# The effects of different mowing regimes on diversity of grasses in lowland meadows

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**Abstract:** This study addresses the question of how changing the mowing regime influences the floristic composition and floristic diversity of grasses in an experimental lowland meadow. The study location is Białowieża Forest, NE Poland. To achieve the aim we used phytosociological data from long-term studies in Białowieża Forest on the course of secondary succession. The relationship between the biodiversity of grasses and type of mowing was determined using statistical analysis. Changes in the dominance and frequency of individual grass species have occurred during the last 28 years of observations. The analysis of floristic similarity demonstrated a turnover of species between the individual years of observation. Principal component analysis showed that the change in mowing method resulted in a change of the species composition, cover, and domination. However, differences in the intensity of disturbance level were rather small (one cut yearly by scythe, by sickle bar mower, and by trimmer), and changes in floristic composition were also moderate in most years. During the initial years (1984–1990), *Dactylis glomerata*, *Agrostis gigantea*, and *Anthoxanthum odoratum* dominated. After 1990, *Arrhenatherum elatius* and *Holcus lanatus* spread and took over, with *Trisetum flavescens* joining them later. Between 2008 and 2012 the cover of *Dactylis glomerata* increased more than two times. The reasons for the floristic transformations were changes in the management mode, e.g., the transition from mowing by scythe (medium disturbance) to mechanized mowing, first by sickle bar mower (strong disturbance) and then by trimmer (weak disturbance).

**Key words:** *Arrhenatherion*, Białowieża Forest, hay meadow, long-term study, mowing regime, Poaceae

## 1. Introduction

Seminatural meadow communities of the *Molinio-Arrhenatheretea* class belong to secondary phytocoenoses that formed as a result of human activity. Many centuries of management shaped the grassland communities forming an integral part of the temperate zone of the European landscape (Linusson et al., 1998; Moog et al., 2002; Isselstein et al., 2005; Heinsoo et al., 2010; Gaujour et al., 2012).

The species composition of meadow turf depends mainly on habitat conditions, e.g., soil fertility (Schellberg et al., 1999; Klimek et al., 2007), pH (Jastrzębska et al., 2009), and humidity (Gaujour et al., 2012). However, unlike in natural plant communities, the persistence and nature of meadow communities are determined by the variety of meadow management methods, and of these mowing and grazing are the key factors influencing the structure and species composition of individual meadow phytocoenoses (Fischer and Wipf, 2002; Gaisler et al., 2004; Klimek et al., 2007; Cousins and Eriksson, 2008; Gaujour et al., 2012; Socher et al., 2012; Zarzycki and Korzeniak, 2012). Each change in the management method has an impact on the

botanical composition of the sward (Isselstein et al., 2005; Köhler et al., 2005).

One of the most important factors determining the structure and composition of meadow communities is mowing management disfavoring woody plants (Moog et al., 2002; Zechmeister et al., 2003; Gaisler et al., 2004; Planationreux et al., 2005; Gaujour et al., 2012; Socher et al., 2012). Changes in mowing management or abandonment of grasslands from agricultural use cause disturbances in the structure and species composition of meadow communities (Moog et al., 2002; Silvertown et al., 2006; Lanta et al., 2009). Many researchers have shown that cessation of grassland management leads to successional change and to a loss of plant species diversity. Vegetation succession facilitates the expansion of woody taxa, the dominance of taller species from later successional stages, and the decline of species typical for managed grasslands (Moog et al., 2002; Pykälä, 2003; Gaisler et al., 2004; Kahmen and Poschlod, 2004; Rosenthal, 2010).

The effects of some management methods may be revealed only after many years (Linusson et al., 1998; Schellberg et al., 1999; Berlin et al., 2000; Moog et

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al., 2002). That is why long-term experiments are of considerable importance for discovering the impact of applied treatments on the floristic composition of meadow phytocoenoses, both under regular management and after abandonment. Long-term studies on permanent plots provide an opportunity for regular registration of ongoing changes (Moog et al., 2002; Silvertown et al., 2006; Adamowski and Bomanowska, 2011a).

All changes in the use of meadows are particularly clear in the species diversity and frequency of grasses (Berlin et al., 2000; Gaisler et al., 2004; Bomanowska and Adamowski, 2007; Adamowski and Bomanowska, 2009, 2011b, 2013; Rosenthal, 2010). The specific position of meristems makes grasses much more tolerant to mechanical damage than other plants (Peeters et al., 2004). Mowing and grazing promote the growth of grasses, in this way ensuring the persistence and stability of meadow phytocoenoses (Kucharski, 1999; Berlin et al., 2000; Peeters et al., 2004).

The aim of the study was to assess the effects of different levels of anthropogenic disturbance due to changes in the mowing regimes on the floristic composition and floristic diversity of grasses in an experimental lowland meadow.

