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Research Article

WATER STORAGE CHANGES IN UPPER SOIL LAYERS IN DIFFERENT FOREST HABITATS

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ABSTRACT

Trends in changes of water storage in upper soil layers were analyzed. The observations were carried out from 2002 to 2016 hydrological year in a small forest catchment in the district of Siemianice Forest Experimental Farm (LZD). The samples were taken from the upper soil layer of profiles located in different forest habitats, both at the beginning and at the end of hydrological half-years. Water storage was evaluated separately for two layers at the depths of 0–15 cm and 15–100 cm. Changes in water storage determined using the Mann-Kendall test were found to indicate multi-year trends. Results of the study are inconclusive. There were no statistically significant long-term trends in water storage changes in soil profiles in moist mixed broadleaved and coniferous forest and also in the soil profiles of fresh habitats. However, it is worth noting that statistically significant downward trends of water storage in two soil profiles located in ash alder swamp forest and moist broadleaved forest were observed. To some degree, they can be accounted for by long-term downward trends of groundwater levels in the area.

Keywords: water storage, forest habitats, forest soils water management

INTRODUCTION

The soil water dynamics as well as groundwater levels are determined mainly by precipitation and air temperature (Hodnett et al. 1995, Komisarek et al. 2008, Liberacki, Szafrański 2013, Yeh et al. 2006). Climate changes observed in the last decades can lead to deterioration of water management [Grajewski et al. 2013, Kędziora et al. 2014]. The increase in air temperature can increase the transpiration and thus decrease the water content and lower the groundwater levels. It is worth noting that water resources of Wielkopolska lowland are the poorest in Poland. The results of recent studies carried out in a small forest catchment located in Wielkopolska lowland indicated a downward trends in groundwater levels in all forest types [Stasik et al. 2016], however, not all decreases observed were statistically significant. As a continuation of this recent investigation the aim of this study was to analyze multi-year water storage changes in different forest stands.

STUDY AREA, MATERIALS AND METHODS

The study was carried out in a small forest located in Marianka Siemiańska forest district (Rakowski Ditch catchment, which is denoted as G-ditch on the map). The district belongs to the Siemianice Forest Experimental Farm (LZD). According to Regional geography of Poland [Kondracki 2011] the forests of LZD Siemianice are located in Wieruszowska Plateau. This area is located in the South Wielkopolska Lowland and makes its southern frontier (Fig. 1).

In terms of hydrography, the object is a part of Pomianka River catchment area, which is a left-bank tributary of the Prosna River. Marian-

Fig. 1. Location of Siemianice Forest Experimental Farm against Wielkopolska map

ka Siemiańska forest district is located in north-east part of Oleśnicka Plain mesoregion, Silesia nature woodland country, according to the 2010 nature-forestry regionalization [Zielony, Kliczkowska 2012]. Swampy forest stands (about 51% of wooded area) dominate in the catchment area. Moist forest stands have also a significant share (31%) in the wooded catchment area. The total fresh forest stands occupy 18% of the area.

The data on the soil and forest type at particular sites were taken from the soil-forest site maps contained in Soil-Habitat Assessment of LZD Siemianice (1999) as well as from the forest database (www.bdl.lasy.gov.pl).

Nine soil profiles representing individual forest stands were chosen for analyses. The data were collected for the soil profiles: 1.3 and 2.12 located in ash-alder swamp forest (OlJ), 2.8 in moist broadleaved forest (Lw), 2.11 in moist mixed broadleaved forest (LMw), 3.12 and 4.2 in moist mixed coniferous forest (BMw), 4.8 and 5.5 in fresh mixed broadleaved forest (LMśw), and G3.9 located in fresh mixed coniferous forest (BMśw). Permeable formations – mostly loose sands, loamy sands and sandy silt were found to dominate in the analyzed soil profiles (1.3, 2.8, 2.11, 3.9, 4.2, 4.8. 5.5), although loamy silt and sandy loam (2.12, 3.12) were also present.

