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Monitoring Soil Degradation in The Mesopotamian Plain Using GIS and Remote sensing Techniques

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HIGHLIGHTS

- Climate changes and the nature of the land made it vulnerable to desertification and land degradation.
- Agricultural lands deterioration is due to the increase of sand dunes area.
- Most of the expansion in sand dunes was from the western and northwestern directions to the east.

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ABSTRACT

In the present work , various remote sensing techniques have been used to investigate soil degradation in Iraq (The Mesopotamian plain) for the period (1976 - 2021) using different research and data like satellite image such as (Landsat 1-5 MSS 1976 , Landsat 4-5 TM C1 Level-1 1996, Landsat 8 2016 and sentinel-2 2021) , using different Program and software (ENVI 5.3 which extract data from image satellite by using TCT , EMI and NDVI indicators , Eras image 2015 use to subset area of interest ,layer stack and merge resolution , Arc GIS 10.7 use to make database and maps production),the article use some of filters and indicators , Normalized Difference Vegetation Index (NDVI), Elian Mapping Index (EMI), Tasseled Cap Transformation (TCT) to extract a set of indicators (area of vegetation cover (NDVI), soil erosion index (EMI) , classification of wet and dry soils, and water cover calculation (TCT), the article will be calculate the areas accurately to know the type and causes of degradation by comparing those lands with past years by observing them with satellites for different years (advanced remote sensing techniques).

1. Introduction

Land degradation is a negative trend in land conditions caused by direct or indirect human activities, expressed as long-term reduction or loss of at least one of the following: biological productivity, ecological integrity or human value, Arid, semi-arid, dry, and sub-humid areas, together with hyper-arid areas constituting dry lands [1].Land degradation: It is the land that suffers from decreased productivity, biological or economic diversity, or a lack of crops for a reason or others, resulting from the wrong use of the land or due to human activities or climatic factors [2]. Universally, an expected 954.8 million ha of land is influenced by saltiness. About 1.9 billion hectares of land worldwide (a region roughly the size of Canada and the USA) are influenced by land degradation [3]. The scale of vegetation cover in agricultural land in Iraq is expected to decrease by about 8% in 2020, according to the assumption of an increase in the average temperature of 1 ^{o}C and a decrease in precipitation rates of 2.4% [4]. The problem of degradation has increased in this year (2020) for many reasons, the most important is the lack of rain and Wrong use of land, the amount of water is coming to Iraq, and the phenomenon of land degradation has become a problem that extends to the public life of people in the aspects, starting with the decline of green areas, in addition to the effect of the phenomenon of frequent dust storms and intensively, which is exacerbating the degradation problem in Iraq, also From the filed survey in last ten years and follow satellite image for Forty years ago, also from past research " The region of Mesopotamian Plain has transformed in a relatively short period of time from a plain (called the land of blackness) and is dominated by agriculture in all its summer and winter varieties and its surface is covered by many components of natural biological cover such as pastoral plants into an effective dune field that threatens the neighboring areas with direct and indirect encroachment in many parts, especially the southern region " [2] and from Conferences (Desertification and Drought Conference turkey 2010), forums (World Desertification Day Ministry of Environment Iraq Baghdad 2017, 2018) and seminars for the relevant ministries(Seminars of the National Committee for Dust Storms and Desertification Ministry of Environment Iraq Baghdad 2013- 2019) have proven that there is a great degradation and decline in vegetation cover in the Mesopotamian Plain.

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2. Related works

(Abujery, I, A 2001) used geographic information systems, a study of land degradation in the province of holy Karbala for the period (1980-2000) was based mainly on some maps and aerial images to design a special system for the study area. This system included the effect of the main factors causing the increase in desertification. The thesis also included an analytical and statistical study. According to the available data, the summary of the most important results of land degradation and desertification is sand dune encroachment, waterlogging, salinization, and erosion as a face of desertification. [12]

(Panah, S., K. and Ehsani A.H 2004) The study used remote sensing techniques and satellites image to sensors (MMS, TM, and ETM+) for the period (1977, 1988, and 2000) to study the land cover change in (afghan playa). The result shows the desertification change in the study area for the mentioned period up to 68%, and this change is explained on maps. [13]

(Ali K. Muhammad 2010) the study dealt with the spread of desertification and desert encroachment in the southern regions of the Mesopotamian Plain in Iraq, the spread of sand dunes (active and others) and the processes of developing and expanding vegetation cover in it, using geographic information systems and remote sensing technique, The result is the degradation of the environmental potential and the functional efficiency of agricultural lands in the Mesopotamian Plain in general and the southern region there in particular, resulting from the influence of climatic conditions, water resources and geomorphological processes (and the increase in desertification activity) of its two types of salinity and drought, and the increase in sand dune activity and its encroachment from its formation areas to other regions, which is deeper than its negative impact on the neighboring lands (agricultural and urban), thus changing the effectiveness of the surface, considering that sand dunes are in a permanent movement that not only affect agricultural lands, but also the most important projects within this region (such as irrigation, drainage, etc.) [2].

