MONITORING OF AGRICULTURAL CROPS BASED ON RADAR IMAGES

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***Abstract**: This article presents the importance of RADAR images in general and in particular a way to use Sentinel 1 Radar images in monitoring process of the crops. Sentinel images representing the European Space Agency (ESA) project were used in this research, and was designed to provide a vast amount of data and images for the Copernicus program in Europe. The Sentinel-1 system is equipped with two polar orbital satellites designed to provide spatial data for environmental monitoring. Sentinel 1 satellites take images both during the day and at night, being a Synthetic Aperture Radar - SAR. The captured images were pre-processed and processed using the SNAP program. The study area is part of the lands in the patrimony of BUASVM Timisoara, more precisely within the Experimental Didactic Station. and the monitoring period of agricultural crops was February - October 2020.*

***Keywords:** crop monitoring, RADAR, SAR, Sentinel 1, SNAP*

1. Introduction

The use of remote sensing in agriculture is a technology that is increasingly used to monitor crops and ultimately increase productivity [1,2, 3, 8]. Also, the remote sensing images can be integrated with all GIS Systems [6].

Many studies have the main purpose the use of remote sensing images in agriculture in different directions such as: assessment of plant health [5], identification of areas in need of irrigation, identification of pests in a crop, estimation of agricultural production, identification and classification main types of crops, etc.

Also, remote sensing images can be used in various studies and monitoring [4, 7] such as: determination of LST [10], disaster monitoring (fires, floods, etc.), monitoring of forest areas, etc.

Active remote sensing uses artificially generated electromagnetic radiation using various tools to exploit and record in the form of images, objects and phenomena on the earth's surface. Remote sensing with active means offers the possibility to obtain accurate images of objects, using radiation that can propagate in conditions different from those used in passive remote sensing. The best known principles of active remote sensing are related to the use of microwaves (radar), polarized light or laser (LiDAR), respectively sound waves (sonar) [9].

The fundamental concepts of radar (radiolocation) are based on the laws of radio wave reflection, which are inherent in the equations that determine the behavior of electromagnetic waves.

The principle of RADAR is the following: The pulse of the electromagnetic radiation transmitted by the transmitter through the antenna has a wavelength and a specific duration (ie it has a pulse length measured in microseconds, msec). Wavelengths are much longer than in the visible spectrum, near infrared, medium infrared or thermal infrared used in other remote sensing systems. Therefore, the energy in the microwave spectrum is usually measured in centimeters and not in micrometers [11-17].

Radar systems encode microwave regions in the following frequency bands, as in the table below:

Band code	Wave length (cm)
Ka	0,8 – 1,1
K	1,1 – 1,7
Ku	1,7 – 2,4
X	2,4 – 3,8
C	3,8 – 7,5
S	7,5 – 15
L	15 – 30
P	30 - 100

In remote sensing, radar systems are classified into 2 categories, as follows:

- Vertical aperture radar - SAR (Synthetic aperture radar). The result is a narrow image, similar to a topographic terrain profile. This radar is used in air navigation, in various aerial photography missions, because it is necessary to know the exact flight ceiling.
- Airborne side radar - SLAR (Side Looking Airborne Radar). The mobile antennas are located obliquely on the fuselage of the aircraft on both sides or sideways and perpendicular to the direction of flight emit microwaves and result in very good ground coverage, for example 9km at a ceiling of 3000m or 20km at a ceiling of 7000m. Thus, the ground cover increases in direct proportion to the flight ceiling.

Radar systems, including SAR systems, have an antenna that transmits and receives electromagnetic energy. The larger the antenna size, the more concentrated the beam of radio frequency radiation that is sent and the higher the spatial resolution - or amount of detail - that can be captured as the energy returns. Simply put, the term "diaphragm" is related to how much energy an antenna can receive.

In a SAR system, an active remote sensor mounted on a satellite or aircraft transmits radio frequency (RF) energy pulses to an area of interest. These radar signals interact with the Earth's surface. Some of the signals are reflected back to the instrument, in models that contain rich information about the size, orientation, composition, condition and texture of the characteristics encountered - whether they are related to land, water or human activity. This data is collected, digitized, stored and can be processed to form an image for easy interpretation by the human eye.