The procedure of the study included systematic sampling of undisturbed monolithic soil samples. Three samples were taken from each genetic layer of each individual soil profile (Fig. 2), in the end of winter (April) and summer (October) hydrological half-year. Water storage was evaluated for two separate layers: 0–15 cm and 15–100 cm in each soil profile. The water content in the aeration zone was determined using the gravimetric method, while the water content in the saturated zone was taken as equal to porosity. Daily measurements of precipitation sums and air temperature, were carried out at LZD Siemianice. The above data were taken from 2002–2016 hydrological period.

Non-parametric statistical Mann-Kendall test was used to analyze the changes in water storage trends in soil profiles as well as the trends in the changes in precipitation and air temperature. The Mann-Kendall test is defined as [Hirsch et al. 1982, Gilbert 1987, Maksymiuk et al. 2008].:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k)$$

where:

$$\operatorname{sgn}(x_j - x_k) = \begin{cases} 1 \text{ if } (x_j - x_k) > 0 \\ 0 \text{ if } (x_j - x_k) = 0 \\ -1 \text{ if } (x_j - x_k) < 0 \end{cases}$$

{x1, x2, …, xn} – data points

If S value is close to zero it indicates no-trend hypothesis, S value significantly higher than zero indicates an upward trend, meanwhile S value significantly lower than zero suggests a downward trend. The tests were made separately for winter and summer hydrological half-years, because water capacity shows seasonal changes.

When Zs>Zkr than the trend is statistically significant; Zkr=1.95 when the confidence level is α=0.05. The value of Zs is calculated from the following formula:

$$Z = \frac{S-1}{\sqrt{\operatorname{Var}(S)}} \quad \text{when: } S>0$$

and $Z = \dfrac{S+1}{\sqrt{\operatorname{Var}(S)}}$ when: S<0

For the time series n>10, the variation is calculated from the following formula:

