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Monitoring Spatiotemporal Environmental Changes in Dakahlia Governorate, Egypt Using Landsat Imagery

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Abstract: Dakahlia Governorate (Egypt) is considered an important area for plant diversity, facing three major problems, namely: high rate of population increase, limited renewable natural resources, limited production of food, forage, and raw materials for industrial purposes. Two multispectral Landsat imageries (TM and OLI 8) on 6th of March 1999 and 19th of March 2019 were calibrated and processed to produce LULC, different spectral indices (land surface temperature (LST), normalized difference vegetation index (NDVI), normalized difference Built-up Index (NDBI), normalized difference moisture index (NDMI), modified normalized difference of water index (MNDWI) and normalized difference salinity index (NDSI)). Furthermore, the surface temperature was obtained by processing the thermal bands of the Landsat image. Applying the indices on the raw digital numbers to produce a comparative study with the resulted values to detect the environmental change over the two last decades. According to the analysis, the results detected a loss in the vegetation areas and the bare land in favor of urban areas and water bodies to fulfill the requirements of the residents and the developers. That was confirmed with the analysis of the NDBI, NDSI, and LST that showed an increase as a result of urban sprawling. On the other hand, the NDVI explained that the uncontrolled urban sprawl caused the loss of agricultural lands. There was a slight expansion in the wild plant habitats, represented mainly by sparse class and partially by moderately dense class. Accordingly, this could be a result of the mutation in the habitats to favor the spreading of the moderate and sparse vegetation class, which MNDWI and NDMI confirmed.

Keywords: Dakahlia Governorate; wild plants; spectral indices; salinity; LULC.

1. Introduction

As the world population continues to grow, great pressure is being placed on arable land, water, energy, and biological resources to provide an adequate supply of food while maintaining the integrity of our ecosystem [1]. Egypt, like other countries of the third world, located in the arid/semi-arid region, is facing three major problems, namely: high rate of population increase, limited renewable natural resources, limited production of food, forage, and raw materials for industrial purposes [2, 3]. Egypt is situated in the southeast of the Mediterranean Sea; with the Egyptian Nile region across temperate grassland, desert, and semi-desert biomes according to the world biomic map [4], with a length of about 1520 km (23% of the total length of the river), and sheltering a population of about 100.4 million people. Egypt has only less than 4% of its total area as reproductive land [5]. Thus, Egypt's management of renewable natural resources is essential to supply food, fodder, and raw materials for industry and energy [6-8].

Egypt is considered an important area for plant diversity, which contains about 28.8% of the threatened plants of North Africa [1, 9]. Natural habitats of the recorded wild species are collected from Boulos [10]. They are grouped into 7 groups as following: Rocky habitats, aquatic habitats, sandy habitats, cultivated habitats, wastelands, wetlands, and salt marshes. Petts [11] states that many of man's activities have direct or indirect effects upon ecosystems. In extreme cases, the consequent environmental changes have been widespread, affecting the in-channel, riparian, flood plain and delta or estuarian, fauna, and flora. Many long-term and irreversible effects cause damage to the genetic structure or even result in the extinction and/or introduction of certain species. Therefore, the development of Egypt's economy strongly depends on its ability to conserve and manage its water resources [12, 13].

The Egyptian Nile region consists of 20 governorates that include various habitats, which contain native wild plants they grow either cultivated or spontaneously. El-Dakahlia Governorate is located in the mid-downstream of the Damietta branch of the River Nile to the northeast of the Nile Delta region of Egypt. The total average area of El-Dakahlia Governorate is about 3459 km2 and inhabited by about 5306322 population [14].

The literature on the human drivers of desertification is substantial [15-17], and there have been several comprehensive reviews and assessments of these drivers very recently [18-20]. Change detection studies on water bodies are of paramount importance as our urban cities are witnessing quick depletion of their water resources. Such studies can now apply suitable digital image processing techniques on multispectral images without manual intervention. Therefore, this paper presents a comparative study on commonly used spectral indices for their accuracy and suitability with Landsat 8 OLI and TM images. We also study the comparative differences in applying the indices on the raw digital numbers to processed values to detect the environmental change over the last decade.

2. Materials and Methods

2.1. Study area.

The Nile Delta is one of the earliest identified deltaic systems globally, which was formed due to depositing alluvial soil fertile of the Nile during frequent floods in geological periods [21]. El-Dakahlia Governorate is located in the mid-downstream of the Damietta branch of the River Nile at 30^o 50`N - 31$^o$ 50`N latitude and 30^{o}E - 32^{o}E longitude to the northeast of the Nile Delta region of Egypt (Figure 1). The total average area of El-Dakahlia Governorate is about 3459 km^2 and inhabited by about 5306322 population. The total agricultural area is about 645813 feddans [14]. There are many water sources in the study area viz: rainfall, Nile water (comes from Damietta branch), Mediterranean Seawater, northern Lake Manzala water, and underground water. Consequently, the agriculture in El-Dakahlia Governorate mainly depends on the Nile water of the Damietta branch and partly on winter rainfall.

