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Monitoring of growth of wheat's height using time series analysis of synthetic aperture radar (SAR) images and the corresponding parameters

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Abstract

In today's word, precision agriculture is one of the practical solutions in increasing agricultural products and timely monitoring to increase food security in today's world. Today, remote sensing technology and GIS are used for this purpose. Classification of various crops, especially wheat, in order to monitor its growth stages in multispectral images due to limitations such as dependence on weather conditions and lack of night imaging. At the same time, SAR images are capable of capturing images in all weather conditions, as well as day-to-day imaging, overcoming the limitations of optical images. Due to the identification of the phenomenon based on the geometry, hardness and orientation of objects, it provides us with a lot of information. Therefore, the main purpose of this study is to evaluate the feasibility of using RADAR images to monitor the growth cycle of wheat. For this study, a bipolar radar image of Sentinel 1 with polarization (VV and VH) will be used to obtain plant growth parameters such as height and biomass. Then, the parameters obtained in order to analyze the time series to understand the plant growth cycle will be performed unsupervised in the Google Earth Engine system. The results will show that band C in the early stages of wheat growth is most sensitive to wheat height and have appropriate information. Field data will then be used to assess accuracy. Final result demonstrates that VV polarization is far better indicator of Wheat growth in early stage, however, VH polarization is more sensitive to middle stage of plant growth cycle. Moreover, neither VV nor VH can detect Wheat growth cycle in their last stage. Both VV and VH showed high connection with the peak of Wheat growth in early May. In fact, it is said that it would be better way to use L band and longer wavelength for Wheat growth in its last stages.

1. Introduction

Agriculture is one of the most important infrastructures of any society and the food security of nations depends on it. So, get the information When pests and plant diseases occur, especially strategic crops such as wheat, it is considered necessary and important. In addition, this is agriculture as a growth engine for most communities in terms of basic human needs (including food and fiber), (Awokuse T.O, 2015 and Gillespie, S, 2017).

Precision farming is the right management in making decisions such as the use of pesticides and pesticides, chemical fertilizers, irrigation rates. And seeks the required labor force for the farm through information analysis, which always leads to increased production and reduced Water loss and reduction of destructive effects on the environment (2010, R, Gebbers and 2012, A B, Aubert).

Remote sensing is one of the most important techniques used in precision agriculture in monitoring the vegetation of the land surface and today the development of large-scale monitoring of agricultural products with the help of remote sensing techniques to implement reasonable management in relation to resources Natural land is especially important for populous countries that rely on agricultural products. Ability of radar sensors compared to optical sensors to provide images in different polarization channels with high spatial accuracy and wide coverage, penetration, sensitivity to roughness and humidity, and day-to-day

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imaging and night and all-weather conditions have made it a key tool for agricultural applications.

The sunlight reflected from the plant depends on the morphological and chemical structure of the plant. In fact, the type of product, the amount of water stored in the plant, the canopy and the health status of the plant in terms of photosynthesis depends on the reflection of sunlight from the plant and causes differences in energy received recorded in different visible and infrared bands. And this has led to the creation of various plant indices to monitor the condition of the plant (2017, J, Xue) so having up-to-date information about the plant growth cycle and changes in this cycle can make timely and cost-effective decisions.

Optical images are used in many fields related to precision agriculture, but due to the limitation of imaging in cloudy conditions, they do not have the necessary efficiency, and this leads to precision agriculture in the field of using radar images that can capture images in any water conditions. And are airborne. Optical images are completely affected by environmental factors such as smoke, rain, fog, dust, clouds and so on. In contrast, optical images are SAR images that have removed the limitations that existed in optical images. SAR images are independent of weather conditions and use replication and redistribution properties Provides rich information about the object's texture and structure to a variety of components, including: shape, moisture, roughness, and directions (Garcia, F W, 2002).

