Original Research Article

Assessing environmental sensitivity Areas (ESA) using MEDALUS model in TelKaif district of northern Iraq

Abstract

This study conducted in Tel Kaif district in the northern part of Nineveh Governorate, located between longitudes (″42′33°41– ″20′19°43) east and latitudes (″20′23°36-″14′54°36) north to assess its environmental sensitivity to desertification (ESA). Fifteen representative sites selected based on the agricultural uses, vegetation cover, and topography. The geographical coordinates of the study sites were determined using a GPS device, and climatic and descriptive data for the study area taken, and soil samples taken for the required laboratory analyses. The obtained data converted into weighted evidence from special tables, so that four indices were calculated, namely the Soil Quality Index (SQI), Vegetation cover Quality Index (VQI), Climate Quality Index (CQI) and Management Quality Index (MQI) required according to the requirements of achieving the Mediterranean Desertification and Land Use (MEDALUS) model. Finally, the Environmentally Sensitive Areas Index (ESAI) equation applied to classify the study area and evaluate its environmental sensitivity to desertification, and then the Kriging technique was used within GIS programs to employ the results of the study by classifying the lands and representing them cartographically. The results showed that most of the study sites have a high environmental sensitivity to desertification (ESA) of the Critical type and below the C3 type, site 15 was Critical - C2, while sites (7 and 9) were Fragile - F2, and Site 6 was Fragile - F3. Therefore, the study area is located within the areas threatened by desertification, according to the assessment of the Environmental Sensitivity to Desertification Index, which is based on the MEDALUS model.

Keywords: Soil Quality, vegetation cover quality, management quality, climate quality, desertification, MEDALUS, ESA

Introduction

The phenomenon of desertification is a serious environmental problem in environments with arid and semi-arid climates, which are highly sensitive to the causes of desertification and include large areas of land around the world [1]. Lands sensitive to desertification affected by extreme conditions and unsustainable over-exploitation of land resources, which leads to ecosystem disturbance over time and thus land degradation and desertification [2], which affects food security and increases poverty, violence, migration, and social disintegration [3].Therefore, desertification must be combated through strict environmental policies to improve the environmental conditions of drylands, and maintain sustainable development globally [4,5].

One of the modern methods for assessing land degradation and desertification is the use of mathematical models to predict areas that are environmentally sensitive to desertification. In light of the expectations obtained from these predictions, appropriate measures can be adopted to reduce land degradation in a timely manner [6].The Mediterranean Desertification and Land Use Modeling (MEDALUS) method [7] used to identify areas sensitive to desertification (ESA) by using four indicators related to land degradation: soil characteristics, climate, Vegetation coverage, and Management methods. This model provided acceptable results for monitoring desertification risks in Mediterranean countries such as Greece, Spain, Italy, Turkey and Greece [8,9,10,11], Egypt and Syria [12,13] and neighbouring regions such as Iraq and Iran[14].

Under the conditions of Iraqi lands, the modified MEDALUS model was implemented in several regions that include influential criteria for predicting the soil quality index, such as electrical conductivity (EC), slope, organic carbon and calcium carbonate [15] and Normalized Differential Vegetation Index (NDVI) also used to express the vegetation index [15].

The current study conducted due to the limitations of such studies in northern Iraq and the challenges of economic and social conditions related to water scarcity, climate change, and degradation and desertification of agricultural lands, with the aim of assessing the environmental sensitivity to desertification in TelKaif district.

Materials and methods

1. Description of the investigated area: The center of TelKaif District is located about 10 km north of the city of Mosul within Nineveh Governorate, between longitudes (″42′33°41 and ″20′19°43) and latitudes (″20′23°36 and ″14′ 54°36) (Figure 1). The region's lands characterized by varying degrees of undulation, which increases towards the north, while the southern parts are slightly inclined to almost flat.The climate of the study area is hot, dry summers and moderately cold winters. The average annual temperature is 21.1℃, and the average annual rainfall is 345 mm, based on climate data for the period 2002-2022. It is located within Thermic and Xeric system according to Soil Survey Staff 2014.