Synthetic aperture (SAR) radars simulate the effect of a very large antenna. As element A is targeted by the first radar beams (Figure 1), the retro-reflected signals are recorded throughout the time the element is illuminated by the radar. The point in the orbit that corresponds to the moment when the element is no longer illuminated determines the simulated length of the antenna (synthetic aperture B) [15, 16, 17].

Radar emits and receives linearly polarized waves, rapidly switching from horizontal to vertical polarization and backward, from pulse to pulse or from burst to burst of pulses.

The following abbreviations are sometimes used to describe how it works:

- HH - transmission on horizontal polarization and reception also on horizontal polarization
- VV - transmission on vertical polarization and reception also on vertical polarization
- HV - horizontal polarization emission and vertical polarization reception
- VH - transmission on vertical polarization and reception on horizontal polarization

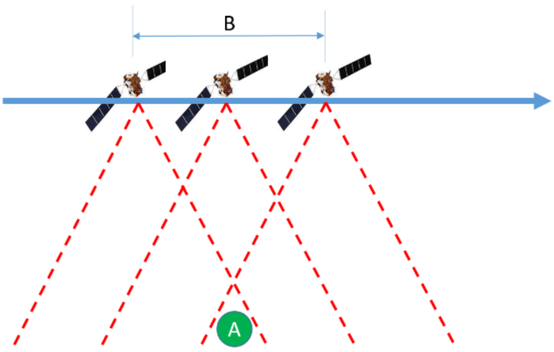

Fig.1. The principle of obtaining a synthetic SAR aperture

The spatial resolution of radar systems depends on the specific properties of the signal. The distance resolution (spatial resolution in a plane perpendicular to the direction of movement of the platform) is dependent on the pulse length of the radar signal (the smaller it is, the better the distance resolution will be). The azimuth resolution (spatial resolution in parallel with the direction of movement of the platform) is determined by the angular size of the beam emitted by the radar system and the inclined distance [15, 16, 17, 18].

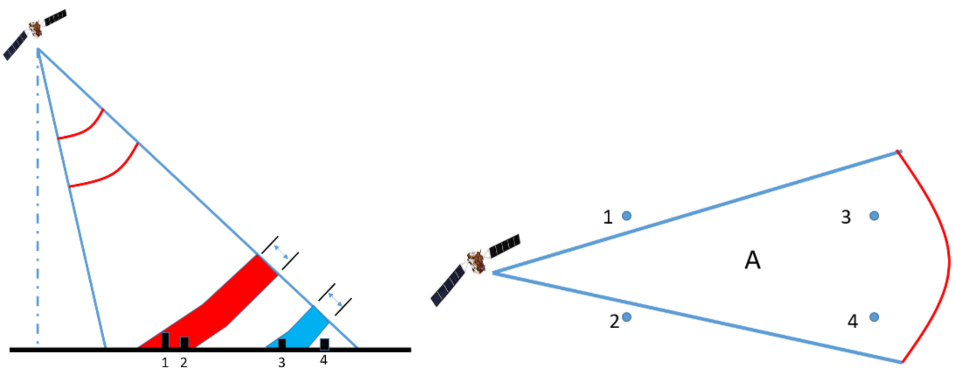

Fig.2. The spatial and azimuth resolution of SAR images

Advantages and disadvantages of using RADAR images:

- ADVANTAGES:
    - Purchase images regardless of weather conditions
    - Acquisition of images during the day and night
    - Vegetation penetration
    - Minimal atmospheric effects
    - Sensitivity to dielectric properties (liquid vs. frozen water)
    - Sensitivity to structures
- DISADVANTAGES:

- The information is stored differently from optical sensors and difficult to interpret
- Photographic granulation effects
- Effects of land topography

2. Materials and Methods

Sentinel images representing the European Space Agency (ESA) project were used in this research, and was designed to provide a vast amount of data and images for the Copernicus program in Europe. The Sentinel-1 system is equipped with two polar orbital satellites designed to provide spatial data for environmental monitoring. Sentinel 1 satellites take images both during the day and at night, being a Synthetic Aperture Radar - SAR.