Various studies conducted in agricultural applications indicate the very good ability of radar remote sensing to monitor plant growth stages. These studies are often very complex because radar systems provide different information at different wavelengths, polarizations, and angles of impact. Different characteristics of plants such as: plant mass, structure) leaf size, stem density, leaf area, etc. (as well as soil moisture, surface unevenness, etc. have different effects on the return signal from plant surfaces. Interaction of radar parameters) Wavelength, polarization and angle of impact (with each other as well as its interactions with the plant, It can lead to the useful use and interpretation of this information and at the same time it is very complex. For this reason, in agricultural studies, radar parameters that signal relay and target-related parameters should be carefully studied (Karjalainen et al, 2008).

In Iran, however, the issue of monitoring agricultural products has been considered due to its importance and place in planning to ensure food security (Gozar Jomhor, 1311) and so far various studies in the field of agriculture have been conducted using optical sensors (Mirbagheri et al. 1310; Asadi Rashed et al. 1311; Jahan Afrooz et al. 1315, Roghan Cheraghi et al., 1344.) But radar remote sensing tools have received less attention due to limited access to data and radar software. In this research, Tal is based on the use of radar sensor data such as Sentinel-1 in monitoring dryland wheat. Changes due to plant phenological characteristics in specific geographical conditions of the country and the variety of environmental parameters in agricultural areas along with the multiplicity of species and species used, the issue of using new radar remote sensing techniques to monitor wheat production is important. . This strategic product is widely cultivated in Iran and has stages of germination and emergence, stem elongation and rivet development, maturation and seed formation and development.

The purpose of this study is to use radar data to analyze the sensitivity of this data in different polarizations to the height of wheat crop at different growth stages. Since the redistribution of radar waves is different in different polarizations and in different bands (2019, N, Rouhollah), so by comparing the data in polarizations (VH and VV) with ground data to the best parameter to determine the height of wheat and finally the growth stages of wheat We will arrive. Dual redistributions have greater potential for detecting biophysical parameters and phenological stages of plants (2014, all et Nelson).

The Google Earth Engine Web site has become a very useful platform for beginners and professionals in the field of remote sensing. It leads to this functional cloud environment and with the help of this system, different polarizations can be done without the need for

2. Method

In this study, we will use the advantage of remote sensing and different polarizations of Sentinel-1 GRDH format images to detect the plant phenological cycle. The study area is located in the northwestern part of Hamedan province and dryland wheat products are cultivated in it. Due to the presence of clouds during the plant season, more accurate results can be obtained if radar images are used. Therefore, radar images were used and to perform time series analysis, Sentinel-1 images were called to the online platform of Google Earth Engine to increase the speed of work and do not need desktop software. Finally, by comparing the redistribution in different bands and in different stages of growth, the best band composition can be achieved to better show the plant growth cycle.

The study field is under dryland wheat cultivation, so the possibility of errors in radar images due to excessive irrigation is reduced.

Figure 1. Wheat in different stage of its growth

Table 1. Wheat growth stages

Field survey	Growth Stage	Height
3 April 2021	Emerging	4cm
2 May 2021	Heading	15cm
9 May 2021	Filling	21cm
1 June 2021	Harvesting	36cm

The current study focuses mainly on images of the Sentinel-1 satellite from the European Space Agency (ESA), which is a collection of SAR observations from the Sentinel-1 project (two satellites). October 3, 2014. The project involves combining two platforms A and B in a circuit board with a phase difference of 182 degrees.

has it. This age sensor can receive radar images in the form of HH, HV, VV and VH polarization. The Sentinel-1 satellite can cover the entire planet once every 12 days, which is reduced to 6 days using both Sentinel-1 projects. The angle of impact of this sensor is between 29.1 to 46 degrees and the image bandwidth is 252 km. Spatial resolution in azimuth and slope directions are 5 m and 22 m, respectively) (Lazecky, et al., 2017).

Sentinel-1 images are taken from radar for analysis. Sentinel-1 images, in GRDH format in IW sensor mode, are wide-angle interferometers.

