Evaluation of the Efficiency of Circular Wheat Crop Farms Using GIS and Remote sensing Techniques

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Abstract. Evaluation of agricultural crop efficiency is one of the most important applications dealt with remote sensing (RS) science and geographic information systems (GIS) because of their economic importance and relevance to countries food security. Therefore, to know the locations of the farms and count the ones specialized in cultivating the wheat crop, the farms of the Ain al-Tamur Cultivation Division, which are famous as being the pivotal farms dependent on groundwater, were chosen as a study area in this research. The research tries to enumerate and estimate the areas cultivated with the wheat crop, which are difficult to access due to the large cultivated area and assess the quality of the crop simultaneously based on the indicators of remote sensing. Eleven satellite images of Landsats and Sentinel-2. They covered the entire agricultural seasons of the period from 01/10/2015 to 01/06/2016. Moreover, the GIS program, a spatial database was prepared, depending on the meteorological data of the Iraqi Ministry of Agriculture, and using the Cropwat program to calculate the germination evaluation of the crop. Infrared (IR) bands & Normalized Difference Vegetation Index (NDVI) maps and crop change detection maps created in addition to color maps representing farm areas and their quality. The research results showed good results in estimating areas and the quality of the crop grown with the technique of pivot sprinklers.

Key words: Wheat, GIS, Remote sensing, Geomatics, land classification.

1.Introduction

The agricultural production in Iraq plays a significant role in environmental, social, and economic aspects and, in particular, the strategic crops and their relation to food security [1]. Today, the factor of controlling agricultural lands has become a necessity in order to know the size of natural resources and the amount of output because natural resources have become dwindling in relation to the increase in population size [2]. Modern technologies such as satellites, computers, and specialized programs have given an advantage in this era of the possibility of measuring the number of land resources and determining the use of the land on a global basis [3]. Agricultural monitoring and mapping are considered one of the most important goals of remote sensing since its emergence after the science of aerial photography was the only technology used for this purpose before 1972. Upon launching the first multispectral Landsat satellite, the latest revolution in agricultural mapping and monitoring was made available. In the seventies, in addition to several programs specialized in analysis and classification. [4]. Remote sensing satellites offer several options for reducing crop-forecasting errors, particularly in data-sparse regions [5]. The Landsat8 satellite system is the latest program. The first Landsat satellite commenced over 50 years ago in 1967[6]. Landsat represents the world longest continuously acquired collection of space-based moderate-resolution land remote sensing data. Four decades of imagery provide a unique resource for those who work in monitoring agriculture and monitoring the health status of crops. The Landsat 8 satellite (launched as the Landsat Data Continuity Mission - LDCM- on February 11, 2013) became available [6]. The Landsat8 and Sentinel2 continue to collect high-quality data and provide its data through the US Geological Survey USGS & agency NASA platform to monitor the lands and changes that occur to them [7]. The spatial resolution for eight bands 30 m and one Pan Band 15 m, and two bands thermal with a spatial resolution 100m. Sentinel-2A was launched on 23 June 2015 on a Vega rocket from Europe Spaceport near Kourou in French Guiana, an overseas France department. The Sentinel-2 mission is based on a
constellation of two satellites, both orbiting Earth at an altitude of 786 km but 180° apart. This configuration optimizes coverage and global revisit times. As a constellation, the same spot over the equator is revisited every five days, even faster at higher latitudes. Imageries satellite sentinel-2 consists of 13 bands distributed into three types according to the spatial resolution, 3 bands in the visible range and one near infrared with band 10m, six bands at near infrared with 20m, and three atmospheric bands with 60m.

2. Background

2.1. Growth Stage Scales Feekes
Growth Stage Scales Feekes are used to describe the stages of crop growth (Figure 1). It is essential to understand the growth and development of the wheat plant to use fertilizers and plant growth regulators and pesticides properly for crop production. Many pesticide marks constrain the application until the crop in certain growth stages (see Table 1) indicated Feekes growth tables. Growth is the increase in the size and number of leaves and stems, therefore depending on farm management in the Ain al-Tamur need to experience and connect with guiding teams in the Division of Agriculture. In order to choose the right time for fertilization and pest control, and irrigation in time and quantity required to meet the needs of the crop.

