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(RESEARCH ARTICLE)

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Changes in the soil salinity index revealed (Normalized Difference Salinity Index) NDSI in Al-Muthanna Governorate

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Abstract

The study was conducted on Salinity index Al-Muthanna Governorate, located in southern Iraq, is bordered to the north by Najaf Governorate, to the east by Al-Qadisiyah Governorate, and to the west by the Kingdom of Saudi Arabia.The aim is to study the use of the Soil Salinity Index (NDSI) to monitor and analyze soil salinity levels. In the region, by using satellite imagery, especially images Landsat 8 OLI For the two time periods 2015 and 2025. This is to analyze the changes between 2015 and 2025, to provide accurate maps showing changes in soil salinity over time. The analysis revealed that most of the land in the Muthanna region has moderate salinity or is unpolluted, while some areas have high or very high salinity. It was observed that areas of high and very high salinity decreased between 2015 and 2025, while areas of mild and moderate salinity witnessed a significant expansion Although there are some areas that still suffer from high salinity, the results indicate a marked improvement in soil salinity in most agricultural areas. By integrating this data with geographic information systems (GIS), maps were created showing the distribution soil salinity and identifying areas experiencing change in salinity These maps help identify areas that may need special treatments to ensure healthy plant growth and improve the sustainability of agricultural lands

Keywords: Salinity index; Soil salinity; Geographic information systems

1. Introduction

Understanding soil salinity is crucial for farmers and land managers, as it influences crop selection and farming practices. Salt-sensitive crops may struggle under saline conditions, necessitating the selection of varieties capable of withstanding these challenges. Moreover, salinity affects not only crops but also the wider ecosystem. It can lead to changes in plant communities and soil microbes, which play a role in nutrient cycling and fertility Soil.

The relationship between soil salinity and its impact on ecosystems is complex. As salinity levels rise, the balance of plant and animal life can shift, often leading to a decline in biodiversity. This understanding paves the way for exploring the broader effects of soil salinity on ecosystems, as these changes can have long-term consequences for environmental health and sustainability. Soil salinity refers to the concentration of dissolved salts in the soil, significantly impacting plant growth and agricultural productivity. High salinity levels often impair crops' ability to absorb water and nutrients, leading to reduced yields and poor crop health. This phenomenon is of particular importance in agriculture, where soil salinity management is essential for achieving sustainable farming. Salinity can arise from various environmental factors, including irrigation practices, climatic conditions, and the natural composition of the soil. For example, frequent irrigation can lead to salt accumulation from water sources, while arid climates may contribute to natural salinization through evaporation. (Xie et al., 2022). The analysis of long-range, large-scale remote sensing data produces diverse and rich information, thanks to the increasing number of high-resolution satellites and the rapid development of quantitative remote sensing technologies. Remote sensing has numerous applications, including land cover classification, soil moisture measurement, forest species classification, quantification of plant water content, snow

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mapping, sea ice classification, and oceanographic studies. Multispectral remote sensing images carry important spectral and spatial properties of objects. Different. Chouhan, 2012And from Among common sensing technologies, Y counting The Non-Salinity Standardized Index (NDSI) is a remote sensing tool specifically designed to assess soil salinity levels. Calculated using satellite imagery, it enables researchers and land managers to monitor salinity changes over time without extensive fieldwork. By analyzing the reflections of different wavelengths, the NDSI provides a clearer picture of salinity variations in different environments. (Mohamed and Ahmed, 2023)

Research objective

- Assessment the value of NDSI in the period between 2015 and 2025.
- Identifying changes in saline lands areas in Al-Muthanna Governorate during the period between 2015 – 2025.

2. Material and methods

2.1. Study Area

Al-Muthanna Governorate is located in southern Iraq, bordered to the north by Najaf Governorate, to the east by Al-Qadisiyah Governorate, and to the west by the Kingdom of Saudi Arabia. Latitude: 31.3100°N Longitude: 45.2800°EandThe region has a hot, dry desert climate in the summer, and relatively cold in the winter with long periods of drought. Al-Muthanna Governorate covers a vast area of approximately 51,000 square kilometers, making it one of the largest governorates in Iraq.