Sentinel 1 carry a C-band synthetic-aperture radar instrument which provides a collection of data in all-weather, day or night. This instrument has a spatial resolution of down to 5 m and a swath of up to 400 km. The constellation is on a sun synchronous, near-polar (98.18°) orbit. The orbit has a 12-day repeat cycle and completes 175 orbits per cycle. There are a wide range of applications for the data collected via the Sentinel-1 mission. A few of these uses include sea and land monitoring, emergency response due to environmental disasters, and economic applications. A major goal of the mission was to provide C-Band SAR data [15, 16, 17, 18].

The captured images were pre-processed and processed using the SNAP program. The study area is part of the lands in the patrimony of BUASVM Timisoara, more precisely within the Experimental Didactic Station (Figure 3).

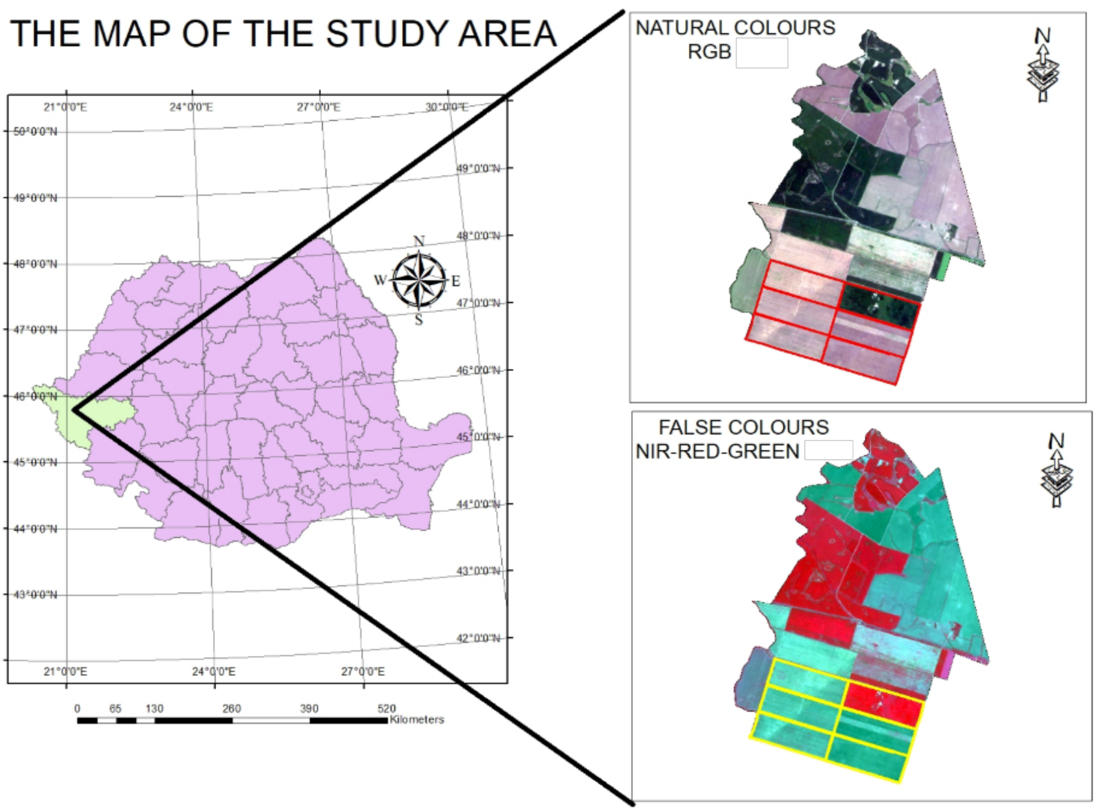

Fig.3. The map of study area

3. Results and Discussion

In this study, 12 RADAR - Sentinel 1 images were used taken from the portal https://scihub.copernicus.eu/dhus/#/home from 2020. The images were subjected to the following pre-processing processes [14]:

- **Calibration** - in order to process SAR data as accurately as possible, this data must be calibrated, especially when using data to make a mosaic of multiple images at different angles of incidence and relative brightness levels. Through the Calibration process, a radiometric correction of the SAR images is performed in such a way that the pixel values represent in a more accurate way the backscatter radar of the reflecting surface. The calibration process is essential when using quantitative SAR images. . The calibration allows the values of the images to be directly related to the backscatter of the surface

- **Speckle Filter** - this improved filter improves the quality of SAR images. Speckle is one of the biggest noise sources in SAR data

- **Terrain Correction** - this process will geocode the image by correcting the geometric distortions of SAR images using a DEM (Digital Elevation Model). Geometric corrections are very necessary due to the topographical variations of the scenes and the inclination of the radar sensor, which distort SAR images

- **Linear to From dB** - this process will allow to view products in decibel scale, creating a virtual band.

