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ANALYSIS OF LAND COVER AND LAND USE CHANGES USING SENTINEL-2 IMAGES

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Abstract: Earth observation and space analysis of land areas, oceanic and atmospheric phenomena is a necessity nowadays.
European Space Agency (ESA) is developing a new family of satellites, called Sentinel, in order to perform the operational needs of the environmental monitoring program, Copernicus. Since 2014 until now ESA have successfully launched four satellites, which have a proven track record.
This paper contains information about Sentinel constellation, features of the satellite images and also the applications of Sentinel satellite images. This paper also describes how to purchase satellite data and the software that can be used to view and analysis data are named.
The aim of this paper is to analyze the changes of land cover and land use of study area, in two different periods, based on Sentinel satellite images.

Introduction

The Copernicus European program, founded in 1982, also known as GMES (*Global Monitoring for Environment and Security*), it is coordinated by the European Commission in partnership with the European Space Agency (ESA). The aims of Copernicus, named in honor of the great scientist and astronomer Nicolaus Copernicus's, is to monitor the state of the environment on land, at sea and in the atmosphere and also to improve citizens' security".

In order to meet the operational needs of Copernicus program, ESA developed the Sentinel family of missions (Fig. 1). There are six Sentinel mission, each relying on two identical satellites. So far were launched the radar satellites

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Sentinel-1A (April 2014) and Sentinel-1B (April 2016), the multispectral satellite Sentine-2A (June 2015) and also the ocean monitoring satellite Sentinel-3A (February 2016). The Sentinel mission 4, 5, 5P and 6 are expected to be released until 2020.

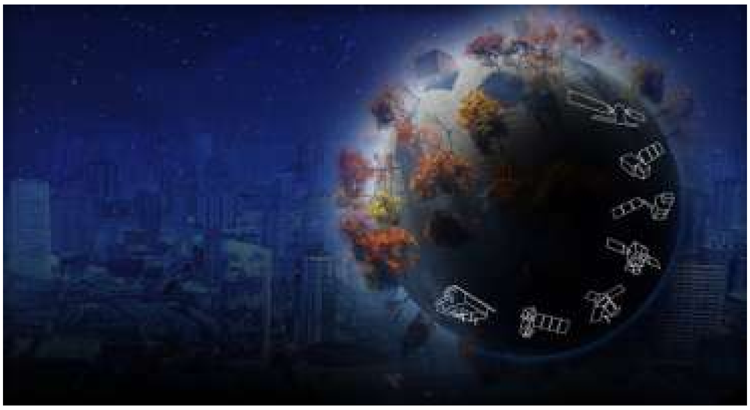


Fig. 1 Sentinel satellite family. Source: www.esa.int

The satellite images taken from the launched Sentinel so far, have a wide range of applications and can be acquired for free, having different levels of processing.

The multispectral images taken over by Sentinel-2A have resolutions up to 10 meters and have applications in agriculture for crop monitoring, monitoring of water, forests, risk assessment etc.

1. Sentinel Constellation

Sentinel missions are designed to increase the safety of European citizens by providing vital information in areas such as soil, sea, atmosphere, climate change, management of emergency situation and security.

The constellation contains a number of six Sentinel missions planned to be launched by 2030 (Tab. 1).

Sentinel-1 is a radar mission composed by two satellites, Sentinel-1A and Sentinel-1B, which provides images of Earth's surface regardless of weather conditions, day or night. Satellites have a capacity of 6-day revisit, providing information in various fields, from monitoring the effects of floods up to monitor ice from polluted waters. Radar images provided by Sentinel-1A satellite are currently used for monitoring Fogo Island, in the Republic of Cape Verde, under threat following the eruption of the Fogo volcano, on 23 November 2015 (fig. 2).