The Nile Delta area lies in the arid belt of the southern Mediterranean region. Its climate is rather arid to semi-arid, where the evaporation rate exceeds many times the precipitation [22]. El-Dakahlia Meteorological Station (Climatological Normal of Egypt) showed that the monthly minimum, maximum, and mean air temperature at 2 meters varies from 10.68, 18.76

and 14.09 °C in January to 12.63, 20.42, and 15.89 °C in August with a total annual temperature of 16.83, 27.33 and 21.46 °C, respectively. On the other hand, the relative humidity at 2 meters varies in values from 65.98% in January to 65.14% in December. Moreover, the presence of numerous water bodies, e.g., Lake Manzala, River Nile (Damietta branch), and the Mediterranean Sea, and the thick transpiring vegetation, play an important role in increasing the values of this climatic element. The total annual humidity in the study area was recorded at 58.29%.

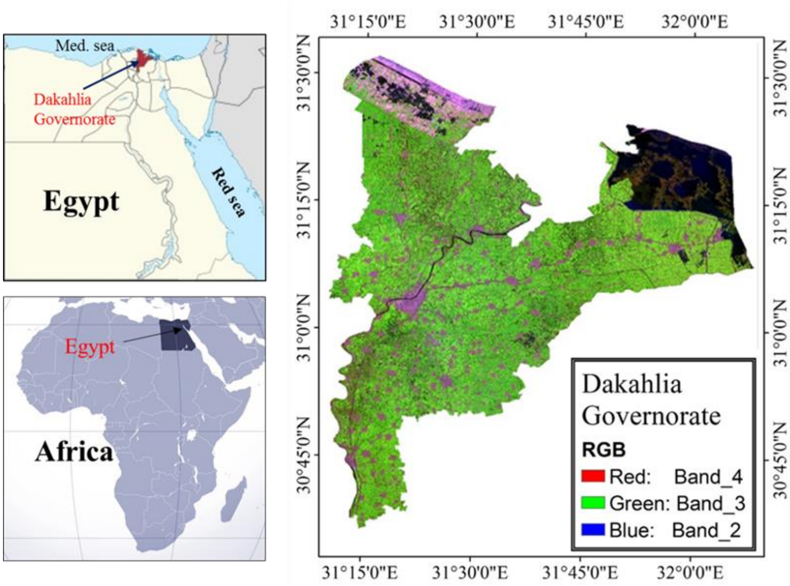


Figure 1. Map of Egypt showing Dakahlia Governorate study area.

2.2. Spectral analysis.

2.2.1. Satellite images acquisition and preprocessing.

Initially, two multispectral Landsat imageries (TM and OLI 8) on the 6th of March 1999 and 19th of March 2019 were freely downloaded for Dakahlia Governorate. The data type is level 1, which provides systematic radiometric and geometric accuracy derived from data collected by the sensor and spacecraft. The study area is located in two scenes; 176-38 and 176-39. Radiometric calibration and atmospheric correction were the basic preprocessing steps followed in correcting Landsat data collected together to create a mosaic for the whole area, then cropped using the shapefile of the governorate administrative boundary resize the River Nile area of the Governorate.

2.2.2. Image processing.

Image processing is applied to change and alert the original raw data to bring out visual details [23]. Multi-temporal calibrated Landsat images were processed to produce land use/cover (LULC) maps and three spectral indices based on empirical equations identified in ENVI 5.1 (Band Math). LULC and indices maps were assessed at two years, 1999 and 2019, to monitor environmental changes in the River Nile region. The maximum likelihood classifier (MLC) was applied to produce LULC maps since the field validation visits were elaborated to confirm classification accuracy. The investigated spectral indices include land surface temperature (LST), normalized difference vegetation index (NDVI), normalized difference Built-up index (NDBI), normalized difference moisture index (NDMI), modified normalized difference of water index (MNDWI), and normalized difference salinity index (NDSI). The calculation formulas for spectral indices and their class ranges are presented in Table 1.

Table 1. Various spectral indices and classes formulas used in the present study.

Index	Formula	Classes (ranges)	References
Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$	-1-0.25 No vegetation 0.25-0.5 Sparse vegetation 0.5-0.75 Moderate vegetation 0.75-1 Dense vegetation	[24, 25]
Normalized difference salinity index (NDSI)	$NDSI = \frac{(Red - NIR)}{(Red + NIR)}$	-1-0 Non saline 0-0.25 Slightly saline 0.25-0.5 Moderately saline 0.5-1 Highly saline	[26]
Normalized difference moisture index (NDMI)	$NDMI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$	NDMI > 0.1 High humidity NDMI < -1 Low humidity	[27]
Modified Normalized Difference Water Index (MNDWI)	$MNDWI = \frac{(Green - SWIR)}{(Green + SWIR)}$	< -0.3 Vegetation along fallow land (0.1 - 0.3) Built up intermediate > 0.4 Water bodies	[28, 29]
Normalized Difference Built-Up Index (NDBI)	$NDBI = \frac{(SWIR - NIR)}{(SWIR + NIR)}$	< 0 Vegetation and water bodies >0.1 Built up areas & bare lands	[30]
Retrieving Land Surface Temperature (LST)	$LST = \frac{T_B}{1 + \left(\frac{\lambda \sigma T_B}{hc}\right) ln\varepsilon} - 273.15$	Celsius	[31]

NIR: near infrared, SWIR: short wave infrared, λ: is the effective wavelength (10.895 µm for band 10 TM+), σ: is Boltzmann constant (1.38 _ 10_23 J/K), h: is Plank's constant (6.626×10^{-34} Js), c: is the velocity of light at a vacuum (2.998×10^{-8} m/sc), ε: is emissivity.