## 2. Materials and methods

### 2.1. Sampling design and data collection
Since 1974 the Experimental Ecological Garden of the Białowieża Geobotanical Station, Warsaw University, located in Białowieża, NE Poland, has been the site of long-term studies on the course of secondary succession on abandoned agricultural land (Figure 1A). A detailed description of the site of the experiment, its habitat conditions, and the treatments used can be found in earlier papers by Faliński (2002), Adamowski and Bomanowska (2009, 2011a, 2011b, 2013), and Bomanowska and Adamowski (2007, 2009, 2012).

Since 1984, 15 observations have also been carried out biannually on a control plot ($22 \times 10$ m²; Figure 1B) maintained as an annually mown, unfertilized meadow, classified as a community of *Arrhenatherion* alliance. The following features were recorded: overall species composition, structure of the plant community, and appearance of seedlings and small individuals of woody species (Faliński, 2002; Adamowski and Bomanowska, 2009). Biomass was removed after observation, i.e. in the first or second week of July.

The study was based on phytosociological relevés made on permanent plots (one relevé per each basal plot of 10 m²) at the -beginning of July by the classical Braun-Blanquet method. For each species in a single relevé, the cover and abundance values were evaluated using the numerical scale of Braun-Blanquet and in the decimal scale of Londo

(Dzwonko, 2007). This variant of the experiment is used to evaluate the effects of the anthropogenic modification (inhibition) of the secondary succession process by controlled mowing.

Until 1992 plots were mown by scythe, and later by mechanical means – first by sickle bar mower (1993–2007), and since 2008 by trimmer. These mowing regimes differ in disturbance level: higher in the low cutting sickle bar mower regime (sward cut at height of 20–50 mm), disrupting the developing tufts of *Dactylis glomerata* and ant hills, and lower in the trimmer regime (sward cut at height of 60–100 mm), leaving more biomass on the plot. Mowing by scythe gives an intermediate level of disturbance (sward cut at height of 50–80 mm).

The authors used data from the 1984–2012 (subplots F1–F10 and F13–F19; 170 m²) kept in the archive of BGS UW. Data from subplots F11–F12 and F20–F22 were not included in the analysis due to shading by neighboring trees (Figure 1).

The site was described (from 1984 to 2012 every 2 years) using six habitat parameters from the Institute of Meteorology and Water Management database: the average daily air temperature (DAT), average relative humidity (RH), average wind speed (WS), daily sum of precipitation (SP), average snow depths (SD), and time of snow cover (SC).

The Latin names of vascular flora were used according to Mirek et al. (2002).

### 2.2. Data analysis
Biodiversity indices (Shannon diversity index *H'*; evenness index *J'*) were calculated based on phytosociological relevés, replacing the degrees on the Londo abundance scale with the following values of percentage cover: 0.1-0.5%, 0.2- 2%, 0.4- 5%, 1- 10%, 2- 20%, etc. (Dzwonko, 2007).

The Shannon diversity index (*H'*) was calculated based on the following formula (Shannon and Weaver, 1949): $H = -\Sigma pi \log pi$, where $pi = ni/N$, $pi$ = probability of the importance of the ith species in the set, $ni$ = the coefficient of importance of a species, and $N$ = the sum of the coefficients of significance of all species.

The evenness index (*J'*) was calculated based on the following formula: $J = H_{obs}/H_{max}$. The evenness index (*J'*) is the ratio of the diversity observed to the maximum for a given number of species (Pielou, 1974).