Figure 1: Growth Stage Scales Feekes for the wheat crop. (Source: [13])

Table 1: Major steps for the management of wheat crop depending on the growth scale Feekes stages. (Source: [14])

| Feekes Growth Stage | Management Considerations |
|---------------------|----------------------------|
| 1.0                 | Check stands for emergence and uniformity. Check for weeds and apply herbicides if necessary. Begin monitoring for various aphid species (continue through season). Check seedlings for Hessian fly feeding damage. |
| 2.0                 | Make early nitrogen applications to enhance tillering in thin stands. Avoid excess nitrogen. |
| 3.0                 | Scour for insect and disease problems. Check stands for heaving caused by freezing/thawing cycles. Decide whether post-emergence weed control is warranted. |
| 4.0                 | Make spring top dress nitrogen applications. Apply herbicides as needed for weed control. |
| 5.0                 | Cut off for nitrogen applications to avoid leaf injury. |
| 6.0                 | Cut off for some growth regulator herbicides. |
| 7.0                 | Scour for insect and disease problems. |
| 8.0                 | Apply fungicides to protect flag leaf from foliar diseases if necessary. |
| 9.0                 | Cut off for any further herbicide applications unless harvest aid treatments are needed. |
| 10.0                | Check for armyworm feeding. Consider control measures if armyworm feeding is clipping leaves. |
| 10.5.1              | Apply fungicides to suppress Fusarium head blight if necessary. |

2.2. Temperature Limits to the Wheat Crop.
Agricultural production is significantly affected by several factors, from the stage of seeding until the harvesting stage, the main effects of soil and weather where they treat the weakness of the health status of the soil through fertilizer and the fertility is increased by diversifying agriculture each year.
As a result, yield forecasting represents an important tool for optimizing crop yield and to evaluate crop-area insurance contracts [11]. The temperature is one of the most specific climatic elements for planting and producing crops, directly impacting the crop and indirect. Among other climate elements, in turn, are the determinants of agricultural production, as the success of planting these crops primarily. The fundamental nature of the thermal situation in the planting area affects the stages of growth on various physiological processes that take place within the crop and its role in locating their concentration and spread [12]. Three degrees thermal are the maximum thermal class upper limit thermal and micro-class or lower limit minimum and their thermal class optimum, which is the most efficient temperature, which grows staple crops. Table 2 illustrates temperature limits to the wheat crop. In paragraph irrigation, explain how it was to control the temperature and make it within the temperature limits.

Table 2: Temperature limits to the wheat crop. (Source: [10] [12])

| Wheat Growth Stages          | Month      | Maximum Temperature °C | Optimum Temperature °C | Minimum Temperature °C |
|------------------------------|------------|-------------------------|------------------------|------------------------|
| Planting – Emergence         | November  | 25-30                   | 18                     | 12                     |
| Emergence- Start Tillering   | December  | 20                      | 12-14                  | 3-5                    |
| Vegetative Tillering Growth  | January - February | 20-22                  | 16-18                  | 10                     |
| Heading                      | March      | 25-30                   | 22                     | 15                     |
| Ripening                     | April - May | 32-40                  | 24-26                  | 17-22                  |

2.3. Crop Diseases and Integrated Management of Weeds in Crop

Plant diseases can severely affect wheat yields. There are three types of diseases: leaf, head, & virus diseases. Several diseases can cause significant yield reduction in wheat, stunting, and delayed maturity: Symptoms include lack of nutrients or stunting growth uneven, yellowing, and the weakness of vitality, low agriculture, low yield, and seed quality. The symptoms include yellow streaks of white. These viruses are transmittal in many ways and lost productivity depends on the type of the virus, a strain of the virus, wheat variety, time of infection, and environmental conditions [9].

2.4. Pivot Irrigation

Irrigation is the synthetic application of water on the ground for agricultural production. Efficient irrigation will influence all of the growth processes from seed preparation, germination, root growth, and nutrient use to grow plants and re-growth, yield, and quality. Centre Pivot system is a self-propelled irrigation system, which applies water to pasture or crop, generally from above the canopy. Centre Pivot systems are anchored at one end and rotate on a fixed central point. Pivot spray systems are suspended at the height of 2 to 4 meters on a central tube. The sprinkler rotates from a central axis in the middle of the farm and rotates faster at the ends from the center, but the water pumping is gradual from large pipes to small nozzles in order to give an equal amount along with the line spraying. Pivotal System Center requires an energy source to move the water from the source added the energy to move the machine on a farm station [13]. Center pivot irrigation usually uses less water than multiple surface irrigation and furrow irrigation technology, which reduces costs and maintains water. It also reduces labor costs compared with some ground irrigation techniques, which are often more labor-intensive.

