Detection and monitoring crop of wheat and barley by using NDVI stacking technique and spectral angle mapper algorithm

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Abstract.

Differentiating agricultural crops using remote sensing techniques is essential in the economic planning for countries and strategic alternative to field measurements. The methodology for this work is selection of satellite data (Sentinal-2A) with spatial resolution (10m) for months of the agricultural season to wheat and barley crop (September 2017 to July 2018) in the middle of Iraq between (33^0 $0'33.92''$ N - 33^0 $0'$ $45''$ N) latitude and ($44^0 26' 7.43''$E - $44^0 26' 55.98''$E) longitude which is famous for planting different types of agricultural crops. After doing spatial subset of interested bands, The Normal differences vegetation index (NDVI) were calculated for all images then NDVI stacking technique were done, the spectral angle mapper classification were applied with different spectral angles after determinate signatures of wheat and barley extracted from NDVI stack layer with determine NDVI values for march month more than 0.45. The results showed that cultivated areas of wheat and barley represents (31.5%) of the study area. Overall accuracy assessment were calculated for SAM classification with ground truth which gave highly accuracy assessment when choosing spectral angle (0.2).

Keywords: wheat , barley , SAM, NDVI , stacking.

1.Introduction

Distinguishing agricultural lands of wheat and barley crops from the rest of crops is a very important issue in the national economy, the development of systematic crop area monitoring and remote sensing tools is important for the country. Many studies in calculating agricultural crop land using remote sensing and satellite imagery with different working methodologies, most researches have adopted NDVI time series technique to distinguish between types of agricultural crops using the moderate resolution imaging spectroradiometer (MODIS), MODIS -NDVI time series and the Fourier transform technique were used to identify croplands over the state of Mato Grosso, Brazil [3], other method for detecting crops and map agricultural areas through a two successive classifications based on (MODIS)-Terra /EVI (Enhanced Vegetation Index) time series [1], development remote sensing based method to detect crop land in central and southern Queensland, Australia through time series analysis of the NDVI layer of MODIS-Terra MOD13Q1 (250-m pixel) imagery and local auto-regression was used to characterize phonological cycles in the NDVI time series [7], A new method to identify wheat crop over large regions in China by: first, extracted winter wheat mapping method based on the 250 m for 8-day composite(MODIS), second based on the Enhanced Vegetation Index (EVI2) differences between estimated heading and seedling/harvesting dates and the change amplitudes [8], Sentinel-2 data has gained more importance in monitoring and classifying agricultural lands due to the spatial accuracy of 10 meters, i.e. access to small agricultural areas, using Sentinel-2 time-series data stack was adopted and using multi-resolution segmentation algorithm, the resulting image objects were classified using the Time-Weighted Dynamic Time Warping (TWDTW) method in the south-eastern

part of Romania to map wheat, maize, rice, sunflower and forest [6], pre-operational (August 2015) Sentinel-2 data ,a study presents the results of two classification exercises assessing the capabilities for tree species and mapping crop types [4], a study introduced a generic methodology for mapping cropland along the agriculture season at high spatial resolution with the use of globally available baseline land cover [5], while other studies have adopted spectral indices to predict wheat [10].
The objective of the study is to apply SAM classification technique on stack layer of height resolution time series images to distinguish wheat and barley area from other plants.

2. Study area and dataset

The study area located in south of Baghdad at middle of Iraq. The study area extends between two latitudes ($33^0\ 0'\ 33.92''$ N - $33^0\ 0'\ 45\ ''$N) and longitudes ($44^0\ 26'\ 7.43''$ E - $44^0\ 26'\ 55.98''$ E) of about (1.52) km^2, Figure 1 shows the geographical location for the study area.