The Kruskal–Wallis test was used to test differences in grass species richness between the various methods of mowing. This test is recommended for small datasets that do not show normal probability distributions and is a nonparametric alternative to one-way ANOVA (van Emden, 2008). The significance level for statistical analyses was $P \leq 0.05$.
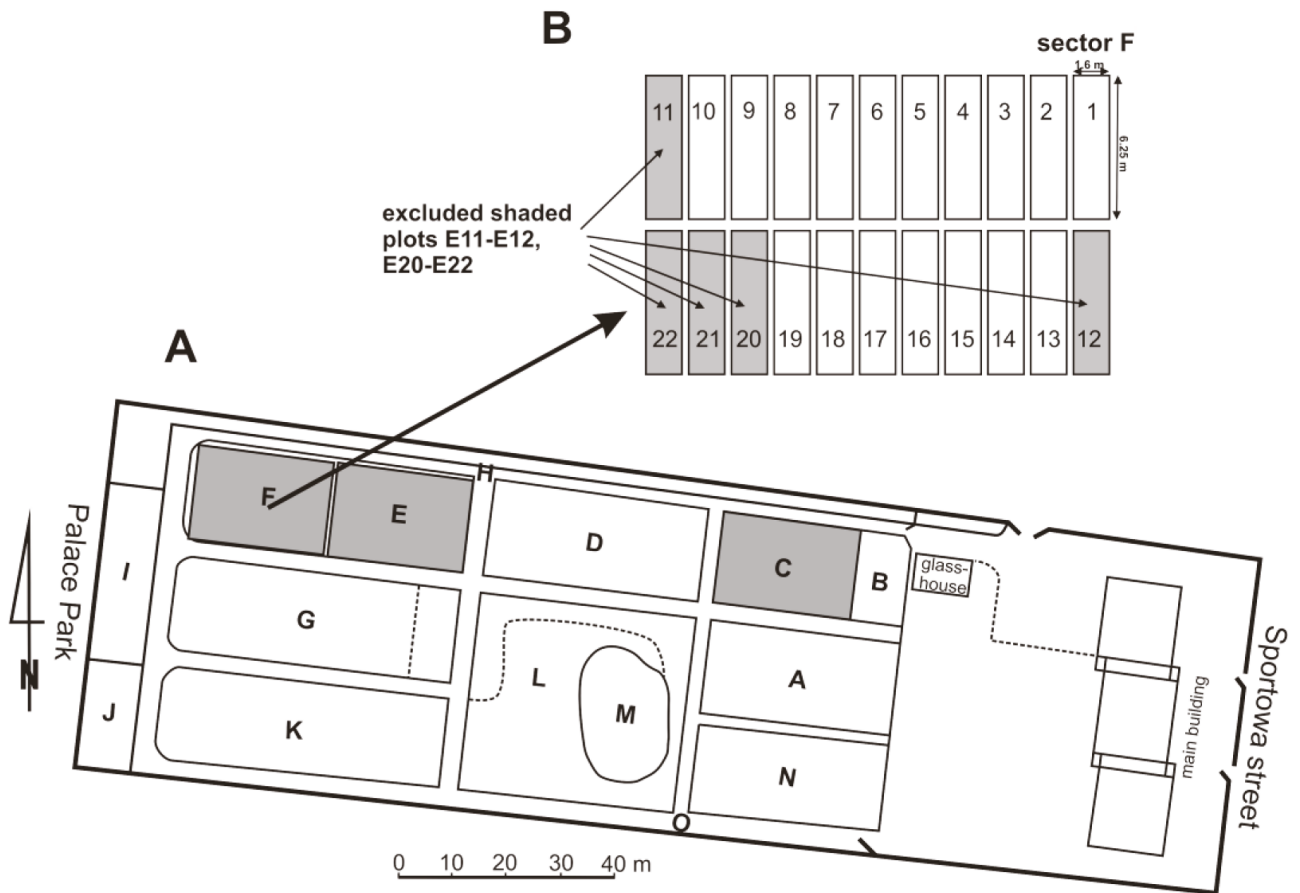
**Figure 1.** Study area. A) Plan of the Experimental Garden of the Białowieża Geobotanical Station of Warsaw University (shaded sectors are used for observation); B) internal division of sector F.

The similarity between grass floras in particular years of the experiment was evaluated using Jaccard's similarity coefficient ($C_J$), with object grouping by the unweighted pair group method (UPGMA; Jongman et al., 1995).

To detect differences in grass species composition caused by various types of mowing an ordination of the floristic data was performed using principal component analysis (PCA; van Emden, 2008). The analysis was performed on a plot basis using the percentage cover of grass species. The correlation between the metric traits and the habitat parameters was tested using Pearson's correlation coefficient and the following values were adopted: less than 0.20 - correlation very poor, 0.21–0.39 - weak correlation, 0.40–0.69 - moderate correlation, 0.70–0.89 - strong correlation, and above 0.89 - correlation very strong (van Emden, 2008).

The statistical analyses were performed using the program packages STATISTICA 10.0, CANOCO 4.5, and MVSP 3.22

