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THE USE OF SATELLITE IMAGES FOR THE IDENTIFICATION OF SALINIZED SOILS IN BRĂILA COUNTY

Assim Shabeeb AbdulHussein ABDULHUSSEIN, Mircea MIHALACHE

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania

Corresponding author email: aseemshabeeb87@gmail.com

Abstract

The high salt content in the soil raises special problems regarding the use of soils affected by salinity and alkalinity. In Romania, there is an area of approximately 614,000 ha of land where salinization-alkalization processes occur, causing a low fertility of these soils and at high concentrations, these soils cannot be used for agricultural production. In order to identify the areas occupied by these soils, research was carried out based on satellite images in three localities in Brăila county: Măxineni, Racoviță and Tudor, where laboratory determinations such as: soil reaction, content in chlorides, sulfates, magnesium, calcium, sodium and potassium. With the help of remote sensing and satellite images, maps were made regarding the salinity index (SI), Bare Soil index (BSI), Soil Adjusted Vegetation Index (SAVI), Tasseled Cap Transformation Wetness (TCW). Our study demonstrated the ability of remote sensing techniques and geographic information systems to survey, monitor, identify, analyze and classify land degradation manifestations and to detect spatial and temporal variables occurring in the study area. The digital indicators (INDEX) contributed to highlighting the terrain characteristics very effectively helping in clarifying the spatial distribution picture and the quantitative and qualitative evaluation of the types of soil degradation manifestations in the studied area.

Key words*: salinity, soil, remote sensing, GIS, deterioration index.*

INTRODUCTION

In all countries, there are concerns regarding the improvement of soils affected by salinization and of those at risk of salinization, for the purpose of increasing agricultural production, reducing the content of soluble salts in the soil and therefore, increasing the range of crops suitable for these lands, obtaining the techniques of the elements required for improving reproduction technologies, environmental protection and the economic efficiency of improvement technologies, as well as for increasing the standard of living in areas with saline and alkaline soils (Coteț Valentina, 2010).
Soil salinity adversely affects seed germination, crop productivity and soil and water quality, especially in semi-arid and arid regions of the world, leading to loss of arable land and soil degradation. It is continuously increasing at an alarming rate and is accepted as a widespread environmental problem that endangers agricultural practices, as detailed by scientists in different parts of the world, at different intervals of time (Zhu, 2001; Metternicht and Zinck, 2003; Zheng et al., 2009). In general, there are two main reasons for soil salinity. One relates to human-induced activities and the other is due to natural factors. Extensive use of poor quality irrigation water, due to the occurrence of extreme drought events, combined with intensive fertilizer application are the main human-induced activities resulting in soil salinization (Perez-Sirvent et al., 2003; Barbouchi et al., 2014).
Soil salinization is a dynamically unfolding process with significant social and economic aspects. Thus, for the sustainable management of arable regions and natural ecosystems, adequate and accurate information on the spatial magnitude and variability of salinity distribution is essential in order to monitor it in a timely manner and to prevent further growth of salt-affected areas (Allbed and Kumar, 2013). Periodic monitoring of soil salinity is a must for proper management of soil and water resources, however it is quite difficult to detect the required soil information in regions affected by salinity as referred by Taha Gorji et al. (2015). The Food and Agriculture Organization of the United Nations (FAO) has estimated that nearly 397 million hectares of the world's surface are

covered by salinized and alkalinized soils including almost all continents. Research carried out worldwide has established that soil salinity can be assessed using salinity indicators such as the Difference Vegetation Index (NDVI) with which soil salinity can be assessed (Albed and Kumar, 2013).

To overcome this limitation, several techniques have been developed to assess soil salinity. One such technique is based on remote sensing (RS), which has demonstrated considerable success in mapping and assessing soil salinity (Wu W, Mhaimeed A.S., 2014; Asfaw E., 2018; Garcia L., 2005).

Metternicht (1998), Metternicht and Zinck (2003), Eldeiry and Garcia (2010) and Furby et al. (2010) noted that significant results could be obtained by studying the spectral properties and radar backscatter of saline soils. Some researchers (e.g., ref. Brunner P., Li H., 2007) have studied soil salinity based on moisture content using the normalized difference infrared index. Other researchers have evaluated the relationships between soil salinity and vegetation indices (Ibrahim M., Koch B., Data P., 2020). Other studies analyzed soil salinity using thermal and short infrared wavelength bands (Ibrahim M., Abu-Mallouh H., 2018) to examine the relationship between soil salinity and land surface temperature (LST). These studies used satellite images containing thermal bands, such as Moderate Resolution Imaging Spectroradiometer (MODIS), which provide useful information on soil properties (Zhang T.-T., Zeng S.-L., Gao Y., Ouyang Z.-T., 2011). Recently, multispectral data derived from sources such as System Pour I, Observation de la Terre (SPOT), IKONOS, Quick Bird, Indian Remote Sensing and Landsat satellites have been used to explore soil salinity maps. Several other indices, such as the salinity index and soil-adjusted vegetation index (Brunner P., Li H., Kinzelbach W., Li W., 2007), are also commonly used to monitor soil salinity. However, Eldeiry and Garcia and Hu et al. recommended the combined use of the spectral response index and the best band (Ibrahim M., Ghanem F., Al-Salameen A., Al-Fawwaz A., 2019).