$$\operatorname{Var}(S) = \frac{1}{18} n(n-1)(2n+5)$$

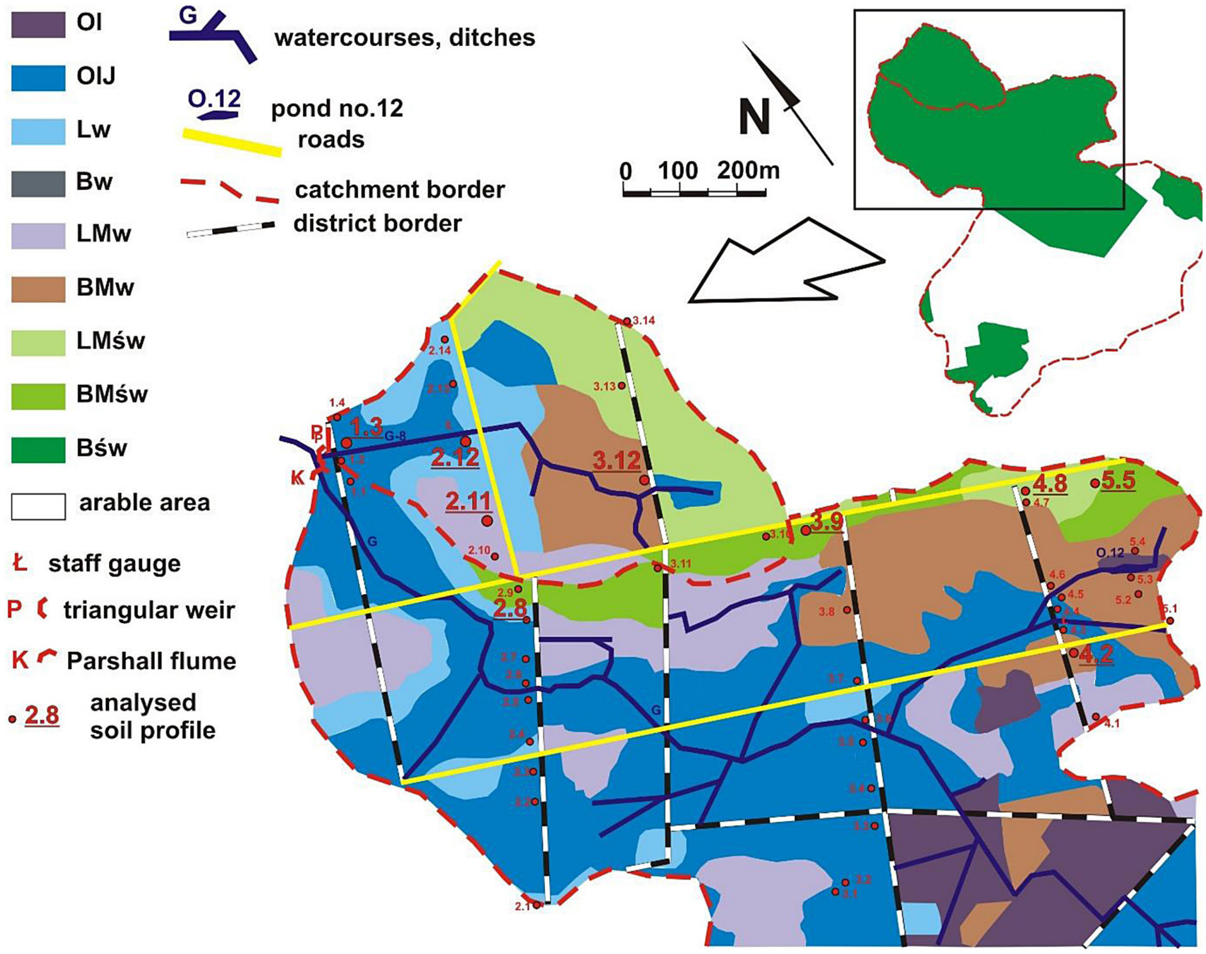

Figure 2. Forest habitat maps of analyzed parts of G ditch with soil profile location. Descriptions of forest site types: Ol – alder carr forest, OlJ – ash-alder swamp forest, Lw – moist broadleaved forest, LMw – moist mixed broadleaved forest, BMw – moist mixed coniferous forest, LMśw – fresh mixed broadleaved forest, BMśw – fresh mixed coniferous forest, Bśw – fresh coniferous forest Lśw – fresh broadleaved forest

RESULTS AND DISCUSSION

Average air temperatures and precipitation sums in the period of 2002–2016 hydrological years indicate changeability of weather conditions (tab. 1). Very cold and very warm as well as very dry and extremely moist half-years were observed. The results of Mann-Kendal statistical calculation for the air temperature suggest a slight increase in the average half-year temperatures, however the S value is not statistically significant. The S describing the amount of precipitation suggests a slight decrease in precipitation sums in the winter half-year and their slight increase in the summer half-year. However, both S values are not statistically significant.

The values and linear trends indicate a decrease in water storage in the 0–15 cm layer for soil profile 2.12 located in ash alder swamp forest and 2.8 in moist broadleaved forest, measured in April in the end of winter half-year in 2002–2016 hydrological years (Fig. 3A). This decrease is also confirmed by statistically significant S values for these soil profiles, S=–65 and S=–78 respectively. No trend in water storage changes was observed for profile 1.3 in ash alder swamp forest. The S=+41 for moist mixed broadleaved forest (2.11 profile) also indicates statistically significant decreasing trend in the water storage in the upper layer. Both soil profiles 3.12 and 4.2 in moist mixed coniferous forest show slightly downward trends, but they are not statistically significant (Fig. 3B). In the soil profiles in the fresh mixed broadleaved and coniferous forest, no trend in water storage changes in the upper layers is observed (Fig. 3C).

