ISSN 0354-8724 (hard copy) | ISSN 1820-7138 (online)

REVIEW ARTICLE

Water shortage and drought monitoring in Bačka region (Vojvodina, North Serbia) – setting-up measurement stations network

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Received: November 2013 | Accepted: December 2013

Abstract

Water shortage and drought, as the most important hydro-climatic hazards, cause significant damages in case of most continents including SE Europe.
An experimental field established in Bačka region (Vojvodina Autonomous Province, North Serbia) for the purpose of droughts/water shortage monitoring and remote sensing under ongoing IPA project „Water shortage hazard and adaptive water management strategies in the Hungarian-Serbian cross-border region" (WAHASTRAT). The main objective of this project is to determine water shortage conflicts on a local and regional level, and to reveal the frequency, extent and severity of future hydro-climatic hazards.

The locations of eight measurement stations selected on the principle of representativeness in term of terrain configuration and soil cover.

An area in which measurement stations were placed, covers about 1000 km^2 (12% of total area of Bačka) and includes geomorphic units which reliable represent the relief of the whole Bačka region.

Measurement stations were placed on 4 out of 5 most common soil types in the Bačka and Vojvodina: chernozem, alluvial soils, smonitza and saline and alkali soils.

A measurement equipment system was constructed for the requirements of the WAHASTRAT project. The aim was to design a user-friendly and affordable IT solution, which would enable continuous remote monitoring of meteorological parameters and soil moisture. Independent solar-powered measurement stations are able to automatically measure air temperature, air humidity, wind speed, wind direction, precipitation and soil moisture.

Key words: water shortage, drought monitoring, relief, soil types, measurement stations, Bačka, Vojvodina, WAHASTRAT

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Introduction

In the 20th century a 0.8°C rise in surface temperature and a 60–80 mm decrease in precipitation were detected in the Carpathian Basin, where water shortage is one of the greatest natural hazards causing serious damages to national economy, especially to agriculture and water resources in the affected years (Rakonczai, 2011). As global temperatures increase, not only is there more flooding with increasing occurrence of extreme precipitation events, but also more droughts are recorded in the Northern Hemisphere (e.g. Folland et al., 2002).

The annual temperature trend over Serbia is also following the global changes, but there is a difference between the northern part, where the increasing trend is registered, and the southern part, where the linear trend is negative. Drought is a quite often natural hazard in Serbia and dry years were particularly frequent in the last two decades of the 20th century (Spasov et al., 2002; Gocic and Trajkovic, 2013; Tošić and Unkašević, 2013). According to Rakićević (1988) and Dragićević et al. (2009) four regions in Serbia with the highest rist of drought were singled out. Two of them are in Vojvodina province – NE Bačka and N Banat. Gocic and Trajkovic (2014) were pointed out region of North Serbia as region with precipitation values under average of Serbia.

Water shortage and drought, as the most important hydro-climatic hazards, cause significant damages in case of most continents including SE Europe (United Nations Convention to combat desertification – United Nations, 1994). Due to their diverse consequences, the cost of drought damages is hard to estimate, however all studies identify these as the most harmful hazard of the next decades. Previous researches proved that the changes of the two main climate elements (precipitation and temperature) have contributed to significant trend-like alterations in the Carpathian Basin during the last decades. Furthermore, natural processes are amplified by the consequences of anthropogenic activities, and lead finally not just natural but significant social and economic problems. Decreasing precipitation also causes groundwater-table sinking. In summer months the decrease of available water resources can result further conflicts which must be resolved.

Therefore there is an increasing pressure to develop and maintain an integrated and sustainable water management in the region of the Carpathian Basin to overcome shortage problems. It must be taken into consideration that fresh water is a finite and valuable resource, essential to sustain agriculture and the environment. Water stress is a reality and human activities are changing the local and regional water household without adequate knowledge of the consequences. A complex research is necessary thus to elaborate cross-border strategies and take measures of mitigation. The sustainable management of water resources should be based on a participatory approach, involving users, planners and policy makers at all levels. Scientists and creators of policy can advance water security by focusing on interdisciplinary research, and ensuring that all stakeholders are involved in developing sustainable solutions to water problems The main types of drought are meteorological, agricultural, hydrological and socioeconomic droughts (Wilhite and Glantz, 1985). Droughts are induced by natural climate variability and its propagation through the hydrological cycle (Figure 1).

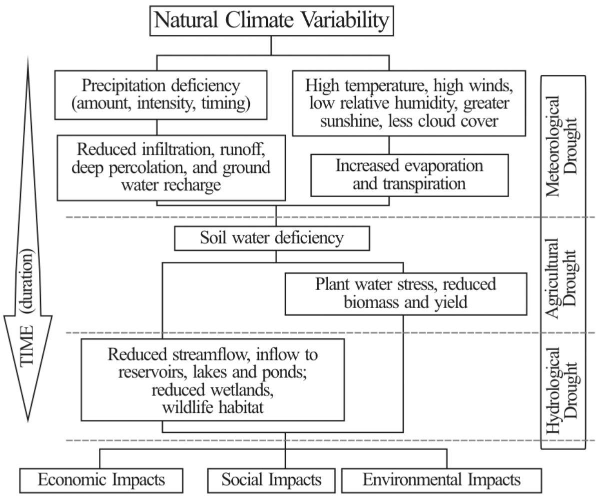

Figure 1. Drought occurence and impact for drought types
Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.