RS instruments and data must be integrated with field measurements of salinity to perform soil salinity assessment and monitoring. RS is an effective tool for spatial analysis of soil salinity in arid and semi-arid areas. We, therefore, aim to estimate soil salinity in Abu Dhabi using specific spectral indices combined with field measurements. The soil salinity mapping model developed in this study is based on soil electrical conductivity (EC) and shows a promising correlation, which can be further improved by considering the soil salinity-LST relationship. This model is useful to develop effective soil salinity forecasting strategies for sustainable development and land management.

MATERIALS AND METHODS

The methods used were:

Determination of pH in aqueous suspension 1:2.5; SR 7184-13:2001; PTL 04.

Determination of soluble salts from aqueous extract 1:5 (carbonates, bicarbonates, chlorides, sulfates, calcium, magnesium) STAS 7184/7-87; PTL 18.

Determination of soluble forms: potassium (K), sodium (Na); PTL 18.

Determination of electrical conductivity and estimation of the total content of soluble salts; STAS 7184/7-87 ch. 3.2; PTL 0.

Research was carried out in 2021 in three localities in Brăila County, respectively Măxineni, Racoviță and Tudor, in order to determine the distribution area of soils affected by salinization and alkalization processes. Soil samples were collected at a depth of 0-20 cm and 20-40 cm and the following chemical analyzes were performed: soil reaction in aqueous suspension 1:2.5, determination of soluble salts from aqueous extract 1:5 (carbonates, bicarbonates, chlorides, sulphates, calcium and magnesium), determination of soluble forms of potassium and sodium and determination of electrical conductivity and estimation of total soluble salt content. With the help of Landsat satellite images, maps were processed and made regarding the salinity index (SI), Bare Soil index (BSI), Soil Adjusted Vegetation Index (SAVI), Tasseled Cap Transformation Wetness (TCW). The INDEX digital indicators contributed to highlighting the characteristics of the land in the researched area and the manifestation of degradation phenomena.

RESULTS AND DISCUSSIONS

Regarding the reaction of the analyzed soils, the highest values on the 0-20 cm depth were recorded at profile 1 and 2 in the town of Racoviță, where the reaction shows values of 7.96 and 8.04 (slightly alkaline reaction). All the points analyzed show a slightly alkaline reaction at the depth of 0-20 cm, and the lowest value was of 7.42 at profile 2 from the town of Tudor.

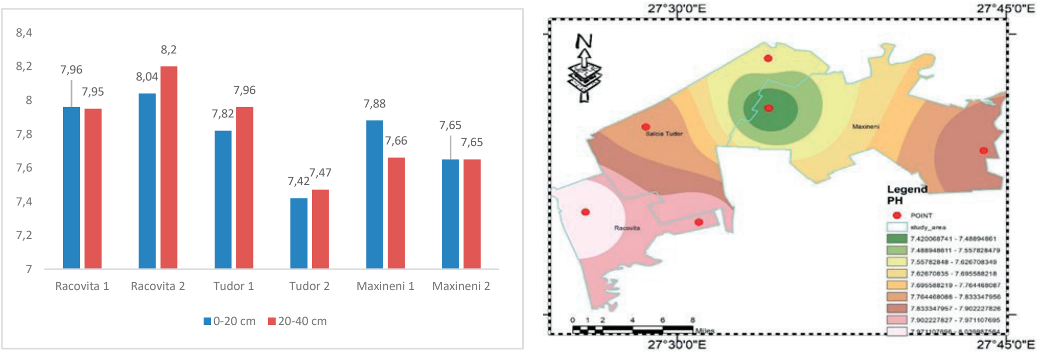

Figure 1. Soil reaction and its distribution in the investigated area

As for the depth of 20-40 cm, the highest values of the reaction were recorded at the profiles from the Racoviță locality, respectively of 7.95 and 8.2 - slightly alkaline reaction, while the lowest value of the soil's reaction at this depth was recorded at profile 2 from the land of Tudor.