Figure 4 presents the result of water storage in the deeper layer, 15–100 cm, of the soil profiles measured also in April in the end of winter half-year in 2002–2016 hydrological years. Statistical-

Table 1. Average temperatures (T) and thermal classification by Lorenz (by Czernecki and Miętus 2011), precipitation (P) and their classification according to relative precipitation index RPI (Tomaszewska 1994) as well as S value for winter and summer hydrological half-years in analyzed period 2002–2016

Hyd. year	Winter half-year (November-April)				Summer half-year (May-October)			
	T		P		T		P	
	[°C]	classification	[mm]	classification	[°C]	classification	[mm]	classification
2002	+2.1	normal	213	average	+15.6	normal	325	average
2003	+0.1	very cold	150	very dry	+15.4	normal	371	average
2004	+3.2	slightly warm	273	very moist	+15.0	slightly cold	2535	very dry
2005	+0.9	slightly cold	223	average	+16.3	slightly warm	237	very dry
2006	+0.2	very cold	371	extremely moist	+16.4	warm	262	very dry
2007	+2.4	normal	252	moist	+15.1	normal	301	dry
2008	+2.7	normal	252	moist	+15.4	normal	244	very dry
2009	+1.2	slightly cold	184	dry	+14.8	slightly cold	441	moist
2010	+0.5	cold	243	moist	+14.4	cold	563	extremely moist
2011	+2.2	normal	229	average	+16.2	slightly warm	270	dry
2012	+1.9	normal	175	dry	+15.7	normal	427	moist
2013	+0.0	very cold	258	moist	+15.5	normal	453	very moist
2014	+4.5	very warm	169	dry	+16.1	slightly warm	368	average
2015	+3.5	slightly warm	156	very dry	+16.4	warm	182	very dry
2016	+3.8	warm	256	moist	+16.3	slightly warm	357	average
S	+27		-11		+21		+13	

