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Wheat Crop Management and growth stage monitoring in some gypsiferous soil units using remote sensing

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ABSTRACT

The study used remote sensing to manage and monitor wheat crop health in some gypsiferous soil units. Five sites cultivated with wheat and irrigated by a central pivot irrigation system were selected within gypsiferous soil units in some agricultural lands. Soil and plant samples were collected at the best spectral and vegetative growth stage (grain filling stage) from each site. Three samples of the plant and soil were collected with three replicates, resulting in a total of (5 × 3 × 3 = 45 samples for both soil and plant). Samples were prepared for conducting laboratory analyses Satellite imagery of the OLI type from the Landsat 8 satellite, acquired on 24/2/2020, was used to calculate the following spectral indices: NDVI, SAVI, OSAVI, GOSAVI, GDVI, NDMI, CMFI, LAI. The results showed a variation in the concentration of fertile elements in the soil and plants between the study sites, with the third site relatively outperforming the other sites. On the other hand, we observed a variation in the values of spectral indices between the study sites for all the spectral indices and an increase in values with the progress and increase in the size of the canopy cover to reach the best spectral growth stage at the stage of ear fullness, which is the stage of spectral stability and appropriate for monitoring crop productivity and assessing plant health. The results also concluded that NDVI and LAI are among the most important pieces of evidence that have a strong relationship with plant density and estimation of its general condition, as the relationship was strong logarithmic and linear with nitrogen, as the values of R2 reached 0.91 and 0.88, respectively, and the value of the coefficient of determination R2 reached with The phosphorus concentration was 0.67 and 0.67, respectively. Also, the use of spectral indices depends on the spectral bands that fall at the wavelength of 0.6-0.7 micrometers, which is the region where a high absorption process occurs if the vegetation cover is intact and healthy, especially the NDVI index.

إدارة محصول الحنطة ومراقبة مراحل النمو في بعض وحدات الترب الجبسية باستخدام التحسس النائي

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الخلاصة

حدات الترب الجبسية باستخدام التحسس النائي. تم اختيار خمس مواقع مستغلة بزراعة محصول الحنطة صنف إباء 99, وهي ترب جامعة تكريت ، حقلين غرب تكريت في قرية الأيوبي وحقلين شمال شرق تكريت (الجلام) وجميعها تروى بنظام نظام الري بالرش المحوري ضمن وحدات ترب جبسية في بعض الأراضي الزراعية وتم جلب عينات من التربة والنبات عند افضل مرحلة نمو طيفي وخضري (مرحلة ملىء السنابل) من كل موقع بواقع 3 عينات للنبات وتربة وبثلاث مكررات ليصبح العدد الكلي (5×3×3= 45 عينة لكل من التربة والنبات) وثبتت احداثياتها باستخدام جهاز GPS. تم تهيئة العينات لاجراء التحاليل والقياسات المختبرية اذ تم تقدير النتروجين والفسفور والبوتاسيوم الكلي في عينات النبات والتربة. تم استخدام مرئيات فضائية من نوع OLI للقمر Landsat 8 مكتسبة بتاريخ 24شباط، 2020 وتم حساب الأدلة الطيفية التالية NDVI, SAVI, OSAVI, GOSAVI,GDVI ,NDMI, CMFI, LAI, . تم اعتماد دليل الاختلاف الخضري الطبيعي Normalized Difference Vegetation Index NDVI ودليل حرارة سطح الأرض Land Surface Temprature- LST لتقييم واعداد خرائط مراحل النمو الطيفي لمحصول الحنطة. أجريت علاقة الارتباط والانحدار الخطي والمتعدد بين الأدلة الطيفية ومحتوى العناصر في عينات النبات، فضلا عن كشف التغيرات في حالة نمو النبات. تم انتاج خرائط التوزيع المكاني باستخدام تقنية Kriging. توصلت النتائج الى تغاير في تركيز العناصر الخصوبية في التربة والنبات بين مواقع الدراسة وتفوق الموقع الثالث نسبيا على المواقع الأخرى. في حين نلاحظ تباين في قيم الأدلة الطيفية بين مواقع الدراسة عند جميع الأدلة الطيفية المستخدمة وارتفاع القيم مع تقدم وزيادة حجم الظلة التاجية لتصل الى أفضل مرحلة نمو طيفي عند مرحلة امتلاء السنابل وهي مرحلة الاستقرار الطيفي والمناسبة لرصد إنتاجية الحاصل وتقييم صحة النبات. كذلك توصلت النتائج الى ان دليل الغطاء النباتي NDVI ودليل المساحة الورقية LAI من اهم الأدلة التي لها علاقة قوية مع الكثافة النباتية وتقدير حالته العامه، اذ كانت العلاقة لوغارتمية وخطية قوية مع النتروجين اذ بلغت قيم R2 0.91و 0.88 على التوالي وبلغت قيمة معامل التحديد R^2 مع تركيز الفسفور 0.67 و 0.67 على التالي وصنفت هذه الترب مستوى تحت الرتبة للترب الجافة الى Gypsids .

الكلمات الافتتاحية: الترب الجبسية ، تقنية كريكنج ، دليل الإختلاف الخضري الطبيعي، دليل حرارة سطح الأرض، دليل المساحة الورقية

INTROUCTION

Gypsum soils in Iraq are distributed over large areas, with an estimated area of B. What distinguishes these soils is the low fertility state and the imbalance of their nutritional elements due to the gypsum content, especially the main elements, which are nitrogen, phosphorus, and potassium, which are very important elements in the growth of field crops and increasing their productivity.)) As well as The use of these soils for crop production is limited due to the high gypsum level, which affects the soil's structure and capacity to hold water, affecting productivity(Al-Asafi & Al-Hadeethi, 2024; Al-Jumaily *et al.*, 2022; Al-Qaisi & Al-Tikrity, 2024; Barazanji, 1973; Khalefah *et al.*, 2022)Therefore, to overcome these fertility problems and face the challenges of food shortages, successful management must be used to ensure the sustainability of these soils (Al-Badri , 2023 ; Al-Qaisi & Al-Tikrity, 2024). Technological advancements in the field of natural resource management, especially agricultural resource management, play a significant role in developing sustainable strategies and successful planning for conserving these resources and achieving food and environmental security This is achieved through the significant progress in the application of remote sensing and geospatial technologies, which aid in the management and analysis of natural resources as a spatial geographic tool, providing valuable and timely spatial and spectral information, These technologies can determine agricultural exploitation patterns, predict the spectral behavior of soil and plants, provide spatial data on the type of agricultural crop, estimate the cultivated area, and consequently assess crop productivity andToday's remote sensing technologies can reduce the risk of degradation of natural ecosystems through predictive spatial modeling and the use of multiple spectral indices and thus have the potential to conserve these numerous resources.(Kumar *et al.,* 2022; Rane *et al.,* 2023 and Jebril *et al.,* 2023).

Wheat is one of the most important strategic crops around the world as it is the primary crop for food consumption, which affects the economy and politics of most countries in the world, as approximately 35% of the world's population depends on the wheat crop. Many countries in the world contribute to its production, including our country, Iraq. The annual production in Iraq is estimated at 1.3 million tons, which constitutes one-third of the actual need of the population, estimated at about 3.3 million tons annually. Gypsiferous soils constitute large areas of land in Iraq and are estimated at about 12.5 million hectares, or (28.5)% of the total area of Iraqi soils (Barzanji *et al.*, 2002; Jafarzadeh & Zinck, 2000, and Kudury *et al.*, 2023).