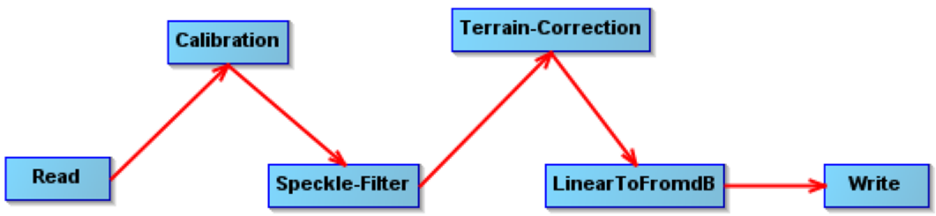

Fig.4.The steps of pre-processing process

In order not to pre-process the images individually, an automatic pre- processing model has been created, and the logical scheme is shown in Figure 4.

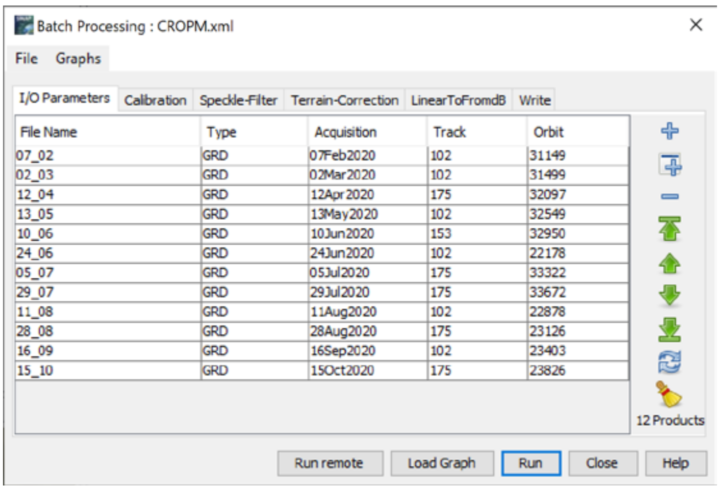

Fig.5. The Batch Processing window

After pre-processing the Time series, a stack was created with all the products and the result is a single product that contains all the information from the pre-processed images (Figure 4).

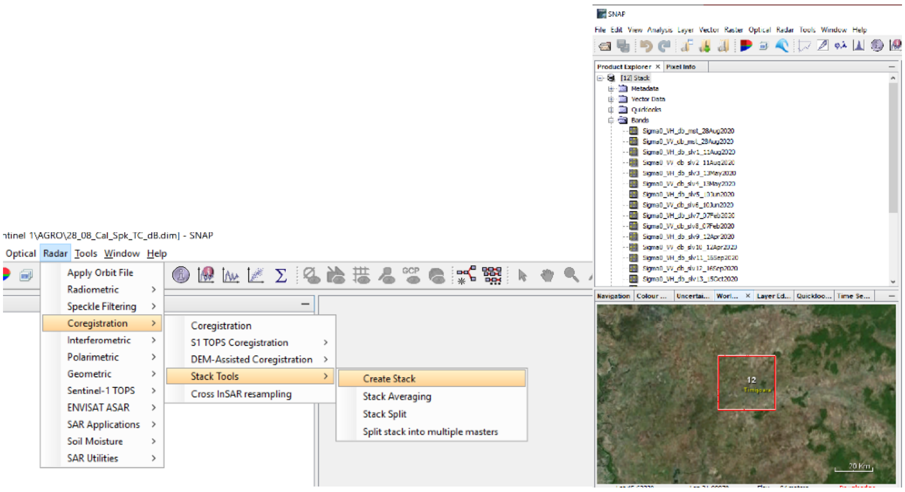

Fig.6.Creating a stack from all images

Based on the newly created product, various RGB products can be created depending on their utility.

