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Effect of Land Use Change on Chemical Soil Degradation and Improvement in Drylands in Egypt

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ONE OF THE MAJOR environmental issues threatening agricultural land and impeding sustainable development is land degradation. This research work was conducted to assess and monitor soil degradation and improvement under medium-term of land use changes in a dryland area in Egypt. Soil salinization and sodification were assessed in 2022 and the results were compared with those of an earlier study conducted in 2008. Salinization and sodification rates were estimated and mapped to reflect the chemical soil degradation and improvement in conjunction with land use change. In terms of soil degradation and improvement rates, the results revealed that the study area witnessed a non-to-slight (0-2 dS m^{-1}/year) and moderate to high (2 to more than 5 dS m^{-1} /year) decrease in the soil salinity by 58% and 9.4%, respectively. This is due to the change of land use such as change from natural vegetation to crop production or due to crop rotations such as the transition of summer and winter crops to the perennial lucerne (Medicago sativa L.). The impact of cropping pattern change was also obvious on the decrease of sodicity levels, where the non-to-slight rate (0-1 decrement a year) occupied 45.6 % of the study area while the moderate rate (1-2 decrement a year) occupied 0.8%. The effect was more evident in the southeastern part of the study area. On the other hand, the development of soil degradation rate took place, where 22.1% of the area witnessed a non-to-slight salinity increase while the moderate, high, and very high salinity increase occupied 10.26%. At the same time, the increase in soil sodicity rate was observed, where the non-to-slight rate (0-1/year) occupied 53% of the study area while the moderate rate (1-2/year) occupied 0.6%. The increase in the soil degradation rate was due to the change of land use from crop production to natural vegetation where water irrigation was no longer applied to the soil, especially under such dryland conditions.

Keywords: *Soil degradation and improvement; salinity, sodicity; land use change; dryland*.

1. Introduction

Recently, the world has been facing major environmental challenges, as awareness of environmental protection has begun to rise, along with climate changes and environmental hazards (Abd El-kawy 2023). Land degradation is one of the main challenges to environmental and agricultural development (Saeed and Bedair 2024). Land degradation refers to a negative change or long-term loss of the quality of land services (Imbrenda et al., 2021). The impacts of this process could lead to loss of ecosystem services (e.g., land productivity) and functions, biodiversity, natural capital and soil (Nedd and Anandhi 2024).

According to the report of UNEP (2021), land degradation affects 40% of the world's population. It addressed that the world countries must meet their commitments to face the challenges of climate change and pollution through the restoration of more than one billion hectares of degraded land during the period 2021-2030, an area larger than China (UNEP 2021). It is estimated that about 33% of the world's land area is degraded (FAO 2015). About 1.9 billion hectares of global land are affected by degradation (Naseer and Pandey 2018).

In terms of regions affected by land degradation, up to 65% of the productive land is degraded in Africa, with estimated 132 million hectares of degraded cropland (Mansourian and Berrahmouni 2021). The process of land degradation can be in the form of soil salinization or sodification which directly contributes to food insecurity and ecosystem unsustainability, especially in arid and semi-arid regions. Like many dryland regions in the world, some parts of Egypt have witnessed inappropriate land use management that leads to land degradation through soil salinization, sodification and waterlogging (Abou-Kota et al., 2024; El-Ramady et al., 2018, El Baroudy, 2015).

Soil salinity becomes a land use issue when it affects plant growth and crop production, thus contributing to changes and transitions between land use types (Abdullahi et al. 2023; Allbed et al. 2017). In light of this, continuous monitoring of land use change is an

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important step to understand soil salinity change and its impacts on other land use types (Thiam et al. 2021). The management of soil salinization involves the adaptation of different cropping patterns to reduce the impact of salinization on crops (Cuevas et al 2019). For instance, growing salt-tolerant plants extract salts from the soil system (Qadir et al 2006). One option in this context is lucerne (*Medicago sativa L.*) species (Connor 2004).

According to FAO–UNEP (1984), three components are included in the assessment of land degradation: current status, rate and vulnerability to risk or hazard. Geographic information systems (GIS) play a vital role in identifying and mapping land degradation trends and risks. GIS can be applied in various environmental aspects of land degradation through the study of real units such as water erosion (Ali et al. 2017), soil salinization (Dehni and Lounis 2012), and dangers and natural disasters (Abd El-kawy 2019). GIS has the functionality to perform numerous tasks utilizing both attribute and spatial data (Shokr et al. 2022).

The main objectives of the present study are to assess and monitor soil degradation and improvement under medium-term of changes in land use and crop patterns in a dryland area in Egypt.

2. Materials and Methods

2.1. Study Area

The study area is situated geographically between 30º 50' 57" to 30º 51' 39" North latitudes and 29º 25' 7" to 29º 25' 59" East longitudes (Fig. 1). It lies within the Northwestern coastal zone of Egypt and characterized by the Mediterranean climate conditions. The area is surrounded by El-Hamam drain from North and West and bordered by Matruh-Alexandria railway from the South. The study area covers 65.18 hectares (155.19 faddans). The study area belongs to Alexandria University's dryland farm. The irrigation system used in the area is irrigated agriculture. The main source of irrigation is El-Hamam drain, which surrounds the farm from the East and Northwards. The cropping system followed in the area consists of growing winter crops such as wheat, barley and artichoke, and summer crops such as maize and sorghum. Recently, lucerne has been cultivated as a perennial crop in remarkable parts of the study area. Most of the agricultural practices are concentrated in the western part of the study area, while the eastern part is dominated by natural vegetation of desert shrubs and halophytes.