This soil has unique physical and chemical properties compared to other soils around the world. Its low ability to supply nutrients and its low organic matter and moisture content are among these properties. Consequently, these factors affect agricultural production in the region and require appropriate plans for management and monitoring crop growth throughout the growing season, which is now available through recent satellite. Remote sensing has been successfully used as an effective means to obtain field information by analyzing the reflection or radiation of digital numbers for specific ranges (Benedetti & Rossini, 1993). According to different types of platforms, remote sensing can generally be classified into satellite, aerial, and close-range remote sensing. Multispectral satellite images have long been used to detect plant areas, monitor crop growth, estimate crop productivity, and more, on a wide scale(Basnyat *et al.*, 2004; Mulla, 2013). The spectral growth profile for monitoring crop productivity using remote sensing images, through the interaction between crop canopy and chlorophyll content with the Normalized Difference Vegetation Index (NDVI) for a long growing season. Wheat growth characteristics using AVHRR images in the 1987-1988 season in the Punjab and Haryana states in India using the Normalized Difference Vegetation Index (NDVI) through proposed functional modelling to describe the spectral behavior, have been evaluated for crop yield estimation using remote sensing and geographic information systems over the past decades, proving to be a useful tool for estimating crop yield through spectral indices such as NDVI, Soil-Adjusted Vegetation Index (SAVI), and Leaf Area Index (LAI) throughout the growing season(Badhwar & MacDonald, 1986). Monitoring the growth status of wheat crops is vital for obtaining reliable data on crop productivity estimates. Remote sensing techniques have been applied in agricultural fields, especially in the field crops, to monitor the vital physical characteristics of crops and predict their productivity using multiple spectral indices. These indicators describe the relationships between Land Surface Temperature (LST) and the vegetation cover index for winter wheat in order to identify sensitive indicators for changes in the health status of wheat, as well as multiple vegetation indices such as the (NDVI) and the Green Normalized Difference Vegetation Index (GNDVI). The thermal spectral index can be applied in agricultural fields, especially field crops, as well as the natural variation index, which is a good spectral indicator to evaluate the growth status of wheat plants.(Mashaba *et al.,* 2016).

Remote sensing techniques are a good tool in monitoring plant growth based on different wavelengths (Cohen *et al.,* 2005; Mulla, 2013, Ghanem and Ibrahim , 2023; and Al-Obaidy, et al.,2023). Many studies have been carried out to evaluate the spectral growth stages of agricultural crops using satellite imagery by combining vegetation spectral evidence, such as the NDVI, LAI, and other spectral evidence, with crop canopy and chlorophyll content, particularly nitrogen (Guo *et al.,* 2012; Jiang & Tian, 2010; Khalaf *et al.,* 2022; Skakun *et al.,* 2019; Sripada *et al.,* 2008). Today, after the great technical progress in using these technologies to evaluate and diagnose the status of nutrients, especially nitrogen, which is a very important nutritional element in photosynthesis processes, and thus the possibility of preparing maps of the distribution of nitrogen content for large field areas, which achieves correct management.. There is also the possibility of performing a spatial spectral analysis of the spectral characteristics of the soil under multiple agricultural uses, thus preparing digital maps of the soil and plants(Hamad *et al.,* 2021) Additionally, monitoring the crop N content in the mature growth stages can indicate crop quality and health, thereby achieving appropriate management and continuous monitoring of optimal growth(Wang *et al.*, 2021). Johnson (2014) used the NDVI to estimate wheat crop productivity in Faisalabad, Pakistan, at different growth stages. They found a coefficient of determination (R2) between NDVI and grain productivity at the Booting, Grain filling, and Maturity stages to be 0.90, 0.90, and 0.95, respectively. Another study by Mashaba *et al.,* (2016) revealed a relationship between LST and vegetation indices for wheat crops in Bloemfontein, South Africa. NDVI provided better results than the GNDVI for estimating wheat crop productivity. LST is used to monitor environmental conditions affecting agricultural production by predicting surface temperature for maize and soybean crops in the United States, with a noted negative correlation between LST and NDVI(Johnson, 2014). In ideal conditions, plant leaves reflect higher levels of near-infrared radiation and lower levels of red radiation. However, when plants age, and suffer from diseases, water and nutrient deficiencies, or salt accumulation, the reflection of near-infrared radiation decreases and approaches that of red radiation(Puri *et al.*, 2017). Given the extensive gypsiferous soil areas in Iraq and the importance of wheat crops in meeting societal needs, it has become essential to utilize and assess the condition and health of agricultural crops in these soils. Therefore, this study aimed to manage wheat crops and monitor their growth stages in gypsiferous soil units using remote sensing (Al-Khater and Neamah, 2023) .

MATERIAL AND METHODS

Study Area:

Office Work: Based on reference data represented by satellite data and some maps of gypsiferous soil classification projects, multiple agricultural fields within various soil units in some agricultural lands in Tikrit City and Al-Alam district in Salah al-Din Governorate/Iraq were selected to monitor wheat crop growth in a gypsiferous soil environment using remote sensing. The area is located between 43 32 52.311 and 34 37 19.741 east and latitude (43˚ 56' 30.577 and 34˚ 43' 27.062) north (Figure 1).

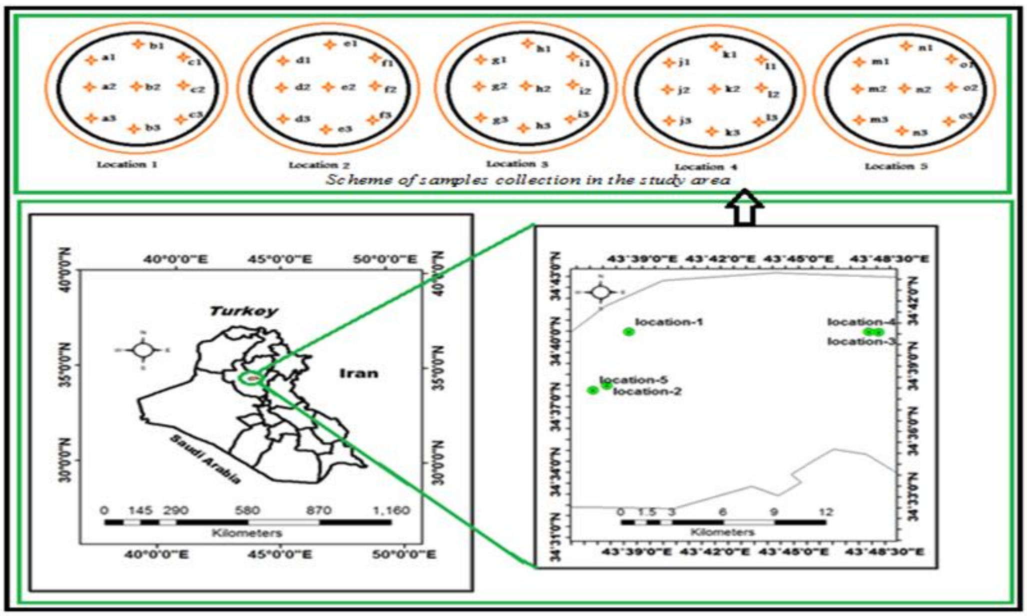


Figure 1. Map of the study area.

Field Work and Field Investigations:

Several field investigations were conducted to identify the nature of variations within the study sites in Tikrit district and Al-Alam. Within some identified and classified gypsiferous soil units, (Abdulstar & Abdulah, 2001), such as Loamy fine, Gypsic, Typic Haplogypsids in Al-Alam district and, such as Fine loamy, Gypsic, Typic Calcigypsids in the city of Tikrit. According to(Heeshan *et al.*, 2022; Kamal & Rashid, 2020). The presence of gypsum and calcareous horizons was identified, with various forms of gypsum including powder, fibrous, and acicular crystalline forms, as well as the presence of carbonates in various forms. A number of agricultural fields cultivated with wheat were selected based on the management methods used by farmers in terms of the type and quantity of fertilizers applied, methods of application, and tillage systems. The farmers rely entirely on groundwater for irrigating the crops using the fixed and movable central pivot irrigation system, covering an area of 20 hectares (radius of 250 m).

The irrigation frequency depends on the crops' water requirements and the amount of rainfall, based on the farmers' experience. The area is characterized by moderately undulating topography but suffers from high gypsum content in the soil, low fertility, and nutrient availability (Table 1), prompting farmers to use chemical fertilizers to increase agricultural production. The study area is in an Arid and semi-arid climate with rainfall ranging from 100-200 mm, and high summer temperatures reaching up to 50°C. Five agricultural projects cultivated with Triticum aestivum L. were selected, with 3 sampling points in each project and three replicates, resulting in a total of 45 plant samples collected on 28, February 2020. The coordinates of each point were recorded using a GPS device

Table 1: Physical and chemical properties of the soil unit in the study area.

