Soil moisture condition in a spruce ecosystem after applying wood ash on the soil surface

Ladislav Tužinský, Marián Homolák, Juraj Gregor, Viliam Pichler, Juraj Bebej

Department of Natural Environment, Faculty of Forestry, Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, SR, e-mail: tuzinsky@tuzvo.sk, homolak@tuzvo.sk, gregor@tuzvo.sk, pichler@tuzvo.sk, juraj.bebej@tuzvo.sk

Abstract

Tužinský, L., Homolák, M., Gregor, J., Pichler, V., Bebej, J. 2013. Soil moisture condition in a spruce ecosystem after applying wood ash on the soil surface. *Folia oecol.*, 40: 130–136.

We examined the effects of wood ash applied on soil surface in a spruce ecosystem on the course of soil moisture content, available water reserves and soil water conductivity in the upper 20 cm soil layer. The study was carried out in the growing seasons 2011 and 2012, on three parallel plots: a plot supplied with wood ash at an amount of 5 t ha^{-1} in spring, a plot supplied with the wood ash in the same amount in autumn, and a non-treated control plot. In the layer with the highest occurrence of sucking roots, we analysed two hydro-pedological cycles: the prevailing semi-uvidic interval defined with the limits of maximum capillary capacity (MCC) and the point of diminished availability (PDA), and the semi-arid interval defined with the hydrolomits PDA and wilting point (WP) in the growing season 2011 in summer. The soil moisture content and hydraulic conductivity (with several exceptions due to micro-differences in soil properties) were higher on plots supplied with the wood ash.

Keywords

available water, forest ecosystem, hydrolimits, soil moisture content, wood ash

Introduction

Changes to ecological conditions in the natural environment are responded by changes in specified units of the system atmosphere – forest ecosystem – aeration zone. Today we are experiencing extreme rainfall events with alternating periods of considerable precipitation deficit and episodes showing extreme precipitation totals. As the result, the water regimen of soils is changing, mostly due to increase in temperature and evapotranspiration and due to reduced precipitation totals. In soils, these changes most significantly affect the superficial layers and the zone with the highest occurrence of active roots in which, apart from water intake, transport and storage, also the content of nutrients for plants in soil solutions is decisive (Bublinec et al., 2006). In this context, spruce ecosystems appear as the most critically endangered by drought. Growing mostly on acid soils poor in mineral nutrients, spruce trees also suffer from notably fluctuating nutrients availability – possible to overcome with a suitable fertiliser (Bublinec, 1994; Bublinec and Machava, 2009; Bublinec and Voško, 1987). A promising option seems to be wood ash applied on soil surface or incorporated into upper soil layers after clear cutting or natural disturbances. The wood ash provides a reserve of nutrients removed from the forest environment by wood harvesting (Bublinec et al., 2005). Thanks to its structure, mimicking clayey materials, the wood ash can serve as a medium enhancing the soil water retention capacity, enabling to increase the soil water storage capacity.

This work analyses the moisture content in surface soil layers in a spruce ecosystem supplied with wood ash. This substance, apart from delivering elements necessary for plant nutrition and controlling soil physical properties, should also improve the plants´ resistance against drought and frost (Otepka and Tóthová, 2011). The problem is solved also with the aim to increase the efficiency of soil physical and hydric performance. The study of wood ash effects on water regimen in soils was conducted within the project of EU structural funds ITMS 262202 20016 "Wood ash use in forest management" and the project APVV-0580-10 "Transformation, transport and distribution of materials in the surface horizon of forest soils".

Material and methods

The research plots are situated in the forested area of the Veporské vrchy and Stolické vrchy Mts, forest management unit Hriňová, in an 80-year-old spruce ecosystem, compartment 138 B, area 3.59 ha. The local climate is moderately warm and wet; the average temperature in July is 16 °C, the annual precipitation sum is 800 mm. In this locality (Table 1) we chose three monitoring plots, each 20 × 20 m in size. The soils on plots are clayey-sandy to sandy-clayey, moderately moist to moist. Wood ash was applied in an amount of 5 t ha^{-1} throughout plot S in spring 2010, and throughout plot A in autumn 2010. Plot K was left without ash as a control.

