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Research Paper

SENTINEL-2 Imagery for Mapping and Monitoring Flooding in Buna River Area

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Abstract: Monitoring open water bodies accurately is an important and basic application in remote sensing. Various water body mapping approaches have been developed to extract water bodies from multispectral images. The method based on the spectral water index, especially the Normalized Difference Water Index (NDWI) calculated from the Green and Near Infrared (NIR) bands, is one of the most popular methods. The Sentinel-2 satellite can provide fine spatial resolution multispectral images. This new dataset is potentially of important significance for regional water bodies' mapping, due to its free access and frequent revisit capabilities. It is noted that the green and NIR bands of Sentinel-2 have same spatial resolutions of 10 m, respectively. In this paper NDWI was produced from Sentinel-2 at the spatial resolution of 10 m. This scheme provides the detailed information available at the 10-m resolution.

Keywords: *Flooding, NDWI, Sentinel-2, Image*

Introduction

Sentinel satellite constellation of the Copernicus program of the European Union (Berger, Moreno, Johannessen, Levelt, & Hanssen, 2012,) provides synthetic aperture radar (SAR) and multispectral data with global coverage. Every year, flood events cause great economic losses and victims (Ward, et al., 2013). For this reason, precise flood mapping and modelling are essential for flood hazard assessment (Moel, Alphen, & Aerts, 2009), damage estimation (Amadio, Mysiak, Carrera, & Koks, 2016) and sustainable urban planning to properly manage flood risk (Ran & Nedovic-Budic, 2016,). In such a context, satellite remote sensing is currently a low-cost tool that can be profitably exploited for flood mapping (Fayne, Bolten, Lakshmi, & Ahamed, 2017).

At present, remote sensing has become a routine approach for land surface water bodies' monitoring, because the acquired data can provide macroscopic, real-time, dynamic and cost-effective information, which is substantially different from conventional in situ measurements (Chen, Zhang, Ekroos, & Hallikainen, 2004) (Feng, et al., 2012,). Each remote sensing technique for flood mapping presents advantages and drawbacks (Malinowski, Groom, Heckrath, & Schwanghart, 2017) that must be evaluated on a case-by-case basis. The frequent passes of satellites and the availability of rapid processing chains allowed the development of services providing automatic and quasi-real time flood mapping such as, for example, the Copernicus Emergency Management Service (EMS) performed by the European Union (online:) (Ajmar, Boccardo, Broglia, Kucera, & Wania, 2017). However, these services provide rapid mapping products that can be affected by uncertainty and are not always validated (Revilla-Romero, et al., 2015,). Maps of flooded areas produced by official authorities and based on bespoke aerial photos and field surveys are more accurate, although they are time-consuming and require higher costs to be generated. Various methods, including single band density slicing (Work & Gilmer, 1976), unsupervised and supervised classification (Sivanpillai & Miller, 2010,) and spectral water indexes (Li, et al., 2013), were developed in order to extract water bodies from different remote sensing images. Among all existing water body mapping methods, the spectral water index-based method is a type of reliable method, because it is user friendly, efficient and has low computational cost (Ryu, Won, & Min, 2002). In this work, we present the Normalized Difference Water Index (NDWI) proposed by McFeeters (McFeeters, 1996), using the green and Near Infrared (NIR) bands of remote sensing images based on the phenomenon that the water body has strong absorbability and low radiation in the range from visible to infrared wavelengths. NDWI can enhance the water information effectively in most cases, but it is sensitive to built-up land and often results in over-estimated water bodies.

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Open Street Map data were used for visual interpretation of the results. The image processing and analyses was carried out in ESA SNAP Desktop and QGIS Desktop.

Materials and Method

Study Site and Data Set

The River Buna runs in the last North-west segment of the Albanian Montenegrin border. This river springs from Lake of Shkoder, quite close to the city of Shkoder. Buna runs to the south, alongside Taraboshi up to its mouth in Adriatic Sea. The river has a length of 44 km. Lake Shkodra, Drin and Kir Rivers, drain into the Buna, which flows towards and empties into the Adriatic Sea. The combined flow from the other rivers and the lake into the Buna River can sometimes add up to more water volume than the Buna River can hold, causing it to overflow. It is of great interest to extract surface open water bodies and to monitor their changes in the Buna river area.

