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Analyzing rice farming between sowing and harvest time with Sentinel-1 SAR data

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Abstract

Agriculture has always been in an important position throughout human history. Today, the development of technology has accelerated studies to increase productivity in agriculture. With the use of remote sensing in agriculture, different crop types in large regions could be observed and their differences from each other could be examined with a spectral sight. With the observations obtained, instant surface monitoring in the agricultural sector makes it possible to perform analyzes. In the study, the paddy fields, where the rice product was named at the time of first planting, were examined by remote sensing method. Differences in Synthetic Aperture Radar (SAR) observations were analyzed between the first crop sowing and harvest time. In addition, in order to check the consistency of the results, the differences in the values obtained according to the representation of the samples distributed in the field were determined. Considering the results, it was seen that the lowest backscatter values were obtained for the paddy fields in the 35-day period after the first planting time and these values increased as the harvest time approached. There is an approximately 69% change in the lowest and highest mean backscatter values. Finally, when the time series analysis is performed according to the control samples in the field, it has been determined that the points represented by a single pixel have a more irregular distribution comparing the samples obtained in the form of polygons. This shows that pixels cannot be evaluated independently due to noise in SAR data.

1. Introduction

Rice is a food source for more than half of the world's population [1]. Paddy fields planted to obtain rice mature in about 130 days and become ready for harvest [2]. Agricultural applications such as plant health monitoring, estimating water stress, and sensitive classification of different agricultural products are carried out with remote sensing satellites [3-5]. Radar satellites have started to be used in this field as much as optical satellites, especially due to their advanced features [6]. One of the biggest advantages of radar images is that they do not contain some of the restrictions found in optical images. It is not possible to use optical images, especially in bad weather conditions. However, radar images work even in cloudy weather conditions [7].

Radar images can be used in different applications for the detection of water surfaces since they record differences in backscatter values according to surface properties [8]. Especially for crop yield, backscatter (dB) values obtained in Synthetic Aperture Radar (SAR) system are used [9]. In the paddy fields, water is used intensively from the first planting time to the harvest time [10]. There are different studies using SAR backscatter values in paddy fields [11-13]. The water level is monitored with the radar backscatter values and the process of

the rice production in the paddy field can be followed from the moment of sowing to the harvest time. In the study of Kim et al., the backscatter values obtained with different radar bands such as X, C and L and different incidence angles in rice fields were investigated. As a result of the observations, they emphasized that different backscatter values can be found with different incidence angles and emphasized that the values obtained with different polarization types may vary according to the period between sowing and harvesting of the product [14]. In the study conducted by Phan et al. in 2021, one of the agricultural regions of Vietnam were examined. As a result of a 5-year time series analysis in the study, they concluded that the backscatter values constantly progressed in the same profile. They also stated that they could not obtain consistent results when the crop sowing and harvesting times were different in the same region [12].

The aim of this study is to examine the rice cultivation in the Thrace region between May and October with multi-time images obtained from the Sentinel-1 SAR satellite. For that purpose, evaluating and analyzing the backscatter values obtained during the period between planting and harvesting according to months is the main object of the study.

2. Material and Method

Within the scope of the study, firstly the study area was determined; then Sentinel-1 SAR data, which passes through the same region every 12 days, was obtained for the study area. After that, preprocessing steps were carried out in order to remove the noise and for the improvement of the image. Then, the obtained images were combined and the average backscatter values were examined and the period between sowing and harvesting time was examined in the form of a time series table.

2.1. Study Area and Dataset

The İpsala district of Edirne province was chosen as the study area. Edirne province has more than 40% of the cultivated paddy fields in Turkey, while the district of İpsala has more than 17% of the cultivated paddy fields in Turkey [12]. The data used is the Sentinel-1 SAR satellite data, available free of charge from the European Space Agency (ESA). 15 SAR images taken every 12 days at equal intervals from the paddy planting time of May to the end of the paddy harvest time of October were used. The study area is shown in Figure 1. In Figure 2, SAR images are shown which are used for the study.

