Ecological-agricultural perspective on the quality of pasture vegetation

Ekologicko-zemědělský pohled na kvalitu pastevních porostů

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Abstract

One of the important goals of current research is to find a balance between the diversity of grass covers and their economically sustainable use for farming purposes. The aim of this study was to find relationships between the number of species (N), the Shannon-Wiener index (H), the forage value of vegetation (FV) and the proportion of grasses (G), legumes (L) and other forbs (F). Eleven extensively grazed pasture vegetations, located at the foothills of Šumava and Nové Hrady mountain ranges in South Bohemia, were selected with permanent plots marked out for phytosociological monitoring.

The results proved a statistically confirmed positive correlation between the N and H factors and a negative correlation between these two diversity indicators and the forage value of vegetation. Pasture vegetations are significantly influenced by the proportion of grasses, legumes and other forbs. The average number of species and the Shannon-Wiener index increases with the growing proportion of other forbs while the forage value decreases. The observed pasture vegetations were predominantly evaluated as “good/valuable” and “very good/most valuable”.

Keywords: diversity, forage value, pastures, Shannon-Wiener index, species richness

Abstrakt

Důležitým úkolem současného výzkumu je hledání rovnováhy mezi diverzitou travních porostů a jejich ekonomicky udržitelným hospodářským využíváním. Cílem této studie bylo hledání vztahů mezi počtem druhů (N), Shannon-Wienerovým indexem (H), pícninářskou hodnotou porostu (FV) a poměrem pokryvností trav (G), leguminóz (L) a ostatních bylin (F). Vybráno bylo 11 extenzivně pasených travních porostů v šumavském a novohradském podhůří v jižních Čechách, na kterých byly vytyčeny trvalé plochy pro fytocenologické snímkování. Výsledky potvrdily statisticky průkaznou pozitivní korelaci mezi N a H a negativní korelaci těchto dvou ukazatelů diverzity k pícninářské hodnotě. Na pastevní porost má podstatný vliv poměr trav, leguminóz a bylin. Průměrný počet druhů a Shannon index s rostoucí pokryvností bylin stoupá, zatímco pícninářská hodnota klesá. Sledované pastevní porosty byly převážně vyhodnoceny jako dobré a velmi dobré.

Klíčová slova: diverzita, druhová bohatost, Shannon-Wienerův index, pícninářská hodnota, pastviny

Introduction

Current species diversity exists as a result of a rich medieval agricultural landscape (a mosaic of pastures, patches of agricultural land, balks, fallows, groves, springheads and floodplains) where grazing was one of the most important factors forming the European nature (Mládek, et al., 2006; Šarapatka and Niggli, 2008). Farming methods did not change much throughout the centuries. The first major changes in agriculture influencing directly biodiversity took place in the 19th century (involving new crops and technologies) with more to follow after the Second World War mostly in today's post-communist countries of the former East block which included land unifying, intensification of production and the use of fertilizers and pesticides. Another controversial issue is the farming practice witnessed in the last decade, i.e. depending on the EU subsidies, with farmers holding excess lands and maintaining their covers by "extensive" grazing. However, such extensive grazing starts on one side of the pasture in the spring to end on the other in the autumn, ignoring the quality or long-term development of the particular cover (Hejcman, et al., 2002), which ultimately leads to the disappearance of other species, including forbs and invertebrates. This means that agriculture and human influence was the reason of the high biodiversity of non-forest habitats as well as its contemporary dramatic decline (Šarapatka and Niggli, 2008).

The aim of a number of current researches and projects is to find a balance between the diversity of grass stands and their economically sustainable use for farming purposes (Piro and Wolfová, 2008; Vargová, et al., 2011). The relationship between agricultural production and biodiversity is called the "functional biodiversity" in general (Šarapatka and Niggli, 2008). The biodiversity of grasslands is very often assessed based on the number of species or the Shannon-Wiener diversity index (e.g. Bullock, et al., 2007; Marion, et al., 2010; Hakrová, et al., 2012).

The forage value is used in order to assess grasslands in terms of agricultural production mostly in Central and Eastern Europe. Various grassland assessment systems were developed focusing on the classification of species into different numbers of quality classes in terms of nutritional content and the volume of biomass produced (e.g. Stahlin, 1970; Klapp, 1971; Filipek, 1973). In the Czech Republic, for instance, species are divided into six quality classes based on Regal (1980), and it is five quality classes in Romania (Grozavu, et al., 2010). Newly also forage value of individual species in Slovakia dealt Novák (2004).

