QUANTIFICATION OF SOIL WATER STORAGE AVAILABLE TO PLANTS IN THE NITRA RIVER BASIN

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Abstract. Soil water storage is systematically studied by expert from various scientific disciplines. This increased interest is mainly due to anthropogenic activities of human beings, but also due to activities of natural processes influencing the dynamics and amount of water in this water resource. The aim of this study is determination of amount of plants available soil water in the Nitra river basin for year 2013. Water storage was calculated in periods from January to March, from April to August and from October to December. Available soil water storage was determined as a difference between actual soil moisture and a hydrolimit limited water availability. Measured soil moisture was interpolated on base of point values from the net of hydrological stations in basin. Retention curves were used to calculation of limited water availability. Available soil water storage was the highest in first period (273.89 mm). In period from May to August was lower (194.32 mm) and in last period was only 152.14 mm.

Key words: soil water storage, plant available soil water, the Nitra River basin

INTRODUCTION

One of the fundamental natural resource is water. Without it life is not possible on this planet. Water has many functions from agricultural point of view. Soil water as a main source of water for plants is significant for agricultural and crop production. Water supply in aeration zone form water supply for biosphere and alongside surface water, as 1st water source, and groundwater, as 2nd water source, in system of water sources represent 3rd water source [Šútor and Rehák 2009].

Soil moisture changes and heat flux among earth surface and atmosphere are stimulus for weather development and climate system. Soil water resources in aeration zone and especially in root system are key parameters to surface water and groundwater state and total hydrological and energetic balance [Igaz 2010].

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As we have mentioned soil water is one of the basic water resources for plants. Not whole current amount of water in soil is available for plants. In agricultural practice it is necessary to monitor soil moisture and maintain it in levels of plants available soil water with taking to consideration irrigation and crop maximization. Levels of available soil water for plant are hydro limits field capacity and wilting point [Šútor and Štekauerová 2001, Antal and Igaz 2012].

$$\Theta_A = \Theta_{FC} - \Theta_{WP} \tag{1}$$

where:

Θ_A – plant available soil water,
Θ_{FC} – field capacity,
Θ_{WP} – wilting point.

Soil water needs to be in this interval if it supposed to be available for plants. We have considered the capacity of available soil water in our research. Soil samples data set from various locations and from hydrological station network that are continuously measuring soil moisture. We have calculated amount of plants available soil water in the Nitra River basin on agricultural land for 2013.

MATERIALS AND METHODS

Study area

The Nitra river basin is sub-basin of river Váh basin. Basin of the Nitra river is located exclusively in Slovak republic. Area of the basin is 5080 km^2. Northern and western neighbour of the Nitra river basin are the Váh river basin and the Hron river basin. The Nitra river is more than 170 km long. Spring of river is in southern slopes of Malá Fatra. It flows through Hornonitrianska kotlina, between Strážovské vrchy and mountain chain Vtáčnik and Tribeč. Stream continues to Podunajská pahorkatina where it forms Nitrianska niva all the way to join river Váh in Podunajská rovina.

Our area of interest is mainly agricultural land (61% of the area) and forest land (30% of the area). Moderate weight soils are most common soil type by soil texture in our area of interest. Figure 2 represent map of soil types. Since the Nitra River basin is relatively large and dissected hill land, many soil types are represented there. Northern areas in more mountainous parts are soil represented mainly by Haplic Luvisols, Eutric Cambisols and Rendzic Leptosols, on the other hand southern part of river basin is represented by Chernozems and Mollic Fluvisols [Atlas krajiny SR 2014].

Department of Biometeorology and Hydrology within the Centre of Excellence for integrated management of basin has established 6 meteorological stations and 25 hydrological stations in whole the Nitra river basin with online data transfer. These stations are set to measure soil moisture and other meteorological characteristics. Meteorological stations are observing data of humidity, evapotranspiration and depth of soil freezing.