Location	**PSD $g.kg^{-1}$**			**Soil Texture Class**	**pH**	**EC $dS.m^{-1}$**	**O.M**	**$CaCO_4$**	**Gypsum**
Soil unit	**Sand**	**Silt**	**Clay**				**$g.kg^{-1}$**		
L1	465	450	85	Loam	7.5	4.09	0.91	213	61.6
L2	630	325	45	Sandy Loam	7.4	3.67	0.40	217	50.8
L3	177	728	95	Sily Loam	7.1	3.27	1.46	185	24.9
L4	330	560	110	Silt Loam	7.3	3.75	0.98	189	11.5
L5	530	420	50	Sandy Loam	7.6	3.40	0.58	208	127.4

Laboratory Work:

After transferring the samples to the laboratory and preparing them through drying, grinding, and digestion following the basic steps in the Soil Science and Water Resources Department laboratory. The nutrient content of the leaves was estimated, which is the total concentration of nitrogen, phosphorus, and potassium (%). The plants were ground, and 0.2 grams of them were taken and digested using sulphuric and perchloric acids, and the digestion product was transferred to a 100 cm3 volumetric flask and made up to the mark with distilled water according to Nitrogen was estimated using a micro-Kjeldahl apparatus according to the Bremner method as reported in(Page *et al.,* 1982)Phosphorus was estimated using ammonium molybdate and ascorbic acid and a Spectrophotometer apparatus according to the Olsen and Watnab method(Page *et al.,* 1982)Total potassium was estimated using a Flame photometer apparatus as reported in(Haynes, 1980)The organic matter was estimated using a 0.5N potassium dichromate solution and titration with ammonium iron sulphate using the diphenylamine indicator as described in(Tandon, 1998)Total nitrogen was estimated using Semi-Micro-Kieldahl according to the Bremner method reported by(Page *et al.,* 1982)The available nitrogen was estimated according to the Kjeldahl method outlined by(Bremner, 1965)as cited in (Black, 1965)using a micro-Kjeldahl apparatus. The available Phosphorus was extracted from the soil using the Olsen method according to (Olsen, 1954)The available potassium was extracted with N1 of calcium chloride CaCl2 and estimated using a Flame photometer apparatus as reported by(Page *et al.,* 1982).

Satellite Landsat images: Processing of Landsat 8 images involved using multitemporal OLI satellite images (7th January 2020, 24th February 2020, and 13th April 2020) obtained from the USGS website over a period of crop growth. Surface reflectivity, defined as the ratio of reflected radiation to incident radiation(Salifu *et al.,* 2011).

$$p_\lambda = \frac{M_p * Q_{Cal} + A_p}{\sin(\theta_{SE})} \quad \text{..........................(1)}$$

Where:

p_λ = The Top-of-Atmosphere (TOA) reflectance.

M_p = The specific multiplicative rescaling factor for the band.

Q_{Cal} = The quantized and calibrated standard product pixel digital number (DN) value.

A_p = The specific additive rescaling factor for the band.

θ_{SE} = The local Sun elevation angle

Land Surface Temperature (LST): Bands 10 and 11 of Landsat 8 were utilised to calculate surface temperature using an equation. Brightness Temperature (TB) of Band 10 and 11 represents the electromagnetic radiation emitted from the Earth's atmosphere. The conversion involves translating the thermal *DN* values of raw thermal bands of *TIR* into *TOA* Spectral Radiance and subsequently using Brightness Temperature.

$$\mathbf{TB} = \frac{K_2}{Ln[\left(\frac{K_1}{L\lambda}\right)+1]} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Were:
$L\lambda$: Top of Atmospheric Radiance
K1 and K2 : Thermal constant of band 10 and band 11 from the metadata image file.

The Fractional Vegetation Cover (FVC): for an image is calculated using the NDVI values for soil and vegetation obtained earlier from Table 2, using equation (3). This estimation provides the fraction of the area covered by vegetation.

$$\mathbf{FVC} = \frac{\mathbf{NDVI - NDVI\ (SOIL)}}{\mathbf{NDVI\ (VEGETATION) - NDVI\ (SOIL)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(3)}$$

NDVI soil = 0.2 and NDVI vegetation= 0.5741 ………....(4)

Land Surface Emissivity (LSE): is derived from the FVC layer in step 4 using the algorithm described in equation (5). It represents the inherent characteristic of the earth's surface, indicating its capacity to convert thermal or heat energy into radiant energy. Estimating LSE involves the emissivity values of soil and vegetation for both Band 10 and 11, The LSE for Band 10 and 11 is calculated separately.

$$\mathbf{Mean\ of\ LSE} = \bar{\varepsilon} = \frac{LSE_{10} + LSE_{11}}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(5)}$$

$$\mathbf{Difference\ of\ LSE} = \Delta\varepsilon = LSE_{10} - LSE_{11} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(6)}$$

The land surface temperature index was then calculated using the following formula:

$$\mathbf{Ts} = TB10 + C1(TB10 - TB11) + C_2\,(TB10 - TB11)^2 + C_0 + (C_3 + C_4W)\,(1 - \bar{\varepsilon}) + (C_5 + C_6W)\Delta\varepsilon \ldots\ldots \mathbf{(7)}$$

Where:

Ts: Land Surface Temperature (K);

C0 to C6: Split-Window Coefficient values (C0=-0.268; C1=1.378;C2=0.183;C4=-2.238;C5= -129.2;C6=16.4).

$\bar{\varepsilon}$ = mean LSE of TIR bands

W= Atmospheric water vapor content (0.013)

$\Delta\ \varepsilon$= Difference in LSE

Spectral indices: The spectral indices were selected for monitoring and evaluating of wheat crop growth and it protictivity (table 2).

Table 2: Spectral Indices used in the study region.

No.	Indices	Formula	Reference
1	**Normalised Difference Vegetation Index**	$\mathrm{NDVI} = \frac{(\mathrm{B5} - \mathrm{B4})}{(\mathrm{B5} + \mathrm{B4})}$	(Rouse *et al.*, 1974)
3	**Soil Adjusted Vegetation Index**	$\mathrm{SAVI} = \frac{1.1 \times (\mathrm{B5} - \mathrm{B4})}{(\mathrm{B5} + \mathrm{B4} + 0.1)}$	(Huete, 1988)
4	**Optimised Asoil Adjusted Vegetation Index**	$\mathrm{OSAVI} = \frac{(\mathrm{B5} - \mathrm{B4})}{(\mathrm{B5} + \mathrm{B4} + 0.1)}$	(Rondeaux *et al.*, 1996)
5	**Green Optimised Soil Adjusted Vegetation Index**	$\mathrm{GOSAVI} = \frac{(\mathrm{B5} - \mathrm{B3})}{(\mathrm{B5} + \mathrm{B3} + 0.1)}$	(Sripada *et al.*, 2005)
6	**Green Normalized Difference Vegetation index**	GNDVI=(B5-B3)/(B5+B3	(Gitelson *et al.*, 1996)

Yield productivity: The leaf area index (LAI) has been used to determine wheat crop productivity, as outlined in (Sehgal *et al.*, 2005). The relationship is represented by the equation

$$Y = 1571.2 \times \ln(\mathrm{LAI}) + 2033.6 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where: Y stands for yield productivity and LAI represents the leaf area index obtained from satellite images.

statistical analysis

The data was analyzed using the Excel program v.2016.

RESULTS AND DISSCUSION

The results in Table 3 indicate variations in the concentration of essential nutrients for plant growth in each soil, as well as within each individual site. The concentration of nitrogen generally ranges between 12 – 39 mg kg^{-1}, with standard deviation values ranging from 1.32 – 3.41 at the location 2 and location 1 sites, respectively. The coefficient of variation ranged between 4.61 – 19.28 at the first and fifth sites, respectively. When comparing the average nitrogen concentration in the five agricultural sites, the order is as follows: Loc 5 > Loc 2 > Loc 1 > Loc 2 > Loc 4 > Loc 3.