Completely accurate information on the nutritional composition of the stand provided only chemical analysis of forage. Forage value, calculated on the basis of species composition of vegetation seems to be a suitable equivalent for expensive analysis in the current economic situation. We were interested in how diversity of vegetation (expressed in number of species and Shannon-Wiener index) affects the forage value of grassland and what effect of this characteristic has species composition of vegetation, respectively the ratio of abundances of grasses, legumes and other herbs.

Materials and Methods

Long-term observation of pastures located at the foothills of Šumava and Nové Hrady mountain ranges in South Bohemia, Czech Republic has taken place under various projects by the Faculty of Agriculture, the University of South Bohemia (Hakrová, 2004; Frelich, et al., 2006; Hakrová, et al., 2009). Pastures were rotationaly grazed with extensive density, mainly by cows, in two cases by sheep (Tab. 1).

Three to five permanent plots, each covering 16m^2, were marked out in selected pastures. The coverage percentage of all vascular plant species was visually estimated in each plot in May, July and September in the year 2011. The nomenclature of plants followed Kubát (2002). Biomass was not sampled.

The average number of vascular plant species in one relevé (N) and the Shannon-Wiener diversity index (H) were calculated based on phytosociological observations. The Shannon-Wiener index was calculated using the following formula: $H' = -\Sigma i \; pi \ln(pi)$, where p*i* is the proportional abundance of the *i* species. In addition, the percentages of grasses (G), legumes (L) and forbs (F) were calculated from the total coverage of each relevé.

The forage value (FV) was calculated following Veselá, et al. (2009), using the following formula: $FV = \Sigma D_{B1} + 0.75\Sigma D_{B2} + 0.50\Sigma D_{B3} + 0.25\Sigma D_{B4} – \Sigma D_{B6}$, where D is the sum of covers of the individual species of a given B quality class. The B_1 class includes yielding species of a superior quality; B_2 includes yielding species with a lower forage value and, vice versa, less yielding species with a high forage value; the B_3 class includes less yielding species of an inferior quality; B_4 includes inferior, non-yielding, low quality species; the B_5 class includes unusable, thorny, unpalatable species; and B_6 includes poisonous species. The classification of species was used after Regal (1980).

The Pearson correlation coefficient was calculated for the observed parameters – i.e. N, H, FV, G, L and F – using the Statistica 9.0 (Statsoft, Inc.) software.

Table 1. Characterisation of pastures (altitude, year of sowing, age,grazing, total N, ratio G:L:F in numbers and in %, dominant species), mean values of observed parametres (N, H, FV) and dominant species, dominant grasses, legumes and herbs.. Numbers in parenthesis are ±StD and abundance in %.

