Handbook of Research on Agricultural Policy, Rural Development, and Entrepreneurship in Contemporary Economies

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Chapter 24
Analysis of the Vegetation State of the Territory of Central Iraq Using Landsat Data

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ABSTRACT

In agricultural production, there is a change in the properties of soils and the problem of land degradation is rising. It is especially important for Iraq, whose economic well-being is in oil and agriculture. The objects of authors' study are the territories of Central Iraq; the subject of authors' research is the temporary-territorial variability of vegetation. This chapter analyzes the vegetation dynamics of the five provinces' territory of Central Iraq by determining the values of the Normalized Difference Vegetation Index (NDVI) from remote sensing data in the period from 2003 to 2017. Regional features are reflected in the variability and change rate of these processes and in the valley plots occupied by vegetation of different state classes, from the total area of the province. The differences in the state classes of vegetation on the territories of Central Iraq are conditioned not by natural, but by other reasons, in particular, by the state of meliorative systems.

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INTRODUCTION

Agricultural production affects the properties of soils and can cause the problem of land degradation (Bogdanov et al., 2016, Manshard, Ruddle, 1981). It can lead to decreased yields (Johnson, Lewis, 1995) or restriction of land use, such as cattle overgrazing (Behnke et al, 1993, Pomelov et al., 2015). For instance, desertification of arid, semi-arid and dry sub-humid areas under the influence of such factors (Barrow, 1991, Barrow, 1995) as climate change and human activities (United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa, 1994). Land degradation begins with damage of the vegetation cover (Barrow, 1995), which biomass is considered to be ints most dynamic characteristic (Opustynivaniye zasushlivykh zemel Rossii: novyye aspekty analiza, rezultaty, problemy/ otv. red. akad. V.M. Kotlyakov, 2009). In dry areas of the planet, where plants exist near the boundaries of ecological tolerance, even minor changes in environmental factors can lead to degradation (plowing, cattle grazing, deforestation, etc. (Barrow, 1995; Skoupy, 1993). The growth of deserted area, which, a decrease of biological productivity of ecosystems, plant biomass, crop and livestock production take place here. To prevent them, a complex of organizational, economic and technical measures for radical land improvement (artificial irrigation of soil, reclamation of saline lands, new agro technical methods and technologies) are used.

The above-mentioned problems are especially important for Iraq, which economic well-being basis is lies in oil and agriculture (Agriculture in Iraq, 2017). Agricultural lands cover about a fifth of the territory of Iraq, half of which is in the valleys of the Euphrates and Tigris and belong to irrigated lands (Tokareva et al., 2016). Until 1995 Iraq was one of the ten top countries of the largest area of irrigated land (3.5 million hectares). The key irrigated summer crops are rice, maize, cotton, vegetables and fruits as well as winter crops (Agriculture in Iraq, 2017). Forage crops (alfalfa and other legumes) are grown for cattle breeding as an addition to barley. In summer, less than 3% of the area of agricultural crops is occupied by seed cotton, clover, vegetables, including eggplant and pumpkin, leguminous plants, including beans and peas, even smaller – apple, potato, onion, grapes and sesame. In the course of military operations taking place on its territory since 2003, a part of meliorative structures has been destroyed. For the most effective agricultural production under extreme conditions of natural and anthropogenic origin, reliable data on the geographic and temporal variability of the state of vegetation is needed.

It is possible to use remote sensing and GIS-technology of spatial analysis of data as a powerful and effective land monitoring means. The use of time-varying data allows us to quantify the dynamics of the processes of the state of the object based on the found differences (Mjachina et al., 2018). For example, in a work (Al-doski et al., 2013), by analyzing images of Landsat-5 Thematic Mapper, changes in the vegetation classes of the city of Halabja (Iraq), fired on by chemical weapons on March 16, 1988, were revealed. It is determined as sharp decrease in dense, rarefied and moderate vegetation by 55%, 7% and 9%, respectively, and an increase in the territory on which vegetation is absent (No vegetation) is 5%. As a result of distant studies between 1990 and 2001, in the province of Baghdad, the growth of planting areas from 44760.25 hectares to 75410.67 hectares and a reduction in the areas of degraded land was detected (Najeeb, 2009). Then (Saleh, 2012) obvious ecological changes have occurred to the vegetation cover of the Mesopotamian and southern Iraq in period between 1973 and 2004. Areas of vegetation cover and surface water were decreased, and infertile arid and waterlogged were increased.

The need to assess the effectiveness of destroyed economy restoring for maximum savings in natural and anthropogenic conditions calls for monitoring the status of irrigated agricultural lands, concentrated primarily in Central Iraq. In the literature there is no information about such systemic observations to identify changes and assess the state of vegetation. The problem of vegetation monitoring in the region is has not been yet solved. The problem is complicated by the incompleteness of space images archives of the military operations' territories or their low quality due to natural phenomena (dust storms, etc.).

The purpose of the study is to analyze the dynamics of vegetation in the territory of five Central Iraq provinces by determining the values of Normalized Difference Vegetation Index (NDVI) received by remote sensing data in a period from 2003 to 2017.

To achieve this goal, we used multi-temporal Landsat data in the provinces of Baghdad, Karbala, Diyala, Wasit, Babil during the period of maximum vegetation change (February–April). NDVI values were calculated for the quantitative estimation of vegetation density in the studied areas of the surface. The classification of the vegetation state is based on the NDVI values (No vegetation, Poor vegetation, Moderate vegetation, Dense vegetation, Very dense, High vegetation). The annual and seasonal dynamics of their changes and redistribution of areas of vegetation state classes, the degree of equalization of NDVI values and areas with the most and least stable ratios of vegetation state classes are revealed.

The scientific novelty of the study is to assess the annual and seasonal dynamics of the vegetation state of territories that were previously unexplored. The results are practically significant for making timely management decisions.

BACKGROUND

The Republic of Iraq is located in the Middle East between Iran and Saudi Arabia, borders in the west with Jordan and Syria, in the north – with Kuwait, in the south - with Turkey (Jeffrey, 2019). The total area of the country is 437.072 square kilometers. Climate in the north is sharply continental; in the south it is hot and dry (Fig. 1a). Air temperature in the regions varies from

50–60 ºC (July, August) to zero and lower (January). The maximum precipitation falls from November to April (90%), late autumn and winter rains are extremely rare, drop out irregularly (Klimat, 2019). During droughts, the level of water in rivers falls, yields decrease, drinking water becomes hardly available. There is almost no snow. Wind phenomena and dust storms are typical of the region (Ziboon et al., 2015).

The whole country is crossed by the Tigris and the Euphrates, the most full-flowing rivers of the Middle East, which play a crucial role in the economy of Iraq. Their flows depend on the melting of snows in the Armenian Highlands; in February-May they approach the maximum level and in September and October come to their minimum (Reki Iraka, 2017; Soppe & Saleh, 2017).