Regarding the content of SO_4^{2-} at the soil surface and the depth of 0-20 cm, the highest value of 347 me/100 g was recorded at profile 2 from Măxineni, indicating a moderately salinized soil, while the lowest values were recorded at the profiles from Racoviță.

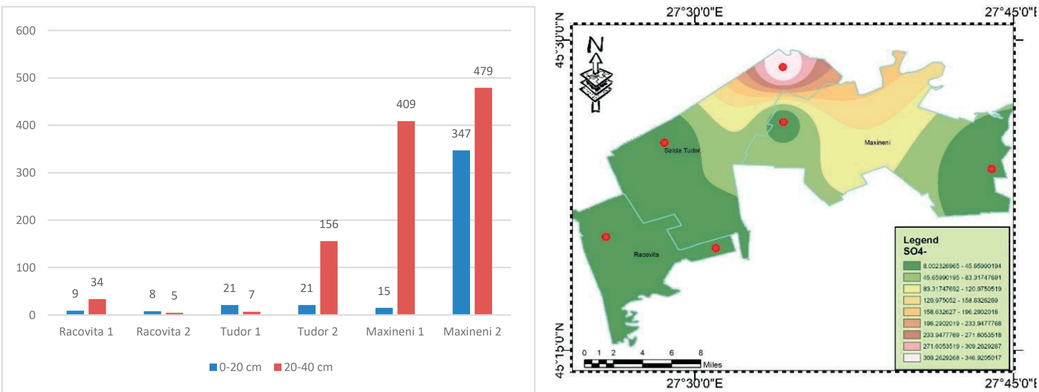

Figure 2. SO_4^{2-} content and distribution

At the depth of 20-40 cm we observed high values in the Măxineni profiles and in the Tudor profile 2, with values that vary between 156 and 479 me/100 g of soil, indicating a highly salinized soil. The highest Cl^- content at a depth of 0-20 cm was recorded at profile 2 from Măxineni, with a value of 215 me/100 g soil and in the case of profile 2 from Tudor, where the soil is weakly salinized and moderately salinized at profile 1 from Măxineni.

The lowest values were recorded at the two profiles from Racoviță.

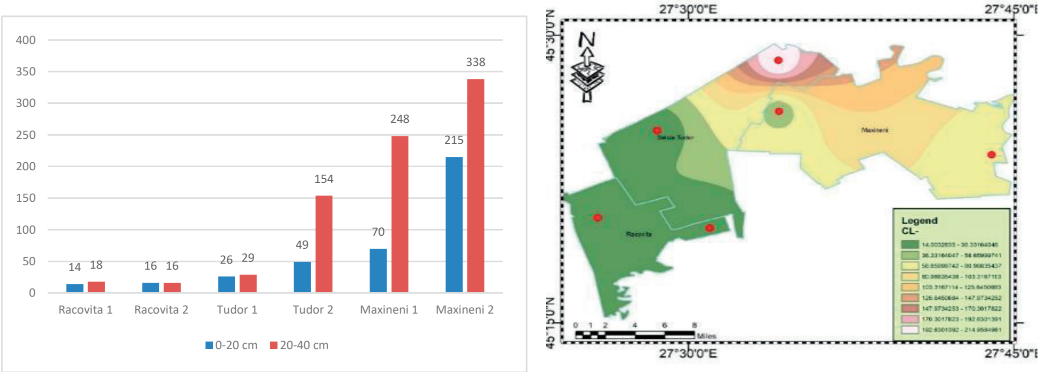

Figure 3. Cl⁻ ion content and distribution

In the case of the 20-40 cm depth, values between 154 me/100 g of soil were recorded at profile 2 from Tudor and 248, respectively 338 me/100 g of soil at the two profiles from Măxineni, which means that the soils are slightly to strongly salinized.

It can be seen that both SO_4^{2-} and Cl^- contents in the analyzed soils increase with depth, therefore, at a depth of more than 40 cm, the soils become moderately to strongly salinized.

The Ca content is high in all samples analyzed at the depth of 0-20 cm with the highest values of 86 mg/100 g soil at profile 2 from Măxineni. A very low value of 7 mg/kg was recorded in profile 1 from Măxineni.

At the depth of 20-40 cm, higher calcium content values of 41 mg/kg were recorded at profile 2 from Tudor and at Măxineni with 81 mg/kg in profile 1 and 98 mg/kg in profile 2.