	Jenín 1	Jenín 2	Jenín 3	Rychnov 1	Rychnov 2	Stropnice 1	Stropnice 2	Vlčí Jámy 1	Vlčí Jámy 2	Pasečná 1	Pasečná 2
Altitude (m.a. s.l.)	760	760	680	625	605	580	580	795	795	785	795
year of sowing	1999	2001	1991	hist. pasture	1994	2005	2006	hist. pasture	hist. pasture	1993	1993
Age (years)	13	11	21	> 30	17	7	6	> 30	> 30	19	19
Grazed by	cow	cow	cow	cow	cow	sheep	sheep	cow	cow	cow	cow
Grazing density	0.45 LU.h^{-1}	0.45 LU.h^{-1}	0.45 LU.h^{-1}	0.5 LU.h^{-1}	0.5 LU.h^{-1}	0.87 LU.h^{-1}	0.87 LU.h^{-1}	0.45 LU.h^{-1}	0.45 LU.h^{-1}	0.5 LU.h^{-1}	0.7 LU.h^{-1}
Mean N	**19.5** (±2.17)	**24.5** (±2.29)	**18.0** (±3.23)	**18.7** (±1.71)	**16.4** (±2.88)	**9.1** (±1.54)	**11.6** (±1.5)	**16.5** (±1.8)	**24.9** (±5.1)	**21.3** (±2.06)	**24.5** (±3.08)
Mean H	**2.28** (±0.35)	**3.20** (±0.30)	**2.55** (±0.79)	**2.69** (±0.34)	**2.67** (±0.32)	**1.52** (±0.40)	**2.25** (±0.44)	**2.6** (±0.34)	**3.18** (±0.77)	**2.6** (±0.18)	**3.14** (±0.42)
Mean FV	**79.8** (±6.72)	**76.1** (±4.41)	**80.9** (±8.04)	**77.8** (±7.49)	**86.5** (±4.33)	**92.1**(±2.1)	**86.5** (±4.59)	**58.95**(±10.7)	**66.6** (±11.9)	**67.2** (±5.72)	**66.7** (±12.81)
total N	52	58	43	40	36	21	25	31	47	43	39
G:L:F	10 : 6 : 36	14 : 6 : 38	11 : 6 : 26	9 : 3 : 28	10 : 2 : 24	9 : 3 : 9	9 : 4 : 12	9 : 3 : 19	14 : 5 : 28	14 : 2 : 27	10 : 6 : 23
G:L:F (%)	83.8 :1.5:14.7	69:10.7:20.4	80.7:5.0:14.3	74.6:0.9:24.6	72.6:8:19.4	71:18.9:10.1	79.9:6.1:14	73.6:9.8:16.6	75.9:2.6:21.5	82.2:2.7:15	76.8:7.4:15.9
Dominant species (%)	*Dactylis glomerata* (51.5)	*Dactylis glomerata* (21)	*Festuca rubra* (39.2)	*Festuca rubra* (34)	*Festuca rubra* (22.5)	*Lolium perenne* (60.3)	*Lolium perenne* (44.9)	*Poa annua* (35.8)	*Alopecurus pratensis* (17.4)	*Agrostis capillaris* (39.7)	*Agrostis capillaris* (27)
Other dominant grasses (%)	*Poa trivialis* (14)	*Lolium perenne.* (14.3), *Agrostis capil.* (11.5), *Poa trivialis* (6.1)	*Phleum pratense* (11.6), *Festuca pratensis* (9.2), *Dactylis glomerata* (7.8)	*Agrostis capillaris* (13.6), *Dactylis glomerata* (11.1)	*Poa pratensis* (20.8), *Lolium perenne* (12), *Phleum pratense* (6)	*Festuca pratensis* (2.2)	*Phleum pratense* (14.1), *Festuca pratensis* (6.6), *Poa pratensis* (6.1)	*Lolium perenne* (14.9) *Elytrigia repens* (4.2)	*Agrostis capillaris* (16.9), *Avenula pubescens* 9.9), *F. rubra* (7.3), *Dactylis glomerata* (6.5)	*Poa pratensis* (20), *Dactylis glomerata* (5.7)	*Festuca rubra* (14.5), *Poa pratensis* (7.7), *Dactylis glomerata* (7)
Dominant legumes (%)	*Vicia cracca* (0.6)	*Trifolium repens* (7.3)	*Trifolium pratense* (4.6)	*Trifolium repens* (0.4)	*Trifolium repens* (7.2)	*Trifolium repens* (18)	*Trifolium repens* (5.6)	*Trifolium repens* (7.6)	*Lathyrus pratensis* (1)	*Trifolium repens* (2)	*Trif.pratense* (2.1), *Trif. repens* (1.9)
Dominant herbs (%)	*Taraxacum* sect. *Ruderalia* (4.2)	*Taraxacum* sect. *Ruder.* (4.2), *Plantago lanceolata* (3.7)	*Taraxacum* sect. *Ruderalia* (7.1)	*Achillea.milefolium* (7.2), *Plantago lanceolata* (4.1), *T.* sect. *Ruder* (3.6)	*Achillea milefolium* (5.4), *Taraxacum* sect. *Ruder.*(5.3)	*Taraxacum* sect. *Ruderalia* (8.9)	*Taraxacum* sect. *Ruder.* (6.1), *Rumex obtusifolius* (4.8), *Urtica dioica* (1.5)	*Ranunculus. repens* (5.3), *Plantago major* (3.4), *Taraxacum* sect. *Ruder.* (2.4)	*Aegopodia podagr*(3.3) *Alchemilla monticola* (2.8) *Ranunculus acris* (1.9)	*Ranunculus repens* (4.9)	*Taraxacum* sect. *Ruderalia* (3.5), *Veronica chamaedrys* (1.6)

Legend: 1LU = 500kg of live weight

Results

Mean number of species (N) range from 9 to 25 species per site, mean value of diversity index (H) range from 1,5 to 3,2 and mean forage values range from 59 to 92 (Table 1). Proportion of grasses in swards fluctuate between 69% and 84%, proportion of legumes fluctuate between 0,9% and 20% and proportion of forbs fluctuate between 10% and 25% (Table1).