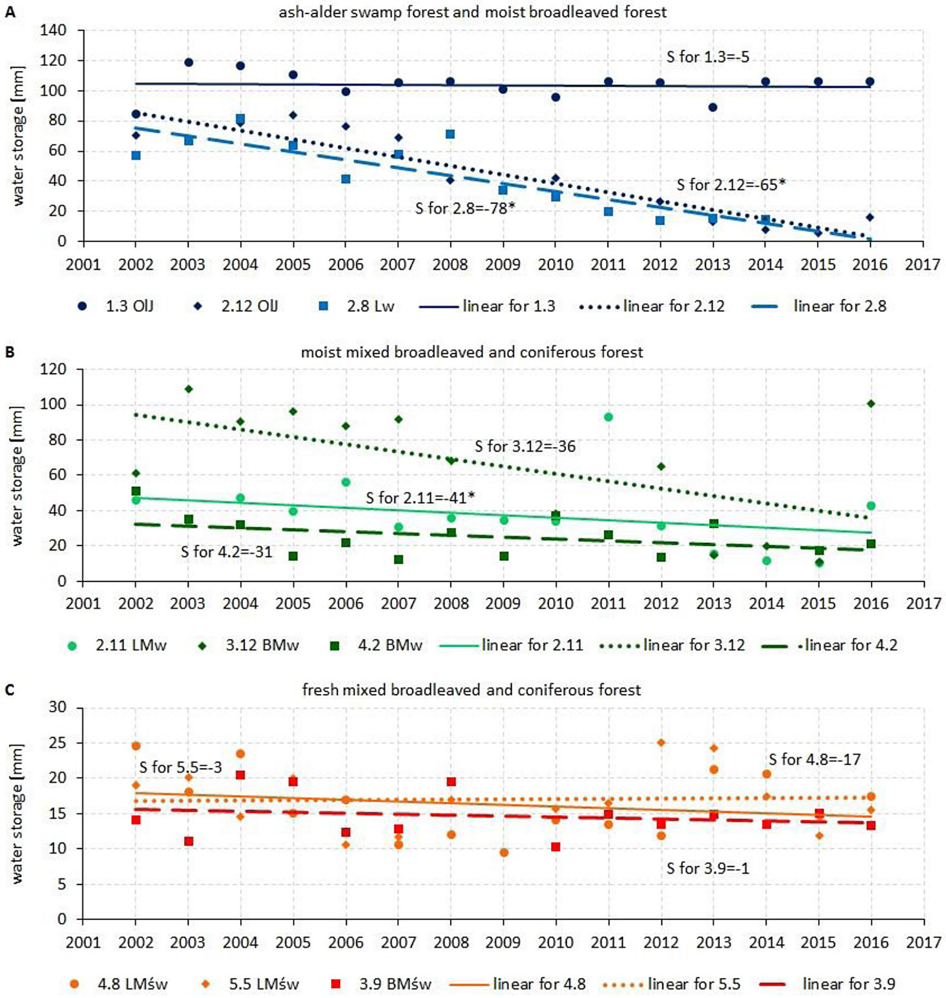

Figure 3. Water storage in the layer 0–15 cm of the analyzed soil profiles, linear trends in its changes and S value (* – statistically significant), measured in April in 2002–2016 hydrological years. Description of forest site types abbreviation the same as in Figure 2.

ly significant downward trends of water storage is observed in the soil profiles 2.12 and 2.8 (–55 and –74 respectively), similarly as it is observed in the layer 0–15 cm (Fig. 4A) . It is worth noting that the upward trend is observed in profile 1.3 for the deeper layer 15–100 cm , however the trend is not statistically significant. Upward trends of water storage are also observed in the fresh habitats in profiles 3.9 and 5.5 (Fig. 4C). The S value for profile 5.5 located in the fresh mixed broadleaved forest is statistically significant (S=+45).

Similar downward trends in water storage in the layer 0–15 cm in soil profiles in swampy habitats are observed also in the end of summer half years (Fig. 5). The trend at profile 2.12 , located in the moist broadleaved forest is statistically significant, meanwhile the other trends at profiles 1.3 (slightly increased) and 2.12 located in the ash-alder swamp forest are insignificant (Fig. 5A). There are no statistically significant trends in water storage changes in the layer 0–15 cm in the soil profiles located in the moist mixed broadleaved and coniferous forest (Fig. 5B). It is worth noting that in the fresh mixed habitats slightly upward trends are observed at profiles 3.9 and 4.8, however, the trends are not statistically significant (Fig. 5C).

Figure 6 presenting water storage changes in the layer 15–100 cm measured in the end of summer half-year also indicates a statistically significant (S=–57) downward trend in water storage change in soil profile 2.8 in the moist broadleaved forest. The trend in profile 2.12 in the ash-alder swamp forest (Fig. 6A) is also downward and statistically significant (S=–49). Statistically insignificant downward (S=–21 for profile 2.11) and