In 2012 started IPA project „Water shortage hazard and adaptive water management strategies in the Hungarian-Serbian cross-border region" (WAHASTRAT) made by the Department of Physical Geography and Geoinformatics (University of Szeged), Faculty of Sciences and Faculty of Technical Sciences (University of Novi Sad) and Lower Tisza District Water Directorate. The main objective of this project is to determine water shortage conflicts on a local and regional level, and to reveal the frequency, extent and severity of future hydro-climatic hazards.

In order to implement the project, it is necessary to properly select a location setting of automatic measuring stations, which would be accompanied by meteorological and hydrological parameters that are important for the understanding of the occurrence of drought. Some of the key points of this research are to determine the influence of the geomorphological environment, soil cover and agricultural activity on water shortage or drought phenomenon.

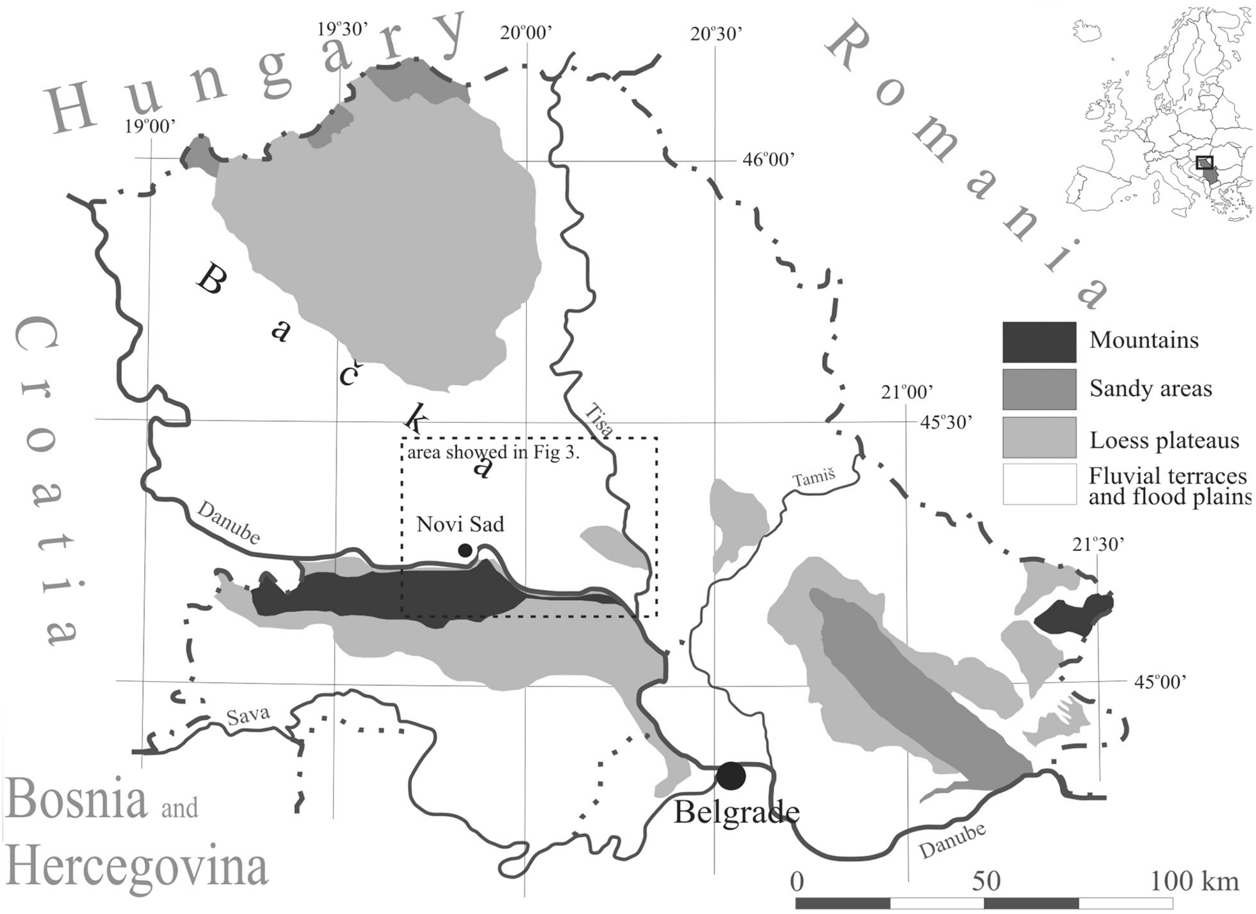

Figure 2. Geographical position of Vojvodina province and Bačka region on simplified geomorphological map

Study area

Bačka region is the southern part of the Great Plain of Carpathian (Pannonian) basin. As a part of Autonomous Province of Vojvodina, is located in the NW part of Serbia, limited by the Danube on the west and south, Tisa on the east, and the state border between Serbia and Hungary from the north. Bačka covers 9.244 km², and more than 75% of its area has altitude bellow 100 m.

