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Machine learning techniques in agricultural flood assessment and monitoring using EO and hydromorphological analysis †

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Abstract: Climate change could exacerbate floods on agricultural plains by increasing the frequency of extreme and adverse meteorological events. Flood extent maps could be a valuable source of information for agricultural land decision makers, risk management and emergency planning. We propose a method that combines various types of data and processing techniques in order to achieve accurate flood extent maps. The application aims to find the percentage of agricultural land that is covered by the floods through an automatic map estimation methodology based on from the freely available Sentinel-2 (S2) satellite images and machine learning techniques.

Keywords: flood assessment; remote sensing; data processing; machine learning;

1. Introduction

Floods are among the most catastrophic natural disasters causing human loss, crops, livestock and property loss, permanent damages to infrastructures and communication systems. It is estimated that worldwide more than 5000 deaths are caused by flash floods that are events occurring on small spatial scales within short time, under conditions of rapid production of surface runoff [1]. In the future, climate change could exacerbate these phenomena by increasing the frequency of extreme and adverse meteorological events [2]. On this notion, we implement Remote sensing (RS) techniques as a tool for synoptic view over large areas, frequent observations and historical archives [3]. More specifically, we exploit image data from Sentinel-2 (S2) mission of European Space Agency (ESA) that offers advanced spatial resolution and revisit frequency.

Two major flood events occurred during summer 2020 in Greece, Evia floods and Ianos Cyclone floods. Subsequently, the objective of the study is to propose a method to synergistically combine various types of data and processing techniques in order to achieve greater, more consistent and robust mapping accuracy of areas affected by flooding.

1.1 Pilot areas

Three sites were selected for algorithm set up and the assessment of flood mapping products that is Evia Politika area, Kefalonia and Thessallia plains (Figures S1, S2a, S2b and Table 1).

Table 1. Location/extent of the study sites and characteristics/conditions of the surface water areas.

Site	Location	Surfacewaterconditions	Dimension(km²)
EVIA	Politika	Flooded areas due to severe rainfall event – 3 fatalities	84
KEFALONIA	Municipality Pilareon	Flooding event-natural hazards	59
THESSALIA	Enipeas Pinios rivers	Flooded cotton fields	76

1.2 Data

Data used are Sentinel2 [4] multi-temporal satellite data, orthophotos DEM and ancillary land cover / use maps.. The acquisition dates of satellite images for the respective areas are:

- Evia: 29/7/2020, 3/8/2020, 13/8/2020, 28/8/2020,
- Kefalonia: 05/9/2020, 20/9/2020 and
- Thessalia: 31/8/2020, 20/9/2020.

2. Methodology

Various image processing and vector GIS techniques have been used for the analysis of both the satellite imagery and the collected map data and field information. Two methodologies are used for the analysis of data as shown on Figure S3 and Figure S4. The hydrological analysis was based on Reuter, H. I., et al. [5], who suggested a comprehensive approach for DEM preprocessing and hydrological analysis. Initially, administrative boundaries of Greece were downloaded from GEODATA [6], to select the pilot project areas. The DEM of 5 m resolution of the Greek Cadastre was also used. Various image processing and vector GIS techniques were used in order to define watersheds and streams of the pilot areas.

Concerning the methodology for identifying changes to land cover due to flood events in the three pilot areas, two machine learning techniques were applied namely Self Organising Maps (SOM) [7], [8] and isodata clustering [9].

For Evia Politika area and Thessalia plain, both spectral index and Image -Unsupervised Classification Self-Organizing Map on the S2 images in order to discriminate all inherent land/flood cover classes of the satellite images. The raster output of the classification and/or interpretation process was converted to vector data and these data were analyzed with the corresponding map data and observation acquired on the Ortho-photos. Further processing and analysis was performed to derive information concerning land cover changes due to flooding in the pilot study areas.

For the Kefalonia pilot area, the isodata unsupervised classification technique [9] was applied on S2 images. The classified as flooded areas were converted from raster to vector and combined with agricultural data from the Greek Payment Authority of Common Agricultural Policy were to identify land cover types affected by floods.