Tab. 1- Sentinel missions

Mission Name	Launch Date	EOL Date	Orbit type	Orbit altitude	Orbit period	Orbit inclination	Orbit sense
Sentinel-1 A	3-Apr-14	Jan-16	Sun-synchronous	693 km	98.74 mins	98.19 deg	Ascending
Sentinel-1 B	Feb-16	Apr-16	Sun-synchronous	693 km	98.74 mins	98.19 deg	Ascending
Sentinel-1 C	2019	2026	Sun-synchronous	693 km	98.74 mins	98.19 deg	Ascending
Sentinel-2 A	23-Jun-15	Jul-16	Sun-synchronous	786 km	100.7 mins	98.62 deg	Descending
Sentinel-2 B	Jul-16	May-16	Sun-synchronous	786 km	100.7 mins	98.62 deg	Descending
Sentinel-2 C	2020	2027	Sun-synchronous	786 km	100.7 mins	98.62 deg	Descending
Sentinel-3 A	Dec-16	Dec-16	Sun-synchronous	814 km	100 mins	98.65 deg	Descending
Sentinel-3 B	May-16	Jan-16	Sun-synchronous	814 km	100 mins	98.65 deg	Ascending
Sentinel-3 C	2020	2027	Sun-synchronous	814 km	100 mins	98.65 deg	Ascending
Sentinel-4 A	2021	2029	Geostationary	N/A	N/A	N/A	N/A
Sentinel-4 B	2029	2037	Geostationary	N/A	N/A	N/A	N/A
Sentinel-5 precursor	Apr-16	Dec-16	Sun-synchronous	824 km	17 mins	98.742 deg	Ascending
Sentinel-5A	2021	2028	Sun-synchronous	N/A	N/A	N/A	N/A
Sentinel-5B	2022	2030	N/A	N/A	N/A	N/A	N/A
Sentinel-6 A	2020	2025	Inclined, non-sun-synchronous	1336 km	112 mins	66 deg	N/A
Sentinel-6 B	2025	2030	Inclined, non-sun-synchronous	1336 km	112 mins	66 deg	N/A

Source: http://database.eohandbook.com/database/missiontable.aspx

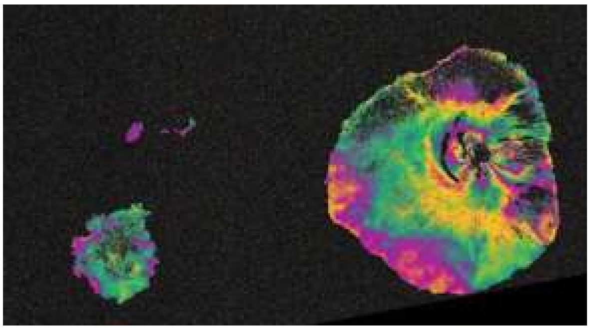


Fig. 2 Interferogram – before and after
Source: Copernicus data (2014)/ESA/Norut-PPO.labs–COMET-SEOM InSARap study

In Romania, during the drought of august 2015, images taken by the satellite Sentinel-1B, were used to monitor shipping on the Danube River, near the locality of Zimnicea (Fig. 3).

Fig. 3 Shipping along the Danube river, near Zimnicea, captured by Sentinel-1A on August 2, 2015. Source: Copernicus Sentinel/ESA

Sentinel 2 is a multispectral high-resolution mission aiming at monitoring the land zones, vegetation, soil, water, coastal areas, etc. Satellite Sentinel-2A was launched in June 2015, while the Sentinel-2B satellite will be launched in July 2016.

Sentinel-3 mission is a multi-use tool supporting global land and ocean monitoring services, in particular: sea/land color data and surface temperature; sea surface and land ice topography; coastal zones, inland water and sea ice topography; vegetation products. The satellites will be able to monitor the algae from the ocean surfaces and their movement directions. Sentinel-3A satellite was successfully launched in February 2016 while the Sentinel-3B will be released in May 2017.

Sentinel-4 mission aims at supporting European services composition and monitoring air quality. Sentinel satellites-4A and 4B are scheduled for launch in the year 2021, 2029 respectively.

The Sentinel-5 mission also has the atmospheric monitoring goal. Sentinel-4 and Sentinel-5 will be carried as a payload on meteorological satellites Meteosat Third Generation-Sounder (MTG) satellite, respectively MetOp Second Generation.

The Mission of Sentinel-5 Precursor is developed in order to reduce the gap between observations taken from Envisat and Sentinel-5 satellites. The mission will support global atmospheric composition and air quality monitoring services.

Sentinel-6 mission aims are to provide continuity of the reference, high-precision ocean topography service after Jason-3.