Soil moisture content was measured gravimetrically, at intervals of ten days, to the depth of 80 cm, with each measurement repeated 3–5 times. The detailed description of the sample analysis and hydro-limits setting is in our papers published formerly (Tužinský, 2004, 2007). The water storage and soil water characteristics were assessed according to Kutílek (1966, 1978). The results of the analyses were evaluated by the one-way analysis of variance and the Duncan's test in the Statistica package (Sokal and Rohlf, 1995).

Results

Soil moisture content and available water reserves in the growing season 2011

The rainfall sum over the growing season 2011 was 400 mm. Deficit in rainfall were April (17 mm), August (23 mm) and September (10 mm). The highest amount of precipitation had fallen in July (215 mm), from which more than 70% was in the second half of the month. Fairly favourable was also June (93 mm), mainly due to uniform precipitation pattern over this month (Fig. 1).

Table 1. Research site Hriňová

Tree species	Stocking density	Canopy density	Age	GFT°	Soil type	Exposure, altitude
Spruce 100%	0.8	85–90	80	*Fagetum typicum*	Cambisol Typical	NNE 825

° – typological unit.

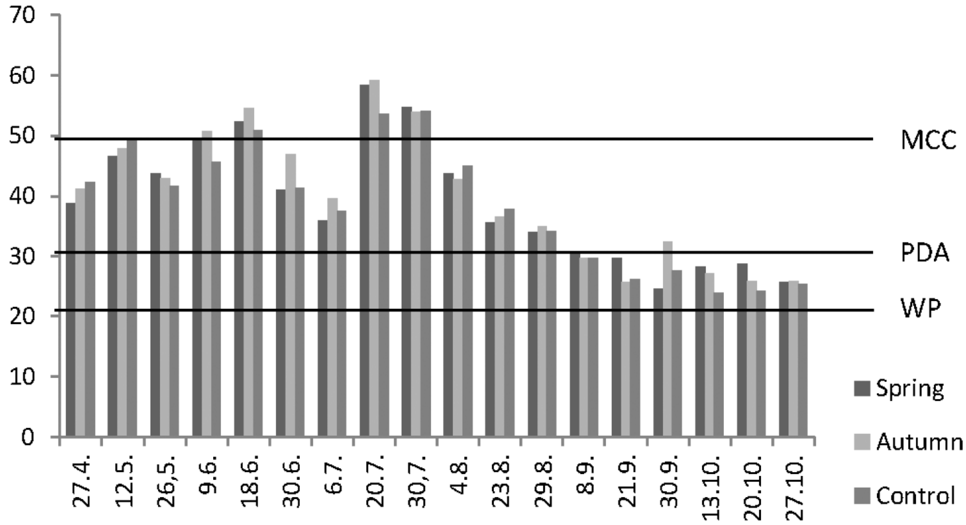

Fig. 1. Water storage [mm] in the growing season 2011.

In terms of hydrological limits, the moisture content in surface soil layers on the monitoring plots at the beginning of the growing season was between the point of maximum capillary capacity point (MCC) and point of diminished availability (PDA). The capillary pores were saturated with water in the first two ten-day periods of June, evidently due to long-lasting precipitation. At that time, the soil water occurred also in form of capillary free water. Maximum soil moisture values were recorded in the second and the third ten-day period of June when the 161 mm monthly total resulted in a soil moisture increase above the lower MCC limit. In August, deficient in rainfall, there followed the most distinct decrease in moisture content (by 21% vol.) and transformation of free water to immobile water. Then, until the end of the growing period, the soil moisture fluctuations on the plots were damped considerably, with the values fluctuating between the point of diminished availability and the wilting point (WP), the water being capillary fixed.