(Sumira N. Zaz, Shakil Ahmad Romshoo 2012) The research took the Kashmir region as a geographical model for the study. The study aimed to assess land degradation, change in vegetation cover, and water area loss from the year (1991 - 2009) by using geometrics engineering technique (geographic information systems and remote sensing) and selecting the vegetation index (NDVI) to determine the level of degradation in the study area. The summary obtained results indicating a significant degradation of up to (48.27%) within the study area and a significant water retreat in (pirpangel) with soil erosion due to weak rock formation along the (pirpangel). [14]

(Alaa G. Kalaf 2012) In this study, he covered the (Karbala holy government) Landsat satellites and the satellite Spot (ETM +, TM, MSS) for the years (1976, 1990, and 2001) and the satellite (SPOT5) (2011), respectively, to analyze and study them. A selected area has been identified according to the images above for the purpose of study, investigation, and special operations, including classifying images and extracting evidence from them. This research used a set of evidence: the tasseled Cap transformation TCT, the NDVI, and the EMI. To find out the change in the land cover for the four time periods, three methods were used for this purpose, the first method relied on the direct detection of the changes that occurred through the descriptive and quantitative interpretation of the above evidence images that were used to isolate the land cover units, the second method was used to identify and analyze the land cover changes during that period by extracting the differences between the images of evidence algebraically, As for the third method, the classification process was used, Directed for classifying images and analyzing the changes occurring to the land cover during that period as well, where the directed digital classification of land cover was performed and the categorized maps were produced , the results of the analysis showed that the study area suffers from severe desertification Wind and sand dunes erosion, water erosion, urbanization, less Water sources, especially in the western part of them, and the results of the analysis are also shown the rate of desertification decreased between (1976) and (2001) and increased during the period from (2001 to 2011) , especially sand dunes, at a rate of (8.78) km2 per year, and the emergence of the waterlogging problem At a rate of (0.65) km2 per year and an increase in urban area at a rate of 0.38 km2 per year In addition to the effects of bad weather conditions during that period.[15]

(Aseelabbas 2009) The study used GIS and Eras image ver8.3 (2003) programs to classify the study area supported by field survey data and use a ground position System(GPS) device. The most important conclusion is that the region covered large areas of clay and silt soils and showed high levels of salts. The maps were produced for the study area by supervised and unsupervised classification methods. The first method gave an accuracy of up to (99.7 %). [16]

(Alaa G. Kalaf 2019) The study used satellite imagery for Landsat and Sensors TM, ETM +, and OLI. The dates for these images are for the years 1988, 1993, 2000, 2005, 2010, and 2018. The agricultural drought indicators used in this study are VCI, TCI, and VHI. The VCI index gave good results about drought in the study area compared to TCI and VHI. For areas with an area of about (26,611) Km2, the study area included five governorates, namely: Karbala, Babil, Najaf, Qadisiyah, and Al-Methane. The study found severe drought and a green area regression for the mentioned governorates. [17]

3. Study Area and Data Collection

3.1 Data Collection

Data from MSS (1976) and TM (1996), Land sat 8 (2016), sentinel (2021) sensors were used by ERDAS imagine 2015 and NDVI 5.1, ARC GIS 10.7 software. All images got from the USGS website [5]. See appendix 4.

3.2 Study Area

The study area is a part of the Mesopotamian plain in the middle and south of Iraq. It is bounded by the coordinate upper left (44° 58' 38" E to 32° 31' 35 " N) and lower right (46° 3' 27.68" E to 31° 32' 48.90" N) at zone 38N according to Universal Transverse Mercator (UTM) projected coordinate system. It also covers an area of about 7000 Km^2, as shown in Figure (1), to recognize the study area from the satellite image.

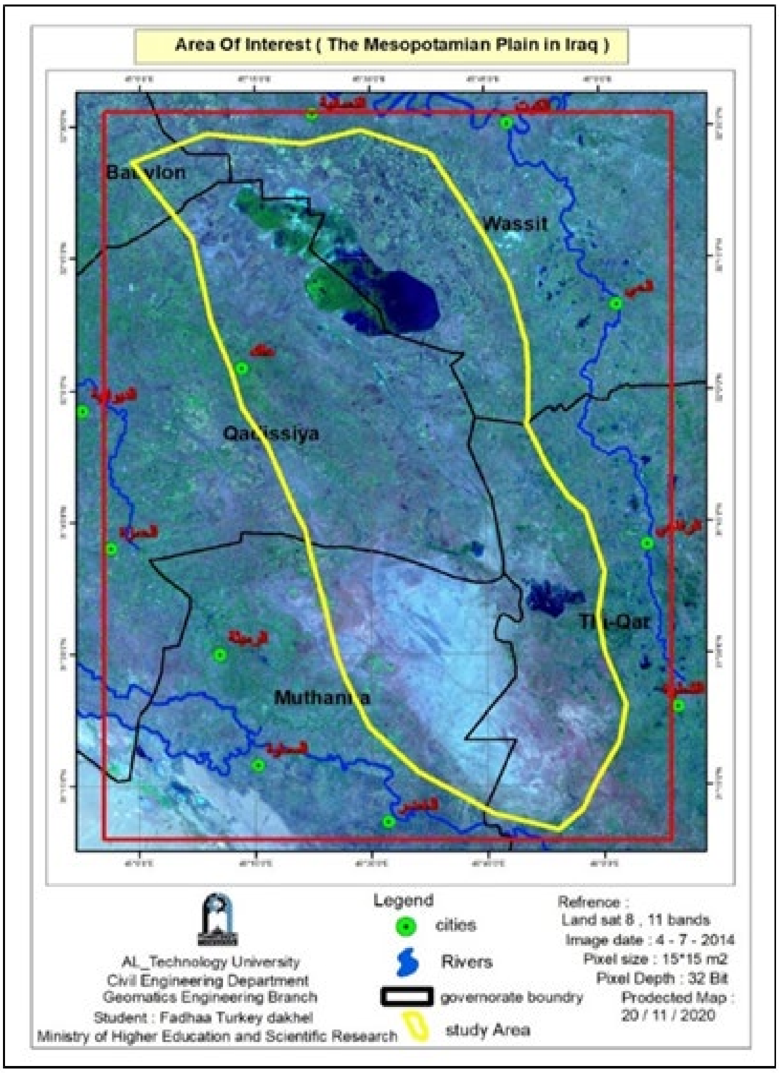

Figure 1: satellite image represents the selected study area

4. Aim of article

The present work's main objective is to monitor the soil degradation in Iraq (Mesopotamian plain) for the period (1976 - 2020) by using remote sensing techniques and put a series of contexts and proposed successful solutions for these lands to reduce sand dune encroachment and land degradation.