The average nitrogen content in the third site indicates a moderate nitrogen content in the soil. As for phosphorus, the results in Table 3 show variations in its concentration among the selected five agricultural sites, ranging between 2.02 – 10.55 mg kg^{-1} at the fifth and third sites, respectively. The standard deviation values ranged between 0.76 – 1.21 at the fourth and second sites, respectively, while the coefficient of variation ranged between 8.15 – 27.44% at the third and second sites, respectively. The order of average phosphorus concentration in the five agricultural sites is as follows: Loc 5 > Loc 2 > Loc 1 > Loc 2 > Loc 4 > Loc 3. Regarding the potassium concentration in the soil, as indicated in the results of Table 3, it ranged between 109 – 141 mg kg^{-1}. The standard deviation values ranged between 1.99 – 6.55 at the fourth and third sites, respectively, while the coefficient of variation ranged between 1.60 – 4.86% at the fourth and third sites, respectively. The order of average potassium concentration in the five agricultural sites is as follows: Loc 5 > Loc 2 > Loc 1 > Loc 2 > Loc 4 > Loc 3.

The superiority of the third site in soil content of nitrogen, phosphorus, and potassium is attributed to the nature of the good physical and chemical soil properties and their contribution to influencing the content of these elements. It is noted that the pH values at the third site were low compared to the other sites, with a recorded lowest value of 7.1 (Table 1). Also, the high organic matter content compared to the other fields, with a recorded value of organic matter content of 1.46 g kg^{-1}. Similarly, the calcium carbonate content was lower in the third agricultural field, recording 185 g kg^{-1}, which did not affect the availability of these elements in the soil. The gypsum percentage was low and did not have an impact on the availability of important nutrients. On the other hand, the lowest content of major nutrients was recorded at the fifth site, which was ranked the lowest compared to the other agricultural fields, this is certainly due to the unsuitable soil environmental conditions, which negatively affected the availability of important plant nutrients. Among the influential soil properties are the high pH value compared to the other sites, in addition to the low organic matter content, which recorded the lowest value of 0.58 g kg^{-1}, along with the decrease in clay content and the negative impact of soil texture, recording a clay content value of 50 g kg^{-1}. The clay content affects the increase in the availability of these elements in the soil.

In addition to the high salt concentration compared to other sites, the negative impact of the high calcium carbonate content on nutrient availability and plant productivity was observed. The fifth site recorded the highest gypsum content at 127.4 g kg^{-1}. The deterioration of fertility levels at the second and fifth sites can be attributed to their geographical proximity, both characterized by high gypsum and carbonate content, as well as poor soil and crop management. These sites are affected by inadequate soil preparation before planting, poor crop management, and an abundance of wild plants that compete with the main crop for nutrients. Inadequate nitrogen fertilization management and failure to monitor its transformation in the soil not only result in nutrient loss for plants but also disrupt the ecological balance and lead to soil degradation and reduced fertility, especially when proper farming management systems are not implemented or when the land is left uncultivated. This may be one of the main causes of soil deterioration and decreased nitrogen content.

The difference in fertility characteristics between sites and within the site is attributed to certain factors related to the formation of local soil, such as slope characteristics. Some sites may be uneven in their levelness, which affects the nature of crop growth, as well as the processes of soil service and maintenance, in addition to the optimal management of water distribution. Furthermore, the uneven topography of the land affects the tillage processes and consequently the uniformity of soil structure formation, which will impact the distribution of chemical fertilizers and their variation between large and small soil structures, thereby affecting the distribution and homogeneity of their application in the field.

Table 3: shows the descriptive statistics of nutrient elements in soil and plant leaves.

Location	Statistical	Leaf			Soil		
		N	P	K	N	P	K
		%			g kg^{-1}		
Loc 1	**Min**	1.13	0.08	0.60	28	4.64	116
	Max	3.33	0.35	2.66	33	7.24	125.23
	Mean	2.34	0.16	1.52	30.66	5.58	121.42
	Std	0.76	0.08	0.70	1.41	0.80	3.08
	CV%	32.42	52.50	46.05	4.61	14.40	2.53
Loc 2	**Min**	0.60	0.04	1.01	24	3.23	115.32
	Max	3.07	0.22	2.22	28	6.85	121.62
	Mean	1.86	0.13	1.72	25.66	4.43	119.11
	Std	0.65	0.05	0.48	1.32	1.21	2.080
	CV%	35.02	38.97	27.82	5.15	27.44	1.75
Loc3	**Min**	2.66	0.18	2.51	33	8.11	121.23
	Max	3.81	0.37	3.41	39	10.55	141.63
	Mean	3.26	0.26	3.02	35.44	9.61	134.61
	Std	0.37	0.07	0.25	2.29	0.78	6.55
	CV%	11.28	26.07	8.21	6.48	8.15	4.86
Loc4	**Min**	1.61	0.14	1.66	24	6.26	121.65
	Max	2.98	0.22	3.51	36	8.52	128.12
	Mean	2.20	0.18	2.54	31.77	7.43	124.11
	Std	0.49	0.03	0.62	3.41	0.76	1.99
	CV%	22.16	15.19	24.60	10.76	10.33	1.60
Loc 5	**Min**	0.55	0.06	0.71	12	2.02	109.65
	Max	2.08	0.18	2.55	21	4.98	116.52
	Mean	1.38	0.11	1.63	16.88	3.25	113.26
	Std	0.66	0.04	0.60	3.25	0.85	2.34
	CV%	47.92	34.60	36.92	19.28	26.38	2.06

Table (3) results showed variation in the concentration of essential plant nutrients according to the agricultural site and within the same site. The nitrogen concentration ranged from 0.55% to 3.81% with a standard deviation ranging from 0.37 to 0.76 and a coefficient of variation between 11.28% to 47.92%. Comparing the nitrogen levels in the green part of the wheat crop across different sites, the following ranking was observed: Loc 3 > loc 1 > loc 4 > loc 2 > loc 5. The phosphorus concentration ranged from 0.04% to 0.37%, with sites 2 and 4 showing higher levels at 0.26 and 0.18 respectively, and a standard deviation of 0.08. The coefficient of variation CV % was notably high in the first site at 52.50%, while the lowest value was observed in the fourth site at 15.19%. This may be attributed to the inconsistent use of DAP phosphate fertilizer by farmers due to its cost-effectiveness compared to other fertilizers, reflecting variations in nutrient concentration within the same field due to farmers' management and experience. As for potassium concentration, the highest level was 3.02% in the third site and the lowest was 1.52% in the first site, indicating the significant impact of site and local management practices on the availability of essential nutrients for optimal growth and higher yield. Additionally, the varying local factors such as soil quality, fertilizer quantity and type, and irrigation water quality have clear effects on nutrient concentration, with relatively higher levels typically observed in the field center due to appropriate moisture content, reduced sunlight impact, and the protective canopy cover providing high soil protection and minimizing the effects of wind.

The results in Table 4,5,6 and Figure 2 indicate the local variations in the values of spectral evidence between study sites, as well as differences in growth stages. It was observed that the spectral evidence values were relatively low at the beginning of the growth stage, when temperature rates are low and reach freezing, affecting the activity of microorganisms, root expansion, and the plant's optimal functioning, in addition to the early growth stage. Meanwhile, the spectral evidence values increased as the plant's growth stages progressed, reaching their highest level in April, the stage at which the plant almost stops growing and its spectral reflectance values become almost constant, with no significant differences due to the plant reaching its peak growth, completing its external appearance, and starting the grain formation and food production stage. The local variations in the spectral evidence values at each site, and one site's superiority over the other as the growth stages progress, reflect administrative practices and their correct implementation to increase productivity. There are clear differences in the spectral evidence values between study sites, consistent with laboratory analysis results and the availability of nutrients at the best plant growth stage.

It is noticed that the fifth site had relatively low indices values, while the third site had relatively high spectral indices values in the early stage of growth on 7th January. It is also observed that most of the spectral evidence rates on 13th April were high at the first site. This difference may be due to local factors and successful management requirements that help achieve optimal crop growth. The initial stages of growth may differ due to local factors such as soil type, fertility, and characteristics. The difference in the progress of growth stages may be attributed to the agricultural management impact and the farmer's method of adding fertilizers, as well as the quantity and quality of irrigation water.