The data describing water available for plants (Fig. 2) distinguish two phases within the growing season: the first from the end of April to the first ten-day period of August, interrupted with only a short episode at the beginning of June, with sufficient amount of water susceptible by plants (>20 mm) in the upper 20 cm soil layer. Any other time, the soil water reserves available for plants were not sufficient: from the second ten-day period of September on plots with ash scattered in spring and on the control plot maintaining within the bottom third of this interval.

Soil moisture content and available water reserves in the growing season 2012

The total rainfall in the growing season 2012 was 363 mm. Compared with the growing season 2011, in 2012 were recorded higher precipitation totals at the beginning and at the end of the growing season, and the precipitation pattern over the whole period was more uniform. Like in 2011, the major part fell in June and July (219 mm), in July 2012 it was by 80 mm less than in July 2011.

The graphical representation of soil moisture content by means of hydrolimits (Fig. 3) shows that the fluctuation range of soil moisture content was relatively small, with the values mostly within the limits MCC and PDA. In spring, soil moisture content on plots treated with ash (plots S and A) varied close to the upper hydrolimit PDA, with prevailing mobile capillary water. In the other days of the growing season, the water storage on these plots maintained within the lower third of the range PDA–MCC, with water reduced to immobile capillary water. The reserves of plant-accessible water (Fig. 4) on monitoring plots varied like in the growing season 2012, from sufficient until the first ten-day period of June followed by insufficient until the end of the growing season. The most dramatic drop in water reserves occurred already in the second ten-day period of June (a drop of 14 mm in less than ten days), the maximum of 20 mm on the plot supplied with ash in autumn. Such a moisture reduction was a surprise, because of 90 mm precipitation fallen on the plots in 11 rainy days in the first and second ten-day periods of June. Similar situation with water reserves was in August. The total rainfall in this month was 135 mm fallen in 20 days, however, the water reserves maintained below the lower limit of sufficient storage, with exception of the last days of the second ten-day period.

Analysis of soil moisture condition on parallel plots

The analysis of moistening, duration of moistening and moisture stratification within the surface soil layers by

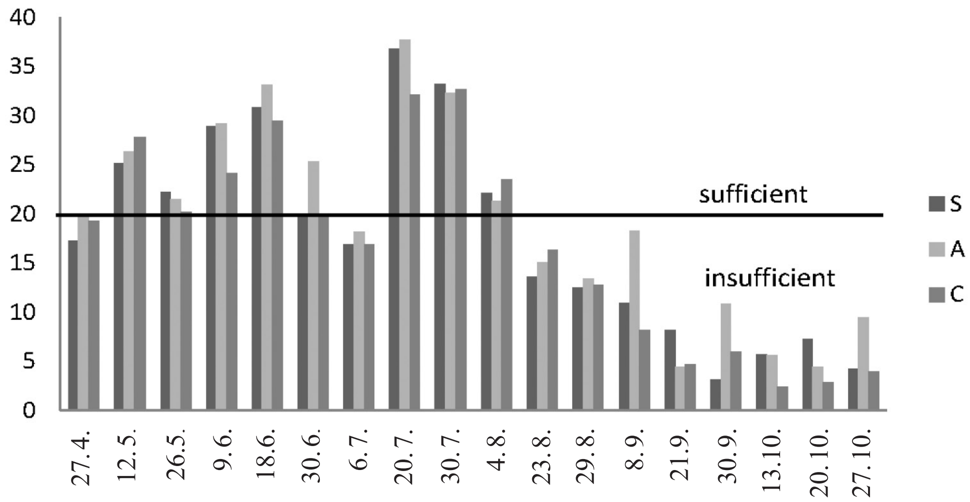

Fig. 2. Available water reserves [mm] in the upper 20 cm soil layer.