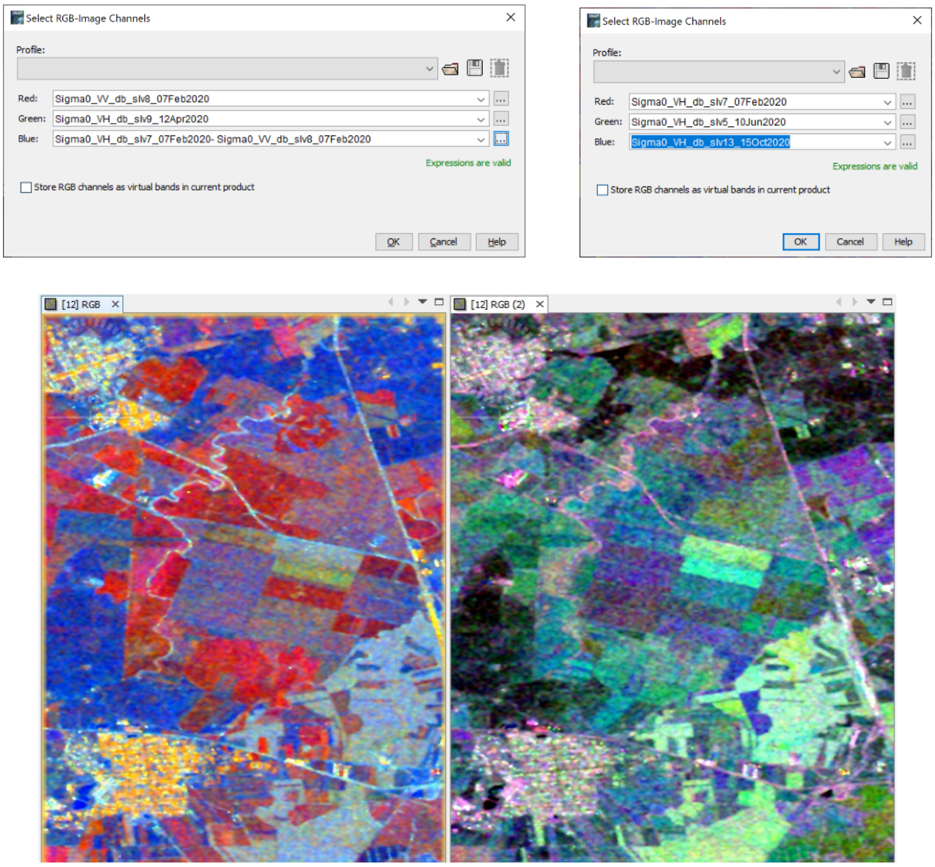

Fig.6.Creating RGB products
(R: VV_07_02_2020, G: VH_12_04_2020, B: VH_07_02_2020 – VV_07_02_2020)
(R: VH_07_02_2020, G: VH_10_06_2020, B: VH_15_10_2020)

The SNAP program allows the import of vector data, as an ESRI Shapefile format. Next 6 polygons were loaded on which the crops from 2020 are known, namely: Soybean, Rape and Barley.

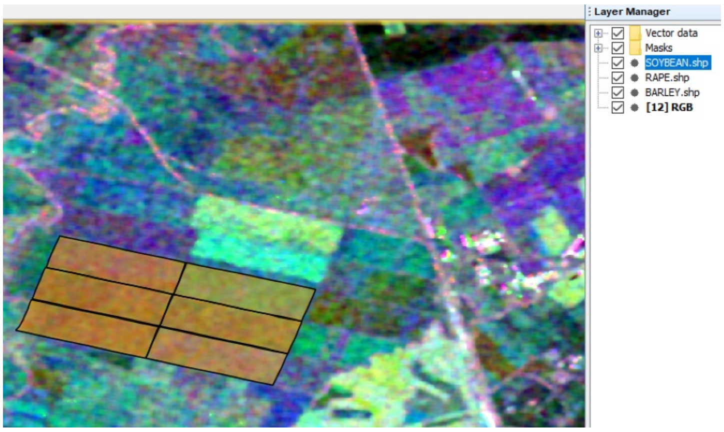

Fig.7.Adding the shapefiles of study area

In order to view the backscatter of the radar throughout the monitoring, a Time Series product was created with the pre-processed images, and then the agricultural crops were identified by marking each crop with a PIN.