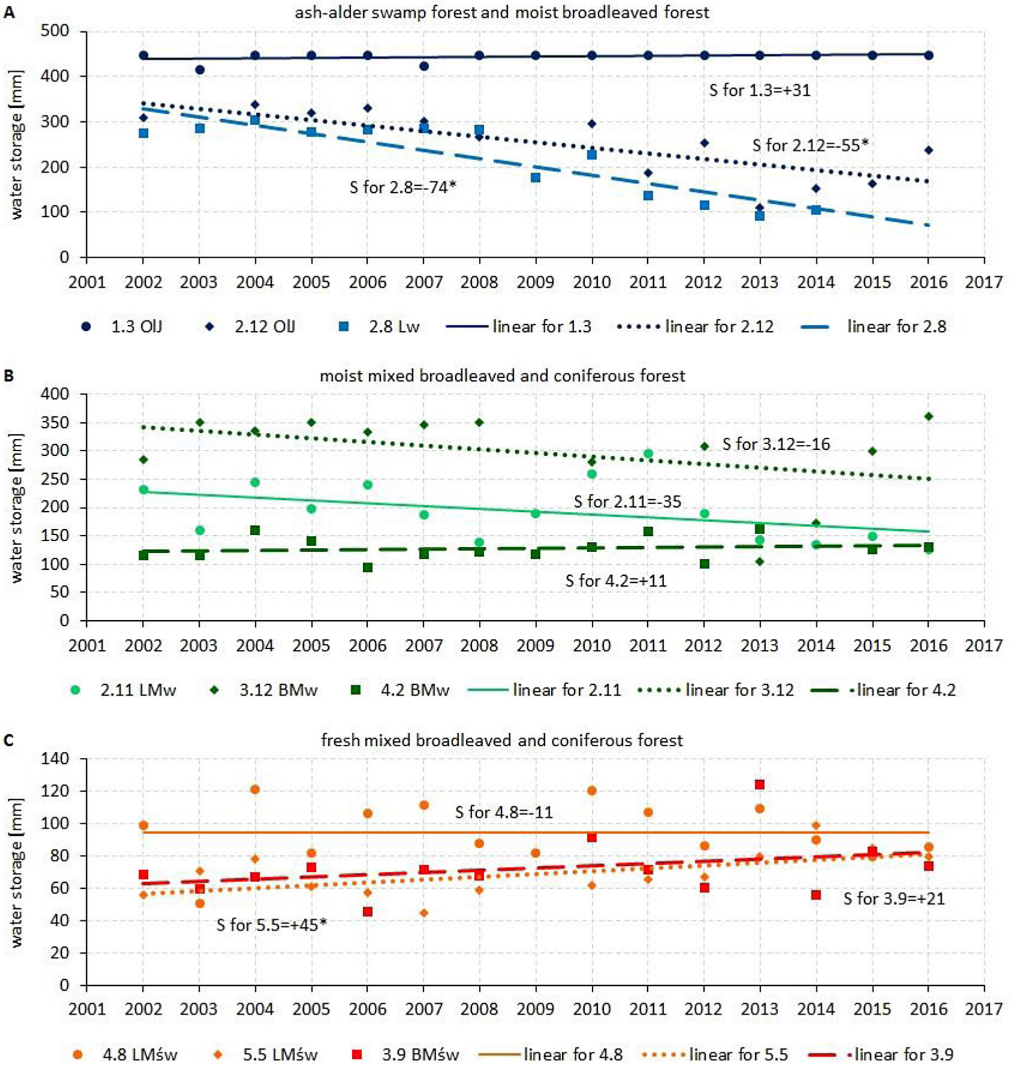

Figure 4. Water storage in the layer 15–100 cm of the analyzed soil profiles, linear trends in its changes and S value (* – statistically significant), measured in April in 2002–2016 hydrological years.