Soil moisture is measured in 10 depths of soil profile (10, 20, 30, 40, 50, 75, 100, 150, 200 and 250 cm) by the sensor 10HS Decagon Devices. These sensors use frequency domain reflectometry. Accuracy of these devices is ±0.03 m$^3 \cdot$ m^{-3} in mineral soils with
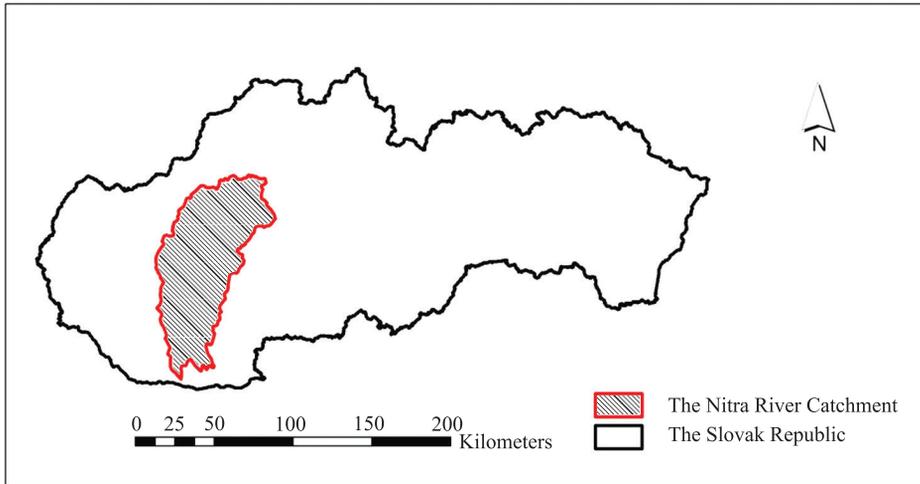
Fig. 1. Location of the Nitra river catchment in the Slovak Republic

use of standard calibration equation or ± 0.02 m$^3 \cdot$ m^{-3} i *n* use with calibration for specific soil (Decagon Devices). In the Nitra River basin were withdrawn soil samples from 112 locations from agricultural land. These samples were tested for hydro physical characteristics and texture, reduced density, hydraulic conductivity, moisture retention curve and soil carbon content. Department established web server Hydro Physics. These soil hydro physical characteristics are available for the Nitra River basin.

Collection of meteorological and hydrological data

Current soil moisture is important to determine available water capacity for plants. From collected data from meteorological stations we calculated average soil moisture values for 3 soil horizons (0–30, 30–100, 100–250 cm) from 2013. We divided year 2013 into three intervals (I–IV, V–VIII, IX–XII) where we calculated average values of soil moisture. We created network of points with soil moisture values for whole the Nitra River basin. From area of interest we took off all non-agricultural land (forest area, built-up area, road etc.). Point values have been transformed into spatial form by standard GIS tools. In GIS program ArcMAP we used tool kriging. This method been used by many authors like Orfánus (2005) or Lakhankar et al. (2010). Pecho (2014) kriging method evaluated as method able to interpolate more accurate data with use of direct measures and estimate examined values also in area with lower density of sampling points. Raster map outputs were created with cell resolution 200 × 200 m.

Determine the quantity of plants available soil water

Boundaries of plants available soil water hydro limits field capacity and wilting point were estimated from soil characteristics from 112 sampling points. For these soils we estimated moisture retention curves. In pursuance of retention curves particular hydro limits characteristics were calculated. Value for field capacity was estimated as 2.3

(200 cm w.c.) and for wilting point value was estimated as 4.18 (15 000 cm w.c.). Same as soil moisture point values were estimated hydro limits point's values by kriging method for its spatial interpretation for agricultural land of the Nitra River basin. We used cell size 200 × 200 m for output raster.

