SUCCESSION CHANGES IN EXTENSIVELY USED AGRICULTURAL LAND

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Abstract

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The research was aimed at the evaluation of succession changes in extensively used agricultural landscape in the part of Horná Orava region. The object of the research was the vegetation of meadows, pastures, and shrubs. The succession process was in connection with changes in land use, reducing of traditional using (grazing, cutting) of the habitats and next climax succession to the forest. Succession changes were observed in the ecotones between meadows or pastures and forests. Statistical methods of direct analyses were used for the evaluation changes of species abundance.

Key words: grassland, direct gradient analysis, environmental site conditions, Orava region

Introduction

After 1990, changes in management of agriculture land came up more significantly, particularly because of economic reason. Traditional land use is in subsidence in many mountain regions, which agriculture is not very profitable, and many outlying pastures and meadows became abandoned. As a consequence of gradual succession of grassland to forest, environmental site conditions has been changed significantly. Gene pool of meadows and pastures communities, melliferous and medicinal herbs, as well as conditions for typical communities of birds, reptiles and insects are threatened (Sláviková, 1998).

The research was aimed at the assessment of succession changes of non-forest vegetation in extensively used agricultural land, which were connected with reducing of traditional use (grazing, cutting) of grassland and consequently with climax succession to the forest. The research was realized in the study area of Veselovianka river basin, situated in the north-east of the Protected Landscape Area Horná Orava (PLA).

Material and methods

Veselovianka river basin, represented by pastures and meadows land, is located in 3 municipalities (Oravská Jasenica, Oravské Veselé, Mutné). According to soil, climatic and relief conditions, the study area belongs to mountain and sub-mountain region. The natural potential of the area is mostly conditioned by abiotic terms, characteristic dense hydrological net, great segmentation and different slope. The area belongs to moderately cool climatic sub-region, very humid, which is conditioned by altitude, location to prevailing wind and forest density of the area. Rainfall ranges from 800 to 1200 mm per year, on Pilsko peak to 1600 mm per year. The most spread soil-forming substrates are flysh shale and sandstones. Reaction of soil is from acid to low acid, somewhere neutral with high carbonate content. Different Cambisol subtypes (75.4%) were developed on the soil-forming substrates. Some other types of soil are also represented in the study area, as Planosols and Stagnosols, Rendzic Leptosols, Podzols and Fluvisols, randomly occurred Histosols and Leptosols.

The subject of the study were the succession stages in the ecotones between the meadows or pastures directed to forests. The assessment of state and trends of succession changes in the land was based on investigation of processes of spreading individual species in several succession stages and habitat changes in the transects with different environmental site conditions. Our aim was to understand the reasons and try to predict the development of the vegetation or consequences of different interference to the landscape.

The phytosociological sampling was carried out by the method of the Zürich-Montpellier school. The phytosociological data were put into the database of TURBOVEG program (Hennekens, 1996, 2001) and phytosociological table was designed in the JUICE program (Tichý, 2001).

The monitoring of habitat changes and survey of land use changes were the starting-point for study succession. The research was limited by time, therefore we used the method of comparison with several plots in the different phylogenies stages at the same time (in the relatively identical site conditions). The development of vegetation and plots management were also taken into consideration. This method is simpler from the time-based point of view, but the results are approximate (Moravec et al., 1994).

Succession changes were observed in the ecotones between semi-natural and man-conditioned habitats (forest – meadows, pastures) in the field. Four succession stages were characterized according to the species composition and tree-layer cover. Methods of direct gradient analysis were used for the analysis of species composition changes in relation to environmental variables, recorded in the field (slope, exposition, altitude, layer cover, soil, soil-forming substrates).

Species composition was compared in the transects and following, average Ellenberg indicator values were calculated (Ellenberg, 1974). The database of plant species attributes, created by Halada (1998), was applied in the evaluation of the species characteristics. The data and the phytosociological relevés were evaluated by multivarious analyses of the CANOCO program (ter Braak, 1988, 1990; ter Braak, Šmilauer, 1998; Lepš, Šmilauer, 1999). The primary data contains records on a collection of observations phytosociological relevés, which represent the species composition of communities. Each sample collects environmental variables, or *covariables* (slope, exposition, altitude, layer cover).

The significance of relationships with environmental variables was tested by the Monte Carlo permutation test. In CANOCO, the distribution of the test statistics under the null hypothesis of independence is not known, the distribution depends on the number of environmental variables, on their correlation structure, on the distribution of the species abundance etc. (Herben, Münzbergová, 2001).

