GIS SUPPORTED AVAILABLE WATER CONTENT CALCULATION FOR WATERSHED IN DROUGHT IMPACTED AREAS

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ABSTRACT

In many regions of Europe (among others in Hungary) agricultural production has been affected by droughts over the past decades. Global Water Partnership (GWP) Central and Eastern Europe (CEE) wanted to supported European countries in developing of an early warning system, which consists of monitoring, prediction and combine national drought policies. In order to use risk assessment – in which prevention of drought is emphasized - available water content calculation of watershed should be prepared for drought impacted areas. The aim of our study was to create a high-resolution, trans - border database, which takes into account the most important water regime properties of soils and it can be uniformly used in other countries of Tisza River Basin. Based on traditional soil maps, a soil database was created, where soil water content - in 2m layer depth of soil - can be estimated for different horizons and for different soil types. First of all, digital soil maps of different countries were adjusted to WRB (World Reference Base for Soil Resources), and calculation mapping was worked out for the total area of the Tisza River Basin. After allocations of the soil layers, physical limit values of soils were estimated by using pedo-transfer functions. Water storage capacity and available water content were determined by the depth of the impermeable layer. Finally, spatial queries were carried out in the Tisza River Basin and in units of administration. These data were integrated into a geographic information system, in which the data clearly showed that the impact of drought was more severe in extreme water management soils. In case of large-scale long-term droughts, local differences decreased the reliability of the calculations to a lesser degree. However, with further methodological development, the effect of these local differences can be reduced.

Keywords: soil water holding capacity; Tisza River Basin; border-less drought monitoring; GIS

1. Introduction

The weather and hydrological extremes are characteristics of the study area in Hungary. Furthermore, the large inland waters inundations (flooding, over-moistening) and the risk of drought sensitivity, often occurs in the same year, in the same area. This situation usually happens because of the atmoshperical precipitation has very high spatial and temporal variability, and the increase of the frequent and serious high-intensity rainfalls. In addition to these, the soil potential water storage ability is under-utilized. The effects of extreme weather conditions can be reduced by the better use of soil potential water retention capacity and the increase of useful water retention ability, which is also effective for the extreme water situations such as drought (Várallyay, 2011).

The largest natural water reservoir potential is the soil in CEE, this capacity is only at low utilization level at present. Better and a more complete use of this capacity can reduce efficiently and effectively the drought sensitivity and the direct effects of the drought, as well. This ability was determined by the vegetation water demand and the available amount of water storage in the soil. The agricultural crop plants and weeds consume a lot of water and transpiration of this and it is utilized in another basin. It can cause water deficit in water balance. Mainly it is important to know water balance in sandy soil in the neighbourhood Nyírbator, because it is a nitrate sensitive area. The hydro-physical characteristics are the basic elements of the soil drought sensitivity. The aim of this study was to create a trans-border database with high-resolution and unified nomenclature, which provides information about the transpiration of plants and the amount of soil moisture content in root zones, as well as create a calculation map for the Tisza River Basin.

2. Material and methods

Our solution would be the modelling of the Tisza River Basin, because it does have territories in Hungary, Romania, Slovakia, Ukraine and Serbia. In this project the pilot phase of digital transformation of these countries was performed to WRB system (Michéli, 2007).On the other hand we had the opportunity to use the guidelines of JRC to calculate the soil moisture regime for the whole Tisza River basin. Figure 1 presents the digital elevation model of Tisza River Basin.