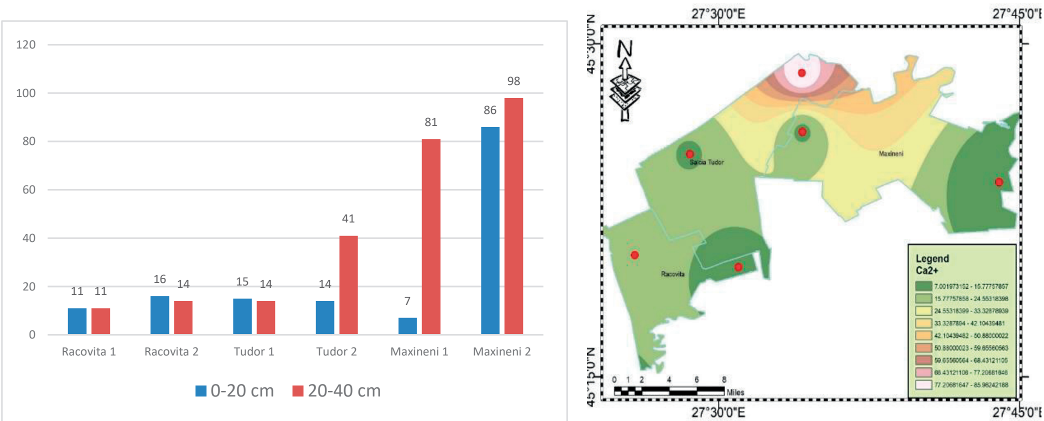

Figure 4. Calcium ion content and distribution

The magnesium content at the depth of 0-20 cm varies between 0.24 and 75 mg/kg, which represents a low to very low content.

And at the depth of 20-40 cm magnesium has a low to very low content with maximum values reaching 108 mg/kg in profile 1 from Măxineni.

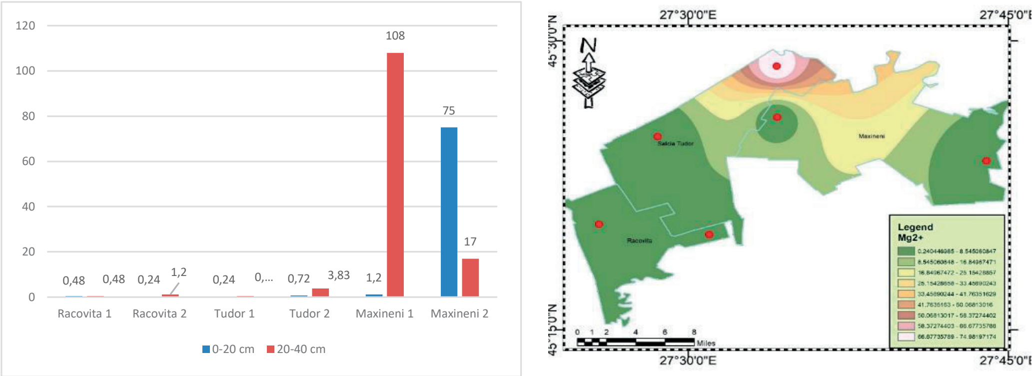

Figure 5. Magnesium content and distribution

The highest values of 58 and 89 mg/kg of the sodium content are at the profiles from Măxineni and the lowest at the profiles from Racoviță, with a maximum sodium content of 2 mg/kg.

Along with the depth, the sodium content in the soil also increases, even if the values are low in the Racoviță profiles, at the other point's very high sodium values were recorded at a depth of 20-40 cm.

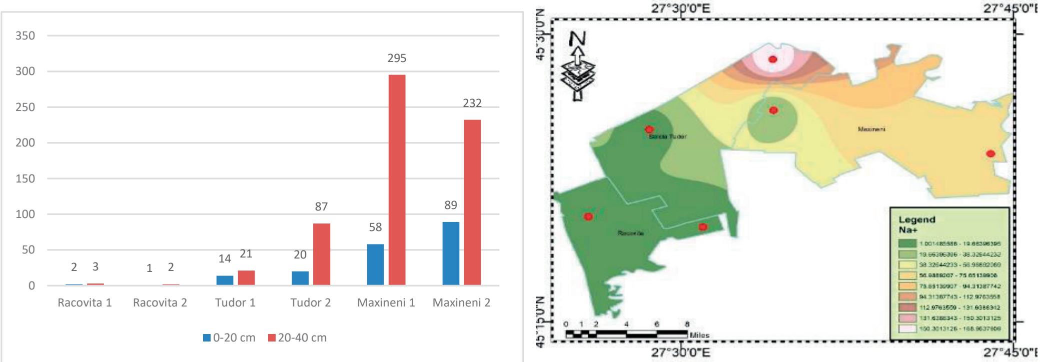

Figure 6. Sodium ion content and distribution

The potassium content varies between 8 and 15 mg/kg at the depth of 0-20 cm, which represents a low and very low content. The state of potassium supply at the depth of 20-40 cm is medium only in profile 1 from Măxineni, with a value of 26 mg/kg and in the other profiles the potassium content in depth is low.