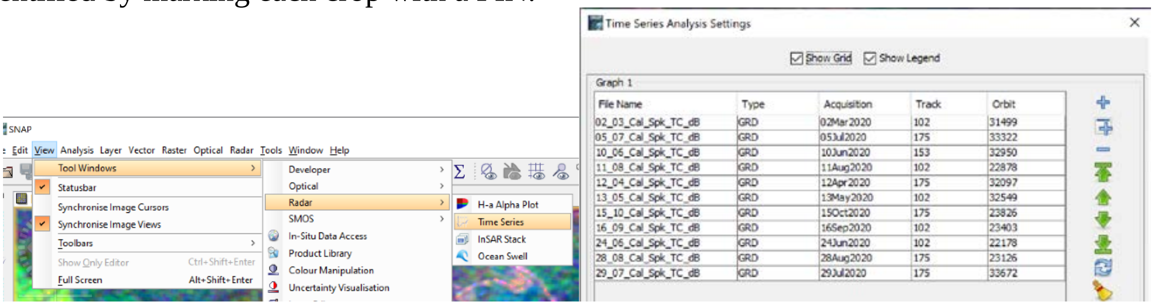

Fig.8. Creating a Time Series product

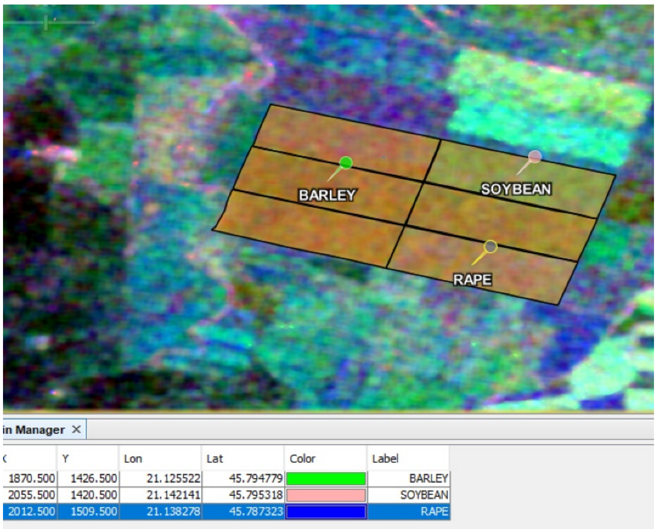

Fig.9. Identifying the crops

The backscatter of each crop throughout the monitoring period can be seen in the figures below.

