Climate change and its impact on the change of rice production and related industries in Al-Qadisiyah Governorate for the 2022 Agriculture season, using digital processing of Sentinel-2 data

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Abstract:

The process of monitoring any crop, nowadays and determining its needs is still facing a great difficulty in developing countries due to the lack of data. Therefore, remote sensing data of multiple spectra and different times are effective tools to support monitoring systems and recognize the needs of plants in appropriate time.

The present study uses multi-source data Sentinel 2, Landsat 7 & 8, which are multi-Bands to determine the adequacy of irrigation water for rice. By using the Band–Ratio method, researchers are able to analyze spectral information.

In the same vein, researchers used Sentinel 2 data as a basis of medium spatial and spectral accuracy to monitor the farms in the territory rice of Iraq in Al-Qadisiyah Governorate. The results of the digital analysis indicate that the crop does not get sufficient irrigation water. As a result, the expected yield is currently estimated at 450 kg/acre only, which is a very low level of productivity as a direct result of climate change and draught in addition to unfair water policies of the upstream countries (Turkey & Iran). Therefore, we find that the danger of climate change and its effects seems to be evident through its impact on the productivity of this important strategic crop for the Iraqi people.

Moreover, this method can contribute to estimating the irrigation time and determining the area that can be successfully cultivated of rice or other crops during the dry season. The phenological dataset can also be used with multi-source remote sensing data to explore the crop area and monitor its condition during the season.

Keywords: Rice crop, Climate change, Band – Ratio, Remote sensing, Iraq, Sentinel-2

التغير المُناخي وأثره السلبي في إنتاج محصول الرُز والصناعات المرتبطة به في مُحافظة القادسية بإستخدام المعالجة الرقمية لمرئيات **Sentinel**-٢

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الملخص – **Abstract** :

ان عملية مراقبة اي محصول وتحديد احتياجاته وإدارة زراعته، لا تزال تواجه صعوبة بشكل خاص في البلدان النامية، نظرا لعدم توفر البيانات الضرورية في الوقت المناسب. حالياً، تعد بيانات الاستشعارعن بعد متعددة الازمنة والاطياف، ادوات فعالة لدعم انظمة المراقبة و معرفة احتياجات النبات بصورة آنية .

تستخدم ورقة البحث هذه بيانات متعددة المصادر Sentinel-٢ و Landsat-٧، ٨ ، وهي بيانات متعددة الاوقات لتحديد مدى كفاية مياه الري لمحصول الرز، باستخدام طريقة قسمة الحُزم – Band Ratio، لتحليل المعلومات الطيفية والمؤشرات الناتجة، مع إعتماد بيانات مرئيات Sentinel-٢ بالدرجة الاساس .

في هذا السياق قمنا باستخدام بيانات Sentinel-٢ ذات الدقة الطيفية والمكانية المتوسطة، لمتابعة حالة مزارع الرز للموسم الزراعي ٢٠٢٢ في اقليم الرز في العراق، تحديدا ضمن الجزء الواقع في محافظة القادسية.

تدل نتائج التحليل الرقمي إلى تعرض المحصول في المنطقه طيلة فترة نموه (٦ اشهر)، الى العطش وعدم حصوله على كفايته من مياه الري. نتيجة لذلك فان الغلة المتوقعة للمحصول حاليا، تقدر بنحو ٤٥٠ كيلوغرام لكل دونم، وهو معدل غلة متدنية جدا، كنتيجة مباشرة للجفاف وتغير المناخ ، بالاضافة الى السياسات المائية غير العادلة لدول المنبع المجاورة للعراق. لذلك نجد ان خطر التغير المناخي هو خطر حقيقي واثاره تبدو جلية، من خلال أثره في إنتاجية هذا المحصول الستراتيجي المهم للشعب العراقي.

يمكن ان تساهم هذه الطريقة في تقدير وقت الري وتحديد المساحة التي يمكن زراعتها بنجاح لمحصول الرز او غيره، خلال الفصل الجاف او عند شُح المياه. كما يمكن استخدام مجموعة معلومات الفترة الفينولوجية مع بيانات الإستشعار عن بعد متعددة المصادر، لاستكشاف منطقة المحاصيل ومتابعة حالتها اثناء موسم النمو.

الكلمات المفتاحية : محصول الرُز، التغير المُناخي، قسمة الحزم، التحسس النائي، العُراق، **Sentinel-2**

1. Introduction:

Rice (**Oryza sativa**) belongs to the Gramineae family and is part of the Oryzeae family. It is an herbaceous annual and semi-aquatic plant (**Arabic Encyclopedia, 2022**). The history of rice cultivation is a multidisciplinary topic that is studied by archaeological and documentary evidence to explain how rice was first domesticated by humans and its spread and cultivation in different regions of the planet.

Generally, the current scientific consensus that based on archaeological and linguistic evidence indicates that Oryza sativa rice was first domesticated in the Yangtze River Basin in China 13,500-8,200 years ago, while the local varieties of Oryza sativa changed into more than 40,000 types. (**Normile, 1997; Vaughan, Lu & Tomooka, 2008; Kuenzer & Knauer, 2013**). First Iraqi people knew how to cultivate this crop and used it in different food products[1]. Domesticated rice is one of the most widely consumed staple grains for more than half of the world's population, especially in Asia and Africa (**Khush, 2005**). As a result of its great importance, this crop has the third highest global production of crops after sugar cane and maize (**UN - FAO, 2020**).

In Iraq, there are several different varieties of this crop but the most famous local and international type is the Iraqi amber rice, which is grown mainly in Najaf and Qadisiyah governorates within what is known as (**The Iraqi Rice Territory**) (**Karem Dragh Mohamed, 2014**). It is also cultivated in limited parts of Babil, Dhi Qar, Maysan, and Wasit governoarates in the central and southern regions of Iraq. In the northern Iraq, a variety of rice, which is locally called Aqrawi is planted in the mountainous areas surrounding the Aqrah district in the Dohuk governorate in northern Iraq and northeastern Mosul. The amber rice variety is considered the best and most productive in Iraq due to its intense whiteness, distinctive aroma, and high protein content in addition to the large size of the seed. There are other types of rice that are medium to high quality including (Al-furat, Al-Na’imya, Al-yasmin, Al-khadhrawy, Abbasia and Al-Hwizawy).

Throughout this study, remote sensing data and applications were used due to their great importance in most scientific specialties, for they demanded to obtain adequate information on the study area, especially the large area of it, such as the topics of geomorphology and mineral detection (**Al-Gurairy & Al- Al-Edami, 2023**), forest monitoring, monitoring and management of agricultural crops and many others (**Ahmad et al., 2014**).

Moreover, the importance of using remote sensing applications lies in the fact that it does not need to make direct contact to the target on the ground, except in a few cases that require field verification of the accuracy of the information and its analysis in the environments of remote sensing applications. Therefore, remote sensing data is a valuable resource to monitor and map vegetation as well as other vegetation cover indicators including slope-dependent and distance-dependent vegetation. (**Giovos et al., 2021; Tun et al., 2022**).

Hence, remote sensing has become a major and effective role in modern agriculture by monitoring and forecasting crop yields in any part of the world. It has an effective role in

1 like bread made of rice flour (Al-Siah bread) or sweet made of rice like (halawat Al-Timan)

providing very important information on crops growth at different stages and places and the condition of the plant at the harvest season. This can be done through merging satellite images, and other available means and applications to evaluate and monitor crops accurately. (**Ghosh et al., 2018**). This method also provides efficient ways to monitor, forecast crops productivity. (**Atzberger, 2013**).

Therefore, the importance of monitoring rice crops using remote sensing based on biophysical parameters related to crop strength and health is a very important process nowadays for predicting the level of the annual crops yield. It is also a reliable, low-cost method that can be performed in a very short time. (**Ahmad et al., 2014**). The process of controlling agricultural crops with these available means in developed or developing countries can increase agricultural production and help reduce the negative effects that face humanity as a result of climate change and drought (**Tang, 2019**).

It is worth to mention that rice is one of the most important main meals of Iraqi family. Iraq consumption is estimated by more than 1.5-1.8 million tons annually. Although the population of the country is estimated at 41-42 million people. The annual amount of consumption per person is about 37-38 kg/year (**Qusai Al-Klidar, Falih Hassan & Wael Shamil, 2014**). So, it becomes clear the nutritional importance of this strategic crop for the Iraqi people, which requires the use of the best available techniques to monitor this crop in order to achieve food security in Iraq.

1.1. Locations of Study Area:

Rice is cultivated mainly in Iraq in the governorates of Al-Qadisiyah and Al-Najaf al-Ashraf in particular, where **1162 km2** are used (representing about **464,800** Iraqi acres) of agricultural land suitable for the cultivation of this strategic food crop. This area constitutes about **95%** of the total agricultural land that is used to grow this crop. While the area of land suitable for growing rice in Al-Qadisiyah governorate alone is about (**465.75 km^2**), which represents about **38%**, while Najaf exceeds the governorates of Iraq with a rate of about 57% of the total agricultural area of the crop in Iraq. Figure (1).