The geological evolution of the Carpathian Basin from the Late Miocene onward, especially during the Quaternary, determined style of sedimentation, type of sediments, and thus hydrogeological characteristics of the area and thus also soil cover.

Fluvial sediments transported by the Danube and Tisa Rivers and their tributaries filled the Carpathian Basin during the whole Quaternary. Changes in subsidence rates in space and time throughout the Quaternary resulted in the evolution of a complex drainage pattern (Nador et al., 2007). During Early and Middle Pleistocene, the rapidly subsiding central part of the Great Plain, forced direction of the palaeo-Danube to the southeast (Nador et al., 2007).

In Bačka region, from the late Middle Pleistocene, simultaneously with fluvial sedimentation, aeolian sedimentation increased, which led to formation of loess plateaus (Marković et al., 2008, 2009, 2001, 2012; Jovanović et al., 2010, 2011). Waste areas covered by loess were dissected by rivers into two loess plateaus in Bačka - Bačka Loess Plateau and Titel Loess Plateau. In the youngest phase of sedimentation, the northernmost parts of Bačka get a cover of eolian sand (Figure 2)

Loess plateau

The highest relief unit is Titel Loess Plateau - an unique loess "island" with an area of 90 km² on the confluence of the Tisa and Danube rivers. Plateau consisted thick loess-paleosol sequences, in which five fossil pedocomplexes were discovered (Jovanović et al., 2010, 2011). Different phases of fluvial erosion and slope processes modeled ellipsoid shape of the plateau. Steep loess bluffs, up to 55 m high, confine it to the west, north and east while its southern part reveals more gentle morphology with small hypsometric differences (Zeeden et al., 2007).

Differences in inclination and heights of bluffs are results of active fluvial process and/or time elapsed time since the termination of fluvial and predomination of slope processes (Jovanović et al., 2011).

The surface of the Titel plateau, with heights between 100 and 128,5 m is characterized by numerous depressions – loess dolinas which forming an undulating landscape.

Despite thick recent soil and five fossil pedocomplexes which are incorporated ih the structure of the plateau with up to 50% of clay content (Bronger, 2007), cracks and mainly sub-vertical joint systems provide conduits for rapid transmission of water through the loess and paleosol (Derbyshire, 2001). High porosity (30-50%) and significant carbonate content of loess also explains its great permeability and moisture absorption capacity (e.g. Leger 1990). Phreatic aquifer is therefore very deep bellow the recent soil cover – in level of the plateau's base. Only occasionally, percolated waters can partly accumulated as a hanging aquifer above fossil soils (Lukić et al., 2009).

A typical recent soil cover of the plateau is represented by chernozem calcareous (micellar), chernozem limeless (Nejgebauer et al., 1971; Živković et al., 1972).

Fluvio-paludal and fluvial terraces

Terraced relief between loess plateaus in Bačka and the flood plains of the Danube and Tisa, Bukurov (1953, 1975) specified as (a) South Bačka loess terrace of diluvial age and (b) alluvial terrace. Košćal et al. (2005a,b) as the spatial equivalent of loess terrace, recognized fluvio-paludal floor of the Pannonian basin (5 on Fig. 3) and higher river terrace (4 on Fig. 3). Equivalent of Bukurov' alluvial terrace is the lower river terrace. In a recent study of Popov (2012), Upper Pleistocene age of the lower river terrace is determined by absolute dating. Moreover, whole terraces system, including fluvio-paludal floor, higher and lower river terraces, got a name – Upper Pleistocene terrace (Popov, 2012)

The fluvio-paludal floor of the Pannonian basin is a landform produced by the superseded fluvial process. It is identified at the bottom of the Pannonian basin in a large part of Vojvodina, at elevations from 80 to 90 m (Košćal et al., 2005b). In SE Bačka, this relief unit is placed between Bačka loess plateau on north and west, Tisa flood plain in east, and (Danube) higher river terrace on the south (Fig. 3). Relative height of the floor