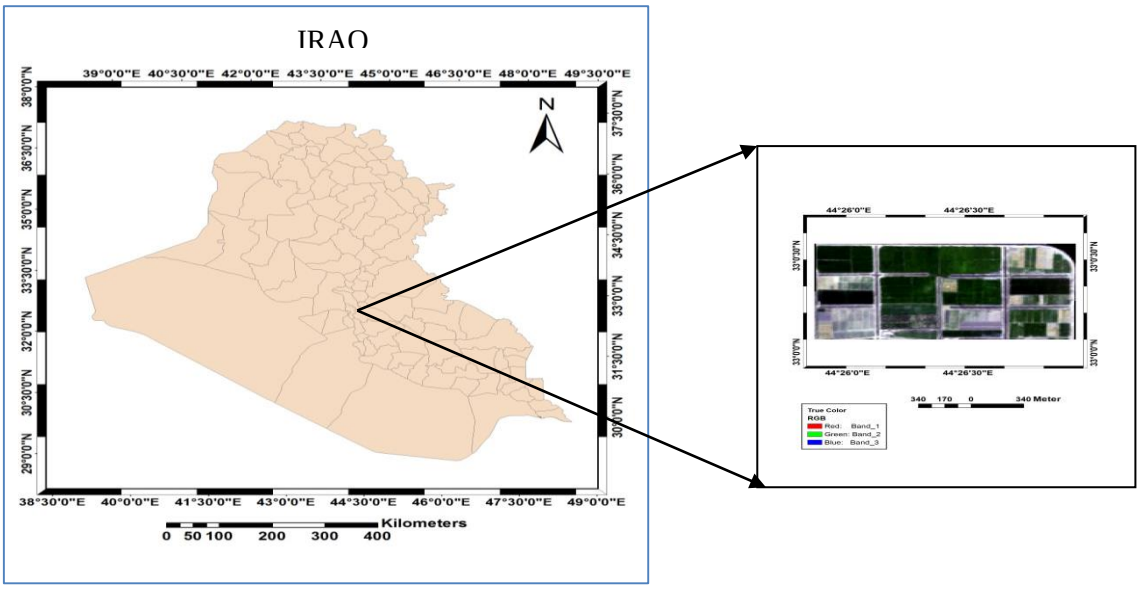

Figure1. Location of Study Area

Sentinel-2A images were used for the agricultural season from September 2017 to July 2018 with spatial resolution 10m and coordinate system (WGS_1984_UTM _zone_38N). The images were processed by ENVI 5.3 software by cutting the study area and converting the image values from DN to Reflectance and selecting four bands: b2 (490nm), b3 (560nm), b4 (665nm) and b8 (842nm) with spatial resolution 10m.

3.Methodology

Sentinel-2A satellite images for (SEP., OCT. ,NOV. & DEC. for 2017) and (JAN. ,FEB. ,MAR., APR., MAY.,JUN. & JUL. for 2018) where the days of images selected about middle of each month, at the beginning, images were processed by SNAP6.0 software to make spatial subset for study area and spectral subset for bands b2, b3, b4 and b8 with coordinate system (WGS_1984_UTM _zone_38N) , then export all raster images to ENVI format. Figure 2 shows the processing steps to achieve our objective**.**