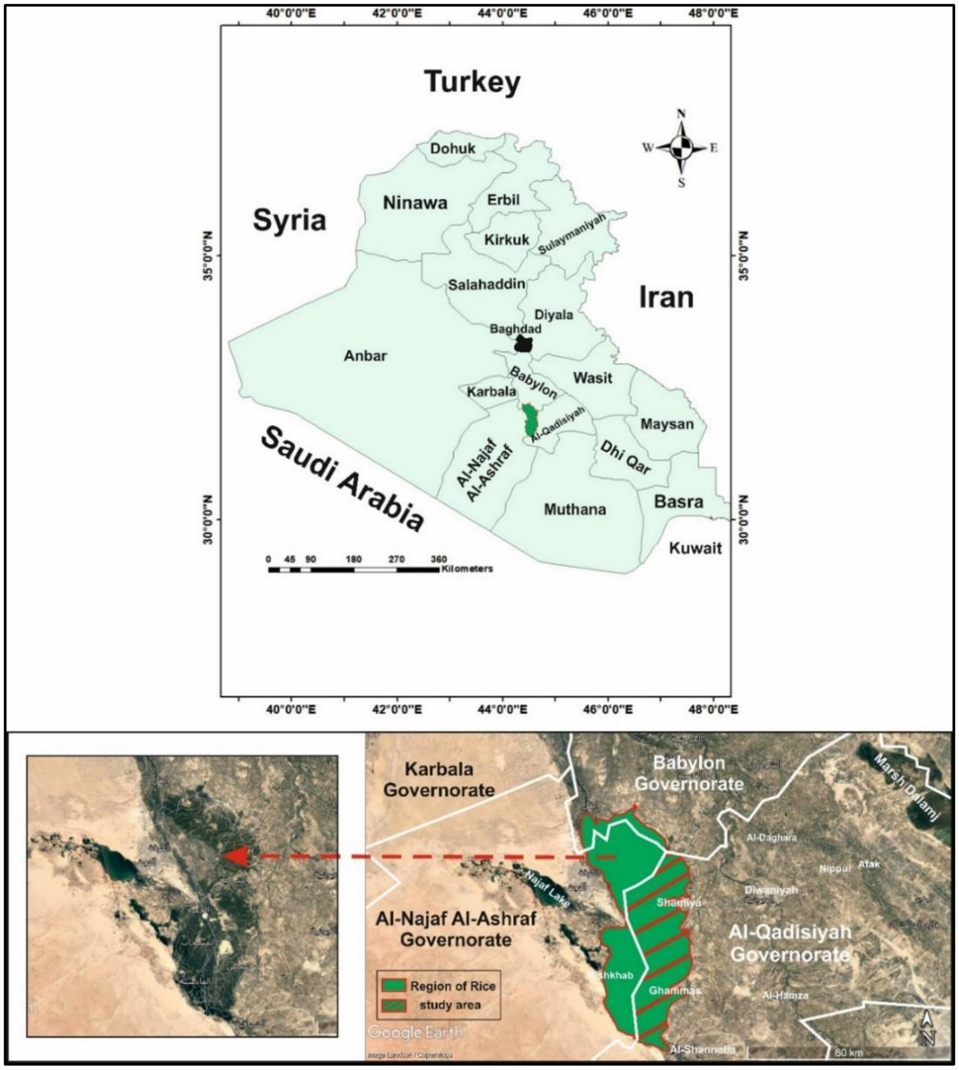

Figure (1) map of Iraq shows the location of the Rice territory and study area (Landsat satellite imagery and data using Arc GIS software)

It is noted that a large part of the rice territory is located within the administrative borders of the Al-Qadisiyah Governorate that reflects its importance in providing a large proportion of this crop locally. The cultivation of these agricultural lands fluctuates from year to year according to the prevailing climate conditions annually especially rainfall and drought and the consequent annual water revenues that reach these agricultural lands via **Euphrates River** and its branches that penetrate from the north towards the south.

2. Human-Natural factors:

There are different components (natural and human) for each agricultural crop that contributes to increasing its cultivation areas and productivity. These factors may be local or regional, which have the greatest impact on the process of increasing the production of this crop, as shown in the following:

1.2. Human Factors:

1.1.2. Cultivated area and consumption:

It is possible that the great importance of this crop results from the large and increasing number of the world's population especially in developing countries. For example, rice is the main meal for the population of Malaysia consumption rate is about 80 kg/year per capita. (**Omar et al., 2019**). In 2050, there will be an additional 2 billion mouths to feed. (**Dodds and Bartram, 2016**). Given its high nutritional importance resulting from the high percentage of protein in it and high percentage of nutritional minerals as calcium, iron, and various vitamins. Due to its importance and nutrients, it entered into many food industries (local and international) and its leftover used as animal feed. (**Salma Abdul Razak & Ahmad Hammoud, 2016**).

Rice has many different varieties but the most prominent one that has the nutritional benefit of high economic value represented by Iraqi rice known as (Iraqi amber rice). The cultivation of this type in Mesopotamia dated back to hundreds years ago. This variety is characterized by the whiteness of its grain, with a soft texture and a distinctive pungent flavor, and it has a high protein content of about 7.75% of a single grain, while the oil content is about 3.2% (**Salma Abdul Razak & Ahmad Hammoud, 2016; Khudair Abbas Hamied, 1997**).

Globally, the importance is evident from the area planted with rice in the world is estimated at 153 million hectares (**1.53 x 106 km²**) for the year 2005, distributed in more than a hundred countries. The major countries are located in tropical and subtropical regions, but few million hectares are also cultivated in temperate regions, Table (1).

Table (1) World rice area and production for the period (1948-2005) (UN – FAO)

world rice	1948	2000	2005	Percentage of increase %
Area (million hectares)	86.70	153.77	153.78	177.35
Production (million tons)	145.40	598.85	618.53	425.39
Productivity (tons/ha)	1.68	3.89	4.02	239.29

Large portions of sugarcane and maize crops are used for purposes other than human consumption, rice has become the most important food crop for human nutrition and the amount of calories it provides more than a fifth of the calories it consumes worldwide. It is also the dominant source of food energy for 17 countries in Asia and the Pacific, about 9 in North and South America and 8 in Africa. Rice provides about 20% of the world's food energy supply, while wheat provides about 19% and maize about 5%. (UN - FAO, 2004)

2.1.2. World Trade:

Less than 8% of the internationally rice produced is traded in the world. The developing countries represent the main players in the global rice trade, as their role in this global trade is represented by the fact that they constitute about 83% of the exporting countries. At the same time, they represent about 85% of the importing countries. It is noted that there are many rice consumers and importers, with a small number of rice exporters, as there are only five countries

(Thailand, Vietnam, China, the United States, and India) about three-quarters of global of rice exports in 2002 (**UN - FAO, 2004**).

In 2020, the global production of non-hulled rice reached (**756.7 million metric tons**), which represents about (**834.1 million short tons**). China and India topped the rice-producing countries with a global total of 52% (**UN - FAO, 2021**). The other major producers were Bangladesh, Indonesia, and Vietnam. The five major producers accounted for 72% of the total world production and the 15 largest producers accounted for 91% of the total world production in 2017, with developing countries producing about 95% of the total world rice production (**UN - FAO, 2021**).

The main importers include (Nigeria, Indonesia, Bangladesh, Saudi Arabia, Iran, **Iraq**, Malaysia, Philippines, Brazil, and some African and Gulf countries) (**Shareholders call for intensified consultation on Nigerian rice sector trade, 2014**). Iraq is shown as one the largest global rice importers. Although China and India are the world's largest rice producers, both countries consume the majority of domestically produced rice leaving only a few to be traded internationally.

3.1.2. The techniques used and wastage of yield:

Many rice-producing countries suffer significant post-harvest losses due to poor methods, poor or inadequate storage techniques, inefficient supply chains, and the inability of farmers to bring products into retail markets dominated by small shopkeepers.

Thus, World Bank and FAO study claim that the average of 8% to 26% of rice is lost in developing countries each year due to post-harvest problems and poor infrastructure. While some other sources expect that post-harvest losses exceed 40% of the total production in those countries (**Zorya et al., 2011**). The global climate change may cause other great losses at the global level in the productivity of this important crop for human life, be its impact is seen labour on Iraq.

4.1.2. Labor:

Labor is one of the main elements associated with the cultivation and production of the rice crop, and it is represented by the presence of the trained person to grow it. Labor represents the main pillar in the agricultural production process, as the land and the machine complete this production circle with the laborer. Thus, the trained labor remains the main element of agricultural operations starting from preparing and plowing the land until harvesting and ending with marketing. Providing and obtaining labor is related to the size of the population and their spatial distribution in the region. (**Abbas Fadhel Al Saadi, 1990**). It is available all over Iraq in general and in the study area in particular, which is one of high population density.

2.2. The natural features of the study area:

The main natural factors area of cultivation and production of this crop represented by many factors as:

1.2.2. topography and surface:

The study area is located within the plain geomorphological unit represented by (the Iraqi alluvial plain), which is characterized by a flat, low-slope surface. The surface heights of the area range between 15-24 m above sea level, and most of them lie within the range of 16-20 m, as shown in Figure (2). The flatness of the surface here ensures the process of controlling the irrigation water and preserving the fertile soil, which is characterized by its quality as an alluvial soil and access to different roads that facilitate the transportation process. (**Salma Abdul Razak & Ahmad Hammoud, 2016**).