Figure 2. Image information in Google Earth Engine

Date of acquiring image	Satellite pass	Polarization	orbit number
3 April 2021	Ascending	VH and VV	108
2 May 2021	Ascending	VH and VV	108
9 May 2021	Ascending	VH and VV	108
1 June 2021	Ascending	VH and VV	108

Processors were performed in the Google Earth engine block and the amount of redistribution and the type of polarization were investigated in selecting the best parameter to avoid the plant growth cycle. VV polarization actually performed best in showing plant growth.

After entering the account and calling the data with the desired specifications, we apply spatial and temporal filters. Then, by averaging the images in the intervals in which the ground data were collected, we calculate their time series in VV and VH re-representations, as well as in the pass-through and down-pass modes.

In this study, images of Sentinel-1 have been prepared. Necessary filters were also applied. Sentinel-1 images were prepared for time series analysis after calling. Google Earth system engine performed time series analysis at high speed and the results were shown as a chart. Then the redistribution of radar images in different bands was compared.

3. Results

The study was conducted to analyze the time series of Sentinel-1 satellite images to study the phenological cycle of the wheat plant and was conducted in the context of the online platform of Google Earth Engine. Sedeps were compared with ground data to obtain the best redistribution in showing the phenological cycle of the plant.

The Google Earth Engine online system was able to process data in a very short time, as well as obtain time series diagrams. Another advantage of Google Earth Engine is shown in the following figures. Since bad time series requires several images from different times and downloading a large number of images also requires high storage space on the user's computer, Google

Inheritance of the engine has overcome all these limitations and provided the best to achieve the desired time series with the least form.

In Figure 1, we can see the redistribution changes according to the plant growth stages, which reached its maximum height in late May and has the highest redistribution on the graph.

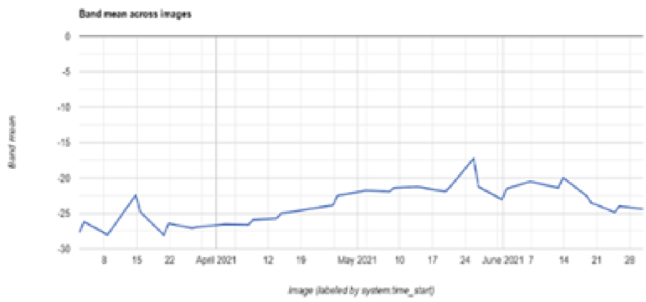

Figure 3. VV polarisation in accending mode

According to Figure 3, it can be understood that there is still a direct relationship between plant height at its maximum and the rate of redistribution. VV redistribution has fluctuations that can be due to wind and bending of wheat ears or due to field spraying that has added a little moisture to the wheat ears.

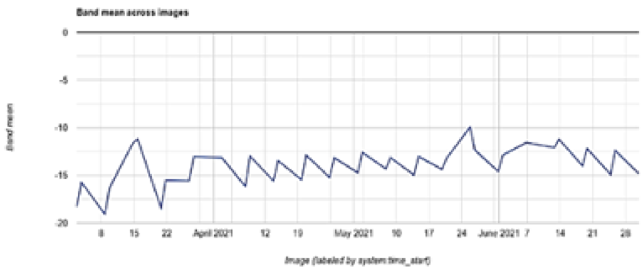

Figure 4. VH polarisation in accending mode

VV images fluctuate more in high-pass and low-pass modes because the wave redistribution in Co-Polarize mode has more contrast and is more sensitive to factors affecting redistribution such as surface roughness and moisture. What is evident in both types of redistribution is that the redistribution of radar images is directly related to the rate of product growth. Thus, with increasing plant height and density, volumetric redistribution occurs and causes more redistributions to reach the satellite sensor.

After downloading the numerical values of the VV and VH redistributions in the transient state and normalizing the numbers (placing the numbers on a scale between 0-1 were compared with the ground-based values) Figure 5.