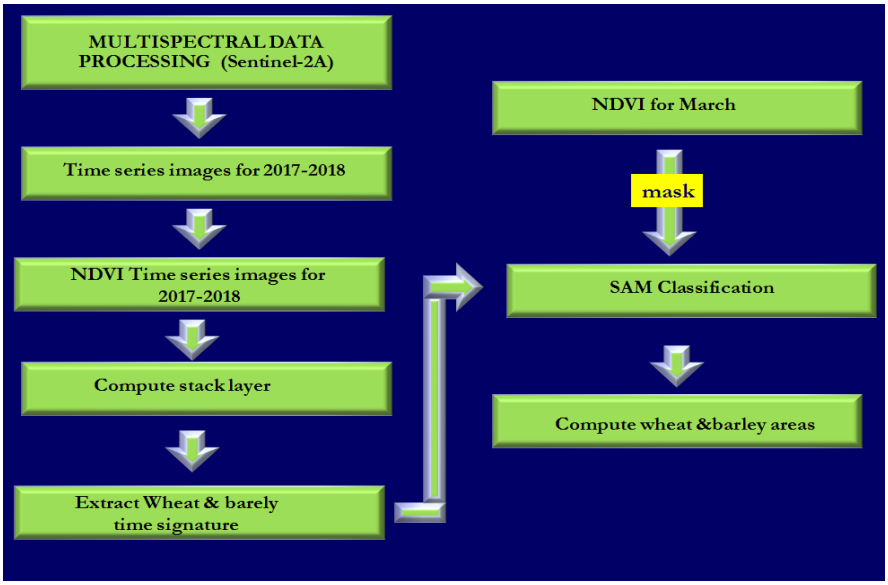

Figure 2. Methodology flow chart of classification

3.1 Normalized Difference Vegetation Index(NDVI)

Nonlinear mathematical transformation used to identify dense and health plant through the relationship between spectral data stored in red spectral bands and infrared spectral bands as in equation (1) [10]:

NDVI= (NIR-RED) / (NIR+RED)…….. (1)

For Sentinel image B4 and b8 correspond NIR and RED bands respectively.

3.2 Spectral Angle Mapper Classification(SAM)

SAM algorithm in this work is based on the assumption that pixels in a stack image represent variance in chlorophyll values over the agricultural cycle of wheat and barley in stack raster image and reference pixel specified by the ROI as a single class for a wheat and barley category. The angle between the two vectors is a measure of their similarity by calculating the angle between the two vectors as in the equation below:

$$\propto = \cos^{-1}\left(\frac{\sum_{i=1}^{nb} t_i r_i}{\sqrt{\sum_{i=1}^{nb} t_i^2}\sqrt{\sum_{i=1}^{nb} r_i^2}}\right)$$

Where nb represents the number of bands, r represents the spectrum of pixels, t represents the reference spectrum, and α represents the spectral angle [11].

3.3 Overall Accuracy and Kappa Statistics

The accuracy of spatial data has been defined by the USGS: "The closeness of results of observations, computations, or estimates to the true values or the values accepted as being true" (USGS, 1990)[12]. Accuracy assessment is a very important step when analyzing remote sensing data. The results of remote sensing can lead to economic and political decisions. Decision-makers must know the reliability of the data when facing the maps extracted from the data of remote sensing researchers.

The Overall accuracy is calculated by dividing the number of correct pixels in one class (sum of values in the main diagonal) by the total number of pixels as derived from reference data [2]**.**

The Kappa coefficient is a measure of overall agreement of a matrix. But with overall accuracy is the ratio of the sum of diagonal values to total number of cell counts in the matrix, the Kappa coefficient takes also non-diagonal elements into account [9].

4. Results and Discussions

The processing steps used to calculate the areas of wheat and barley as follows:

4.1 Calculating NDVI for time series images

By using ENVI5.3 software , converting all raster 10 images for a time series from November (2017 to July 2018) from digital number to reflectance, then calculate NDVI (Normalized Difference Vegetation Index). Figure 3 shows green area for march(2018) image where the total green area with NDVI values more than (0.51) and represents (54.33%) from study area , Note that the peak/maximum greenness stage for wheat and barley at march in IRAQ.

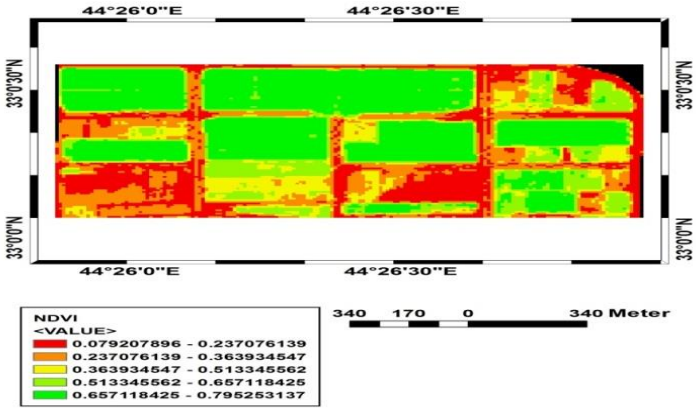

Figure3. NDVI image for march/2018

4.2 NDVI stacking technique

Layer stack where done to the time series of ten NDVI images to get one raster image to obtain the changes of chlorophyll values over the agricultural cycle of wheat and barley. Figure 4. shows stack layer image.