## 3. Results

An overall number of 20 (12–17 in given observations) grass species was recorded as occurring in the experimental plot during the experiment period (Figure 2A–2C). The coverage of grasses ranged from 12.4% in 1984 to 48.1% in 2008 and their frequency per basal plot from 6 in 2000 to 9 in 2012 (Figure 2B). During the initial years (1984–1990), *Dactylis glomerata*, *Agrostis gigantea*, and *Anthoxanthum odoratum* were dominant species in terms of their cover (Figure 2C). After 1990, cover of *Arrhenatherum elatius* and *Holcus lanatus* increased, and cover of *Trisetum flavescens* increased as well after 2000. *Dactylis glomerata* and *Anthoxanthum odoratum* were present in almost all plots in the whole study period. Some grass species (*Agrostis gigantea*, *Alopecurus pratensis*, *Holcus lanatus*) showed significant fluctuations in their frequency and/or coverage. Other species (*Elymus repens*, *Poa pratensis*, *P. palustris*) were more frequent at the beginning of the study and later receded.
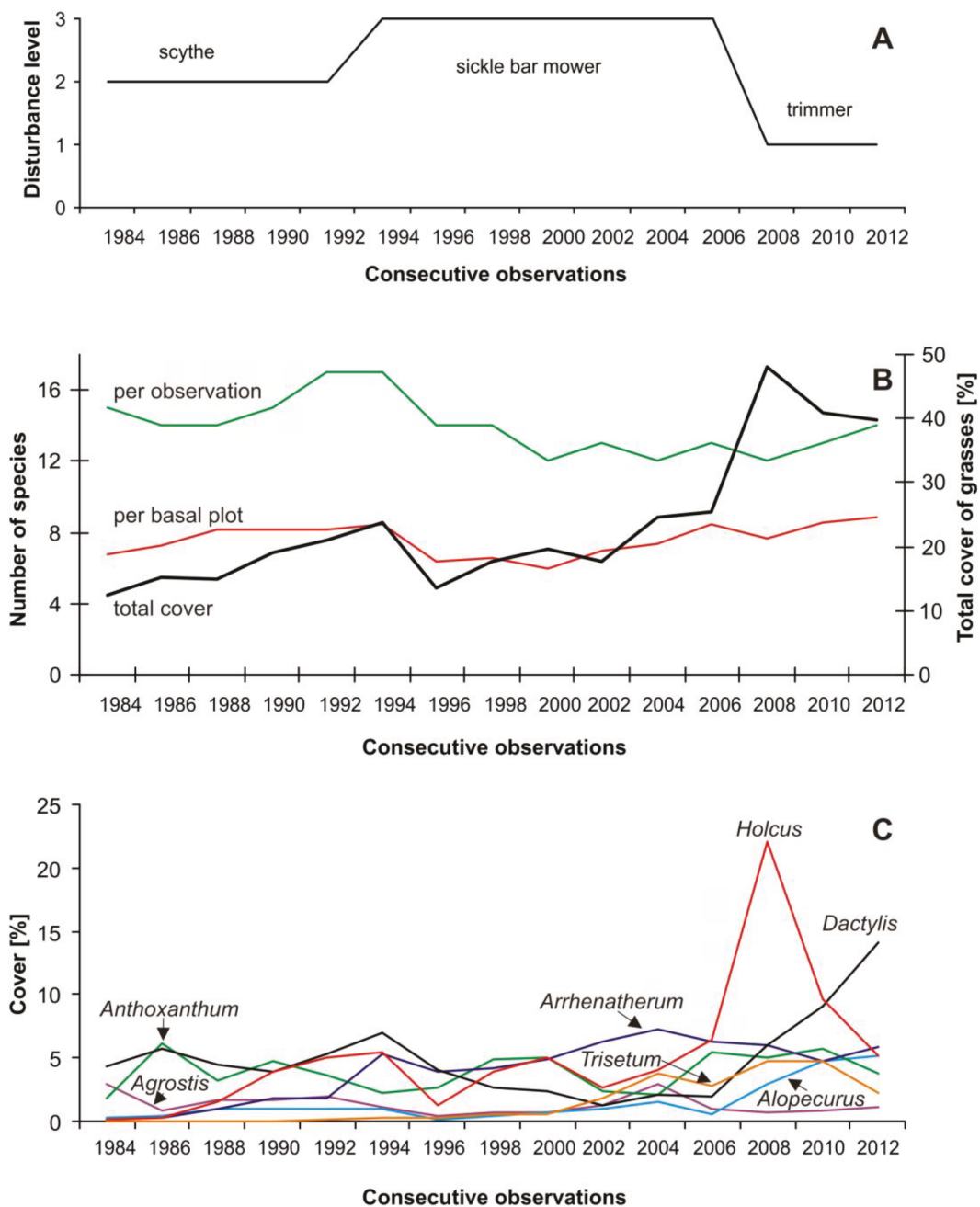
**Figure 2.** Characteristics of the experimental meadow in the period 1984–2012. A) Mowing regime and distur-bance level. B) Total cover of grasses, number of grass species per observation and per basal plot. C) Cover of the seven most abundant grass species.

The year 2008 was marked by an exceptionally lush development of grasses (Figure 2B). The entire percentage of the area covered by them increased nearly twice with regard to the previous observation (*Holcus lanatus* increased more than three times; Figure 2C). Between 2008 and 2012 the cover of *Dactylis glomerata* increased

more than two times, whereas the total cover of grasses diminished (from 48.1% in 2008 to 39.8% in 2012). In the same time the cover of *Holcus lanatus* decreased four times, and *Trisetum flavescens* two times (Figure 2C).