1. Characteristics of Sentinel-2 satellite imagery

The Sentinel-2 mission is based on a constellation of two satellites Sentinel-2A and Sentinel-2B (2016) and duration of the assignment is 7 years. The orbit of Sentinel-2 satellite is sun- synchronous, the orbit altitude is 786 km and the swath width of Sentinel-2 is 290 km. The satellite images can be acquired in JP2000 and XMP format, in UTM/WGS84 projection.

The Sentinel-2 products are available to users in two levels: Level-1B (Top-of-atmosphere radiances in sensor geometry) and Level-1C (Top-of-atmosphere reflectance in cartographic geometry). Users can process the satellite images to the Level-1C, using Sentinel-2 Toolbox, produced by ESA.

The revisit time of Sentinel-2A is 10 days, but with the launch of the satellite Sentinel-2B the time will be reduced to 5 days.

The Multispectral Instrument has 13 spectral bands, from visible and near infrared to shortwaves infrared, at different spatial resolution (Fig. 4).

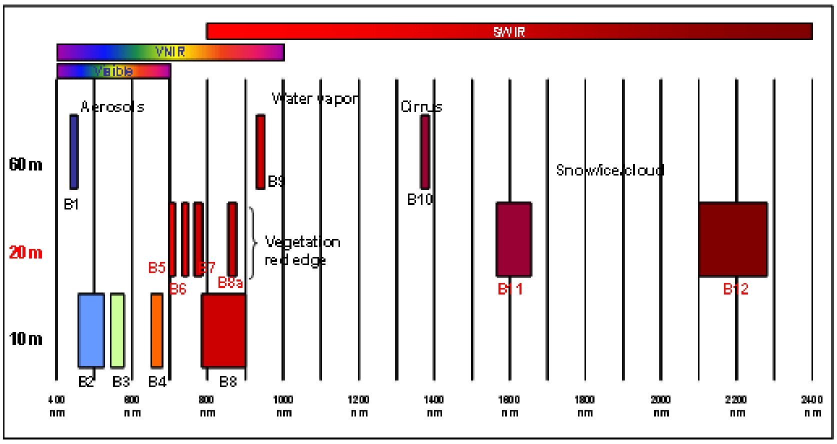


Fig. 4 Sentinel-2 bands
Source: [http://www.cesbio.ups-tlse.fr/us/index_sentinel2.html]

The spatial resolution of SENTINEL-2 is dependent on the particular spectral band: 10 meters for: B2, B3, B4 and B8; 20 meters for: B5, B6, B7, B8a, B11 and B12; and also 60 meters for B1, B9 and B10.

Sentinel-2 images can be acquired for free from the Sentinels Scientific Date Hub [https://scihub.esa.int] using a user account.

Image processing and analysis of Sentinel-2 can be done using free software produced by ESA: Sentinel Application Platform (SNAP), Sentinel-2 Toolbox. The satellite images also can be easily managed and analyzed using ArcGIS 10.4 software, recently released by the ESRI.

Tab. 2 Sentinel-2 Bands

Bnad	Description	Central Wavelength (µm)	Resolution (m)
B1	Ultra blue (Coastal and Aerosol)	0.443	60
B2	Blue	0.49	10
B3	Green	0.56	10
B4	Red	0.665	10
B5	NIR2	0.705	20
B6	NIR3	0.74	20
B7	NIR4	0.783	20
B8	NIR1	0.842	10
B8A	NIR5	0.865	20
B9	Water vapour	0.945	60
B10	Cirrus	1.375	60
B11	SWIR1	1.61	20
B12	SWIR2	2.19	20

Source: www.esa.int

2. Application of Sentinel-2 satellite imagery

High-resolution multispectral system formed by the Sentinel-2 satellites intended to continue providing observations, along with SPOT and Landsat missions, by improving the ROI time, area covered, the spectral bands as well as radiometric and geometric qualities control of images, ensuring operational needs of Copernicus program.

Fig. 5 Danube river, monitorized using Sentinel-2A images, on July, 26th 2015.
Source: Copernicus Sentinel/ESA

Sentinel-2 mission is aimed at supporting land monitoring related services, including: monitoring changes in land coverage for environmental assessment, crop monitoring and food safety, detailed monitoring of vegetation and forests, as well as the index of vegetation (the concentration of chlorophyll, estimating carbon mass, leaf area, leaf water content), observations upon the coastal areas (marine environment monitoring) and the monitoring of inland waters.