3. Results and Discussion

3.1. Regional assessment of LULC changes.

Two LULC maps dated 1999 and 2019 were extracted to study the temporal changes in land use. Due to the Governorate's location in the middle area of the Nile- delta, it is considered one of the most important agricultural governorates characterized by fertile soil. Thus, the most abundant class in LULC map is vegetation representing areas of 3082.01 (78.15%) and 2879.93 (73.02 %) Km^2 in 1999 and 2019, respectively. It turns out that there was a clear decline over the last 2 decades (i.e., from 1999 to 2019).

Water bodies are considered the second class, mainly represented by the Nile River branch and El-Manzala Lake with areas of 382.34 (9.69 %) and 450.93 (11.43 %) Km2 in 1999 2019, respectively. As shown in Figure 2b, the bare land was distributed in the northwest region exhibiting 258.50 (6.55 %) and 247.68 (6.28 %) Km^2 in 1999 and 2019, respectively. On the other hand, the urban class occupied 221.03 Km^2 (5.60 %) in 1999 and 365.30 Km^2 (9.26 %) in 2019.

The study area is a part of the Nile Delta region, which is continuously subjected to urbanization expansion [32], that was mostly at the expense of the vegetation class, which was shown in the annual rate of change where the annual loss of the vegetation class (10.10 km^2) that was close to the annual expansion of the urban area (7.21 km^2) and the water bodies (3.43 km^2), that served this suburbanization, as represented in map Figure 2a, while non-significant change was observed in the loss of the bare land (0.54 km^2) similar conclusion was reached by Radwan *et al*. [33] and Elagouz *et al*. [34].

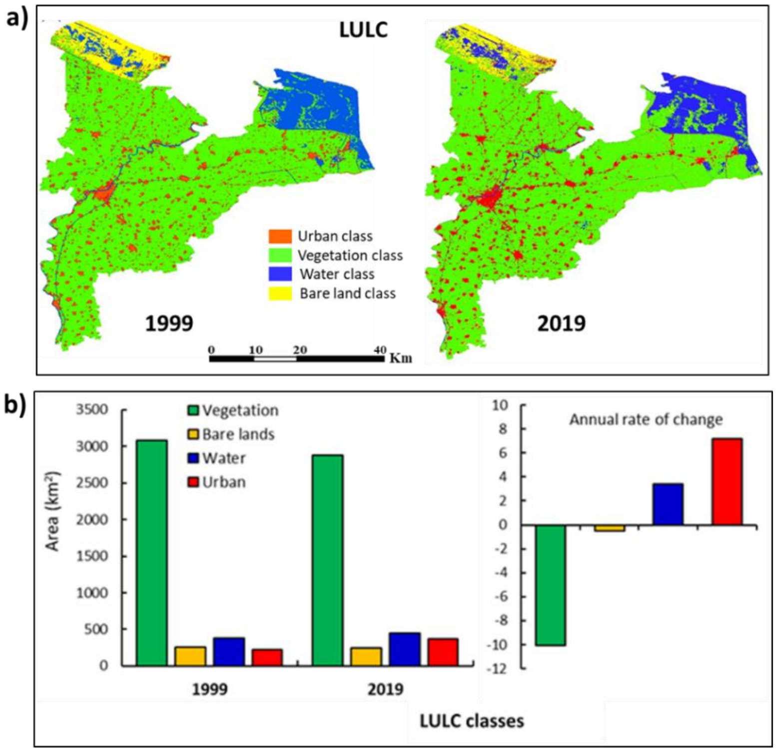


Figure 2. Areas in sq. km of land use/ land cover (LULC) classification for Dakahlia Governorate study area: a) LULC distribution map, b) classification comparison and the annual rate of change for each class.

3.2. Monitoring and assessing land surface temperature (LST) and spectral indices changes.

Spatial and temporal variations of LST in the study area are illustrated in Figure 3. The statistics in 1999 of the whole Governorate indicate that the maximum temperature is 28.77°C, while the minimum temperature is 14.25°C with a mean value of 18.89 °C. However, the LST statistics in 2019 show a clear increase in the mean value to 19.82 °C; the minimum value also increased to 15.28 °C. Otherwise, the maximum value decreases to 28.59 °C. This indicates a total increase in the temporal variations in LST during the whole studied period. The slight increase in the LST could be an indicator of the lands affected the urbanization, desertification, and transportation facilities [35], which with time lead to the elimination of the vegetation that couldn't stand the temperature increase and affected the dense vegetation total area as demonstrated in the NDVI analysis.