2.5. Normalized Difference Vegetation Index (NDVI):

Transforming the simplest vegetation index is (NIR–RED) because that difference has a positive and large value much more so than would be obtained for the other land covers. Since the NIR domain is
invisible to the human eye, the higher reflectance in the green band. Chlorophyll does not absorb all wavelengths of sunlight; it absorbs the blue and red wavelengths, while green light is reflected. The reflection of visible radiation is mainly a function of leaf pigments, whereas the internal mesophyll structure of leaves reflects the Near-Infrared (NIR). NIR radiation passes through the first layer of the leaf (the palisade tissue); when it reaches the mesophyll and the internal leaf cavities, it is scattered both upwards (which is referred to as reflected radiation) and downwards (transmitted radiation). The NIR reflectance behavior is also a function of leaf area index (LAI), cell turgor, leaf thickness, leaf internal air, and water content \[^{11}\]. In general, NDVI values from +1 to -1 range from open fields have a value of about 0.2 NDVI and vegetation health of about 0.8. NDVI values give an indication of stress on crops. This could be the reason for the lack of water, lack of fertilizers and pesticides, or an abundance of weeds. At present, it can be a low-cost sensor in the infrared spectrum revealed stress crop about two weeks before the human eye can see this. Based on the information, farmers make decisions about where to do what in terms of irrigation and the use of fertilizers and pesticides \[^{15}\]. In addition, remote sensing imagery can be a better and quicker method compared to the traditional method for managing nitrogen efficiently \[^{11}\]. Abundance and deficiency nitrogen affects chlorophyll and therefore, can measure nitrogen from the index NDVI.

\[
\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}
\]

Where:
- NIR (Near-Infrared band)
- Red (band visible)

2.6. Change of Detection
Extraction of Intake Dual "change / no change" information using two date images is one of the most widely used manner change detectings. The analog logic visualization on a computer screen using two or three dates for the remote sensing data recorded and placed in the RGB memory banks. It can be used as a) original gangster individual and/or b) multiple data transformations of the original data, such as NDVI \[^{16}\].

3. Study Area
The study area has been selected for this research because of the availability of the best way for evaluating the efficiency of pivot farm production using geomatics techniques. The study area is selected due to being famous for the agriculture of strategic wheat crop, which is considered a major source of food security and irrigation by the pivotal fixed (sprinklers irrigation). The study area is located in the west of the holy Karbala' province, as shown by red color in Figure 2. The study area includes the Ain al Tamur Nahia border at Ain al Tamur Agriculture of Division. Locally study area extends between latitude (32°08'32°47") north and longitude (43°09' 44°49") east, an area of (1968.378893) km².
4. Material and Methods

4.1. Material:

1. **Landsat 8 Satellite Data** download from the website USGS every 16 days. They are starting to download from 11 October 2015 to 06 May 2016. Some Landsat 8 images so cloudy there are removed from monitoring. Stop download Landsat 8 images depend on the harvest date calculated in the program Cropwhat.

2. **Sentinel-2 Satellite Data** also download from the website USGS with different periods, and irregular depends on USGS site policy. Starting download from 19 December 2015 to 08 March 2016. Sentinel-2 image download depends on website USGS

3. **Meteorological Data** from the Iraqi ministry of agriculture\ network for agricultural meteorology Iraqi. The data covered daily temporal limits for study regions.

4. **Field Survey Data** (see Figure 3) includes coordinates crop positions, crop growth data, and field sampling data verification.

4.2. **Methods:**

Research methodology followed, as shown in Figure 4.
5. Discussion
Methodology of work began with the program Cropwat 0.8 to determine the calendar germination of wheat crop and know when to harvest according to planting date and know the number of images required. The calculation of crops harvest date after the program provides the date to seed and growth stages and Kc value of each crop (see Figure 5). In addition, some farmers are doing a delay and provide in seed for a few days for various reasons. Such as having a summer crop that was not harvested or after their early agriculture for an early harvest. Hence, the planting wheat on (15/11/2015) was supposed to harvest on (23/04/2016).

5.1. Monitoring Health Status of the Crop
They are using Erdas Imagine 2014 calculation NDVI. NDVI image is derived from Landsat 8
imageries (see Figure 6) in the red region (0.64–0.67 µm) and near-infrared region (0.85–0.88 µm). While NDVI image Sentinel-2, imageries as a (see Figure 7) are derived from the red region (0.665–0.690 µm) and near-infrared region (0.842–0.957 µm).

Figure 6: NDVI scene Landsat 8 on 19-03-2016, rise in the NDVI/chlorophyll index to value 0.537.

Figure 7: NDVI scene Sentinel-2 on 08-03-2016, rise in the NDVI/chlorophyll index to value from 0.807 to 0.826.