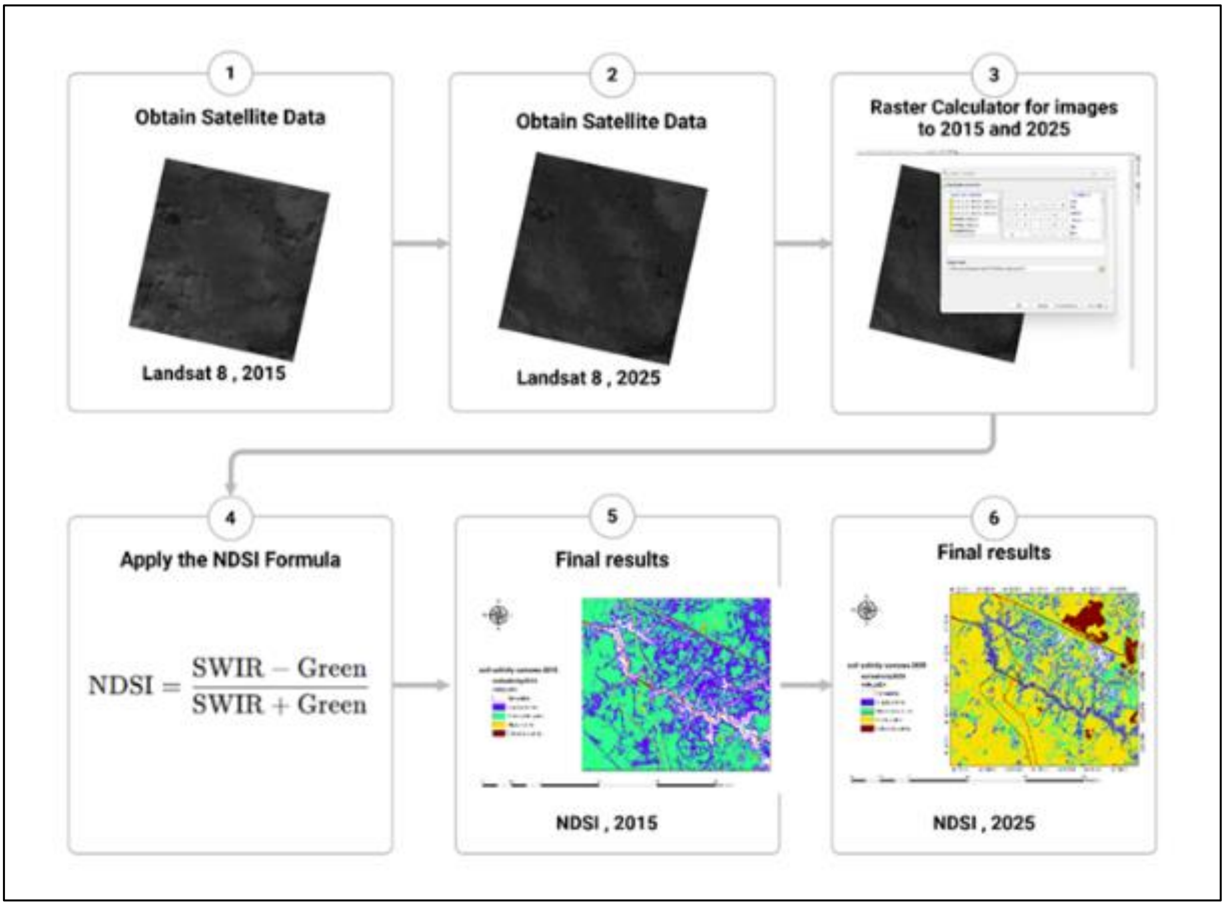

Figure 1 Study Site Map

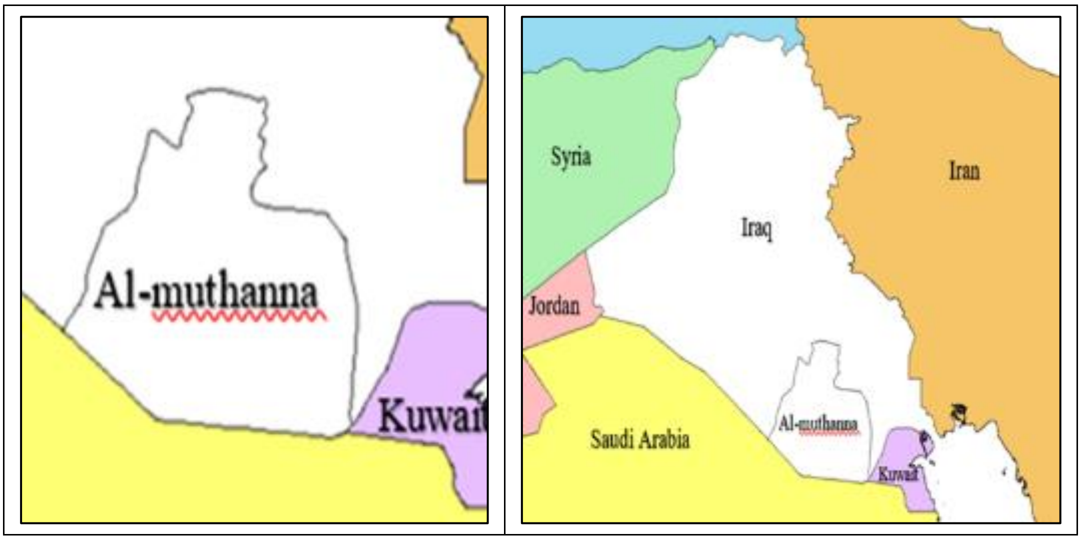

Figure 2 Al-Muthanna Study Site Map

The population of Al-Muthanna is around 1.5 million (according to the latest censuses), with the population density concentrated in the city of Samawah. And Agriculture is one of the most important sources of income in the province, with residents relying heavily on crops such as wheat, barley, and vegetables. The province benefits from groundwater and the Euphrates River for its agricultural needs**.**

2.2. Data Collection

Landsat images were downloaded from the U.S. Geological Survey website. (USGS) onlinehttp://earthexplorer.usgs.gov/) with determining the location of the areaSamawahIn the path168And the row38Landsat 8 images were selected. (OLI) for years2015 and 2025thermal measuring instrument (TIRS) for years2015 and 2025This is available dataFreeLandsat 8 images contain 9 spectral bands, with a spatial resolution of bands 1 to 7 and band 9 of approximately 30 meters, while the resolution of band 8 (the panchromatic band) is 15 meters**.**