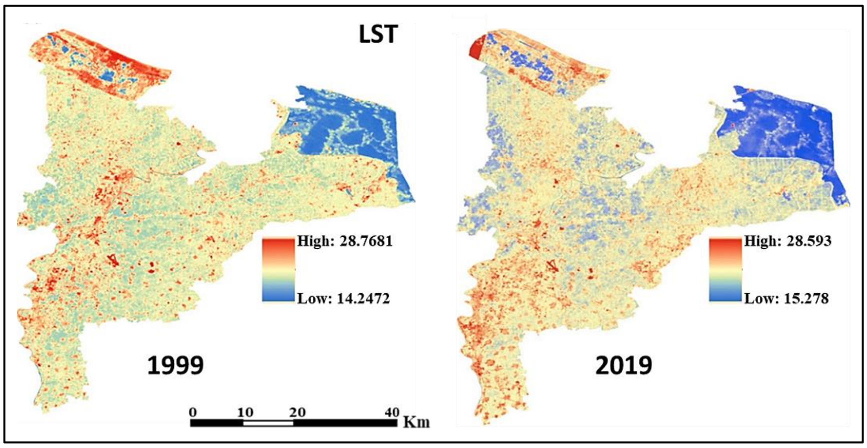


Figure 3. Spatial distribution maps of land surface temperature (LST) at 1999 and 2019 in Dakahlia Governorate.

3.3. Regional assessment of the changes in normalized difference vegetation index (NDVI).

In the present study, NDVI was categorized into four classes Figure 4a; No vegetation, sparse vegetation, moderately dense vegetation, and highly dense vegetation. According to that, spatial and temporal changes in the NDVI over the last two decades had been noticed in the whole Governorate.

In 1999, the classes were distributed as the following; the moderately dense vegetation is the most dominant class over the Governorate, excluding the coastal areas, with the total area of 1434.95 km^2 representing cultivated areas on both sides of the Damietta branch within the Nile River zone, while scattered as little patches along the coastal regions. On the other hand, the high dense vegetation-occupied area of 1023.46 km^2 is the second dominant class over the Governorate. The sparse and no vegetation classes were mostly concentrated at the coastal areas of Gamasa, the north sides of Belkas district, and Manzala Lake, with a total area of 552.33 km^2 and 932.72 km^2, respectively. It is worth mentioning that over the governorate scale, the sparse vegetation class that resembles the wild plants were noticed to be represented as scattered patches on the sides of the Nile River zone and mostly concentrated at the southwest side of the Governorate.

In 2019, the moderate vegetation class was the most dominant class, located mainly in the governorate center, especially in the Mansoura district, north side of El-Senbellawein district, and the east side of Temay El Amdeed district. It occupied an area of 1932.81 Km^2, with an annual increase of 24.9 Km^2 from 1999. As shown in Figure 6a, the most inland areas of the Governorate are covered by highly dense vegetation concentrated especially in the east north by east of El Manzala, Dekernes and Mit-Salsil district, northwest direction and south by southwest direction of Belqas, Nabarouh, Mit-Ghamr, and Aga district, with the total area of 444.0573 km^2, that showed a remarkable annual decline by -29.0 Km^2 during the investigated period (1999-2019).

Sparse vegetation class, including the wild plants as previously mentioned, is mostly concentrated at the coastal side of Gamasa district and the north side of Belqas district, with a total area of 722.83 Km^2. A mild increase of 8.5 Km^2 per year was found compared to 1999. Eventually, no vegetation class concentrated mainly on the coastal side in addition to small patches scattered around the Governorate, exhibiting a total area of 843.77 Km^2. A slight annual decrease was observed with a value of -4.4 Km^2 compared to 1999.

Despite there is a loss in vegetation class as prescribed in the LULC section, represented by dense vegetation and no vegetation class, there are increases in both sparse and moderately dense vegetated areas. These areas are extensively associated with the newly developed urban areas. In other words, although the uncontrolled urban sprawl caused loss of agricultural lands, it leads to expansion on wild plant habitats, represented mainly by sparse class and partially by moderately dense class as described by Gad and El-Zeiny [27] and El-Zeiny and Effat [36].

3.4. Change detection in the normalized difference built-up index (NDBI).

This parameter represents cities, villages, and industries scattered in the whole study area, as illustrated in Figure 9. As shown in Figure 5, NDBI values ranged from -1 to 1 with a mean of -0.35 in 1999. However, it fluctuated from -0.74 to 0.84, with a mean of -0.35 in 2019. This fluctuation with the LULC analysis, which confirms the sprawling of the residential area to fulfill the requirements of the developer and the residents, a similar pattern was obtained in Elnaggar *et al*. [37].

