FLOODS DAMAGE ESTIMATION USING SENTINEL-1 SATELLITE IMAGES. CASE STUDY-GALATI COUNTY, ROMANIA

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Abstract: *Romania has a long and well documented history of flooding, resulting in numerous material as well as human loses. In order to monitor and estimate flood damages in near-real time, numerous techniques can be used, from a simply digitizing on maps, to using detailed surveys or remote sensing techniques. However, when using the last mentioned technique, the results are conditioned by the time of data acquisition (day or night) as well as by weather conditions. Although, these impediments can be surpassed by using RADAR satellite imagery.The aim of this study is to delineate the land surface of Galati County that was affected by floods in October 2016. For this case study, Sentinel-1C-Band SAR data provided by ESA (European Space Agency) were used. The data sets were taken before and after the flood took place, all within 6 days and were processed using Sentinel Toolbox.*

Keywords: *flood map, Sentinel-1, RADAR, pre-processing.*

1. Introduction

In recent decades, the number of weather and hydrological disasters has been gradually increased, at the planetary level being affected hundreds of millions of people every year. Floods represent the most common disaster that may occur at different levels, having an effect on the well-being of the environment, including not only economical damage and ecological imbalances, but also numerous losses of human lives.

Romania has a long and well documented history of flooding and one of the biggest floods occurred in May- June 1970.Along the time, most affected counties in Romania were: Galati, Vrancea, Bacau, Vaslui, Gorj, Arges, Teleorman.

Monitoring the areas affected by flooding and damage to property assessment, represents an important step in managing crisis situations.In order to monitor and estimate flood damages in near-real time, numerous techniques can be used, from a simply digitizing on maps, to using detailed surveys or remote sensing techniques.

However, when using the last-mentioned technique, the results are conditioned by the time of data acquisition (day or night) as well as by weather conditions. Although, these impediments can be surpassed by using RADAR satellite imagery.

Copernicus is a European space flagship program led by the European Union in partnership with the European Space Agency (ESA). In order to meet the operational needs of Copernicus program, ESA developed the Sentinel family of missions.

Sentinel-1 is a radar mission composed by two satellites, Sentinel-1A and Sentinel-1B, which provides images of the Earth's surface regardless the 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.

Over 75% of natural disasters that occurred worldwide involves flooding. SAR's inherent capability to observe during cloud cover and SENTINEL-1's frequent revisits, makes the images taken with this satellite, ideal for flood monitoring. Also, the images can be used to assess the extent of flooded areas and the impact on human, economical and environmental loss.

Furthermore, high-resolution digital elevation models (DEMs) generated through SENTINEL-1's interferometric modes can be used to conduct run-off and inundation analysis in areas previously lacking.

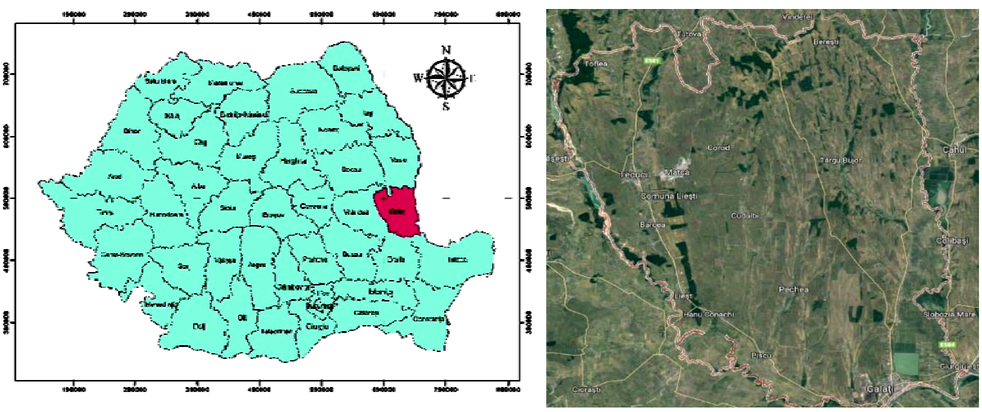
The aim of this study is to delineate the land surface of Galati County that was affected by floods in 10-12 October 2016.