Results

To understand the succession of the ecosystem and landscape processes is important issue in the field of nature conservation and management of protected areas (Križová, 1995). Development of communities is under way in connection with environmental character, and proceeds from the grassland to the next climax stage. The climax stage typical for temperate zone of middle Europe is the forest. The first step for the determination of land

use changes was the comparison of land use between 2 periods: historical land use (maps from 1958) and present land use mapped in 2001. Analysing the changes of historic and present land use, succession processes presented 13.6%. The highest proportion (68%) of all succession changes was represented by the changes of shrubs and pastures extensively being changed to forests. In the period of the collectivisation of agriculture, the outlaying grassland remained non-used, the area of shrubs and trees increased and next climax succession headed gradually again towards forest. These plots – the ecotones between semi-natural and man-conditioned habitats (forest-meadows, pastures) were selected for the observation of succession processes.

Succession at the ecotones between pastures and forest

Succession of the extensively used pastures was studied at the 9 transects: 5 of them with sharp boundary and 4 transects with gradual transition from pastures to forest. The following succession stages were observed at the transects with gradual transition: from intensively and extensively used species-rich *Nardus* grasslands (alliance *Nardo-Agrostion tenuis*), through mixed vegetation of pioneer trees species on the pastures, to completely connected forest. Nomenclature of succession stages was modified according to Ujházy (2003), who studied the secondary succession of *Juniperus communis* formations on grasslands.

Initial stage is characterized as extensively used pastures with starting pioneer trees, in consequence of reducing traditional using by man. Initial process of sprouting starts primarily on the lower-stalked flowering pastures (association *Anthoxantho-Agrostietum*). Trees occur as a solitaire, the cover of wood layer is less than 50%. Dominant species of herbal layer (*Anthoxanthum odoratum, Agrostis capillaris, Briza media,* etc.) are getting together with other typical pastures as well as forest species (*Vaccinium myrtillus, Hieracium lachenalii* etc.). The number of rare and vulnerable species (e. g. *Gladiolus imbricatus*, *Orchids*), which could limitedly grow on the intensively managed pastures, increases and also other processes start. *Rosa canina, Salix caprea, Populus tremula, Sorbus aucuparia* and *Picea abies* start out as the first pioneer species, which bear nicely fully sunlit site. Common side-effect species of the herbal layer are *Chamerion angustifolium, Rubus idaeus* etc. The initial stages are marked out by highest species richness. By virtue of occurrence of many rare and endangered species, these stages should be protected.

Sprouting stage – the cover of wood layer increases, the composition of herbal layer is changed more significantly. Depending on shade of wood cover, herbal layer has tessellated structure, some species composition is similar to previous stage, some to the next stage. Abundance of some less competitive species decreases, mainly lower-stalked pastures species (*Festuca rubra, Agrostis capillaris, Anthoxanthum odoratum, Leontodon autumnalis, Leucanthemum vulgare*). Abundance of other stronger competitive species increases, especially of those intolerant to grazing or cutting (e.g. *Calamagrostis epigejos, Luzula luzuloides*), following *Vaccinium myrtillus* and *Calluna vulgaris* are growing. Open spaces are mostly covered by flowering species, e.g. *Potentilla erecta, Lotus corniculatus, Gentiana asclepiadea, Hypericum maculatum, Centaurea phrygia,* and *Galium mollugo*.

Stage of thickening – wood covers approximately 70–80% of the monitoring plots, abundance of the trees (*Picea abies, Populus tremula, Sorbus aucuparia, Fraxinus excelsior*) expands. The number of species decreases, the more common herbal species include species of *Galio-Urticetea* or *Epilobietea angustifolii* (*Geum urbanum, Galium mollugo, Centaurea phrygia*), which indicates nutrient rich soil as a consequence of plant decomposition.

Stage of connected forest – shrubs are gradually fading and are substituted by highly competitive dominant trees (*Picea abies, Sorbus aucuparia, Populus tremula*), which create almost completely connected cover of tree layer (75–100%). Characteristic species of herbal layer are *Senecio ovatus, Rubus idaeus, Poa nemoralis, Hieracium murorum, Fragaria vesca, Athyrium filix-femina.* Light-demanding species *Sorbus aucuparia* is step by step pushed away by *Picea abies*, which builds up completely connected forest with poorly-covered shrubs and herbal layer. Soil is covered by moss-grown layer of decomposable litter. *Asarum europaeum*, a shadow-tolerable species, seems to be a common species of connected spruce forest.