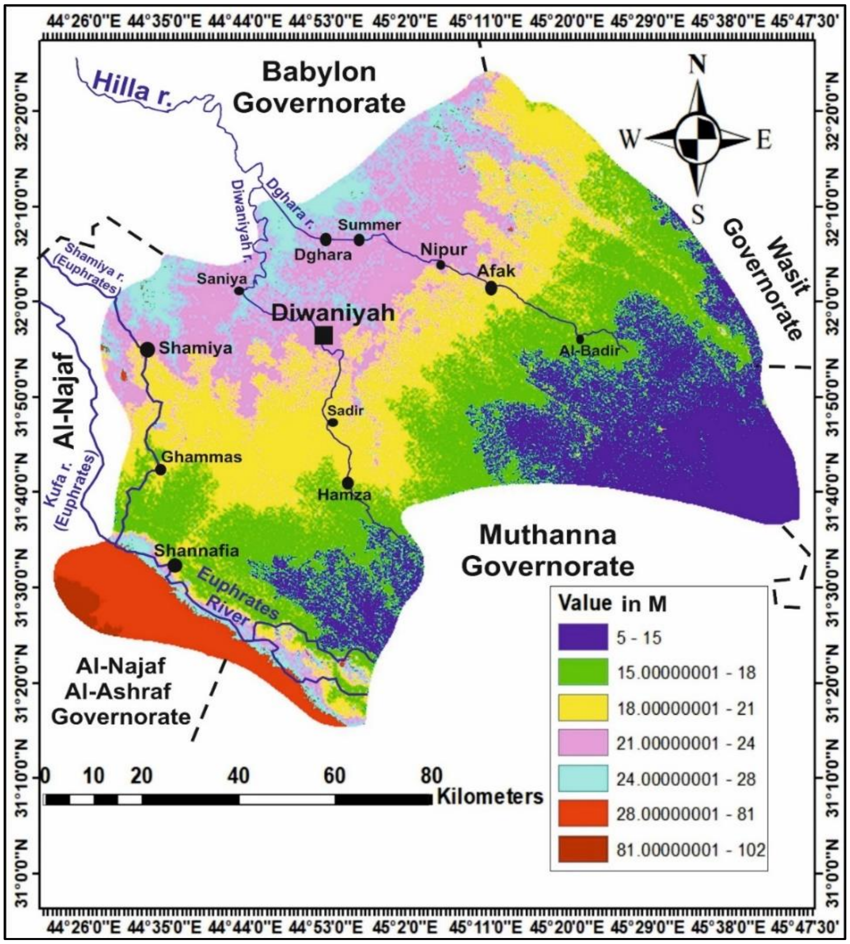

Figure (2) Topographic map of Al-Qadisiyah Governorate (based on DEM data using ArcGIS 10.8)

The region penetrates the main stream of the Euphrates River and its branches, and as a result of the geomorphological work of the courses of these rivers, it has formed natural levees along their streams, which are higher than the level of the surrounding floodplain.

The smooth and flatness of the surface, and the height of the water in the streams of the Euphrates River helped to irrigate the rice farms here directly and without relying on pumps, except for the past years, which required the use of pumps due to the low water levels in the Euphrates River and its branches. (**Al-Gurairy, 2000**). The presence of natural low ground north of the area occupied by (formerly) Ibn Najm marsh transformed into the best area for cultivation of this crop. (**Karem Dragh Mohamed, 2014**).

2.2.2. Climatic characteristics:

The elements of climate are of great importance for the growth of any crop. The study of the climatic characteristics shows that it is located within the dry desert climate region in summer with winter rains. This area is characterized by high temperatures in summer and the sky is clear of clouds, which leads to the arrival of solar radiation for long hours (**11.6 hours/day**) during summer. This is an ideal number of hours for the growth of the crop that needs about 11-12 hours/day of sun. (**Karem Dragh Mohamed, 2014**).

As for the annual average temperature, it is about (**23.8 °C**), and the year is generally divided into two seasons: the hot season (summer) that starts from April until the end of October, with a temperature **(33.8 - 32.9 °C**) during the growing season of the crop. In winter, the temperature decreases during the cold months (winter) from late October to the end of March. the crop requires a maximum temperature of (**40°C**) for the ripening process, and it is available throughout most of the hot summer months. The hot summer is very long and results in a significant rise in temperature rates as well as in evaporation rates, as the amount of evaporation in it reaches (3852.6) mm, and the rate of evaporation in July is 556.3 mm, or 44% of the total Annual evaporation rate. The decrease of humidity and the dominance of hot, dry winds have clear effect on increasing the rates of evaporation in summer. Beside water losses, sufficient quantities of water should be available to continue growing the crops.

It is worth noting that the annual rainfall is very little in the region and it comes outside the crop-growing season (in winter). So, it cannot be counted as a source of irrigation. Consequently, the Euphrates River and its branches represent the main and almost only source of agriculture in the region. (**Karem Dragh, 2014; Salma Abdul Razak & Ahmad Hammoud, 2016**).

In respect to winds in the region, they are two types: the first is local winds resulting from the high temperature during summer that leads to the formation of local thermal, and causes hot winds that increase the evaporation/transpiration process. The second is the regional winds that blow from different directions, but the north and northwest winds are dominant by (86%). The winds are active during May and their frequency reaches about 12 times (**Karem Dragh Mohamed, 2014**) They blow from the mountainous heights and the plateaus of Armenia, and Anatolia towards the lowland in the valley of the Tigris and Euphrates (Mesopotamia).

The annual average wind speed is 3.4 km/s, and it speed varies from month to month, but in general, it increases during the hot season, especially during the growing season of the crop. The increase in wind speed in the hot season associated with drought leads to an increase in evaporation rates and the effects on the need of irrigation water for summer crops. It causes an increase in silt in rivers and irrigation canals. Strong wind and high temperatures during the flowering period lead to a decrease in the percentage of fertilized flowers and a lack of number of grains. (**Salma Abdul Razak & Ahmad Hammoud, 2016**).

3.2.2. Soil properties:

The soil of the study area is part of the alluvial plain. This soil was formed from the sediments carried by the Euphrates River during its frequent floods. This soil is characterized by the presence of several types of:

The soil of rivers natural levees: it is a mixture of sandy or silty clay soil by (60% siltstone, 20-31% clay, and about 15-16.5% sand). It is often higher than the level of the neighboring lands with (2.5-1.5) m), which had an impact on the decrease in the level of its underground water. The increase in the percentage of organic matter made it one of the best types of soil suitable for the cultivation of different types of crops as vegetables, fruits, and palms. In summer, rice is cultivated.

The river basin soil: it is found in areas far from the riverbeds in the areas between the soil of the rivers banks on one hand and the soil of low lands (marshes and swamps) on the other hand. They include most of the lands of the study area. The general characteristic of this type of soil is that it is a silty clay soil with a slow permeability and a medium texture (51.9% siltstone, 30.6% clay, and 6-8% sand), which is 2-3 meters lower than the soil of rivers banks. It is one of the suitable soils for rice cultivation, but the continuation of the rice cultivation process in it for long periods turns it to salty land due to its flat surface, so it needs continuous salinization treatment (**Karem Dragh, 2014; Salma Abdul Razak & Ahmad Hammoud, 2016**).

3.2. Water Resources:

Euphrates River and its branches in the region are the main sources of agriculture. This region needs large water quantities from Euphrates River estimated by 1800-2200 m3/sec in the dry season. (**Muhammad Ali & Redha Sahib, 2012**) It is estimated that one hectare need for water is about (28000 m3). (**Karem Dragh Mohamed, 2014**).

, The cultivated lands recede or no one is able to cultivate them, which is the biggest danger that threatens rice farms in Iraq now with the problems of climate change worldwide. It is not clear how much water is needed for the success of the cultivation the crop. The traditional method of rice cultivation is by flooding the fields during or after placing small rice seedlings in soil preferably impermeable to water to be able to maintain water for a long time. In general, rice growth and production are affected by many conditions most remarkably (environment and climate, soil characteristics, biological conditions, and customs - cultural practices of peoples).

Environmental factors include rainfall, water availability, the required temperature, photoperiod, solar radiation, and in some cases even tropical storms. Rice can also be grown in different environments depending on the availability of water. (**"IRRI rice knowledge bank", 2004**) generally, rice grows in saturated areas with water and can withstand floods, so its cultivation succeeds in low lands with medium depths, low lands flooded with water, flooded lands, prone to floods, and irrigated lands, as well as its ability to grow in both the rainy season and the dry season. (**Bernier et al., 2008; Zu et al., 2017**).

4. Materials and Methods

4.1. Office work:

The desk work included reviewing the previous studies in different regions of Iraq and this region in particular. Also, reviewing various international studies related to this study to examine the areas planted with this crop and follow its growth using remote sensing data. The study importance lies in that there is no scientific article about the current study area.