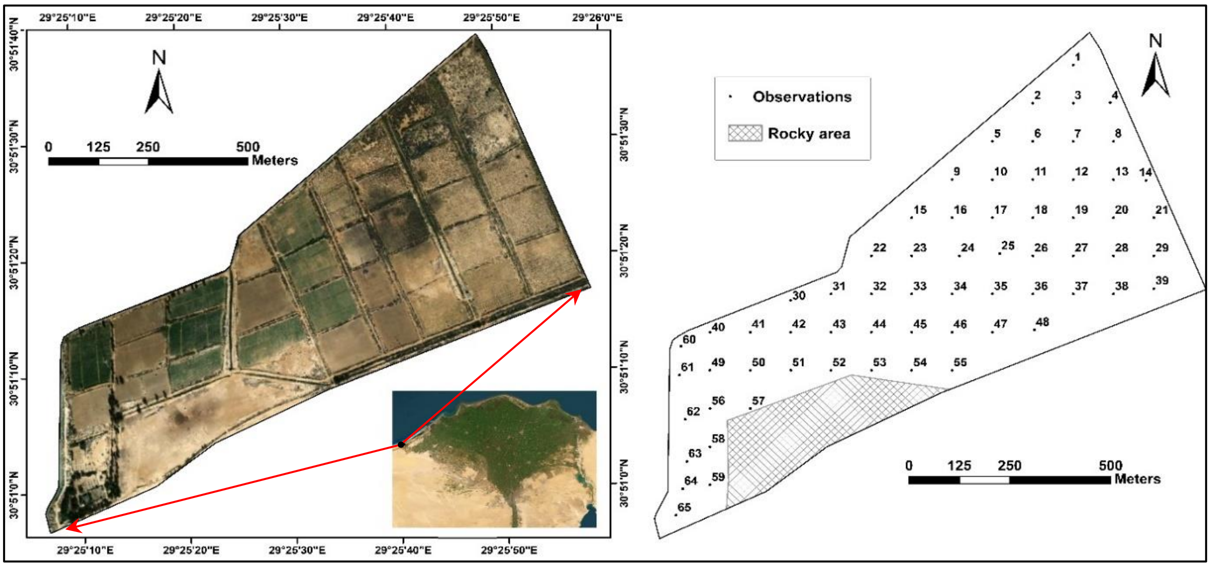


Fig.1. Location map of the study area and soil observations.

Meteorologically, the area is dominated by the Mediterranean climate. It is characterized by a long hot dry summer, mild winter with a short rainy season and high relative humidity. It receives quite low annual rainfall with 100–150 mm/year mean annual precipitation. The maximum temperature (30.8 °C) is recorded in August, while the minimum temperature (9.8 °C) is recorded in January. The average annual temperature is 13 °C. Relative humidity is high throughout the year and decreases in December to about 10% and reaches (60-70%) in April and May. Geologically, the region of the study area is created mainly of various Tertiary and Quaternary sedimentary deposits (Said, 1962, Gindi and Abd-Alla, 2000). It is characterized by a series of three parallel Pleistocene limestone ridges ranging in elevation up to 35 m separated by shallow depressions. Ridges and depressions in the region control the groundwater flow pattern and the Quaternary deposits constitute the main groundwater source (Gindi, 1989).

2.2. Fieldwork and laboratory analyses

This research is a comparative study, which is mainly based on a baseline study that was implemented in 2008 (Bahnassy 2008). In that baseline study, soil survey work was performed at Alexandria University's dryland farm (Fig. 1), where a 100-m-grid sampling strategy was followed for soil observations and sampling. Soil samples were collected at 60 cm below the soil surface and then laboratory analyzed in accordance with Page et al. (1982) and Richards (1954). In the present study, 65 soil auger observations were assigned to soil sampling and geo-referenced using GPS. The baseline study (2008) and the current study (2022) have the same spatial locations for soil observations (Fig. 1). The analyses included electrical conductivity (EC), pH, soluble cations and anions, and calcium carbonate content. Soil analyses were performed in soil paste. The exchangeable sodium percent (ESP) was calculated according to Richards (1954). A sample of water irrigation was taken for further analysis, where the main irrigation source is El-Hamam drain. Figure (2) illustrates the research approach used in this study.

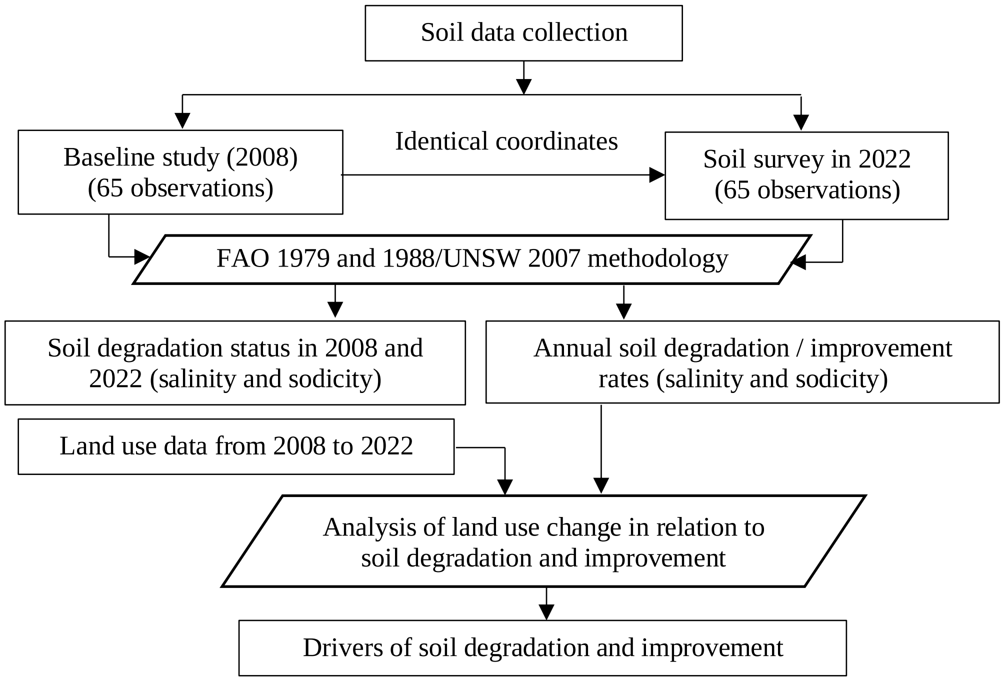


Fig. 2. Flowchart of the methodology adopted for the study.