By determining the difference among measured real soil moisture and hydro limit moisture determining available soil water, and taking to account soil depth, we calculated
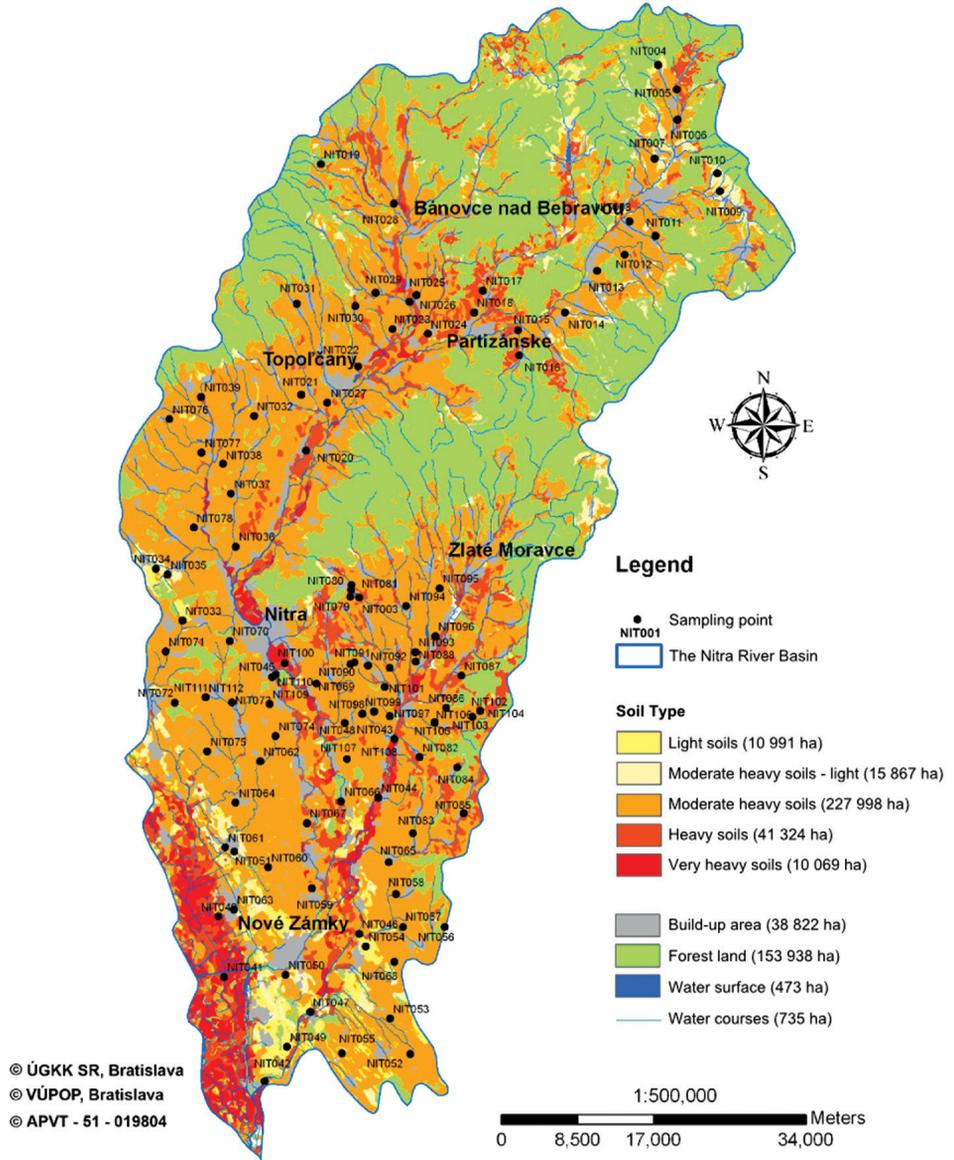
Fig. 2. The Nitra river catchment [Igaz 2010]

plants available soil water amount for 3 particular soil horizons and 3 particular time periods. By counting the amount of water in each soil horizon we were able to determinate the total amount of available soil water in soil profile.

$$W_P = (\Theta_M - \Theta_{WP}) \cdot h_p \tag{2}$$

where:

W_P – amount of available soil water, mm,
Θ_M – soil moisture, –,
Θ_{WP} – wilting point, –,
h_p – soil depth, m.

RESULTS

Through soil moisture and boundaries of available soil water we have determinate amount of available soil water on agricultural land in the Nitra River basin for year 2013. For better representation was this amount determinate in 3 different time periods for year 2013, for months January to April, May to August and September to December. Figure 3 represent amount of available soil water.

Figure 3 analyses says that highest amount of soil water was in months January to April. Summer and autumn 2013 were unusually warm [Pecho 2014]. This fact caused soil moisture decrease to below wilting point. These values are critical for plants.

Maximum storage of available soil water in agricultural land of the Nitra River basin represent 362.47 mm or 1 129 mil. m^3.

Table 1. Average Plant Available Soil Water Storage (0–250 cm)

Time periods	I–IV	V–VIII	IX–XII
Available Water Storage, mm	273.89 (75.6%)	194.32 (53.6%)	152.14 (42.0%)
Available Water Storage, mil. m^3	854.35 (75.6%)	605.43 (53.6%)	474.01 (42.0%)

Table 1 represents average plant available soil water storage in soil horizon thick 250 cm in each time intervals in year 2013 expressed in millimetres and also in million cubic meters. Also meet the maximum available soil water storage. Soil water storage is decreasing during the year periods. In case of continuing this situation, the risk of crop production can be endangerment through lack of soil water storage.