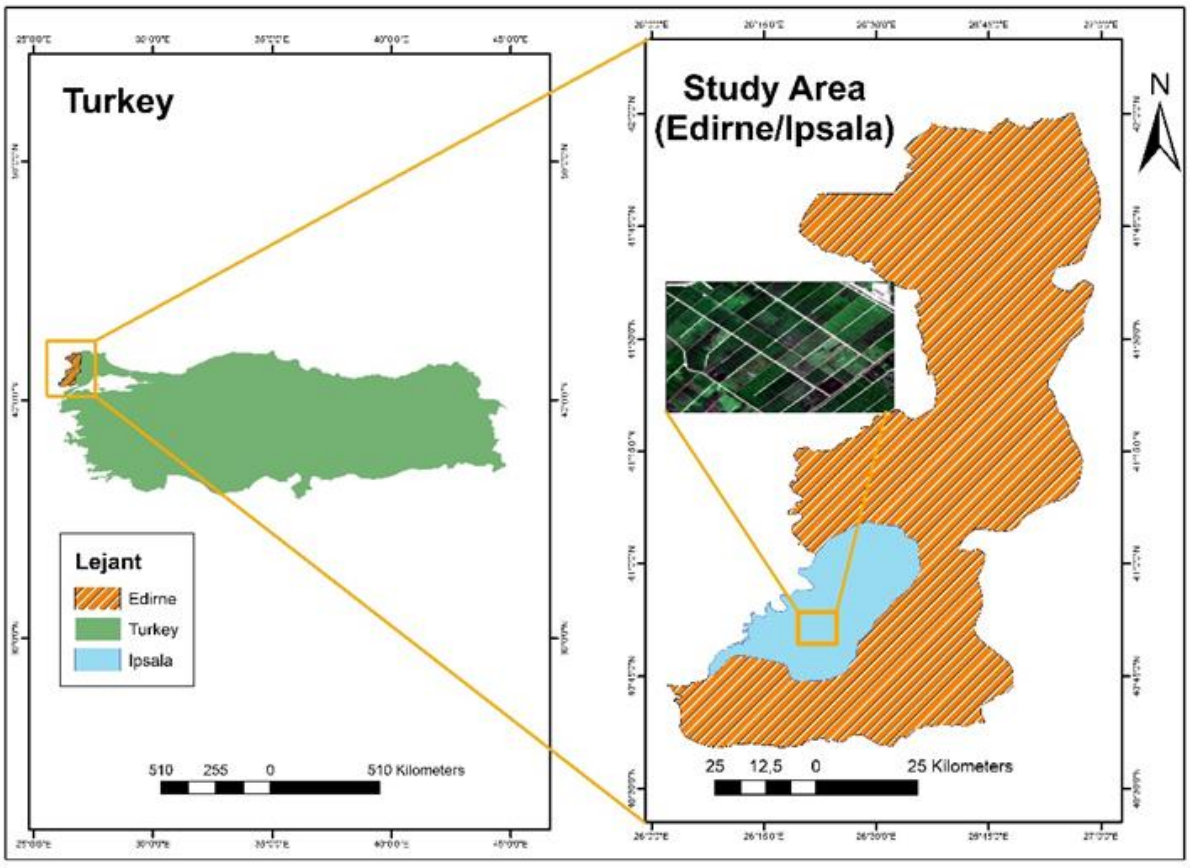

Figure 1. Study Area

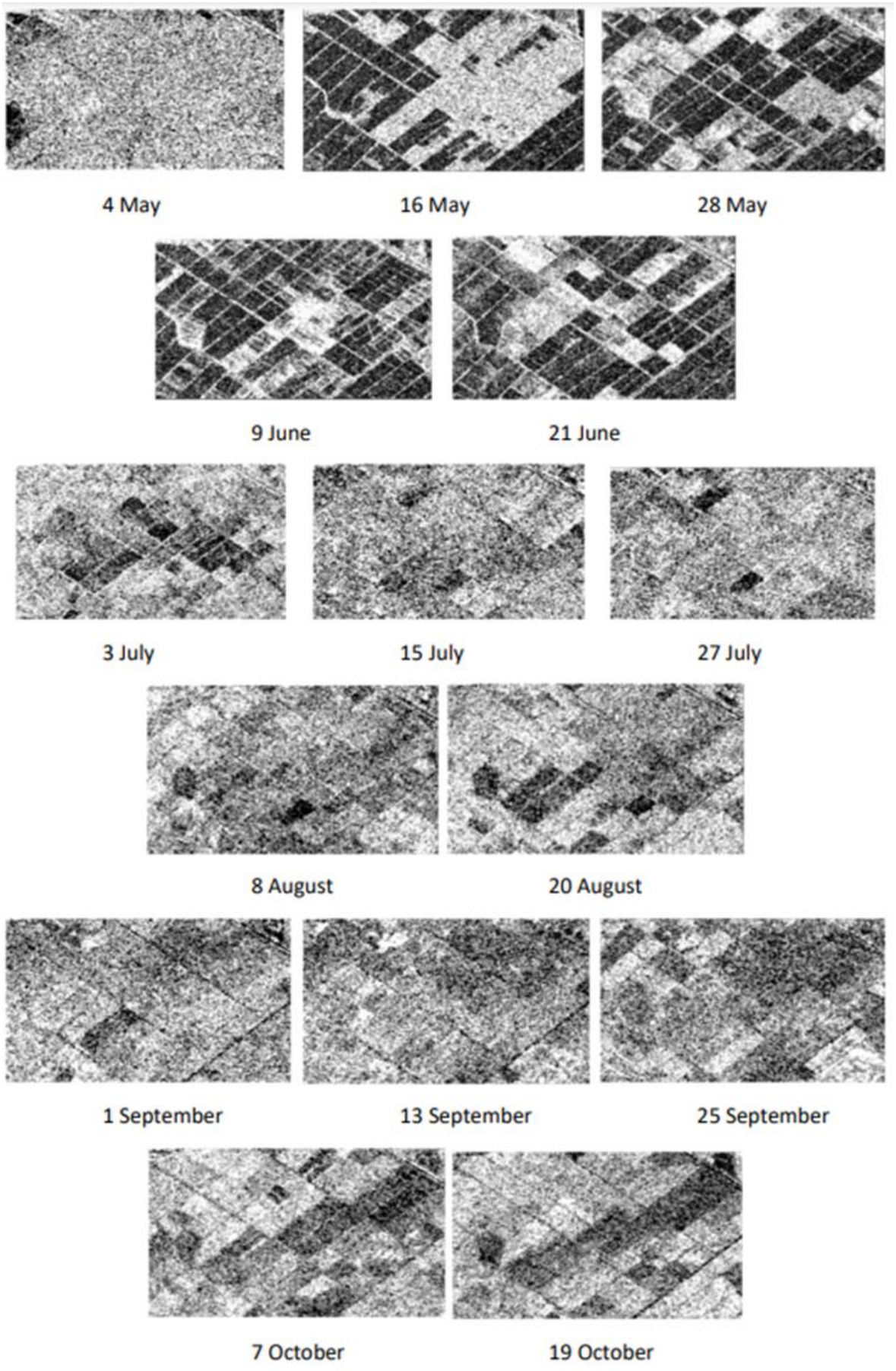

Figure 2. SAR Dataset

2.2. Data Preprocess

SAR images are not suitable for direct use as they are raw data. For this reason, they must first go through a number of pre-processing steps. First, thermal noises in the image are eliminated. Then, orbit files were applied for georeferencing. Afterwards, the calibration process was performed in order to obtain the backscatter values from the image. Finally, terrain correction was performed for the coordinate correction process and the images were ready. The preprocessing steps are shown in Figure 3.

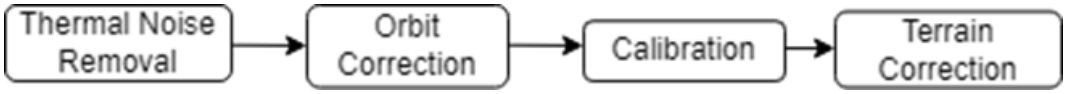

Figure 3. Preprocessing steps

After the preprocessing steps, the backscatter (dB) values in the images were recorded separately for all dates. After that, Sentinel-1 SAR data were combined to analyze