2.3. Assessment of the soil degradation rate

In the present study, change monitoring of soil salinity and sodicity was conducted between the 2008 and 2022 data sets, where soil degradation status was assessed and reported for 2008 and 2022. The soil degradation annual rate was calculated and reported for the study period 2008-2022. For the calculations, we used the methodology and ratings developed by FAO (1979 and 1988) and UNSW (2007) and applied by Abd El-Kawy and Hedia (2018). The assessment of soil degradation was based on the soil salinity and sodicity parameters, where soil degradation was estimated according to the following equation:

$$\mathbf{RSD = [(PV_{\mathit{2022}} - PV_{\mathit{2008}}) / 14]} \quad \text{………….. eq. (1)}$$

where RSD is the rate of soil degradation for each parameter, PV_{2022} donates the parameter value in 2022, PV_{2008} donates the parameter value in 2008, and the value "14" refers to the study duration in years. The classes and descriptions used for the assessment of soil degradation are displayed in Tables (1 and 2). Maps of the soil degradation status and rate were created in the GIS environment.

Table 1. Classes and description of soil degradation hazards for soil salinity and soil sodicity.

Degradation status	Indicators	Soil degradation hazards			
		Non-to-slight	**Moderate**	**High**	**Very High**
Salinization (FAO 1988)	EC dS m^{-1} (soil paste)	< 4	4 - 8	8 - 16	> 16
Sodification (UNSW 2007)	ESP	< 10	10 - 15	15 - 25	> 25

Table 2. Classes and description of soil degradation rate for soil salinity and soil sodicity.

Type	Indicators	Soil degradation rate			
		Non-to-slight	Moderate	High	Very High
Salinization (FAO 1979)	Annual increase in EC (soil paste)	0 to 2 dS m^{-1}/year	2 to 3 dS m^{-1}/year	3 to 5 dS m^{-1}/year	> 5 dS m^{-1}/year
Sodification (FAO 1979)	Annual increase in ESP	0 to 1 percent/year	1 to 2 percent/year	2 to 3 percent/year	> 3 percent/year

2.4. Assessment of the soil improvement rate

In conjunction with the assessment of the soil degradation rate due to salinization and sodification processes, it was important to assess the soil improvement rate under the influence of agricultural practices followed in the investigated area as well as land use changes. To perform this task, a rating of assessment was proposed and applied in this research to evaluate changes in soil improvement (desalinization and desodification). The improvement rate is proposed to be identical to the degradation rate (Table 2), but in an opposite trend (-) as shown in Table (3). Accordingly, the value of RSD from equation (1) may be positive (+), which indicates soil degradation, or it may be negative (-), which indicates soil improvement. Consequently, an analysis of land use changes over the study period was carried out to determine the drivers of potential soil improvement.

Table 3. Proposed classes and ratings for the soil improvement rate.

Type	Indicators	Soil improvement rate			
		Non-to-slight	Moderate	High	Very High
Desalinization	Annual decrease in EC (soil paste)	0 to -2 dS m^{-1}/year	-2 to -3 dS m^{-1}/year	-3 to -5 dS m^{-1}/year	< -5 dS m^{-1}/year
Desodification	Annual decrease in ESP	0 to -1 percent/year	-1 to -2 percent/year	-2 to -3 percent/year	< -3 percent/year

3．Results

3.1. Descriptive statistics

The descriptive statistics of soil parameters in 2008 and 2022 (Tables 4) revealed that the maximum EC values recorded 157.6 and 159.6 dS m^{-1} for 2008 and 2022, respectively. However, the minimum EC values recorded 0.97 and 2.09 dS m^{-1} in the same order indicated.

Table 4. Descriptive statistics of soil characteristics in 2008 and 2022.

Soil parameters	Year	Minimum	Maximum	Mean	Standard Deviation	Coefficient of variance (C.V)
EC (dS m^{-1})	2008	0.97	157.6	41.00	41.01	100.02
	2022	2.09	159.6	36.97	36.04	97.48
ESP	2008	1.95	66.23	23.85	17.03	71.42
	2022	4.95	45.81	24.62	12.01	48.81
pH	2008	7.04	8.22	7.75	0.27	3.54
	2022	7.00	8.16	7.78	0.23	3.02
$CaCO_3$ (%)	2008	4.46	64.73	24.17	12.75	52.75
	2022	19.27	63.3	42.13	8.99	21.35

ESP results showed a higher maximum value (66.23) in 2008 than that of 2022 (45.81). The recorded minimum ESP values were 1.95 and 4.95 in 2008 and 2022, respectively. No remarkable temporal differences were observed in the pH values of 2008 and 2022. A remarkable difference was observed in the mean values of the $CaCO_3$ content in 2008 and 2022. Results of irrigation water analysis of El-Hamam drain revealed that water salinity varied from 4 to 5 dS m^{-1} in winter and summer, respectively.

3.2. Assessment and mapping of soil degradation hazards

The spatial distribution of soil salinity (EC) and sodicity (ESP) as well as their areas are depicted in Figures (3 and 4). In general, soil salinity hazards are categorized into four classes in 2008 and three classes in 2022. The non-to-slight class (EC < 4 dS m^{-1}) occupied 1.23% of the study area in 2008, while it was not represented in 2022. The moderate salinity class (EC: 4-8 dS m^{-1}) represented 4.42% and 6.75% of the total area in 2008 and 2022, respectively. The high salinity class (EC: 8-16 dS m^{-1}) represented 19.18% and 29.8% of the study area in 2008 and 2022, respectively.

The very high salinity class (EC >16 dS m^{-1}) occupied 75.17% in 2008, while it decreased to 63.45% in 2022. In the spatial domain, it was noticed that the lower soil salinity levels (EC <16 dS m^{-1}) are mostly distributed in the western part of the study area, while the higher salinity level (EC >16 dS m^{-1}) is concentrated at the eastern part.