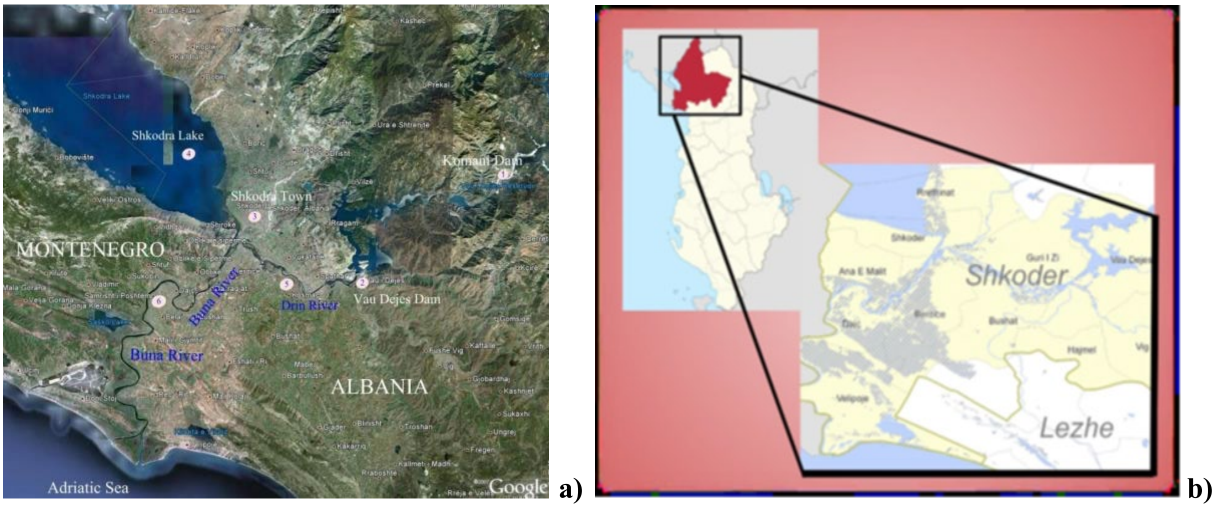


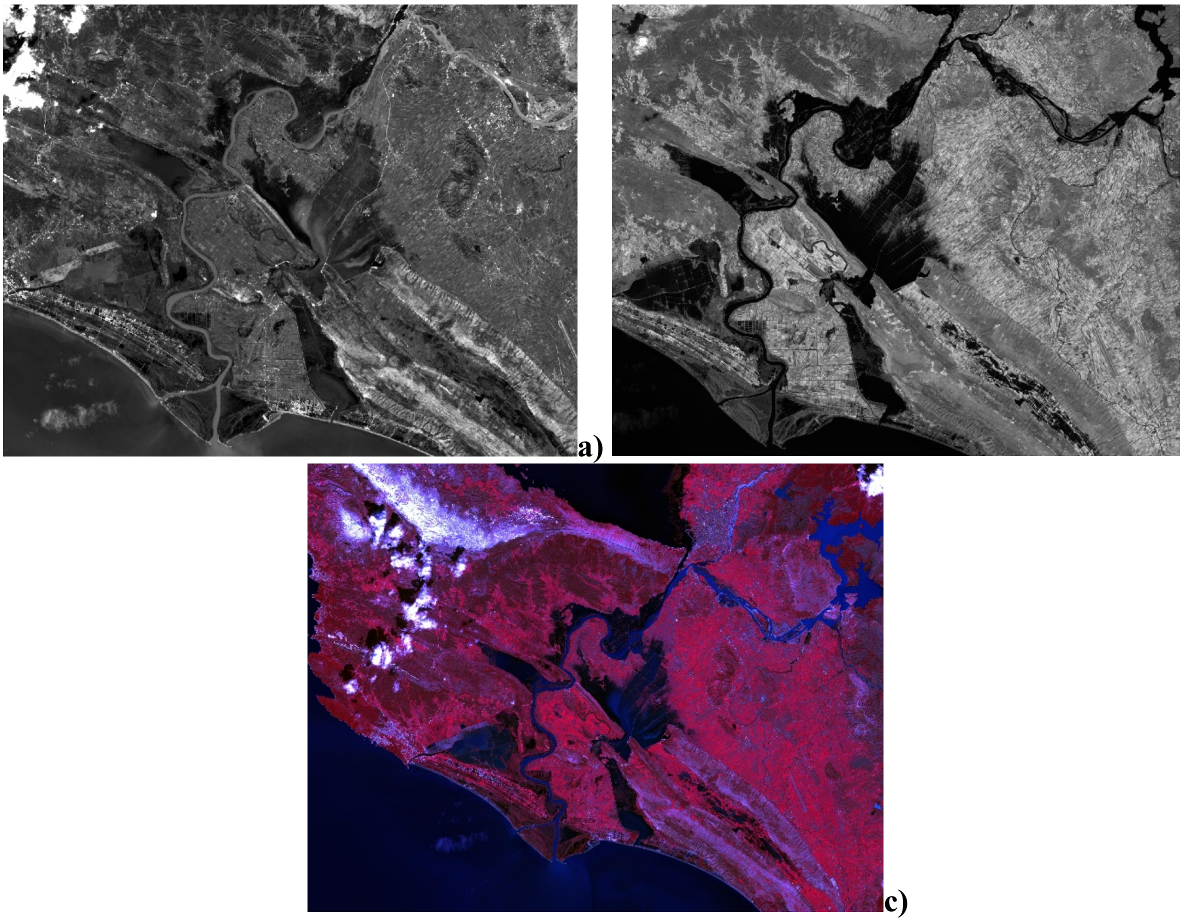
Figure 1. a) Satellite image of the Drin and Buna rivers (Earth, 2020) **b)** Drin and Buna River Basin – overview (GIZ., 2015))

The dataset used in this study is the standard Sentinel-2A Level-2A product, which was produced by radiometric and geometric corrections, including ortho-rectification and spatial registration on a global reference system with sub-pixel accuracy. The Sentinel-2A Level-2A product is composed of 100 km × 100 km tiles in the UTM/WGS84 projection and provides the Bottom-Of-Atmosphere (BOA) reflectance. The UTM (Universal Transverse Mercator) system divides the Earth's surface into 60 zones. Each UTM zone has a vertical width of 6° of longitude and horizontal width of 8° of latitude. This study used a Sentinel-2 Level-2A image scene (date of acquisition: 28.03.2018). It was downloaded from the ESA Sentinel-2 Pre-Operations Hub (https://scihub.copernicus.eu/).

Open Street Map data were used for visual interpretation of the results. The image processing and analyses was carried out in ESA SNAP Desktop and QGIS Desktop

Sentinel-2 Imagery

SENTINEL-2 is a European wide-swath, high-resolution, multispectral imaging mission. The full mission specification of the twin satellites flying in the same orbit but phased at 180°, is designed to give a high revisit frequency of 5 days at the Equator. SENTINEL-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. The orbital swath width is 290 km (ESA, 2020). SENTINEL-2 makes a significant contribution to Copernicus themes such as climate change, land monitoring, emergency management, and security. The false colour composite of the Sentinel-2 image at 10 m is shown in Figure 2a.



a) b) c)

Figure 2. (**a**) 10-m green Band 3); (**b**) 10-m NIR Band 8; (**c**) Ten-meter false color map (R: Band 8; G: Band 4; B: Band 3);