Secondary spruce forest, developed by gradual succession, is characterized by more differentiable physiognomic structure, multilayer and mixed age structure, which make it more stable than artificial spruce plantation. The development of vegetation to the climax formation seems to be a very long-term process, since *Picea abies* is a site native species with plentiful source of seeds, that are proliferated by wind and have a good germinability. This fact makes them highly competitive to other site native species like *Fagus sylvatica* and *Abies alba*.

If the pastures are used intensively, the boundary between forest and pastures is very strict. Ecotones are build by *Sorbus aucuparia, Salix caprea, Rosa canina, Populus tremula* (similarly as it is in transects with gradual changes into forest). Species richness is relatively high (about 30 species). *Pyrola rotundifolia* is a diagnostic species of herbal layer. Herbal layer is mixed by species characteristic for pastures, mesophilous meadows and species typical for forest edge (*Melampyrum sylvaticum, Epipactis helleborine, Antennaria dioica*, *Vaccinium myrtillus, Potentilla erecta, Hieracium lachenalii, Trifolium flexuosum, Senecio ovatus* etc.).

To analyse the changes of species composition in relation to the environmental variables, recorded in the field (slope, exposition, altitude, layer cover, soil, soil-forming substrates), methods of direct gradient analysis were used.

Species composition was compared along the transects and average Ellenberg indicator values were calculated (Ellenberg, 1974). The database of plant species attributes, created by Halada (1998), was applied for evaluation of species characteristics. The data and the phytosociological relevés were evaluated by multivariate analyses of the CANOCO program.

Assessment of succession changes according to ecological site characteristic

The character of environment is determined by primary site nature conditions and indirectly by composition of those species, which reflect demand for light, heat, soil reaction, content of nutrient and microclimatic conditions. Species variability in relation to environmental variables, recorded in the field (slope, exposition, altitude, layer cover – E_1, E_2, E_3) was evaluated by multivariate analyses of the CANOCO program. Characteristic of land use was not included, since all analysed habitats are abandoned in the present; intensity and period

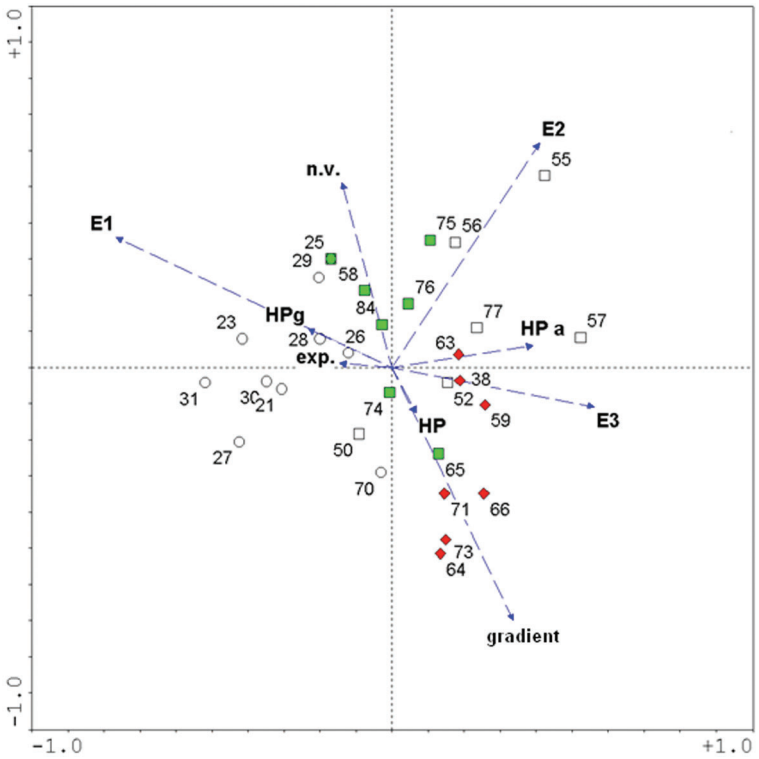

Fig. 1A. Environmental variables – samples biplot of results of RDA of the succession stages at the ecotones between pastures and forest.
Legend: Environmental variables: Gradient; exp. – exposition; n. v. – altitude; E1, E2, E3 – layer cover of E_1, E_2, E_3 – soils: HP – Modal Cambisols; HPa – acid Modal Cambisols; HPg – Gleyic Cambisols. Samples: Initial stage: 59; 63; 64; 66; 71; 73; 103; 108; Sprouting stage: 50; 61; 50; 52; 55; 56, 57; 75; 76; 77; Stage of thickening: 24; 32; 35; 38; 84; 74; 58; 62; 65; Stage of connected forest: 21; 23; 25; 26; 27; 28; 29; 30; 31; 70.

of using pastures and next succession stages are in close correlation with initial wood layer coverage (E_2, E_3). Outcome of soil survey – soil, soil-forming substrates (VUPU, 1989) was added to field environmental variables. Soil-forming substrates (mixed sandstone and clay) was consistent for all the relevés, therefore it was not analyzed.