The results in Table (5) indicated that the area represented by the non-to-slight class in 2008 disappeared completely in 2022. This was to account for the expansion (1.23%) in the area represented by the high salinity classes. Although the total change gained by the moderate salinity class was 6.75%, it lost 4.42% in favor of the high and very high salinity classes, with a net positive change of 2.33% (Net change = Area gain in 2022 - Area loss in 2008**)**. An expansion in the area of the high salinity class (14.66%) took place to the extent of the other classes, where most of this expansion (12.05%) was at the extent of the very high salinity class. A noticeable positive net change (10.62%) in the high salinity class was detected. These spatial changes among soil salinity classes are depicted in Fig.4.

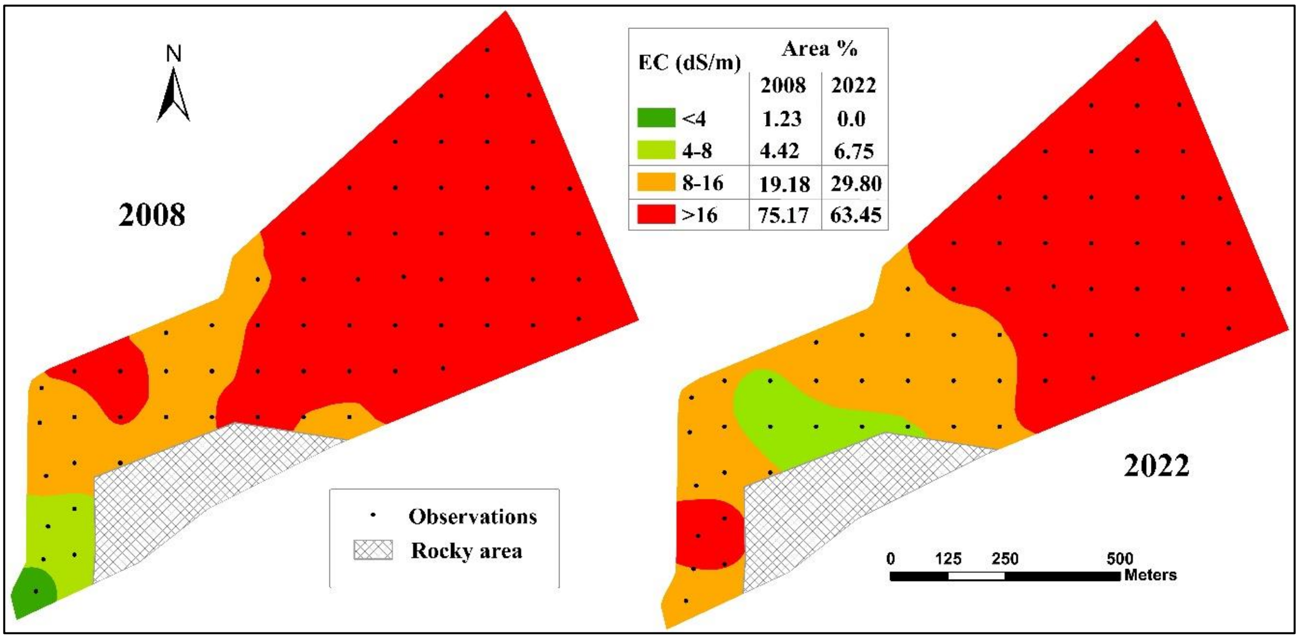


Fig. 3. Distribution of soil degradation hazards of salinity in the study area (2008 – 2022).

Table 5. Area (%) change matrix among soil salinity levels during 2008-2002.

Salinity classes in 2008 (dS m^{-1})	Salinity classes in 2022 (dS m^{-1})				Area (%) loss in 2008	Net changes as percent of the total area (%)
	Non-to-slight (< 4)	Moderate (4-8)	High (8-16)	Very high (> 16)		
Non-to-slight (< 4)	0.00	0.00	1.23	0.00	1.23	-1.23
Moderate (4-8)	0.00	0.00	1.39	3.03	4.42	2.34
High (8-16)	0.00	3.84	15.13	0.21	4.04	10.62
Very high (> 16)	0.00	2.92	12.05	60.21	14.96	-11.73
Area (%) gain in 2022	0.00	6.75	14.66	3.24		

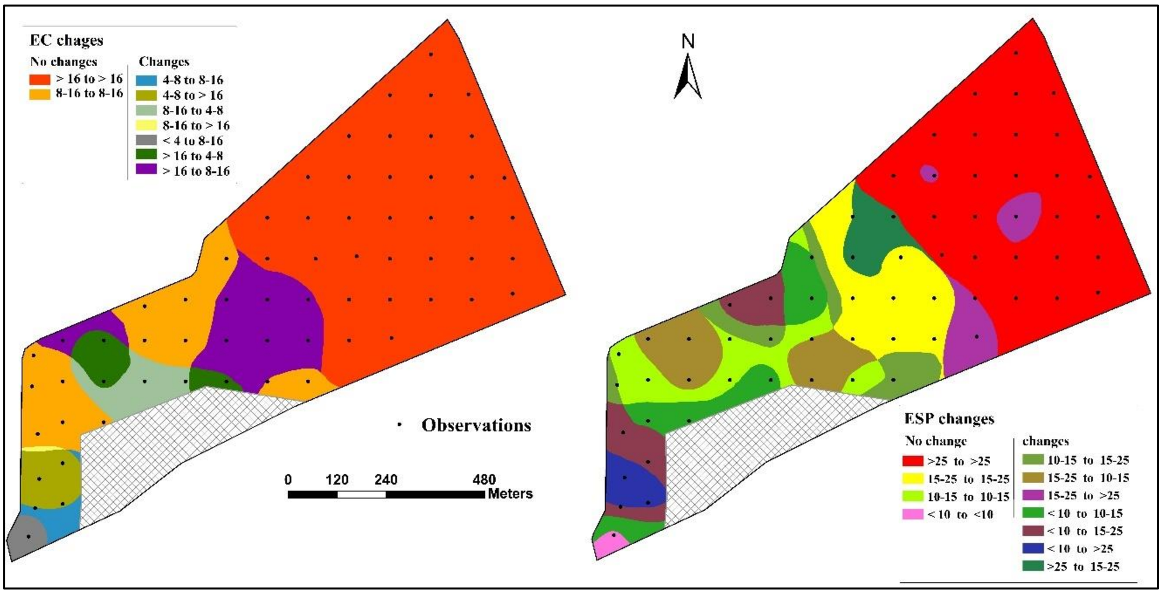


Fig. 4. Spatial changes of soil salinity and sodicity during the period 2008-2022.