2. Field Study: A semi-detailed survey of the study area conducted using a free survey method, where 15 representative sites of the study area were identified and their geographical coordinates were recorded using a global positioning system device (GPS) based on agricultural uses, prevailing plant coverages, and the topography of the land.

The slope, rock fragment, and drainage of the study sites were determined, and soil samples were taken from the selected sites to conduct laboratory analyzes (partial soil distribution (PSD), bulk density, OC, and CaCO3~~)~~ according to the Soil Survey Laboratory Methods Manual, US Department of Agriculture Soil (2014).

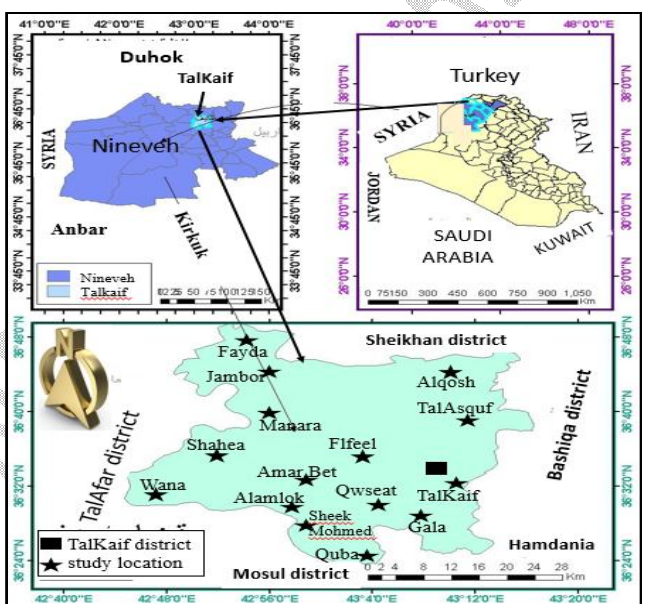

Fig. 1. Map of study sites

Environmentally Sensitive Areas for Desertification Assessment (ESA):

Environmentally Sensitive Areas (ESA) assessed in two stages according to the Mediterranean Desertification and Land Use System model~~Project~~ (MEDALUS) [7]~~(Kosmas *et al.*, 1999)~~. In the first stage: ~~the~~ four ~~indicators~~ indices were calculated separately ~~in~~ for assessing environmental sensitivity to desertification (ESA) according to special equations, namely; Soil Quality Index~~Indicator~~ (SQI), Climate Quality ~~Indicator~~ Index (CQI), Vegetation Quality ~~Indicator~~ Index (VQI), and Management Quality ~~Indicator~~

Comment [a1]: Bracket removed

Formatted: Font: Italic

Index (MQI), based on special tables. In the second stage, the four indicators multiplied according to a special equation for assessing environmental sensitivity to desertification (ESA).

1. Assessment of soil quality (SQ):

Soil quality index (SQI) was evaluated in three steps: First: selecting specific soil characteristics, second: converting the values of the selected soil properties into indices from special tables, and third: entering the indices values into equation (1) to calculate the soil quality index (SQI) contained in the model (MEDALUS) ~~(Kosmas et al., 1999)~~[7].

$$SQI= (IT \times IS \times IP \times IR \times IDr \times IOM \times ICa \times ID)^{1/8} \ldots\ldots(1)$$

As: ~~(~~SQI~~)~~ soil quality index, ~~(~~IT~~)~~ texture index, ~~(~~IS~~)~~ slope index, ~~(~~IR~~)~~ gravel and stone index, ~~(~~IDr~~)~~ drainage index, ~~(~~IOM~~)~~ organic matter index, ~~(~~(ICa~~)~~ calcium carbonate index~~,~~ and (~~I~~D~~)~~ Soil depth index.