Testing characteristic by the Monte Carlo permutation test in CANOCO program was based on the null hypothesis, that the response (the species composition) is independent from the environmental variables.

Calculating indirect gradient analysis (DCA), „Lengths of gradient“ was 3,25. For that reason we decided to use constrained linear method (RDA). Result of RDA can be seen in an ordination diagram (Fig. 1), divided in 2 parts: Fig. 1A displays the distribution of

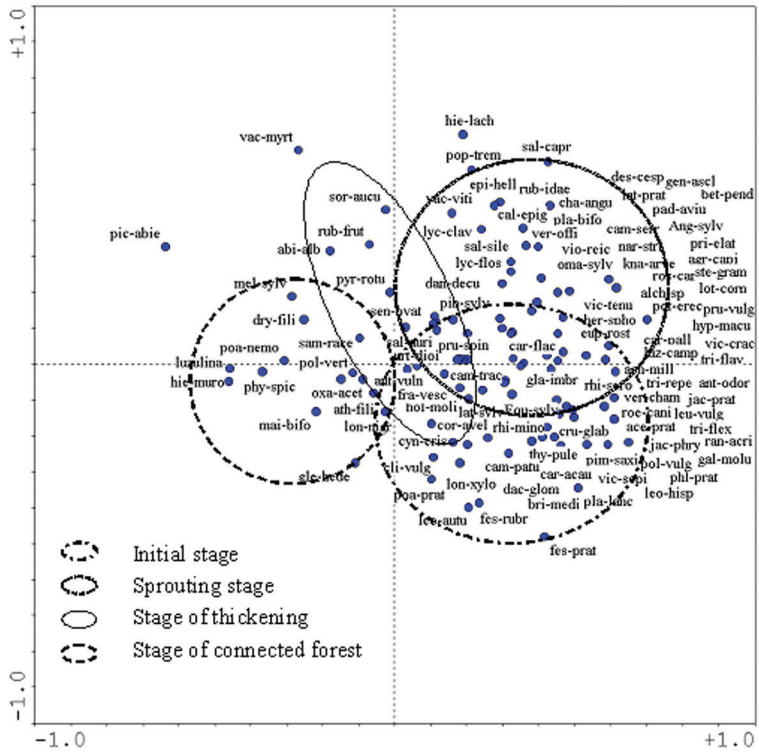

Fig. 1B. Species distribution of results of RDA of the succession stages at the ecotones between pastures and forest.

relevés to environmental variables, Fig. 1B displays species ordination. Species are shown by the arrows (the direction, in which the species abundance increases).

The quantitative environmental variables are shown by arrows (direction, in which the value of environmental variable increases). The results of data analyses show, that 44.4% of the total variation in species data can be explained by 7 tested environmental variables. The cover of herbal and shrubs layer (E_1, E_2), acid Modal Cambisol (HPa) and gradient proved to be the most demonstrable variables. Relatively high error probability (P = 0.12 to 0.28) was calculated for the other environmental variables.

Cover of herbal layer (E_1) explains 17.4% of the total variability in species data (P = 0.005; F = 3.93). This variable is correlated negatively with the trees (E_3) and shrubs (E_2) layers. First two axis (cover of E_1, E_2) explain 25% of the total variability. When the abundance of shrubs and trees layer increases, the cover of herbal layer decreases and vice versa. Species composition is also connected with coverage changes, which shows Fig. 1B. Decline

