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THE ROLE OF PHYTODIVERSITY IN RIPARIAN ALDER FORESTS IN SUPPORTING THE PROVISION OF ECOSYSTEM SERVICES

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Nature, ecosystems and biodiversity provide human society with many benefits known as ecosystem services. Functional diversity is an important aspect of biodiversity. In this paper, we applied inductive approach to the identification, mapping and evaluation of ecosystem services of the *Aegopodio-Alnetum glutinosae* community in Tribeč Mts. The results from 2015 show that the alder floodplain forest represents one of the most productive forest ecosystems with seasonal maximum production of 59.03 g m^{-2}, species diversity of $N_0 = 40$ and functional diversity of $FD = 10$. The forage potential of this community is medium, the melliferous potential is high and the therapeutic potential was estimated as extremely rich in medicinal plants. From the functional groups for providing ecosystem services, woody plants and hemicryptophytes play the most significant role.

Keywords: species and functional diversity, vegetation functions, floodplain forest, Tribeč Mts., Slovakia

The biological diversity or biodiversity of a habitat includes all the species living in an area, all the genotypic and phenotypic variations within each species, and all the spatial and temporal variability in the communities and ecosystems that these species form (Vellend and Geber, 2005). An important component of biodiversity is functional diversity, which refers to those components of biodiversity that influence how an ecosystem operates and functions (Tilman, 2001). A common measure of functional diversity is the number of functional groups represented by the species in a community (Chapin et al., 1996). Functional diversity is an important determinant of ecosystem processes (Chapin et al., 2000; Tilman, 2000; Loreau et al., 2001) and it affects these processes more than the number of species in the community.

Ecosystem services are a product of complex interaction between and within the abiotic (environment) and biotic (species) components of an ecosystem. A generally accepted argument claims that a reduction in the diversity of species is associated with a decline in the ecosystem's functions and consequently its services (Cardinale et al., 2006), which emphasizes the importance of preserving biodiversity.

However, the use of land and resources by the human society, especially in the last century (Steffen et al., 2004), has caused dramatic changes in ecosystems that have always been associated with a decrease in abundance of many species (SCBD, 2010). Therefore, vegetation is justifiably considered to be a significant and often also an essential component of the natural environment with specific and irreplaceable functions in the human environment (Eliáš, 1983). Eliáš (1983) distinguished two basic groups of vegetation functions in the landscape as follows: ecological functions (in the system of ecological relationships) and social functions (in the system of social relationships). The conceptual framework of ecosystem services applied by Millennium Ecosystem Assessment has shown that human well-being is dependent on the services provided by ecosystems (MA, 2005). Many ecosystem services are usually overlooked and underestimated because of the preference of anthropocentrism that focuses on human well-being. (Eliáš, 2010). In this paper, we applied inductive (bottom-up) approach to identifying, mapping and evaluating of ecosystem services (Eliáš, 2014, 2015).

We have studied functions and services of different ecosystems (vegetation) in the Microregion Tribečsko, Tribeč Mts. during the last period. One floodplain forest community (*Aegopodio-Alnetum glutinosae*) was chosen for this study. The aim of this study is to evaluate the diversity of functional groups, their importance and functioning by comparing the biodiversity of the plant community as a potential for providing the ecosystem services.

Material and methods

The fieldwork was conducted in the Microregion Tríbečsko, in Tríbeč Mts., in the western part of Slovakia in July 2015. The data was collected from the location on the bank of the Hlboká brook, near Husárka, 80–100 m from the water reservoir, on the border of the microregion, in the cadaster of Skýcov. Characteristics of natural conditions of the studied area can be found in the studies of Eliáš (1985) and Weiss (1967) that also mention the characteristics of watercourses, hydrology and soil conditions (Eliáš, 1987).

The study area represents a typical floodplain alder forest of the association *Aegopodio-Alnetum glutinosae* V. Karpáti, I. Karpáti et Jurko ex Šomšák 1961 (also referred to as *Stellario nemorum-Alnetum glutinose* Lohmeyer 1957

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in literature). The mesophilous and eutrophic riparian alder forests are distributed along the small brooks in the colline belt. Regular flooding or waterlogging by the groundwater is characteristic for this type of ecosystems (Šomšák, 1961). Information about vegetation is documented in the phytocenological reléves recorded by Eliáš (2015). The relevés were collected in accordance with the principles of the Zürich-Montpelliér school (Braun-Blanquet, 1964).