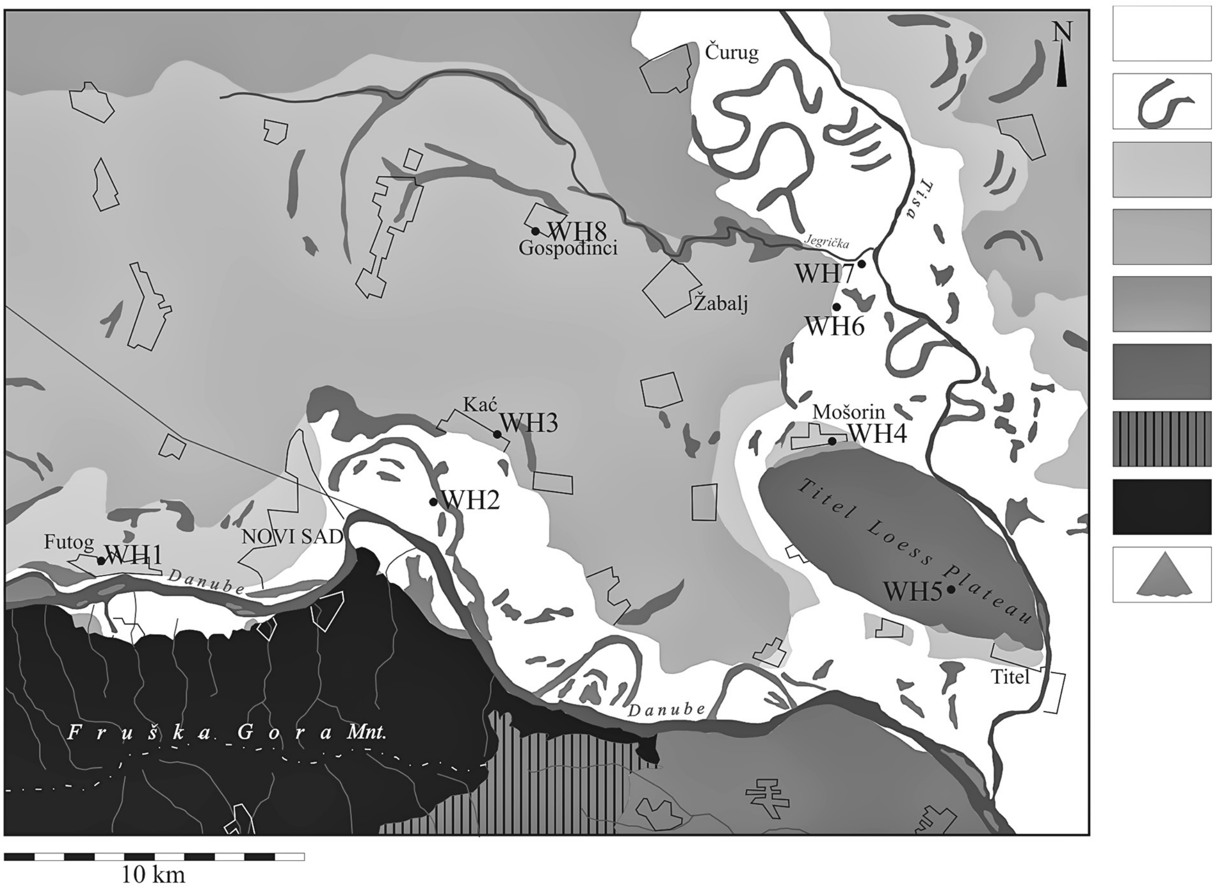

Figure 3. Geomorphologic map of SE Bačka with position of measurement stations (WH)
Legend: 1. flood plain; 2. fluvio-marshy environment (oxbow lakes, abandoned meandes, swamps and marshes); 3. lower river terrace; 4. higher river terrace; 5. fluvio-paludal floor ot the Pannonian basin; 6. loess plateaus; 7. Fruška gora' marine/lacustrine terrace covered by loess; 8. Fruška Gora mountain; 9. proluval fans and deluvio-proluvial pediments (Košćal et al., 2005a). According to Bukurov (1953, 1975), units 4 and 5 are designated as „loess terrace" or „diluvial terrace"; according to Popov (2012) units 3-5 are designated as „Upper Pleistocene terrace".

above the flood plain is 2 to 4 m and border is mainly represent by scarp. Boundary toward higher river terrace is less visible, except partly on left side of Jegrička valley. On the floor the remnants of fossil meanders are not observed nor old river beds or point bars. The surface is disguised with loess like material, on which the Holocene terrain is developed (Marković, 2000).

Typical soil cover on fluvio-paludal floor in SE Bačka represented by chenozem limeless, chernozem with signs of glay in loess and chernozemlike calcareous meadow soil on loess (Nejgebauer et al., 1971a,b)

The higher alluvial terrace in SE Bačka is formed on the left side of the Danube. Because numerous towns and villages were built on this terrace, it was known as "varoška" (town terrace) (Halavacs, 1895; Bukurov, 1950).

Forming was the result of gradual shifting of the river channel to the west and south, and finally Danube took its present position during the Late Pleniglacial (Pecsi, 1959). During Last Glacial Maximum, intensive eolian processes occurred (Marković et al., 2008), and higher alluvial terrace got his loess cover. Many meander-shape depressions on the terrace, as well as point bars, are the remnants of the pre-loess fluvial relief. Some of them survived as oxbow ponds until rivers regulations in the 19th century (Popov, 2012; Popov et al., 2008). Rapid westward migration of Tisa channel at the end of Upper Pleistocene (Timar et al., 2005),did not enable formation of higher terrace on the right side of Tisa.

On the northern edge of the terrace, Jegrička valley cuts a scarp toward fluvio-paludal floor. In SE Bačka, valley is quite narrow – between 20 and 80 m, and shallow – from 2 to 2.4 m (Bukurov, 1950).