The most dynamic development of plants in Iraq occurs in the beginning of the year, which is confirmed by the highest range of variability of NDVI values (Arai et al., 2013). Therefore, long-term series of remote sensing data (February–April 2000–2017) of five provinces were selected for analysis. They are: Baghdad, Karbala, Babil, Vasit and Diyala (Fig. 1b).

Baghdad is in the desert, in the arid climate zone. The average annual temperature is 22.8 °C; the average annual rainfall is 156 mm (Baghdad Climate & Temperature, 2013). Main crops are rice, corn, cotton, vegetables and fruits (FAS, 2003).

Karbala is located in the arid desert climate zone. The average annual temperature is 23.1 °C; the average annual rainfall is 89 mm. The main crop is a palm.

Babil is in the hot desert climate zone. The average annual temperature is 22.9 °C. The are no rainfalls. Main crops: wheat, barley.

Figure 1a. Climate of the Iraq Republic (according to geography of Iraq, 2019)

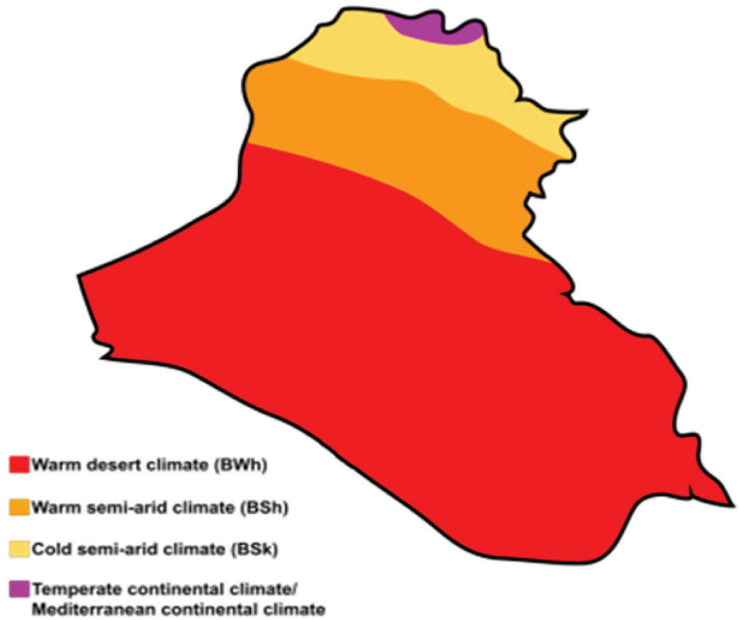


Figure 1b. the location of the provinces selected for this study

Diyala is stretched to north-east of Baghdad. Most of the province is located along the river Diyala, the main affluent of the Tigris. The climate is arid. The average annual temperature is 22.9 ° C; the average annual rainfall is 228 mm.

Wasit is located in the east of Iraq and is bordered by Iran. The climate is arid. The average annual temperature is 23.0 °C. The average annual rainfall is 221 mm (Climate Change Knowledge Portal, Average monthly Temperature & Rainfall for Iraq from 1901-2015, 2019).

The effectiveness of agricultural production in Iraq is affected not only by natural, but also by socio-economic conditions. Until the middle of 1990s, agriculture accounted for 7% of the gross national product, there was an increase in sown areas, large dams and irrigation systems were built, old canals were restored. After the invasion of Kuwait, an economic blockade was launched against Iraq and imports of vital goods were prevented. As a result of military actions, irrigation and drainage systems were destroyed (Iraq Agriculture in Crisis, 2017). To reduce production costs, farmers began to sell livestock, reduce the area of cultivated land and use low-quality fertilizers.

The agricultural productivity fell by 90% after the US troops' arrival at Iraq in 2003. The transition of the labor force to the public sector, the migration of the population to cities, the absence of government subsidies (Metz, 2017), and the long-term severe drought (2004–2010) have caused considerable damage to agriculture (Agriculture in Iraq, 2017). Consequences of the drought were increased by economic sanctions against Iraq, which banned imports of agricultural products, including machinery and fertilizers. The situation was complicated by intercommunal clashes, forcing residents to temporarily leave their villages and lands.

Some positive developments include the activities of the International Committee of the Red Cross. In Diyala, Baghdad, Vasit, Babila and Karbala, drip irrigation systems have been installed due to its activities in recent years (Irak: zhiteli selskikh rayonov ostayutsya v krayne slozhnom polozhenii, 2011). These systems allowed saving water consumption by 67% and significantly reduced the risk of loss of the entire crop in conditions of severe drought.

All these factors have affected the state of agricultural production and vegetation in general.

1. DATA AND METHODS

To assess the distribution and types of vegetation cover, as well as the vegetation state, various vegetative indices (VI) calculated using remote sensing data are used (Roy et al., 2016; Xavier, Vettorazzi, 2004; Chaussard, 2014). VI is the number that is calculated for each pixel in the image based on a combination of remote sensing zones for vegetation and soil characteristics. The NDVI is the most common way and it allows to conduct quantitative assessment of photo synthetically active biomass and, respectively, the density of vegetation at a given surface area (Beck et al., 2011; Brown et al., 2006). NDVI was formulated by Rouse (Rouse et al., 1973) and applied to a wide range of studies using remote sensing data (Sakashita et al., 2013; Tucker et al., 1985; Trishchenko et al., 2002; Walid et al., 2017; MacDonald et al., 1998). It is calculated by the formula:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \tag{1}$$

where ρ_{nir} and ρ_{red} are the intensities of the reflected light in the red and infrared bands of the electromagnetic spectrum (Hamel et al., 2009), received by the sensors of scanners installed on satellites.

Table 1. Description of the used Landsat images

Satellite	Date of Acquisition	Path/ Row
LANDSAT_7	2003.04.09	169/ 37
LANDSAT_8	2013.04.02	169/ 37
LANDSAT_8	2016.04.04	169/ 37

Table 2 describes the images used in the research covering such areas as Diyala, Wasit, Babil, Baghdad.

NDVI, as an indicator of the state of the ecosystem, often correlates with the following parameters: productivity and biomass of vegetation; humidity, temperature, volatility and mineral or organic saturation of the soil; the amount of rainfalls, etc. The relationship between these parameters and NDVI is usually not direct and is due to the characteristics of the study area, its climatic and ecological characteristics (Tucker et al., 2005).

Scanning optical-electronic systems are the main sources of remote-sensing data to solve the problems of natural-resource and environmental monitoring (Zhu et al., 2014). Landsat images in the archives of the US Geological Survey are the unique due to their relation to researching global changes and applications in agriculture, cartography, geology, forestry, regional planning, observation and education for long periods of time (Anderson, 2012; Potapov et al., 2012; Pasko et al., 2016; Kovalev et al., 2016).

