

**MONITORING OF DROUGHT AND INLAND EXCESS WATER IN THE SERBIAN-HUNGARIAN CROSS-BORDER REGION IN THE FIRST HALF-YEAR OF 2019**

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**Abstract**

Due to climate change and its natural geographic conditions, the water supply of the Hungarian-Serbian cross-border region shows extreme variation. The area suffers from both droughts and inland excess water, thus research and geographical observation of the problems is very important. This study demonstrates the development of a monitoring system of the two phenomena by the help of satellite images supplemented by field data using crowdsourcing elements within the framework of the Drought and Excess Water Research and Monitoring Centre, furthermore, evaluates the monitoring results for the first half-year in 2019.

**Introduction**

One of the most important environmental problems nowadays is global climate change, and its regional and local effects. In the last 100 years the average temperature of the Earth increased by +0.7°C and undesirable changes occurred also in case of precipitation, as long periods without rainfall and extreme precipitation events became more frequent in large parts of the temperate zones on both hemispheres [1]. Climate change has a considerable impact on the lowland areas of the Carpatian Basin. Due to climate change and the natural geographic conditions, the water supply of the region is showing extreme variation, the area suffers from both drought [2] and inland excess water [3] – these can take turns, and occur in consecutive years or even in the same year.

It was also observed that the frequency of extreme weather conditions' occurrence has also changed. Years drier than the average have become more frequent, and the distribution of the rainfall is turning less and less favourable, as beside the long dry periods, extreme precipitation events occur especially in the summer causing an increase in runoff of the valuable water resources. For this research and geographical observation of the problems related to climate change and hydrological extremes is very important in the region [5] [6] [7]. This study presents the results of the Drought and Excess Water Research and Monitoring Centre (DERMC) to set up a monitoring system of the two phenomenon by the help of satellite images supplemented by field data using crowdsourcing elements in the Hungarian-Serbian cross-border region, furthermore evaluates its operation for the first half-year in 2019.

**Study area**

The developed monitoring system covers Southeast Hungary (Csongrád and Bács-Kiskun counties) and Vojvodina (Fig. 1a). The majority of the area is lowland, where the mean annual temperature is around 11°C and the annual precipitation is 500-600 mm. The highest mean temperature occurs in July, typically between 21°C and 23°C, while the rainfall is around 300 mm in the summer half of the year [8] [1]. Examining the climate change trends of the last decades reveals that the temperature has been rising and the precipitation level has slightly decreased [9] [10], resulting in a 20-30 mm yearly precipitation shortage in the area. The most important rivers are the Danube, the Tisza/Tisa River, the Maros River, and the Tamiš River; besides these, most of the surface waterflows are artificial canals. The study

area is diverse in terms of soil type, physical properties and soil moisture regime of the soils (Fig. 1b). Chernozem soil and its different variations dominate the area; sandy soils and meadow soils are also common in the region. The land cover and land use of the area is dominated by agricultural land (Fig. 1/c). In the last 200 years large areas of land became used for farming purposes, therefore the proportion of agricultural land is high, and the natural vegetation remained only in relatively small areas. Even in these areas, where the natural vegetation survived, unfavourable processes can be observed, because the climate change of the last few decades and human activities resulted in natural wetland habitats starting to dry out, and this process is accompanied by the degradation and transformation of the vegetation [11].

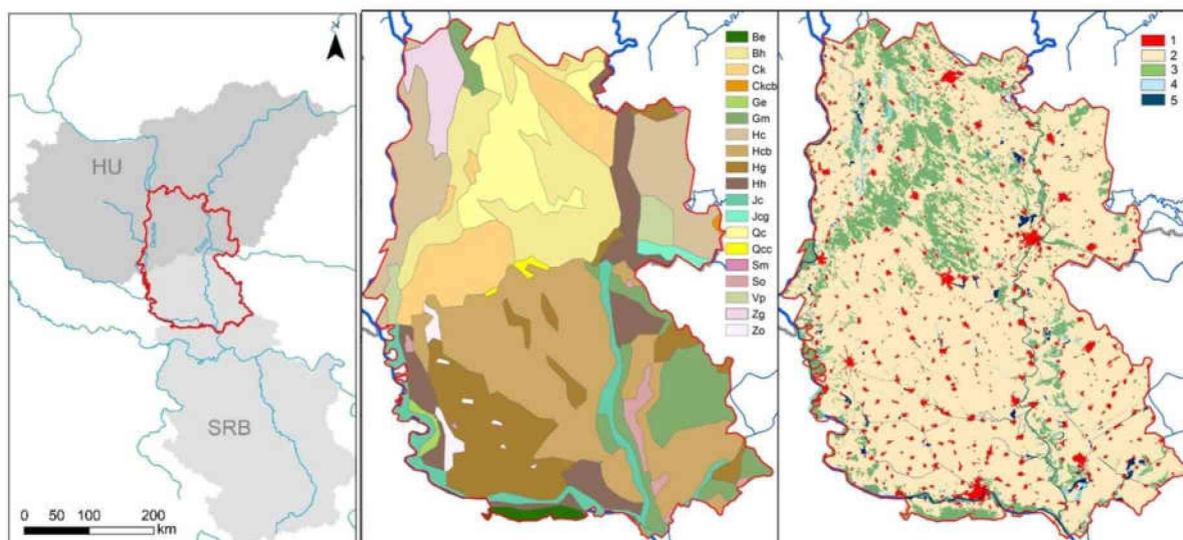


Figure 1. Location of the study area, furthermore its soil types (FAO 1985) and land cover (Corine 2018) (1: Artificial surfaces; 2: Agricultural areas; 3: Forests and semi natural areas; 4: Water bodies; 5: Wetlands)

