THE IMPACT OF EXTREME WEATHER CONDITIONS AND MUNICIPAL SEWAGE DISPOSAL ON VEGETATION USING SENTINEL IMAGES, SE HUNGARY

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Abstract
Land application of municipal sewage can enhance the productivity of biomass production systems and can contribute to a better resistance to extremities in water supply. Understanding the impacts requires the examination of changes in soil characteristics and plant productivity. In this study (paralelly to the soil analyises) Sentinel 2B vegetation index series are assessed to monitor the biomass anomalies related to different water supply conditions and the sewage disposal in the period of 2016-2018 in a study area in SE Hungary (Újkígyós). In the humid year of 2016 there were no spatial differences in biomass production of vegetation stands, but as a result of the dry summer in 2017, biomass production deficiencies were observed on the areas of the ancient river meanders, characterised by different soil properties compared to the surrounding areas. In general, the direct impact of municipal sewage disposal could be detected on biomass by increased productivity, the response is probably related to the nutrient status of the site.

Introduction
There is a worldwide increasing interest in land application of sludge from wastewater treatment plants, since by their usage valuable components can be recycled into the soils: organic matter, nitrogen, phosphorus and other plant nutrients [1] [2]. Municipal sewage can be applied with or without treatment to increase soil organic matter and nutrient content, the conditions of which are regulated by the Government regulation Nr. 50/2001. (IV.3.) and the Decree Nr. 36/2006. (V. 18.) of the Ministry of Agriculture and Rural Development in Hungary. The disposed sewage sludge and compost can provide important macro and micro nutrients for plants, enhance soil organic matter content and adsorption capacity, improve soil structure and can contribute to more favourable soil water management [3]. Understanding the impacts requires the examination of changes in soil characteristics and plant productivity. The enhanced productivity of biomass production systems and the better resistance to extremities in water supply can be easily monitored by remote sensing techniques. The use of medium resolution satellite images provides a cost-effective way of assessing the spatial and temporal patterns of biomass productivity by exctracting vegetation indices (VIs) [4] [5]. Free downloadable remote sensing data such as MODIS imagery has a higher temporal, but a lower spatial resolution and LANDSAT cannot supply good temporal resolution which hardly allow plot scale evaluation of crop development in Hungary. The Sentinel-2 satellite has a more finer resolution, however, it was launched in 2015, thus, there is no possibility for longer-term assessments.

Vegetation and soil are important carbon pools, which are significantly modified by antropogenic activities (e.g. sewage disposal). This study aims at (paralelly to the survey of the soil organic matter and nutrient content, [6] [7]) the investigation of the biomass production of a study area located in SE Hungary, where sewage disposal is regular. Productivity of areas with and without any disposal are also assessed, furthermore the spatial pattern of the anomalies is investigated concerning both disposal and changes in water supply.

Study area and methods

The study area is located in the lowland interfluve area between the Körös and Maros River, in the territory of Újkígyós settlement (Fig. 1). It has an extent of 5.6 hectares where treated municipal sewage is disposed regularly since 2013. Chernozem and meadow Chernozem soils constitute the area, which are both of high fertility. The area, formed by fluvial and eolian processes, belongs to the Körös River Catchment. The static groundwater level was measured at 2 m below the surface during the soil sampling in March 2018. During soil sampling points were assigned where there were no disposal at all, where disposal happened in the past and on areas of disposal in autumn 2017. The field verification of satellite images were done by making a landuse map over the area in July 2018.