The plant nomenclature was united according to the latest checklist of plants by Marhold and Hindák (1998).

Location: Tríbeč, Skýcov, Husárka, near the Hlboká brook, plot area 20 × 20 m, exposition: E, slope: 5°, 489 m.s.n.m., coverage: E_3: 80%, E_2: 5%, E_1: 100%, Pavol Eliáš sen., 28th July 2015.

E_3: *Alnus glutinosa* 4, *Carpinus betulus* 1, *Fraxinus excelsior* 2.

E_2: *Sambucus nigra* 1, *Corylus avellana* 1, *Acer campestre* +, *Acer pseudoplatanus* +, *Fagus sylvatica* +.

E_1: *Aegopodium podagraria* 2, *Impatiens noli-tangere* 2, *Impatiens parviflora* 2, *Circaea lutetiana* 2, *Stachys sylvatica* 1, *Asarum europaeum* 1, *Pulmonaria officinalis* +, *Galeobdolon luteum* 1, *Glechoma hederacea* 1, *Anthriscus sylvestris* +, *Melica uniflora* +, *Brachypodium sylvaticum* +, *Mercurialis perennis* +, *Urtica dioica* +, *Fraxinus excelsior* juv. 1, *Sambucus nigra* +, *Alnus glutinosa* juv. +, *Acer platanoides* juv. +, *Ribes rubrum* r, *Corylus avellana* juv. +, *Acer campestre* juv. +, *Rubus caesius* +, *Rubus idaeus* r, *Dryopteris filix-mas* r, *Chrysosplenium alternifolium* +, *Atropa bella-donna* r, *Viola hirta* +, *Aliaria petiolata* r, *Carpinus betulus* juv. r, *Galeopsis speciosa* r, *Veronica montana* r, *Stellaria media* r,

The phytocenological relevé of the plant community is the base for evaluating the selected characteristics (Eliáš, 2015):

Species diversity was expressed by the Diversity index based on a quantitative measurement that reflects how many different species are in the plant community. The mathematical formulation of the Diversity index is as follows: $N_0 = S$; *N* – species richness of plant community, *S* – number of species in plant community (Hill, 1973).

Plant species were categorized into functional groups and functional diversity (*FD*) was documented. In this paper, we applied the functional group classification of deciduous forests according to Eliáš (1997). Functional groups in herb layer were classified into life-form classes according to Jurko (1990). Following functional groups were recorded in our study area: A – annuals, B – biennials, F – ferns, Gr – grasses, W – woody plants (juv.), Wr – shrubs (juv.), individual functional group was documented for perennial plants – P, where the following functional groups were included: G – geophytes, H – hemicryptophytes, Ch – chamaephytes, Ev – evergreen. Species classification of functional groups was clarified based on the state of current knowledge, occurring species in the study area and their observation.

Primary production is the creation of new organic matter by the process of photosynthesis that converts light energy into energy stored in chemical bonds within the plant tissue. Only herb-layer was considered for evaluation of the seasonal maximum of vegetation in the study area forest community. For estimation of seasonal herb-layer biomass, we applied the harvest method by direct sampling of plants according to Dykyjová et al. (1989) in the selected sample plot. Plants were collected from the sample plot, sized 1 × 1 m, divided into 4 the same quadrats, sized 0.5 × 0.5 m. Harvested plants were sorted according to species and transported to the laboratory in Nitra, Department of Ecology. Plant material was dried to constant mass in an oven at 80 °C. The dry mass was weighed separately for individual species in g m^{-2}.

Functional groups play an important role in providing potentials of ecosystem services of the forest community. Functional groups have some value (percentage) in the evaluated potential providing of ecosystem services. Values were calculated for all potentials and for all functional groups as follows:

Forage potential (P_f) (Jurko, 1990) was calculated from the phytocenological relevé as the sum of percentage of positive eco-values, reduced by negative values, zero eco-values were not considered (Jurko, 1990). Eco-values range from -3 (very harmful) to 5 (very good forage value). According to Jurko (1990), these are the quality grade classes: -2. inadequate <-20%, -1. ineligible -20% to -2%, 0. zero -2% to 2%, 1. extremely low 2% to 10%, 2. very low 10% to 20%, 3. low 20% to 40%, 4. medium 40% to 60%, 5. high 60% to 75%, 6. very high 75% to 90%, 7. extremely high >90%.