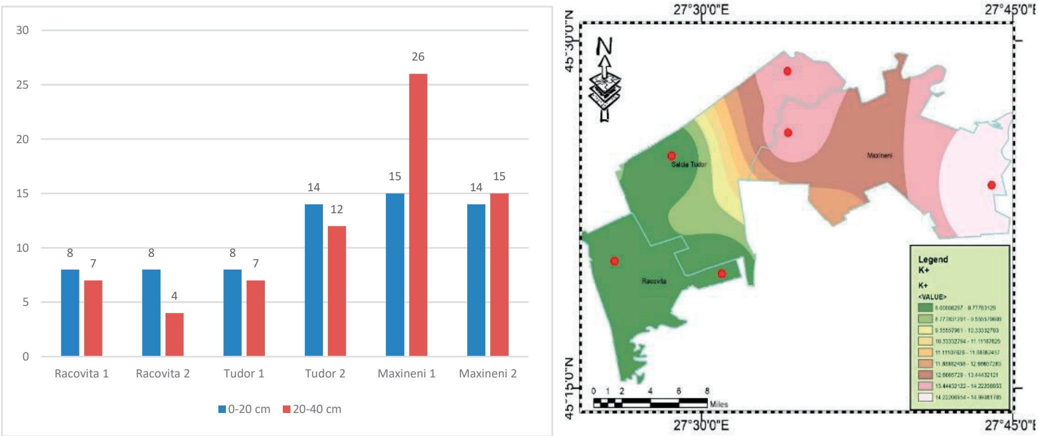

Figure 7. Potassium ion content and distribution

It can be seen from the samples analyzed in the three locations that the salinization and alkalization of the soils increases with the depth due to the influence of groundwater loaded with soluble salts especially of the sodium ion. Following the research carried out, 6 types of salinity index values were identified in the study area.

Table 1. Distribution of surfaces according to the salinity index

Interpretation	The salinized surface, km	Percent
No salinity	524	18.07%
Very low salinity	916	31.58%
Moderate salinity	768	26.46%
High salinity	483	17%
Excessive salinity	210	7%
Total	**2901**	**100%**

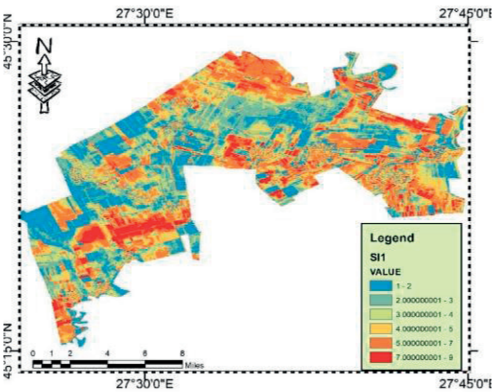

Figure 8. Salinity index (SI)

The Bare Soil index (BSI) was calculated to identify arid land, which includes non-cultivated areas (houses, roads, urban areas, rural urban areas, eroded areas and non-agricultural areas).

The results shown in Table 2 and Figure 9 indicate that there are five types of barren land guidance areas.

The reason may be due to the high percentage of salinity and the impact of difficult climatic conditions and high temperatures, which affect plant growth and thus lead to a decrease in the area covered by vegetation, especially in summer.

Table 2. Distribution of surfaces according to The Bare Soil index (BSI)

Interpretation of the aridity index	The salinized surface, km	Percent
Very dense vegetation	223	7.69%
Dense vegetation	633	21.81%
Harvested vegetation	1007	34.71%
No vegetation	768	26%
Degraded	271	9%
Total	**2901**	**100%**

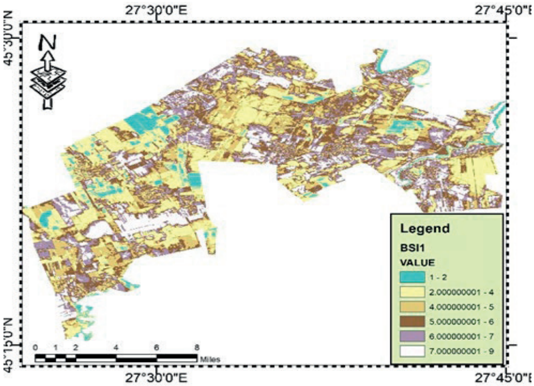

Figure 9. Bare Soil index (BSI)

Soil Adjusted Vegetation Index (SAVI):

Soil Adjusted Vegetation Index (SAVI) is calculated as a ratio of R to NIR values with a ground brightness correction factor (L) defined as 0.5 to accommodate most land cover types. In Landsat 8,

SAVI = ((Band 5 – Band 4) / (Band 5 + Band 4 + L)) * (1 + L).