The stage of satellite remote sensing data came that covered the region by Landsat-7 Landsat-8 satellites, (on a small scale), one image for the year 2007, and the other for the year 2013 for each of them, respectively. The Sentinel-2 satellite imagery provided the primary data for the study. It is done by stacking the spectral beams of the cloudless landscape of Landsat-7 for the ETM+ sensor (7 Landsat) (38-168 captured on 03/08/2007). It is composed of 9 spectral bands, where 4 are within (0.45 to 0.90 **µm**; spatial resolution of 30 **µm**) as seen in Table (2). The same applies to the data of the Landsat 8 satellite images. The beams of the scene captured on 07/06/2013 (cloudless) were stacked and consisted of 11 spectral bands including 6 spectral bands located within (0.433 to 0.885 **µm**; with a spatial resolution ranging between 15 - 30 meters), within the VNIR area as shown in Table (2).

It should be noted that the VNIR spectral bands are particularly sensitive to the mapping of minerals and plants. (**Sekandari et al., 2020**)

Table (2) Technical performance and zones of the Landsat-7 & 8, Sentinel-2 (Lima, Beuchle, Langner, Grecchi, Griess, & Achard, 2019; Sekandari et al., 2020; [Site])

Sensor	Ground Resolution (m)	Spectral Range (μm)	Band Number	Subsystem	Year of Launch
LandSat 7	**30**	**0.45 - 0.52**	Band 1 (**Blue**)		**1999**
	30	**0.52 - 0.60**	Band 2 (**Green)**		
	30	**0.63 - 0.69**	Band 3 (**Red**)		
	30	**0.77 - 0.90**	Band 4 **Near-Infrared**		
	30 **60**	**1.55 - 1.75**	Band 5 **Short-wave Infrared**		
	30	**10.40 - 12.50**	Band 6 (**Thermal)**		
	15	**2.08 - 2.35**	Band 7 **Mid-Infrared**		
		0.52 - 0.90	Band 8 **Panchromatic (PAN)**		
LandSat 8	**15** **30** **30** **30** **30** **30**	**0.500 -0.680** **0.433 – 0.453** **0.450 – 0.515** **0.525 – 0.600**	**PAN (8)** **Coastal aerosol (1)** **Blue (2)** **Green (3)** **Red (4)** **NIR (5)**	**VNIR**	**2013**
	30 **30** **30**	**0.630 – 0.680** **0.845 – 0.885**	**SWIR (6)** **SWIR (7)** **Cirrus (9)**	**SWIR**	
	100 **100**	**1.560-1.660**	**TIRS1 (10)** **TIRS2 (11)**	**TIR**	

		2.100-2.300 1.360-1.390 10.60 – 11.19 11.50 – 12.51			
Sentinel-2	**60 10 10 10 20 20 20 10 60 60 20 20**	**0.433 – 0.453 0.458 – 0.523 0.543 – 0.578 0.650 – 0.680 0.698 – 0.713 0.733 – 0.748 0.773 – 0.793 0.785 – 0.900 0.935 – 0.955 1.360-1.390 1.565-1.655 2.100-2.280**	**Coastal aerosol (1 Blue (2) Green (3) Red (4) Vegetation Red Edge (5) Vegetation Red Edge (6) Vegetation Red Edge (7) NIR (8) Water-vapour (9) SWIR-Cirrus (10) SWIR1 (11) SWIR2 (12)**	**VNIR SWIR**	**2015 - 2017**

Sentinel-2 has 9 spectral bands in the VNIR region from 0.433 to 0.955 **µm**, but its spatial accuracy ranged between 10 to 60 meters. (Table 2) It is useful to identify minerals on the one hand, as well as the possibility of using it in crop follow-up and management on the other hand. So, the multiple scenes sequenced images were stacked within the time period (May, June, July, August, September, and October of 2022) (N0400_R092), which was captured on those dates, and it consisted of 12 bands for each of them.

The analysis of this data depended on GIS programs and applications ArcGIS 10.8, in particular to identify and monitor rice farms in the study area. These stages are preceded by preparing images of Landsat 7 for 2007; Landsat 8 for 2013, and Sentinel-2 images for 2022. The researchers interpreted and analyze the images data within the ArcGIS environment to obtain preliminary results. It was followed by matching processes with the results obtained through the field study and compare it to official scientific and governmental reports that were previously and currently developed for the region.

4.2. Multi-Sensor Data Characteristics:

Multi-sensor satellite images, Landsat-8, Landsat-8, and Sentinel-2, were used to follow the spread of rice farms in the past years, and then accurately monitor the crop for the year 2022 (which is a very dry year). Table 2 has summarized the technical performance and technical characteristics of the Landsat-7, Landsat-8, and Sentinel-2 sensors. Certain spectral bands from Landsat-7, Landsat-8, as well as in Sentinel-2 (mainly) were selected and used to distinguish between cultivated rice areas and the uncultivated. It used to detect farms that were exposed to a major drought because of water decrease of the Euphrates River, and the consequent results during the 2022 agricultural season.

It is worthy to mention that the different ranges of these satellites' sensors can contribute to many different geomorphological, and agricultural applications. They can strongly help determine the percentage of agricultural areas, types of crops, and their classification. The images can provide researchers to build up the spectral feature space, in the applications of mapping crop types and their areas. (**Kang, Xu, X., & Zhang, 2020; Al-Gurairy & Al- Al-Edami, 2023**). The specialized bands were short-wave infrared bands that were used in crop classification for precision agriculture, as well as in the bands of Vegetation Read Edge (B5, B6, B7) in Sentinel-2 (**Nasirzadehdizaji, Sanli & Cakir, 2019; Fernandez-Beltran, Baidar, Kang & Pla, 2021**).

4.3. Preprocessing remote sensing datasets:

First, data layer was created from Landsat 7 and 8 visualizers to determine the cultivated area with rice for the years 2007 and 2013, respectively. Four stacked bands of the images of Landsat_7, and the six stacked bands data from the (VNIR) bands of Landsat_8 were used. There were 6 layers of data created from the stacked Sentinel-2 images for the months of planting the crop in the region, from (VNIR) bands (for bands 2, 3, 4, 5, 6, 7, and 8) with a spatial dimension of 10-20 meters. It has seven bands that can be used to detect and monitor agricultural crops.

4.4. Image processing techniques:

Band ratio image processing procedures were implemented to extract basic information related to the exploration and identification of crop cultivation locations and areas in the region. The previously processed remote sensing datasets matched with various data on rice farms from official government sources to create mineral forecast maps for the study area. Therefore, it can be used to accurately monitor and estimate the needs, and yields of crops before harvest. (**Nasirzadehdizaji, Sanli & Cakir, 2019; Fernandez-Beltran, Baidar, Kang & Pla, 2021**),

4.4.1. Band ratio:

The method of band ratios is widely used for mapping minerals exploration and locating the distribution of plants (**Ott, Kollersberger and Tassara, 2006; Abdul-Qadir & Al-Jaf, 2009; Arsalan and Mohammad, 2010**). It corresponds to some minerals or plants via absorption and reflection, whereby the pixels that contain certain mineral or plant groups are distinguished. (**Ott, Kollersberger, and Tassara, 2006; Mars & Rowan, 2011**).

This can be done by dividing the values of the numerical numbers of a spectral band by the values that correspond to it in another beam. The beam results in a high reflection of a substance is selected and divided by the beam that results in the least wave reflection of the same substance or mineral to distinguish plants and different mineral deposits. (**Arsalan and Mohammad, 2010**). To characterize a particular absorption or emission, the numerator is the sum of the ranges that indicates high reflectivity, and the denominator represents the range of the minimum absorption or emission characteristic. (**Crowley, Brikey, & Rowan, 1989; Onojeghuo et al., 2018**).

The division of packages shown in Table (2) has been prepared to determine the locations and areas of rice farms in the region for different years and compare them with the current situation of the distribution and areas of rice farms for the year 2022. Figure (3).