Although there were visible changes in species cover, there were no significant effects of mowing treatments
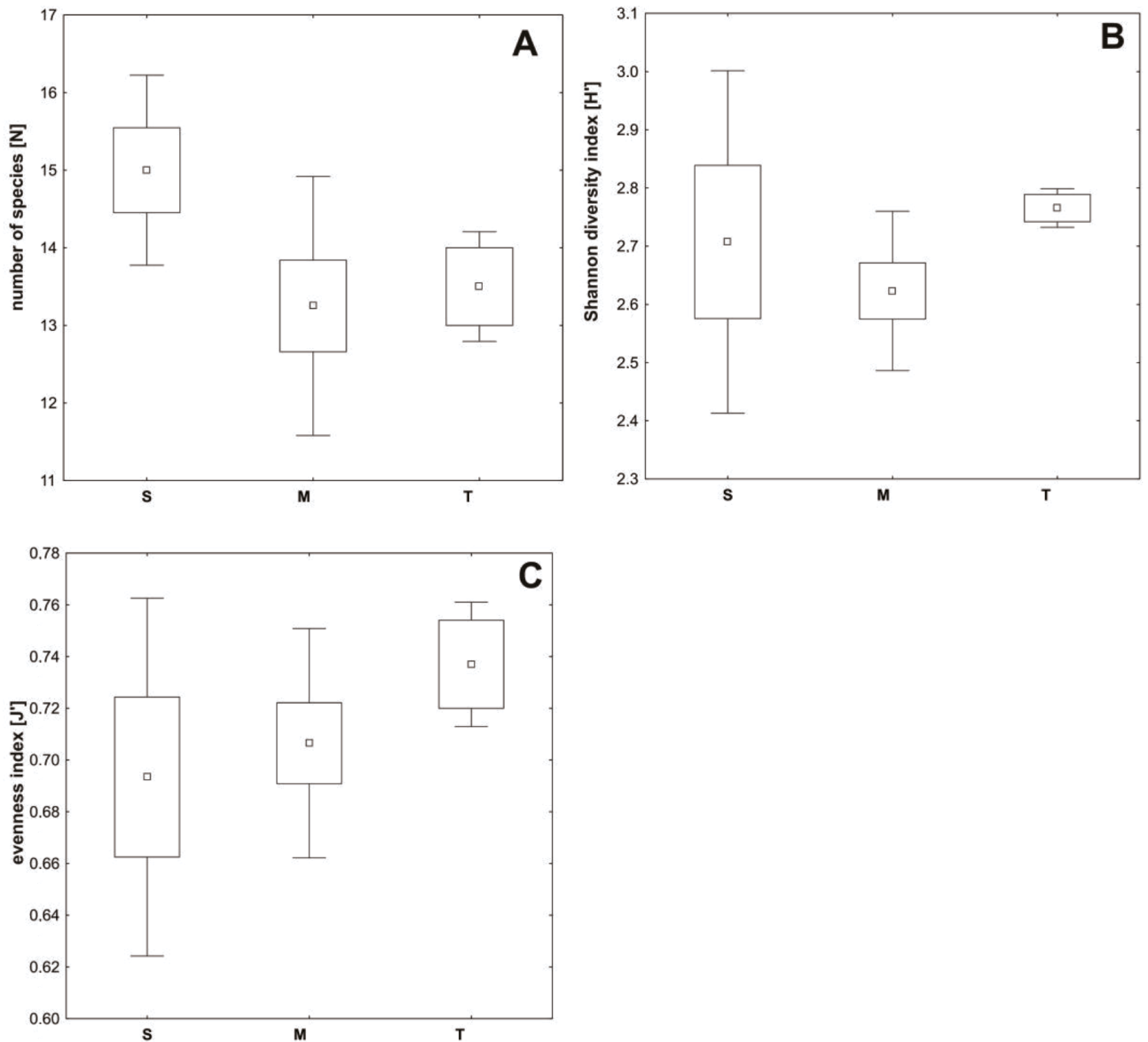
**Figure 3.** Species richness analyzed using the Kruskal–Wallis test with different types of mowing as a main factor. A) Number of species (N); B) Shannon diversity index (*H'*); C) evenness index (*J'*). The boxes represent the average ± standard error, the point within the box shows the average, and the whiskers show average ± standard deviation. Mowing regimes were scythe (S), sickle bar mower (M), and trimmer (T).

on temporal species diversity data (Figure 3). The lowest Shannon diversity index (*H'* = 2.23) was calculated for 1986 (scythe), and the highest (*H'* = 2.92) for 1992 (scythe). In turn, the minimum and maximum values of the evenness index were obtained in 1986 (*J'* = 0.58) and in 2004 (*J'* = 0.78; sickle bar mower), respectively (Figure 3). The absence of significant correlations most probably results from the small number of species in the analyzed group and its uniformity (only grasses were analyzed).

The analysis of floristic similarity demonstrated that there was a turnover of species between the individual

years of observation and enabled the distinguishing of three groups (Figure 4). The highest values of Jaccard's similarity coefficient ($C_J$) were found for 1986–1992 (scythe) and 1994 (sickle bar mower), as well as between 2008 (sickle bar mower) and 2010–2012 (trimmer), which constituted two distinct groups. The third group covers the period between 1994 and 2006 (sickle bar mower), and it is characterized by the lowest homogeneity and lower similarity.