2. Presentation of the Study Area, Materials and Equipment

2.1. Presentation of the Study Area

The study area is represented by Galati county, situated in the South-Est of Romania, in Moldavia region, centered at N45°50′, E27°56′(Fig. 1). Galati county has 2 municipalities, 2 towns and 61 communes and a total area of 4466 km^2.

The county lies on a low plain, with elevation from 5-10 meters in South, up to 310 meters in North.



(a) (b)

Fig. 1.(a) Location of the study area and (b) Galati county

2.2. Materials and Equipment

To analyze the flood damage,Level-1 Single Look Complex (SLC) Setinel-1C-Band SAR data was used, collected in the Interferometric Wide swath (IW) mode. This mode allows the combination of a large swath width (250 km) and it has dual polarization capability (VV+VH), which can provide more ground surface information [1].

The satellite images were captured consecutively by satellite Sentinel 1B, before and after the flood took place. The acquisition date is 08October 2016, at 4:20 a.m. and 15 October 2016 at 4:12 a.m. Sentinel-1 is a two-SAR satellite constellation designed to guarantee global coverage with a revisit time of 6 days.The area covered by the satellite images is presented in Fig. 2.

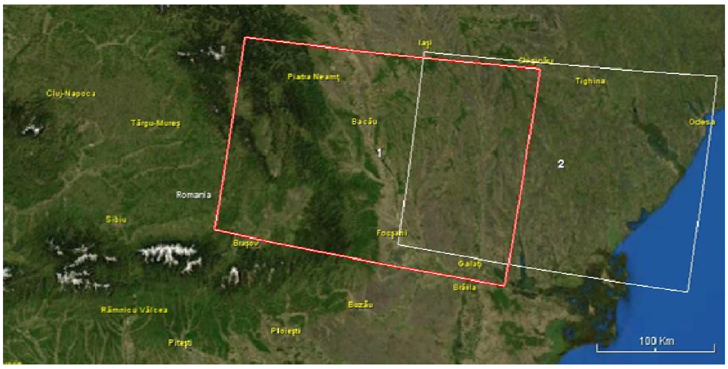


Fig. 2.Area covered by satellite images used in this study

The data used in this study have been downloaded for free from the European Space Agency (ESA) through Sentinels Scientific Data Hub (https://scihub.esa.int/).

2.3 Data processing

The images were processed and analyzed using SNAP software, Sentinel-1 Toolbox (S1TBX) module developed by ESA. The module contains a set of tools for readers, writers, analysis and processing for SAR data. The program can process, besides images from the satellite Sentinel-1, the images taken from satellites such as ALOS PALSAR, TerraSAR-X, COSMO-SkyMed and RADARSAT-2.

The Toolbox includes tools for calibration, speckle filtering, coregistration, orthorectification, mosaicking, data conversion, polarimetry and interferometry. Also, the program can automatically detect ship, windfields, oilspill detection and export them as shape vectors.