In Romania, the images from the satellite Sentinel-2A were used in the process of monitoring the Danube river during the dry summer of 2015 (Fig. 5), and to assess the material damage produced by the floods that have affected southern Romania in April 2014.

2. Analysis of land cover and land use changes using Sentinel-2 images

To analyze the land cover and land use changes using Sentinel-2 satellite images, two satellite images were used, taken within 5months, on November 30, 2015 and April 28, 2016. The study area is located in Galati County, at 45^{o} 54'N 27^{o}58'E.

The satellite images used were taken by Sentinel-2A and have been downloaded from Science Hub. The spatial resolution, for B2, B3, B4 and B8 bands is 10 meters, bands used in analysis of land cover and land use.

The images were processed and analyzed using SNAP software, Sentinel 2 Toolbox module developed by ESA. The module contains a set of tools for visualization, analysis and processing for high resolution satellite imagery. The program can process, besides images from the satellite Sentinel-2, images taken from satellites such as RapidEye, SPOT, MODIS, Landsat (TM) and others.

According to Bogdan M. (2008) "in remote sensing, color images are grouped in images in natural colors, in which spectral signature object is expressed through colors close to those perceived by the human eye, and false color images or images in unconventional colors, resulting from the replacement of natural colors with other colors that the human eye perceives not in reality, but who bring additional information."

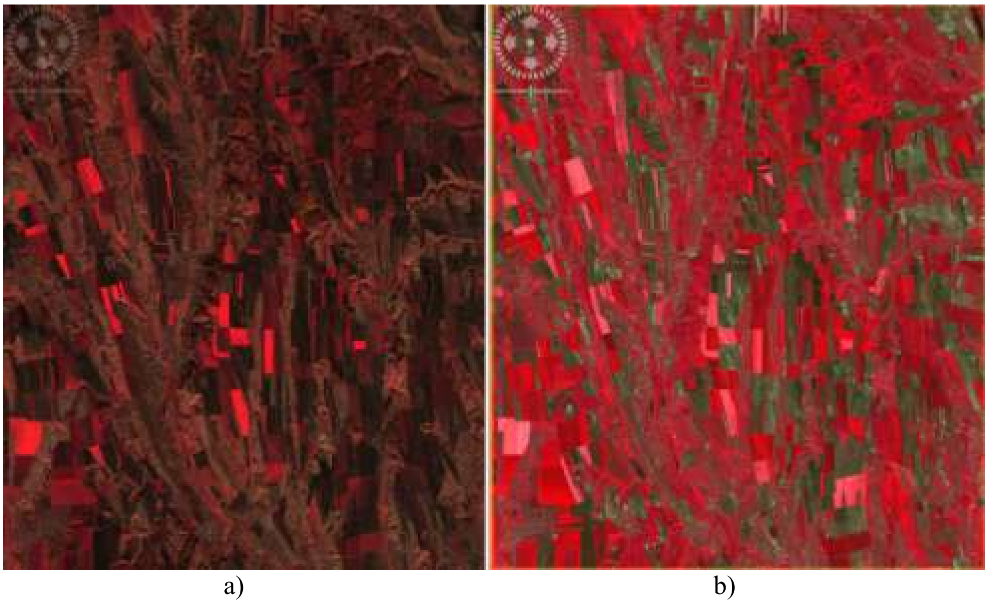
To view the images in natural colors we used red band- B4, green band- B3 and blue band- B2 (fig. 6), while for viewing images in the false colors we used Red band- B8, green band- B4 and blue band- B3 (fig. 7).

Spectral reflectance of vegetation depends on properties of the leaves, including the orientation and structure of them. The amount of energy reflected to a certain wavelength depends on their thickness, pigmentation and cell composition and the amount of water contained in them. Healthy vegetation reflects green light more than blue or red one. Also, the reflectance is higher in the field of near-infrared.

a) b)

Fig. 6 Satellite images in true color

Sentinel-2A image taken on 30.11.2015; b) Sentinel-2A image taken on 28.04.2016.