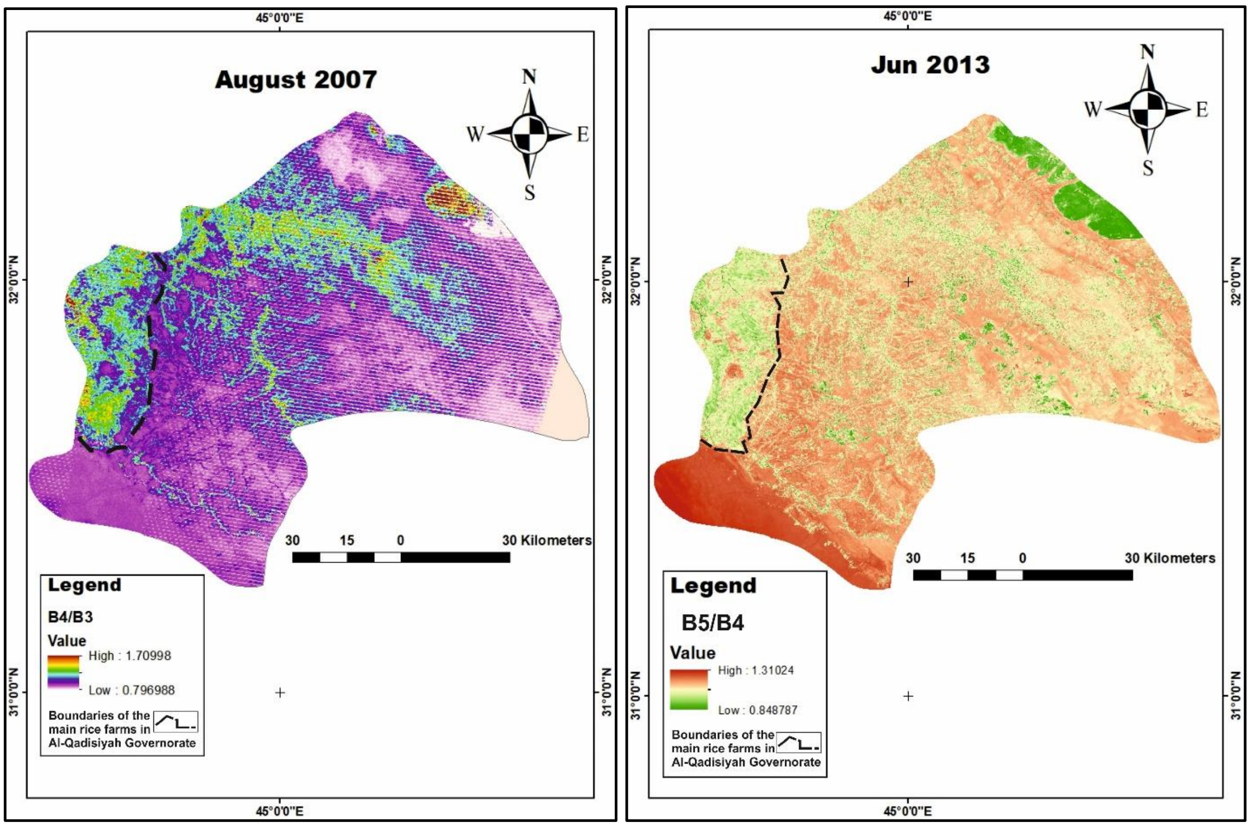

Figure (3) Analysis (using Band-Ratio) of Landsat images data 7 & 8 in ArcGIS, to find the distribution of rice fields in the region

In this paper, and in order to determine the rice cultivation in the region, the ratio of the band **4/3** was chosen from the visible bands of Landsat-7 (**Ott et al., 2006; Abdul-Qadir & Al-Jaf, 2009**). The ration band **4/5** was chosen, from the Landsat-8 bands. Several bands of **Sentinel-2** data were used to determine the places of the spread of this crop and follow up on its water needs by integrating the collection of the bands that give the highest reflective results represent the least reflective bands for the plant in the region. This is done using the following equations:

B5+B6+B7+B8/B4 ……………………………. (1)
B5+B6+B7/B4 ………………………………… (2)
B6+B7+B8/B4 ………………………………… (3)

It was found that the third equation of adding and dividing (in band ratio), gives more accurate and clear results regarding the distribution of the crop, its density, and its need for water and shows the driest soils compared to the wettest ones. The Band-Ratio (**B8/B4**) can be used in the data of Sentinel-2 images to obtain good results in the management of the crop, know its immediate requirements, and for good follow-up and productivity.

4.4.2. Method of use the false colors _ RGB:

To generate a regional view of the rice farms and the rest of the crops in the region, a composite visual of red, green, and blue RGB for bands (3, 4), and 6 for Landsat-8 can be produced. Figure (4). Generally, this method does not achieve many important results, and its information is of great generality so it is not reliable.

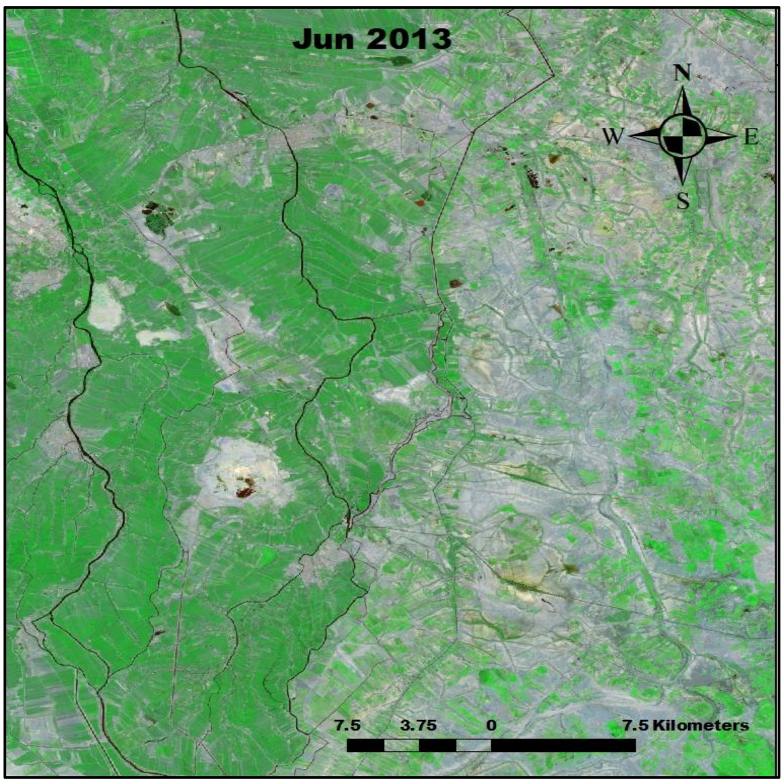

Figure (4) the spread areas of different crop farms using the composite (RGB) of false colors, in bands (6,4,3) of the Landsat-8 image

5. Results

5.1. Mapping rice farms using Landsat-7,8 data:

Band-Ratio process of **B4/B3** beams in the Landsat_7 image of 2007 can give us a somewhat clear picture of the realistic distribution of rice farms in the region and the possibility of defining their areas in general. (Figure _3). Most of the cultivated rice region is shown in the territory. As a result of water irrigation of that season, which resulted in the highest production during the past 20 years amounted to more than 138 thousand tons in 2007, and increased to 170 thousand tons in 2019. (**Iraqi Ministry of Agriculture, 2021**). It also applied to the Landsat _8 image for the year 2013 when dividing the **B5/B4** beams that gave us somewhat acceptable results about the areas and distribution of these farms in the region. It is noted that the emergence of a clear decline in their cultivated areas is due to drought. Figure (3).

The above method of analyzing Landsat image data for agricultural objectives has several drawbacks including comprehensiveness of the presentation. All crops appear in the same color with the lack of other various details. An important role in the follow-up and management of the crop is to observe its different needs especially water needs. Thus, this study did not depend on Landsat images data largely due to these reasons for the period 2007-2013. There were no Sentinel-2 satellite images until 2015, so the study depended on the available ones in Landsat images.

5.2. Mapping the 2022 rice plantations using Sentinel-2 data

Sentinel-2 image data formed the backbone of this study because of its excellent spatial dimension of ranges that can be used to follow-up and manage crops. It helps to estimate farms water needs on a continuous basis, their types, and the expected quantity of productivity before harvest. The spatial accuracy ranges between 10-20 meters that give them crucial importance to provide comprehensive and accurate details.

In this study, the bands (**4, 5, 6, 7, 8**) were used in the process of dividing the bundles (Band-Ratio) to obtain accurate follow-up maps of rice crop in the region because most of these bands are dedicated to study the crops. It is found that the third equation of band ratio (**B6 + B7 + B8 / B4**) would give better and more accurate results to follow-up the crop. Hence, this method is the appropriate basic tool for this area, as shown in Figure (5).

Figure (5) shows the rice farms for the 2022 agricultural season (May, June, July, August, September, and October) are shown in terms of their spread, areas, and water need. The white color represents the waters of Euphrates River and its branches in addition to any water body in the region and newly irrigated farms appeared in this color. The pink color refers to farms whose soil is still wet, retains some water on its surface and is not in need of watering.

The blue color represents all agricultural lands that need irrigation of different degrees. Based on the color gradation from light (moderate need) to dark (great need). The green color represented all the agricultural areas that were not cultivated during the current season. The yellow and dark brown colors indicate two cases: they either refer to agricultural soils that have not been cultivated for long periods, and suffered to severe drought, or they indicate very dry desert soils that can be observed in the lower left parts of the maps in Figure (5).