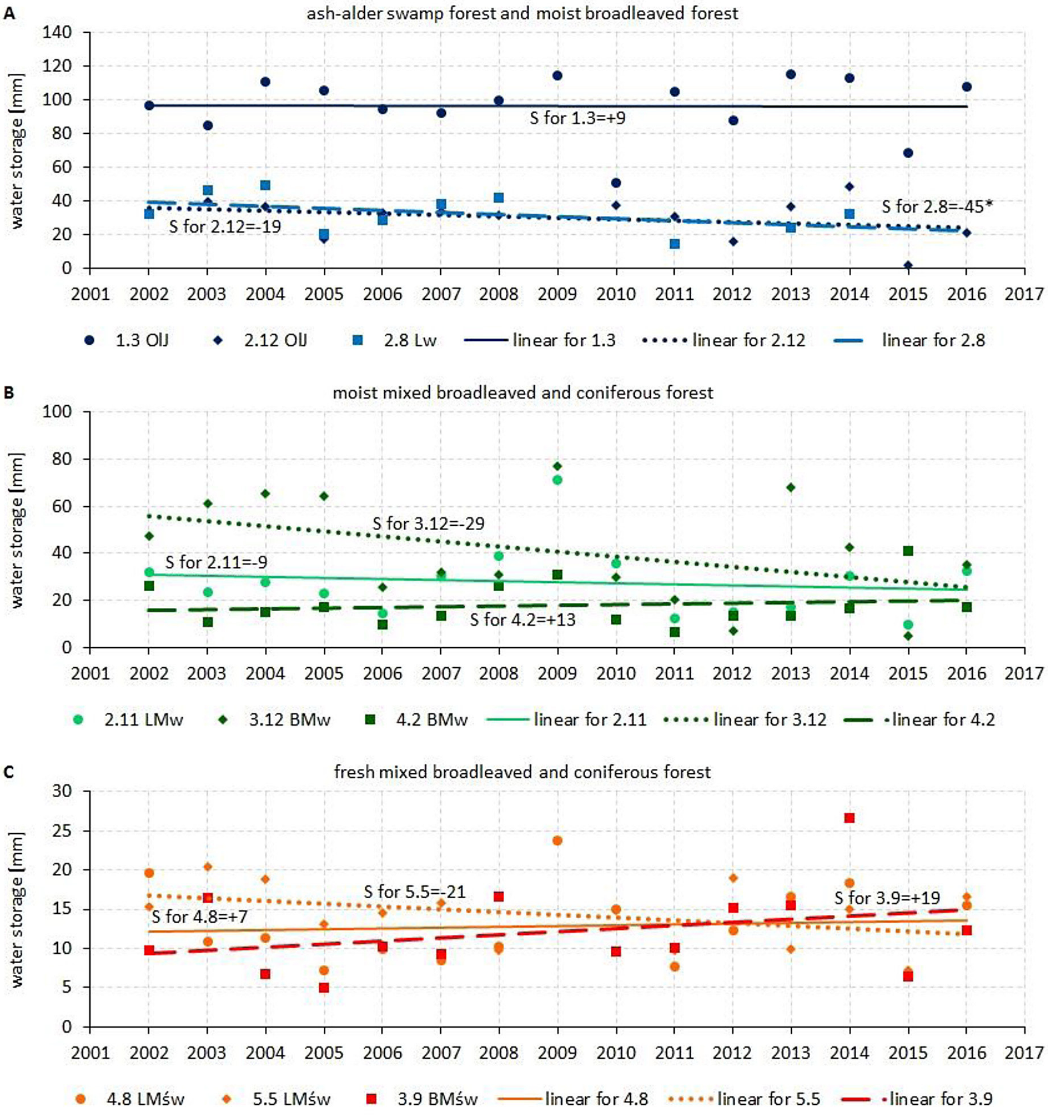

Figure 5. Water storage in the layer 0–15 cm of the analyzed soil profiles, linear trends in its changes and S value (* – statistically significant), measured in October in 2002–2016 hydrological years.

upward (S=+11 for profile 3.12 and S=+37 for profile 4.2) trends are observed in the moist mixed broadleaved and coniferous forest (Fig. 6B).

In the soil profiles located in the fresh mixed broadleaved and coniferous forest (Fig. 6C) statistically insignificant, but slightly upward trends in water storage were observed.

CONCLUSIONS

The results of the study performed are inconclusive. There are no statistically significant long-term trends in water storage changes in the moist mixed broadleaved and coniferous forest. However, in the soil profile located in the moist mixed broadleaved forest, a downward trend of water storage in the layer 0–15 cm is observed. Also in the soil profiles in the fresh habitats no significant trends are observed. Upward trend of water storage is observed only in the soil profile of fresh mixed coniferous forest in the layer 15–100 cm.

However, it is worth noting that statistically significant downward trends of water storage in two soil profiles located in the ash alder swamp forest and moist broadleaved forest are observed, in both layers 0–15 cm and 15–100 cm at the end of winter half-year. It can be affected by long-term downward trends in groundwater levels observed in this area (Stasik et al. 2016). Such downward trends have also been reported by Grajewski et al. (2013).