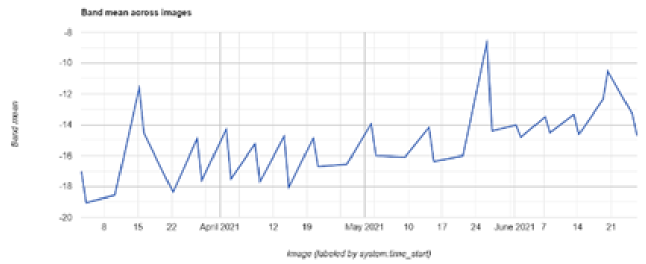

Figure 5. VV polarisation in decending mode

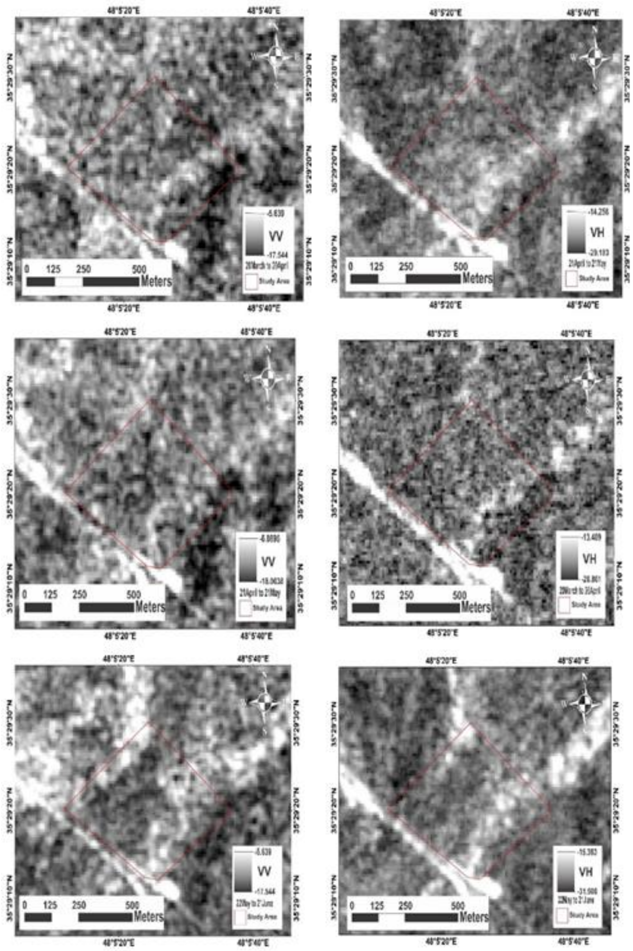

Figure 6. VV and VH in 3 time period (April-May-June 2021)

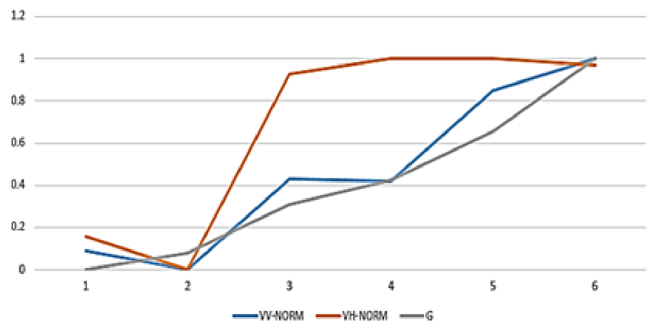

Figure 7. VV, VH and Ground truth dara

In the image above, the blue line represents the VV redistribution, the orange line represents the VH redistribution, and the gray line represents the amount of ground data collected. Depending on the shape, it can be understood that the reason for redistribution in both VV and VH in the early stages of plant growth, which is less than 3 cm, may be due to soil moisture due to rainfall or uneven ground surface due to seeding. It can also be claimed that redistribution in VV mode is closer to the harvested terrestrial values and therefore can better describe the phenological growth cycle of the wheat plant. The Google Earth online engine system was used to show the time series diagrams shown above. With the help of Google Earth Engine system, according to the stages of plant growth, three-time intervals of one month were considered to determine the average redistribution in these intervals. The images below are a visual representation of the same diagrams.