The soil brightness correction factor (L) was varied from 0 to 1 and from 1 to 100 to analyze the effect and sensitivity of NIR-red data space translation on vegetation index improvement and to determine whether a single optimal L value can be applied to a wide range of vegetation densities. Each shaded area illustrates the variations in vegetation index from a constant amount of vegetation on the two soil backgrounds. At L = 0, the NDVI behavior is shown with the width of the shaded area representing smooth variations from light to dark. As the adjustment factor (or change of origin) is increased, there was a continuous decrease in soil-induced variations for small amounts of vegetation (LAI = 0-0.5), and, at L = 1, soil influences nearly disappeared into these canopies. With higher vegetation density (LAI = 1), the optimal fit was found at L = 0.75 because soil influences reappeared at higher "L" values. With even higher vegetation densities, the optimum "L" values decreased to lower values. It was found that the optimal adjustment factor is linearly correlated with LAI (r = -0.990).

The results presented in Table 3 and Figure 10 indicate that in the study area there are five ranges of SAVI index values, in different degrees, distributed between agricultural land, natural vegetation and growing vegetation. The reason is due to the impact of soil salinity and its critical degradation, as well as the decrease in the percentage of cultivated land.

Table 3. Soil Adjusted Vegetation Index (SAVI)

SAVI Interpretation	Area, km	Percent
Water	18	0.62%
Dense vegetation	1266	43.63%
Moderate vegetation	977	33.68%
No vegetation	641	22%
Total	**2901**	**100%**

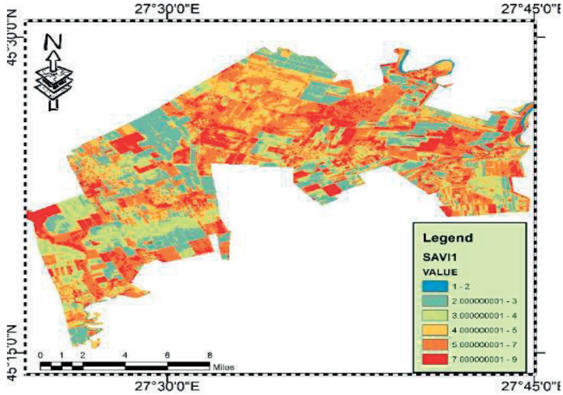

Figure 10. Soil Adjusted Vegetation Index (SAVI)

Tasseled Cap Transformation Wetness (TCW)
Tasseled Cap Transformation Wetness (TCW) was updated by Crist (1985) for use with Landsat TM data. It has been used to determine the amount of moisture retained by vegetation or soil, thus called humidity, as well as other indicators that indicate vegetation and soil radiance. TCW images (representing a measure of humidity determined by comparing the visible and near-infrared spectral response with the short-infrared spectral response) were derived from the ETM_ images of the study area using the ER transform algorithm.

Table 4. Tasseled Cap Transformation Wetness (TCW)

Interpretation, Tcw	Area, km	Percent
<0	996	34.34%
>0	1905	65.67%

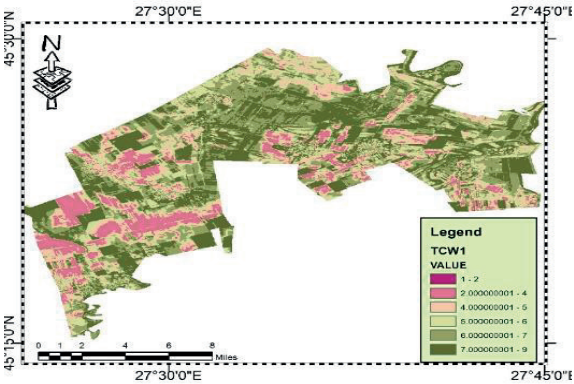

Figure 11. Tasseled Cap Transformation Wetness (TCW)

Topsoil Grain Size Index (GSI)
Topsoil Grain Size Index (GSI) was developed based on the field survey of soil surface spectral reflectance and laboratory analyses of soil grain composition. GSI found has close correlation to the fine sand or clay-silt-sized grain content of the topsoil in sparsely vegetated arid land of Inner Mongolia, China. A high GSI value corresponds to the area with high content of fine sand in topsoil or low content of clay-silt grains. The GSI can be simply calculated by:

$$GSI = (R - B) * (R + B + G)$$
$$= (B4 - B2) * (B4 + B2 + B3)$$

Where: R, B, and G are the red, blue, and green bands of the remote sensing data, respectively. GSI value is close to 0 in the vegetated area, and for water bodies it is a negative value.