PCA demonstrated that the change in mowing method resulted in a change of the species composition of
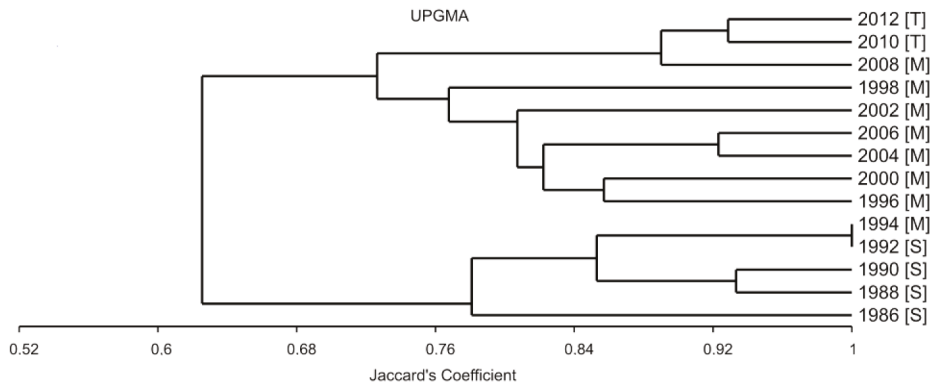
**Figure 4.** Similarity of grass floras in particular years of experiment measured by the Jaccard coefficient. Mowing regimes were scythe (S), sickle bar mower (M), and trimmer (T).
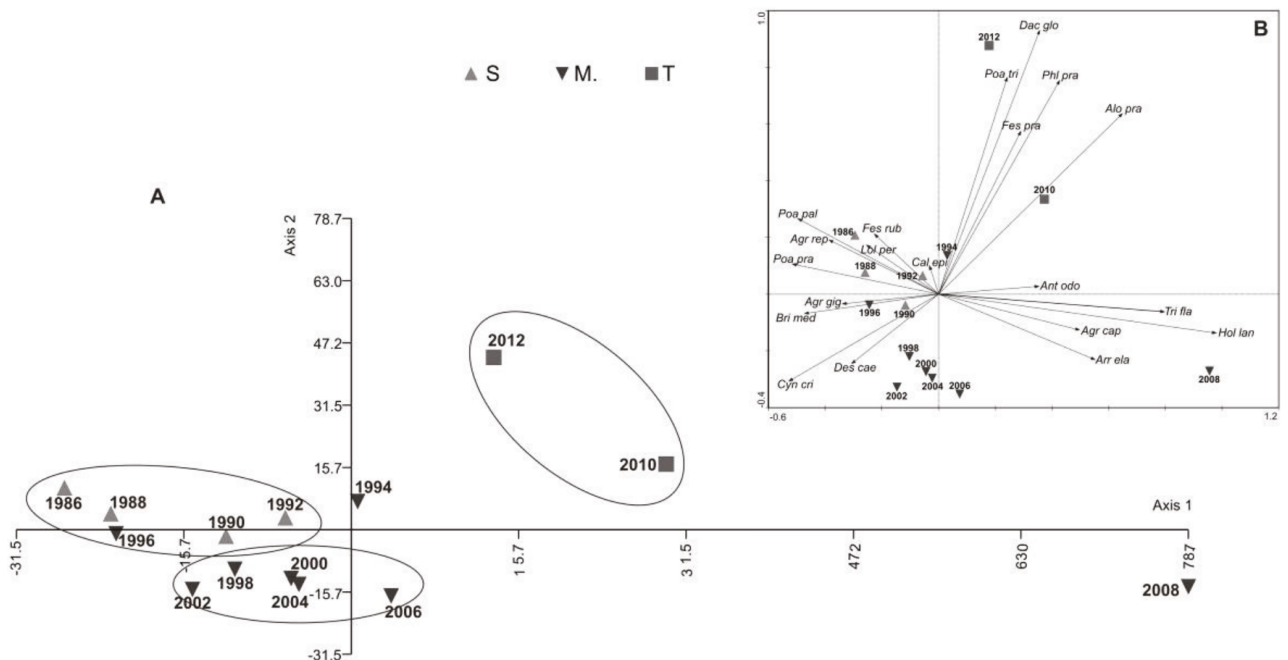


**Figure 5.** Ordination diagrams based on principal component analysis (PCA) of particular years of the experiment. The graphs show the changes in the grass species composition with different mowing treatments: A) graph for the analysis testing the effect of management. Mowing regimes were scythe (S), sickle bar mower (M), and trimmer (T). B) Ordination of species.