Shannon-Wiener index significantly increased with the average number of species ($r=0.775$, $p<0.01$) (Fig.1A). Shannon-Wiener index also increased markedly with increasing abundances of forbs ($r = 0.6929$, $p <0.01$; Fig. 1B) and significantly decreases with increasing abundances of grasses ($r = -0.472$, $p <0.000$) (Fig. 1C). The average number of species increased markedly with increasing proportion of forbs ($r=0.417$, $p<0.001$) (Fig. 1D), and slightly decreased with the increasing proportion of grasses ($r=-0.1507$, $p<0.074$; figure not shown) and with the growing proportion of legumes in particular ($r=-0.2125$, $p<0.011$) (Fig. 1E).

Forage value correlates negatively with the average number of species ($r = -0.573$, $p <0.001$; Fig. 1F) as well as the Shannon-Wiener index ($r = -0.595$, $p <0.001$) (Fig.1G). Clearly, it is influenced by the growing proportion of forbs in a cover, causing its reduction ($r = -0.336$, $p <0.001$) (Fig.1H).

Discussion

The diversity of vegetation and composition are strongly connected. The positive correlation between the number of species and the Shannon-Wiener index is supported by other studies (e.g. Kryzsak, et al., 2011; Parolo, et al., 2011). The Shannon-Wiener index includes species richness as well as species equitability: higher index value means the higher number of species with a relatively lower abundance in a community. The decrease in the average number of species and the Shannon-Wiener index with the growing proportion of grasses in a community was proved by Kopeć, et al. (2010).

Species richness (the number of species) is always a result of local abiotic conditions and farming intensity in particular (Marini, et al., 2007). The number of species, Shannon-Wiener index and therefore also forage value are affected by the altitude, the number of species and SW index increase with increasing altitude, while forage value decreases (unpublished data; see also Gusmeroli, et al., 2012; Parolo, et al., 2011).

The forage value always depends on the species composition of vegetation, which is influenced to a large extent by the farming intensity applied by a particular farmer (e.g. Dumont, et al., 2011). Intensive grazing and mowing support strong, competitive species such as grasses, containing a higher proportion of nitrogen and mineral substances and a lower proportion of fibre and other non-nutritious substances (e.g. Mládek, et al., 2006), which is desired by farmers. A suitable abundance of certain