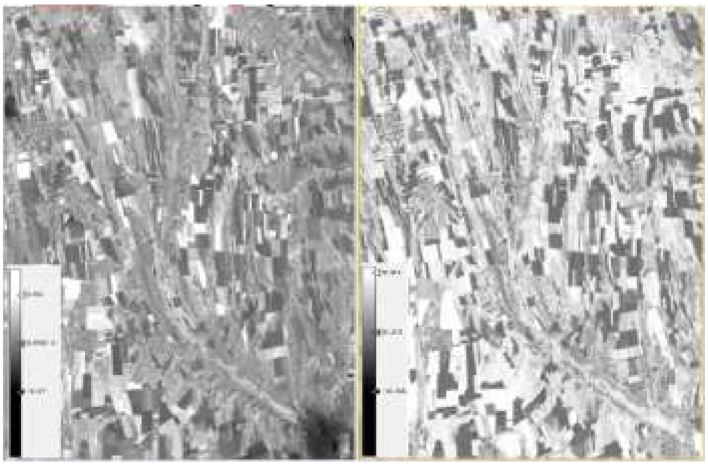


a) b)

Fig. 6 Satellite images in false color

Sentinel-2A image taken on 30.11.2015; b) Sentinel-2A image taken on 28.04.2016.

From the analysis of false color images, we can observe that the uncovered land is represented in greens, depending on the type of soil and its humidity. The vegetation is represented with red.



a) b)

Fig. 8 Normalized Difference Vegetation Index

a)NDVI for Sentinel-2A image taken on 30.11.2015; b) NDVI for Sentinel-2A image taken on 28.04.2016.

Rape seed crops, represented with the yellow in true color images, can be observed pink in false color, while green crops are represented in intense red. Water bodies are represented in the false color image with the color blue.

In order to determinate the area covers by vegetation, the Normalized Difference Vegetation Index (NDVI) was calculated for the two satellite images. NDVI have values between-1 and + 1 and express the dense green vegetation. The index varies depending on the radiation absorption by chlorophyll in the red spectral zone and its reflectance in the near-infrared spectral band.

The calculation formula for Normalized Difference Vegetation Index is:

$$NDVI = (NIR - R)/(NIR + R)$$

Where,

NDVI- Normalized Difference Vegetation Index

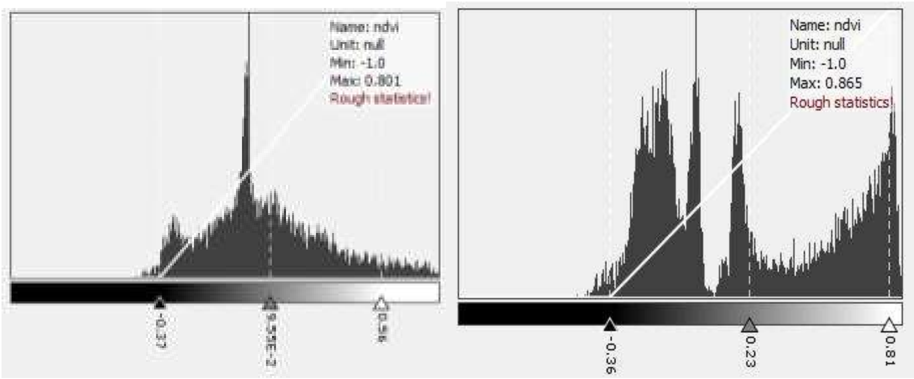
NIR- Near Infrared Band

R- Red Band

To calculate the NDVI of satellite images taken by Sentinel-2A we use Band 4 (Red Band) and Band 8 (Near Infrared Band).

To represent the land use we calculated the NDVI for both satellite images (Fig. 8) and we applied different mask to highlight the NDVI values (Fig. 9).