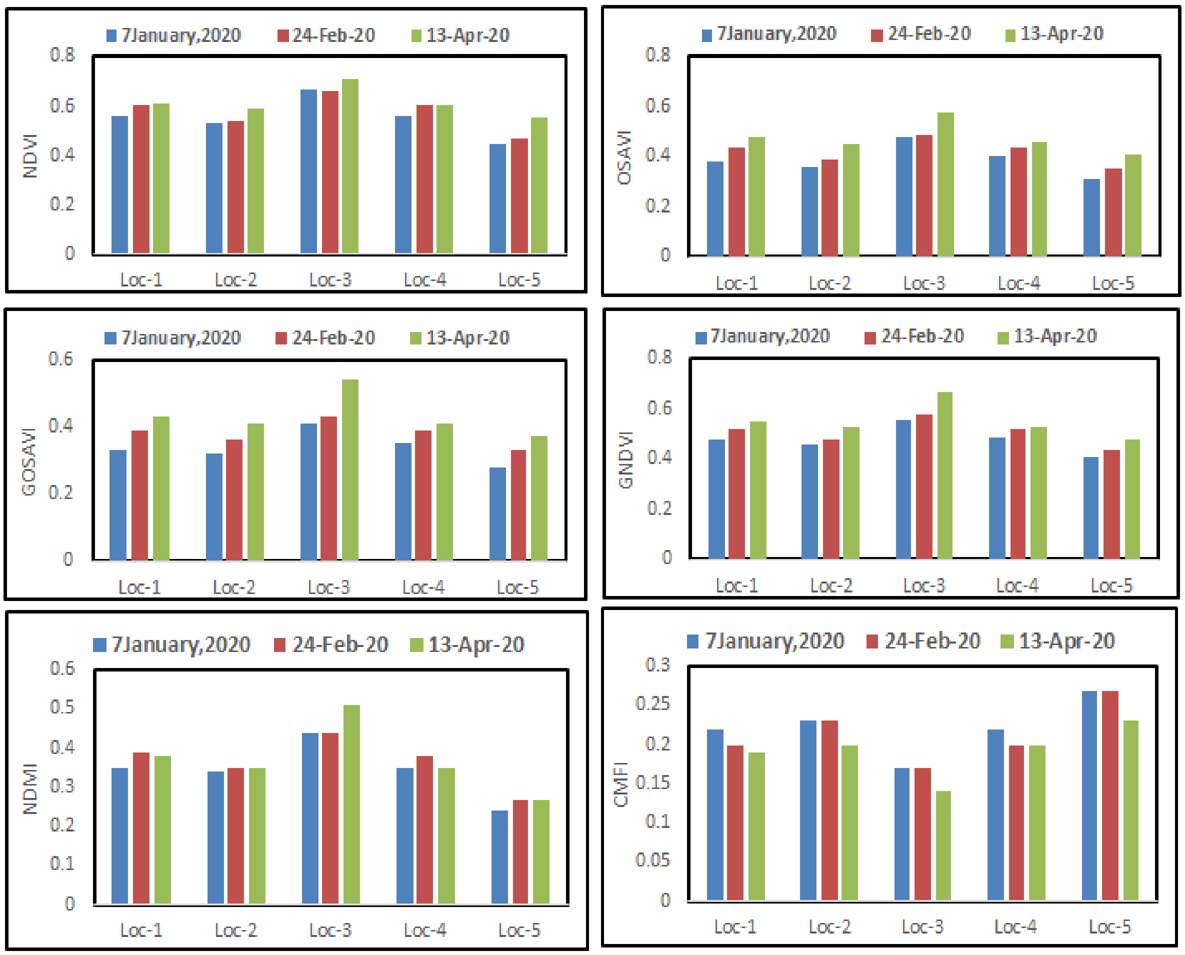


Figure 2. Average spectral indices for all sites.

The Crop Management Factor Index (CMFI) is a plant evidence that reflects the extent to which the crop needs to implement soil management plans, indicating that the fifth site requires higher management requirements than others, reaching 0.27, 0.27, 0.22 for the Image acquired on 7th January, 24th February, and 13th April, respectively. LAI is important evidence related to plant health and its production rate. Therefore, we notice that the index values ranged from 0.54 to 1.88 for the satellite visuals acquired on 7th January, with the highest rate reaching 7.87 for the visuals acquired on 13th April. This significant change in the evidence values reflects the plant's growth rate, development, and the extent of administrative operations, thus providing an indicator of the plant's productivity status. The variation in the values of the NDVI index according to the date of the visuals is related to the season's condition and vegetation density, which is reflected in the relationship between the red spectral band (B4) and the near-infrared spectral band (B5). As the difference between them increases, the vegetation cover density increases and healthy vegetation will lead to an increase in the spectral reflection in the near-infrared spectral band (B5).

Table 4: The spectral indices of the OLI Landsat image (7 January, 2020)

		NDVI	OSAVI	GOSAVI	GNDVI	NDMI	CMFI	SAVI	LAI
					7January,2020				
Loc1	min	0.43	0.30	0.28	0.40	0.26	0.16	0.37	0.67
	max	0.68	0.47	0.38	0.54	0.44	0.29	0.58	1.88
	mean	0.56	0.38	0.33	0.48	0.35	0.22	0.48	1.22
	std	0.09	0.06	0.04	0.05	0.07	0.04	0.08	0.42
	CV%	15.49	15.99	12.30	11.30	19.25	19.68	15.84	34.68
Loc2	min	0.43	0.30	0.28	0.40	0.26	0.18	0.37	0.67
	max	0.64	0.44	0.38	0.54	0.43	0.29	0.55	1.57
	mean	0.53	0.36	0.32	0.46	0.34	0.23	0.45	1.05
	std	0.07	0.04	0.03	0.04	0.05	0.03	0.05	0.27
	CV%	12.29	12.05	9.50	9.13	15.99	13.98	12.10	26.08
Loc3	min	0.59	0.41	0.36	0.51	0.38	0.13	0.51	1.32
	max	0.75	0.55	0.47	0.63	0.51	0.21	0.68	4.04
	mean	0.67	0.48	0.41	0.56	0.44	0.17	0.59	2.24
	std	0.05	0.04	0.03	0.04	0.04	0.02	0.05	0.85
	CV%	7.34	9.24	8.26	6.38	9.76	14.76	8.64	37.94
Loc4	min	0.47	0.33	0.30	0.42	0.27	0.19	0.41	0.80
	max	0.61	0.44	0.38	0.52	0.40	0.27	0.54	1.48
	mean	0.56	0.40	0.35	0.49	0.35	0.22	0.49	1.21
	std	0.05	0.03	0.02	0.03	0.04	0.02	0.04	0.21
	CV%	8.33	8.32	6.58	6.01	10.94	10.61	8.31	17.27
	min	0.39	0.26	0.25	0.37	0.17	0.25	0.33	0.54
Loc5	max	0.51	0.35	0.31	0.45	0.28	0.31	0.44	0.92
	mean	0.45	0.31	0.28	0.41	0.24	0.27	0.38	0.73
	std	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.1
	CV%	9.50	9.6	7.4	7.0	15.4	7.8	9.5	18.0

Table 5. Presents the spectral indices of the OLI Landsat image (24-02-2020)