all the data together. A reference master data is needed for the stacked data. For this reason, the data dated May 4 which is the sowing time was determined as the master image, and all remaining data were selected as slave images. Then, a time-series graph covering all dates was obtained and control samples were placed in certain areas of the field as single-pixel and polygon areas, respectively. The results were compared over these samples and the process of the paddy fields were examined. Control samples obtained as points and areas in the study area are given in Figure 4.

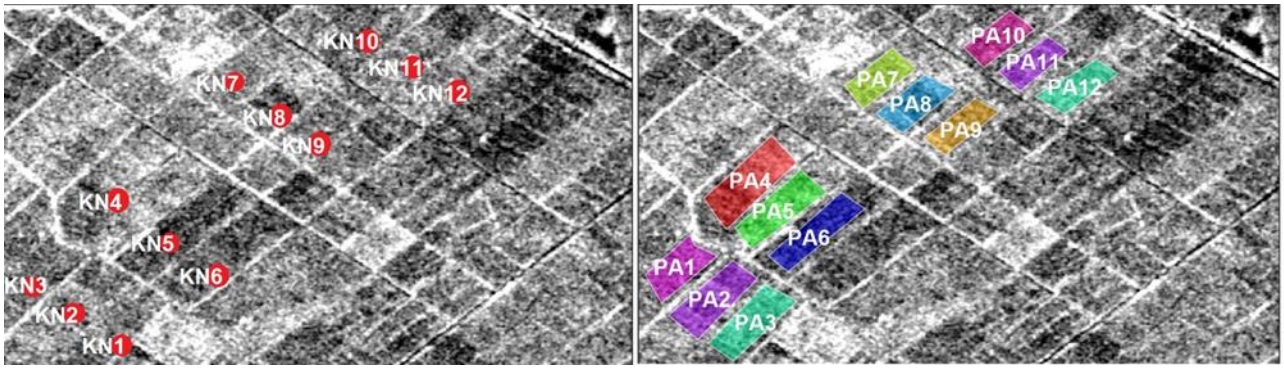

Figure 4. Control samples were taken in the field (Respectively, in the left image, the dots represent a single pixel, and in the right image, they represent approximately one crop parcel)

3. Results

Backscattering (dB) values obtained from the dataset are given in Table 1.