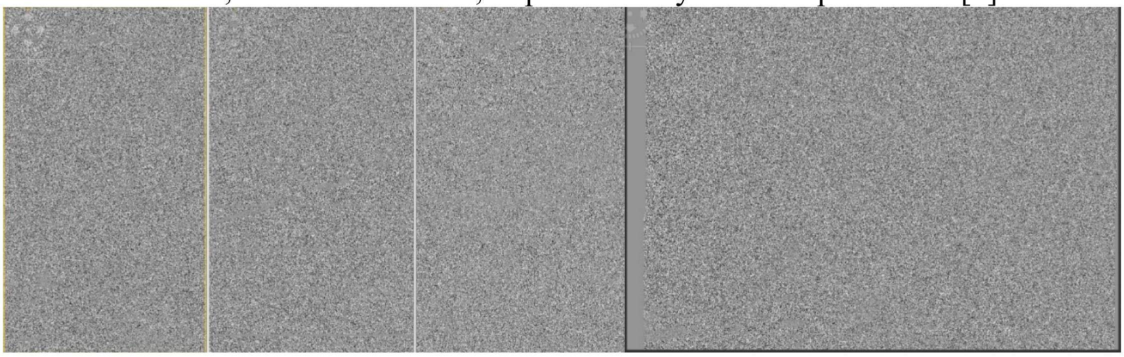
ArcMap 10.1, developed by ESRI, has been used for the surface covered by water determination.

3. Results and Discussion

3.1 Pre-processing corrections

The Toolbox Sentinel-1 of the SNAP software was utilized to pre-process the SAR images. In order to correct the images, the following steps were applied: Calibration, Thermal Noise Removal, TOPSAR- Deburst, Speckle- Filter, SRGr and GRD.

The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter of the scene. Typical SAR raw data processing, which produces Level 1 images (Fig. 3), does not include radiometric corrections and significant radiometric bias remains. Therefore, it is necessary to apply the radiometric correction to SAR images so that the pixel values of the SAR images truly represent the radar backscatter of the reflecting surface. The radiometric correction is also necessary for the comparison of SAR images acquired with different sensors, or acquired from the same sensor but at different times, in different modes, or processed by different processors [2].



(a) (b)

Fig. 3. Sentinel-1 Image-(a) Level-1 SLC and (b) Detail

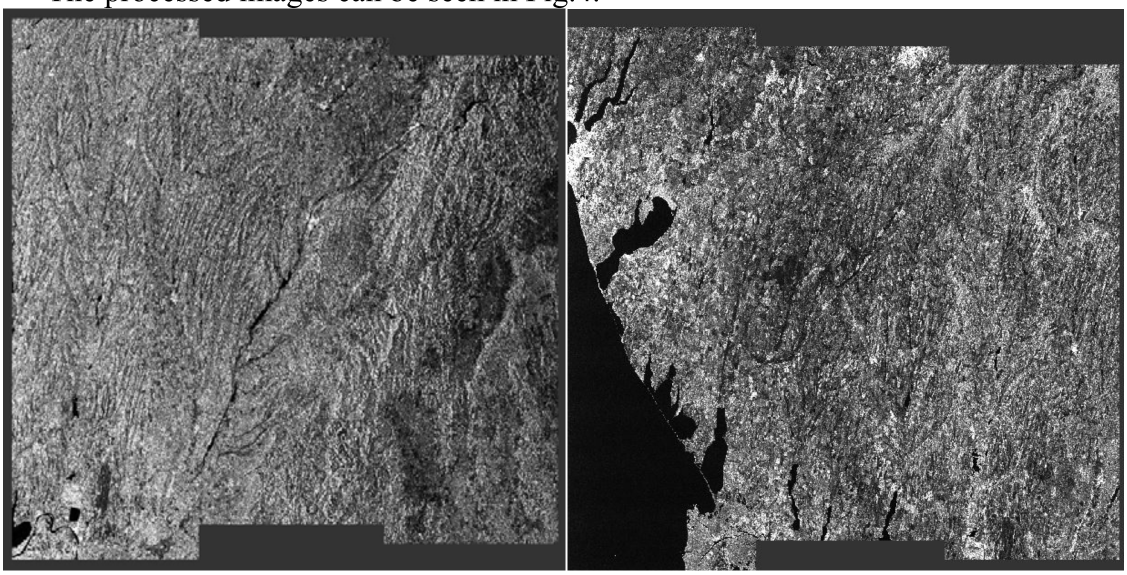
Thermal noise removal uses the noise vectors to remove dark strips near scene edges with invalid data.