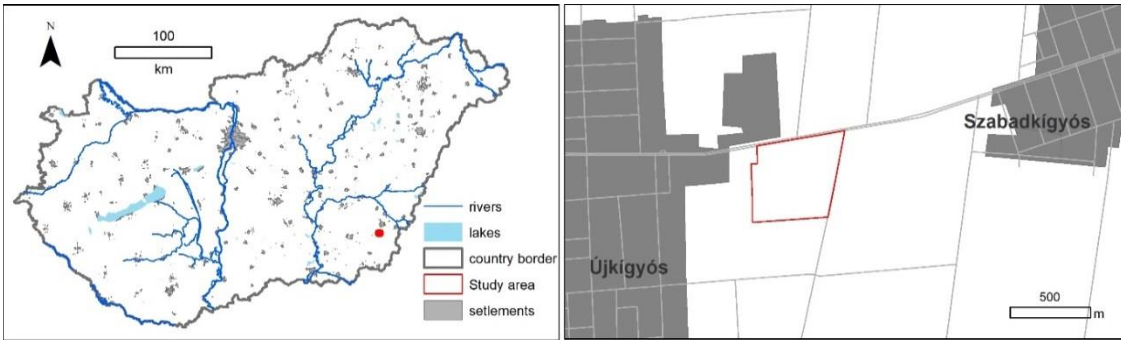

Figure 1. Location of the study area (SE Hungary, Újkígyós)

For data download, preprocessing and composite image generation, Google Earth Engine script was used, the workflow of which can be observed on Figure 2. Sentinel 2B EVI and NDVI data were selected, then images were filtered according to a max. 20% cloud cover. Cloud filtering was also applied using quality bands, and the study area was masked. Finally 32-day composite images were derived and downloaded, which were the basis of the compilation of the phenological curves and the comparison of the spatial pattern of biomass productivity. The statistical analysis and the illustration of the results were made using ArcGIS 10.2 and Microsoft Excel.

Figure 2. Workflow of vegetation index calculation for the study area using Google Earth Engine

Results and discussion

Spatial anomalies under humid and arid summer

Spatial EVI anomalies in August 2016 and 2017 were compared in the study area and its surrounding (Figure 3) to assess the differences in crop biomass production. 2016 was characterised by a precipitation amount between 600-650 mm with almost steady distribution, while in 2017 it was slightly less (500-550 mm), however, May-August (important period concerning crop growth) significantly less precipitation occurred compared to the normal distribution). As a result of the humid year of 2016, there were no significant spatial anomalies within the plots (exceptions are the pits used previously for irrigation and the surrounding forested area in the middle) and the almost bare surfaces in 2016. As a result of the dry and warm summer in 2017, significant decrease in productivity was observed on the areas of the ancient river meanders. The reason for this can be found in the different soil properties (higher ratio of finer particles) compared to the surrounding areas, resulting in less favourable water management properties, which influenced the vegetation water supply.

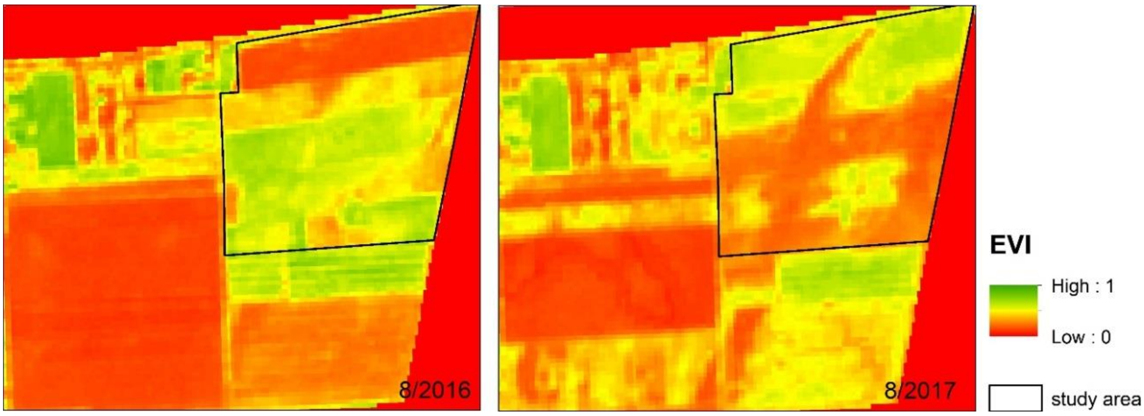

Figure 3. Spatial anomalies of crop EVI values in the study area and its neighborhood

It was difficult to compare crops with and without disposal, since the grown crops were different in the upcoming years. However, two plots could be compared where maize was grown within the study area under sewage disposal in 2016, and an other one from 2017 outside the study area without sewage disposal (Figure 4). The results show that the favourable year resulted in a somewhat earlier crop development, a wider green period in the vegetation period, and higher maximum productivity values. The 2017 maximum values are similar that of 2016, however, the dispersed values of the peak is somewhat lower. It means that a higher production in 2016 was could be observed, however, the reason for this is mostly due to the better availability of water, not the sewage disposal in this case.