Due to diversity of grain size of sediments, their hydrogeological properties, quite small hypsometric differences and vegetation which was formed in different areas on the terrace, diversity of soil cover was formed. Typical soil cover on the higher river terrace in SE Bačka is represented by chernozem limeless, chernozem with signs of glay in loess, chernozem with signs of swamping, chernozem calcareous (micellar) on loess terrace, chernozem salinized and solonchak (Nejgebauer et al., 1971a,b)

Lower river terrace in Bačka, were recognized by Bukurov (1953, 1975) as „alluvial terrace". He found that terrace in Danube alluvial plain upstream of Novi Sad, while he claimed that such unit is not present in alluvial plain of Tisa. Košćal et al. (2005a,b) determined lower river terrace in the alluvial plain of Tisa – north, west and south from Titel loess plateau, as well as on the Banat side of the valley (Fig. 3). Terraces around Titel plateau partly represented terraced deluvial-proluvial pediment, on which Titel and Mošorin settlement were grown. Boundary between Titel terrace and flood plain is scarp of the relative height 5 - 8 m.

Chernozem on sandy loess and hydromorphic black calcareus and salinized soil are recent soil cover (Nejgebauer et al., 1971a,b).

Flood plains

Flood plains are the lowest-lying landscape in SE Bačka. Its altitude is from 75 m near Novi Sad (on Danube) or Čurug (on Tisa), and 73.7 m at Tisa confluence. South from Kać, left side of Danube flood plain is 6 km wide, while south of Titel is 4 km. Right side of Tisa flood plain is between 11 and 2,3 km wide north of the Titel loess plateau.

Morphology of the alluvial plain is consisted of: abandoned channels, oxbow lakes, flooding depressions, point bars, sand bars, hills, and islands. Bar height is equal to the mean bankfull discharge, i.e. 1.5 m above mean water level (Popov et al., 2008). Prior to the regulation of the Tisa River valley in the 19th century, the extensive alluvial plain has been flooded constantly. Nowadays, flooding is strictly limited to the narrow section among the embankments (Fig. 3 and 4).

On alluvial material in flood plains numerous soil types and varieties developed: alluvial soil of sandy loess, hydromorphic black soil, alluvial loamy soil, alluvial swampy soil, alluvaial salilnized soil, hydro-

Figure 4. Northern side of Titel loess plateau and surrounding relief
(Photo M. Jovanović)

morphic smonitza soil, solonchak, solonetz (Nejgebauer et al., 1971a,b).

Matherial and methods

A measurement equipment system was constructed for the requirements of the WAHASTRAT project. The aim was to design a user-friendly and affordable IT solution, which would enable continuous remote monitoring of meteorological parameters and soil moisture.

The system consists of a number of independent solar-powered measurement stations able to automatically measure and report on conditions such as the content of water in the soil, wind speed and direction, air temperature and humidity, rainfall with the possibility of adding sensors for measuring solar radiation, leaf wetness, as well as presence of air pollutants. The measurements are collected from the measuring stations over the mobile phone network and can be viewed by the user over the web, as well as through a smart-phone application, enabling easy access and visualization of the data. The system enables effortless, continuous monitoring of soil moisture in various soil types and meteorological conditions.

The remote sensing station, provide the following functionality:

For the needs of the WAHASTRAT project the following sensors are used for measurements: 6 soil moisture Decagon sensors, air temperature, air humidity, wind speed, wind direction and precipitation.

The analogue soil-moisture-measurement sensors have a measurement time of 10 ms and accuracy of at least 0.03 m^3/m^3 in all soils. With soil-specific calibration ±.02 m^3/m^3 (±2%) can be achieved. They sport a resolution of 0.001 m^3/m^3 VWC in mineral soils, 0.25% in growing media and can operate in the environments of -40 to +60°C.

The weather sensors have the following characteristics:

Table 1. *Characteristics of weather sensors*

	Range/accuracy
Temperature range	-40 to 65°C
Temperature accuracy	0.5°C
Relative humidity range	0 to 100%
Relative humidity accuracy	±3%
Wind speed range	1 to 60 m/s
Wind speed accuracy	±5%
Wind direction range	0 to 360°
Wind direction accuracy	±3°
Rain fall range	0 to 999.8 mm
Rain fall resolution	0.2 mm

Access to current and previously measured sensor data is enabled trough an easy to use, intuitive Web application. The application provides a view of all locations, devices, sensors and allows data export into xml, csv, xls formats and direct access to electrical values measured from the sensors.

Summary description of localities with measurement stations is presented in Table 2.

Station **WH1** is located on plowed land of Secondary Agricultural School in Futog, west from Novi Sad. Locality is placed in the middle part of 6 km wide lower river terrace, on 78 m a.s.l. On the location, remnents of abandoned and completely filled up river channel are visible on topographic map in scale 1:25.000 and GoogleEarth satellite images. On these alluvial sediments, chernozem brownized is formed.