Data obtained from the Landsat 5, 7 and 8 (USGS, USA) are used in our study, as they are of sufficient spatial resolution of 30 m in the visible and infrared ranges, the frequency of the survey is 16 days. They were distributed by the Internet (Earth Explorer of the Geological service of the USA, 2019) free of charge and created specifically for natural-resource monitoring (Kennedy et al., 2010; Hansen et al., 2014). Landsat data are supplied in calibrated Digital Number (DN) values, which was converted into a TOA planetary reflection coefficient (Landast 8, 2019) using the reflection coefficient scaling factor specified in the product metadata file (MTL file).

The Landsat images of different data (on close dates) have been analyzed, as well as on Landsat images of 2017 for the period from January to March. NDVI maps were constructed reflecting the density of vegetation in the territory in accordance to the given scale. The obtained data were processed using the methods of correlation analysis and variation statistics. Table 1 provides a description of the images used in the research covering the areas of Baghdad and Karbala.

Zoning of the territories according to the density of vegetation on the basis of NDVI values by setting the values of the boundaries of classes («No vegetation» (-1–0), «Poor vegetation» (0–0.15), «Moderate vegetation» (0.15–0.3), «Dense vegetation» (0.3–0.45), «Very dense vegetation» (0.45–0.6), «High vegetation» (0.6–1)) was carried out.

This formula is used for calculating an average annual growth rate of vegetation is:

$$100x\left(\left[\frac{P2}{P1}\right]^{1(y_2-y_1)}-1\right) \tag{2}$$

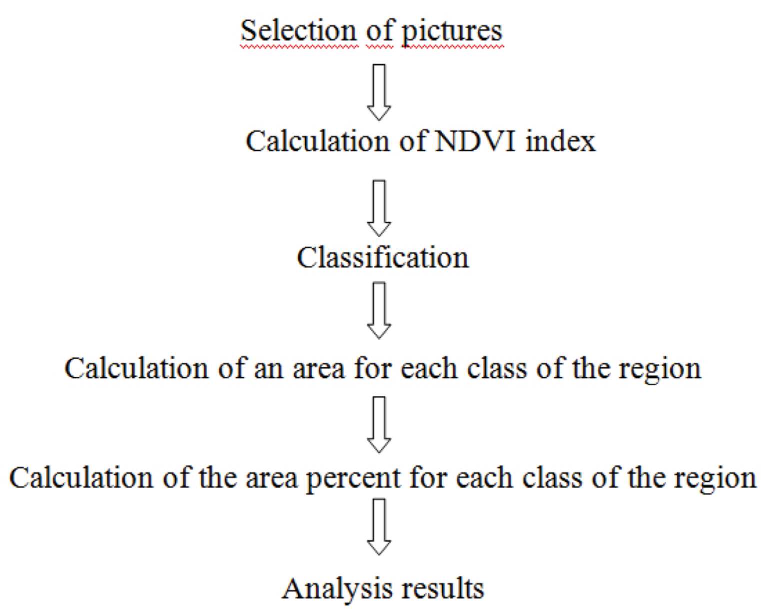
where $P1$ is the vegetation index value in a year y_1, and $P2$ is the vegetation index value in a year y_2 (Mitchell, 2013).

The algorithm of data analysis is shown in Figure 2.

Table 2. Description of the used Landsat images

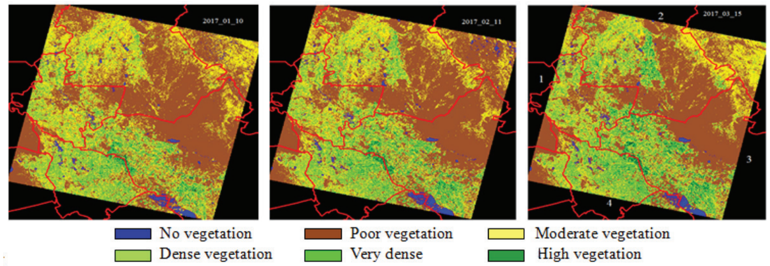
Satellite	Date of Acquisition	Path/ Row
LANDSAT_5	1987.04.30	168/ 37
LANDSAT_7	2000.04.25	168/ 37
LANDSAT_7	2003.04.02	168/ 37
LANDSAT_8	2013.04.21	168/ 37
LANDSAT_8	2014.02.19	168/ 37
LANDSAT_8	2014.03.23	168/ 37
LANDSAT_8	2015.01.05	168/ 37
LANDSAT_8	2015.01.21	168/ 37
LANDSAT_8	2015.02.06	168/ 37
LANDSAT_8	2016.02.09	168/ 37
LANDSAT_8	2016.03.12	168/ 37
LANDSAT_8	2017.01.10	168/ 37
LANDSAT_8	2017.02.11	168/ 37
LANDSAT_8	2017.03.15	168/ 37

Figure 2. An algorithm for analysis



Areas for each class were calculated in square kilometers, the graphs of the change in the area of classes in time (by year and for the vegetation period) and diagrams for the ratio of classes in each region are plotted. The analysis of the obtained data is made.

Figure 3. NDVI classification maps from January to March 2017 of territories: 1 – Baghdad, 2 – Diyala, 3 – Wasit, 4 – Babil



The following software were used to process and present the data: ERDAS Imagine, QGIS and Microsoft Excel. Medium values of NDVI, average square deviations, and correlation coefficients between temperature and NDVI values, coefficients of variation of NDVI values were calculated.

2. RESULTS

There is seasonal dynamics of the vegetative index. Analysis of the NDVI characteristics values for the analyzed dates (Table 1, 2) made it possible to trace the changes in the NDVI values of different vegetation classes in the provinces of Central Iraq (Fig. 3, Table 3).

Table 3. Area of vegetation by state classes in 2017 (sq. km)

Acquisition Date	No Vegetation	Poor Vegetation	Moderate Vegetation	Dense Vegetation	Very Dense	High Vegetation	Total Area
The territory of Baghdad							
2017.01.10	103.89	1948.30	1715.80	529.84	248.49	49.50	4595,83
2017.02.11	114.94	1937.03	1584.70	569.04	309.50	80.63	
2017.03.15	100.98	2018.95	1332.91	594.68	397.02	151.29	
The territory of Diyala							
2017.01.10	170.81	6616.60	3048.02	501.39	185.66	38.60	10561.07
2017.02.11	83.47	6452.17	2928.35	680.05	330.25	86.79	
2017.03.15	63.51	6163.11	2648.26	820.85	549.86	315.48	
The territory of Wasit							
2017.01.10	190	5803	1160	531.78	515.0	138.6	8338.38
2017.02.11	115.15	5037.56	1582.48	668.67	543.87	390.62	
2017.03.15	107.23	4667.03	1632.20	681.57	630.21	620.14	
The territory of Babil							
2017.01.10	90.61	857.45	1119.34	632.73	417.87	203.72	3321.74
2017.02.11	88.76	818.04	1012.54	649.47	484.97	267.95	
2017.03.15	74.96	796.76	930.30	620.86	544.25	354.61	

Comparison of the territories belonging to different classes of vegetation, with the total area of provinces, reveals certain disproportions between the different classes of vegetation in the total area of different provinces. So, in January, the maximum areas in the classes of vegetation «Dense vegetation» and «High vegetation» are noted for the province of Babil, the area which is several times smaller than the areas of other provinces (Diyala & Wasit) (table 3). The province of Wasit, that is inferior in size to the province of Diyala, is characterized by the consistently high rates in the classes of vegetation «No vegetation», «Very dense» and «High vegetation». At the same time, there is a correspondence of the minimum areas of vegetation studied classes to the smaller areas of the provinces of Baghdad and Babil. Attention is drawn to the sharp transition from low values of vegetation development indices in January to Diyala average and maximum in February and March.