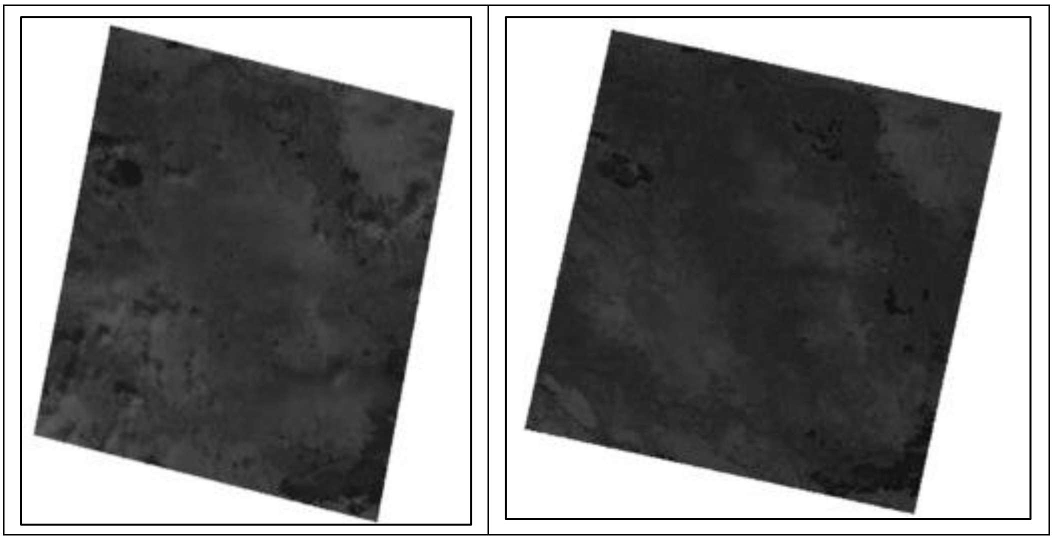

Figure 3 Appearance (Satellite images 2015-2025)

2.3. Image processing

The Landsat images had to be layered because they contained several bands, particularly Band 11. To achieve this, a layering process was performed. Radiometric correction was applied to minimize atmospheric effects on the image. Dust, clouds, and other particles in the atmosphere refract reflected light. Based on the refraction that occurs, radiometric correction was performed using a radiometric calibration instrument before image analysis. Subsequently, atmospheric correction was performed to remove brightness errors recorded in the image due to atmospheric scattering (path radiation) using a correction instrument.FLAASH. All actions have been performed.Using programENVI 5.

2.4. Soil salinity index (NDSI)

An image can be created NDVI by incorporating the reflection into ranges Green (Green)and infrared radiation Short (SWIR) using equation number 1 for calculation. In the electromagnetic spectrum (EMS), to measure soil salinity and its effect on plants.The indicator is used NDVI is primarily used to differentiate between regions. The salinity the Low and areas with the salinity High and Values range NDSI is between -1 and +1, where It indicates Values between -1 and 0 indicate high soil salinity, which negatively affects plants. However, areas with low salinity are represented by values greater than 0. The primary objective of this step is to identify areas that need treatment or those that require special management to ensure healthy plant growth in agricultural or natural environments. And In Table 1 below, the values are classified NDSI and level soil salinity

Table 1 Salinity Level Classification NDSI

Classification Ranges	levels of the soil salinity
-1<NDSI<-0.03	Extremely saline
-0.03<NDSI<0.15	Highly saline
0.15 < NDSI < 0.25	Moderately saline
0.25 < NDSI < 0.35	Slightly saline
0.35<NDSI<1	Non-saline

Using the program Organized Information Geography ArcGIS Desktop 10 to produce maps, especifically tools analysis. Digital spatial distribution maps were created using the Spatial Analyst extension in ArcGIS 10. The Interpolation tool from the Spatial Analyst Toolbox was employed to generate continuous surface maps from the spatial data. These maps enabled the identification, analysis, and comparison of spatial and temporal changes within the study area across different years.

Using the ArcGIS environment, the classified vegetation cover was categorized into five categories based on the NDSI results. The changes in vegetation cover layers during the research periods were then compared using an overlay technique.