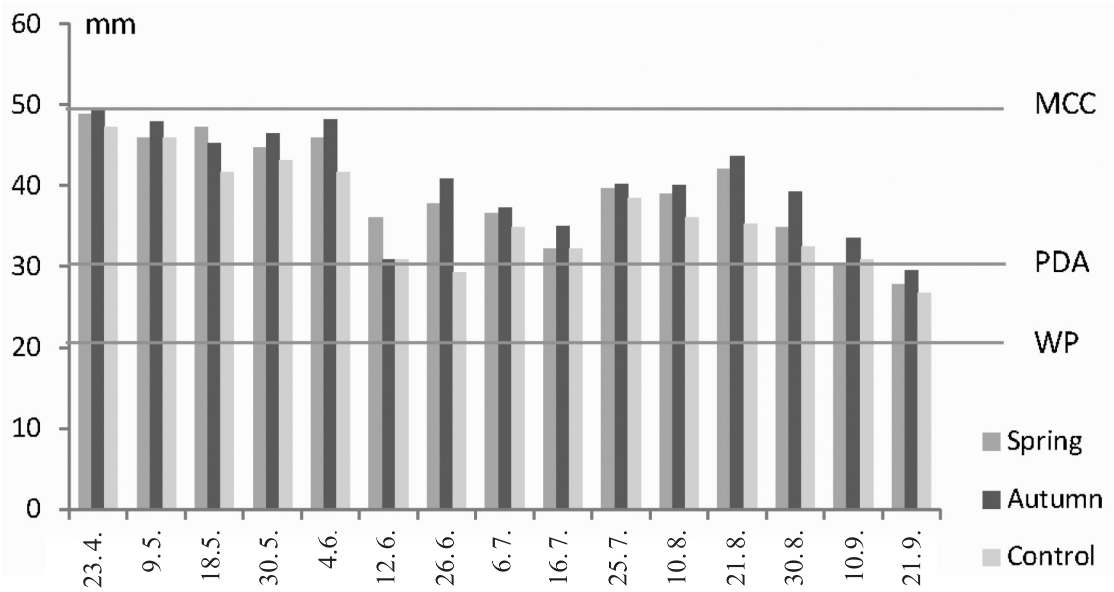

Fig. 3. Water storage [mm] in the growing season 2012.

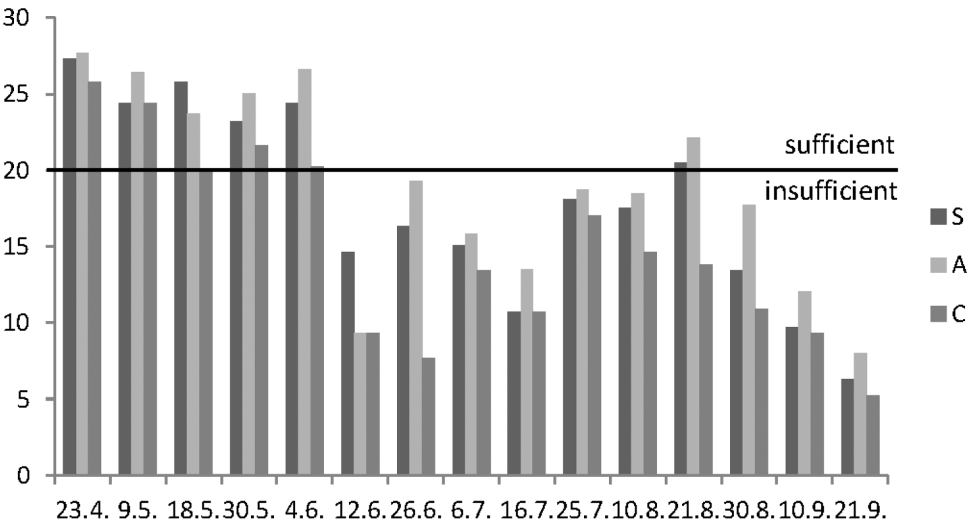

Fig. 4. Available water reserves [mm] in the upper 20 cm soil layer.