Figure (5) shows the spatial distribution of soil sodicity classes as well as their area percent. The non-to-slight class (ESP <10) represented 15.46% and 0.6% of the study area in 2008 and 2022, respectively. The moderate sodicity class (ESP:10-15) represented 12.62 % and 21.92% of the total area in 2008 and 2022, respectively. The high sodicity class (ESP:15-25) represented 23.56% and 25.64% of the study area in 2008 and 2022, in the order indicated. The very high sodicity class (ESP >25) represented 48.36% and 51.84% of the study area in 2008 and 2022, respectively. In general, the lower soil sodicity levels (ESP < 15) are spatially distributed in the western part of the study area, while the higher sodicity levels (ESP > 15) are mainly extended to the eastern part.

In terms of changes in soil sodicity levels during the study period (2008-2022), a consequence remarkable decrease (14.86%), in the spatial extent of the non-to-slight sodicity level, was observed due to the expansion of the higher sodicity levels (Table 6 and Fig. 4). In this respect, an increase was observed in the areas of the moderate, high and very high sodicity levels by 9.3%, 2.08% and 3.5% of the total area, respectively. The major increase was in the moderate sodicity level, which took place at the expense of the non-to-slight (6.9%) and high (7.52%) sodicity levels.

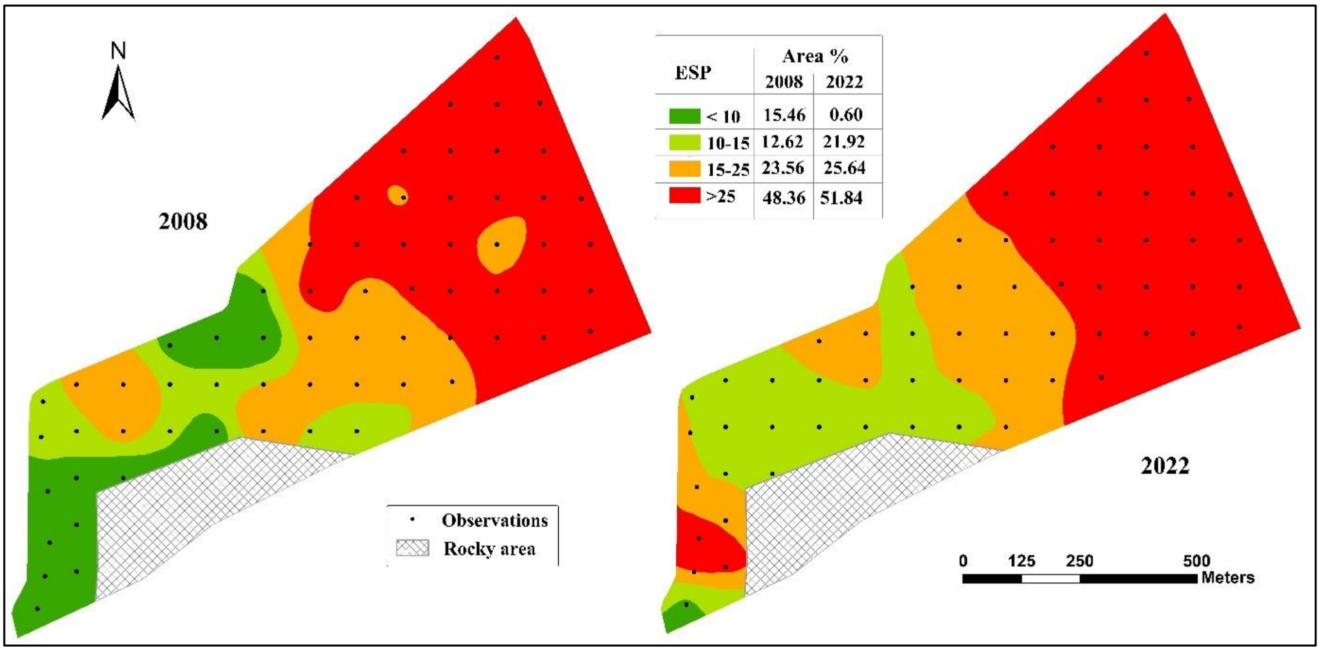


Fig. 5. Distribution of soil degradation hazards of sodicity in the study area (2008-2022).

Table 6. Area (%) change matrix among soil sodicity levels during 2008-2002.

Sodicity classes (2008)	Sodicity classes (2022)				Area (%) loss in 2008	Net changes as percent of the total area (%)
	Non-to-slight (< 10)	Moderate (10-15)	High (15-25)	Very high (> 25)		
Non-to-slight (< 10)	0.60	6.90	5.68	2.28	14.86	-14.86
Moderate (10-15)	0.00	7.50	5.12	0.00	5.12	9.30
High (15-25)	0.00	7.52	11.42	4.85	12.37	1.85
Very high (> 25)	0.00	0.00	3.43	44.7	3.43	3.71
Area (%) gain in 2022	0.00	14.42	14.22	7.13		

3.3. Assessment of soil degradation and improvement in relation to land use changes

The geographical distribution and pattern of soil degradation and improvement rates are displayed in Figure (6). The results showed obvious changes in the rates of soil salinity and sodicity, whether increasing or decreasing, as indicators of soil degradation or improvement rates during the study period (2008-2022). For instance, most of the study area witnessed a non-to-slight annual improvement rate in the soil salinity, as it decreased by 0-2 dS m^{-1}/year in most (58.6%) of the study area (Fig.6). There were also some areas (9.4%) that experienced moderate to high annual improvement in the salinity rate, where the soil salinity rate has decreased by 2 to more than 5 dS m^{-1} a year (Fig.6). This annual improvement in the soil salinity rate (moderate to high) was observed in the central and southeastern parts of the study area. A decrease in the sodicity rate was noticed, where the non-to-slight rate (0-1 decrement a year) occupied 45.6 % of the study area while the moderate rate (1-2 decrement a year) occupied 0.8%. This is more evident in the southeastern part of the study area, where the soil sodicity rate decreased annually by 1 to 1.1 (Fig 6).