The significance of functional groups in forage potential (P_f) was expressed as follows:

$$H_P f_{(Fsi)} = \frac{\left[\sum x_{(Fsi)} - \sum y_{(Fsi)}\right] \times N_{(Fsi)}}{P_f \times N_i} \times \sum x_{(Fsi)} - \sum y_{(Fsi)}$$

$$H_{Pf(Fsi)} = \%$$

where:

- x – percentage of positive eco-values
- y – percentage of negative eco-values
- N_i – number of all species in the plant community
- $N_{i(FSi)}$ – number of all species within the functional group
- P_f – forage potential of the plant community

Melliferous potential (P_m) (Jurko, 1990) was determined by the supplies of honey, honeydew and nectar from the phytocenological relevés in the studied community. The potential was expressed separately for every community layer (Jurko, 1990) according to the significance of species in the community by eco-values (1 – low, 2 – medium, 3 – good, 4 – very good). Melliferous potential (P_m) was evaluated according to the following scale: 1. very low < 20%, 2. low 20–50%, 3. medium 50–150%, 4. high 150–225%, 5. very high 225–275%, 6. extremely high >275% (Jurko, 1990).

The significance of functional groups in melliferous potential (P_m) was expressed as follows:

$$H_P m_{(Fsi)E_i} = \frac{\left(\frac{n_{hEi}}{N_{E_i}} \times 100\%\right) \times N_{i(Fsi)}}{P_{m_{E_i}} \times N_i} \times P_{m_{E_i}}$$

$$H_P m_{(Fsi)} = \frac{HPm_{(Fsi)E1} + HPm_{(Fsi)E2} + HPm_{(Fsi)E3}}{3}$$

$$H_P m_{(Fsi)} = \%$$

where:

n_{hei} – number of plant species with eco-value within the functional group, within the vegetation layer

N_{Ei} – number of all species within the functional group, within the vegetation layer

$Ni_{(Fsi)}$ – number of all plant species within the functional group

Ni – number of all plant species within the vegetation layer

$PmEi$ – melliferous potential of plant community within the vegetation layer

Therapeutic potential (P_t) was calculated by a quantitative method as the percentage rate of medicinal plants in the phytocoenosis, which are identified and used in homeopathic, natural and folk medicine (Jurko, 1990). We assessed the potential according to the rate of medicinal plants as follows: 1. negligible <1%, 2. very poor 1–5%, 3. poor 5–10%, 4. little rich 10–20%, 5. rich 20–30%, 6. extremely rich >30% (Jurko, 1990). The significance of functional groups in therapeutic potential (P_t) was expressed as follows:

$$H_p t_{(Fsi)} = \frac{\left(\frac{n_h}{N_{i(Fsi)}} \times 100\%\right) \times N_{i(Fsi)}}{Pt \times Ni} \times P_t$$

$$H_p t_{(Fsi)} = \%$$

where:

n_h – number of plant species with eco-value within the functional group

$Ni_{(Fsi)}$ – number of all plant species within the functional group

Ni – number of all plant species within the plant community

Pt – therapeutic potential of the plant community

Results and discussion

The Diversity index of *Aegopodio-Alnetum glutinosae* plant community represents N_0 = 40. The species diversity in this type of community was evaluated as high species richness. Similar results were documented by Stanová, Valachovič (2002). The dominant species is alder (*Alnus glutinosa*), the accompanying species that can have an important co-dominant role in the plant community are European ash (*Fraxinus excelsior*) and European hornbeam (*Carpinus betulus*). We also recorded the presence of *Impatiens noli-tangere* in our study area. This type of location and environmental conditions are characteristic for this species (Jašková, 2008). The invasive alien plant *Impatiens parviflora* was documented in the herb-layer. This herb could have a negative effect on the species diversity and forest ecosystem functioning by coverage and occurrence in the plant community in the future. *Impatiens parviflora* started to displace *Impatiens noli-tangere* in some locations mentioned in literature during the 20th century (Jašková, 2008). The studied plant community is characterized by high coverage E_3: 80% and E_1: 100%.