Table 5. Topsoil Grain Size Index (GSI)

Interpretations	Area, km	Percent
Water	227	7.82%
Degraded	1282	44.18%
Moderately degraded	903	31.13%
Severe degradation	490	17%
Very severe degradation	0	0%
Total	**2901**	**100%**

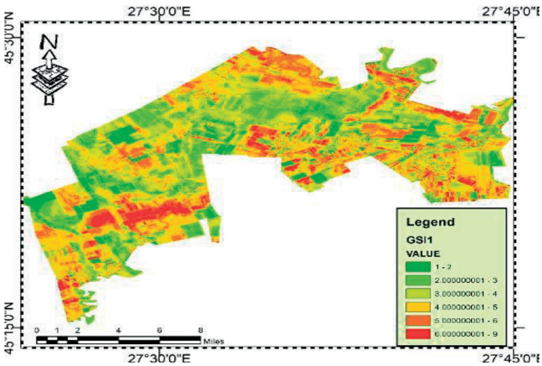

Figure 12. Topsoil Grain Size Index (GSI)

All the results obtained in the laboratory and the processing of satellite images indicated that there is a correlation between the results, especially in the area of Măxineni, where there is a high percentage of salts in the soil. The high content of salts in the soil led to the lack of land cover with vegetation.

CONCLUSIONS

- Natural factors have a direct impact on land degradation problems in our study area. The main factors to mention are climate change, soil and water surface degradation, lack of vegetation cover and groundwater, which have led to the spread and exacerbation of deterioration manifestations in the study area, where climatic action played a major role, with effects such as high temperatures, lack of rain and wind speed which led to the drying of the soil surface, making it vulnerable to erosion and salinization processes and leading to an increase in degraded land.
- Through our study, it became clear to us that the problem of land degradation is prevalent in most of the study area in its various manifestations, but it clarified the occurrence of soil salinization is the most prominent.
- Our study demonstrated the ability of remote sensing techniques and geographic information systems to survey, monitor, identify, analyze and classify land degradation manifestations and to detect spatial and temporal variables occurring in the study area.
- The digital indicators (INDEX) contributed to highlighting the characteristics of the land very effectively by clarifying the spatial distribution picture and the quantitative and qualitative assessment of the types of soil degradation manifestations in the study area, such as the images resulting from the natural difference index of the vegetation cover, Salinity Guide, Arid Soil, Soil Degradation Guide.
- There are clear spatial changes in the intensity of salinization processes in the study area, but by changing water management, through appropriate irrigation practices, can often lead to increased crop yields in saline soil conditions.
- Landsat satellite visual images are used for regional studies that are carried out over a relatively large area, due to the relatively low spatial resolution, which varies between 6-15 meters, the accuracy of its results is increased by spectral, spatial enhancements

and matching operations with reference information, whether it's maps or images.

- Studies have confirmed that geospatial data allows us to obtain graphical and non-graphical information, considering the estimation of land degradation risks through geographic mapping. Land data is extremely important for modeling the erosion of degraded plots and presenting this data in a digital format has significant benefits in terms of fast processing and quality of information obtained.
- Studies have shown that the use of remote sensing techniques and geographic information systems has enabled researchers to obtain accurate and sufficient information and data to understand the causes of land use changes and also to lessen the risk of land degradation as computerized processing, review and additionally exposures to the information acquired in various forms (maps, graphs, tables, text, etc.) are provided. For that reason, they offer some special benefits, including obtaining thematic maps, the ability to process large and multiple heterogeneous databases with spatial reference and high flexibility in terms of IT system configuration, allowing modification of a wide variety of applications and users.
- Previous research has shown us the possibility of combining data related to different things and analyzing the information obtained by computer processing of primary data, as compared to classical procedures (where the calculation areas are larger and of variable size). In this case, land degradation is determined at the primary surface level (pixels/cell). Another great advantage of GIS technology is that it is possible to integrate all factors (natural and human) at the cellular level. Computer processing of data that characterizes the factors that determine the initiation and maintenance of a land degradation process generates multiple possibilities for agricultural land simulation.
- Greater accuracy of research on land degradation due to erosion can also be achieved with GIS technologies by diversifying data acquisition methods (including photogrammetry and remote sensing) and by continuously developing and updating databases.