means of hydrolimits has resulted in detection of two hydro-pedological cycles on the monitoring plots during the study seasons. The dominant was semiuvidic interval defined with the limits MCC and PDA; in the summer months, it was the semi-arid interval with the limits PDA and WP. The occurrence of intervals correlated with the intensity and time course of precipitation totals. In the growing season 2011, the MCC–PDA interval persisted for 4 months, in the season 2012, it covered all the season except the final days of September.

Soil moisture content values in the two growing seasons were determined on all three plots in the second half of July, with small exceptions in the same days. The maximum values were: 58.3% vol. on the plot supplied with ash in spring, 59.2% on the plot supplied with ash in autumn, and 54.1% on the control plot. Expressed in terms of hydrolimits, they represented from 106 to 116% MCC. The minimum values were from 24% vol. (control plot) to 26% vol. (plot with ash applied in autumn), representing from 48 to 52% of the MCC. The average soil moisture content on the control plot was 37.8% vol., on the plot treated with ash in spring 38.9% vol., on the plot treated with ash in autumn 39.9% vol., being from 78–80% MCC.

Evaluating the reserves of plant-accessible water, we recorded the following highest soil water reserves: 37.6 mm on plot supplied with ash in autumn, 36.8 mm on plot supplied with ash in spring, and 32.6 mm on control plot. All these values correspond to sufficient reserves of accessible water.

Especially worth to notice are long periods of lacking accessible water: in the growing season 2011 from the second ten-day period of August, in 2012 already from the first days of the second ten-day period of June. The accessible soil water reserves in the studied growing season varied within: 2.4–32.6 mm on the control plot, 3.1–37.6 mm on plot treated with wood ash in spring, and 4.4–37.6 mm on plot treated with wood ash in autumn.

The results of statistical analysis did not detected statistically significant differences in accessible water storage among the parallel plots in both growing seasons, the extreme values, however, measured on the individual plots, point at positive influence of wood ash application on increase in accessible water reserves. In this case, the statistical differences might be superimposed with extreme character of precipitation events in the studied seasons and also inadequate due to relative short measurement period (two years are not enough for declaring unequivocal conclusions about positive trends in soil amelioration – concerning its hydraulic, retention, textural and structural properties).

However, it is necessary to note that the soil water reserves (with small exceptions) were more abundant on plots treated with wood ash. Considered are to be also other soil properties significantly affecting the soil water retention capacity, such as the original soil texture and structure, humus content, initial moisture content (hydrophobicity), vegetation cover, stand canopy and others.

Discussion

In context of development and utilisation of renewable energy sources sensu the legislation and strategic documents of the SR and EU (Ilavský and Bublinec, 2005), wood ash, as a potential energy source of domestic origin is also characterised, thanks to its qualitative features, as an alternative source of nutrients. In forest management, it becomes considered especially for moderation of forest soils acidification and supply of basic nutrients (Otepka and Tóthová, 2011). The use of sources improving the plants´ resistance, especially against drought, is well-reasoned mainly in case of spruce ecosystems, the most endangered in case of low or insufficient reserves of accessible water. Very important is also the issue of controlling the soil physical properties, such as soil texture and structure (retention or retardation). The hitherto obtained results in research on water regimen in soils in ecosystems with dominant spruce suggest that also in this natural environment, the water reserves across the physiological soil profile are gradually reduced (Tužinský, 2002, 2004, 2011). The results of our research covering two growing seasons 2011 and 2012 are preliminary, possible to summarise in the following way:

- Under relatively equal atmospheric precipitation sums, more favourable moisture conditions and more equilibrated moisture history in surface soil layers in spring 2012 may be explained by more abundant water reserves from winter snow and abundant rainfall in April on all study plots.
- Inspecting the differences in soil moisture content among the plots (S, A, and C) we can see that the water reserves on plots spread with wood ash were higher, so the ash was contributing to retention and retardation of water reserves by affecting humus formation (increasing the humus proportion) and by affecting physical properties of organic and inorganic compartment of the soil.
- Intervals defined with extreme soil moisture values and fluctuations of available water reserves on plots supplied with ash are more favourable for plants than on the untreated control plot; the results of statistical analysis, however, did not disclose statistically significant differences among the variants in the two growing seasons.
- Positive effects of ash application may also be expected in case of water accumulation in the cover soil horizons, infiltration and percolation into deeper soil layers – which would drive the water supply into the most dried-out surface layers by capillary action from deeper situated, wetter soil layers.

Acknowledgements

This publication is the result of implementation of the project ITMS 262202 20016 „Wood ash utilisation in forest management“ supported by the Research development operational programme funded by the ERDF, and the project APVV-0580-10 „Transformation, transport and distribution of materials in the overlying horizon of forest soils“.

References

Bublinec, E. 1994. *Koncentrácia, akumulácia a kolobeh prvkov v bukovom a smrekovom ekosystéme* [Concentration, accumulation and cycle of elements in beech and spruce ecosystem]. Acta dendrologica. Bratislava: Veda. 132 p.

BUBLINEC, E, DUBOVÁ, M., KÚDELOVÁ, D. 2005. Mikroelementy a ich význam pre stabilitu drevín vo verejnej zeleni [Microelements and their important for the forest species stability in the public vegetation]. In BERNADOVIČOVÁ, S., JUHÁSOVÁ, G. *Dreviny vo verejnej zeleni. Zborník z konferencie s medzinárodnou účasťou, 10.–11. 5. 2005, Bratislava*. Zvolen: Ústav ekológie lesa SAV, p. 63–68.

BUBLINEC, E., DUBOVÁ, M., KÚDELOVÁ, D., BACULÁKOVÁ, E. 2006. Kyslé zrážky, ich vznik a vplyvy na biotu [Acid precipitation, their creation and influences to the biota]. In AKIMJAK, A. et al. (ed.). *Týždeň európskej vedy na PF KU v Ružomberku: [druhý ročník]. Zborník prednášok z týždňa euurópskej vedy, Ružomberok, 7.–10. novembra 2005]*. Ružomberok: Pedagogická fakulta Katolíckej univerzity, p. 45.

BUBLINEC, E., MACHAVA, J. 2009. Pedodisturbančné procesy v lesných ekosystémoch [Pedodisturbantion processes in the forest ecosystems]. In HLAVÁČ, P., KODRÍK, M. *Ochrana lesa 2009: disturbančné procesy pôsobiace na ekologickú stabilitu lesných ekosystémov a krajiny. Zborník recenzovaných vedeckých prác a referátov z medzinárodnej konferencie* [electronic resource]. Zvolen: Technická univerzita vo Zvolene, 2009, p. 203–209.

BUBLINEC, E., VOŠKO, M. 1987. The input of chemical elements in the central European forest ecosystems and ecological investigation of lanscape. *Ekológia (ČSSR)*, 6: 15–21.

ILAVSKÝ, J., BUBLINEC, E. 2005. Ecological impact of wood residues harversting for energy production. In *Biomass for energy, industry and climate protection: 14th European Biomass Conference & Exhibition. Proceedings of the international conference held in Paris, France, 17 – 21 October 2005*. [Florence]: ETA-Renewable Energies, p. 451–454.

KUTÍLEK, M. 1966. *Vodohospodářská pedologie* [Water management related soil science]. Praha: SNTL. 275 p.

KUTÍLEK, M., 1971. Ekologická klasifikace půdní vlhkosti [Ecological classification of soil moisture content]. *Vod. Hospod*., 9: 250–256.