2.Assessment of Climate Quality Indicateor (CQI): To calculate the drought index the average annual rainfall and temperatures for the years mentioned above were converted into indices using special tables, then the climate quality index (CQI) was calculated using equation (2) according to ~~(~~Kosmas *et al.*~~,(~~-1999), then the climate quality was classified and divided into three classes, depending on the ranges mentioned in Table (1).

Formatted: Font: Italic

$$CQI =(Rainfall \times Aridity)^{1/2} \ldots\ldots\ldots..(2)$$

3. Vegetation Quality Indicator (VQI):

The vegetation quality was evaluated by determining: (a) Fire Risk, (b) Erosion Protection, (c) Drought Resistance, (d) Vegetation Cover, and the vegetation quality index was classified into three categories using equation (3) and as in the table (1):

$$VQI= (Fire\ Risk \times Erosion\ Protection \times Drought\ Resistance \times Vegetation\ Cover)^{1/4} \ldots\ldots\ldots (3)$$

4. Management Quality Indicator (MQI):

Land Use Intensity and Policy Enforcement were used to evaluate the management quality (MQI) according to the main uses of land or the degree of stress resulting from human activities, using equation (4) according to Kosmas *et al*., (1999), then the management quality category ~~will~~ was determined from the following table (1).

Formatted: Font: Italic

$$MQI = (Land\ Use\ Intensity \times Policy\ Enforcement)^{1/2} \ldots\ldots(4)$$

Finally, the four indicators (SQI, CQI, VQI, MQI) were classified into three categories: high quality, medium quality~~,~~ and low quality according to the following table.

Table 1. range and classification of (SQI, CQI, VQI, MQI)

Grade	SQI	CQI	VQI	MQI	Class Description
1	1-1.6	1.15 >	1-1.6	1-1.25	~~h~~High quality
2	1.13-1.45	1.15-1.81	1.7 -2.7	1.26 -1.50	Medium quality
3	1.46 <	1.81<	2.8 -16	1.51<	Low quality

Environmental Sensitivity Assessment to Desertification (ESA):

The results of the four indices (soil quality index, climate quality index, vegetation quality index, and management quality index) were used to evaluate environmentally sensitive areas for desertification (ESA) based on the (MEDALUS) model according to Kosmas *et al.*~~,~~ (1999) and according to the following equation:

Formatted: Font: Italic

$$ESAI = (SQI \times CQI \times VQI \times MIQI)^{1/4} \ldots\ldots\ldots\ldots.....(5)$$

Finally, the environmental sensitivity (ESA) of the study area was classified based on Table (2), and based on these results, a map of the environmental sensitivity to desertification was created using the Kriging program.

Table 2. Types of environmentally sensitive areas for desertification (ESAI)

ESAI range	Type	Sub type
1.17 >	Non affected	N
1.22 – 1.17	Potential	P
1.26 – 1.23	Fragile	F1

1.32 – 1.27	Fragile	F2
1.37 -1.33	Fragile	F3
1.41 – 1.38	Critical	C1
1.53 -1.42	Critical	C2
1.53 <	Critical	C3

RESULTS and DISCUSSION

<u>Environmental Sensitivity Assessment to Desertification (ESAI)</u>:

Environmental sensitivity to desertification assessed by evaluating four indicators: soil quality, climate quality, vegetation quality, and management quality, according to the MEADAULUAS model, as follows:

1. <u>Soil Quality Assessment</u>:

Soil qualities were determined by applying equation (1) as mentioned by Kosmas *et al*., (1999). The best values of 1.17 and 1.16 were recorded in sites 9 and 15, respectively, while the lowest SQ values of 1.30, 1.31, 1.34, and 1.37 were in sites 5, 6, 12, and 14, respectively, and is considered to be medium quality according to the soil quality classes (table 1).The reason for the low SQ in the study area can be attributed to the low organic matter and the increase in calcium carbonate, in addition to the negative effect of gravel, stony, and undulating topography, especially in the northern sites (5, 11, and 14). These results appear clearly in the SQ map (Figure 2), as the soil quality of all study areas considered to be of medium quality, these results agree with the results of many researchers [8,6].