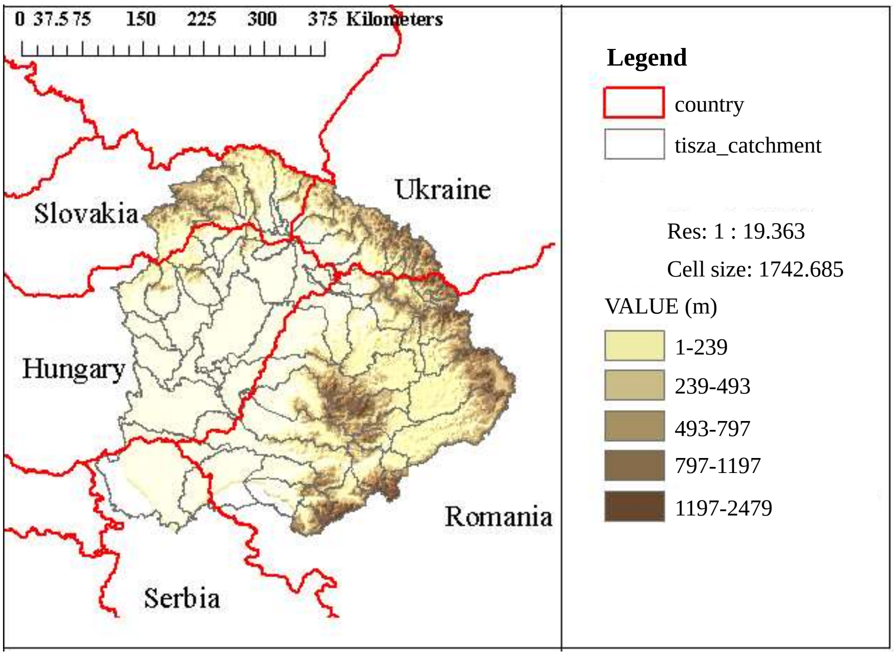

Figure 1: Digital Elevation Model of Tisza River Basin

Hungarian soil classification is based on soil genesis and geography. We described our main soil types with the WRB2006 reference soil groups' names (FAO, 2006). During the GIS work of soil mapping those investments, results and data were used, which were published by the European Soil Portal in ArcMap and Google Earth software environment.

There are several differences among the algorithms concerning parameters or the way of applications (Lamorski et al. 2008; Rajkai et al., 2004). The Joint Research Centre (JRC) of the European Commission published a soil science guideline of database construction for pedo-transfer calculations, which can be used for construction of agricultural drought risk based on digital soil data (Tóth, 2013).

In our study, the calculations for water resources and supply are also concerned the 2 m soil layer. This statement is confirmed by the fact, that as a cumulative effect of drought serial for years root of crops grow deeper and deeper for accessible water sources, and the depth of the drought effected soil layers grows at the same time.

Since this upper 2 m layer is not homogenous, the types of sub layers have to be identified. Furthermore, hydraulic conductivity and the transport processes between layers are also important to know.

In our study 1:100 000, 1:500 000 digital soil maps (Fulajtár and Curlik, 1980; Svoboda, 1965; Hrasko et al., 1973; Florea and Munteanu 1971) were used, where national soil nomenclatures of Central European countries were transformed into the European JRC WRB taxon.

Since the attributive data table of both map types (JRC WRB and national maps) contained the code columns for soil types, this column can be used as secondary key to merge the tables together.

Based on this process such a database was achieved with which water content of different soil layers of different WRB with a certain water storage capacity can be calculated by simple vector operation (the area of each polygon was calculated and multiplied with the area water capacity characteristics of each layer and each soil patches.

3. Results

As a result of this data transformation, the higher spatial resolution of the national maps were preserved transforming them to a common nomenclature. Concerning the PTRDB values saturated water content (SWC) at pF 0, field capacity water content (FC) at pF 2.5, minimum water holding capacity (MWC) at pF 2 and water resources at wilting point (WP) at pF 4.2 were assigned to the soil plots. Hydraulic conductivity (mm/d) were also assigned for the characterization of water transport between layers. These maps make the calculation of water resources possible in different soil layers in different soil plots.

The area of the soil plots were also calculated, thus the layer volume could be calculated, as well. For this layer volumes SWC, WP, FC contents were calculated. After that the total available water content TAW was also calculated by SWC-FC (Figure 2.).