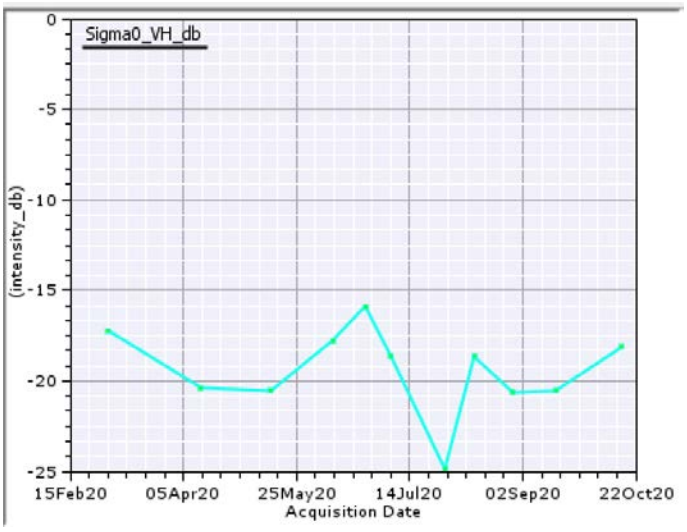

Fig.10. Sentinel-1 backscatter data for BARLEY

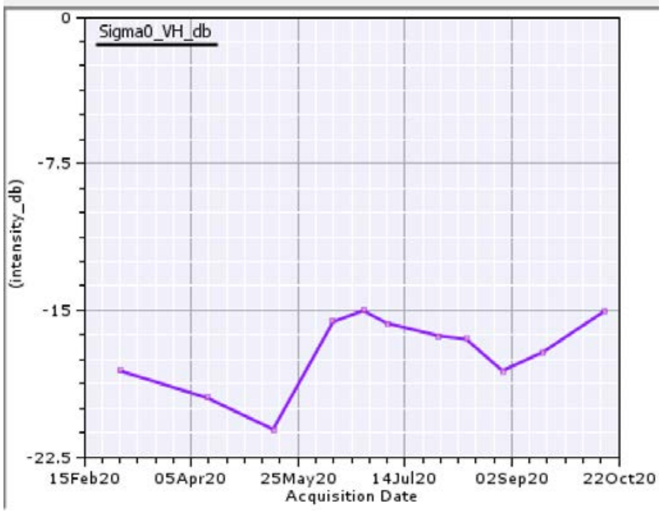

Fig.11. Sentinel-1 backscatter data for SOYBEAN

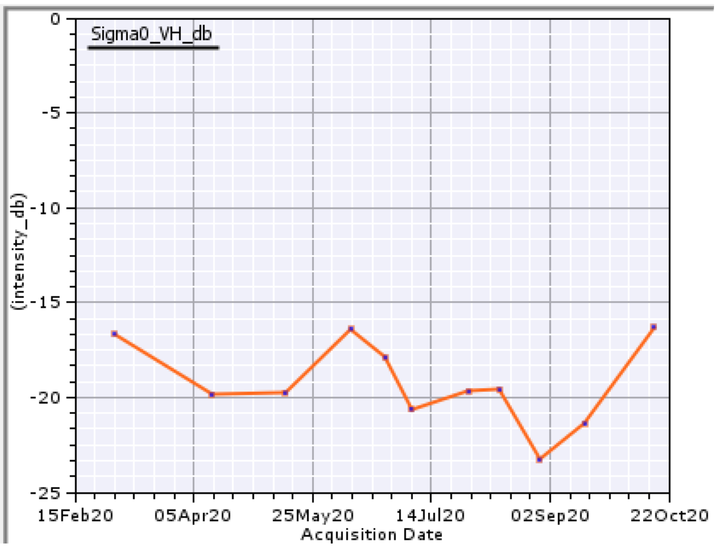

Fig.12. Sentinel-1 backscatter data for RAPE

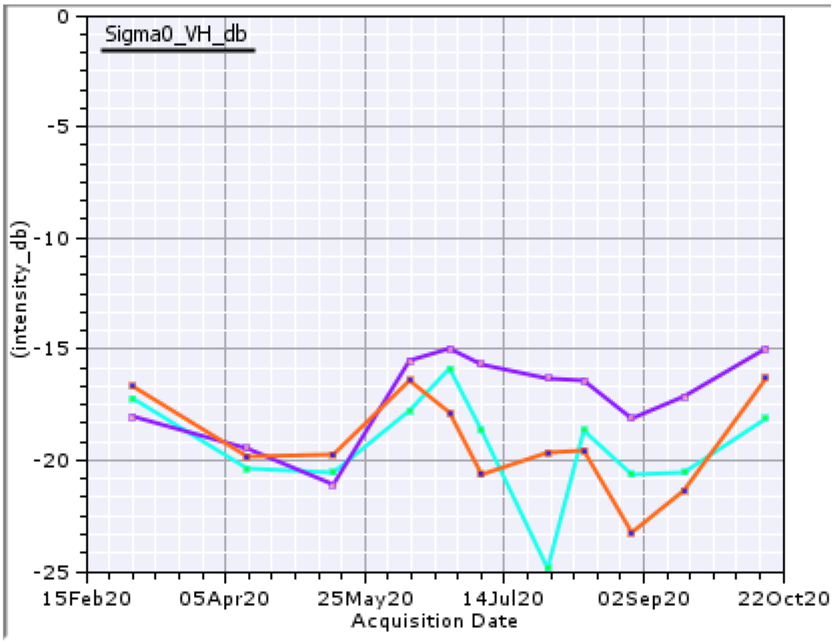

Fig.13. Sentinel-1 backscatter data for all three cultures

4. Conclusions

The results obtained in this study show the usefulness of Sentinel-1 SAR backscatter in the process of monitoring crops. The analysis of time evenings explains how the structure and biomass associated with the culture influence the backscatter throughout the season.

Based on the presented algorithm, similar cultures from other areas can be identified, following the similarities between the backscatters of the radar.

5. References

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