<i>Helianthus annuus</i> L.)	Limited recommendation	High risk (especially in dry years)	Localized chemical amendment; reduced nitrogen fertilization; conservative tillage practices
Soybean (<i>Glycine max</i> L.)	Not recommended	Very high risk – sensitive to salinity	Avoid cultivation on non-ameliorated soils; introduction only after advanced soil amelioration

Pea / Bean (<i>Pisum sativum</i> L. / <i>Phaseolus vulgaris</i> L.)	Not recommended	Very high risk – impaired nodulation	Exclusion from crop rotation on non-ameliorated soils
Potato (<i>Solanum tuberosum</i> L.)	Not recommended	Extreme risk – incompatible with quality class IV	Complete exclusion from cropping structure
Sorghum (<i>Sorghum bicolor</i> L.)	Recommended	Low risk – highly tolerant to salinity	Moderate fertilization; minimum tillage; use as an alternative to maize
Forage barley (<i>Hordeum vulgare</i> L.)	Recommended	Low risk – adaptable to low-fertility soils	Organic fertilization; ameliorative crop rotations
Perennial grasses (<i>Lolium</i> spp., <i>Festuca</i> spp.)	Recommended in rotation	Low risk – ameliorative effect	Rotations aimed at reducing compaction and increasing soil organic matter

CONCLUSIONS

The pedological and agrochemical study conducted on the investigated agricultural land in the Stăncuța area, Brăila County, revealed the presence of a mollic saline–sodic alluvial soil, characterized by weak salinization and sodication, fine texture, deficient drainage, and a high degree of compaction. These edaphic characteristics represent major limiting factors for intensive agricultural use.

The natural land suitability rating obtained for arable use (NN = 37) classifies the land into quality class IV, corresponding to soils with low productive potential. This classification reflects the cumulative impact of unfavorable pedoclimatic and hydrogeological conditions, as well as physical and chemical soil degradation, on agricultural productivity.

Agrochemical analyses indicated a soil reaction ranging from neutral to slightly alkaline, a moderate nitrogen supply, good to very good available phosphorus content, and excessive exchangeable potassium levels. This nutrient status requires the implementation of differentiated fertilization strategies, carefully adapted to soil supply levels and crop requirements. At the same time, the very high cation exchange capacity highlights both the soil's capacity to retain nutrients and the necessity to mitigate the negative effects of exchangeable sodium.

The correlation between the natural land suitability rating (NN = 37) and crop response demonstrates that agricultural land use should be oriented toward crop species tolerant to salinity and compaction, such as barley and other crops with reduced soil quality requirements. In contrast, salt-sensitive crops, including potato and grain legumes, are not recommended on non-ameliorated soils belonging to quality class IV due to the high risk of yield losses.

Under these conditions, adapting crop technologies to the actual land suitability level represents an essential requirement for sustainable land use. The application of chemical and organic soil amelioration measures, reduction of compaction through appropriate tillage practices, rational fertilization, and adjustment of crop structure contribute to yield stabilization and more efficient use of soils with limited fertility.

In conclusion, the classification of the investigated land as quality class IV (NN = 37) does not preclude its agricultural use, but requires a cautious, scientifically based technological approach. Integrating pedological and agrochemical information into the agricultural decision-making process constitutes a key prerequisite for ensuring sustainable agriculture on saline-sodic soils of the Lower Danube Plain.

ACKNOWLEDGEMENTS / PROJECT SUPPORT

This research was conducted within the ADER 20.1 project, financed by the Ministry of Agriculture and Rural Development of Romania. The project support is gratefully acknowledged.

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