Comparison of provinces by vegetation classes in January–March 2017 revealed their regional characteristics. In the initial period of the growing season (January), the maximum values of the class «No vegetation» were found out, which decline in February and March in all the provinces. With the expansion of fields, annual outbreaks and activation of the development of perennial crops, the area is reduced: the maximum is recorded for the province of Wasit, the minimum is for Babil (January & March) and Diyala (February).

The minimum areas of the classes «Poor vegetation» and «Moderate vegetation» are set for the province of Babil, the maximum for Diyala (attention is paid to the high rate of growth of the NDVI values in this region during this period). The territories belonging to the class «Dense vegetation» are maximal in the provinces of Babil January) and Diyala (February & March) and are minimal in the provinces of Diyala (January) and Baghdad (February & March); to the class «Very dense» – minimal in Diyala (January) and Baghdad (February & March), are maximum for Wasit. Territories belonging to the class «High vegetation» are minimal in Diyala (January) and Baghdad (February & March), maximum in Babyl (January) and Wasit (February & March).

The indicated character of the change in vegetation class areas is characteristic for other territories of Central Iraq (Fig. 3). Figure 4 shows the seasonal dynamics of the normalized vegetation index for Diyala and Wasit provinces in 2017, reflecting common features and regional characteristics. In all provinces, the areas of vegetation class «No vegetation» are practically stable. In Diyala, an almost parallel decrease in «Poor vegetation» and «Moderate vegetation» is accompanied by a parallel increase in «Dense vegetation» and «Very dense vegetation». Wasit is characterized by a sharp decline in «Poor vegetation» and «Moderate vegetation» from mid-January to mid-February, a slight decrease in the subsequent, and a weak increase in «Dense vegetation», «High vegetation» and «Very dense vegetation» from mid-January to mid-March. In Baghdad, the area of class «Poor vegetation» squares are stable, «Moderate vegetation» falls, «Dense vegetation», «Very dense vegetation» and «Hight vegetation» grow in parallel.

Regional specific features are reflected in the rate of change. For the regions in the first quarter of 2017, there was an almost parallel decline in the indicator of «Moderate vegetation» and «Poor vegetation» combined with the increase in «Dense vegetation» and «Very dense vegetation». The regional specificity concerns the rate of change – they are insignificant for the territories of Baghdad and Wasit provinces, and are significant for Diyala and Babil territories (taking into account the total area province). Structural changes that vary the relationships between classes of vegetation are shown in Fig. 5 as an example on the Diyala province.

Figure 4. Change in the areas of classes in January-March 2017 in Diyala (a) and Babile (b)

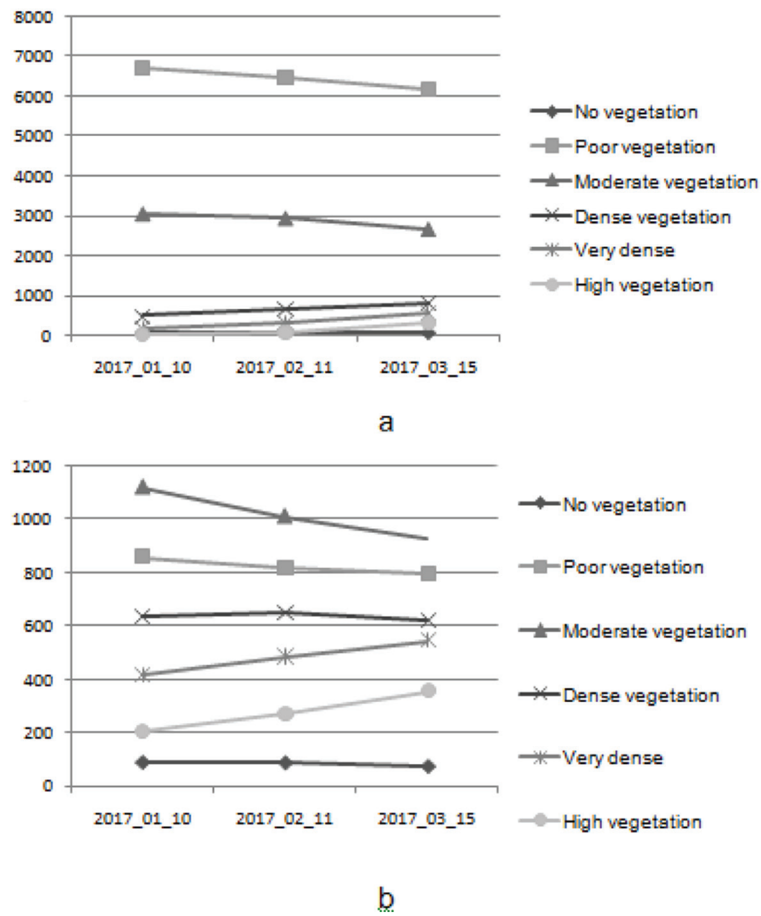


Figure 5. Changes in the structure of vegetation classes in the territory of Diyala in January–March 2017

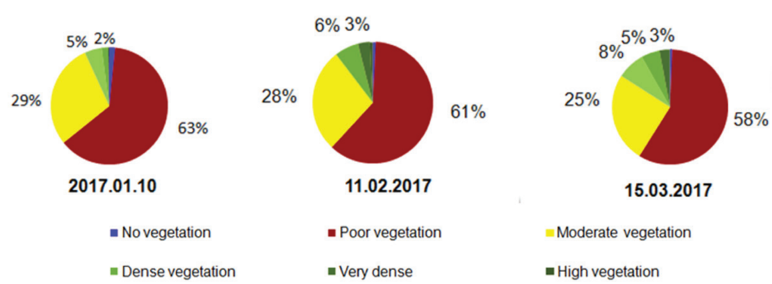


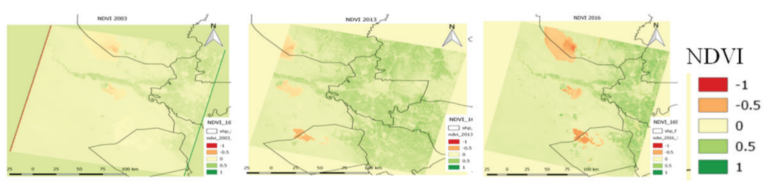
Table 4. Average values of NDVI territories of Central Iraq by years

Years	Baghdad	Karbala
2003	0,162	0,061
2013	0,265	0,117
2016	0,310	0,123

Table 5. Average annual growth rate of NDVI in provinces Baghdad and Karbala

Years	Baghdad	Karbala
2003-2013	5,1	6,7
2013-2016	5,3	1,7

Figure 6. NDVI values map of Baghdad and Karbala territories in 2003, 2013 and 2016



2003 2013 2016

An analysis of the dynamics of the redistribution of territories according to vegetation classes, based on the example of Diyala province, which has the largest territory, revealed a reduction in areas with low NDVI values and compensating for the growth of areas with high NDVI values. The indicator of «No vegetation» is constant and is approximately 1%, Poor vegetation and Moderate vegetation are decreasing (from 63 to 58% and from 29 to 25% respectively). This decline compensates for the growth of «Dense vegetation», «Very dense vegetation» and «High vegetation» (respectively, from 5 to 8%, from 2 to 5% and from 0 to 3%).