Formatted: Font color: Dark Red

Formatted: Font: Italic, Font color: Dark Red

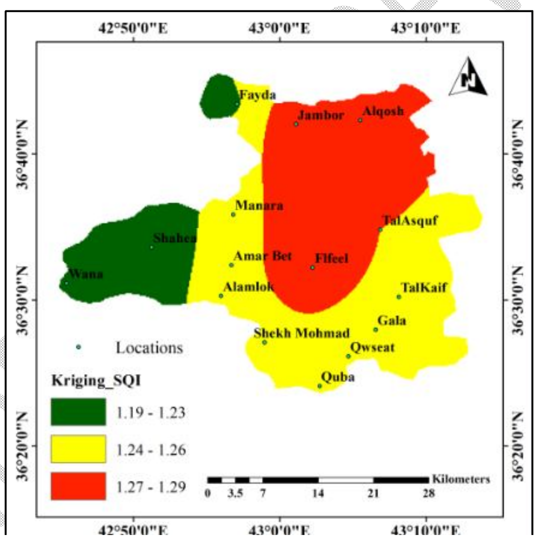

Fig. 2.Map showing the soil quality of the study area according to the Kriging program

2. <u>Climate Quality Indicators (CQI)</u>:

Results mentioned in table (1) and figure (3) showed that the climate quality (CQ) includes two classes: the first is of medium quality which includes the northern region of the study area (4, 5, 13, 14, and 15) sites, and its CQI value is 1.85, and covered 15,006 ha with a ratio of 33.24 % of the study area, and the southern sites (The rest of the sites) considered low quality, its CQI value was 1.79, and covered 30,142 ha, representing (66.76 %) of the study area. These results agree with the results of other scientists [10,5].

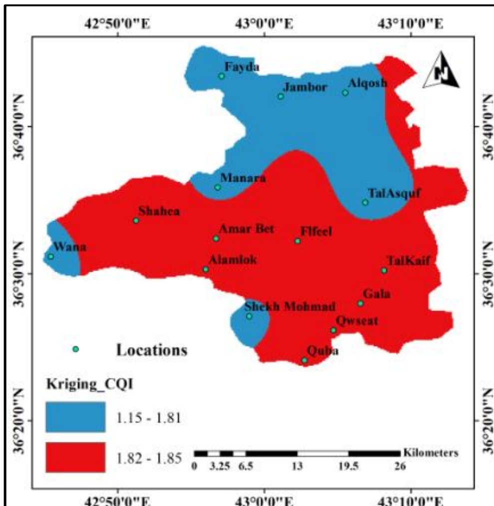

Fig. 3.Climate quality Map of the study area, made by the researcher using Kriging program

3. Vegetation Quality Indicator (VQI):

The vegetation cover quality was evaluated according to the MEDALUS model, which includes four indicators: Fire Risk index (FRI), Erosion Protection index (EPI), Drought Resistance index (DRI) and Plant Cover index (PCI). The results in Figure (4) show that the sites used for growing horticultural crops had a low FR within class 1 and included three sites (6, 7, 9). As for as rest of sites that were used for growing winter grains were considered, they had a moderate fire risk (weighted index 1.3).

As for EPI, the three sites exploited by growing horticultural crops had high protection from erosion, and their weighted index was 1.3, while the rest of the sites were in the class 5 and had a very low protection index (weighted index, 2).

As for DR, the three sites used for orchard cultivation were classified as class 3 with moderate resistance and with a weighted index of 1.4, and the rest of the sites were classified as 5 with very low resistance to drought having weighted index of 2.

As for VCI, the orchard sites are within the class 1 with high VQ and their weighted index is 1, and the rest of the sites are within the class 2 with low VQ and their weighted index is 1.8.

The VQI was evaluated by applying equation 8, where the study area was divided into two parts. The first section included sites used for orchards (6, 7, and 9) which had a quality index of 1.16 and was located within the class 1 of high quality. The rest of the sites used for growing winter grain crops had a quality index of 1.75 and fell within the class 2 with medium quality. These results are consistent with the findings of other workers [3,17,2].