In TOPSAT deburst process the images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information.After de-bursting and merging the sub-swaths, a wide area product is created. The TOPSAR technique greatly reduces scalloping effects over conventional ScanSAR [3].

Speckle is caused by random constructive and destructive interference resulting in "salt and pepper" noise throughout the image. Speckle filters can be applied to the data to reduce the amount of speckle at the cost of blurred features or reduced resolution.[4]

The SRGRoperator re-projects images from slant range (range spacing proportional to echo delay) to ground range.

The processed images can be seen in Fig.4.



(a) (b)

Fig. 4. Processed satellite images taken in (a) 08.10.2016 and (b) 15.10.2016

3.2 Geometric correction

The original SAR image is inverted in the SNAP. It is displayed according to the order of data acquisition, which is not according to a cartographic representation. To reproject the images from geometry of the sensor to the geographic projection, terrain correction was applied. For this case study, the WGS 84geographic projection was used.

Terrain Correction will geocode the image by correcting SAR geometric distortions using a digital elevation model (DEM) and producing a map projected product. Geocoding converts an image from Slant Range or Ground Range Geometry into a Map Coordinate System. Terrain Geocoding involves using a Digital Elevation Model (DEM) to correct for inherent SAR geometry effects such as foreshortening, lay over and shadow [5].

The Digital Elevation Model used to correct the terrain was Shuttle Radar Topography Mission (SRTM) with spatial resolution 3 arc-second.

The geometrically corrected satellite images are presented in Fig. 5.

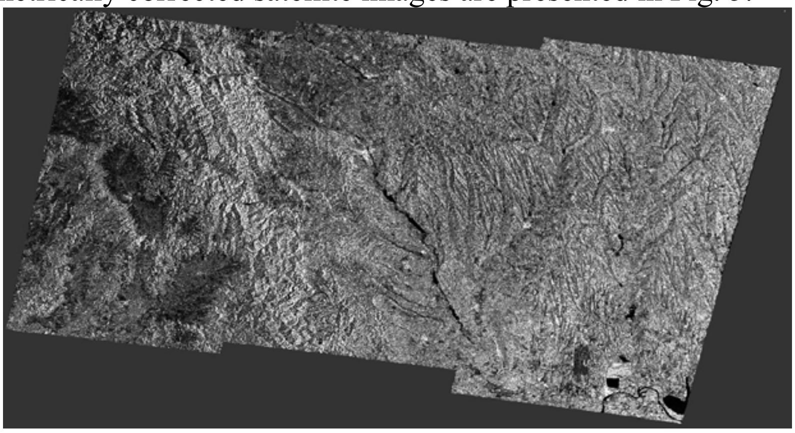
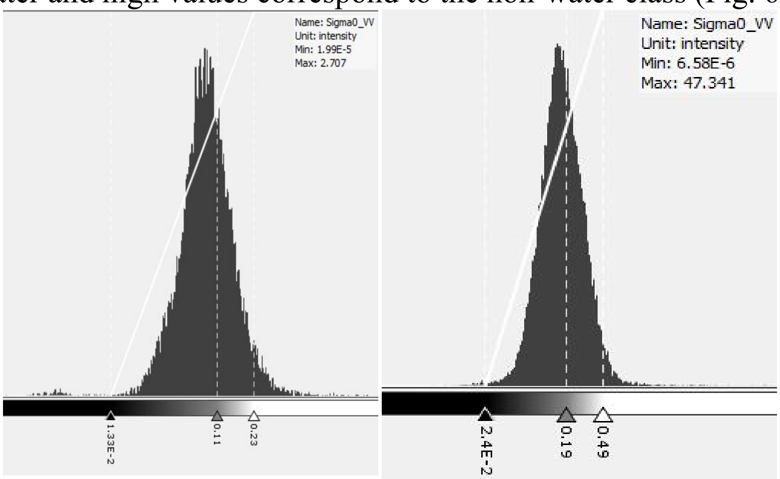