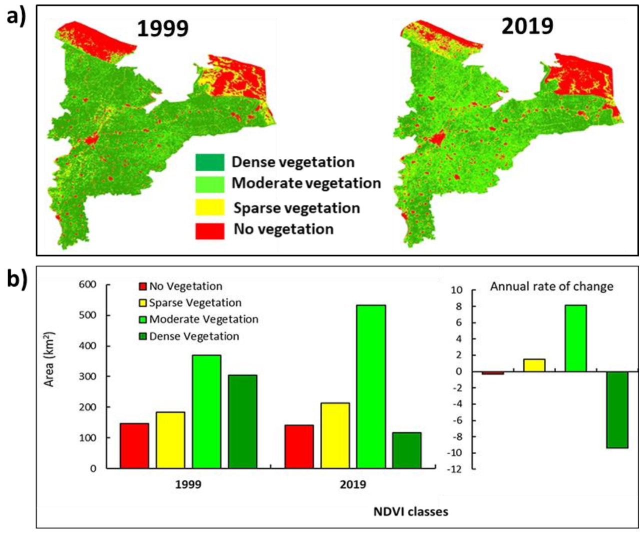


Figure 4. Comparison of normalized difference of vegetation index (NDVI) by area (Km^2) with the annual rate of change in the Dakahlia Governorate study area.

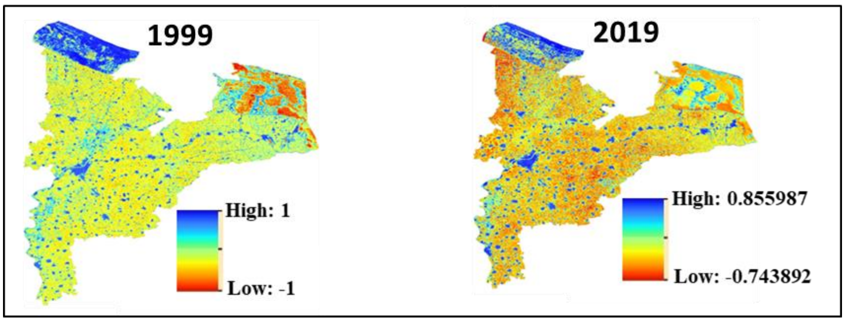


Figure 5. Comparison of normalized difference of built-up index (NDBI) by area (Km^2) with the annual rate of change in the Dakahlia Governorate study area.

3.5. Change detection in the normalized difference moisture index (NDMI).

NDMI evaluates humidity content from the landscape elements, especially for soil, rocks, and vegetation, and is an excellent indicator for dryness. NDMI fluctuation was observed where the minimum value was -1, reaching 1 with a mean of 0.35 in 1999. On the other hand, a slight decline was recorded in 2019 with values ranged from -0.84 to 0.74, with a mean value of 0.35 as represented in Figure 9 and distributed in Figure 6. The decrease in the range values between the minimum and maximum value might result from the noticeable decrease in humidity content presented in the dense vegetation class that was lost to the advantage of the spread of urbanized areas [38].

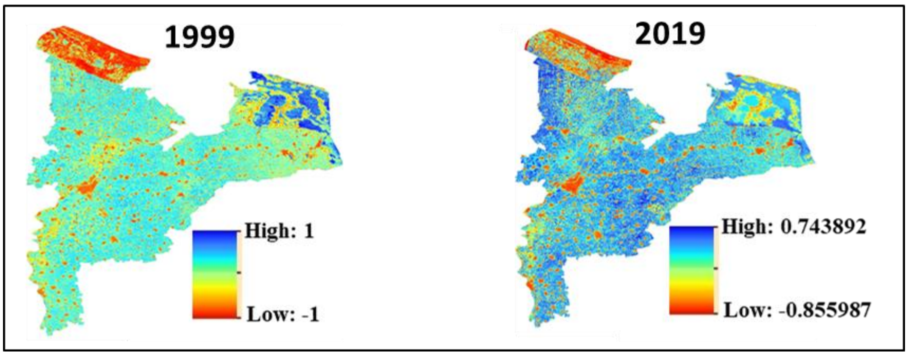


Figure 6. Comparison of normalized difference of moisture index (NDMI) by area (Km^2) with the annual rate of change in the Dakahlia Governorate study area.

3.6. Change detection in the Modified Normalized difference water index (MNDWI).

MNDWI was modified from NDWI to represent water bodies, including; Nile River, drains, canals, and small lakes in the whole study area, with increased accuracy of water extraction and effective reduction and removal of the built-up land noise. , The spatial distribution map of MNDWI, showed a fluctuation ranging between – 1 and 1 with a mean of -0.09 in 1999. However, the values of MNDWI showed a decline ranging from -0.63 to 0.76 with a mean value of -0.08 in 2019 Figure 9 and Figure 7. This matches the LULC analysis that showed an increase in the total area occupied by the water class that served to spread residential areas. Furthermore, it provided a suitable habitat for spreading the sparse vegetation class, representing wild plant habitats, as Chao and Sheng [39] demonstrated.