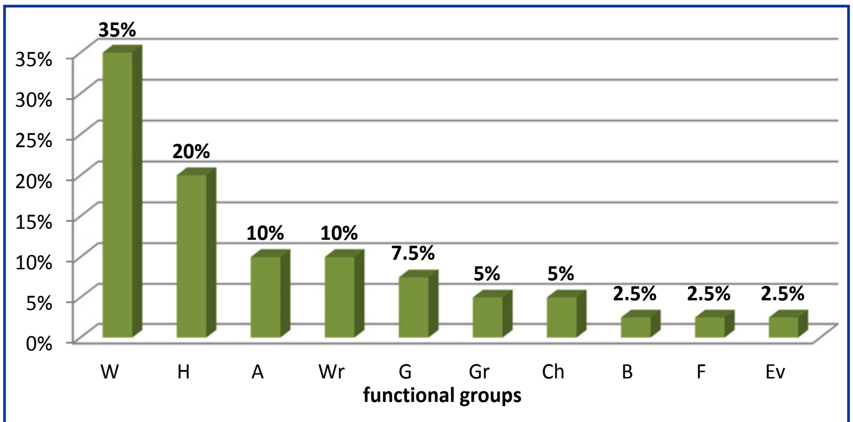

Figure 1 The share of functional groups in the riparian alder forest plant community (*Aegopodio-Alnetum glutinosae*) in Tribeč Mts., in 2015

The functional diversity (*FD*) is 10 (figure 1) in the studied plant community. The share of perennial (*P*) functional group is the highest 36%. Hemicryptophytes (H) 20% are mostly represented in this functional group. The share of this functional group is high. Hemicryptophytes (H) are deemed positive in providing the process functioning in the plant community from the long-term point of view. Woody plants also have high representation, they occur in every layer. Ferns (F) and biennials have (B) the lowest representations of 2%. They are represented by only one species.

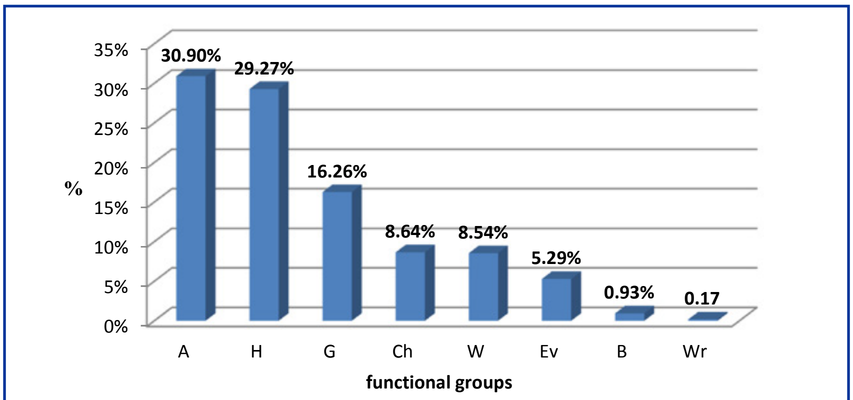

Figure 2 The share of biomass according to plant species in the riparian alder forest plant community (*Aegopodio-Alnetum glutinosae*) in 1 m², in Tribeč Mts., in 2015

The seasonal maximum biomass production was 59.03 g m^{-2} in the herb-layer. Kubíček and Jurko (1975) present their results of seasonal biomass production of the herb-layer as follows: 136.33 g m^{-2} in Stellario – Alnetum in Malé Karpaty Mts., Kollár et al. (2010) recorded 53.6 g m^{-2} in Žalostínska vrchovina (the westernmost part of Biele Karpaty Mts.). Kotrla (2007) estimated the average total herb biomass production of 57.12 g m^{-2} in Ďulov Dvor (in the alluvium of the Váh river). The share of biomass of individual species is displayed in Figure 2.