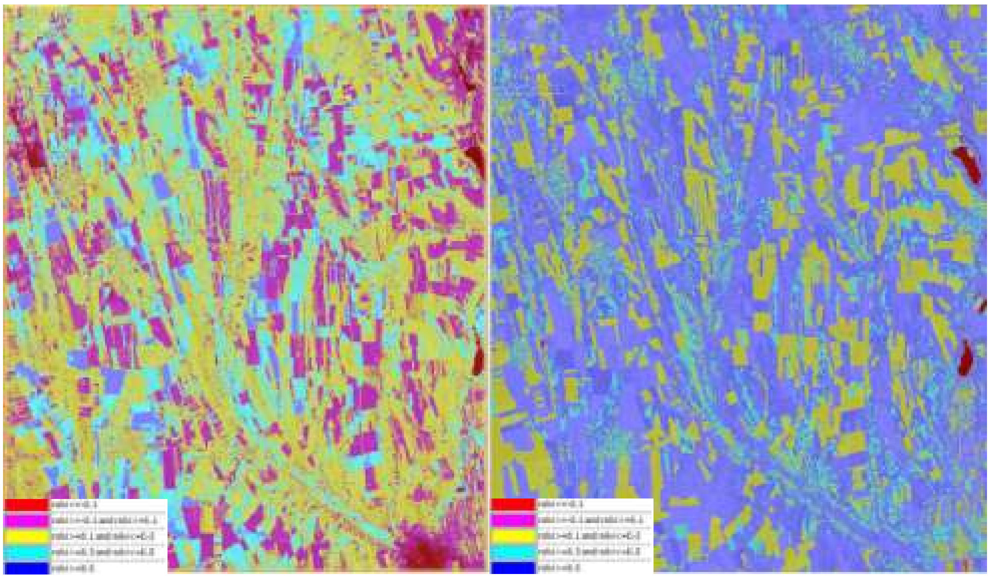
By analyzing those two images depicting a map of NDVI and their histograms (Fig. 9) we can observe that the NDVI values in December are between -0.37 and 0.801, most having values around 0. At the end of April, the NDVI values are between -0.36 and 0865, most values are in the range 0-0.2 and 0.3-0.8, respectively.



a) b)

Fig. 9 The histogram of NDVI

a)Histogram for Sentinel-2A image taken on 30.11.2015; b) Histogram from Sentinel-2A image taken on 28.04.2016.



a) b)

Fig. 10 NDVI with mask

a)NDVI for Sentinel-2A image taken on 30.11.2015; b) NDVI for Sentinel-2A image.

The degree of occupancy of the land and the differences between the two periods can be determined through analysis of NDVI. By applying masks and the establishment of thresholds, it was highlighted the coverage of the land, and its use (fig. 10).

Areas of water have smaller values of NDVI as -0.1, both in December and in April. Land not covered by vegetation, with moist soil or rock have values of NDVI between-0.1 and 0.1. They are prevalent in December and are represented on the map with the color purple. Those permanent grassland NDVI values between 0.1 and 0.3 in the month of December, the same values being relevant for land not covered by vegetation in April.

Low vegetation has values of NDVI between 0.3 and 0.5 being predominant in December and found fewer in April.

NDVI values greater than 0.5 are majority in April and fewer in December. These correspond to the rape crops, wheat and alfalfa.

Conclusions

The operational needs of the Copernicus program, developed by ESA, are met by the six satellite Sentinel missions.

Sentinel missions are designed to increase the safety of European citizens by providing vital information in areas such as soil, sea, atmosphere, climate change, management of emergency situation and security.

The multispectral high-resolution Sentinel-2 aims are monitoring the land areas, vegetation, soil, water, coastal areas etc. The revisit time of Sentinel-2A is 10 days, but with the launch of the satellite Sentinel-2B the time will be reduced to 5 days.

The Sentinel satellite images have already shown the applicability in different situations, from traffic monitoring to the assessment of damage caused by various natural disasters.

Image processing and analysis of Sentinel-2 can be done using free software produced by ESA: Sentinel Application Platform (SNAP), Sentinel-2 Toolbox. The satellite images also can be easily managed and analyzed using ArcGIS 10.4 software, recently released by the ESRI.

Based on the Normalized Difference Index of Vegetation we can determine the degree of occupancy of the land with vegetation. Through the analysis of the two NDVI images, we can observe visible differences between the two periods examined, the coverage of the land and how its use. Unoccupied areas by vegetation, having very low NDVI index in December, have a very high NDVI in April.

The main disadvantage of the Sentinel-2 Imaging is the fact that in the case of adverse weather conditions, the images cannot be used, unlike Sentinel-1 radar images, which can be used regardless of weather conditions.

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