Fig. 5. Geometrically corrected satellite images

3.3 Determination of areas covered by water

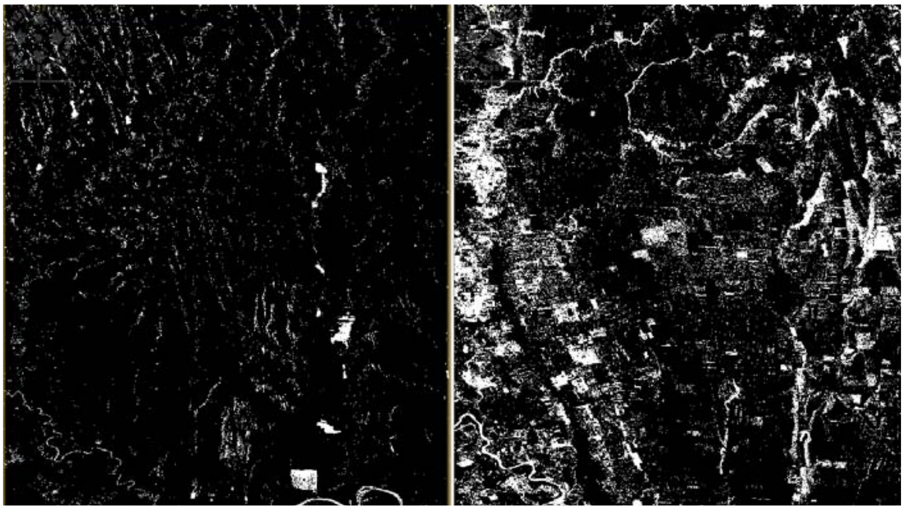
To separate water from non-water a threshold has been selected. For this purpose,the histogram of the filtered backscatter coefficient was analyzed. Low values of the backscatter correspond to the water and high values correspond to the non-water class (Fig. 6) [6][7].



(a) (b)

Fig. 6.Histogram of the image taken on (a) 08.10. 2016 and (b) 15.10.2016

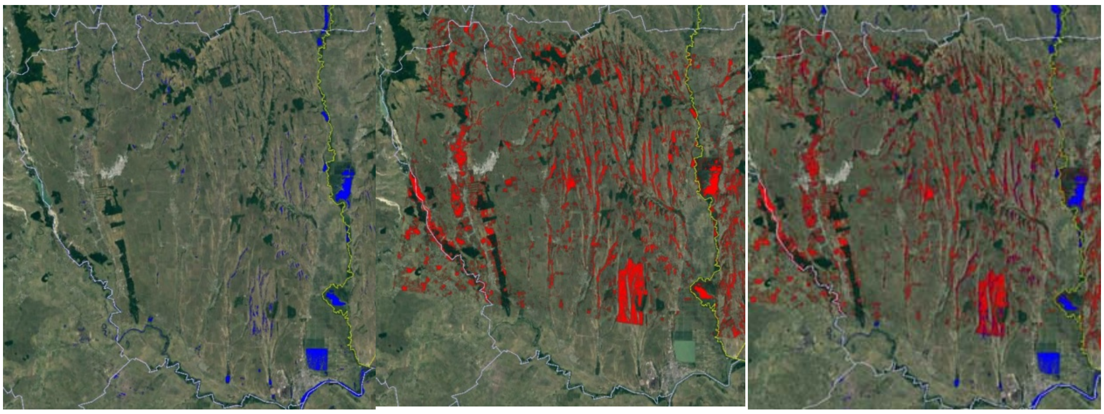
After establishing the threshold,a binary image was created in which, water bodies are represented with white and non-water with black.



(a) (b)

Fig. 7.The resulted satellite images after the binarization process (a) image taken on 08.10. 2016 and (b) image taken on 15.10.2016

In order to view and analyze the areas covered by water, these were represented with different colors. So, the areas covered by waterbefore the floods were coloured in red (Fig. 8 a) and the ones after the floods were coloured in blue (Fig. 8 b).