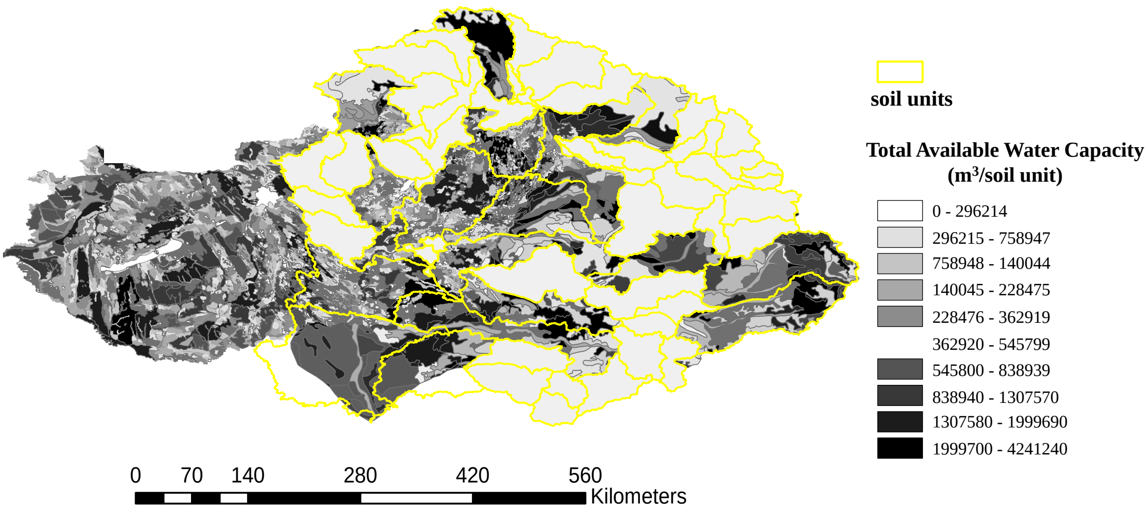

Figure 2: Available soil water content in 2 m depth soil layer
(Yellow lines indicate sub basin of Tisza River)

Eventually all of the water management parameters were totalized for 2 meters soil depth resulting in a water resources map of Tisza Basin (157233.5 km^2) for concerned soil types (Table 1).

Table 1: Water resources of Tisza Basin

The volume of Tisza Basin of 2 m depth soil layer	Water resources of Tisza Basin (157233,5 km^2) in 2 m depth layer			
	MWC	FC	SWC	TAW
314 km^3	45.32 km^3	93.99 km^3	109.13 km^3	48.73 km^3
100%	14.4 %	29.9 %	34.7 %	15.5 %

As a result this, at the first time the calculation of water resources and supply of watersheds or regions were based on water management parameters of high resolution soil data by using different GIS SQLs. These information have been missing from hydrological calculations or were evaluated with high uncertainty. As a summary, the following steps were made:

- Transformation of national soil genetic codes to WRB
- Definition of soil layers
- Data upload of layers for 2m depth
- Upload of soil physical data of layers (with regard to impermeable layer)
- Calculation of water resources of layers (SWC, WP, FC and TAW)
- Calculation of totalized water resources for soil plots
- Spatial query of watersheds and regions
- Cartographic identifications (legend etc.)

The data clearly showed that the impact of drought were more severe in extreme water management soils (for example sandy soils which have low water capacity, extreme heat management; and clay, heavy clay soils which have low available water content and high swelling - shrinking capacity). However, loamy soils (with good water management) have enough available water content for plants in case of moderate severity of meteorological drought, which can buffer the yield loss due to the drought.

Our calculations cannot take into account local differences caused by flash floods, permanent water cover, high salt content and stagnant groundwater or nearly impermeable or compacted clay layers. Due to the lack of detailed and local measurements of these local differences the error values cannot be mapped considerably. In case of large-scale long-term droughts, local differences decreased the reliability of the calculations to a lesser degree. However, with further methodological development, the effect of these local differences can be reduced.
Considering the lack of data on soil water resource and capacity of watersheds, our calculations are significant development in better understanding of droughts risk in hydrological and soil characteristics.

4. Conclusions

This research provides a high-resolution, trans - border database which takes into account the most important water regime properties of soils and it can be uniformly used in different countries of the Tisza river basin. Our calculations can not be implemented to local differences due to flash floods, permanent water cover, high salt content and stagnant groundwater or nearly impermeable clay layers. In case of large-scale long-term droughts, local differences decreased the reliability of the calculations to a lesser degree. However, with further methodological development, the effect of these local differences can be reduced.

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