Then, with the help of redistribution in three values, the color band composite was performed to show the best values in the plant phenological cycle in each redistribution. Dedicated to May 22-June 22. And the visualization results are as follows.

According to Figure 1, it can be concluded that the VH band has performed better than other bands in showing the middle stages of crop growth. On the other hand, VV band, as it is taken from time series diagrams, is more sensitive to the growth stages of wheat, and therefore shows the first stages of wheat growth well, and the blue diagram shows it. It should also be noted that neither VV nor VH performed well in the final stages of wheat plant growth. Due to the volumetric redistribution that has occurred and the inability of C-bond to penetrate into the dense plant canopy, they do not represent a good indication for the final stages of plant growth. It is suggested to use bands with longer wavelengths to show the final stages of wheat growth. Better results will be obtained.

4. Discussion

We conclude that the use of redistribution of Sentinel-1 images with VV band specificity for wheat production and personalization of its phenological cycle has better results because in polarizations of the same name, the image contrast is usually higher. Also, using the online platform of Google Earth Engine has made the work much easier by being able to process several images simultaneously in the shortest time and without the need for storage space inside the computer.

It has also made it possible for all users to submit their code in the form of an online software so that other users can perform the necessary processes just by entering the study area. C-band Sentinel-1 images are available in GRDH format (SLC mode is not available), and then applying the relevant parameters and comparing all three with the ground samples, we conclude that due to volumetric redistribution occurs, the amount of signal penetration into the plant canopy in the last stages is reduced due to crop density.

5. Conclusion

In this study, by using the analysis of temporal cedars in intensifying intervals and in accordance with the ground visit, the stages of phonological development of wheat crop were obtained. This operation was performed with the help of block chain under the Google Earth Engine Web, and finally, by comparing the normalized numbers to a hundred diagrams with ground data, the inaccurate results showed that the VV polarization is higher. Also, by obtaining the color band compounds, it can be claimed that the C band performs well in showing the phonological cycle, provided that the plant is in its early stages. Because of the occurrence of volumetric redistribution, the amount of signal penetration into the plant canopy in the last stages due to crop density is reduced.

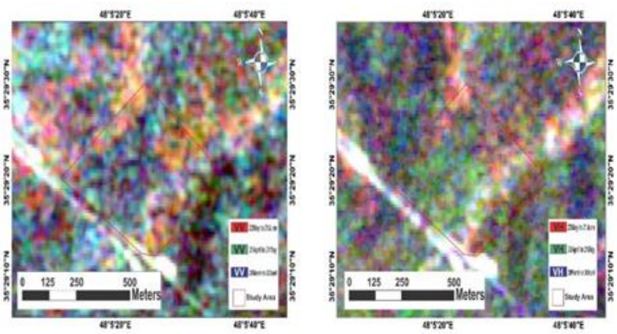

Figure 8. **C**olor composite of VV and VH

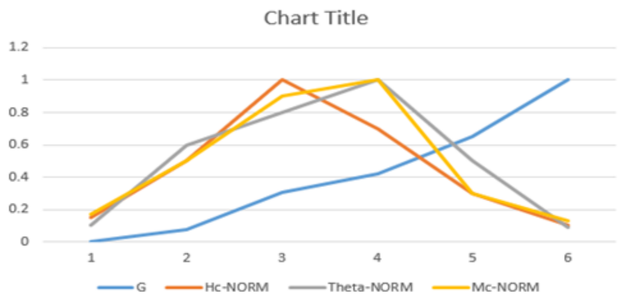

Figure 9. VV, VH and Ground truth data after normalaized (the numbers between 1-0)

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