The abbreviations of the species names are based on the first three letters of the genus and species name: *Agr cap – Agrostis capillaris*, *Agr gig – Agrostis gigantea*, *Alo prat – Alopecurus pratensis*, *Ant odo – Anthoxanthum odoratum*, *Arr ela – Arrhenatherum elatius*, *Bri med – Briza media*, *Cal epi – Calamagrostis epigejos*, *Cyn cri – Cynosurus cristatus*, *Dac glo – Dactylis glomerata*, *Des cae – Deschampsia caespitosa*, *Ely rep – Elymus repens*, *Fes pra – Festuca pratensis*, *Fes rub – Festuca rubra*, *Hol lan – Holcus lanatus*, *Lol per – Lolium perenne*, *Phl pra – Phleum pratense*, *Poa pal – Poa palustris*, *Poa pra – Poa pratensis*, *Poa tri – Poa trivialis*, *Tri fla – Trisetum flavescens*.

grasses (Figures 5A and 5B). A clearly distinct group was distinguished for 2010 and 2012, when the experimental plots were mowed by trimmer. Similarly, two separate but slightly overlapping groups are formed by years when the meadow was mown using a scythe and sickle bar mower (Figure 5A). Mowing with the scythe in the first years of the experiment coincides with a higher abundance of *Festuca rubra*, *Agropyron repens*, and *Poa pratensis* (Figure 5B). In the last years of the experiment the replacement of the sickle bar mower with a trimmer coincided with a higher abundance of *Dactylis glomerata*, *Alopecurus pratensis*, *Poa trivialis*, and *Festuca pratensis* (Figure 5B). We found

no clear trend in the change of species composition during the years when the experimental plots were mown using the sickle bar mower. Year 2008 was characterized by weather anomalies, including an extremely wet spring, and was clearly different from other study years. At that time the contribution of *Holcus lanatus* and *Trisetum flavescens* increased in the plant cover (Figure 5B).

The analysis of the correlation between the values of percentage of plant cover and the habitat parameters showed moderate correlation only between four species (*Agrostis capillaris* (r=0.64); *Arrhenathenum elatius* (r=0.66); *Holcus lanatus* (r=0.60); *Poa pratensis* (r=0.54)) and the average daily air temperature (DAT). Moderate correlation occurred also between cover of *Alopecurus pratensis* and average relative humidity (r=0.52) and daily sum of precipitation (r=0.56). Other correlations were weak or very poor.

## 4. Discussion
Our results confirm the findings of other authors on the influence of changes in management regime, particularly the frequency and timing of cutting, on the floristic composition of meadow turf (e.g., Beltman et al., 2003; Gaisler et al., 2004; Silvertown et al., 2006; Socher et al., 2012). In our studies changes in the mode of mowing stimulated the growth of some grass species and decreased the abundance of others. However, differences in the intensity of disturbance level were rather small (one cut yearly by scythe, by sickle bar mower, and by trimmer), and changes in floristic composition were also moderate in most years.

Among the reasons for the recorded dominance and frequency of individual grass species during the 28 years of the study period were changes in the mode of management, e.g., the transition from mowing by scythe (medium disturbance level) to mechanized mowing (since 1993), first by a sickle bar mower (high disturbance level) and then by a trimmer (since 2008; low disturbance level; Figure 2A).

One of the dominant grasses in different variants of our experiment with secondary succession, both undisturbed and anthropogenically driven, is *Dactylis glomerata* (Adamowski and Bomanowska, 2013). In the literature this species is described as highly competitive under different mowing regimes, and less so under grazing (Peeters et al., 2004). It was also mentioned as one of a few species that tolerate mowing well by Gaujour et al. (2012). However, there is coincidence between the decreasing cover of *D. glomerata* between 1994 and 2006 (Figure 2C) and mowing by sickle bar mower in our experiment. There is also coincidence between the increasing cover of the species in the last years after the start of trimmer use (Figures 2C, 5A, and 5B). However, it needs to be remembered that the effects of the change in the mode of management

became visible at least a year after application (so the effect of increase in disturbance level could be observed first in 2004, and the effect of its decrease in 2010), as mowing was done after observation. Similar species turnover without big changes in species diversity has been observed by other authors, even under unchanged management (Berlin et al., 2000).

*Arrhenatherum elatius* reacts positively to regular mowing (Grynia and Kryszak, 1997; Kryszak et al., 2007), but is not tolerant to low cutting, grazing, and trampling; it disappears under intensive management (Peeters et al., 2004). In our studies *Arrhenatherum elatius* retained its position at the time of the strongest disturbances, when the experimental meadow was mown by sickle bar mower (Figures 2A and 2C). However, even this management regime, with one cut per year, should be regarded as extensive (compare Peeters et al., 2004; Plantureux et al., 2005).

The steady occurrence and abundance of *Anthoxanthum odoratum* (Figure 2C) is remarkable. This species was present in almost all plots during the whole investigation period. *Anthoxanthum odoratum* is the earliest-flowering grass in our area. According to the literature (Hansson and Fogelfors, 2000) the species shows two peaks in vegetative growth. The second growth peak occurs after mowing is performed in the experiment, which might explain its steady occurrence. The species is also mentioned in the literature as one that tolerates cutting well (Gaujour et al., 2012).