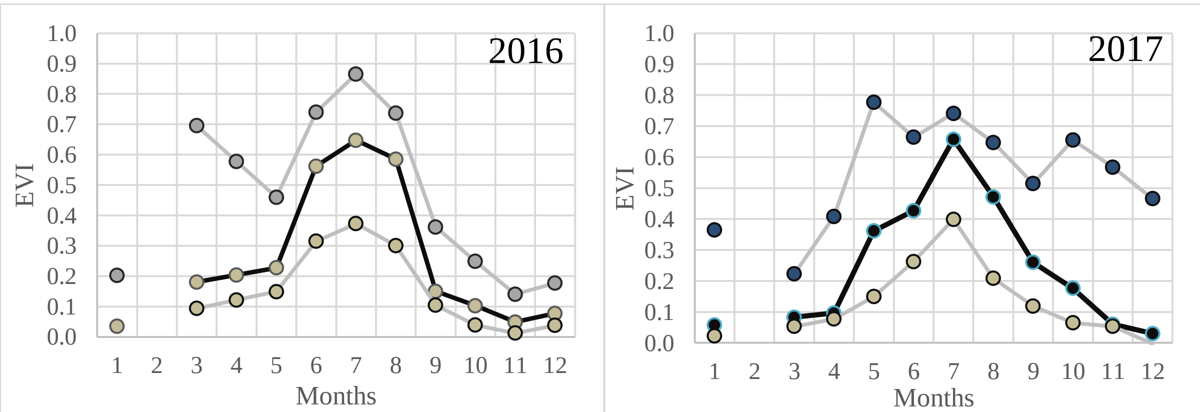

Figure 4. Maize phenological curves in 2016 (with sewage disposal, within the study area) and 2017 (without sewage disposal, outside the study area)

Differences between areas with and without disposal

Land use map of the study area in 2018 was prepared to verify the crops in the field and to surely combine VI data with them. On the study area mostly maize, cereals and oil radish were observed on the fields (Figure 5). Comparison between the area affected by any disposal and not affected areas can be done for maize and cereals only. And the difference between VI of cereals with sewage disposal in 2018 and without disposal can be evaluated.