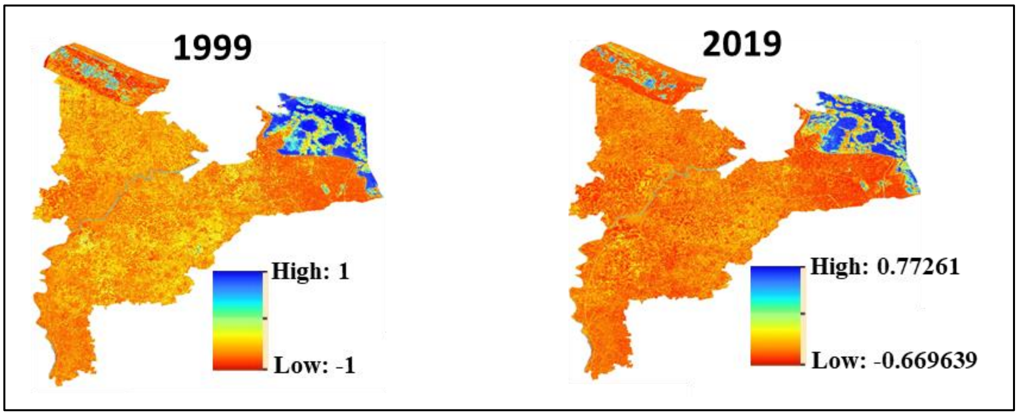


Figure 7. Comparison of modified normalized difference of water index (MNDWI) by area (Km^2) with the annual rate of change in the Dakahlia Governorate study area.

3.7. Change detection in the normalized difference salinity index (NDSI).

Soil salinity index is mostly used to distinguish salt minerals in soils based on different responses of salty soils to different spectral bands. NDSI distribution map showed noticeable variation; the lowest value was -1, while the highest value was 0.5, with a mean of -0.48. During the last decade, the values of NDSI showed an increase from -0.79 to 0.65 with a mean -0.47 in 2019 Figure 8 and Figure 9. The slight increase in the NDSI means might indicate the affected lands with salinization that leads to a decrease in the vegetation for the advantage of urbanization [36]. From another aspect, this increase in salinization might be the cause that flourishes the wild habitat, which mostly in Dakahlia Governorate contained halophytes.

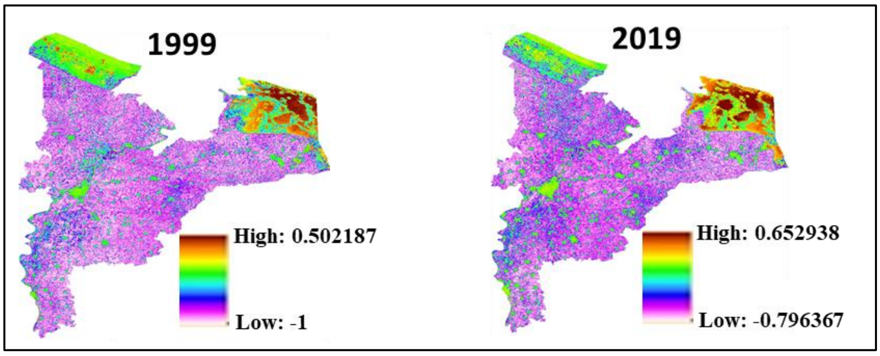
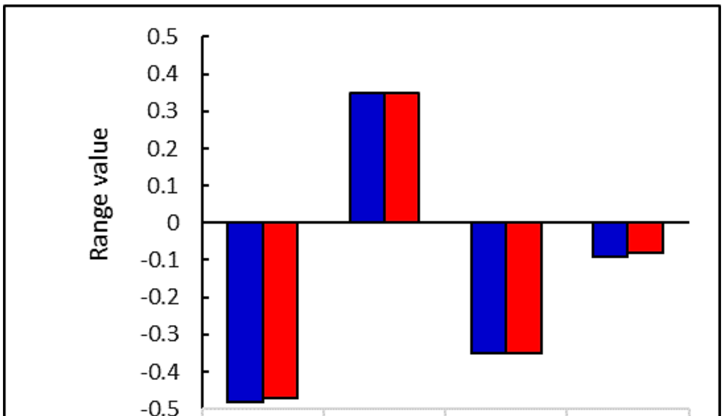


Figure 8. Comparison of normalized difference of salinity index (NDSI) by area (Km^2) with the annual rate of change in the Dakahlia Governorate study area.



	NDSI	NDMI	NDBI	MNDWI
1999 Mean	-0.48	0.35	-0.35	-0.09
2019 Mean	-0.47	0.35	-0.35	-0.08

Figure 9. Spectral distribution map of various spectral indices (NDSI, NDMI, NDBI, and MNDWI) in Dakahlia Governorate.

4. Conclusions

The present study revealed that the wild habitats in Dakahlia governorate are majorly affected by urbanization and the spreading of agricultural land that is considered a result of the population increase and sprawling of the residential area without paying attention to wild habitat deterioration. The analysis of LULC showed an increase in urban areas and water bodies was on account of vegetation and bare land classes. According to the results, we can confirm that the LST and the NDSI are strongly related to the NDBI; as a result of the urbanization and spreading of the residential areas, this lead to urban congestion that causes an increase in the LST and change in the soil characteristics accompanied by the increase in the soil salinity levels (NDSI). On the other hand, the NDVI and NDMI are two indices that are highly correlated with the vegetation. In the present study, they were used as an indicator for the dispersion of wild plant habitats, while the MNDWI detected the change in water levels in the last two decades.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. Leal Filho, W.; Azeiteiro, U.M.; Balogun, A.-L.; Setti, A.F.F.; Mucova, S.A.R.; Ayal, D.; Totin, E.; Lydia, A.M.; Kalaba, F.K.; Oguge, N.O. The influence of ecosystems services depletion to climate change adaptation efforts in Africa. *Science of The Total Environment* **2021**, *779*, https://doi.org/10.1016/j.scitotenv.2021.146414.
2. El-Amier, Y.; AbdulKader, O. Vegetation and Species Diversity in the Northern Sector of Eastern Desert, Egypt. *West African Journal of Applied Ecology* **2015**, *23*, 75–95.