Table 2 shows temporal variability of precipitation in our area of interest during year 2013.
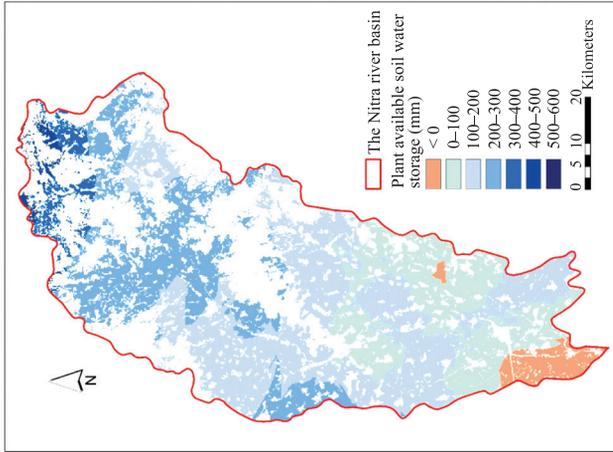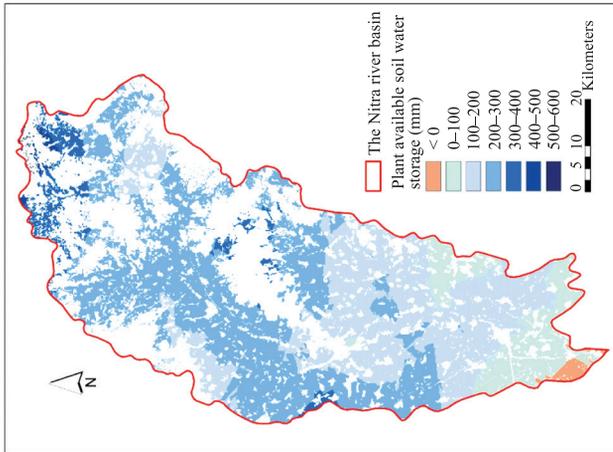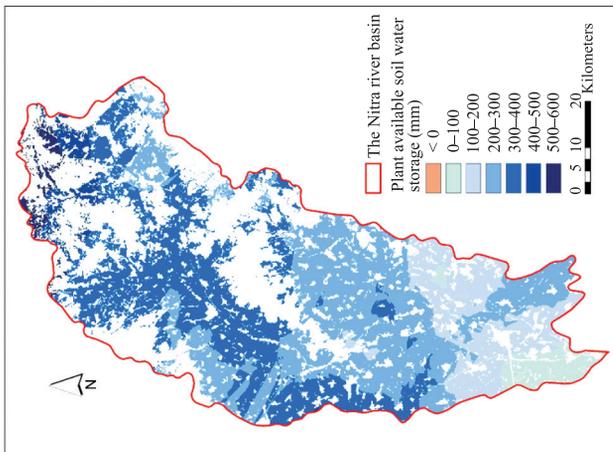
Fig. 3. Average of plant available soil water storage (0–250 cm)

Table 2. Monthly mean precipitation in the Nitra River basin per year 2013
Tabela 2. Średnie miesięczne opady atmosferyczne w zlewni rzeki Nitry w 2013 roku

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Precipitation mm	69.2	79.8	75.4	25.2	76.1	52.7	0.8	7.6	38.0	53.0	70.0	12.2

SUMMARY AND CONCLUSION

In this paper was quantified soil water storage available to plants in the Nitra River Basin. Reference time period was year 2013. Our results document spatial and temporal variability of amount of water in the soil. The highest soil water storage was in period from January to April. On the other hand the lowest storage of water in soil was from September to December.

Results of this paper can be used for further analyses of moisture regime on agricultural soils in the Nitra River basin. From obtained data we are able to analyses available soil water storage. We can suggest location appropriate for crop production certain type of agricultural plants. Analysing areas that are below wilting point we are able to design irrigation. These GIS analyses can be modelled for longer time periods, not only for one year.

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UJĘCIE ILOŚCIOWE MAGAZYNOWANIA WODY W GLEBIE DLA ROŚLIN W DORZECZU RZEKI NITRY

Streszczenie. Magazynowanie wody w glebie jest systematycznie badane przez ekspertów z różnych dyscyplin naukowych. Ten wzrost zainteresowania wynika głównie z działań ludzi, ale także z działania naturalnych procesów wpływających na dynamikę i ilość wody w tym zasobie wodnym. Celem badań było określenie ilości wody dostępnej w glebie dla roślin w dorzeczu rzeki Nitry w 2013 roku. Magazynowanie wody było obliczane w okresach od stycznia do marca, od kwietnia do sierpnia oraz od października do grudnia. Woda dostępna w glebie była określana jako różnica pomiędzy aktualną wilgotnością gleby a dostępnością wody ograniczoną przez tzw. hydrolimit. Pomiar wilgotności gleby był określany na podstawie wartości z siatki stacji hydrologicznych w dorzeczu. Do obliczeń ograniczonej dostępności wody użyto krzywych retencji. Dostępne najwyższe zmagazynowanie wody stwierdzono w pierwszym okresie (273,89 mm). W okresie od maja do sierpnia było ono niższe (194,32 mm), a w ostatnim okresie wynosiło tylko 152,14 mm.

Słowa kluczowe: magazynowanie wody w glebie, woda w glebie dostępna dla roślin, dorzecze rzeki Nitry