According to Živković et al. (1972) this variety of chernozem is one the youngest soil outside of loess terrains in Vojvodina. As others subtypes and varieties of chernozem, typical A-AC-C profile is deeply developed. On the lower terrace, acumulative-humus A horizon is about 30 cm thick, while the thickness of transitional AC is about 15 cm. More of 60% of total sand in A and AC horizons, designated soil as a sandy loam (Živković et al., 1972). Despite to lowest humus content among chernozem type, due to other morphologic, physical, chemical and water properties, chernozems brownized on alluvial sediments have one of the highest producing potential among all soils in the area (Živković et al., 1972).

Station **WH2** is located in the Danube flood plain – in former Danube island („Petrovaradin Military Island"). Abandoned Danube channel, on which right bank station is placed, was active untill the second half of 19^{th} century transition (Acranum, 2007). It is the lowest places measurement station – 73 m a.s.l. On alluvial swampy soil, grass vegetation is present.

Soil is formed on silty and sandy material, which is stratified as typical point bar sediements of meandering river.

Due to very young age of soil, Živković et al. (1972) did not recognize genetic (sub) horizons in the alluvial swampy soil.

Station **WH3** is placed in village Kać, on a higher river terrace. Above the flood plain, this geomorphic unit has thin loess or loess-like cover. On 79 m a.s.l, chernozem limeless (A-AC-C) and chernozem slighty brownized (A-A(B)-AC-C) is developed. Although these types of soil are similar to chernozem calcalerous, they have better water- and air- regime and therefore better producing potential (Živković et al., 1972).

The station is positioned on the backyard lawn.

Station **WH4** is set in village Mošorin, on deluvial-proluvial fan, eroded and terraced by Tisa channel. It is equivalent of lower river terrace (Fig. 3). Chernozem

Table 2. *The position of measurement station in SE part of Bačka*

Station	Geographic coordinates (latitude/longitude/altitude)	Geomorphologic unit/ subunit	Soil type/subtype/variety
WH 1 Secondary Agricultural School, Futog	45° 14'38.47" 19° 41'55.78" 78 m	The lower river terrace	Chernozem brownized on the alluvial deposits
WH 2 Equestrian Club "Graničar"	45° 16'30.97" 19° 54'50.24" 73 m	Flood plain, sediments of the riverbed	Alluvial swampy soil
WH 3 Kać, backyard	45° 17'58.84" 19° 57'35.74" 79 m	The higher river terrace covered with loess/loess like sediments	Chernozem limeless and chernozem slighty brownized
WH 4 Mošorin, backyard	45° 17'56.88" 20° 10'49.16" 76 m	The lower river terrace, terraced deluvial-proluvial fan of Titel plateau	Chernozem on sandy loess
WH 5 Titel plateau, farm	45° 13'59.42" 20° 15'15.69" 116 m	Loess plateau	Carbonated chernozem on loess plateau
WH 6 Žabalj, farm	45°22'27.30" 20°10'22.73" 75 m	Flood plain of Tisa river	Solonchak
WH 7 „Žabalj" pumping station	45°23'19.38" 20°11'31.82" 73 m	Flood plain of Tisa	Hydromorphic smonitza soil
WH 8 Gospodjinci, „Global Seed Co"	45° 23'48.38" 19° 58'46.05" 80 m	The higher river terrace covered with loess	Chernozem with signs of swamping

on sandy loess is typical soil formed on loess plateaus slopes and on contacts between eolian sandy plains and loess plateaus.

Soil has thick A horizon (40-60 cm) but low humus content. It is sandy loam with high porosity and permeability and therefore easily losing soil moisture (Živković et al., 1972).

The station is located on 76 m a.s.l. on the lawn surounded with vegetable plants.

Station **WH5** is located on Titel loess plateau, on 116 m a.s.l. Typical chernozem calcareous on loess plateau is developed.

Average thickness of A horizon on the flat surface is about 50 cm. On the slopes of loess dolinas, A horizon is thinner due to erosion, while in central areas of the depressions, the horizon is about one meter thick (Zeeden et al., 2007).

As regards the basic morphologic, physical, chemical and water properties, chernozem on loess plateau has the highest production potential among all soils in Vojvodina by applying the contemporary agrotehnical measures (Živković et al., 1972). However, because of soil porosity and permeability, and very deep phreatic aquifer, chernozem on loess plateau is very susceptible to drought or water shortage.

Station **WH6** places in Tisa flood plain, on 75 m a.s.l., in area of fluctuating phreatic aquifer, surplus of moisture in the topsoil and strong evaporation in the summer months. As a result of accumulation of alkali salts, solonchak is developed on the locality.

The extremely low hydraulic conductivity and high values of soil moisture retention, solonchak has poor physical characteristics and very low production potential (Živković et al., 1972). On the locality weak pasture vegetation is growing – suitable for cattle grazing.

Station **WH7** is located on a Tisa flood plain, on the confluence of Tisa and Jegrička. On very low terrain (73 m a.s.l) on silty to loamy alluvial sediments of Tisa, hydromorphic smonitza soil (A-ACG-CG-G) is developed.