Table 1. Backscatter (dB) values obtained from the dataset

Image Acquisition Date (2021)	Maximum Backscatter(dB) Value	Minimum Backscatter(dB) Value	Average Backscatter(dB) Value
4 May	-9.6361	-30.6967	-20.0439
16 May	-7.0947	-34.8829	-23.4318
28 May	5.8827	-33.2257	-23.0120
9 June	-10.0764	-35.4931	-23.6802
21 June	-11.2858	-34.4223	-22.6449
3 July	-10.4948	-32.1491	-20.5596
15 July	-9.6795	-28.4936	-18.7282
27 July	-10.0417	-32.2956	-19.9034
8 August	-6.5182	-30.7698	-19.3219
20 August	-10.3978	-29.2372	-18.7064
1 September	-8.4526	-28.6447	-17.5985
13 September	-8.3038	-28.3478	-18.0371
25 September	-7.9786	-28.9482	-18.7683
7 October	-9.1572	-30.4993	-18.4484
19 October	-6.5108	-28.1091	-16.4259

Considering the backscatter (dB) values, the lowest average value was -23.6802 on the 9 June, while the highest average was -16.4259 after the harvest time which the date of 19 October.

4. Discussion

According to the results examined in Table 1, while the lowest level of backscattering values was obtained with field irrigations after the first planting time, the backscatter values begin to increase as the crop dries up at the harvest time and as the drying process takes place. The results we found gave similar results to the study by Phan et al. However, in this study, we have determined that analyzing SAR data with a single pixel can yield inconsistent results, so it would be more accurate to analyze within one area.

The time series tables extracted from the control samples obtained from the field are given in Figure 5.

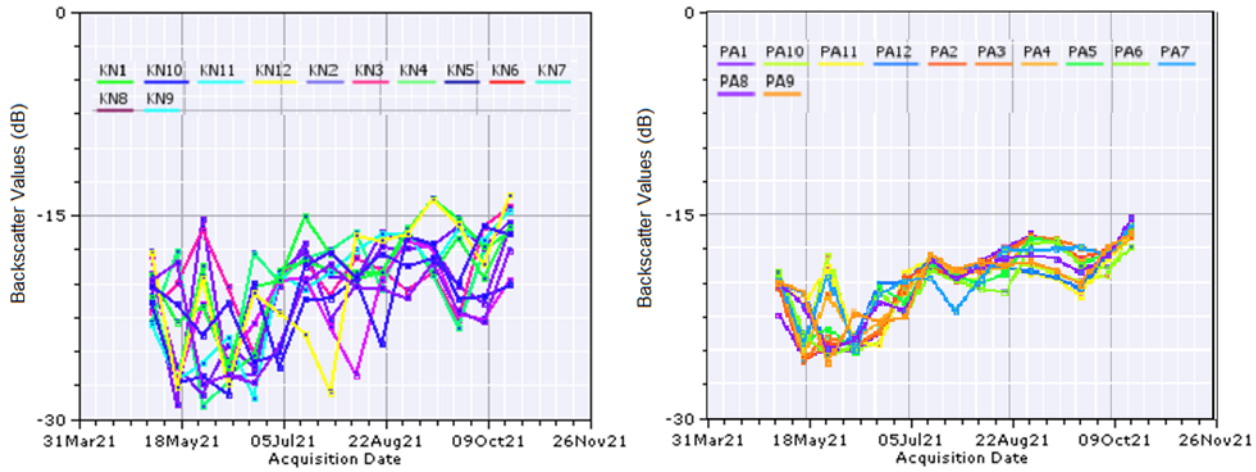

Figure 5. Time series plots obtained from control samples (Respectively, samples representing a single pixel are used in the left chart, while samples covering the area are used in the right chart)

5. Conclusion

In this study, the process of rice, which is an important source of nutrition, from the first planting to the harvest time was examined with SAR images. When the obtained results are examined, it has been observed that the backscatter values on the radar satellites can determine the stage between sowing and harvesting due to the intense demand for water during the growing process of the paddy fields. Again, when examining the backscatter values in radar images, it has been seen that choosing a polygon area instead of a single-pixel representation will give more objective results by choosing an average value. The reason for this is that the excess noise in radar images can detect very different values from each other even in pixels that are next to each other.

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Author contributions

Ahmet Batuhan Polat: Methodology, Writing, Literature, Software **Fusun Balik Sanli:** Validation, Editing. **Ozgun Akcay:** Validation, Editing, Methodology.

Conflicts of interest

The authors declare no conflicts of interest.

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