		NDVI	OSAVI	GOSAVI	GNDVI	NDMI	CMFI	SAVI	LAI
		24 February, 2020							
Loc1	min	0.52	0.37	0.34	0.46	0.30	0.15	0.46	1.02
	max	0.69	0.51	0.45	0.60	0.49	0.24	0.62	2.41
	mean	0.60	0.44	0.39	0.52	0.39	0.20	0.53	1.59
	std	0.07	0.06	0.05	0.06	0.08	0.04	0.07	0.57
	CV%	12.05	13.14	12.24	10.97	20.15	17.72	12.80	35.89
Loc2	min	0.29	0.22	0.26	0.34	0.11	0.18	0.27	0.38
	max	0.64	0.46	0.40	0.55	0.45	0.35	0.57	1.75
	mean	0.54	0.39	0.36	0.48	0.35	0.23	0.48	1.23
	Std	0.80	0.10	0.07	0.06	0.10	0.05	0.09	0.40
	CV%	22.68	19.38	18.29	12.56	29.61	22.39	18.63	32.42
Loc3	min	0.61	0.45	0.40	0.54	0.39	0.15	0.55	1.57
	max	0.70	0.52	0.45	0.59	0.47	0.19	0.63	2.53
	mean	0.66	0.49	0.43	0.58	0.44	0.17	0.60	2.06
	std	0.47	0.03	0.02	0.02	0.03	0.01	0.03	0.31
	CV%	9.53	4.16	4.62	3.47	5.83	8.01	4.46	14.77
Loc4	min	0.56	0.41	0.36	0.49	0.34	0.17	0.50	1.25
	max	0.65	0.49	0.43	0.57	0.43	0.22	0.59	1.97
	mean	0.60	0.44	0.39	0.52	0.38	0.20	0.54	1.53
	std	0.41	0.03	0.02	0.02	0.03	0.02	0.03	0.23
	CV%	10.14	5.19	5.54	4.49	8.24	7.80	5.41	15.08
	min	0.34	0.25	0.27	0.36	0.15	0.19	0.31	0.48
Loc5	max	0.62	0.46	0.41	0.54	0.42	0.33	0.56	1.64
	mean	0.47	0.35	0.33	0.44	0.27	0.27	0.42	0.95
	std	0.82	0.1	0.1	0.07	0.09	0.05	0.09	0.42
	CV%	28.04	22.8	21.7	15.15	34.96	19.93	22.04	44.33

Thermal factor is one of the most important factors that play a crucial role in estimating the productivity of agricultural crops, as it affects the physiological status of the plant, the chlorophyll content in the plant leaves, and the plant's uptake of nutrients. The results in Figure (3) indicate a clear variation in the temperature degrees within the same location and during the growth stages. The lowest temperature rates were recorded in the middle of the cultivated area and ranked as follows: Loc 5 > Loc1 > Loc 2 > Loc3 > Loc4. As for the highest temperature rates, they followed this order: Loc5 > Loc1 > Loc2 > Loc3 > Loc4 for the acquired spatial imagery in January. It is noticeable that the temperature rates increased during the other growth stages, with the highest temperature rates recorded in the spatial imagery acquired in April, reaching the highest temperature values of 28.48, 27.44, 28.68, 25.80, and 27.59, respectively. There is a difference in temperature degrees within the same location, and the increase is towards the outer diameter of the irrigation system, which affects the homogeneous distribution of moisture content across the cultivated area, resulting in relatively lower vegetation density and the land becoming semi-bare. This impacts the high evaporation process and the rise of local temperatures, consequently affecting the growth of vegetation cover and its functions optimally, resulting in lower production. Therefore, proper management and efficient work of agricultural sprayers will lead to higher expected production rates, ensuring food security and prioritizing vertical agriculture. From the results, it is evident that the best distribution of temperature rates was recorded at the third location, which is consistent with the laboratory analysis results, where the best concentration of nutrients was found at this location.

Table 6: spectral indices values the of the OLI Landsat image(13april 2020)

		NDVI	**OSAVI**	**GOSAVI**	**GNDVI**	**NDMI**	**CMFI**	**SAVI**	**LAI**
		13 April, 2020							
Loc1	min	0.52	0.39	0.37	0.48	0.25	0.13	0.39	1.11
	max	0.73	0.58	0.50	0.63	0.50	0.24	0.59	7.87
	mean	0.61	0.48	0.43	0.55	0.38	0.19	0.48	3.01
	std	0.09	0.07	0.05	0.06	0.09	0.04	0.09	2.35
	CV%	14.46	15.30	11.03	10.12	24.10	23.01	15.03	78.06
Loc2	min	0.37	0.30	0.33	0.41	0.18	0.13	0.32	0.62
	max	0.73	0.57	0.49	0.63	0.49	0.32	0.58	4.94
	mean	0.59	0.45	0.41	0.53	0.35	0.20	0.45	2.10
	std	0.10	0.07	0.05	0.06	0.09	0.05	0.09	1.22
	CV%	17.10	16.36	11.98	11.54	24.67	24.88	16.55	57.93
Loc3	min	0.64	0.49	0.45	0.59	0.41	0.11	0.48	1.93
	max	0.78	0.63	0.59	0.72	0.58	0.18	0.68	9.54
	mean	0.71	0.58	0.54	0.67	0.51	0.14	0.61	5.43
	std	0.04	0.04	0.04	0.04	0.05	0.02	0.03	2.48
	CV%	5.75	7.77	8.09	5.92	10.04	14.33	5.12	45.64
Loc4	min	0.49	0.37	0.35	0.46	0.24	0.17	0.37	0.98
	max	0.65	0.51	0.44	0.57	0.40	0.26	0.52	2.24
	mean	0.60	0.46	0.41	0.53	0.35	0.20	0.46	1.67
	std	0.06	0.05	0.03	0.04	0.06	0.03	0.06	0.42
	CV%	9.79	10.18	6.94	6.60	16.30	14.39	10.03	25.13
	min	0.41	0.31	0.28	0.38	0.15	0.16	0.30	0.70
Loc5	max	0.67	0.51	0.45	0.58	0.39	0.29	0.50	2.28
	mean	0.55	0.41	0.37	0.48	0.27	0.23	0.41	1.40
	std	0.10	0.07	0.06	0.08	0.09	0.05	0.09	0.58
	CV%	17.72	17.88	16.70	15.77	34.02	21.28	17.78	41.45

The results in Figure (4) showed that the rates of the NDVI were consistent with the surface temperature index. The highest NDVI values were in the middle of the agricultural area, gradually decreasing towards the outer edge of the cultivated area. It was observed that the highest NDVI values were acquired in the satellite imagery in the month of April, while the lowest were in imagery acquired in January. This represents the early stage of growth, and at the same time, the decrease in temperature does not support optimal crop growth. The highest NDVI value at the early growth stage was at the third site, and the lowest was at the fifth site. Conversely, the highest NDVI value at the maturation stage April was at the fifth site, while the lowest was at the fourth site. This may be attributed to the nature and impact of the administrative processes by the farmers, as there was a deterioration in growth rates at the maturation stage compared to the early growth stages for some sites. On the contrary, there was a decrease in vegetation density at the maturation stage, confirming the significant role of optimal management in preserving the crop's condition and growth throughout the growing season. The best homogeneous distribution of vegetation density at the maturation stage was specifically observed in the satellite imagery at the third and fourth sites, where most of the cultivated area had similar NDVI values, while other sites had large areas with relatively low NDVI values, which may affect the expected productivity.