3. El-Amier, Y.A.; Al-hadithy, O.N.; Fahmy, A.A.; El-Zayat, M.M. Phytochemical analysis and biological activities of three wild *Mesembryanthemum* species growing in heterogeneous habitats. *Journal of Phytology* **2021,** *13*, 1-8, https://doi.org/10.25081/jp.2021.v13.6403.
4. Zahran, M.; El-Amier, Y. Non-traditional Fodders from the Halophytic Vegetation of the Deltaic Mediterranean Coastal Desert, Egypt. *Journal of Biological Sciences* **2013**, *13*, 226-233, https://doi.org/10.3923/jbs.2013.226.233.
5. The IUCN Red List of threatened species. JAN. **2011**; Available from: https://www.iucnredlist.org/.
6. Zahran, M.A.; Willis, A.J. The vedetation of Egypt chapman and Hall. environmental conservation. *Chapman & Hall* **1992,** *20*, 377-378, https://doi.org/10.1017/S0376892900023821.
7. El-Amier, Y.; Abdelghany, A.; Zaid, A. Green Synthesis and Antimicrobial Activity of Senecio glaucus - Mediated Silver Nanoparticles. *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **2014**, *5*, 631-642.
8. El-Amier, Y.; El-Halawany, E.; Abdullah, T. Composition and Diversity of Plant Communities in Sand Formations Along the Northern Coast of the Nile Delta in Egypt. *Research Journal of Pharmaceutical, Biological and Chemical* **2014**, *5*, 826-847.
9. El-Amier, Y.A.; El Hayyany, L.Y. Floristic composition and species diversity of plant communities associated with genus *Atriplex* in Nile Delta coast, Egypt. *Asian Journal of Conservation Biology* **2020,** *9*, 11-24.
10. Boulos, L. *Flora of Egypt Checklist.* Revised Annotated ed. Cairo, Al Hadara Publishing, **2009**.
11. Petts, G.E. Sedimentation within a regulated river. *Earth Surface Processes and Landforms* **1984**, *9*, 125-134, https://doi.org/10.1002/esp.3290090204.
12. Abd-ElGawad, A.M.; El-Amier, Y.A.; Assaeed, A.M.; Al-Rowaily, S.L. Interspecific variations in the habitats of Reichardia tingitana (L.) Roth leading to changes in its bioactive constituents and allelopathic activity. *Saudi Journal of Biological Sciences* **2020**, *27*, 489-499, https://doi.org/10.1016/j.sjbs.2019.11.015.
13. El-Amier, Y.A.; Abo-Aisha, I.A. Phytochemical constituents of common growing *Fagonia* species (Zygophyllaceae) in Egyptian deserts and its biological activities. *Plant Archives* **2019,** *19*, 2213-2219.
14. Food and Agriculture Organization of the United Nations (FAO). AQUASTAT Country Profile - Egypt, **2016**.
15. Yan, X.; Cai, Y.L. Multi-Scale Anthropogenic Driving Forces of Karst Rocky Desertification in Southwest China. *Land Degradation & Development* **2015**, *26*, 193-200, https://doi.org/10.1002/ldr.2209.
16. Varghese, N.; Singh, N.P. Linkages between land use changes, desertification and human development in the Thar Desert Region of India. *Land Use Policy* **2016**, *51*, 18-25, https://doi.org/10.1016/j.landusepol.2015.11.001.
17. Sterk, G.; Stoorvogel, J.J. Desertification–Scientific Versus Political Realities. *Land* **2020**, *9*, https://doi.org/10.3390/land9050156.
18. Secretariat of the United Nations Convention to Combat Desertification (UNCCD). Global Land Outlook, **2017**.
19. Cherlet, M.; Hutchinson, C.; Reynolds, J.; Hill, J.; Sommer, S.; Von Maltitz, G. World atlas of desertification: Rethinking land degradation and sustainable land management, Publications Office of the European Union. **2018,** https://wad.jrc.ec.europa.eu/.
20. Peterson, G.; Harmáčková, Z.; Meacham, M.; Queiroz, C.; Jiménez-Aceituno, A.; Kuiper, J.; Malmborg, K.; Sitas, N.; Bennett, E. Welcoming different perspectives in IPBES: “Nature’s contributions to people” and “Ecosystem services”. *Ecology and Society* **2018**, *23*, https://doi.org/10.5751/ES-10134-230139.
21. Zahran, M.A.; Willis, A.J. *The vegetation of Egypt.* Springer Science & Business Media, Volume 2, **2008**:
22. UNESCO United Nations Educational, S.A.C.O., Map of the world distribution of arid regions, MAB Technical Notes, **1979**.
23. Jensen, J.R. *Introductory digital image processing: a remote sensing perspective*. 2nd ed., Rentice-Hall Inc., **1996.**
24. Rouse, J.W. *Monitoring the vernal advancement and retro gradation of natural vegetation*. NASA/GSFC TYPE II Report, BASAJGSF, **1973**.
25. Khdery, G.; Gad, A.-A.; El-Zeiny, A.M. Spectroscopic Characterization of Plant Cover in El-Fayoum Governorate, Egypt. *Egyptian Journal of Soil Science* **2020**, *60*, 397-408, https://doi.org/10.21608/ejss.2020.36730.1377.
26. Madasa, A.; Orimoloye, I.R.; Ololade, O.O. Application of geospatial indices for mapping land cover/use change detection in a mining area. *Journal of African Earth Sciences* **2021**, *175*, https://doi.org/10.1016/j.jafrearsci.2021.104108.
27. Gad, A.A.; El-Zeiny, A. Spatial analysis for sustainable development of El Fayoum and Wadi El Natrun desert depressions, Egypt with the aid of remote sensing and GIS. *Journal of Geography, Environment and Earth Science International* **2016,** *8*, 1-18, https://doi.org/10.9734/JGEESI/2016/29706.
28. McFeeters, S.K. The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing* **1996**, *17*, 1425-1432, https://doi.org/10.1080/01431169608948714.