An area of 10 km2 of Evia Politika basin has been affected by the flood even. The analysis provides satellite evidence that the disaster was caused by a large mass of rock / sediment / mud / debris dislodged from the slopes of / higher altitude areas of the basin. It started as erosion, slope instabilities and even landslides and then transformed into a mud and debris flow, causing destruction along its path. Fatalities are due to severe stream flow discharge from Polititika village towards the plain (Figure S5). The analysis of satellite images acquired before and after the event can be used to quickly determine and quantify key measures of the event, e.g. elevation differences and travel distances of erosion products / water. This study clearly shows that satellite data could play significant role in future high mountain hazard assessments, in particular for evaluating large and relatively inaccessible areas. It is suggested that due to climate change such events might be happening more frequently, and that the full potential of satellite data and knowledge should be utilized to identify possibly dangerous regions (Figure S6).

For the Thessalia plain the flooded area is about 35% out of total while 15% of summer cultivations have been affected. Changes caused by the flood event have been mapped even at field level, and this can be useful during field inspections. Various summer cultivations and mainly the ready for harvesting cotton fields have been affected S2 images provided precise data for tracking the spatial footprint of surface water changes /flood waters at regional and local scales i.e. field of 23.7 ha (Figure S7 and Figure S8).

2.1. Processing Techniques

Various image processing and vector GIS techniques have been used for the analysis of both the satellite imagery and the collected map data and field information, such as Georeferencing, Resampling, Water / Vegetation spectral features, Colour Composites, Intensity Hue Saturation (HIS) Images, Identification of Areas of Interest (AOI), Automatic combination of the classification result of multi-temporal imagery, Automatic conversion of raster to vector data, Collection / Input / Coding, Storage / Management, Retrieval of various data and Processing / Analysis.

2.2 Presentation / Display, & Map making

Image Classification - Unsupervised Classification techniques using neural networks: Artificial Neural Networks (ANNs) are generally quite effective for the classification of remotely sensed data. For classification purposes, the Self Organized ANN method was used on the Sentinel 2 images in order to discriminate all inherent land / flood cover classes of the satellite images using automated conversion of raster to vector data: the raster output of the classification and/or interpretation process was converted to vector data and these data were analyzed with the corresponding map data and observation acquired on the Ortho-photos. Further processing and analysis was performed to derive information concerning land cover changes due to flooding in the pilot study areas (Table 3).

Table 3. Total areas calulated.

Land Use (LU)	Sum Area of LU (m2)	LU Flooded (m2)	LU Remain (m2)	LU Remain (%)	LU Affected (LC) (%)	Total Percentage (%)
Forest	3043611	210799	2832812	93%	7%	100%
Vineyard	229634	18240	211394	92%	8%	100%
Vineyard Mix	181007	27853	153154	85%	15%	100%
Arable	905322	144450	760872	84%	16%	100%
Arable Mix	3397804	475221	2922583	86%	14%	100%
Olive Growing	9266342	412194	8854148	96%	4%	100%
Olive Growing Mix	3354840	384223	2970617	89%	11%	100%

3. Conclusions

In summary the following areas have been identified during the aforementioned process: Flood, Erosion, abrasion surfaces, Areas of sediment transport due to flood event, Areas of slope Instability, landslides and Land cover types affected by the flood events.

In this work we have evaluated a methodology to automatic map flooded areas from multispectral S2 images. Remote sensing provides valuable information concerning different environmental parameters. The methodolgy enables the identification, delineation, and monitoring of floods and estimates of changes in surface land cover / use. The techniques and the developed methodology could be applied for the Monitoring of aspects of floods and eventually it could be used for the mitigation of their environmental, social and economic footprint. It targets policy and decision makers and generally the competent authorities, which are in charge of development and implementation of policies as well as the authorization and inspection of "flood areas".

Supplementary Materials: The following are available online at: https://tinyurl.com/efita178, Figure S1: Pilot Project Areas, Figure S2a: Evia – Politika area a, Figure S2b: Evia – Politika area b, Figure S3: Hydrological analysis, Figure S4: Change detection due to flood disaster, Figure S5: Mapping changes due to the 9th August Evia flood event, Figure S6: Example of classification of flood surface waters of Thessaly using multitemporal Sentinel 2 images, Figures S7: River basins and Hydrological analysis of the Pilareon municipality and Figure S8: Land use classes due to flood disaster.

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