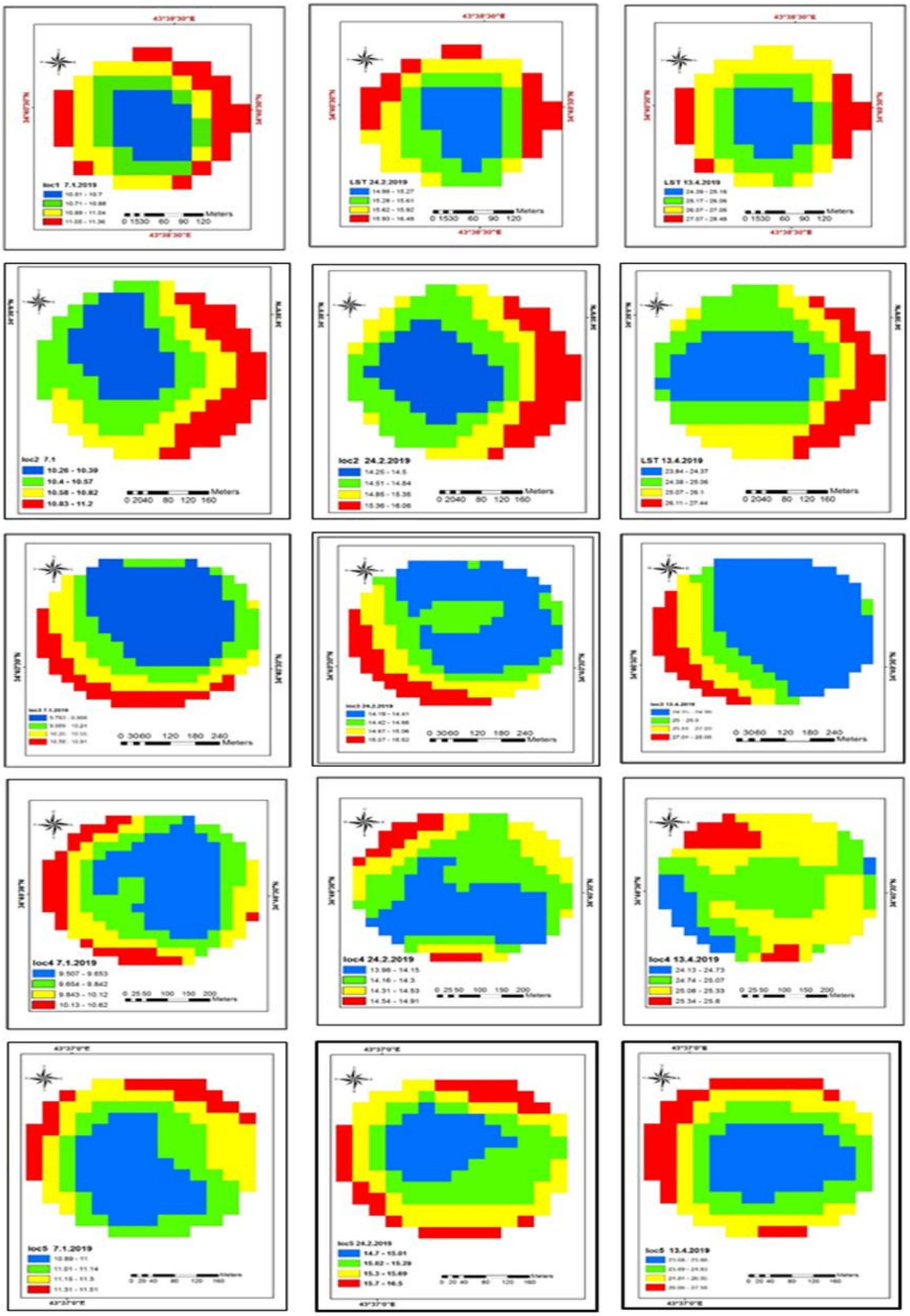


Figure 3. Images showing the surface temperature LST index for the study area.

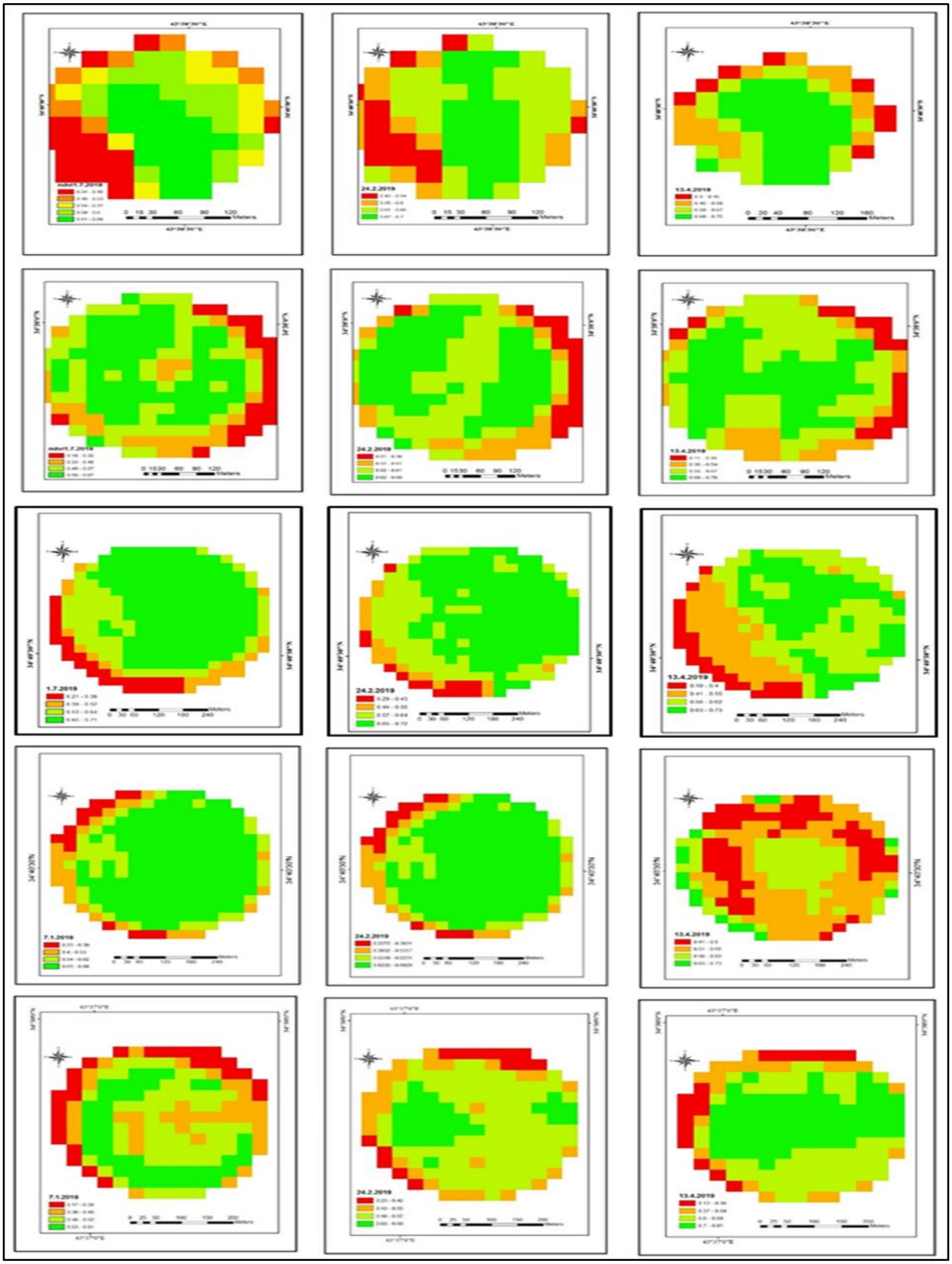


Figure 4. NDVI Normalized Difference Vegetation Index images.

Most spectral indices used to assess the growth and condition of crops and monitor changes depend on spectral bands located at wavelengths of 0.6-0.7 micrometers, where there is high absorption in the case of healthy vegetation with high chlorophyll content. Since nitrogen and magnesium are essential elements in the chlorophyll synthesis process, this range has an inverse relationship with nitrogen concentration in the plant leaf. The relationship was moderately strong with phosphorus and weak with potassium, possibly due to farmers relying on urea fertilizer to increase nitrogen readiness in the plant. Another spectral band, 0.7-1.3 micrometers, reflects the internal structure of the plant leaf, with determination coefficient values of 0.53, 0.46, and 0.24 successively. The NDVI is a significant indicator strongly related to plant density and overall condition, showing a strong logarithmic relationship with nitrogen and phosphorus. Therefore, it is highly suitable for monitoring and evaluating crop conditions and predicting its productivity (Figure 5). This is consistent with Xing *et al.,* (2020) who confirmed a strong determination coefficient value at the milk stage, a stage of relative spectral stability compared to other stages of plant growth. Recent studies have highlighted the importance of spectral evidence in predicting agricultural production, nitrogen content, and plant health, such as (Sultana *et al.,* 2014), which found a determination coefficient value of 0.78 between NDVI and crop yield, attributing it to the effect of nitrogen fertilizers levels on vegetative mass and crop yield. They also confirmed that the milk stage is the best stage for capturing NDVI and LAI readings, with a direct correlation to production estimation compared to previous spectral stages (Babar *et al.,* 2006; Royo *et al.,* 2003).