REFERENCES

Allbed, A., Kumar, L. (2013). *Soil salinity mapping and monitoring in arid and semi-arid regions using remote sensing technology*. Advances in Remote Sensing, 2, 373-385.

Asfaw, E., Suryabhagavan, K., Argaw, M. (2018). *Soil salinity modeling and mapping using remote sensing and GIS: the case of Wonji sugar cane irrigation farm. Ethiopia* J Saudi Soc Agric Sci. 2018; 17:250–8.

Barbouchi, M., Abdelfattah, R., Member, S., Chokmani, K., Aissa, N. Ben, Lhissou, R.,El Harti, A., (2014). *Soil salinity characterization using polarimetric InSAR coherence: case studies in Tunisia and Morocco*. IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 1–10.

Brunner, P., Li, H., Kinzelbach, W., Li, W. (2007). *Generating soil electrical conductivity maps at regional level by integrating measurements on the ground and remote sensing data*. Int J Remote Sens. 2007; 28:3341–61.

Coteţ, V., Dumitru, M., Florea, N. (2010). *Cercetări privind ameliorarea solurilor sărăturate din Câmpia Brăilei*, Ed. Sitech, Craiova.

Coteţ, V. (2010). *The management of soils with salinisation risk from experimental field Lacu Sarat, Braila,* Proceedings of the Global Forum on Salinization and Climate Change, Valencia, Spain, 25-29 October 2010, World Soil Resources Reports No. 105. FAO, Rome, p. 74.

Eldeiry, A.A., Garcia, L.A. (2010). *Comparison of ordinary kriging, regression kriging, and cokriging techniques to estimate soil salinity using LANDSAT* images. J Irrig Drain Eng; 136:355–64.

Furby, S., Caccetta, P., Wallace, J. (2010). *Salinity monitoring in Western Australia using remotely sensed and other spatial data.* J Environ Qual. 2010; 39:16–25.

Garcia, L., Eldeiry, A., Elhaddad, A. (2005*). Estimating soil salinity using remote sensing data.* Proceedings of the 2005 central plains irrigation conference, Citeseer.

Ibrahim, M., Abu-Mallouh, H. (2018). *Estimate land surface temperature in relation to land use types and geological formations using spectral remote sensing data in Northeast Jordan.* Open J Geol. 2018; 8:174–85.

Ibrahim, M., Koch, B., Data, P. (2020). *Evaluate the effect the land surface temperature in the arid and semi-arid lands using potential remote sensing data and GIS technique*. Int J Glob Warm (Forthcoming articles).

Ibrahim, M., Ghanem, F., Al-Salameen, A., Al-Fawwaz, A. (2019). *The estimation of soil organic matter variation in arid and semi-arid lands using remote sensing data.* Int J Geosci. 2019; 10:576.

Metternicht, G. (1998). *Analysing the relationship between ground based reflectance and environmental indicators of salinity processes in the Cochabamba valleys (Bolivia)*. Int J Ecol Environ Sci; 24:359–70.

Metternicht, G., Zinck, J. (2003). *Remote sensing of soil salinity: potentials and constraints*. Remote Sens Environ ; 85:1–20.

Perez-Sirvent, C., Martınez-Sanchez, M.J., Vidal, J., Sanchez, A. (2003). *The role of low-quality irrigation water in the desertification of semi-arid zones in Murcia,* SE Spain. Geoderma 113, 109–125.

Taha, G., Aysegul, T., Elif, S. (2015). *Soil Salinity Prediction, Monitoring and Mapping Using Modern Technologies* – Procedia Earth and Planetory Science 15, 507-512.

Zhang, T.T., Zeng, S.L., Gao, Y., Ouyang, Z.T., Li, B., Fang, C.M.. et al. (2011). *Using hyperspectral vegetation indices as a proxy to monitor soil salinity*. Ecol Indic. 2011; 11:1552–62.

Zheng, Z., Zhang, F., Ma, F., Chai, X., Zhu, Z. (2009). *Geoderma Spatiotemporal changes in soil salinity in a drip-irrigated field*. Geoderma 149 (3–4), 243–248.

Zhu, J. (2001). *Plant salt tolerance*. Trends Plant Sci. 6 (2), 66–71.

Wu, W., Mhaimeed, A.S., Al-Shafie, W.M., Ziadat, F., Dhehibi, B., Nangia, V. et al. (2014). *Mapping soil salinity changes using remote sensing in Central Iraq*. Geo Reg.; 2:21–31.