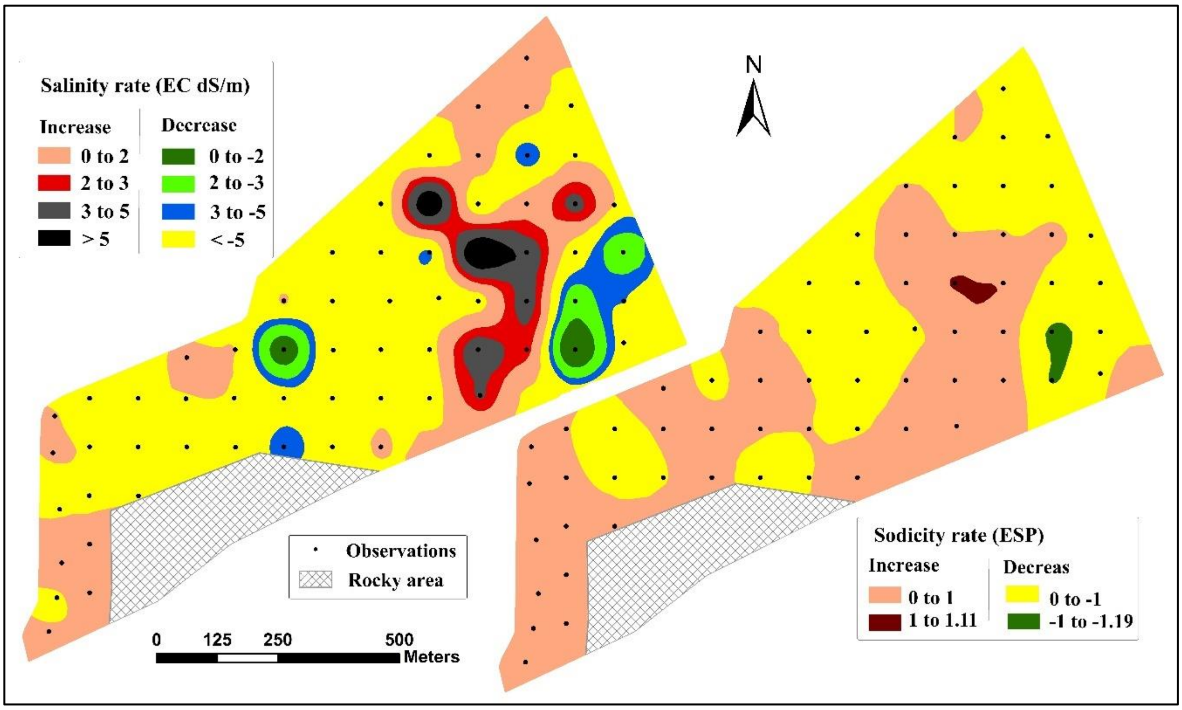


Fig. 6. Spatial distribution of soil degradation and improvement rates in the study area from 2008 to 2022.