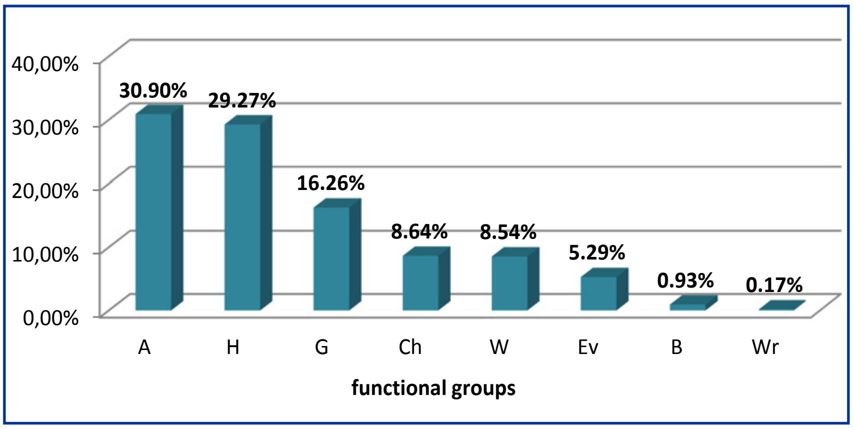

Figure 3 Percentage of biomass according to functional groups in the riparian alder forest plant community (*Aegopodio-Alnetum glutinosae*) in 1 m^2, in Tribeč Mts., in 2015

The share of functional groups biomass is presented in Figure 3. The share of production of the annuals (A) is almost 31%. This functional group has the highest representation, although it is represented only by 4 species. The functional group of perennials (P) represents 60%, which also includes other functional subgroups. Shrubs (Wr) represent 0.17% of the biomass. This share is evaluated as the lowest value of a functional subgroup. This subgroup only was represented by juveniles.

Table 1 shows the plant community potentials according to the functions of vegetation. The forage potential (P_f) of the plant community is evaluated as medium (4th quality grade class). Jurko (1990) found low values of P_f forage potential in the forest understory, the alder floodplain forest evaluated by Jurko represents a very low P_f of 12%. The melliferous potential is high (4th quality grade class). Tóthová, Halada (2015) studied the melliferous potential of different ecosystems. In 84 of the studied localities, they found the melliferous potential of grassland to be medium and high. In regards to the therapeutic potential, the location was evaluated as an extremely rich source of medicinal plants.

The evaluated functional groups provide the potential for ecosystem services in different proportions (table 2). Woody plants play the most important role for providing ecosystem services in black riparian alder floodplain forests. Woody plants were documented in every vegetation layer, which had a positive effect on the importance value of ecosystem services potential. Hemicryptophytes are another important functional group. The values of forage and melliferous potential in this functional group are $H_Pf_{(Fsi)} = 21$, $H_Pm_{(Fsi)} = 12.5$. This functional group is included in perennials. With optimal land use, the plant community potential for providing ecosystem services is high from the long-term point of view. Biennials (B), grasses (Gr), ferns (F) and evergreen (Ev) are of almost zero importance in the studied plant community. These functional groups do not contribute to the provision of ecosystem services regarding the forage potential in the studied plant community. The evaluation of functional groups has to take into account the species composition in the plant community. Functional group are not to be understood as individual sources providing the ecosystem services.

Conclusion

The diversity index of $N_0 = 40$ and functional diversity of % = 10 were recorded in the plant community

Table 1 Potentials of the riparian alder forest community *Aegopodio-Alnetum glutinosae* to provide ecosystem services in Tribeč Mts., in 2015

Name of community	Forage potential (P_f)	Melliferous potential (P_m)	Therapeutic potential (P_t)
Aegopodio-Alnetum glutinosae	52.5%	186.9%	32.5%

Table 2 The significance of functional groups in providing potentials for ecosystem services in the riparian alder forest plant community (*Aegopodio-Alnetum glutinosae*), in Tribeč Mts., in 2015

Functional group	Significance of functional groups in Forage potential HP	Significance of functional groups in Melliferous potential HP	Significance of functional groups in Therapeutic potential HP
W	48.85	51.16	12.35
Wr	2.8	8.33	7.48
A	4.5	6.25	4.88
B	4	0	0
Gr	2	0	0
F	-4	0	0
H	21	12.5	4.88
G	8,03	2.08	2.28
Ch	2	4.17	0
Ev	-2.7	0	0

Aegopodio-Alnetum glutinosae which has a high species richness and high functional richness in the studied forest community. Compared to the other forest communities, the riparian alder forest is the most productive forest ecosystem with the seasonal maximum biomass production of 59.03 g m^{-2}. Medium forage potential was calculated in the studied plant community. The melliferous potential is comparable with the grassland's potential and the therapeutic potential was calculated as extremely rich. The most significant functional group with the potential of providing ecosystem services is the perennial plants, mainly hemicryptophytes and juvenile woody plants. The importance of functional groups cannot be specified for all types of plant communities. It is necessary to express the significance and evaluate the individual functional groups in particular conditions and species compositions.

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