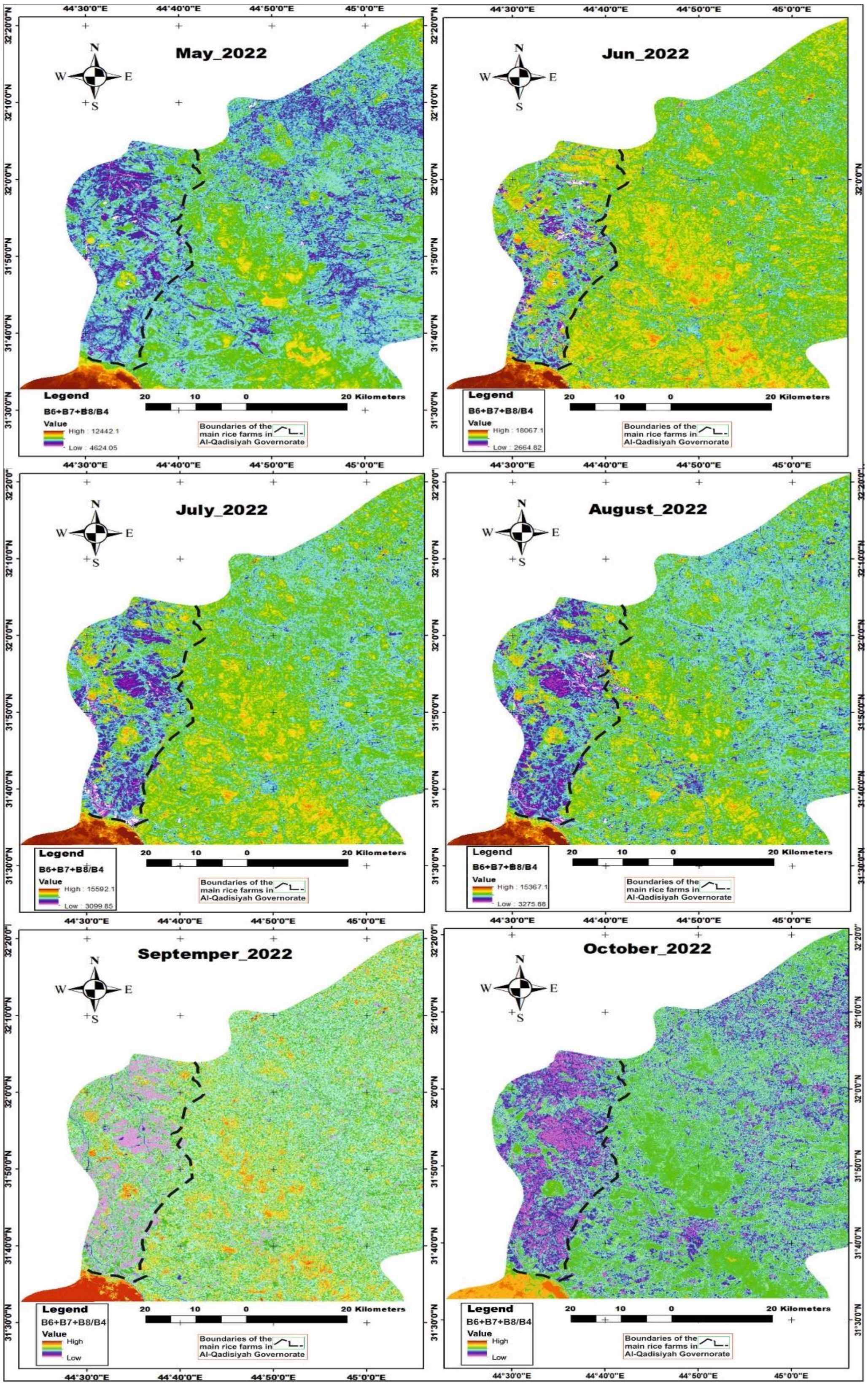
May_2022
Legend
B6+B7+B8/B4
Value
High : 12442.1
Low : 4624.05
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
Jun_2022
Legend
B6+B7+B8/B4
Value
High : 18067.1
Low : 2664.82
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
July_2022
Legend
B6+B7+B8/B4
Value
High : 15592.1
Low : 3099.85
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
August_2022
Legend
B6+B7+B8/B4
Value
High : 15367.1
Low : 3275.88
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
Septemper_2022
Legend
B6+B7+B8/B4
Value
High
Low
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
October_2022
Legend
B6+B7+B8/B4
Value
High
Low
20 10 0 20 Kilometers
Boundaries of the main rice farms in Al-Qadisiyah Governorate
N
S
W
E
44°30'0"E
44°40'0"E
44°50'0"E
45°0'0"E
32°20'0"N
32°10'0"N
32°0'0"N
31°50'0"N
31°40'0"N
31°30'0"N

Figure (5) Analysis using Band-Ratio of Sentinel-2 data image in ArcGIS, to monitor conditions of rice fields in the region, for the year 2022

Based on tracking the conditions of rice crop in the main part of Iraqi rice territory, it is clear that the crop has suffered severely from drought and suffered from poor irrigation. This caused a limitation in the cultivated areas of 2022 season, which led to deterioration of productivity. Official and field reports indicate that the total production of this region may not exceed only 1,000 tons in this year, while the productivity of this region in 2019 amounted to more than 170,000 tons.

The expected production of crop represented less than 1% of the productivity for the year 2019. As a result of the crop failure to reach the harvest season because of drought during months of the growing season, most of the region farms failed to meet expected productivity, as seen in Figure (5). Large part of these agricultural areas turned to be grazing areas for sheep or livestock. The small fields of crop succeeded reaching the harvest stage, the productivity was low by about (50-65%) less than the annual production rate known to farmers in the region. The productivity of one acre is currently about 450 kg, but previously it ranged between 850 - 1200 kg/acre. (**Iraqi Ministry of Agriculture, 2021**).

5.3. Mapping Rice Farms Using Sentinel-2 Data 2017:

The result of dividing the beams (Band-Ratio) **B8/B4** for the 2017 image was used in this study, and it gave very acceptable and high-definition results. They showed that the agricultural lands of dark brown and red color do not need water because they are irrigated farms. Figure (6).

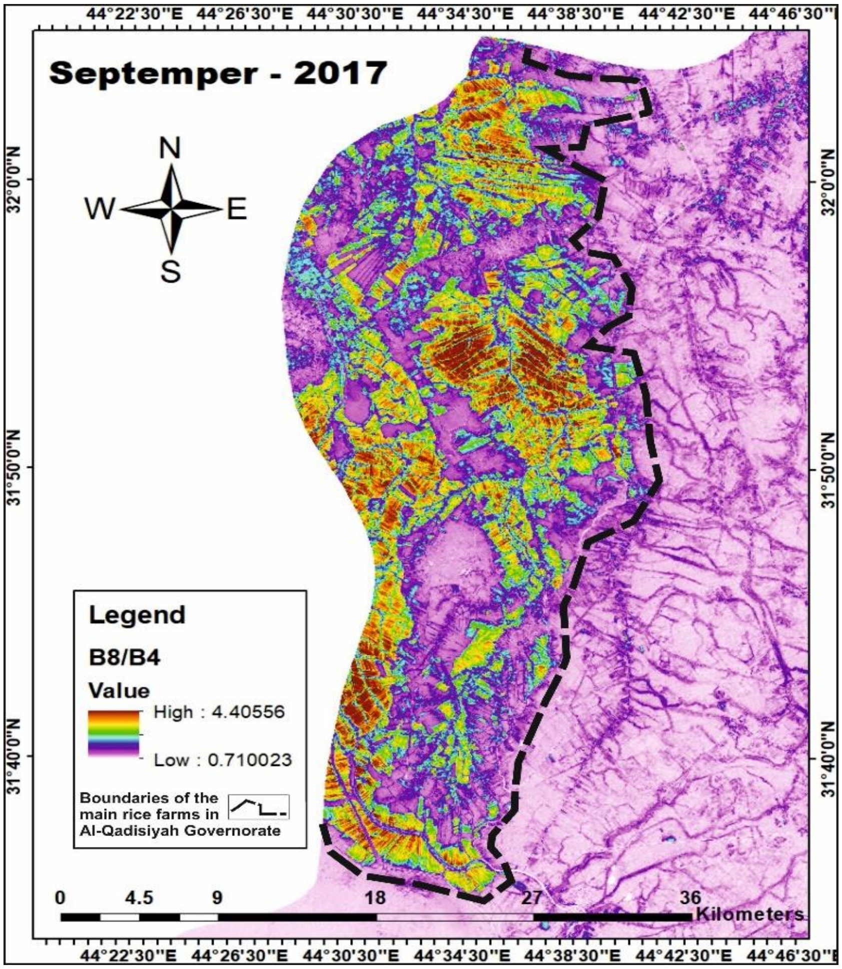

Figure (6) Map of the part of the rice territory in Al-Qadisiyah governorate for the 2017 agricultural season, from the analysis of Sentinel-2 data

The yellow and green colors indicate those farms that need new water. The cyan and blue color indicate agricultural lands whose cultivation can fail since they need great quantities of water. The pink color refers to the agricultural lands that were not originally cultivated due to water scarcity. The area that cultivated in 2017 with the crop amounted to more than 56 km2 (more than 670 hectares), with 93 thousand tons productivity; (1000 kg /acre) per acre. (**Iraqi Ministry of Agriculture, 2021**).

So, remote sensing images are excellent tools to support different agricultural systems, through careful monitoring and estimation of crop needs, and even estimation of yields before harvest. Throughout this study, the using and analyzing Sentinel-1,2 satellite data with available remote sensing applications has proven its great importance in various studies mostly agricultural via its ability to determine crops water needs. Also, they help to identify and recognize the problems that crops face during its growth.Sentinel-2 data are an ideal preference for these studies due to their free availability and long-term continuous data archive. The great importance of the great benefits that these data can provide to people, cultivating crops, monitoring their growth, and estimating their yield effectively, especially in developing countries that lack modern technologies. (**Nasirzadehdizaji, Sanli & Cakir, 2019; Fernandez- Beltran, Baidar, Kang & Pla, 2021**)

It can also be said that the results provided by the Sentinel-2 images data are more accurate than others. (**Sun, Bian, Zhou & Pan, 2019**).