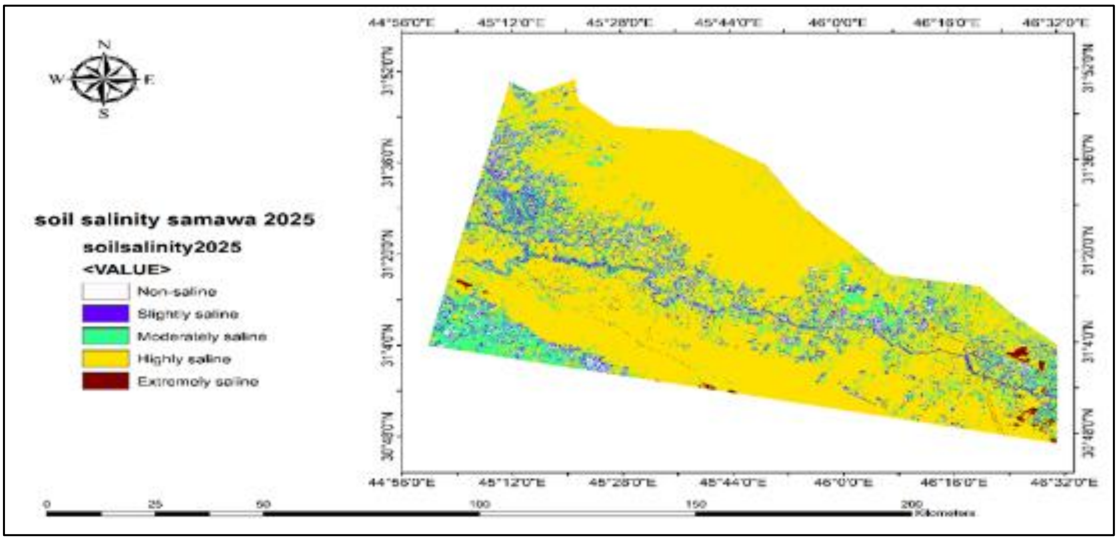

Figure 4 Appearance (Indicator Application Map NDSI)

The areas of the classified categories were calculated by counting the number of pixels of each category in the satellite image. Then, the area was determined using the following equation Area (km^2) = (Count × 30 × 30) / 1,000,000 Where Count is the number of pixels, and 30 × 30 m is the resolution of the satellite picture. The result is given in square kilometers. The computation was done in the boundaries of research area using the given polygon. Thus the area of each group in the classification table was acquired.

3. Results and discussion

3.1. Calculating the soil salinity index (NDSI)

It was created Maps related to the index Soil salinity (NDSI) for the years 2015 and 2025 in Al-Muthanna Governorate (Samawah). The analysis results showed the following:

Symbol	Range	Label
	-0.476337194 - -0.226075877	Extremely saline
	-0.226075877 - -0.133874339	Highly saline
	-0.133874339 - -0.075919087	Moderately saline
	-0.075919087 - -0.004792186	Slightly saline
	-0.004792186 - 0.195416868	Non-saline

Figure 5 Classification Values NDSI 2015

Each categorized based on the subject classification and NDSI measurement for the year 2015, extending to the color white (highly salted). This indicates soil with extremely high salt, with values ranging from -0.549 to -0.162. Blue (very saline) denotes soil with elevated salinity, with values ranging from -0.162 to -0.090. But green (Moderately salted) denotes soil with moderate salinity, characterized by values ranging from -0.090 to -0.033. Widdely yellow (Slightly salted) This indicates somewhat saline soil, with values between -0.033 and 0.051. The brown colour (non-salted) signifies unaltered land, with values spanning from 0.051 to 0.316.

3.2. Classification values NDSI 2025

While the ranking results showed NDSI For the year 2025Value distributions follows The color white (Extremely saline) This represents soil with very high salinity, where its value ranges between -0.476 and -0.226. Color blue (Highly saline) represents soil with high salinity, where its value ranges between -0.226 and -0.133. But green (Moderately saline) represents soil with moderate salinity, where its value ranges between -0.133 and -0.075.and yellow (Slightly saline) This represents slightly saline soil, with values ranging between -0.075 and -0.004. The brown color... (Non-saline) represents unpolluted land, with values ranging between -0.004 and 0.195