It was formed by overmoistening the soil with underground and surface water. Therefore the content of clay particles in smonitza is greater than in other soils in Vojvodina. Top horizon A on the locality is average 40cm thick but its depth can be even 100 cm. As regards its grain size content, hydromorphic smonitza soil belongs to clays or heavy clays. It is very hard for cultivation but potential fertility is very high (Živković et al., 1972).

Station **WH8** is positioned on the northern edge of the higher river terrace, just south of Gospodjinci village, on 80 m a.s.l. Below the surface, point bar sediments of meandering river are accumulated.

Chenrozem – with signs of swamping (A-AC-C-CG) represents top soil. It was formed under influence of surface or underground waters and overmoistening of soil. Before regulations of influence of surface or underground waters and over-moistening of soil. Before regulations of Tisa and irrigation of terrace, high Tisa waters where inflow into Jegrička and its tributary valleys. Therefore, such inland excess waters caused changes in soil structure and grain size. Porosity and permeability of this variety are lower than in other chernozems.

The station is located on the lawn in yard of „Global Seed" company.

Discussion

An experimental field established in SE Bačka for the purpose of droughts/water shortage monitoring and remote sensing. The locations of eight measurement stations selected on the principle of representativeness in term of terrain configuration and soil cover. Vicinity of Novi Sad is important because of maintaing of stations and reduction of travel costs.

An area in which measurement stations were placed, has geomorphic units which represent the relief units of the whole Bačka region, except eolian dune relief (Figure 3).

The maximum distance between outermost stations in a direction W-E (WH1-WH4) is 50 km, while in the S-N direction (WH1-WH8) distance is 17 km. Therefore, study area covers about 1000 km², or 12% of Bačka and 5% of Vojvodina.

In Danube realm, measurement stations were placed on flood plains (WH2), lower river terrace (WH1) and higher river terrace (WH3, WH8). In Tisa realm, two stations were located in a flood plain (WH6, WH7), and one on the lower terrace (WH4). One station (WH4) loess plateaus.

Thinking in consideration the fact that more than 75% of Bačka region has altitudes bellow 100 m, therefore seven stations are placed on the altitudes between 73 an 80 m, and only one over 100 m – as representative of loess plateaus (Fig. 5)

For the whole Vojvodina region, the selected locations are also highly representative.

According to Ćurčić et al. (2012), fluvio-paludal floor and higher river terrace covers 38% of Vojvodina area, on which 60% settlements were established. Alluvial plains and lower river terraces covers 35% of province surface, with 11% of settlements (including Novi Sad). Loess plateaus in Vojvodina covers 22% of area with 20% of settlements. Therefore, our experimental field represents 96% of the Vojvodina province area with a total of 91% settlements.

Measurement stations were placed on 4 out of 5 most common soil types in Bačka and Vojvodina

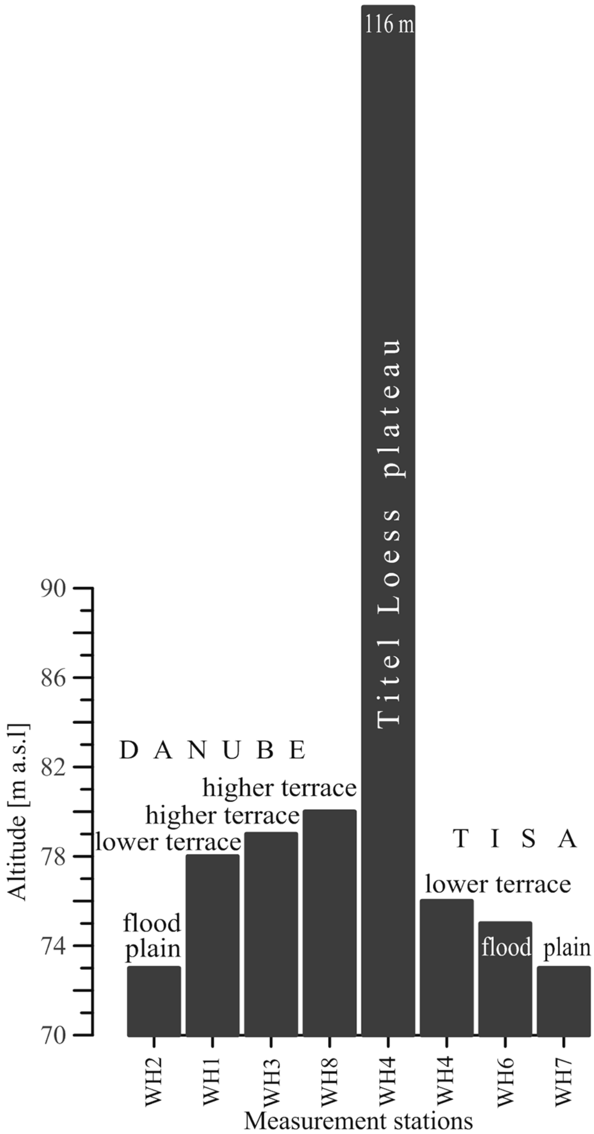

Figure 5. Measurement stations distributions according altitude and geomorphic units

(Živković et al., 1972). Out of five most abundant soil types in Bačka and Vojvodina (Figure 6) which make 92% or 74% respectively of land cover, four types of soil are covered with measurement stations: chernozem, alluvial soils, hydromorphic smonitz soils, saline and alkali soils. These four types constitute 62% of the land cover of Bačka, or 63% of the land cover of Vojvodina.