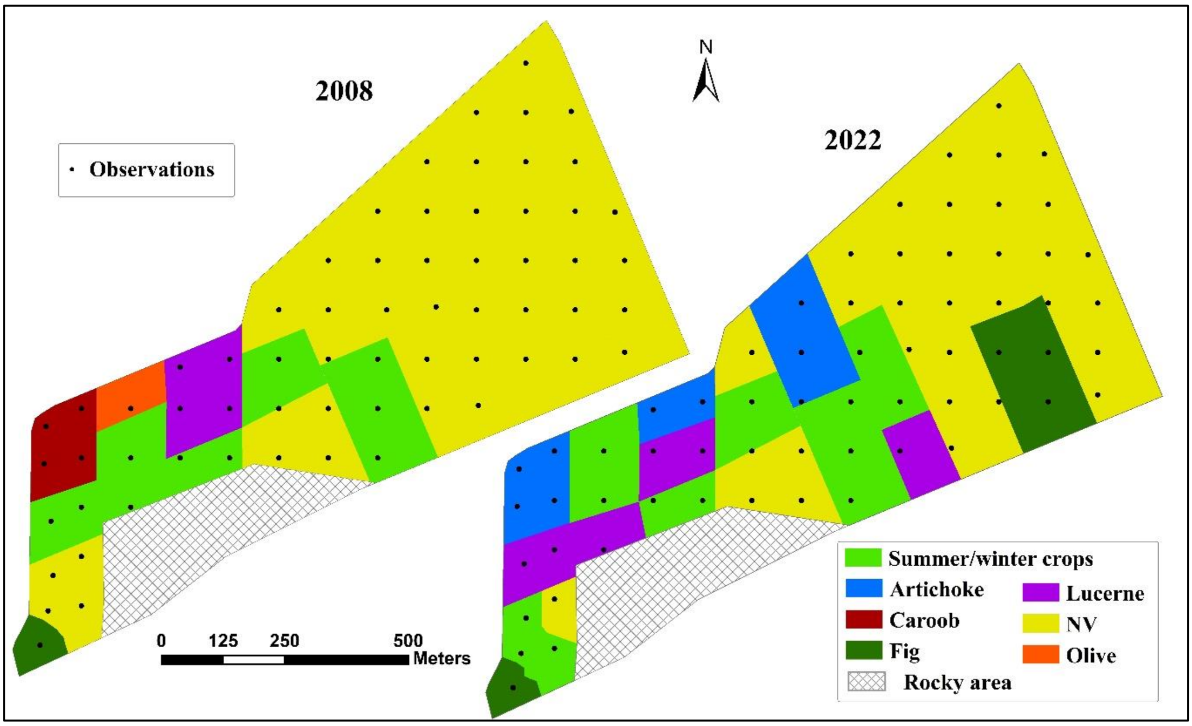
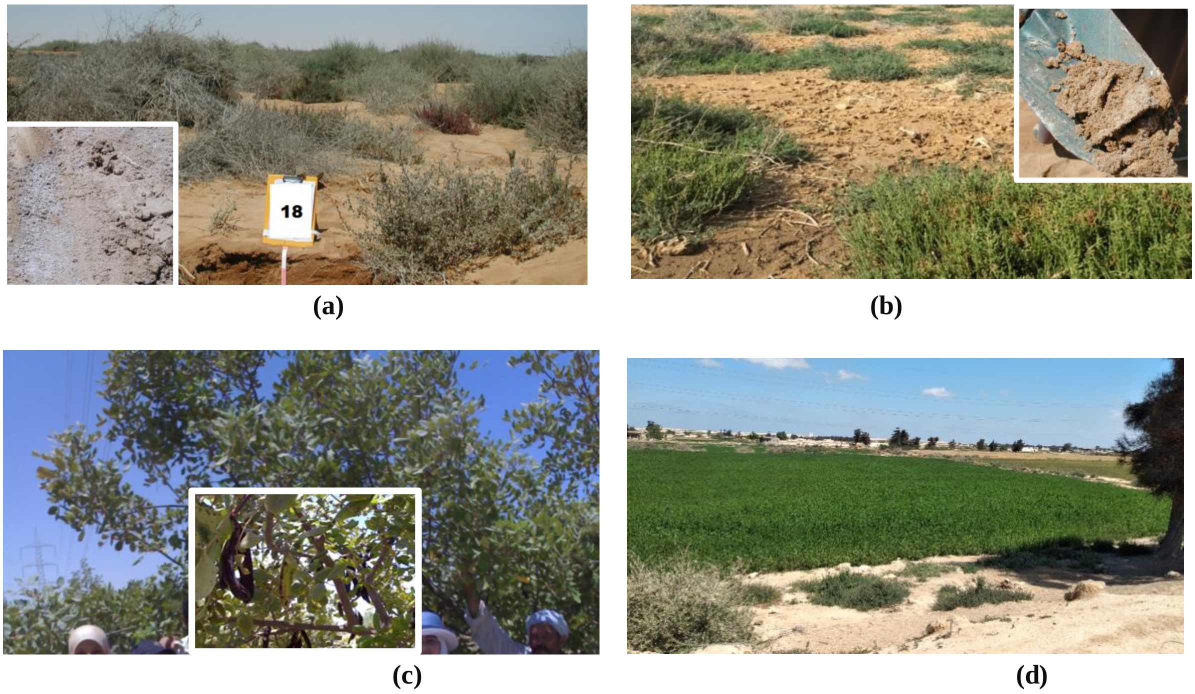


Fig. 7. Land use types in the study area in 2008 and 2022. NV refers to natural vegetation.

On the other hand, the development of soil degradation rate took place in some parts of the investigated area. For instance, the soil salinity rate witnessed a non-to-slight increase (0-2 dS m^{-1} a year) at scattered patches (24.1%) in the study area. The increase in the moderate, high and very high salinity rates (2 to 5 dS m^{-1} a year) concentrated in the eastern part of the study area (10.26%). This part is dominated by natural desert shrubs of specific types of halophytes (Figs. 7, 8a and 8b). At the same time, the increase in soil sodicity rate was observed, where the non-to-slight rate (0-1/year) occupied 53% of the study area while the moderate rate (1-2/year) occupied 0.6%.



(a) (b) (c) (d)

Fig. 8. Different land use and crop types in the study area: Natural vegetation of halophytes (a, b), carob (c) and lucerne (d).

Table 7. Crop rotations and land use types in the study area from 2008 to 2022.

<table>
<tr><th rowspan="2">Observations</th><th colspan="15">Years</th></tr>
<tr><th>2008</th><th>2009</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th></tr>
<tr><td>1:14, 17:21, 25,27,29, 39, 53, 54, 58</td><td colspan="15">NV</td></tr>
<tr><td>15</td><td colspan="3">NV</td><td colspan="4">SWC</td><td colspan="2">NV</td><td colspan="4">SWC</td><td colspan="2">Artichoke</td></tr>
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<tr><td>26</td><td colspan="9">NV</td><td colspan="2">Quinoa</td><td>SWC</td><td colspan="3">NV</td></tr>
<tr><td>28</td><td colspan="12">NV</td><td colspan="3">Fig</td></tr>
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<tr><td>40</td><td colspan="9">Caroob</td><td colspan="4">SWC</td><td>Artichoke</td><td>Artichoke</td></tr>
<tr><td>41</td><td colspan="2">Olive</td><td>NV</td><td colspan="4">SWC</td><td colspan="7">Lucerne</td><td>SWC</td></tr>
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<tr><td>62</td><td colspan="5">SWC</td><td colspan="10">Lucerne</td></tr>
<tr><td>63</td><td colspan="3">NV</td><td colspan="12">SWC</td></tr>
<tr><td>64</td><td colspan="3">NV</td><td colspan="12">SWC</td></tr>
<tr><td>65</td><td colspan="15">Fig</td></tr>
</table>

Where: NV is natural vegetation and SWC is summer and winter crops.

The results revealed that the soils that were cultivated with perennial artichokes (Fig.6) witnessed a non-to-slight salinity rate increase (Figs. 5, 7c and Table 7). There was also a development in the rate of soil degradation in the southwestern part of the study area, where it is characterized by a non-to-slight salinity rate increase (Fig.5). It was also shown that the changes in land use from the winter and summer cropping pattern to natural vegetation cover increased the rate of soil degradation (2 to 5 dS m^{-1} increment a year), as displayed in Figures 5 and 6 and recorded in Table 7.