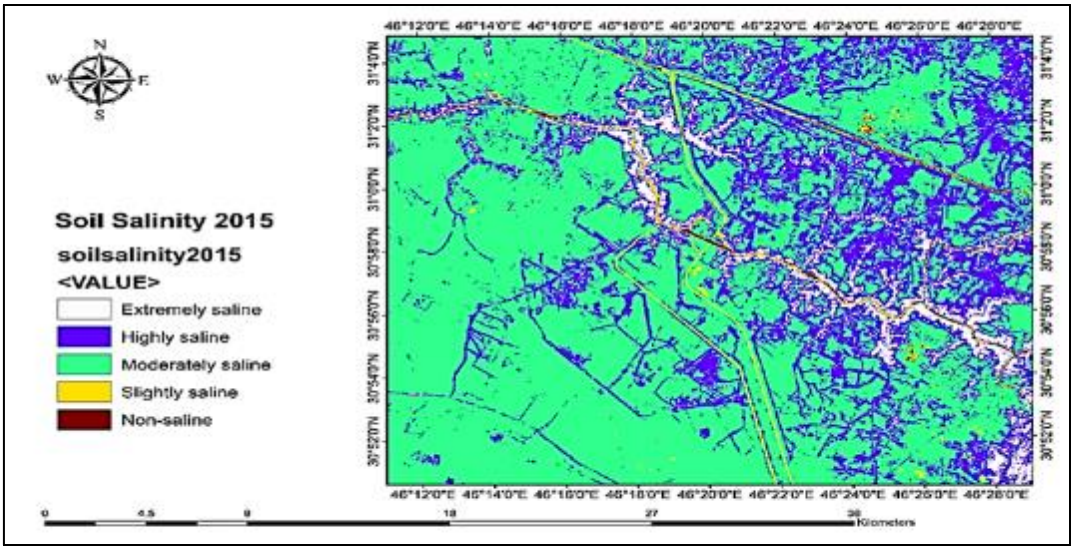

Figure 6 2015 Classification Map NDSI

As obvious from the map of 2015, most of the land has moderate salinity or is unpolluted, while some areas have high or very high salted. This map helps identify areas suitable for agriculture or those that may require special treatment due to salinity..

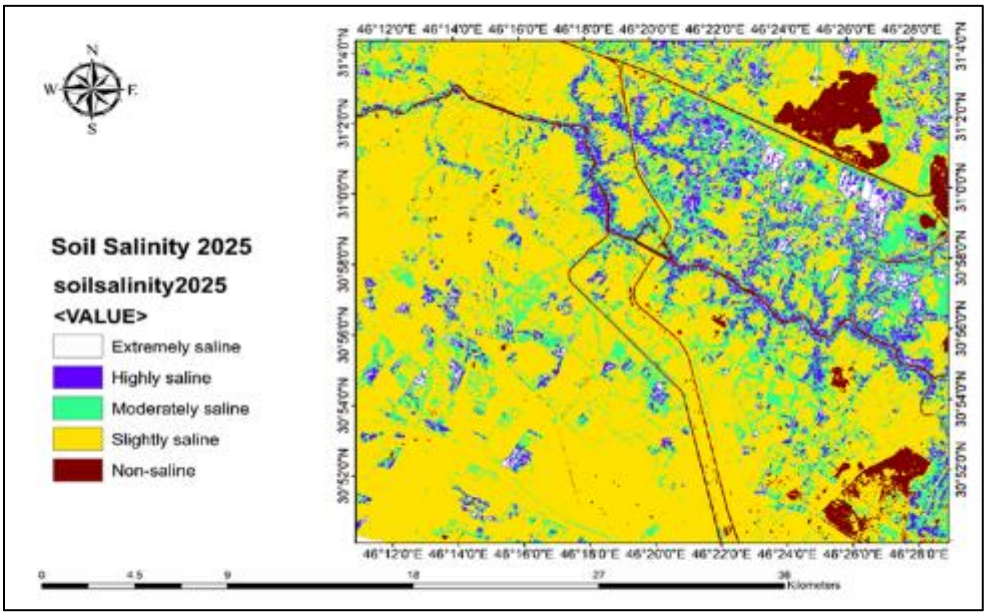

Figure 7 Classification Map 2025NDSI

While the maps of the year2025 will show a change At salinity levels It can be observed that there is an expansion in areas with mild or moderate salinity compared to those with high salinity, indicating a possible improvement in soil salinity between 2015 and 2025. The area is classified into 5Main categories based on the index soil salinity (NDSI) For the year 2015 This classification resulted in the following data.