5. Methodology work

To achieve the study aims, the following processing steps were applied:

5.1 Pre-processing

Pre-processing operations, referred to as image restoration and rectification, are intended to correct for sensor- and platform-specific radiometric and geometric distortions of data. Radiometric corrections may be necessary due to variations in scene illumination and viewing geometry, atmospheric conditions, and sensor noise and response. These will vary depending on the specific sensor and platform used to acquire the data and the conditions during data acquisition. [6]

"Regarding the time between the sequence of images, features may have shifted from one scene to the next scene. So geometric correction is required to geo-reference all images before making change detection or classification. The correction used here is not by ground control points, where the target not to produce a map, the old image assumed as a reference image and all other images registered to that image". [18] Figure (3) explains the situation of image geo-referencing to the area of interest.

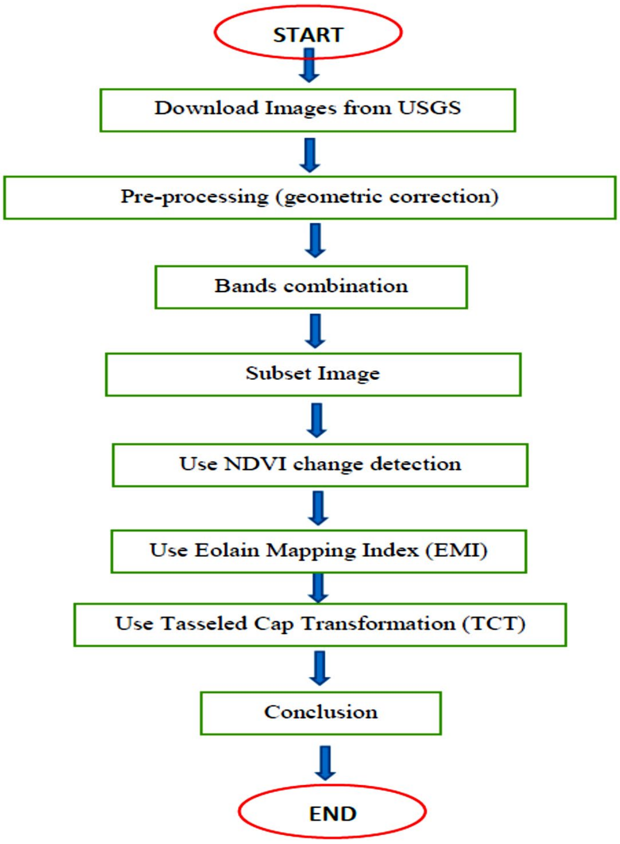

Figure 2: Methodology of study flow chart

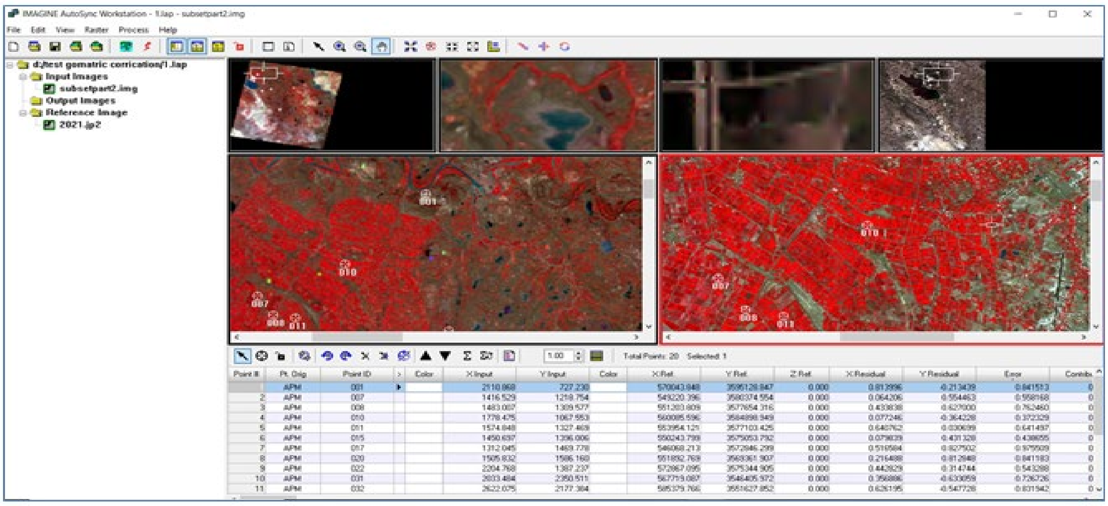

Figure 3: explain the situation of image geo-referencing to the area of interest

5.2 Bands combination

Stacking is the name of the process where the different bands (or layers) of information are overlaid in one file. This process allows us to display true or false-color images. Four bands B (blue color), G (Green color), R (red color), and IR (infrared), were selected and stacked together for all stages 1976-1996 and 2016-2021. These bands were selected to use regarding the study's objective, Where USGS assigned the band combination for each application.

5.3 Subset

Subsetting an image will minimize the amount of data used and stored by subsetting based on a specific geographic area [7]. This process used only the area of interest from the big size of the LANDSAT image, which is already greater than 180 x 180 Km. Therefore, this process reduces the image area and reduces the time of the process and the size of the data.

The subset was made to set the same AOI and corners to all images. This process was done two times, one in the beginning to reduce all the processed areas and another one after the geometric correction where a traditional shift happened [8].