These results appear clearly in the VQ map of the study area (Figure 4), where the first section with high VQ with area of 9279 ha, representing 20.55% of the study area, and the rest of the areas with medium VQ with an area of 35,869 ha representing 79.45% of the study area.

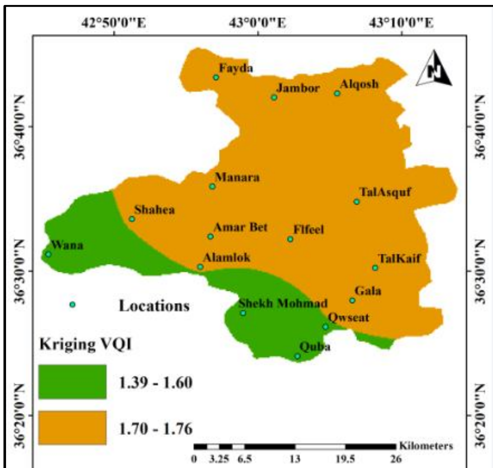

Fig. 4. Vegetation cover quality map, made by the researcher using the Kriging program

4. Management Quality Indicator (MQI):

The management quality was evaluated through two indicators such as Land Use Intensity (LUI) and Policy Enforcement (PE). The results showed that all the study sites have moderate land use intensity (MLUI) and are within class 2 and have a weighted index of 1.5 according to the ranges of the agricultural index (LUI). With respect to PE, the results showed that most of the study sites had partial (medium) protection and were within class 2 with a weighted index of 1.5, with the exception of the sites 6, 7, and 9 which had complete protection within class 1 and with weighted index of 1.

Equation (4) applied to evaluate MQ that includes LUI and PE, indicated that most study area fall in class 2 of medium (MQ) with weighted index of 1.5 (table 3), which is clearly shown in the MQ map (Figure 5), covering an area of 42,326 ha that represent 93.75% of the study area. The sites 6, 7, and 9 fell within the class 1 with high quality covering an area of 2822 ha representing 6.25% of the study area (Figure 5). The reason for the difference in the VQ may be due to the sites used for orchard cultivation that provide good LUI and PE, while the other sites have less LUI and PE and thus described as having medium MQ. These results are consistent with earlier workers [9,10,18].

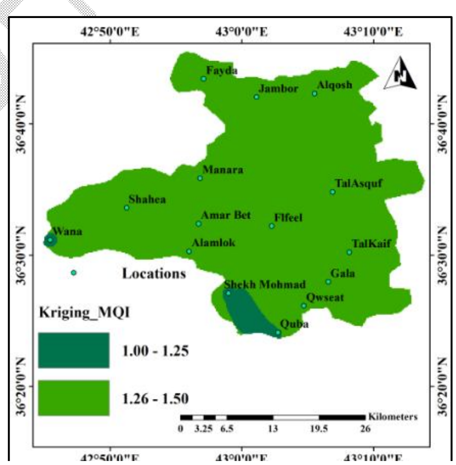

Fig. 5. Management quality map, made by the researcher using the Kriging program

Environmental Sensitivity Assessment to Desertification (ESA):

The environmental sensitivity to desertification (ESA) were assessed through the indicators of SQI, CQI, VQI, and MQI. These results appear clearly in table 3 and in ESA map (Figure 6) that most the sites of study area are highly (ESA) (Critical-C3), including sites 1, 2, 3, 4, 5, 8, 12, 13, 14 having an area of 32,912 ha, representing 72.90% of the study area, while site 15 was sensitive to Critical - C2, with an area of 5,948 ha, representing 13.18% of the study area and site 6 was Fragile- F3 with an area of 3225 ha, representing 7.14% of the area of the study area. As for as sites 7 and 9 are concerned, they were less environmentally sensitive to desertification than all other sites (Fragile- F2) with an area of 3063 ha, representing 6.78% of the study area. These results are consistent with the findings of other workers [10,13,5].