(a) (b) (c)

Fig. 8. Land covered by water (a) before the floods 08.10.2016, (b) after the floods 15.10.2016 and (c) overlapping of the two images

Details of the image obtained by overlapping the water body, before and after the floods, can be seen in Fig. 9.

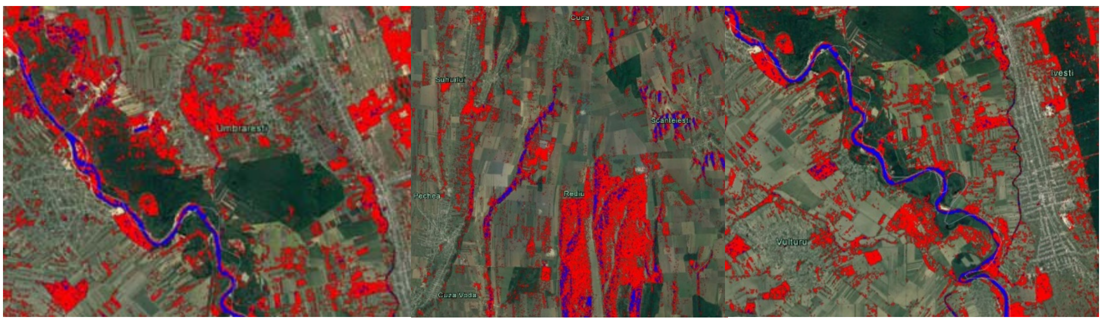


Fig. 9. Overlaying the water body in the two-timeperiods-details.

In order to calculate the surface covered by water after the flood, the images have been processed in ArcMap software. In a first step, the binary rasterswere converted in shapefile, using Raster to Polygon tools (Fig. 10).