5.4 Normalized Difference Vegetation Index (NDVI) change detection

Normalized Difference Vegetation Index (NDVI) is a value between (1, -1), and each value from this range has a fixed Normalized Difference Vegetation Index value. If the value is in a positive direction, it indicates high reflectivity and represents dense vegetation. Else, if the value is negative direction, it indicates weak or no vegetation cover. Rouse et al. (1974) were some of the first to use what has become known as the (NDVI) and use the equation NDVI = (NIR – RED) / (NIR + RED) [9] see figure (4) and appendix (1) explain NDVI production maps for years (1976, 1996, 2016, and 2021).

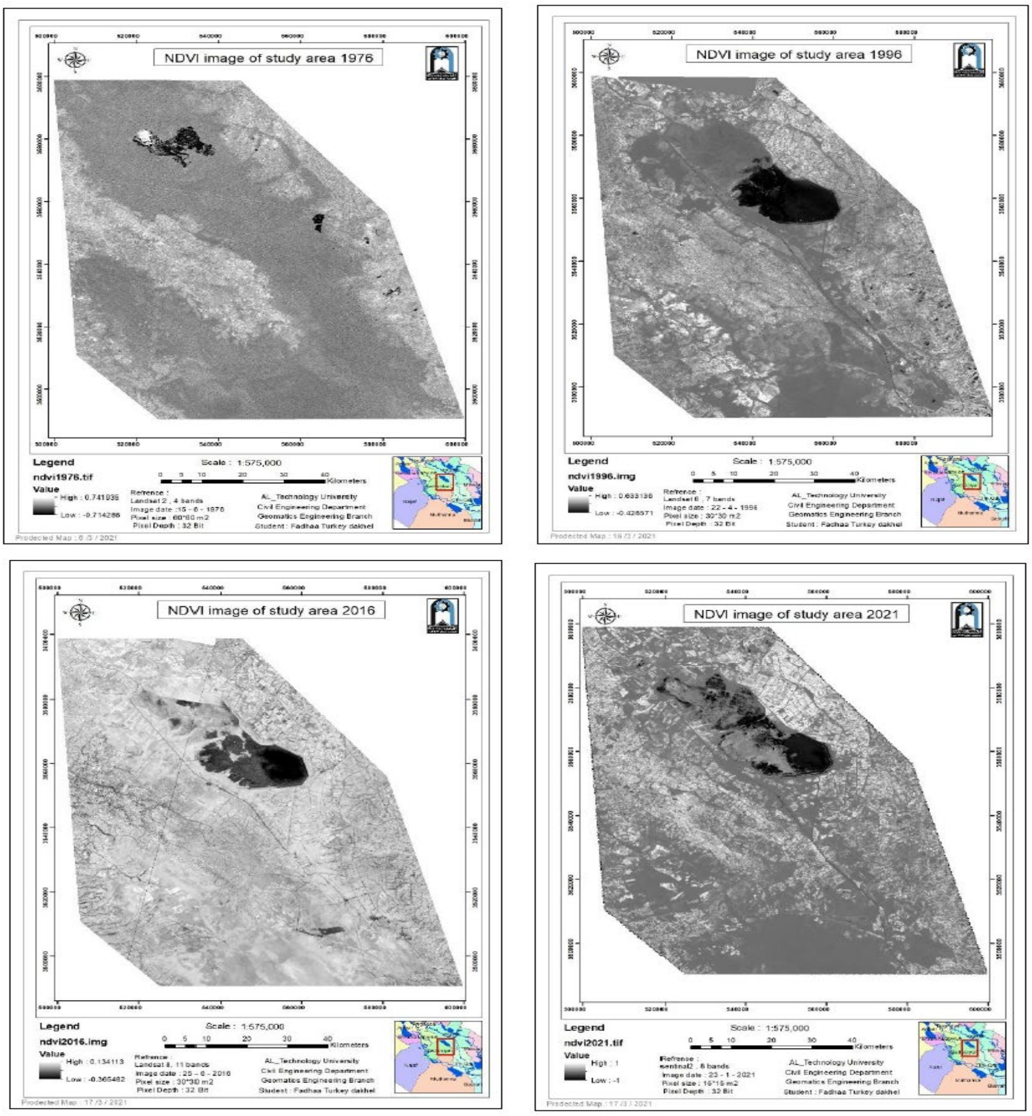

Figure 4: NDVI Maps to the study area (1976-2021)

5.5 Elian Mapping Index (EMI) Change Detection

This study has been using a set of indicators to produce thematic maps related to the issue of deterioration, including the Elian Mapping Index (EMI) indicator, using multi-spectral digital satellite data, where many factors affect the amount of erosion resulting from the winds. However, two basic and critical factors affect the Eolainmapping index: vegetation cover and the soil surface type in general. Therefore, the model allows for creating a map focusing on areas with low vegetation density and highly reflectance soil (soil type, general surface soil density, amount of vegetation cover) in areas with a degraded environment and soils more prone to wind erosion [10]. See appendix (2) explain (EMI) production maps for years (1976, 1996, 2016, 2021).

Elian Mapping Index (EMI) change detection uses satellite image bands (R, IR, R/IR) and the components of natural red, green, and blue colors (RGB). Those bands formed the Elian Mapping Index (EMI) by layer stack, which produces a yellowcolored image indicating the level of density of varieties and the reflection of the soil exposed to erosion, which is dark yellow. It also identifies areas with weak vegetation and dry soils with high spectral reflectance [11].

5.6 Tasseled Cap Transformation (TCT) Change Detection

Knuth and Thomas (1976) developed an orthogonal transformation of the original Landsat MSS data space to a new four-dimensional feature space. It was called the *tasseled cap* or*Kauth-Thomas transformation*. It created four new axes: the soil brightness index (*B*), greenness vegetation index (*G*), yellow stuff index(*Y*), and none-such (*N*). The names attached to the new axes indicate the characteristics the indices were intended to measure. The coefficients are [9]:

$B = 0.332MSS1 + 0.603MSS2 + 0.675MSS3 + 0.262MSS4$

$G = -0.283MSS1 - 0.660MSS2 + 0.577MSS3 + 0.388MSS4$

$Y = -0.899MSS1 + 0.428MSS2 + 0.076MSS3 - 0.041MSS4$

$N = -0.016MSS1 + 0.131MSS2 - 0.452MSS3 + 0.882MSS4$

See appendix (3) explain (TCT) production maps for years (1976, 1996, 2016, 2021).