Methodology

Spectral Water Indexes

The NDWI proposed by McFeeters (McFeeters, 1996) is designed to: (1) maximize the reflectance of the water body in the green band; (2) minimize the reflectance of water body in the NIR band (Sun, Sun, Chen, & Gong, 2012,), (Xu, 2006,). NDWI is calculated as:

$$\text{NDWI}=\frac{\rho Green-\rho NIR}{\rho Green+\rho NIR} \qquad (1)$$

Where ρGreen is the BOA reflectance value of the green band and ρNIR is the BOA reflectance value of the NIR band. Therefore, no additional pre-processing is required, and the NDWI for Sentinel-2 can be directly calculated as:

$$\text{NDWI}_{10m}=\frac{\rho 3-\rho 8}{\rho 3+\rho 8} \qquad (2)$$

Note that both Band 3 and Band 8 of Sentinel-2 have the spatial resolution of 10 m, and thus, the calculated NDWI in Equation (2) also has the spatial resolution of 10 m.
Afterwards, the NDVI was computed with the well-known method as follows: Then, impervious mask was obtain using threshold values for NDVI.

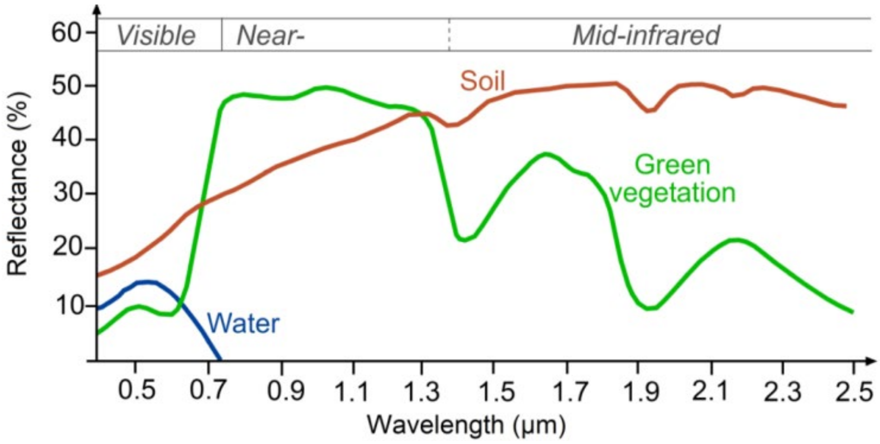


Figure 3. The spectral reflectance curves for water, soil and green vegetation;

Results

Sentinel-2 products contains 13 spectral bands in three different spatial resolutions.

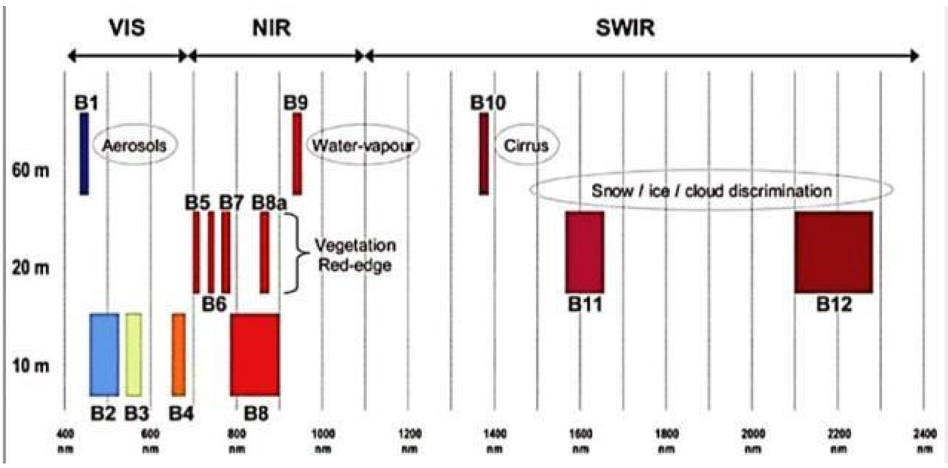


Figure 4: SENTINEL-2 spatial resolution bands **(ESA, 2020)**

The surface area measured on the ground and represented by an individual pixel. Many operators in SNAP toolbox do not support products with bands of different sizes so first we need to resample the bands to equal resolution. We define the size of resampled product by reference band B2.