5.2. Monitoring the Change in Crop
Using Erdas Imagine 2014 calculation changes the detection by equations illustrated below for original bands and NDVI equation (1). Change detection, between NDVI imageries derived from Landsat 8 scene (Figure 8) Change detection, between Landsat 8 imageries at near-infrared region (0.85–0.88 µm) equation (2) is shown in (Figure 9).

\[ \Delta \text{NDVI}_{i, j} = \text{NDVI}_{i, j} (1) - \text{NDVI}_{i, j} (2) + (c) \]  

(1)
Where:
\[
\Delta \text{NDVI}_{i, j} = \text{change in pixel value at NDVI}
\]
\[
\text{NDVI}_{i, j} (1) = \text{NDVI value on date 1}
\]
\[
\text{NDVI}_{i, j} (2) = \text{NDVI value on date 2}
\]
\[
c = \text{a constant (e.g. 127)}
\]
\[
i = \text{line No.}
\]
\[
j = \text{column No.}
\]
\[
k = \text{a single band (e.g. Landsat 8 band 11)}
\]
\[
\Delta \text{BV}_{i, j, k} = \text{BV}_{i, j, k} (1) - \text{BV}_{i, j, k} (2) + (c)
\]  

Where:
\[
\Delta \text{BV}_{i, j, k} = \text{change in pixel value}
\]
\[
\text{BV}_{i, j, k} (1) = \text{brightness value on date 1}
\]
\[
\text{BV}_{i, j, k} (2) = \text{brightness value on date 2}
\]

**Figure 8:** Change detection, between NDVI imageries Landsat 8 on 31 Jan. & 16 Feb. A gradual increase in the wheat crop at the most farm.
Figure 9: Change detection, between Landsat 8 imageries on 16 Feb. & 03 Mar. for band 5 NIR. Increase and Some increase at stem extension and heading stage.

5.3. Linking the Different Remote Sensing Data:
Ain al-Tamur Agriculture Division farms have been monitored by using Landsat 8 imageries (Figure 10) at true color (4, 3, 2), and the sentinel-2 imageries (Figure 11) at true color (4, 3, 2), and linked with change detection NDVI, change detection NIR band, and NDVI. The color red represents a decrease; the green color represents an increase in growth.

Figure 10: Monitoring stage farm (A), view1 Sentinel-2 image at the band (8, 4, & 3) on 08 Mar., view2 NDVI on 08 Mar., view3 change detection band NIR on 17 Feb. & 08 Mar., & view4 change detection between NDVI on 17 Feb. & 08 Mar.

Figure 11 Monitoring stage farm (A), view1 Landsat 8 image at the band (5, 4, & 3) on 19 Mar., view2 NDVI on 03 Mar., view3 change detection band NIR on 03 Mar. & 19 Mar. & view4 change detection between NDVI on 16 Feb. & 03 Mar.

5.4. Pivotal Farms Evaluation:
Using ArcGIS 10.3 in preparing spatial database (Figure 12) for work inquiring on statistical data, and creating a histogram for farm area (Figure 13) for work, evaluate the efficiency. In addition, maps production of the final classification outputs, after the conversion format of imageries from raster to vector (polygon), finally export feature wheat crops (Figure 14). It has been classified into seven classes depending on three standard areas (0.17, 0.2,0.3) Km square and the highest and lowest.
**Figure 12:** The identify farm by selecting and showing spatial database for the farm.

**Figure 13:** Histogram Evaluation of the Efficiency of Agricultural Production at Ain al-Tamur Agriculture of Division. Of the total 128 pivotal farms, firstly (46 farms) the limited area between (81-119 dunam) produced very high. Secondly, (41 farms) limited area between (69-79 dunam) produced very high. Thirdly, (17 farms) limited area between (48-67 dunam) production is weak.
Figure 14: Evaluation of the Efficiency of Agricultural Production at Ain al-Tamur Agriculture of Division for wheat crop depending on the area.

6. Conclusion

1. The results of the evaluation showed that most of the Ain al-Tamur pivotal farms are highly efficient.
2. The results of change detection for the NDVI and NIR are more effective techniques for distinguishing the crop status of health and need for fertilizer, irrigation, and control of diseases of agricultural crops to reach the high efficiency of production during the season (from seeding stage to harvesting stage).
3. Linking remote sensing data (raw image, NDVI, change detection NIR, and change detection NDVI) with meteorological data theoretically. Results showed an entirely variation in productivity according to farm management and weather situation.
4. The crop density in Ain al-Tamur is higher, because of the superiority of the agricultural condition (non-sparse vegetative cover, good irrigation, and high contrast between soil and
crop in true color bands).
5. Heterogeneity of soil at some farms and the need for fertilizer because of poor soil.
6. The meteorological data (that belong to the same study region) have been utilized to give a more precise interpretation for the satellite images.
7. The spatial resolution for Landsat 8 (30m) is not very active to distinguish crop states in the cultivated area, so a higher spatial resolution (Sentinel-2) with its 10-meter resolution was sufficient for this task.
8. The change detection results for the NDVI and NIR are more effective techniques for distinguishing the crop status during the season (from seeding stage to harvesting stage).
9. The early stages of crop stress have been investigated using IR bands of the satellite images. This could give a change to the treatment of the crop and increase its productivity.
10. The detailed information related to the crop regions and yields is essential for enhancing the spatial database for the crop monitoring process.

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