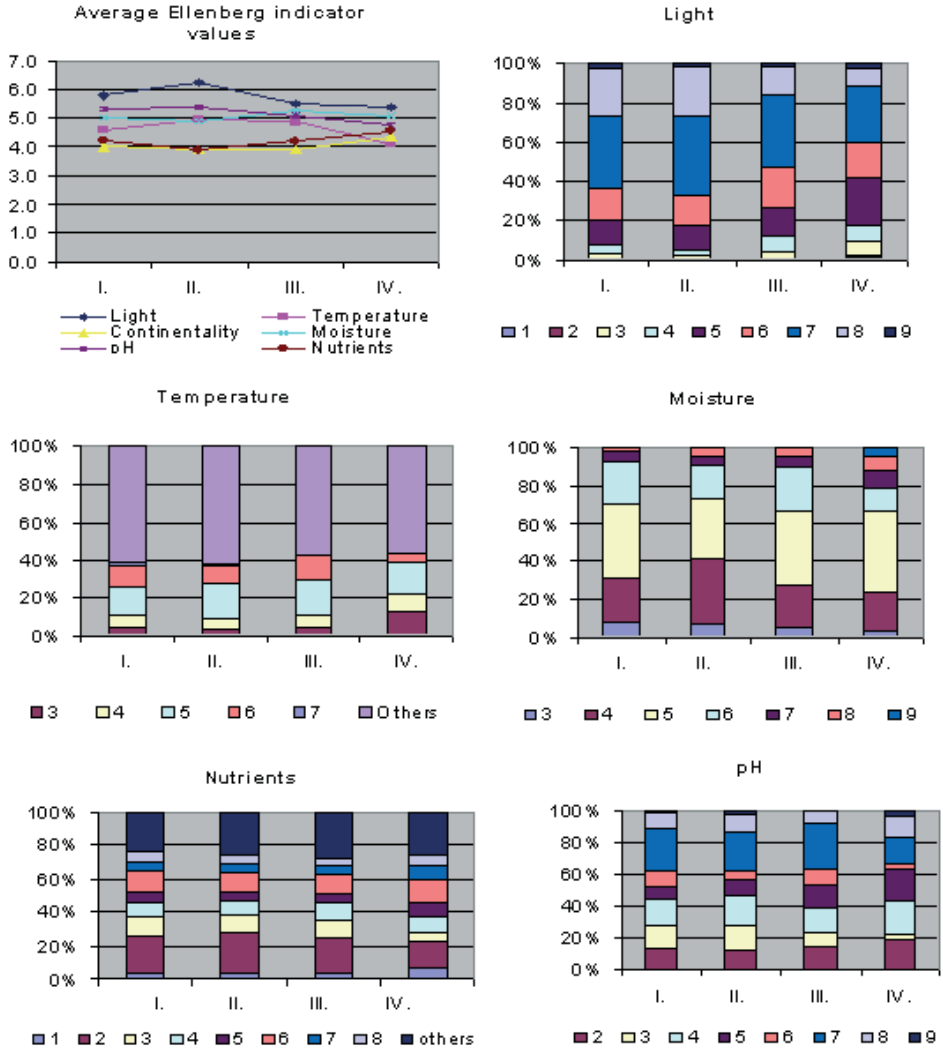

Fig. 2. Indication of ecological site characteristics at the ecotones between pastures and forest.
Legend: I. – Initial stage, II. – Sprouting stage, III. – Stage of thickening, IV. – Stage of connected forest

Eco-numbers:
Light: 1 – very shade-tolerant species; 2 – between 2 and 3; 3 – shade-tolerant; 4 – between 3 and 5; 5 – penumbra species; 6 – between 5 and 7; 7 – semi-light-demanding species; 8 – light-demanding species; 9 – species demanding full sunlight
Temperature: 3 – indicator of cold; 4 – between 3 and 5; 5 – indicator of moderate temperature; 6 – between 5 and 7; 7 – thermophilic species; 8 – between 7 and 9, (categories 1, 2, 9 were not presented within the study area).

Moisture: 3 – indicator of dry place; 4 – between 3 and 5; 5 – indicator of fresh soil; 6 – between 5 and 7; 7 – indicator of humid soils; 8 – between 7 and 9; 9 – indicator of wet soils, 10 – indicator of alternately flooded soils, (categories 1, 2, 11,12 were not presented within the study area).
Nutrients (Productivity): 1 – the nitrogen poorest site; 2 – between 1 and 3; 3 – nitrogen poor site; 4 – between 3 and 5; 5 – nitrogen average rich site; 6 – between 5 and 7; 7 – upper nutrient rich site; 8 – nutrient rich site, 9 – exceptionally nutrient rich site.
ph: 1 – strong acid; 2 – between 1 and 3; 3 – acid; 4 – between 3 and 5; 5 – moderately acid; 6 – between 5 and 7; 7 – thin acid to thin alkaline; 8 – between 7 and 9; 9 – alkaline to calcic.

of cover of herbal layer (E_1) is closely correlated with Gleyic Cambisol, and the relevés of forested areas are bound to these environment conditions.