6. Results and Discussion

6.1 Normalized Difference Vegetation Index (NDVI) change detection

Through the analysis and calculation, the vegetation cover area for the Alluvial plain observed a positive increase in the area of vegetation cover for the period (1976 - 1996). The reason is due to the hard work and large projects during twenty years to eliminate the effective sand dunes movement in that period, while a positive change was observed for the period (1996 - 2016). However, also negative change was observed in the spread of vegetation cover for the year 2021comparing with 2016. Figure (5) explains the percentages of vegetation cover area over the years (1976, 1996, 2016, 2021). From the above, the vegetation cover index recorded the highest percentage in (2016) (28%) and the lowest percentage in (1976) (21%), while the index recorded a gradual decline in vegetation cover for the year (2021) (26%).

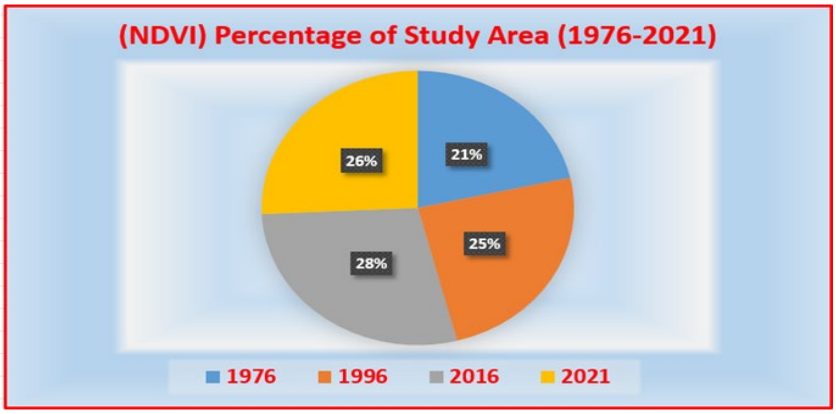

Figure 5: Explain (NDVI) Percentage of the study area (1976-2021)

6.2 Elian Mapping Index (EMI) change detection

As indicated previously, the Elian Mapping Index (EMI) reveals soils exposed to erosion due to wind erosion, which are dark yellow. Through visual interpretation, it was found in the final maps produced for the study area years (1976-2021) that the study area suffered from severe soil erosion in a year (1976). While this effect generally decreased in (1996) and for the period (2016-2021), we observed the presence of erosion effects (Increased gradually) in the south of the study area, see appendix (2) to explain Elian Mapping Index (EMI) maps period (1976-2021).

6.3 Tasseled Cap Transformation change detection

This index classifies satellite images into three categories (Barren lands TC1, vegetation cover TC2, and water cover TC3). We calculate the changes and percentages of each category for years (1976-2021). We obtained data from (TC1, TC2, TC3) and compared it with the years (1976,1996,2016,2021) by visual interpretation and statistical analysis to extract the results.

The results related to (TC1) for the year (1976) show a significant increase in the Barren Land, which the percentage reached (33%) while this percentage decreased in the year (1996) to reach (20 %). The indicator (TC1) also recorded a gradual increase in the area of arid lands to reach (23%) and (24%) during the period. (2016, 2021). See figure (6).

The results related to (TC2) for the year (1976) show a decrease in Vegetation cover, which the percentage reached (18%) only of the total area, while this percentage increase in the year (1996) to reach (29 %). The indicator (TC2) also recorded a gradual decrease in the area of vegetation cover to reach (27%) and (26%) during the period. (2016, 2021). See figure (7).

The results related to (TC3) for the year (1976) show a significant decrease in the water cover, which the percentage reached only (6%), while this percentage decreased in the year (1996) reaching (38 %). Although the reason for the increase in water cover is the establishment of Lake Dolman during twenty years, the indicator (TC3) also recorded a gradual decrease in the area of water cover reach to (31%) and (25%) during the period. (2016, 2021) see figure (8).

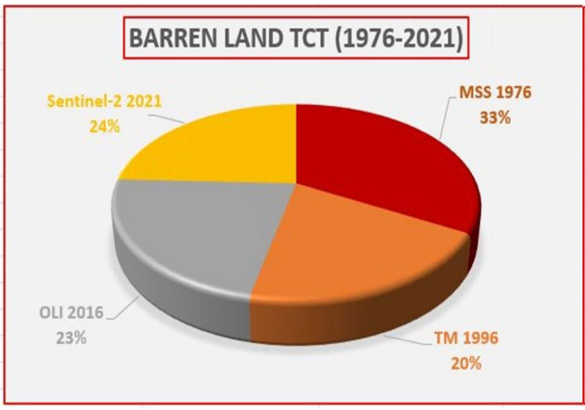

Figure 6: Explain (TC1) Percentage of Barren Land Area (1976-2021)

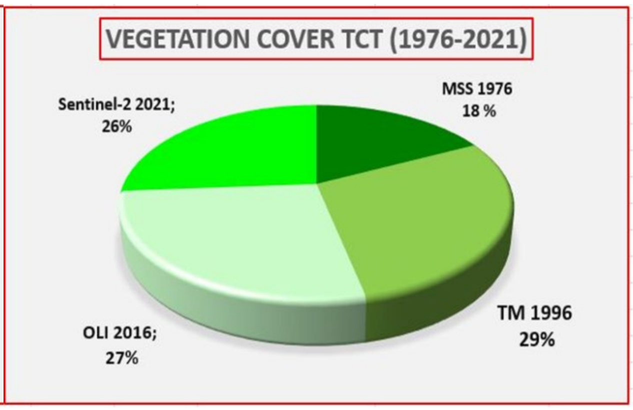

Figure 7: Explain (TC2) Percentage of Vegetation Cover Area (1976-2021)