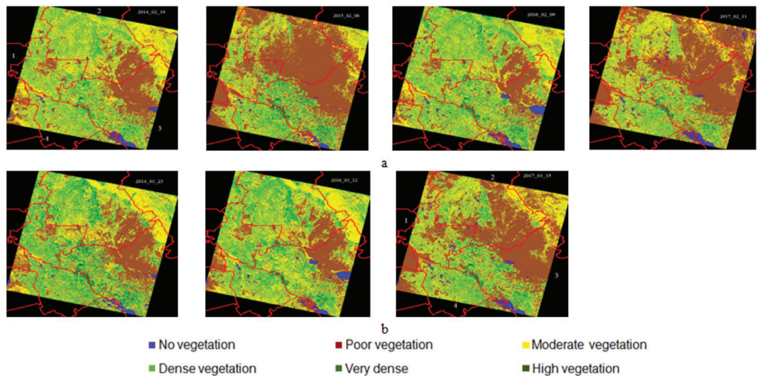
A study of the annual variability of the NDVI values in the provinces of central Iraq confirmed their regional characteristics. An increase in the average values of the NDVI territories of the provinces of Baghdad and Karbala, between 2003 and 2016 (Table 4), was established from different initial and final data.

There are significant regional differences in the average annual growth rate of NDVI. These indicators at different time intervals (2003–2013 and 2013–2016) are close enough for Baghdad and are very different for Karbala (an almost fourfold decrease) (Table 5)

Figure 6 shows us how the NDVI territories' values of Baghdad and Karbala provinces changed.

The minimum average NDVI was recorded in Baghdad in 2003 and is probably related to America's invasion to Iraq territory. In March-April 2003, the famous battle of Karbala took place, when the American troops after numerous attempts to capture Karbala city for an offensive against Baghdad, bypassed it and transferred the task of «mopping up» to the paratroopers. As a result, a lot of infrastructure facili-

Figure 7. Maps of NDVI classification by year in February (a) and March (b) 2014–2016 of territories: 1 – Baghdad, 2 – Diyala, 3 – Wasit, 4 – Babil



ties were destroyed, in particular, agricultural production, which led to the destruction of the irrigation system and a sharp reduction in the areas of irrigated land.

A comparative analysis of the vegetation classes area change in the provinces of Central Iraq revealed that during the last four years in February-March, the No-class areas were the maximum in the provinces of Baghdad and Wasit and the minimum in Diyala province; Class «Poor vegetation» maximum in Wasit province and the minimum in Babil province; Classes Moderate, Dense and Very dense vegetation maximal in the province of Wasit and minimal in the province of Babil; class High in the provinces of Diyala and Wasit and minimal in Baghdad province (Fig. 7, Table 6).

To estimate the spread and the equalization of the NDVI values, the coefficients of variation were calculated. According to the adopted approaches, a coefficient of <10% indicates a slight variability in the variation series, in the range of 10–20% – about an average, 20–33% – significant. Up to 33% variability is considered homogeneous, and > 33% is inhomogeneous.

An analysis of the variability of the NDVI values according to years in different provinces revealed the maximum variability of the areas of the class «Poor vegetation» – the coefficients of variation changed from 8 to 83 (Table 7). The coefficients' values of the variation in the areas of the classes «No vegetation», «Dense vegetation», «Very dense» and «High vegetation» range from 40 to 50. The maximum stable coefficients for variation in the area of the vegetation class «Moderate vegetation», the coefficients of variation of the NDVI values had not exceeded 33%, which made the sample of data homogeneous.

The variation coefficients of the NDVI values for «No vegetation» and «Poor vegetation» for February–March 2014 are very similar, in «Moderate vegetation», «Dense vegetation» and «Very dense vegetation» they grow significantly (by 23–42), «High vegetation» falls by 33; in 2015, they are higher than in 2014; in February–March 2016, «No vegetation» are close, according to «Poor vegetation», «Moderate vegetation» and «High vegetation» fall (4.5, 1.5 and 1.7 times, respectively), «Dense vegetation» falls significantly weaker, and as for «Very dense vegetation» increase in 3 times. In February–March 2017, the variation coefficient of NDVI values according to «No vegetation» grows, and according to «Poor vegetation» falls, and according to «Moderate vegetation», «Dense vegetation» and «Very dense vegetation» are close.

Table 6. Area of vegetation classes in the provinces of Central Iraq in 2014-2017 (sq km)

Shooting Date	No Vegetation	Poor Vegetation	Moderate Vegetation	Dense Vegetation	Very Dense	High Vegetation
Baghdad, February						
2014.02.19	87.67	996.42	1620.73	1125.13	619.00	146.90
2015.02.06	88.72	2190.77	1296.93	517.29	332.90	169.25
2016.02.09	112.33	918.12	1495.15	1101.33	683.22	285.68
2017.02.11	114.94	1937.03	1584.70	569.04	309.50	80.63
Baghdad, March						
2014.03.23	91.25	1010.99	1317.70	892.05	715.82	568.04
2016.03.12	88.09	788.89	1418.98	1137.89	769.85	392.14
2017.03.15	100.98	2018.95	1332.91	594.68	397.02	151.29
Diyala, February						
2014.02.19	35.51	2770.30	3383.541	2725.40	1333.12	313.23
2015.02.06	20.88	8374.33	1402.47	441.47	223.64	98.310
2016.02.09	39.79	2478.25	3032.34	2679.53	1622.84	708.33
2017.02.11	83.47	6452.17	2928.35	680.05	330.25	86.79
Diyala, March						
2014.03.23	35.29	3204.07	3340.25	1767.00	1163.47	1051.04
2016.03.12	30.81	2775.39	3285.61	2109.63	1446.63	913.02
2017.03.15	63.51	6163.11	2648.26	820.85	549.86	315.48
Vasit, February						
2014.02.19	84.84	4018.36	2146.85	877.64	735.13	475.56
2015.02.06	82.12	4847.04	1403.70	630.29	590.48	784.74
2016.02.09	169.83	3337.06	2326.15	1060.46	753.24	691.63
2017.02.11	115.15	5037.56	1582.48	668.67	543.87	390.62
Vasit, March						
2014.03.23	91.10	3980.10	1919.71	725.50	614.48	1007.48
2016.03.12	128.66	3248.66	2491.51	1028.00	873.31	568.23
2017.03.15	107.23	4667.03	1632.20	681.57	630.21	620.14
Babil, February						
2014.02.19	72.50	527.58	1110.87	822.04	575.58	213.16
2015.02.06	72.44	746.61	911.55	620.57	522.65	447.92
2016.02.09	84.21	620.62	1077.61	718.38	507.13	313.78
2017.02.11	88.76	818.04	1012.54	649.47	484.97	267.95
Babil, March						
2014.03.23	67.59	513.42	856.34	669.17	598.20	617.02
2016.03.12	72.62	460.99	1061.01	758.67	593.87	374.58
2017.03.15	74.96	796.76	930.30	620.86	544.25	354.61