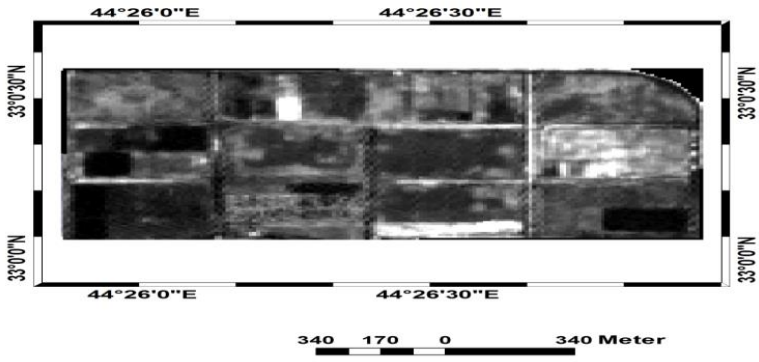

Figure4. Stack Layer image

Then determined time signatures for Wheat and barley as shown in Figure 5 from stack layer where Wheat and barley cultivation begins in October or November and yields the highest values in chlorophyll are in February and March, the crop is harvested in April and May.

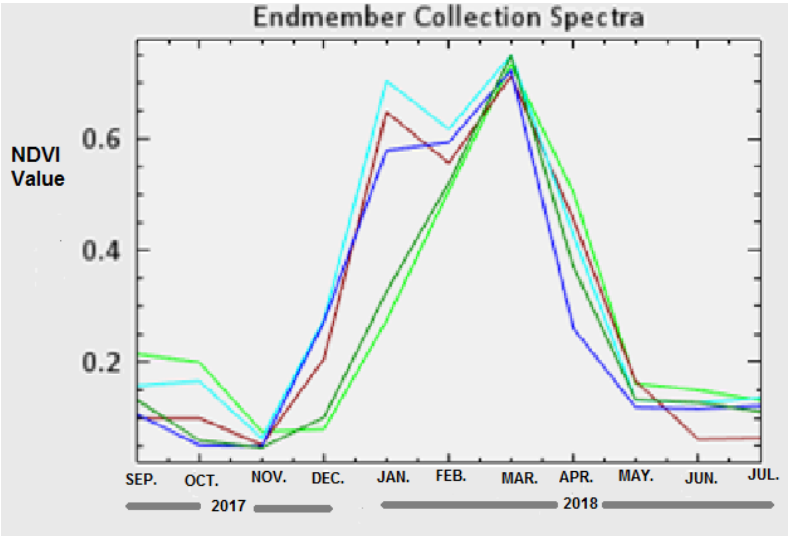

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Figure 5:Time signatures for Wheat and Barley

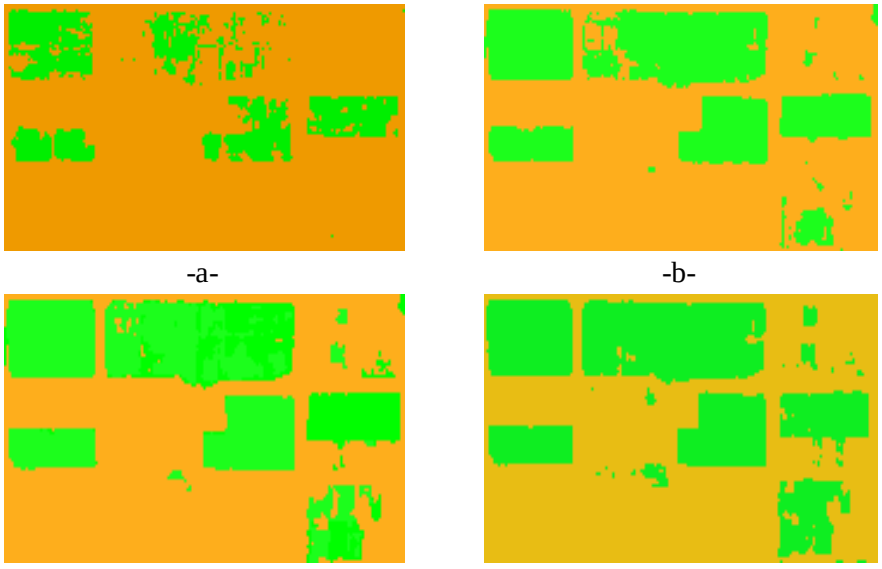
4.3 Classification for Wheat and Barley areas