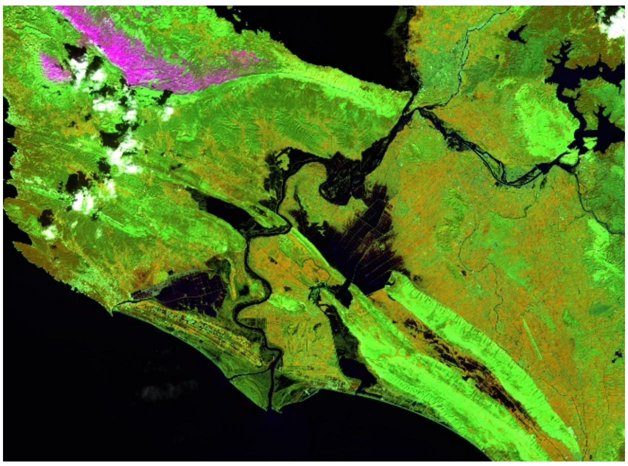
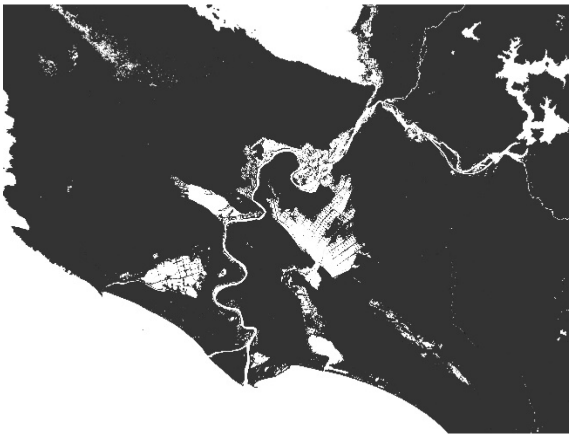


Figure 5: Ten-meter RGB image (R: Band 8; G: Band 11; B: Band 4);

To detect the water bodies we will use the Normalized Difference Water Index - NDWI it was proposed by McFeeters (McFeeters, 1996) and it is designed to: i) maximize the reflectance of the water body in the green band; ii) minimize the reflectance of water body in the NIR band. In figure 6 the open water pixels appear much brighter than other surfaces.

Figure 6. Image of the water bodies with Normalized Difference Water Index – NDWI

After detected the water bodies with NDWI, we create another new band that will only contain water surfaces. We will set the threshold for pixel to be classified as water to >= 0. In figure 7 we see the water mask.



a)

b)

Figure 7. a) The water mask of Buna river Area; **b**) The visualization of water mask in QGIS with base map the world map

Conclusions

The newly-launched Sentinel-2 can provide fine spatial resolution multispectral imagery at a fine temporal resolution, which makes it an important dataset for water bodies' mapping at the global scale. In this paper, a method is proposed for water bodies' mapping from the Sentinel-2 image by producing the 10-m NDWI image.

The experiment on the subset Sentinel-2 image located at Buna river area demonstrates that NDWI is efficient to enhance water bodies and to suppress built-up features than NDWI.

To estimate the flood water level, we developed a method that involves three steps, namely, To detect the water bodies we used the Normalized Difference Water Index - NDWI that was proposed by McFeeters2 and it is designed to maximize the reflectance of the water body in the green band and to minimize the reflectance of water body in the NIR band.

The implementation of this technique will provide invaluable information for water management and water security

References

Giz DG, (2015). doi:https://www.giz.de/en/downloads/giz2015-en-portfolio-albanien.pdf

Li EA, Won J, Min K, (2002) Waterline extraction from Landsat TM data in a tidal flat-A case study in Gomso Bay, Korea. . *Remote Sens. Environ*, **83**, 442–456.

Ajmar A, Boccardo P, Broglia M, Kucera J, Wania A, (2017) Response to flood events: The role of satellite-based emergency mapping and the experience of the Copernicus emergency management service. Flood Damage Surv. Assess. New Insights Res. Pract. 2017. *Flood Damage Surv. Assess. New Insights Res*, 213-228.

https://emergency.copernicus.eu/mapping/ems/response-flood-events-role-satellite-based-emergency-mapping-and-experience-copernicus-emergency

Amadio M, Mysiak J, Carrera L, Koks E, (2016) Improving flood damage assessment models in Italy. *Nat. Hazards*. **82**. 2075–2088.