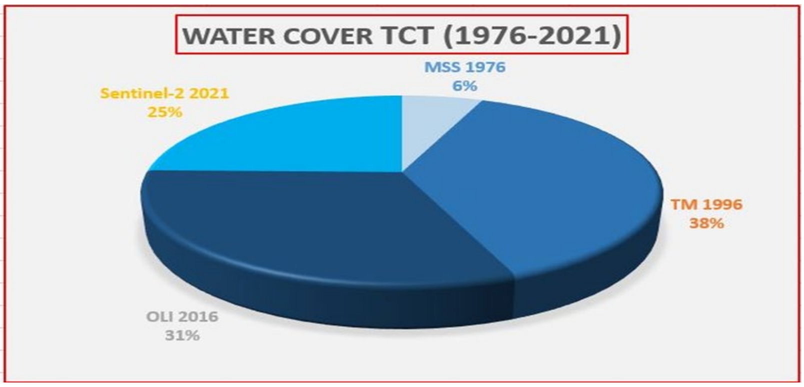

Figure 8: Explain (TC3) Percentage of Water Cover Area (1976-2021)

Finally, the indicator Tasseled Cap Transformation (TCT) recorded a gradual decrease in the percentages area of classes (TC1), (TC3) during the years (2016-2021) while the best percentage area was recorded to Barren and Water cover in the year (1996),

Also, the indicator (TC2), the vegetation Cover Specialist in the same case, recorded a gradual decrease in the percentages area (2021) while the best percentage area was recorded (2016).

The recorded data during the year (1976) for indicators (TC1, TC2, TC3) were considerd the worst result during the study period.