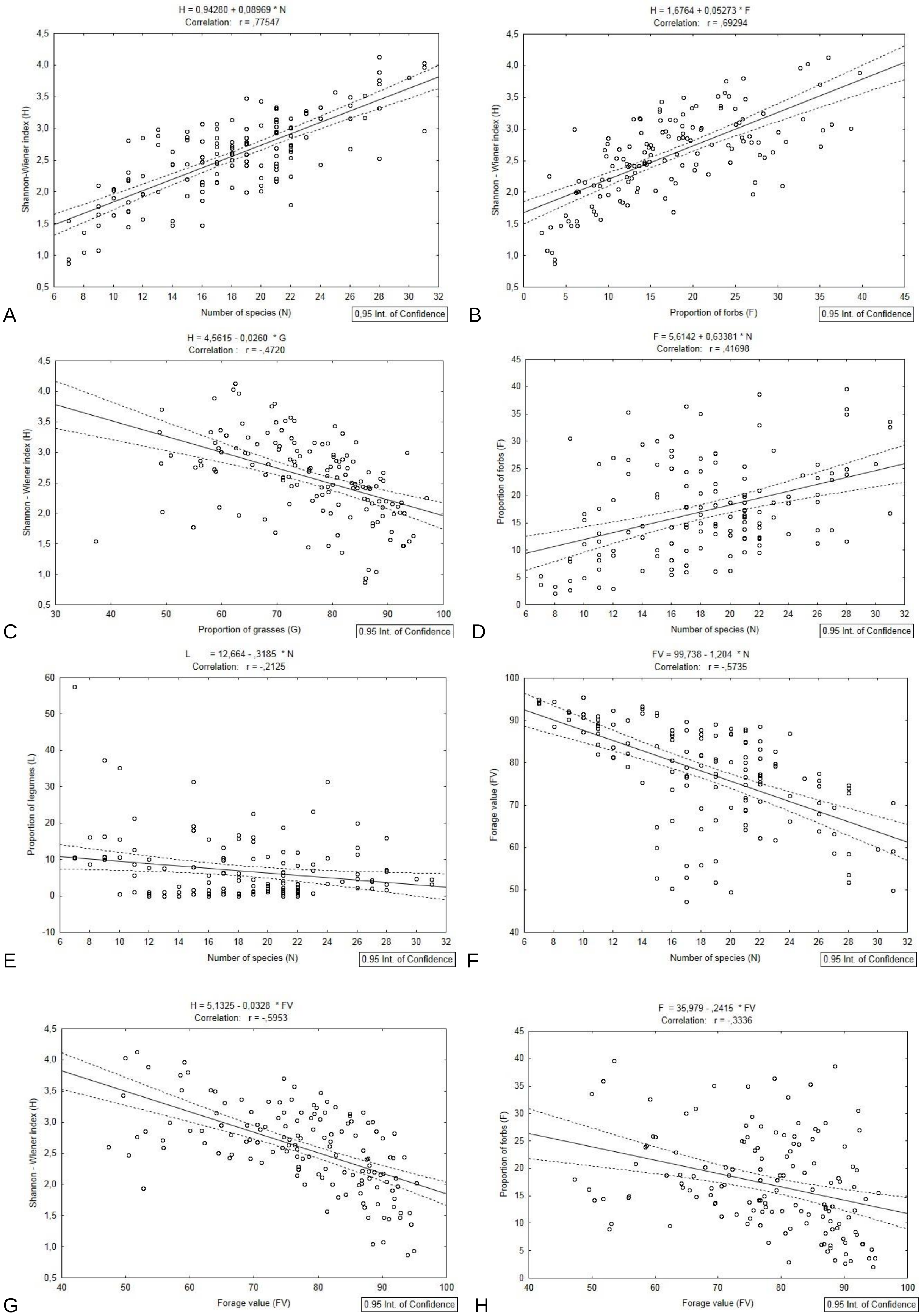

Figure 1. Correlation of the number of species (N), the Shannon-Wiener index (H), the forage value (FV) and the proportion of forbs (F) and legumes (L)

forbs, on the other hand, improves livestock health and their immunity (Mládek, et al., 2006), and their content of aromatic substances also improves the taste and consumption of forage (Jendrišáková, et al., 2011; Šantrůček, et al., 2007).

Rich grasslands with a high proportion of forbs do not lose nitrogen and mineral substances or digestibility after the blooming phase as quickly as sown grass-clover mixtures, and it is also possible to postpone the harvest by several weeks, if necessary (Mládek, et al., 2011; Jendrišáková, et al., 2011). These grasslands can therefore be managed with a lower intensity, which supports the species diversity of forbs as well as other related groups of organisms, mainly invertebrates (Šarapatka and Niggli, 2008).

Proportion of grasses in swards is relatively high (69-84%), usually range from 50 to 70% (Novák, 2004; Pozdíšek,et al., 2004). The proportion of legumes is rather smaller (1-20%) and very variable, optimal range is 15-25% (Novák, 2004; Pozdíšek,et al., 2004).

However, it is necessary to pay attention to shrub encroachment in extensively grazed stands. The increased shrub cover in the stands affects the species composition, decreases cover of herbs and legumes and reduces forage value as well as the digestibility of biomass (Kesting, et al., 2009).

According to the final value of the forage crops are pastures divided into several categories of quality. Pastures in Romania are divided into five categories from “very good”, ranging from 75 to 100, to “degraded” stands with the value of less than five (Grozavu, et al., 2010), in Slovakia into seven categories from “most valuable” (90-100) to the ”toxic” stands with zero (Novák, 2004). Forage values of our observed pasture vegetation range, with few exceptions, from 50 to 95, which would classify them by the Romanian scale as “good/valuable” and “very good/most valuable”. However, when we comparing the final forage values,is necessary to take into account the used classification of species, which vary according to different authors. Novák (2004) compared forage values counted with his values and with the values after Regal (1980), and he found forage value after Regal was about 8% higher.

It may therefore seem that the negative relationship between forage value and diversity of vegetation creates a disproportion between the needs of farmers and biologists. The results, however, show that also species richer stands retain relatively high forage value and, furthermore, forbs diversity also improves dietetic properties of forage and naturally supports livestock health.

Conclusions

The study confirmed a statistically significant positive correlation between number of species (N) and Shannon-Wiener index (H), and a negative correlation between these two diversity indicators and the forage value of stands. Grazing on vegetation has a significant impact ratio of grasses, legumes and especially herbs. The average number of species and Shannon index increases with the growing proportion of other forbs while the forage value decreases. The observed pasture vegetations were predominantly evaluated as “good/valuable” and “very good/most valuable”.

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