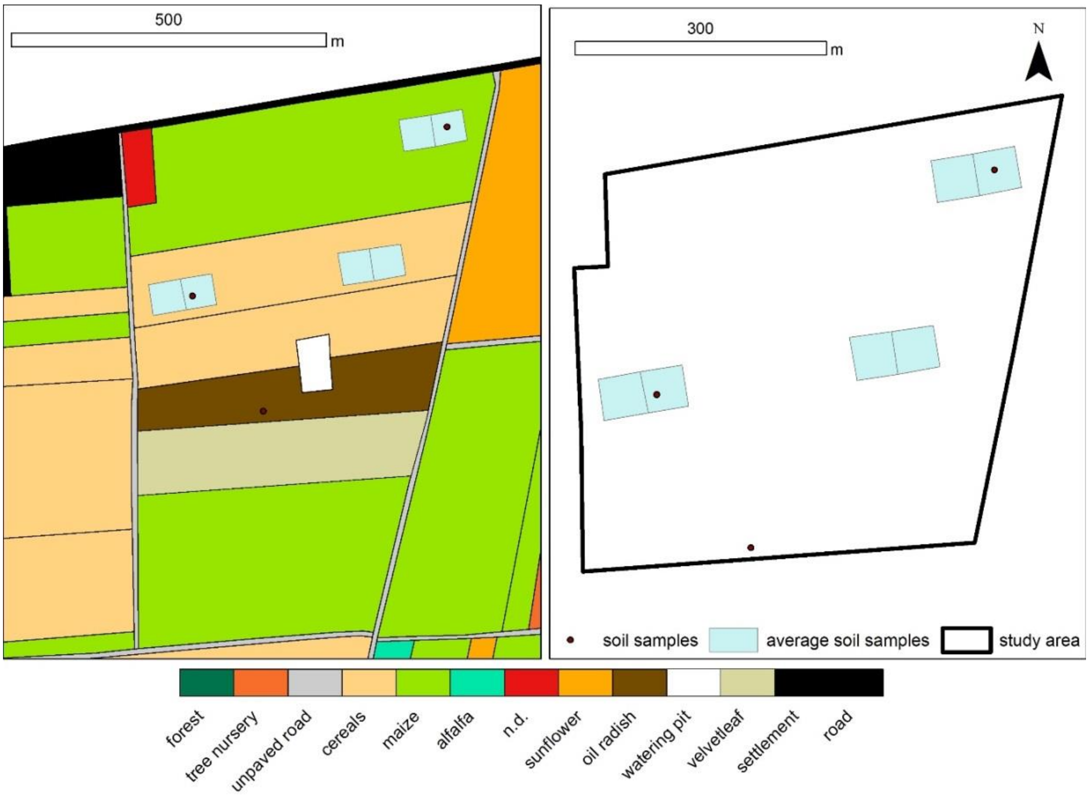

Figure 5. Land use map of the study area from 2018 marking the places of soil sampling (with, without sewage disposal and a control area in 2018)

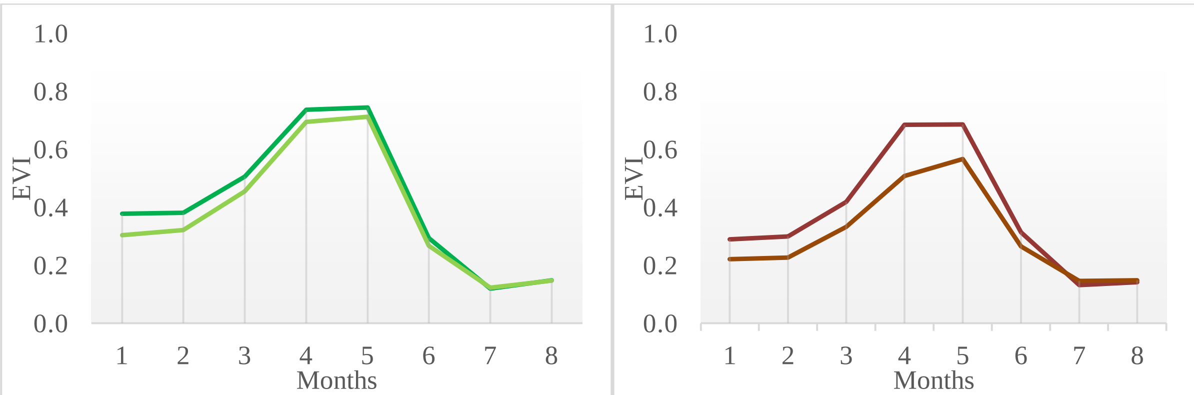

Figure 6. Winter wheat phenological curves (based on EVI) in 2018 at soil study sites with (green) and without (brown) sewage disposal in Autumn 2017

Based on the EVI phenological curves the study site (Figure 6) with sewage disposal showed increased peak values compared to the 'control' site without disposal, especially at the farthest study site, where a later peak was observed based on the average pixel values of the sample field.

Conclusion

Sentinel 2B vegetation index series were assessed to monitor the biomass anomalies related to different water supply conditions and the sewage disposal in the period of 2016-2018 in a study area composed of Chernosem soil. In the investigated humid year the vegetation indices of the crops showed an even spatial pattern, however, in the year under unfavourable, dry conditions spatial differences in biomass production could be observed. The deficiencies revelaed the ancient river meanders, characterised by different soil properties compared to the surrounding areas. The direct impact of municipal sewage disposal could be detected on biomass by increased productivity, the response is probably related to the nutrient status of the site.

Acknowledgements

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