7. Conclusion

Through the aforementioned, a set of the following conclusions were obtained: -

1) The study demonstrated the seriousness of the ministries and government institutions related to addressing land degradation in the Mesopotamian plain from the period (1976-1996). This was done through the establishment of irrigation projects, lakes, and artificial marshes such as the third river (the general estuary), the establishment of the Dolman lake, Vitality and biological treatment of the soil, the establishment of agricultural projects, and the addressing roads to protect it that cause daily accidents, such as the Al-Bathe road, which is located between the two governorates (Nasiriyah - Samawah), actually reclaimed more than (90%) of the study area during the period (1976 - 1996).
2) Climate changes such as (high temperatures, lack of rain, wind speed, etc.), human factors, and the nature of the land (Alluvial plain) made it vulnerable to the problem of desertification and land degradation.
3) The movement of sand dunes increased since the year (2014-2021), and most of the expansion was from the western and northwestern direction to the east, according to the movement of the direction winds.
4) Through satellite images (MSS 1976, TM1996, OLI 2016, Sentinel 2021) and maps created by remote sensing technology and geographic information systems, the results proved the changes occurring in the study area (Land cover), the deterioration of agricultural lands is generally due to the increase of sand dunes area, in particular, this area increases overtime on the Mesopotamian Plain. See appendix 5 for some solutions and recommendations suggested by the author.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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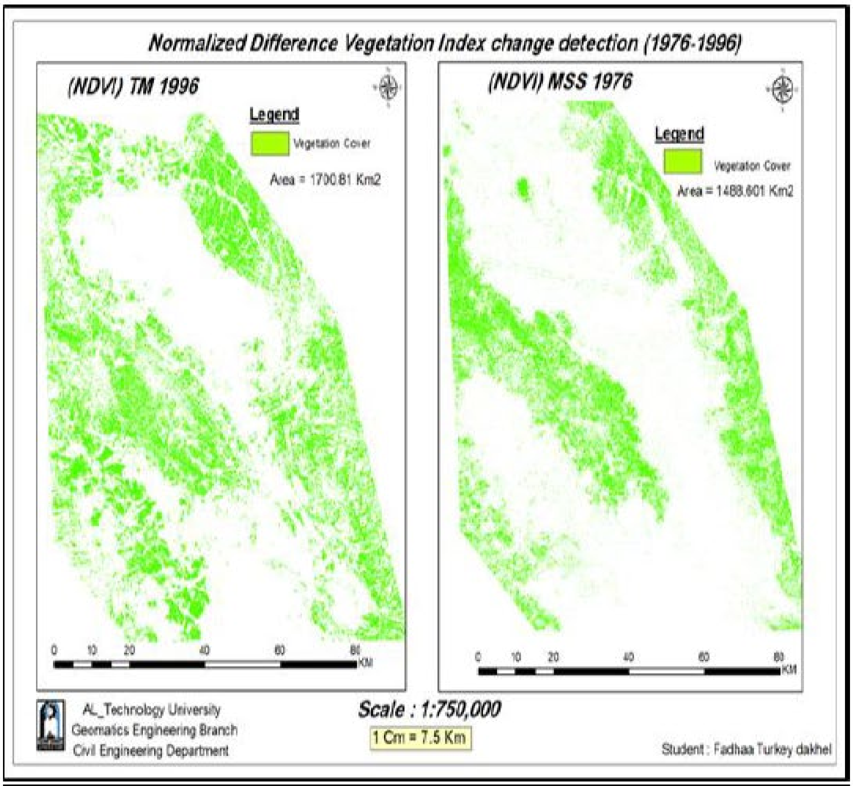
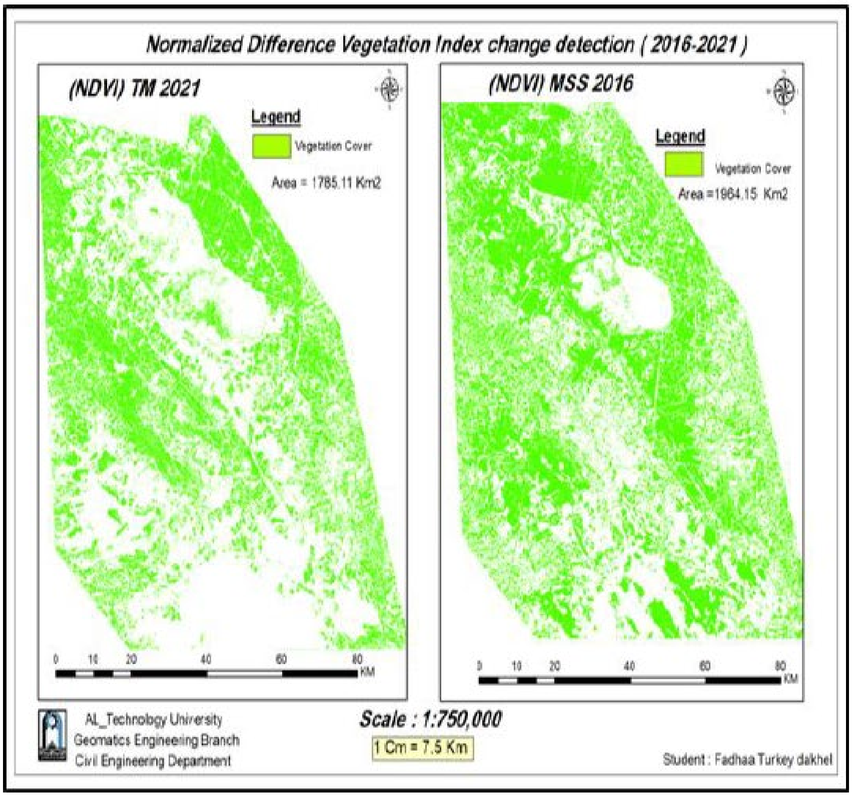
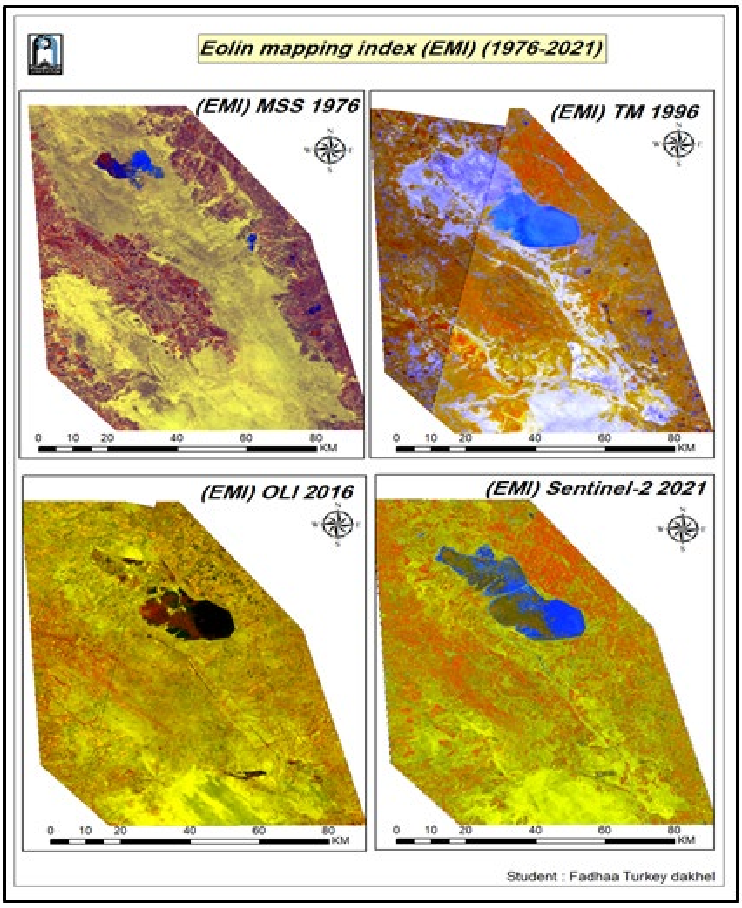
Appendix (1)