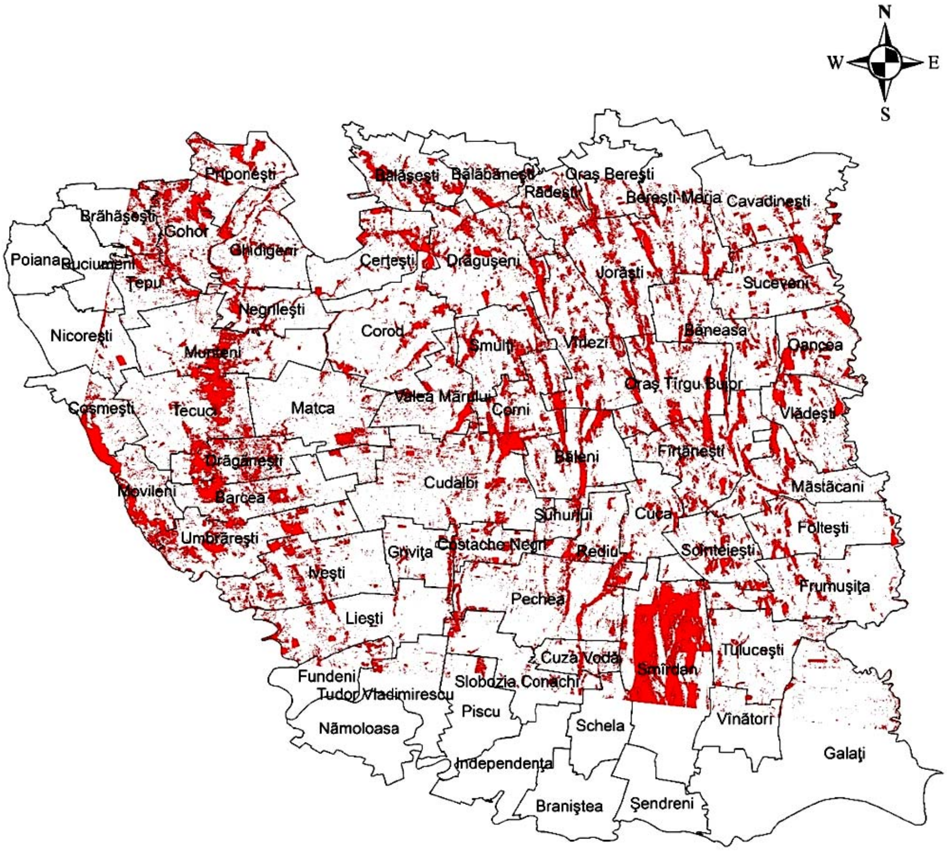


Fig. 10. Land covered by water, represented with red colour

Analyzing the results,it can be seen that,from the total surface of 446600 ha of Galati County, 120346 hahave been affected by floods, representing over a quarter of the total surface. The result is not comprehensive, because there is no info for the southern area of the County. For communes Poiana,Namoloasa, Branistea andSendrenithere are no data, while for 14 other communes the data are incomplete.

The most affected municipalities wereCorni, Gohor, Smardan, Tepu and Varlezi, where more than 60% of the territory was covered by water. Other communes affected by flood were: Fartanesti (49%), Jorasti (57%), Munteni (52%), Pechea (38%) andValeaMarului (38%).

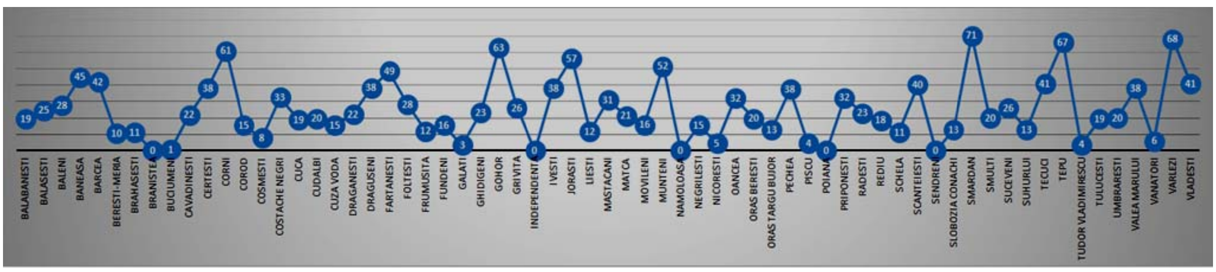


Fig. 11. Percentage of communes area covered by water

4. Conclusions

Sentinel-1 provides images of the Earth's surface regardless of weather conditions, day or night and have a capacity of 6-day revisit, providing information in various fields, from monitoring the effects of floods up to monitoring ice from polluted waters.

To analyze the flood damage Level-1 Single Look Complex (SLC) Setinel-1C-Band SAR data was used, collected in the Interferometric Wide swath (IW) mode. This mode allows the combination of a large swath width (250 km) and it has dual polarization capability (VV+VH), which can provide more ground surface information.

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The images were processed and analyzed using SNAP software, Sentinel-1 Toolbox (S1TBX) module developed by ESA.

After the pre-processing stage a histogram of backscatter coefficients was generated and it was used to determine a value which most accurately reflects the threshold between water and non-water. Finally, the resulting binary raster images were converted into a vector dataset for analysis.

The floods that took place in 10-12 October 2016, affected more than a quarter of the Galati county total surface, i.eabout 120000 ha.The most affected communes from Galati county were Smardan, Varlezi, Pechea, Munteni andTecuci.

Floods taking place in Romania, are the consequences, first of the climate change and global warming, and secondly in the anthropogenic intervention.

In Romania, amid these global changes, flood's production of small river basins is caused by the uncontrolled deforestation made after 1990, which lead to a drain of water on slopes,intensification of soil erosion and landslides, of clogging riverbeds minor and construction of housing and other facilities in the fields of virtual spaces.

5. References

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