Reclass_soil2015

OBJECTID *	Value	Count	Area
1	1	322886	290.5974
2	2	1686036	1517.4324
3	3	7555769	6800.1921
4	4	31249	28.1241
5	5	11838	10.6542

Figure 8 Area Values 2015 NDSI

The maps illustrate the potential for enhancements in water management or sustainable agriculture, including the implementation of advanced irrigation methods, the utilization of suitable fertilizers, or the amelioration of local climatic conditions. This may indicate the efficacy of some environmental or agricultural measures in enhancing soil quality.

The figure (9) indicates the extreme salinity category.Value 1 It has 322,888 units and encompasses an area of 290.5974 square kilometers. The elevated salinity classification. Value 2 comprises 1,868,036 units and encompasses an area of 1,517.4324 square kilometers. The moderately saline category (Value 3) has the largest area, with 7,555,769 units and spanning 6,800.1921 square kilometers. The mildly saline category (Value 4) comprises 31,249 units and encompasses an area of 28.1241 square kilometers. The non-saline terrain category, Saltiness (Value 5), comprises 11,838 units and covers an area of 10.8542 square kilometers. Based on this analysis, it can be observed that most of the Earth in 2015 had moderate salinity, then This is followed by high salinity. On the other hand, the non-domesticated lands saltiness It represents the smallest area compared to the other categories. As for In 2025, some changes occurred in the distribution soil salinity In the area. The results showed a change in the areas of the 5 selected classifications.

Reclass_soil2025

	OBJECTID *	Value	Count	Area
▶	1	1	298311	268.4799
	2	2	665648	599.0832
	3	3	1710032	1539.0288
	4	4	7375418	6637.8762
	5	5	105470	94.923

Figure 9 Area Values 2025NDSI

The High Salinity category (Value 1) comprises 298,311 units and encompasses an area of 288.4799 square kilometers. The high salinity category (Value 2) comprises 686,848 units and encompasses an area of 599,083 square kilometers. Moderate salinity classification.Value 3 It comprises 1,710,032 units and encompasses an area of 1,539,028 square kilometers. The salinity is moderately elevated (Value 4), comprising 7,375,418 units and covering an area of 6,837.8762 square kilometers. The non- salted land (Value 5) comprises 105,470 units and covers an area of 94.923 square kilometers.