Table3. Environmental sensitivity of the study area to desertification (ESA)

Locations	SQI	CQI	VQI	MQI	ESAI	Type	Sub Type
Qwseat	1.20	1.85	1.75	1.50	1.55	Critical	C3
Gala	1.24	1.85	1.75	1.50	1.56	Critical	C3
TalKaif	1.24	1.85	1.75	1.50	1.56	Critical	C3
TalAsquf	1.24	1.79	1.75	1.50	1.55	Critical	C3
Alqosh	1.30	1.79	1.75	1.50	1.57	Critical	C3
Quba	1.37	1.85	1.16	1.23	1.38	Fragile	F3
Shekh Mohmad	1.23	1.79	1.16	1.23	1.33	Fragile	F2
Alamlok	1.26	1.85	1.75	1.50	1.57	Critical	C3
Wana	1.17	1.79	1.16	1.23	1.31	Fragile	F2
Amar Bet	1.24	1.85	1.75	1.50	1.56	Critical	C3
Shahea	1.20	1.85	1.75	1.50	1.55	Critical	C3
Flfeel	1.34	1.85	1.75	1.50	1.60	Critical	C3
Manara	1.24	1.79	1.75	1.50	1.55	Critical	C3
Jambor	1.37	1.79	1.75	1.50	1.59	Critical	C3
Fayda	1.16	1.79	1.75	1.50	1.53	Critical	C2

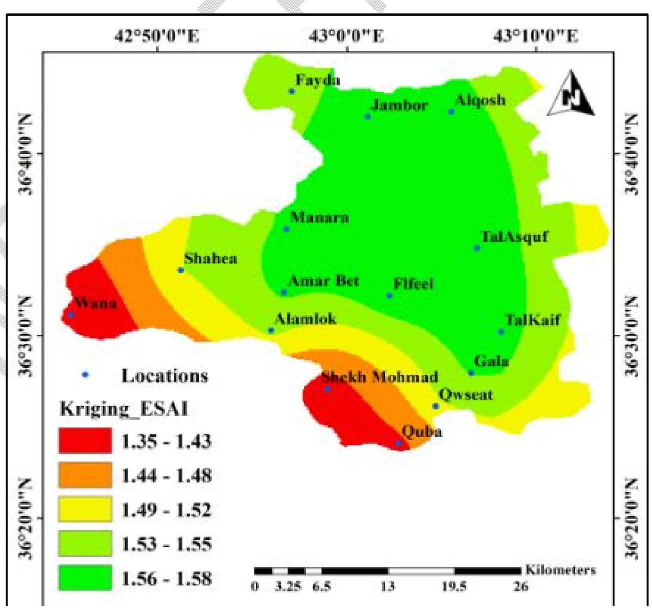

Fig. 6. Map of environmental sensitivity to desertification for the study area

CONCLUSION

The study was conducted in the northern part of Nineveh Governorate to assess its environmental sensitivity to desertification (ESA). Fifteen representative sites were selected and their data transformed into weighted indices to calculate four indices, namely SQI, VQI, CQI and MQI, required according to the requirements for achieving the MEDALUS and ESAI models. The results showed that most of the study sites were of type C3 with the exception of site 15, which was C2, sites 7 and 9 which were F2, and site 6 was F3. Therefore, the study area falls within the areas threatened by desertification, according to the assessment of the Environmental Sensitivity to Desertification Index based on the MEDALUS model.