OTEPKA, P., TÓTHOVÁ, S. 2011. *Vlastnosti drevného popola a možnosti jeho využitia pri pestovaní energetických rastlín* [Wood ash properties and its possible use in growing energetic plants]. Bratislava: Agentúra na podporu výskumu a vývoja. 32 p.

SOKAL, R.R., ROHLF, F.J. 1995. *Biometry: the principles and practice of statistics in biological research.* New York: Freeman. 887 p.

TUŽINSKÝ, L. 2002. Soil moisture in mountain spruce stand. *J. Forest Sci*., 48: 27–37.

TUŽINSKÝ, L., 2004. *Vodný režim lesných pôd* [Water regime in forest soils]. Zvolen: Technická univerzita. 101 p.

TUŽINSKÝ, L. 2011. Vodný režim lesných pôd v smrekovom ekosystéme [Soil water regime under spruce ecosystem]. In STŘELCOVÁ, K., SITKOVÁ, Z., KURJAK, D., KMEŤ, J. (eds). *Stres suchom a lesné porasty: aktuálny stav a výsledky výskumu.* Zvolen: Technická univerzita, p. 100–108.

Vlhkostné pomery po aplikácii drevného popola v smrekovom ekosystéme na povrch pôdy

Súhrn

Predkladaná práca sa zaoberá hodnotením vplyvu povrchovej aplikácie drevného popola vo vegetačných obdobiach rokov 2011 a 2012 na priebeh vlhkosti pôdy, zásoby využiteľnej vody (ZV) a vodivosť pôdy v povrchovej 20 cm vrstve. Za týmto účelom boli pripravené tri varianty aplikácie drevného popola: kontrolná plocha bez aplikácie drevného popola, plocha s jarnou aplikáciou drevného popola v množstve 5 t ha^{-1} a plocha s jesennou aplikáciou drevného popola v množstve 5 t ha^{-1}. Vo vrstve pôdy s najvyšším výskytom sacích koreňov (0 – 20 cm) boli analyzované dva hydropedologické cykly, dominantný semiuvidický interval s vlhkosťou pôdy medzi hydrolimitmi maximálna kapilárna kapacita (MKK) a bod zníženej dostupnosti (BZD) a vo vegetačnom období roka 2011 v letných mesiacoch semiaridný interval s vlhkosťou pôdy medzi hydrolimitmi BZD a bod vädnutia (BV). Nebezpečenstvo z ohrozenia suchom vyplýva pre smrekové porasty z nedostatočnej zásoby využiteľnej vody, do oblasti ktorej sa znížila vlhkosť pôdy v roku 2011 v druhej polovici vegetačného obdobia, v letných mesiacoch pri minimálnych zásobách až do spodnej tretiny variačného rozpätia, v roku 2012 už na začiatku 2. dekády júna s trvaním do konca vegetačného obdobia.

Vlhkosť pôdy a jej hydraulická vodivosť (až na malé výnimky spôsobené mikrorozdielmi vlastností pôdy) bola vyššia na plochách s aplikáciou drevného popola.

Výsledky štatistickej analýzy nepreukázali štatistickú významnosť v rozdieloch zásob využiteľnej vody medzi jednotlivými variantmi aplikácie počas oboch vegetačných období, napriek tomu intervaly extrémnych hodnôt z jednotlivých experimentálnych plôch poukazujú na pozitívny vplyv aplikácie drevného popola na zvýšenie zásob využiteľnej vody. Štatistické rozdiely mohli byť v tomto prípade zahladené extrémnym charakterom zrážkových situácií v sledovaných vegetačných obdobiach a tiež relatívne krátkym časovým úsekom merania, nakoľko dva roky predstavujú v tomto smere krátky čas na výrazné preukázanie pozitívneho trendu zlepšovania vlastností pôdy (hydraulických, retenčných, textúrnych ako aj štruktúrnych).

Received November 8, 2012
Accepted November 12, 2012