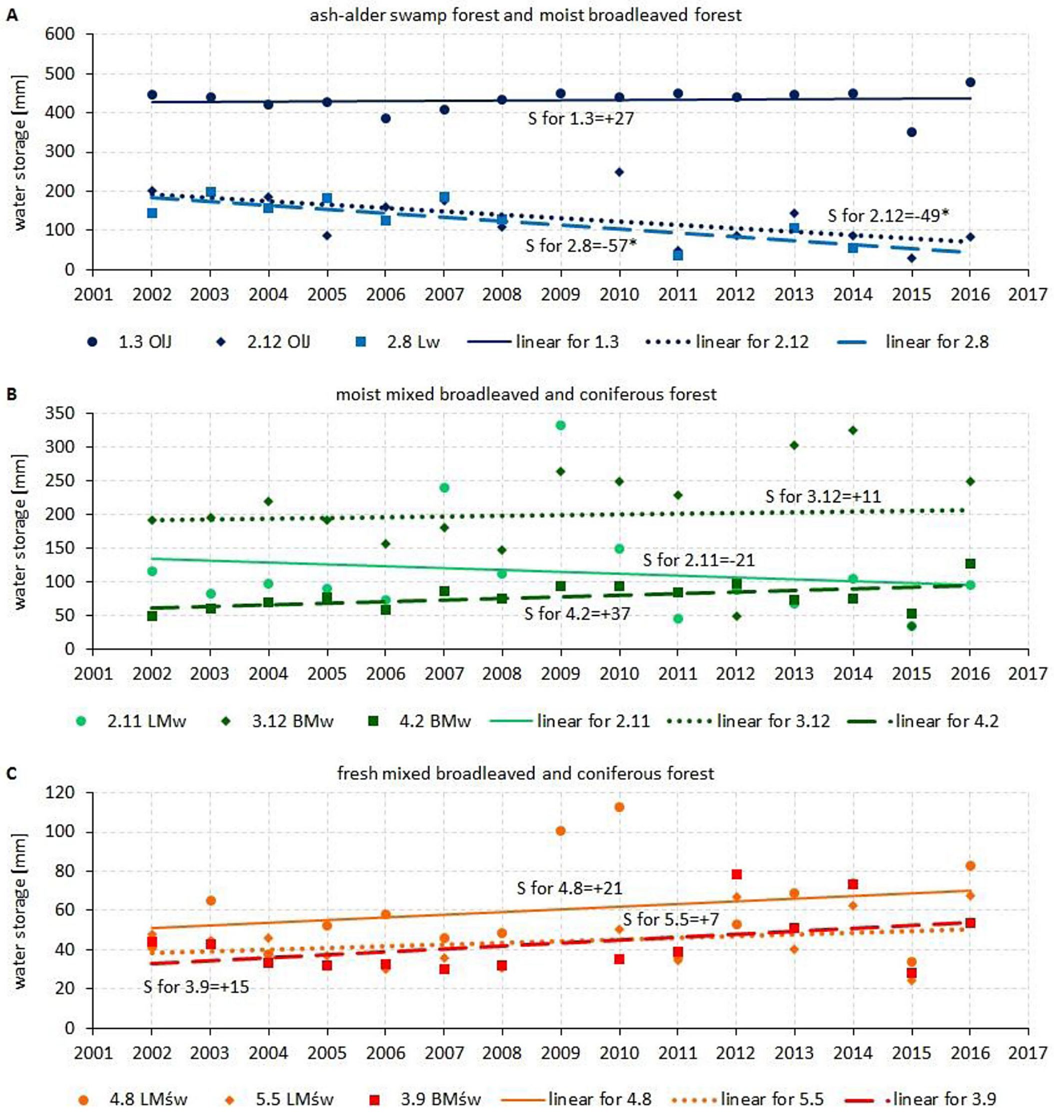

Figure 6. Water storage in the layer 15–100 cm at the analyzed soil profiles, linear trends in its changes and S value (* – statistically significant), measured in October in 2002–2016 hydrological years.

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