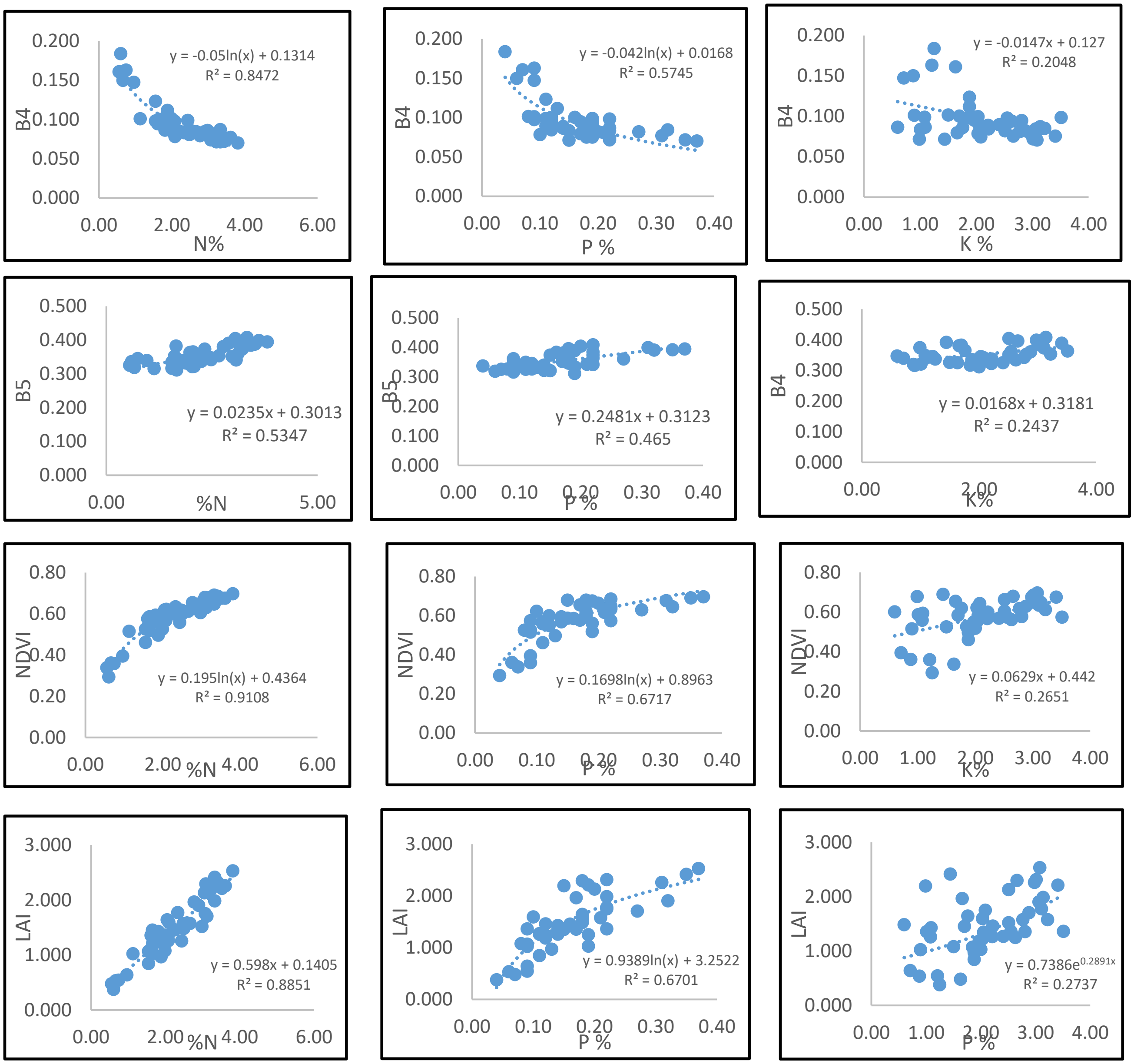
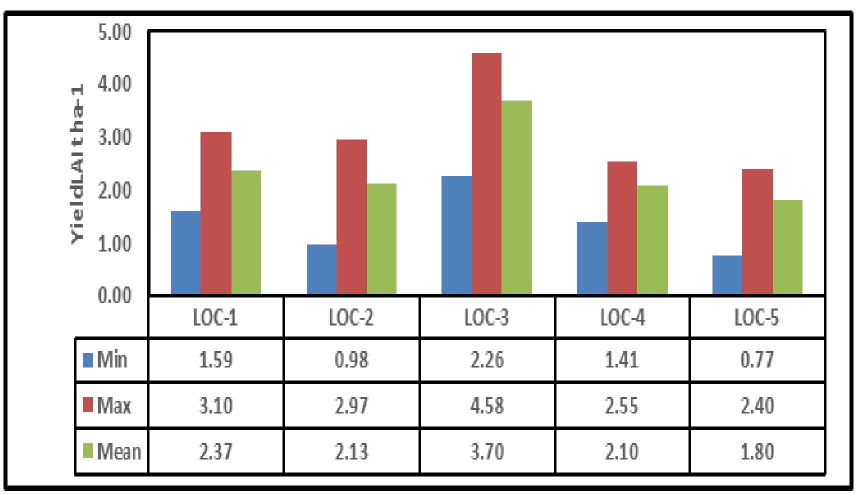


Figure 5. Shows the relationship between some spectral indices and the concentration of nutrients in the total vegetation at the ripening stage

By LAI spectral indices through the application of productivity estimation algorithms from spectral data for the linear growth stage (S3) revealed in Figure 6 the expected production values for the lowest and highest points in each field, as well as the overall expected production rate for each field, based on the LAI. The minimum expected production ranged from 0.77 to 2.26 tons per hectare, indicating a decrease in production, possibly indicating a malfunction in the plant's physiological functions, a deficiency in the appropriate moisture content for growth, the influence of insect and fungal pests, and a decrease in fertility content at these points in the field. When considering the site rankings, the fifth and second sites suffer from low-quality management practices. According to the statistical standard for the highest values, we notice the superiority of the third field, reaching the highest production at 4.58 and 3.10 tons per hectare for the third and first fields, respectively. When comparing the sites in terms of the expected production rate, the following ranking was observed: LOC3 > LOC1 > LOC2 > LOC4 > LOC5. This sequence of fields in terms of productivity values indicates that crop service and management are not well-studied and do not adhere to a scientific and strategic programme based on knowledge and empirical studies, but rather reflect the personal efforts and general experience of farmers, and their additions to fertilisers may be higher than the necessary plant requirements (Figure 7). A study by Sehgal *et al.*, (2005) noted a strong logarithmic relationship between the LAI and wheat crop productivity, with a determination coefficient (R2) value of 0.83, which is consistent with the determination coefficient value obtained in this study. Meanwhile, a study by Skakun *et al.*, (2019) found that the determination coefficient (R2) value between the AccNDVI index and wheat crop productivity was 0.58, 0.58, and 0.60 for the 2016, 2017, and 2018 seasons, respectively.



	LOC-1	LOC-2	LOC-3	LOC-4	LOC-5
Min	1.59	0.98	2.26	1.41	0.77
Max	3.10	2.97	4.58	2.55	2.40
Mean	2.37	2.13	3.70	2.10	1.80

Figure 6. Predicting wheat crop production based on LAI index

CONCLUSION

The indices has shown that the Crop Management and Fertility Index (CMFI) demonstrates good efficiency in tracking and diagnosing the deterioration of agricultural crop growth, and the need for an optimal agricultural land management system that provides it with the requirements for good growth. This is evident in the diagnosis of the fifth site, which aligns with field observations and reflects the pedological properties suffering from weakness in their physical, chemical, and fertility attributes. These can be addressed through the implementation of appropriate scientific soil and crop management plans, including scientifically maintaining and levelling the soil, as well as implementing a scientific fertilisation management programme that provides the necessary nutrients for the soil and plants at the required times, based on the spectral growth data provided by satellite imagery. The study has proven that the Normalised Difference Vegetation Index (NDVI) is an important and accurate indicator for tracking the growth and distribution of vegetation cover density, and for monitoring the spectral growth of strategic agricultural crops such as wheat, as well as for wide agricultural lands and fields, thereby estimating the health and deterioration of agricultural crops. In the final growth stage, the crop becomes ready for harvesting, and there is stability in the spectral reflectance values at a distance of 210 metres, where it is observed that the spectral absorption is low, meaning that the spectral values are high compared to the fifth spectral band, where the spectral reflectance is very low. This is a result of the vegetative part reaching the drying stage compared to other stages, confirming the important role of the near-infrared spectral part in monitoring vegetation cover and the growth of agricultural crops, and thus diagnosing the changes that occur and monitoring the deterioration it undergoes, thereby enabling the possibility of addressing the deterioration in crop productivity.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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