## Methods

The methods for drought and excess water monitoring were based on selected parameters like surface moisture, vegetation and water abundance using medium and low-resolution satellite data and crowdsourcing methods. The main goal was to estimate the spatial and temporal changes of the two hydrological extremes under study. The developed monitoring system collects and processes remotely sensed (drone, Sentinel 1 and MODIS satellite) and in situ surveyed datasets (soil moisture and meteorological data and inland excess water patches). The data is stored in a geodatabase and published online using web mapping technologies.

### *Inland excess water, vegetation anomaly and surface moisture monitoring using medium and low-resolution satellite images*

The work process that was developed for inland excess water monitoring utilises a combination of satellite images from Sentinel 1 radar data and Sentinel 2 multispectral data to produce regional scale inland excess water maps in an operative way, on a weekly basis. The radar and optical data-based processing phases use imagery from Sentinel 1A, 1B, 2A and 2B. These satellites provide a full coverage of the sampling area approximately every third day. Thanks to the C-band active remote sensing technology, data can be acquired regardless the part of the day or weather conditions. The workflow combines radar thresholding, and optical image classification and index based thresholding to generate weekly inland excess water maps (see methods in more details in [12]).

The vegetation assessment uses MOD09A1 surface reflectance images and MOD13A1.006 vegetation index products and data were processed using the Google Earth Engine cloud computing platform (see methods in more details in [13]). For the demonstration of the current condition of vegetation anomalies compared to the long-term average (2000-2017), the NDDI drought index was applied where a positive deviation indicates drought conditions:

$$\text{NDWI} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR})$$

$$\text{NDDI} = (\text{NDVI} - \text{NDWI}) / (\text{NDVI} + \text{NDWI})$$

$$\text{NDDI}_{\text{standardised}} = (\text{NDDI} - \text{NDDI}_{\text{average}}) / \text{NDDI}_{\text{deviation}}$$

where NIR and SWIR are respectively the near infrared and the short-wave infrared bands of the MODIS instrument. NDVI is Normalized Difference Vegetation Index, NDWI is Normalized Difference Water Index.

Based on the standardised anomaly the water shortage of the studied period can be identified, which reduces the biomass production or delays its temporal dynamics.

Surface moisture monitoring is based on the normalized difference moisture index (NDMI) calculation using Google Earth Engine:

$$\text{NDMI} = (\text{NIR} - \text{SWIR}) / (\text{NIR} + \text{SWIR})$$

where NIR is the narrow near infrared band 8a and SWIR is the short-wave infrared band 11 of atmospherically and geometrically corrected Sentinel 2 level 2 data.

To reduce the missing data due to cloud cover, composites were created for the median pixel value of 10 days. This ensures that the pixels of at least 2 images per composite were considered.

#### *GeoApp and crowdsourcing contributing to inland excess water inundation mapping*

The location-based data collecting application for Android and iOS devices enables the monitoring of inland excess water patches. The application has an editable layer, during data collection, the features of the inland excess water patches can be provided according to a predefined categorical system, and the location of the observed phenomenon can be specified on the map by manually or using the GPS position. A photograph can be attached to the observation using the camera of the device. The collected data are automatically transferred to the interactive maps of the project. The app can be downloaded for free, but registration is required.

### **Results and discussion**

All data collected and processed in the framework of the project is made available via the public project website (<https://aszaly.geo.u-szeged.hu/wateratrisk/>) and maps or diagrams. Data can be downloaded for further analysis.

Due to the low amount of precipitation between October 2018 and March 2019, drought formed in winter/early spring in 2019, which can be considered extraordinary. There was hardly any water stored in the upper soil layer, resulting in reduced crop growth during the autumn-winter period. At the end of April, a more humid period began, and the soil moisture deficit was recharged, resulting in favourable condition for agriculture e.g. autumn wheat. In May, however, a lot of precipitation fell (more than two times more than the long-term average), causing rather unfavourable impacts (e.g. plant infections) and water management challenges (Fig 2). As a result, also minor inland excess water inundations could form between the end of May and mid-June, which is uncommon in normal years.



## Conclusion

This study presented the satellite image based and in situ monitoring results of the Drought and Excess Water Research and Monitoring Centre for the HU-SRB cross-border area for the first half-year of 2019. It was shown that substantial drought occurred in the winter-early spring period, which had significant impact on agriculture. Due to the humid May, the situation was balanced, however, the extraordinary amount of precipitation in May and June, resulted in small inland excess water inundations in the study area. The developed methods and the applied used indices for monitoring proved to be useful to demonstrate the drought and excess water conditions in the studied region.

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