5.4. Climate change and the deterioration of agricultural production

It is known that ancient Iraqis (**Sumerians**) were the first to invent the cuneiform in history. Also, they had great experiences in implementing irrigation projects including the complex canal network systems they created with the engineering works related to them in addition to different crops cultivation. They were pioneers of irrigation at the world level because their land is plain and the two great rivers irrigating those lands (Tigris and Euphrates). Sources had shown that the Sumerians were familiar with hydraulic principles, had their methods of preparing the land, sowing, irrigation, harvesting, which confirmed that they were farmers. They were skilled farmers (**Adamo & Al-Ansari, 2020**), but their descendants faced major problems in this field because of global climate change and the unfair water policies of neighboring countries against Iraq and its people.

Climate change causes many serious problems related to world food security because of its effect and danger on agriculture in particular and in serious negative forms represented by drought, high temperatures, hurricanes...etc. For example, rice was grown experimentally under high levels of carbon dioxide, which are to be similar to those expected for the year 2100 as a result of human activity polluting the environment. The result was a rice containing less iron, zinc and protein, as well as lower levels of thiamine, riboflavin, folic acid, and pantothenic acid. (**Wishart, July–August 2018**). So, the issue of global food security posed many dangerous conditions whose consequences have begun to manifest in different regions of the world including Iraq, which was evident in the agricultural season in Iraqi rice territory of 2022.

The crop is related to water revenues that are in turn related to the wetness or dryness of the agricultural year on the one hand, in addition to its direct connection with the unfair water policies pursued by the upstream countries neighboring Iraq (Turkey and Iran) on the other hand. The amount of its production fluctuated from year to year and reached its lowest during agricultural season 2022. The productivity of the rice territory ranged between 75-90% of the total production of Iraq, based on the climatic footprint[2] of previous years. (**Muhammad Ali, 2011**) Rice productivity may reach less than 5% only for the year 2022, in best conditions. Figure (7).

[2] **Climatic footprint: we mean it here, the state of drought and its severity or humidity and its high degrees associated with the amounts of winter precipitation, as well as the annual rates of temperatures.**

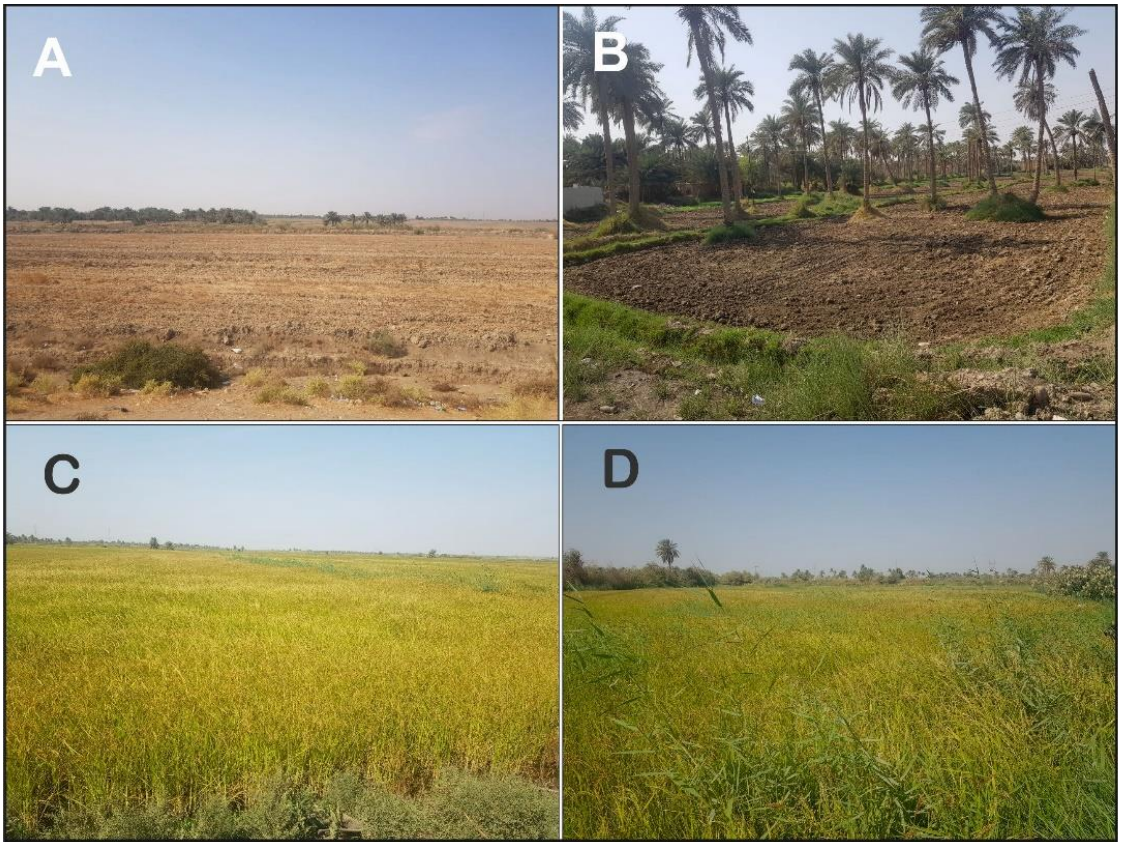

Figure (7) Pictures of the rice fields in the study area in October – 2022

Where: A and B show two rice fields that were plowed after crop failure due to lack of water; C and D, show two rice fields that have been successfully cultivated and are expected to yield less than 50% compared to previous seasons, as a result of water scarcity.

Food industries related to this crop began to suffer greatly as many people in the region lost this source of their seasonal livelihood since rice cultivation requires much labor. Furthermore, some small factories of purifying, and peeling the crop for the local market did not find much production because of lack of rice that leads to labor laying off.

6. Conclusion

Based on the study results, it is possible to conclude important findings related to the general use of Sentinel-2 and the auxiliary data, and related them to the direct impact of climate change and the policies of neighboring countries on the issue of rice cultivation, its products for the study area in particular and Iraq in general. The multi-time Sentinel-2 images analysis process and the accurate results obtained are crucial and effective factors to monitor and improve rice cultivation in the region. So, the process of using the Band-Ratio method for Sentinel-2 images data gives accurate and important results for the development of agriculture in the region by using its information in monitoring this crop and recognizing its immediate requirements.

It is found that the great value was using multi-time Sentinel-2 images data, along with other data available in developing countries to perform automatic rice yield monitoring that contributes to more efficient farming systems and practices in the future. This study can be extended to include other strategic crop types, which may be also important to ensure food security. The study has referred to the great and devastating impact of climate change on crops in general, and on the strategic rice crop in Iraq in particular, which was evident during the agricultural season of 2022.

Climate change pressures everyone; many countries seek to practice unjust policies to look after its own interests, at the expense of the countries. This is clear in the unfair practices of Turkey and Iran towards Iraq, which included, reducing water quotas for Iraq, and changing the streams of the Border Rivers inside those countries. So, depriving Iraq of its water quotas at a very difficult time causes serious agricultural problems in Mesopotamia. The severe drought phenomenon that struck Iraq in particular during 2022 caused the loss of its production of rice. It led to many negative effects including the cessation of most of the economic-industrial activities related to this crop, unemployment, where people lose their source of livelihood, which is based on the cultivation and harvesting of this crop.

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References:

1. Abbas Fadhel Al Saadi, (1990). Food Security in Iraq: Reality and Ambition, Baghdad, University of Baghdad, p. 233. **(Arabic).**
2. Abdul-Qadir, A. M., & Al-Jaf, A. A. (2009). Digital processing of Landsat images to detect iron and kaolin deposits in selected sites in the Western Desert of Iraq. *Iraqi J. Sci. (Baghdad Univ., Baghdad, Iraq)*, *50*(4), 519-532. **(Arabic)** [Google Scholar]
3. Adamo, N., & Al-Ansari, N. (2020). The Sumerians and the Akkadians: the forerunners of the first civilization (2900-2003BC). *Journal of Earth Sciences and Geotechnical Engineering*, *10*(3), 17-39 [Google Scholar].
4. Ahmad, I., Ghafoor, A., Bhatti, M. I., Akhtar, I. U. H., & Ibrahim, M. (2014). Satellite remote sensing and GIS-based crops forecasting & estimation system in Pakistan. Crop monitoring for improved food security [Google Scholar].