REFERENCES

1. Tumwesigye W, Bedadi B and AtwiineJ. Effect of Climate Change on Soil Health and Implications on Food Security: A Review, International Research Journal of Multidisciplinary Technovation.2021, 3 (3):38-46. DOI: 10.34256/irjmt2136.
2. Ashraf MM, Abd El-Kawyl OR, Mohamed Y andNor Al-Deen NK. Desertification Sensitivity Analysis East of Siwa Using GIS and Remote Sensing, Alexandria Sci.Exchange J., 2020, 41(1)1-14. DOI:**10.21608/ASEJAIQJSAE.2020.70346**
3. Dedova E, Goldvarg B and Tsagan-Mandzhiev N. Land degradation of the Republic of Kalmykia: problems and reclamation methods. Arid Ecosystems, 2020, 10(2), 140-147. DOI:**10.1134/S2079096120020043**
4. Younus SS. and Al-Naser YH. Morphological and Physicochemical Characteristics of Agricultural Soils in Zummar Region, Northwest Iraq. Sci Res. J. Agr. Lf. Sci.,2022, 2(6)6-11.
5. Gad, A. (2020). Qualitative and quantitative assessment of land degradation and desertification in Egypt based on satellite remote sensing: urbanization, salinization and wind erosion. In Environmental Remote Sensing in Egypt (pp. 443-497): Springer. DOI:**10.1007/978-3-030-39593-3_15**
6. Hamad A, Alagele S and Hamid B. Assessment of Environmental sensitivity to Desertification with MEDALUS Model in GIS in Maymona project, south of Iraq. The Iraqi Journal of Agricultural Science, 2021, 52(4), 1058-1069.
7. Kosmas C, Kirkby M and Geeson N. Manual on Key Indicators of Desertification and Mapping Environmentally Sensitive Areas to Desertification. European Commission, Energy, Environment and Sustainable Development, EUR, 1999, 18882.
8. Karamesouti M, Detsis V, KounalakiA, Vasiliou P, Salvati L, Kosmas C. Land-use and land degradation processes affecting soil resources: Evidence from a traditional Mediterranean cropland (Greece), CATENA, 2015, 132, 45-55. DOI:**10.1016/j.catena.2015.04.010**
9. Salvati R, Salvati L , Corona P,Barbati . and Ferrara A. Estimating the sensitivity to desertification of Italian forests, iForest - Biogeosciences and Forestry, 2015, 8(3) 287-294. DOI:**10.3832/ifor1111-008**
10. Prăvălie, R., I. Săvulescu, C. Patriche, M. Dumitrașcu, G. Bandoc (2017). Spatial assessment of land degradation sensitive areas in south western Romania using modified MEDALUS method, Catena, 153 , pp. 114-130
11. PrăvăliR, Patriche C, Borrelli P and Bandoc G. Arable lands under the pressure of multiple land degradation processes. A global perspective. Environmental Research, 2021, 194,**DOI: 10.1016/j.envres.2020.110697**
12. Khalil AA, Abdel-Wahab MM, Hassanein MK,Ouldbdey B Katlan B and Essa YH. Drought Monitoring over Egypt by using MODIS Land Surface Temperature and Normalized Difference Vegetation Index. Nature and Science, 2013, 11(11):116-122.
13. Moghadam MH, Kamran KV, Rostamzadeh H. and Rezaei A. Assessing the Efficiency of Vegetation Indicators for Estimating Agricultural Drought Using MODIS Sensor Images (Case Study: Sharghi Azerbaijan Province). International journal of Advanced Biological and Biomedical Research, 2014, 2(2) 399-407.
14. Ramadan M. Iraq faces an environmental disaster. Cities without green belts and agriculture await funding, 2021. https:// www.rudawarabia.net/arabic/business /23052021
15. Alkhulaif M. The future threat of desertification in Iraq, Bionatura j, 2023, 8(2) 1-9. DOI: **10.21931/RB/2023.08.02.85**

16. Al-Daghastani HS. Land use and Land cover Map of Ninvah Governorate using remote sensing data. Iraq Journal of earth Sci.2008, 8(2) 17-26
17. Al-Naser YH and Al-Kafagi QD. (Soil Surface Crust: its Significance, Types and Mechanics of Formation. A REVIEW, Mesopotamia J. of Agric. 2020, 4(48). DOI:**10.33899/magrj.2020.128485.1076**
18. Acir N and Gunal H. Soil quality of a cropland and adjacent natural grassland in an arid region. Carpathian Journal of Earth and Environmental Sciences. 2020, 15(2): 275-288 DOI:**10.26471/cjees/2020/015/128**.