Table 7. Values of variation coefficient of NDVI values according to vegetation classes, years and months

2014 February	2014 March	2015 February	2016 February	2016 March	2017 February	2017 March	Difference Max - min	
No vegetation								
36	32	58	21	25	18	25	40	
Poor vegetation								
67	68	83	60	8	62	52	75	
Moderate vegetation								
19	52	17	42	27	39	31	33	
Dense vegetation								
13	55	56	40	32	7	11	49	
Very dense vegetation								
7	30	54	15	57	16	13	50	
High vegetation								
57	24	70	70	40	31	30	46	

Table 8. Values of coefficient of variation of NDVI values by vegetation classes in provinces

Provinces	No Vegetation	Poor Vegetation	Moderate Vegetation	Dense Vegetation	Very Dense	High Vegetation	Difference Max - min
Baghdad	9	34	7	25	27	47	40
Diyala	24	26	7	24	24	29	22
Wasit	10	12	15	16	14	16	16
Babil	7	17	7	6	6	20	13

The coefficients of the NDVI values' variation during the period from February to March by «No vegetation» are predominantly stable, they grow for «Very dense vegetation», by «Poor vegetation» and «High vegetation» drop, by «Moderate vegetation» and «Dense vegetation» grows, and are equal and fall. There is a minimum variation in the years for all «Moderate vegetation», maximum variation for «Poor vegetation», close to «Dense vegetation», «Very dense vegetation» and «High vegetation». The obtained results can be interpreted as follows. Areas, on which vegetation is completely absent, are not suitable for the growth and development of plants in principle, so their area remains stable in time and space. «Very dense vegetation» can appear in the territories occupied by vegetation of all previous classes (except for «No vegetation»), so the growth of its area is maximal. The variability of the areas of the remaining groups is relatively uniform, because, a transition between neighboring classes is similar depending on the conditions of vegetation development.

Analysis of different vegetation groups' areas and provinces revealed their insignificant and average variability for Babil and Diyala provinces, the average for the province of Wasit, insignificant, medium and significant for Baghdad province (table 8).

Table 9. Average daily weather conditions

Shooting Date	Air Temperature, °C		Amount of Precipitation, mm	
	Baghdad	Karbala	Baghdad	Karbala
2014.02.19	14,7	13,0	0	0
2015.01.21	9,0	9,5		
2015.02.06	Нд*	Нд	0	0
2016.02.09	10,2	16,2	0	0
2017.02.11	Нд	Нд	0	0
2014.03.23	Нд	15.1	0	0
2016.03.12	18,4	19,4	0	0
2017.01.10	Нд	Нд	0	0
2017.02.11	10,3	12,5	0	0
2017.03.15	19,0	19,0	0	0

Note: Nd - no data

This allows us to conclude that the most sustainable conditions for the growth and development of vegetation in this period were in Babil and Diyala and were extremely unstable in Baghdad. The temporal variability of the values of such different groups of vegetation areas turned out to be substantially higher than the territorial one.

Calculations were made of the average daily air temperature to explain the obtained regularities. According to the data (Pogoda i klimat, 2019), the temperature was summed up and divided by the number of observations. The data of meteorological stations geographically close to the studied provinces, which are located in the cities of Baghdad and Karbala, are used. The results are shown in Table 9.

Natural droughts in Baghdad province and nearby territories in 2015 and 2017, in the Diyala province in 2015, were noticed.

Correlation analysis between the indices of the NDVI, the territories of different vegetation classes and weather conditions (temperature, precipitation) revealed weak and unreliable connections. This led to the conclusion that the differences in the vegetation classes of the Central Iraq territories are stipulated not only natural but also political, social and economic reasons.

There are numerous cases when extremists lowered the floodgates of the dam on the rivers in the captured settlements, depriving the peasants of the possibility of watering agricultural land. Other reason that is specific to Wasit, Baghdad and Karbala provinces is the lack of water for agricultural land located far from the river and for generating electricity (there is no permanent electricity in the provinces); there is also an inability of the government to pay financial contributions to farmers for the purchase of quality seeds, the state of reclamation systems.

The revealed reduction of areas occupied by high density vegetation, very dense, medium density and the growth of areas occupied by poor vegetation in Diyala province during specified years are explained by the lack of fertilizers, high costs for seeds, and imports. The fighting and the lack of state support due to violence in this region led to the destruction of about 100 villages. Causes of deterioration in

Babil province can be considered as dust storms, droughts, excessive grazing of pastures, as well as migration of people from rural areas to cities during the fighting. It is necessary to adopt an agricultural policy focused on irrigated lands, create artificial wells for water extraction, developing and creating new irrigation projects.

CONCLUSION

As a result of our study, the general regularities of seasonal dynamics of the state vegetation in studied provinces were established – the stability of the class «No vegetation» areas and the compensation for the decrease in «Poor vegetation» and «Moderate vegetation» by the parallel growth of «Dense vegetation» and «Very dense vegetation». Regional features are reflected in the variability and change rate of these processes and in the valley plots occupied by vegetation of different state classes, from the total area of the province.

Comparison of provinces according to state classes of vegetation in January–March 2017 revealed their regional characteristics. In the initial period of the growing vegetation season (January), there is their maximum values of «No vegetation» class vegetation, which decline in February and March in all studied provinces. As the fields are opened, the annuals sprout and the development of perennial crops is activated, the area is reduced: the maximum is recorded for the province of Wasit; the minimum is Babil (in January & March) and Diyala (in February).

The areas of the classes «Poor vegetation» and «Moderate vegetation» are minimal in the province of Babil, the maximum in Diyala. Territories of «Dense vegetation» class are maximum in the provinces of Babil (in January) and Diyala (in February & March); are minimal in the provinces of Diyala (in January) and Baghdad (in February & March); «Very dense vegetation» class is minimal in Diyala (in January) and Baghdad (in February, March), but maximum in Wasit; «High vegetation» class is minimal for Diyala (in January) and Baghdad (in February & March), they are maximum for Babil (in January) and Wasit (in February & March). Regional features are also evident in the annual variability of NDVI values. For example, at different time intervals (2003–2013 and 2013–2016), the change in the mean values of the NDVI territory of the province of Baghdad is stable, Karbala is almost for 4 times lower.