Among other factors influencing the share of grasses in temperate meadows (see Beltman et al., 2003; Peeters et al., 2004), weather fluctuations are certainly important and well known (Morecroft et al., 2004; Silvertown et al., 2006; Zarzycki and Korzeniak, 2012). In our studies, 2008, with its wet spring, was marked by an exceptional overgrowth of grasses, with the absolute peak of *Holcus lanatus* cover (22%). The cover of *Alopecurus pratensis* and *Dactylis glomerata* also increased (Figures 2B, 2C, 5A, and 5B). Despite unfavorable conditions in the following years the cover of *D. glomerata* and *A. pratensis* still increased. It is still, however, too soon to decide whether this is a permanent change or a simple fluctuation of abundance.

It seems improbable that the observed changes of floristic composition were driven by changes in soil humidity. In Białowieża Forest a decrease in groundwater level (water table) was observed (Pierzgalski et al., 2002), whereas the spread of *Holcus lanatus* indicated an increase in humidity (Zarzycki et al., 2002). The species is a strong competitor, spreading when pastoral agricultural practices are neglected or after complete abandonment of meadow use (Grynia and Kryszak, 1997; Kryszak et al., 2007; Kompała-Bąba and Bąba, 2007) as well as under high fertilization and a low cutting regime (Kucharski, 1999). The spread of *H. lanatus* is also promoted by its

early flowering – at the time of observation (end of June – beginning of July) this grass sheds seeds and its stems die. In this way observers can act as dissemination factors, and removal of biomass has little effect on the further growth of this species. It is difficult to say, however, what induced the peak of abundance of the species in 2008 (Figures 2C and 5B). However, other moisture-loving grass species, especially *Poa palustris*, had different dynamic tendencies on this particular plot (Figure 2C). Locally, soil humidity could have been modified by increased shading and a decrease in wind velocity caused by nearby trees (sector F is close to the border of Palace Park, with 100-year-old trees, and close to sector E, where the highest trees are more than 20 m high). Data from most shaded plots were removed from the analyzed dataset. This allows for the diminished influence of shading on the floristic composition of experimental meadow turf but does not eliminate it completely.

Other factors governing the grasses composition of the investigated meadow seem to be: i) the relatively late time of mowing, which occurred in July, making it possible for a number of grasses (especially *Anthoxanthum odoratum*, *Holcus lanatus*, and *Trisetum flavescens*) to ripen and spread their seeds; ii) competitive interactions between particular species (see, for example, the decrease of *H. lanatus* and *T. flavescens* in the last two observations coinciding with the expansion of *Dactylis glomerata*; Figure 2C); iii) biannual trampling of the plant cover by observers, which made it more difficult for mowers to remove biomass from the meadow. Trampled stems are difficult to remove, more biomass is left on the ground, and a fertilization effect appears. Fertilized meadow turf is even more leafy and trampled at the time of the next observation – positive feedback develops. This last phenomenon could also increase soil moisture by the accumulation of rainwater, protecting the soil against evaporation (Kaźmierczakowa, 1999).

Of course, the estimation of the influence of changes in management regimes on the floristic composition of meadow turf could have been much easier if the experiment had included three groups of plots, each of these groups managed differently during the whole investigation period, as in studies by Gaisler et al. (2004) or Köhler et al. (2005). An additional factor hampering the estimation of the influence of changes in the management regime on the floristic composition of meadow turf could be microhabitat variability and the uneven floristic composition of particular plots at the time of the start of observation (Zarzycki and Korzeniak, 2012), clearly visible in our primary data (not shown). Microhabitat variability (for example humus content) is a very probable phenomenon because of the history of present sector F. Some facts show that our experimental meadow was used as meadow for a rather short time. These facts are: very low share of grasses, uneven floristic composition of particular plots in the first years of observation, and gradual spreading of first *Arrhenatherum elatius* and *Holcus lanatus* and later *Trisetum flavescens* (Figure 2C), together with the domination of easily spreading *Leontodon hispidus*, reaching high abundance after 11 years of secondary succession on the abandoned field (Bomanowska and Adamowski, 2007). According to information obtained from former workers of the Białowieża Geobotanical Station, when the Experimental Garden was established clay-pits existed in the place of present sector F. Meadow vegetation probably developed after the flattening of the terrain of present sector F in 1973–1974, and before the start of observations in 1984. This way at least some of the observed changes derive simply from anthropogenically driven secondary succession, which in the case of grassland communities takes at least several dozen years to complete (see Reid et al., 1980; Albert et al., 2014).

Our observations show that even small changes in the management regime, e.g., the transition from mowing by scythe to mechanized mowing together with yearly weather fluctuations and competitive interactions between particular species, can have an unexpectedly strong influence on the qualitative and quantitative composition of meadow turf, especially grasses.

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