5. Al-Gurairy Ahmad S. Yasien & Al-Edami Rahman Rabat (2023). Geographical survey to explore minerals & clays economic-industrial deposits in different geomorphological units in Al-Qadisiyah Governorate using digital processing of Landsat 7,8 and Sentinel-2 – Iraq. Journal College of Arts – Baghdad University, Baghdad-Iraq, 144 (March – **in publishing**) **(Arabic).**
6. Al-Gurairy Ahmad S.Y., 2000. The Geomorphological Characteristics of the Stream of Euphrates River and Tow Branches Al-Atshan and Al-Sebil Between Al-Shannafia and Al-Samawa, College of Arts – University of Baghdad, Baghdad, Iraq, p.162 **(Arabic)** [Google Scholar].
7. Arsalan A. Al-Jaf and Mohammad A. Al-Azawy, (2010). Integration of Remote Sensing Images and GIS Techniques to Locate the Mineral Showings in Halabja Area, NE Iraq. Iraqi Bulletin of Geology and Mining, Volume (6), Issue (1), P. 31- 46 **(Arabic)** [Google Scholar] محمد عبد المحسن العزاوي، & أرسلان احمد الجاف. (٢٠١٠). مكاملة نظم المعلومات الجغرافية مع مرئيات التحسس النائي لتحديد الشواهد المعدنية في منطقة حلبجة، شمال شرق العراق. *Iraqi Bulletin of Geology and Mining*, *6*(1).
8. Atzberger, C. (2013). Advances in remote sensing of agriculture: Context description, existing operational monitoring systems and major information needs. *Remote sensing*, *5*(2), 949-981 [Google Scholar].
9. Bernier, J., Atlin, G. N., Serraj, R., Kumar, A., & Spaner, D. (2008). Breeding upland rice for drought resistance. *Journal of the Science of Food and Agriculture*, *88*(6), 927-939 [Google Scholar].
10. Crowley, J. K., Brickey, D. W., & Rowan, L. C. (1989). Airborne imaging spectrometer data of the Ruby Mountains, Montana: mineral discrimination using relative absorption band-depth images. *Remote Sensing of Environment*, *29* (2), 121-134. [Google Scholar]
11. Dodds, F., & Bartram, J. (Eds.). (2016). *The water, food, energy and climate Nexus: Challenges and an agenda for action*. Routledge [Google Scholar].
12. Fernandez-Beltran, R., Baidar, T., Kang, J., & Pla, F. (2021). Rice-yield prediction with multi-temporal sentinel-2 data and 3D CNN: A case study in Nepal. Remote Sensing, 13(7), 1391**[Google Scholar].**
13. Ghosh, P., Mandal, D., Bhattacharya, A., Nanda, M. K. and Bera, S., 2018, Assessing Crop Monitoring Potential of Sentinel-2 in a Spatio-Temporal Scale. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science*s, Vol. 425, 227-231[R.G].
14. Giovos, R., Tassopoulos, D., Kalivas, D., Lougkos, N., & Priovolou, A. (2021). Remote sensing vegetation indices in viticulture: a critical review. *Agriculture*, *11*(5), 457 [Google Scholar].
15. Karem Dragh Mohamed, (2014). The Territory of Rice agriculture in Al- Najaf and Al-Qadisiyah governorates. Geographical Research Journal, Issue (19), 197-219 **(Arabic)** [Google Scholar].
16. Khudair Abbas Hamied (1997), The Conditioning System for the Rice Crop, Technical and Extension Bulletin issued by the General Authority for Agricultural Extension and Cooperation, Baghdad, p. 402. **(Arabic).**

17. Khush, G. S. (2005). What it will take to feed 5.0 billion rice consumers in 2030. *Plant molecular biology*, *59*(1), 1-6 [Google Scholar].
18. Kuenzer, C., & Knauer, K. (2013). Remote sensing of rice crop areas. *International Journal of Remote Sensing*, *34*(6), 2101-2139 [Google Scholar].
19. Lima, T. A., Beuchle, R., Langner, A., Grecchi, R. C., Griess, V. C., & Achard, F. (2019). Comparing Sentinel-2 MSI and Landsat 8 OLI imagery for monitoring selective logging in the Brazilian Amazon. *Remote Sensing*, *11*(8), 961. [Google Scholar].
20. Mars, J. C., & Rowan, L. C. (2011). ASTER spectral analysis and lithologic mapping of the Khanneshin carbonatite volcano, Afghanistan. *Geosphere*, *7*(1), 276-289. [Google Scholar]
21. Muhammad Ali Kadhem & Redha Sahib Abu Hamad (2012). Rice cultivation in Iraq between reality and prospects. *The Islamic college university journal*, (17) **(Arabic)** [Google Scholar]. أ. م. د. محمد علي كاظم & أ. د. رضا صاحب أبو حمد، (2012). Rice cultivation in Iraq between reality and prospects. *The Islamic college university journal*, (17).
22. Muhammad Ali Kadhem (2011). The extent of the possibility of continuing rice cultivation in the governorates of Najaf and Qadisiyah. Kufa studies center journal, 2011, Volume 1, Issue 21, Pages 287-334. **(Arabic)** **[Google Scholar]**
23. Nasirzadehdizaji, R., Balik Sanli, F., Abdikan, S., Cakir, Z., Sekertekin, A., & Ustuner, M. (2019). Sensitivity analysis of multi-temporal Sentinel-1 SAR parameters to crop height and canopy coverage. *Applied Sciences*, *9*(4), 655 [Google Scholar].
24. Normile, D. (1997). Yangtze seen as earliest rice site. *Science, 275*(5298), 309-309 [Google Scholar].
25. Nutrient data laboratory. United States Department of Agriculture. Retrieved August 10, 2016 [**site**].
26. Omar, S. C., Shaharudin, A., & Tumin, S. A. (2019). The status of the paddy and rice industry in Malaysia. *Khazanah Research Institute. Kuala Lumpur [Google Scholar].*
27. Onojeghuo, A. O., Blackburn, G. A., Wang, Q., Atkinson, P. M., Kindred, D., & Miao, Y. (2018). Mapping paddy rice fields by applying machine learning algorithms to multi-temporal Sentinel-1A and Landsat data. *International journal of remote sensing*, *39*(4), 1042-1067 [Google Scholar].
28. Ott, N., Kollersberger, T. and Tassara, A., 2006. GIS analyses and favorability mapping of optimized satellite data in northern Chile to improve exploration for copper mineral deposits. Geological Society of America Geosphere, Vol.2, No.4, p. 236 – 252. http://geosphere.geoscienceworld.org/cgi/content/abstract/2/4/236. [Google Scholar]
29. Qusai Qassem Al-Klidar, Falih Hassan Alwan & Wael Shamil (2014). Economic forecasts for rice production and consumption in Iraq for the period 2012-2020. Journal of Baghdad College of Economic Sciences University, Issue 42, Pages 1-16. **(Arabic)** **[Google Scholar].**
30. Salma Abdul Razak Abdul, Ahmad Hammoud Muheisen (2016). Geographical Analysis in the Effecency of Rice Agriculture in Khmas. Basic Education College Magazine For Educational and Humanities Sciences, Issue (29), 178-195 **(Arabic)** [iasj].

31. Sun, C., Bian, Y., Zhou, T., & Pan, J. (2019). Using of multi-source and multi-temporal remote sensing data improves crop-type mapping in the subtropical agriculture region. Sensors, 19(10), 2401 [Google Scholar].
32. Tang, K. H. D. (2019). Climate change and paddy yield in Malaysia: A short communication. *Global Journal of Civil and Environmental Engineering*, *1*, 14-19 [Google Scholar].
33. The Republic of Iraq, Ministry of Agriculture, Directorate of Agriculture in Al-Qadisiyah Governorate, Statistics Department - Agricultural data for the period 2000-2021. **(Arabic).**
34. Tun, S. B. M., Latip, A. S. A., Yacob, N. A. I. and Latif, Z. A., (2022). Crop Monitoring of Paddy Field Using Landsat 8 OLI, International Journal of Geoinformatics, Vol.18, No.4, pp: 35-43 **[Site].**
35. UN – *FAO World Food and Agriculture – Statistical Yearbook 2021*. *www.fao.org. 2021. doi:10.4060/cb4477en. ISBN 978-92-5-134332-6. S2CID 240163091. Retrieved December 10, 2021.*
36. UN – FAO (Food and Agricultural Organization of the United Nations), 2004. Archived (PDF) from the original on November 10, 2011. Retrieved November 21, 2011.
37. UN – FAO (Food and Agriculture Organization), Corporate Statistical Database (FAOSTAT), 2020. Archived from the original on May 11, 2017. Retrieved October 11, 2019 [Site].
38. UN – FAO) Food and Agriculture Organization of the United Nations (, 2003. Archived from the original on June 15, 2014. Retrieved March 14, 2014.
39. Vaughan, D. A., Lu, B. R., & Tomooka, N. (2008). The evolving story of rice evolution. *Plant science*, *174*(4), 394-408 [Google Scholar].
40. Wishart S (July–August 2018). "Second-rate grains". *New Zealand Geographic* (152): 25. Archived from the original on August 3, 2018. Retrieved August 3, 2018 [Site].
41. Zhang, H., Kang, J., Xu, X., & Zhang, L. (2020). Accessing the temporal and spectral features in crop type mapping using multi-temporal Sentinel-2 imagery: A case study of Yi'an County, Heilongjiang province, China. *Computers and Electronics in Agriculture*, *176*, 105618 [Google Scholar].
42. Zorya, S., Morgan, N., Diaz Rios, L., Hodges, R., Bennett, B., Stathers, T., ... & Lamb, J. (2011). Missing food: the case of postharvest grain losses in sub-Saharan Africa [Google Scholar].
43. Zu, X., Lu, Y., Wang, Q., Chu, P., Miao, W., Wang, H., & La, H. (2017). A new method for evaluating the drought tolerance of upland rice cultivars. *The Crop Journal*, *5*(6), 488-498 [Google Scholar].
44. https://www.usgs.gov/media/images/landsat-7-band-designations
45. IRRI rice knowledge bank". *Knowledgebank.irri.org*. Archived from the original on May 22, 2004. Retrieved April 20, 2013.
46. Shareholders call for intensified consultation on Nigerian rice sector trade" (2014). *Agritrade*. Archived from the original on February 24, 2014.
47. Syrian Arab Republic, The Arabic Encyclopedia, Damascus, 2022. **(Arabic)** [Site].