The high variability of vegetation status class areas was determined by years and seasons: «Poor vegetation» (coefficients of variation 8–83%), middle classes «No», «Dense», «Very High» vegetation (40–50%), low «Moderate vegetation» (up to 33%); low and medium variability for the provinces of Babil and Diyala, the average for the province of Wasit is insignificant, there is medium and significant (in different periods) for the province of Baghdad. It is established that the most stable conditions for the growth and development of vegetation are in Babil and Diyala and extremely unstable in Baghdad. The temporal variability of the values of the areas of different vegetation groups is substantially higher than the territorial variability. Weak and unreliable correlations between NDVI values, areas of different classes of vegetation conditions and weather conditions (temperature, precipitation) are established. The conclusion is made that the differences in the state classes of vegetation on the territories of Central Iraq are conditioned not by natural, but by other (political, social and economic) reasons, in particular, by the state of meliorative systems.

For further research, it is useful to draw archival factual material (if any) on the state of meliorative systems and crop productivity in Central Iraq in 2003–2017. It would be actual to transfer the used set of methods for the researches in other regions of Iraq in order to obtain a complete picture of the state of its vegetation.

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REFERENCES

Agriculture in Iraq: Resources, potentials, constraints, and research needs and priorities. Retrieved from http://www.ars.usda.gov/SP2UserFiles/Place/50600000/Products-Reprints/2002/1107.pdf

Al-doski, J., Shattri, B., Mansor, Z. H., Shafri, M. (2013). NDVI differencing and post-classification to detect vegetation changes in Halabja City, Iraq. *Journal of Applied Geology and Geophysics, 1*(2), 1-10.

Anderson, L. O. (2012). Biome-scale forest properties in Amazonia based on field and satellite observations. *Remote Sensing (Basel)*, *4*(5), 1245–1271. doi:10.3390/rs4051245

Arai, K., Sakashita, M., Shigetomi, O., & Miura, Y. (2013). Estimation of protein content in rice crop and Nitrogen content in rice leaves through regression analysis with NDVI derived from camera mounted radio-control helicopter. *International Journal of Advanced Research in Artificial Intelligence*, *3*(3), 13–19.

Baghdad Climate & Temperature. Retrieved from http://www.baghdad.climatemps.com

Barrow, C. J. (1991). Land degradation: development and breakdown of terrestrial environments, Cambridge University Press, 295.

Barrow, C. J. (1995). *Developing the environment problems and management* (p. 313). England: Longman Group Limited.

Beck, H. E., McVicar, T. R., van Dijk, A. I. J. M., Schellekens, J., de Jeu, R. A. M., & Bruijnzeel, L. A. (2011). Global evaluation of four AVHRR–NDVI data sets: Intercomparison and assessment against Landsat imagery. *Remote Sensing of Environment*, *115*(10), 2547–2563. doi:10.1016/j.rse.2011.05.012

Behnke, J., Scoones, I., & Kerven, C. (1993). Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African savannas. *London: Overseas Development Institute for the Overseas Development Institute, the International Institute for Environment and Development and the Commonwealth Secretariat*, 259. Retrieved from http://hdl.handle.net/10919/66476

Bogdanov, V. L., Pasko, O. A., Kovyazin, V. F., & Posternak, T. S. (2016). The issues of weed infestation with environmentally hazardous plants and methods of their control, *IOP Conference Series: Earth and Environmental Science*, *43*(1), 012036. 10.1088/1755-1315/43/1/012036

Brown, M. E., Pinzon, J. E., Didan, K., Morisette, J. T., & Tucker, C. J. (2006). Evaluation of the consistency of long-term NDVI time series derived from AVHRR, SPOT-vegetation, SeaWiFS, MODIS, and Landsat ETM+ sensors. *IEEE Transactions on Geoscience and Remote Sensing*, *44*(7), 1787–1793. doi:10.1109/TGRS.2005.860205

Chaussard, E., Shimon, W., Cabral-Cano, E., & Amelung, F. (2014). Comparison of different BRDF correction methods to generate daily normalized MODIS 250 m. *Remote Sensing of Environment*, *140*, 46–59. doi:10.1016/j.rse.2013.08.019

Climate Change Knowledge Portal. Average monthly temperature & rainfall for Iraq from 1901-2015. Retrieved from http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisCCode=IRQ

Earth Explorer of the Geological service of the USA. Retrieved from https://earthexplorer.usgs.gov

FAS. Retrieved from https://apps.fas.usda.gov/scriptsw/attacherep/legacy.asp

GeographyI. Retrieved from https://www.worldatlas.com/webimage/countrys/asia/iraq/iqland.htm

Hamel, S., Garel, M., Festa-Bianchet, M., Gaillard, J.-M., & Côté, S. D. (2009). Normalized Difference Vegetation Index (NDVI) predicts annual variation in timing of peak faecal crude protein in mountain ungulates Steeve. *Journal of Applied Ecology*, *46*(3), 509–733. doi:10.1111/j.1365-2664.2009.01643.x

Hansen, M. C., Egorov, A., Potapov, P. V., Stehman, S. V., Tyukavina, A., Turubanova, S. A., ... Bents, T. (2014). Monitoring conterminous United States (CONUS) land cover change with Web-Enabled Landsat Data (WELD). *Remote Sensing of Environment*, *140*, 466–484. doi:10.1016/j.rse.2013.08.014

Irak: zhiteli selskikh rayonov ostayutsya v krayne slozhnom polozhenii. 14-12-2011. [Iraq: residents of rural areas remain in extremely difficult situation]. Retrieved from https://www.icrc.org/rus/resources/documents/update/2011/iraq-update-2011-12-14.htm

Iraqi Agriculture in Crisis. Retrieved from http://www.al-monitor.com/pulse/originals/2013/01/iraq-farmers-abandon.html

Jeffrey, P. (n.d.). Iraq and borders. Retrieved from https://infograph.venngage.com/p/72111/iraq-geography-and-borders

Johnson, D., & Lewis, L. (1995). *Land degradation: Creation and destruction* (p. 335). Oxford, UK: Blackwell.