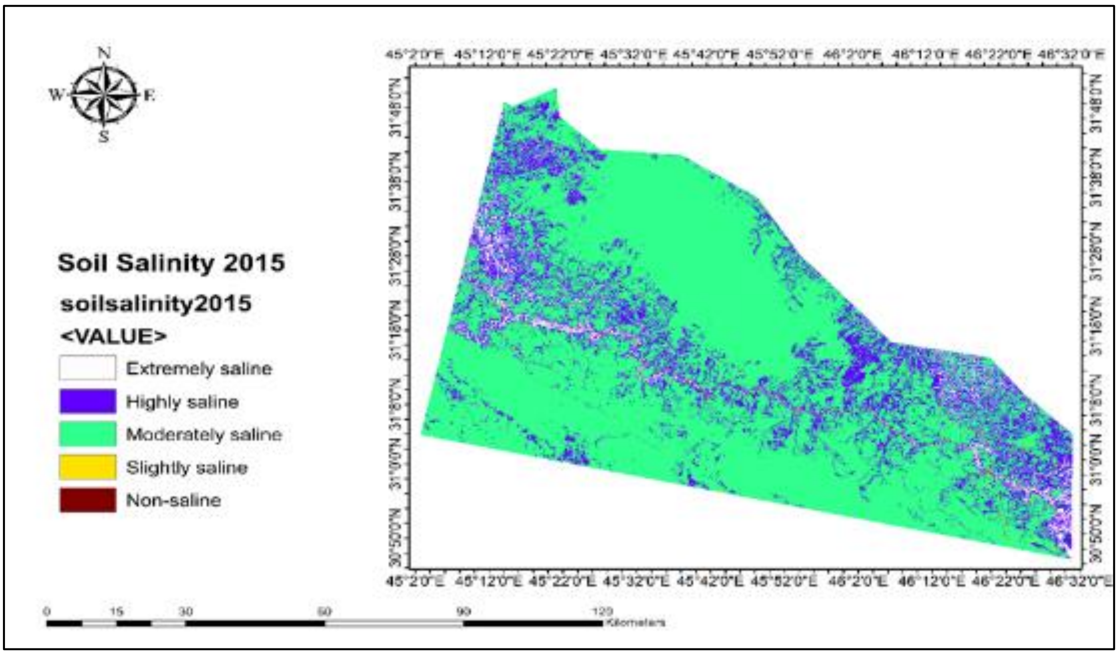

Figure 10 Comparative Map of Classification 2015-2025NDSI

Comparing the results from 2015 and 2025, it is evident that high salinity (Value 1) is observed. In 2025, there was a notable decrease, with the area in 2015 being 290.5974 square kilometers, which reduced to 288.4799 square kilometers in 2025, signifying a reduction in regions of excessive salinity. The region of high salinity (Value 2) experienced a minor reduction from 1,517.4324 square kilometers in 2015 to 599.0832 square kilometers in 2025. Moderate salinity (Value 3) experienced substantial growth in 2025, with the area expanding from 6,800.1921 square kilometers in 2015 to 1,539.0288 square kilometers in 2025. The light salinity (Value 4) experienced substantial growth, with a marked increase in area from 28.1241 square kilometers in 2015 to 6,837.8762 square kilometers in 2025. Concerning non-land saltiness (Value 5), it exhibited minimal change in size, with the area experiencing a slight increase from 10.8542 square kilometers in 2015 to 94.923 square kilometers in 2025.

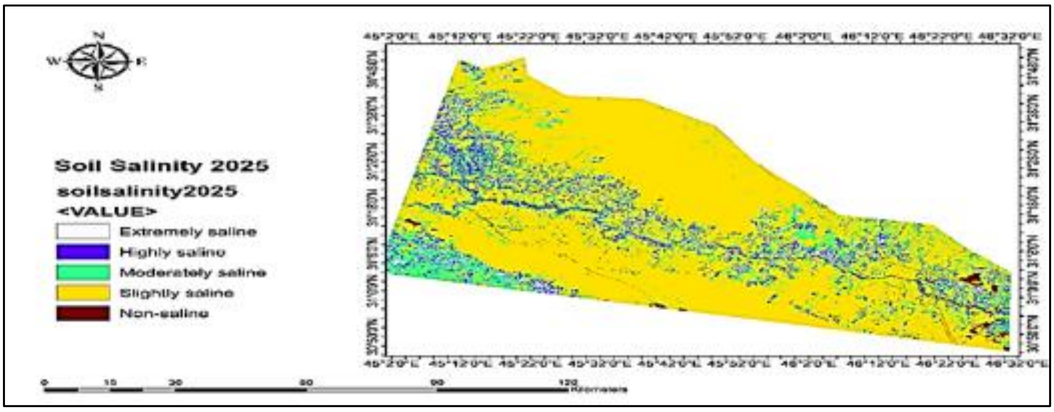

Figure 11 Soil Salinity 2025

4. Conclusion

Based on these results obtained from the study, the following can be concluded:

- The study revealed that most agricultural land in Al-Muthanna Governorate has moderate salinity or is unpolluted. A significant decrease in areas with high and very high salinity was also observed between 2015 and 2025.
- While some areas still suffer from high salinity, the results indicate a significant improvement in soil salinity in most agricultural areas, reflecting the success of certain initiatives or environmental factors in improving the soil.
- The integration of satellite images (Such as Landsat 8 OLI images) with Geographic Information Systems (GIS) An effective tool for providing accurate maps showing changes in soil salinity over time

Recommendations.

- Encouraging the use of modern irrigation techniques such as drip irrigation to reduce salt intrusion into the soil and prevent excessive salinity buildup.
- Training farmers and the city Local farmers on using tools GIS and remote sensing are used to monitor soil salinity, helping them make informed decisions about land management.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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