Berger M, Moreno J, Johannessen J, Levelt P, Hanssen R, (2012) ESA's sentinel missions in support of Earth system science. *Remote Sens. Environ.* **120**, 84–90.

Chen, Q., Zhang, Y., Ekroos, A., & Hallikainen, M. (2004). The role of remote sensing technology in the EU water framework directive (WFD). *Environ. Sci. Policy*, **7**, 267–276.

Google Earth, (2020) Retrieved from https://www.google.com/earth/

ESA, Coop. (2020) Sentinel-2_User_Handbook. https://sentinel.esa.int/documents/247904/ 685211/ Sentinel-2_User_Handbook

Fayne J, Bolten J, Lakshmi V, Ahamed A, (2017) Optical and Physical Methods for Mapping Flooding with Satellite Imagery. In Remote Sensing of Hydrological Extremes;. *Remote Sens. Hydrol. Extremes; Springer:* pp. 83–103. doi:10.1007/978-3-319-43744-6_5

Feng L, Hu C, Chen X, Cai X, Tian L, Gan W, (2012,). Assessment of inundation changes of Poyang Lake using MODIS observations between 2000 and 2010. *Remote Sens. Environ.*, **121**, 80–92.

Li W, Du Z, Ling F, Zhou D, Wang H, Gui Y, Zhang X, (2013) A comparison of land surface water mapping using the normalized difference water index from TM, ETM plus and ALI. *Remote Sens.* **5**, 5530–5549.

Malinowski R, Groom GB, Heckrath G, Schwanghart WD, (2017) Remote Sensing Mapping Practices Adequately Address Localized Flooding? A Critical Overview,. *Springer Sci. Rev.*, **5**, 1–17. doi:https://doi.org/10.1007/s40362-017-0043-8

McFeeters S, (1996) The use of the normalized difference water index (NDWI) in the delineation of open water features. *Int. J. Remote Sens.* **17**, 1425–1432.

Moel, H., Alphen, J., & Aerts, J. (2009). Flood maps in Europe–methods, availability and use. *Nat. Hazards Earth Syst. Sci.*, **9**, 289–301.

online:, C. E. (n.d.). Retrieved 3 7, 2018, from http://emergency.copernicus.eu/mapping/list-of-components/EMSR120

Ran J, Nedovic-Budic Z, (2016) ntegrating spatial planning and flood risk management: A new conceptual framework for the spatially integrated policy infrastructure. . *Comput. Environ. Urban Syst.*, **57**, 68–79.

Revilla-Romero B, Hirpa FA, Pozo JT, Salamon P, Brakenridge R, Pappenberger F, De Groeve T, (2015) On the use of global flood forecasts and satellite-derived inundation maps for flood monitoring in data-sparse regions. . *Remote Sens.* **7**, 15702-15728.

Ryu J, Won J, Min KWA, (2002) Waterline extraction from Landsat TM data in a tidal flat-A case study in Gomso Bay, Korea. *Remote Sens. Environ.*, **83**, 442–456.

Sivanpillai R, Miller S, (2010) Improvements in mapping water bodies using ASTER data. . *Ecol. Inform.* **5**, 73–78.

Sun F, Sun W, Chen J, Gong P, (2012) Comparison and improvement of methods for identifying waterbodies in remotely sensed imagery. *Int. J. Remote Sens.* **33**, 6854–6875.

Ward P, Jongman B, Weiland F, Bouwman A, van Beek R,., Bierkens M, Winsemius H. (2013) Assessing flood risk at the global scale: Model setup, results, and sensitivity. *Environ. Res.. Lett*, **8**, 044019-10.

Work E, Gilmer D, (1976) Utilization of satellite data for inventorying prairie ponds and lakes. *Photogramm. Eng. Remote Sens*. **42**, 685–694.

Xu H, (2006) Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. *Int. J. Remote Sens.*, **27**, 3025–3033.