Kennedy, R. E., Yang, Z., & Cohen, W. B. (2010). Detecting trends in forest disturbance and recovery using yearly Landsat time series: 1. LandTrendr –Temporal segmentation algorithms. *Remote Sensing of Environment*, *114*(12), 2897–2910. doi:10.1016/j.rse.2010.07.008

Klimat [Climate]. Retrieved from https://ru.climate-data.org/region/2054

Kovalev, A., & Tokareva, O. (n.d.). Using MODIS NDVI products for vegetation state monitoring on the oil production territory in Western Siberia. *MATEC Web of Conferences*, 2016, 48, 05003. doi:10.1051/matecconf/20164805003

Landsat 8 (L8) Data User Hand Book-Section 2. Retrieved from https://landsat.usgs.gov/landsat-8-l8-data-users-handbook-section-2

MacDonald, A. J., Gemmell, F. M., & Lewis, P. E. (1998). Investigation of the utility of spectral vegetation indices for determining information on coniferous forest. *Remote Sensing of Environment*, *66*(3), 250–272. doi:10.1016/S0034-4257(98)00057-1

Manshard, W., & Ruddle, K. (1981). *Renewable natural resources & the environment pressing problems in the developing world.* Tycooly International Publishing Limited, Dublin, 409.

Metz, H. C. (1988). A country study. Washington: GPO for the Library of Congress. Retrieved from http://countrystudies.us/iraq/58.htm

Mitchell, R. (2013). Christianity in its Global Context: 1970-2020. *The Center for the Study of Global Christianity*. Retrieved from http://www.ocresearch.info/sites/default/files/How%20to%20calculate%20AAGR_0.pdf

Mjachina, K., Hu, Z., & Chibilyev, A. (2018). Detection of damaged areas caused by the oil extraction in a steppe region using winter Landsat imagery. *Journal of Applied Remote Sensing*, *12*(1), 016017. doi:10.1117/1.JRS.12.016017

Najeeb, A. A. (2009). Estimation of the Normalized Difference Vegetation Index (NDVI) variation for selected regions in Iraq for two Years 1990 & 2001. *Journal of University of a Bar for Pure Science, 3*(3), 20-132.

Opustynivaniye zasushlivykh zemel Rossii: novyye aspekty analiza, rezultaty, problemy/ otv. red. akad. V. M. Kotlyakov. [Desertification of the drylands of Russia: New aspects of analysis, results, problems/ otv. Ed. acad. V.M. Kotlyakov], Moskow, 2009, 298.

Pasko, O., Makartsova, E., Ushakova, N., Tokareva, O., & Mochalov, M. (2016). The possibility of distance methods application for snow dump sites monitoring. *MATEC Web of Conferences*. Retrieved from http://www.matec-conferences.org/articles/matecconf/abs/2016/11/matecconf_tomsk2016_05002/matecconf_tomsk2016_05002.html

Pogoda i klimat [Weather & Climate]. Retrieved from http://www.pogodaiklimat.ru/weather.php?id=40656&bday=15&fday=15&amonth=3&ayear=20

Pomelov, A. S., Pasko, O. A., & Baranova, A. V. (2015). Comparative analysis of land management in the World, *IOP Conference Series: Earth and Environmental Science*, *27*(1). 012039. 10.1088/1755-1315/27/1/012040

Potapov, P. V., Turubanova, S. A., Hansen, M. C., Adusei, B., Broich, M., Altstatt, A., ... Justice, C. O. (2012). Quantifying forest cover loss in Democratic Republic of the Congo, 2000–2010, with Landsat ETM+data. *Remote Sensing of Environment*, *122*, 106–116. doi:10.1016/j.rse.2011.08.027

Reki Iraka [The rivers of Iraq]. (n.d.). Retrieved from http://www.best-country.org/asia/iraq/water_source

Rouse, J. W., Hass, R. H., Schell, J. A., & Deering, D. W. (1973) Monitoring vegetation systems in the great plains with ERTS. *Third ERTS Symposium, NASA*, SP-351 I, 309-317.

Roy, D. P., Kovalskyy, V., Zhang, H. K., Vermote, E. F., Yan, L., Kumar, S. S., & Egorov, A. (2016). Characterization of Landsat-7 to Landsat-8 reflective wavelength and normalized difference vegetation index continuity. *Remote Sensing of Environment*, *185*, 57–70. doi:10.1016/j.rse.2015.12.024

Sakashita, A. K., Shigetomi, O., & Miura, Y. (2013). Estimation of protein content in rice crop and Nitrogen content in rice leaves through regression analysis with NDVI derived from camera mounted radio-control helicopter. *International Journal of Advanced Research in Artificial Intelligence*, *3*(3), 13–19.

Saleh, S. A. H. (2012). Studying of the environmental changes in marsh area using landsat satellite images. *Journal of Asian Scientific Research*, *2*(8), 427–435.

Skoupy, J. (1993). Raising the productivity of arid lands by planting trees & shrubs. *Desertification Control Bulletin*, *22*, 55–59.

Soppe, R., & Saleh, R. O. Iraq salinity project. Technical report 8. Retrieved from http://iraq-salinity-platform.icarda.org/Iraq%20Salinity%20Platform/Technical%20reports/08_CompB_Review_Agricultural_Production.pdf

Tokareva, O. C., Pasko, O. A., Alshaibi, A., & Mochalov, M. V. (2016). Monitoring-based analysis of agriculture in Iraq. *IOP Conference Series: Earth and Environmental Science*, 43, 012035.

Trishchenko, A. P., Cihlar, J., & Li, Z. (2002). Effects of spectral response function on surface reflectance and NDVI measured with moderate resolution satellite sensors. *Remote Sensing of Environment*, *81*(1), 1–18. doi:10.1016/S0034-4257(01)00328-5

Tucker, C. J., Pinzon, J. E., Brown, M. E., Slayback, D. A., Pak, E. W., Mahoney, R., & El Saleous, N. (2005). An extended AVHRR 8-kmNDVI dataset compatible with MODIS and SPOT vegetation NDVI. *International Journal of Remote Sensing*, *26*(20), 4485–4498. doi:10.1080/01431160500168686

Tucker, C. J., Townshend, J. R., & Goff, T. I. (1985). African cover classification using satellite data. *Science*, *227*(4685), 229–235. doi:10.1126cience.227.4685.369 PMID:17815712

United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa (1994). Retrieved from https://treaties.un.org/doc/Publication/MTDSG/Volume%20II/Chapter%20XXVII/XXVII-10.en.pdf

Walid, A. A., Abdulateef,, M. A., & Ghazi, H. A.-S. (2017). Using Normalized Difference Vegetation Index (NDVI) to identify hydrocarbon seepage in Kifl Oil Field and adjacent areas South of Iraq. *Journal of Environment and Earth Science*, *7*(1), 16–30.

Xavier, A. C., & Vettorazzi, C. A. (2004). Monitoring leaf area index at watershed level through NDVI from Landsat-7/ETM+ data. *Scientia Agrícola*, *61*(3), 243–252. doi:10.1590/S0103-90162004000300001

Zhu, Z., & Woodcock, C. E. (2014). Continuous change detection and classification of land cover using all available Landsat data. *Remote Sensing of Environment*, *14*, 152–171. doi:10.1016/j.rse.2014.01.011

Ziboon, A. R. T., Alawan, I. A., & Khalaf, A. G. (2015). Study and analysis of desertification phenomenon in Karbala governorate by remote sensing data and GIS. Iraqi. *Bulletin of Geology and Mining*, *11*(1), 143–156.