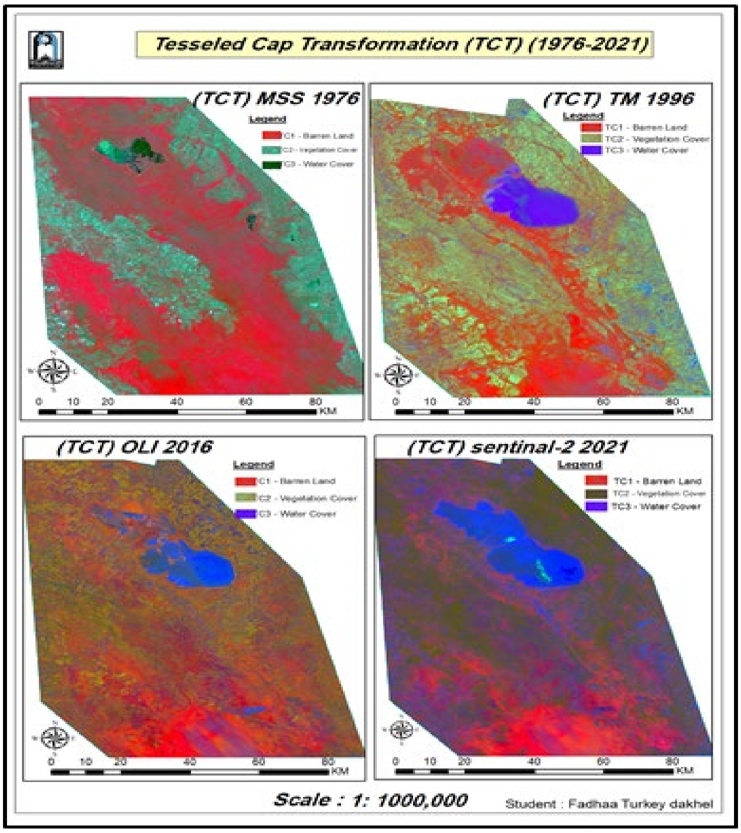

Normalized Difference Vegetation Index change detection (1976-1996)
(NDVI) TM 1996
Legend
Vegetation Cover
Area = 1700.81 Km2
(NDVI) MSS 1976
Legend
Vegetation Cover
Area = 1488.601 Km2
0 10 20 40 60 80 KM
AL_Technology University
Geomatics Engineering Branch
Civil Engineering Department
Scale : 1:750,000
1 Cm = 7.5 Km
Student : Fadhaa Turkey dakhel


Normalized Difference Vegetation Index change detection (2016-2021)
(NDVI) TM 2021
Legend
Vegetation Cover
Area = 1785.11 Km2
(NDVI) MSS 2016
Legend
Vegetation Cover
Area =1964.15 Km2
0 10 20 40 60 80 KM
AL_Technology University
Geomatics Engineering Branch
Civil Engineering Department
Scale : 1:750,000
1 Cm = 7.5 Km
Student : Fadhaa Turkey dakhel

Appendix (2)



Appendix (3)



Annex 4

Satellite images where all available satellite images for the study area were used since 1976, 1996, ,2016, 2021, using Landsat MSS, TM, ETM+ and Sentinel- 2 and land sat8 (OLI) sensors with the same specifications and characteristics shown in the table (1-1), (1-2) and (1-3) show as below:

Table (1-1) Main characteristics ofsentinel-2 image used in the study

Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 - Vegetation Red Edge	0.705	20
Band 6 - Vegetation Red Edge	0.740	20
Band 7 - Vegetation Red Edge	0.783	20
Band 8 - NIR	0.842	10
Band 8A - Vegetation Red Edge	0.865	20
Band 9 - Water vapour	0.945	60
Band 10 - SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

Table (1-2) Main characteristics of image used (OLI) in the study area

Sensor	Satellite	Band Width (µm)	Spatial Resolution (m)
RBV	Landsat 1, 2	0.475–0.575	80
		0.580–0.680	80
		0.690–0.830	80
	Landsat 3	0.505–9.750	30
MSS	Landsat 1–5	0.50–0.60	79 (1–3)/82 (4–5)
		0.60–0.70	79/82
		0.70–0.80	79/82
		0.80–0.11	79/82
	Landsat 3	10.4–12.6	240
TM	Landsat 4, 5	0.45–0.52	30
		0.52–0.60	30
		0.63–0.69	30
		0.76–0.90	30
		1.55–1.75	30
		10.4–12.5	120
		2.08–2.35	30
ETM	Landsat 6	Same as TM	Same as TM
		0.50–0.90	15
ETM+	Landsat 7	Same as TM	30 (60 m thermal)
		0.50–0.90	15

Annex 5

Recommendation and solution

A matrix of proposed policies from the risks of land degradation for the study areas

Future policy	Analysis and planning	Legislation and institutional system	Calculating economic costs	Projects and programs
- Treatment sand dunes in the study areas	-Taking the results of environmental studies to determine the best way to treatment sand dunes. - Reducing human activities that work to dismantle lands	-putting laws and legislations to limit illegal encroachment on the lands near sand dune areas. -Emphasis on the use of modern methods for treating sand dunes, and they should be not cause harm to the environment. -Determine the periods time to visiting the study areas on a regularly, the purpose of monitoring the land cover classification areas change.	- Funding specialized studies for students and researchers working in agricultural and environmental fields. - Inviting professional institutions and companies to allocate a percentage of their profits to support the treatment of sand dune encroachment.	- Conducting some specialized studies for the types of soils that have been previously classified for the study area to find out the possibility of the most useful types of crops and vegetation cover that helps in stabilizing the land.
- A program to monitor the land cover of the study area by means of satellite imagery	- putting plans for training and developing skills on specialized programs for geographic information systems and remote sensing	- Establishing a national center for (GIS) and (RS) specialized in environmental and agricultural issues	-Financing training courses and managing the National Center through high-level government supervision	- Creating a database for the study area that includes (field data, maps and satellite images)
-Increase vegetation cover and encourage people to afforestation.	-Conducting studies on the state of vegetation cover in the study areas. -Developing a plan to collect and propagate seeds of local plants that are able to withstand the desert climatic characteristics of some study areas -Create a plan to grow natural plants in the right environment.	-putting laws and legislations to prevent logging and bypassing irrigation and drainage networks. -Protection of degraded vegetation areas.	-Setting heavy fines for the unsustainable use of natural resources and the causes of agricultural and environmental degradation.	-Establishing specialized nurseries and stations to produce plants and seeds that are highly tolerant to drought and degradation.
- Limiting the expansion of sand dune areas. Most of them are seen from the western and northwestern sides of the country.	-Determine the best sites for establishing centers to raise awareness of the population and educate them in terms of land use.	-Reviewing and updating the land use plans for the study areas. -Work on the entry of environmental and agricultural management systems for the study areas.	-Establishing the economic costs of the project sites in the study area -Providing the necessary funds for the study areas	-Preparing comprehensive and integrated maps for the study areas, defining residential areas and areas for growing crops.

Explain the matrix of proposed policies from the risks of land degradation for the study areas (Mesopotamian Plain)