The most abundant soil type in the area – chernozem, in our experimental field is represented with five varieties: carbonated chernozem on loess plateau, chernozem limeless and chernozem slighty brownized, chernozem with signs of swamping, chernozem brownized on the alluval deposits, chernozem on sandy loess.

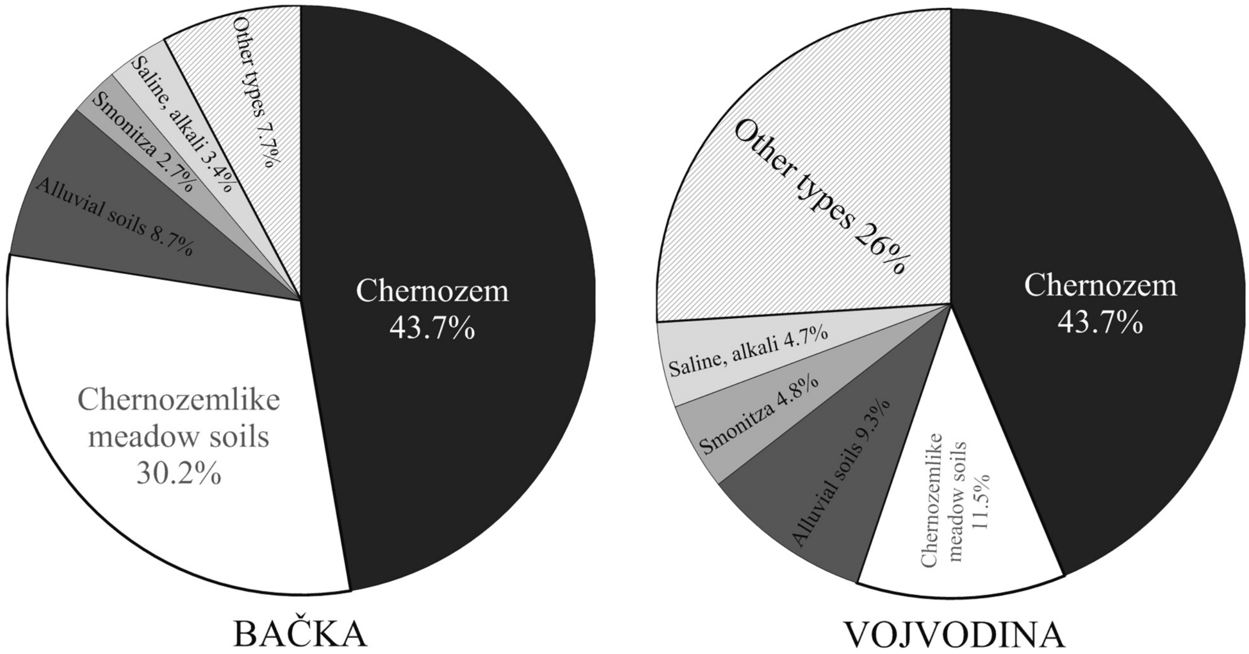

Figure 6. Most abundant soil types in Bačka and Vojvodina
Source: Živković et al., 1972

Conclusions

Drought is such a natural hazard, that is the most difficult to define: to give its actual beginning, duration, ending and to quantify its intensity and impacts. Drought is caused by climate variability, which cannot be prevented, but its effects can be reduced through management systems that include self-monitoring and drought early warning of its possible occurrence. Impact of a drought can be identified through the determination and monitoring of various parameters such as the amount of available water, crop condition, the degree of degradation of land, farm productivity, adverse economic impacts through reduced production, loss of profits, staff redundancies, the requirements related to the size of irrigation systems and fields etc.

Water shortage affects the environment and human activities, having social and economic consequences, such as drinking water shortages, agricultural yield reduction, and limitations on touristic activities. Preparing for prospective drought by developing a more optimal land use and water management should be a key objective of the spatial planning to mitigate the damage of droughts.

The WAHASTRAT project therefore aims to find integrated water management solutions for the increasing problem of water shortage.

In order to implement the project, a network of eight automatic measurement stations was setting-up in SE Bačka. Study area covers about 1000 km², or 12% of Bačka or 5% of area of Vojvodina.

The locations of eight measurement stations are selected on the principle of representativeness in term of terrain configuration and soil cover. The stations are placed on geomorphic units which reliable represent the relief of the whole Bačka region.

Measurement stations are placed on four out of five most common soil types in Bačka and Vojvodina.

Some of the key points of this research are to determine the influence of the geomorphological environment, soil cover and agricultural activity on water shortage or drought phenomenons. Installed monitoring network associated continuous data recording, transmission and processing, as well as the real time public display.

Acknowledgements

This paper is part of the IPA project „Water shortage hazard and adaptive water management strategies in the Hungarian-Serbian cross-border region" (WAHASTRAT)

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