4. Discussion

Although a remarkable difference was observed in the mean values of the $CaCO_3$ content in 2008 and 2022, it is considered high as the soil is composed of limestone parent material. Compared to the remaining soil characteristics, soil salinity witnessed high variability as strong variations were noticed in the EC values in 2008 and 2022 as indicated by the highest spatial variability (CV%).

Although a soil salinity value of less than 4 dS m^{-1} was measured in 2022 (only one observation), it was not mapped. In the process of geostatistical analysis, the values and weights of surrounding observations affect an observation with an extreme value, and in some cases, the measured values are not enough to create a significant mapped area (ESRI 2001).

The non-to-slight annual improvement rate in the level of soil salinity, that took place in most of the study area, is largely in line with the expansion of the land reclamation process. In other words, the shift in the land use from natural vegetation to crop production (summer and winter crop rotation) slightly redused soil salinity (Fig.6 and Table 7). In this context, Mustafa and Akhtar (2019) pointed out that crop rotation of wheat and rice helps in salt management. These crops yield straw, a residue that can be used to manage salt problems. They reported that, in comparison to the control, the salinity value of the soil modified with rice, rye straw, and maize stalk was reduced. Incorporation of straw in soil effectively mitigates soil salinization (Tarolli et al,. 2024). The high content of organic matter improves the water holding capacity of the soil, thus reducing the concentration of soluble salts and limiting their accumulation in the root zone (Amini et al,. 2016)

The areas that experienced moderate to high annual improvement in salinity levels is regarded to following a particular pattern of crop rotation (Fig.6 and Table 7). For instance, the cultivation of lucerne in the central part of the study area (Fig.5 and Table 7), led to an annual decrease in the soil salinity by 2 to more than 5 dS m^{-1}. Also, the annual improvement in soil salinity that took place in the southeastern part of the study area was due to the crop rotation, where the land use was switched from natural vegetation to fig/eggplant cultivation since 2020. The high to very high improvement rate (-2 to < -5 dS m^{-1}/year) of the soil salinity in the southeastern part may be attributed to the continuous application of water to the soil surface by drip irrigation, which often leads to rapid movement of accumulated salts downward the soil profile. According to Mustafa and Akhtar (2019), drip irrigation continuously supply water in the immediate vicinity of plant roots. This method reduces salt level through continuously high soil moisture in the root zone.

In general, the analysis of cropping pattern change revealed that the cultivation of the perennial lucerne (Fig 7d) during the last five years in several parts of the study area led to an improvement in soil salinity levels. In this case, the soil salinity rate decreased annually by zero to < 5 dS m^{-1} as shown in Figure (5) and Table (7), these findings go along with what was stated by Connor (2004) and Cuevas et al (2019).

The cropping pattern changes have also a remarkable impact on the decrease of sodicity levels especially in the southeastern part of the study area, where soil sodicity decreased annually by 1 to 1.1 (Fig 5) at observations 28 and 38.

The increase in the soil degradation rate that took place in the eastern part of the study area (desert shrubs) could be explained by the accumulation of salts on the surface and subsurface soil layers, especially under the high evaporation rates and scarcity of rainfall (Fig. 7a and 7b).

The non-to-slight salinity increase that observed in the artichoke soils may be because these soils are left uncultivated during the summer months, which exposes them to salinization problems, especially under the high evaporation rate during summer.

The reason for the soil degradation rate increase in the southwestern part of the study area (Fig.5) may be explained that this part was dedicated to experimental plots before 2010 using the drip irrigation system and high water quality (about 0.6 dS m^{-1}) and soil salinity did not exceed 8 dS m^{-1} in 2008 (Fig 3). It was later designated for crop production using the surface irrigation system and poor water quality (4-5 dS m^{-1}), which led to the soil salinity increase in 2022 due to the accumulation of salts in the surface layer (Fig 3).

5. Conclusion

Soil degradation and improvement rates under land use changes were assessed in a dryland area in Egypt. The Integration between soil and spatial analysis efficiently examined the status and rate of soil degradation. This was done by collecting and analyzing 65 soil samples from different land uses in 2022. Soil salinization and sodification were assessed and mapped. The results were compared with those of an earlier study conducted in 2008 and salinization and sodification rates were estimated and mapped to reflect soil degradation and improvement in relation to land use changes. This study found that the non-to-slight salinity class (EC < 4 dS m^{-1}) occupied 1.23% of the study area in 2008, while it was not represented in 2022. The moderate salinity class (EC: 4-8 dS m^{-1}) represented 4.42% and 6.75% in 2008 and 2022, respectively. The high salinity class (EC: 8-16 dS m^{-1}) occupied 19.18% and 29.8% in 2008 and 2022, respectively. The very high salinity class (EC >16 dS m^{-1}) occupied 75.17% in 2008, while it decreased to 63.45% in 2022. Concerning sodicity hazard, most of the study area is characterized by the high and very high sodicity levels (ESP > 15), where they together occupied 71.92% and 77.48% in 2008 and 2022, respectively.

Most of the study area witnessed a non-to-slight (58.6%) and moderate to high (9.4%) annual decrease in the rate of soil salinity. This is due to changes in land use such as the change from natural vegetation to crop production or due to crop rotations such as the transition of summer and winter crops to the perennial lucerne. The impact of cropping pattern changes was also obvious on the decrease of sodicity rate, where the non-to-slight rate (0-1 decrement a year) occupied 45.6 % of the study area while the moderate rate (1-2 decrements a year) occupied 0.8%. The effect was more evident in the southeastern part of the study area.

On the other hand, the development of soil degradation rate took place, where 22.1% of the area witnessed a non-to-slight salinity rate' increase while the moderate, high and very high salinity rates' increase occupied 10.26%. At the same time, the increase in soil sodicity rate was observed, where the non-to-slight rate (0-1/year) occupied 53% of the study area while the moderate rate (1-2/year) occupied 0.6%. The increase in the soil degradation rate was due to the change in land use from crop production to natural vegetation where water irrigation was no longer applied to the soil, especially under such dryland conditions.

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