29. Elbeih, S.F.; El-Zeiny, A.M.; Negm, A.M.; Kostianoy, A. Update, Conclusions, and Recommendations of “Environmental Remote Sensing in Egypt”. In: *Environmental Remote Sensing in Egypt*. Springer, Cham., **2020;** pp. 608-597, https://doi.org/10.1007/978-3-030-39593-3_19.
30. Zha, Y.; Gao, J.; Ni, S. Use of normalized difference built-up index in automatically mapping urban areas from TM imagery. *International Journal of Remote Sensing* **2003**, *24*, 583-594, https://doi.org/10.1080/01431160304987.
31. Rousta, I.; Olafsson, H.; Moniruzzaman, M.; Zhang, H.; Liou, Y.-A.; Mushore, T.D.; Gupta, A. Impacts of Drought on Vegetation Assessed by Vegetation Indices and Meteorological Factors in Afghanistan. *Remote Sensing* **2020**, *12*, https://doi.org/10.3390/rs12152433.
32. El-Alfy, M.A.; El-Amier, Y.A.; El-Eraky, T.E. Land use/cover and eco-toxicity indices for identifying metal contamination in sediments of drains, Manzala Lake, Egypt. *Heliyon* **2020**, *6*, https://doi.org/10.1016/j.heliyon.2020.e03177.
33. Radwan, T.M.; Blackburn, G.A.; Whyatt, J.D.; Atkinson, P.M. Dramatic Loss of Agricultural Land Due to Urban Expansion Threatens Food Security in the Nile Delta, Egypt. *Remote Sensing* **2019**, *11*, https://doi.org/10.3390/rs11030332.
34. Elagouz, M.H.; Abou-Shleel, S.M.; Belal, A.A.; El-Mohandes, M.A.O. Detection of land use/cover change in Egyptian Nile Delta using remote sensing. *The Egyptian Journal of Remote Sensing and Space Science* **2020**, *23*, 57-62, https://doi.org/10.1016/j.ejrs.2018.10.004.
35. Jones, P.D.; Groisman, P.Y.; Coughlan, M.; Plummer, N.; Wang, W.C.; Karl, T.R. Assessment of urbanization effects in time series of surface air temperature over land. *Nature* **1990**, *347*, 169-172, https://doi.org/10.1038/347169a0.
36. El-Zeiny, A.M.; Effat, H.A. Environmental analysis of soil characteristics in El-Fayoum Governorate using geomatics approach. *Environmental Monitoring and Assessment* **2019**, *191*, https://doi.org/10.1007/s10661-019-7587-9.
37. Elnaggar, A.A.; Azeez, A.A.; Mowafy, M. Monitoring Spatial and Temporal Changes of Urban Growth in Dakahlia Governorate, Egypt, by Using Remote Sensing and GIS Techniques. (Dept. C. (Public Works)). *MEJ. Mansoura Engineering Journal* **2020**, *39*, 1-14, https://doi.org/10.21608/bfemu.2020.102842.
38. El-Zeiny, A.; El-Hefni, A.; Sowilem, M. Geospatial techniques for environmental modeling of mosquito breeding habitats at Suez Canal Zone, Egypt. *The Egyptian Journal of Remote Sensing and Space Science* **2017**, *20*, 283-293, https://doi.org/10.1016/j.ejrs.2016.11.009.
39. Zhenhua, C.; Ming, S. Study on extraction methods for water information in Nantong city, China using Landsat ETM+ data. In: *Proceedings of the 2011 International Conference on Remote Sensing, Environment and Transportation Engineering*. 24-26 June 2011, **2011;** pp. 771-774, https://doi.org/10.1109/RSETE.2011.5964391.