The classification algorithm SAM (Spectral angle mapper) were applied for the stack layer after selecting wheat and barley classes (time signature for wheat and barley) and specifying the spectral angle with deferent values 0.1,0.2,0.25 and 0.3, also determine NDVI values range for march (2018) more than 0.45. Table 1 shows the cultivated areas of wheat and barley and their percentage in relation to the study area.

Table 1: Areas of Wheat & Barley

Spectral Angle for SAM	Areas of Wheat & Barley (Km2)	Percentage of Study Area
0.1	0.19	12.6%
0.2	0.48	31.5%
0.25	0.54	36.6%
0.3	0.60	39%

Figure 6 shows the areas of wheat and barley extracted using SAM algorithm with different spectral angles 0.1,0.2,0.25 and 0.3.



-a- -b-

-c- -d-

Figure 6: SAM classification with different spectral angles, a: spectral angle=0.1 , b: spectral angle= 0.2, c: spectral angle=0.25 , d: spectral angle=0.3.

4.4 Accuracy Assessment

Figure 7 shows a ground truth map where real data have been provided for the study area
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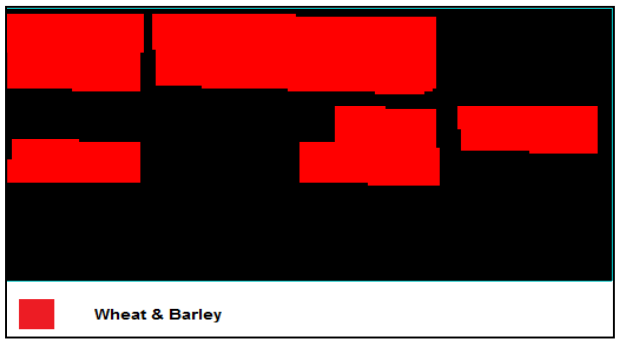

Figure 7: Ground Truth for study area

A confusion matrix tool in ENVI software were used to calculate the overall accuracy and kappa coefficient with all classification images that were previously extracted. Table 2 shows the Accuracy comparison for SAM images with different spectral angles.

Table 2: Accuracy comparison for SAM images

Classified Images	Overall Kappa (K^) statistics	Overall Accuracy
SAM 0.1	**0.3604**	**65.7227%**
SAM 0.2	**0.8528**	**93.6028%**
SAM 0.25	**0.8403**	**92.7478%**
SAM 0.3	**0.8202**	**91.9411%**

5-Conclutions

Iraq is one of the countries known to cultivate wheat and barley and other types of agricultural crops, wheat crops start in November and harvest in May. The study adopted Sentinal-2A satellite images with a spatial resolution of 10 meters for (2017-2018) agricultural season, and number of images used are 10 images for a time series from November 2017 to July 2018. Analysis methods were performed for all multi-spectral images. NDVI (Normalize Differences Vegetation Index) was calculated for all images, then a stacked layer was made for all NDVI images to obtain a single raster layer and then classes were extracted for wheat and barley, these classes represent the stages of change of chlorophyll values over the agricultural cycle of wheat and barley. Finally SAM (spectral angle mapper) has been applied over the stack layer with different spectral angle 0.1,0.2,0.25 and 0.3. Results showed that the cultivated areas of wheat and barley amounted to (0.48) km2, representing (31.5%) of the study area.
Below the most important results that were extracted from the research work:
1-NDVI stacking technique is important method for calculating crop lands Because it gives the behaviour of crops from the beginning of cultivation until harvesting**.**
2-SAM classification method used with time signature which represent chlorophyll values over the agricultural cycle of crop to get areas for wheat and barley.
3- Different spectral angles were used to get a best angle for classification for wheat and barley.
The results showed that the choice of the spectral angle 0.2 is the most appropriate in classifying wheat and barley since overall accuracy were 93.6% and kappa coefficient 0.85.

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