Slope (gradient), the other explanatory (environmental) variable, explains 7% of the total variability. Slope is correlated positively with extensively used pastures, which could be explained by the fact, that coverage of trees and shrubs layer in more extreme conditions is reduced. Only some trees species, such as *Crataegus* sp., *Lonicera nigra, Lonicera xylosteum* can grow there, in good growing conditions.

Ecological site characteristics were calculated as average Ellenberg indicator values (Ellenberg, 1974) of light, temperature, continentality, moisture, pH, nutrients (productivity) for every record at the transect (Fig. 2). They were not tested by using statistics method, because it can not be assumed, that the response (the species composition) is independent from the environmental variables. The species without indicator values were excluded from the assessment.

Light. First three succession stages are mostly represented by light-demanding or semi-light-demanding species. They have quite high abundance in the stage of thickening, where the coverage of light-demanding pioneer trees is high. Gradually, the abundance of penumbra and shade-tolerant species increases.

Temperature. The curve of average temperature indicates smooth process, slightly declines in forest, and there the proportion of indicator of cold increases. Vegetation is composed mostly by species demanding moderate temperature, but this assessment can be considered only approximate, because almost half of species were without indicator values.

Moisture. Average figures of moisture moves around eco-number 5 (indicators of fresh soils). According to species indication, the character of environment is quite stable. From the sprouting stages to the connected forest, abundance of species of fresh or humid soils increases.

pH. Average number of pH indicates the localities with moderately acid conditions. According to species composition, abundance of acid species decreases moderately in sprouting stages and then increases in the other subsequent stages.

Nutrients (Productivity). Species composition of individual stages is very similar from the point of nutrients (productivity). Average figures move around number 4 – relatively poor nutrient site. Bigger nutrients supply occurs in the stage of thickening and connected forest.

Discussion

Observed succession items of mesophilous pastures are located in the mountain or submountain regions. The potential natural vegetation of this area consists of the climax eutrophic mixed fir-beech forests (Michalko et al., 1987; Maglocký, 2002). Toward the central mountain ranges of the Western Carpathians and in higher-situated basins the beech woods, which occurs on the crystalline mountain ranges, have a different composition. The mixed fir-beech forests grade into the spruce-fir and pine-spruce forests. At the present time the species composition of fir-beech forests is completely changed. Most of them were replanted by spruce, while in the past the spruces were just added trees. The forb synusia within this unit generally has high coverage and contains many species of the *Fagion*. The abundance of some of them (*Galium odoratum, Galeobdolon luteum*, e.g.) decreases, as a result of acidification by spruce plantation. The considerable part of fir-beech forest, which had occupied the areas with favourable climate, relief and soils, was destroyed and utilized for agriculture, especially during the period of gelding colonization. Meadows and pastures became secondary natural communities. The complex of rich meadows was preserved at those spots, which were not destroyed last century during the period of agricultural intensification.

Analysing the species composition of succession, coverage of herbal layer (E_1) was shown as the most important environmental variable, which closely correlates with developing wood cover. Coming to the conclusion, it is necessary to know the extent and intensity of man's activities and to regulate them consciously. Abandonment or reduction of traditional using (grazing, cutting) of pastures and meadows is connected with arising species richness. Abundance of vulnerable and rare species, which could limitedly grow in the intensively managed pastures, increases. Succession could be considered as a positive process in the initial stages, if the man's disturbing activities decrease. Unprompted succession heads more often towards secondary spruce forests, which are on one hand more stable, but their conservation and landscape ecological value is lower. Gene pool of meadows and pastures communities are also threatened. In many cases, the succession could be considered as an undesirable process, which causes declining of species richness within the communities and along the ecotones.

Conclusion

According to mapping habitats and vegetation assessment, the extensively used pastures and wet meadows were evaluated as habitats with the highest conservation value. These habitats are threatened by succession too much. Decline of traditional using of grassland as well as intensification of agriculture impact on environment and habitat's changes, and condition other process in the landscape.

Decline of intensive grazing starts succession and first succession stage is characterized by increase of species richness and occurrence of several rare and vulnerable species. Spe-

cies-rich pastures have remained by extensive grazing or combination cutting and grazing, or as remnants on the border with intensively grazed pastures.

Too low management intensity, or not using grassland, causes succession changes. Grassland goes out and communities of shrubs are developing, later on replaced by secondary spruce forest. The speed of wood spreading process depends on seeds (their size, seedling, germinability) and communities, which they occupy.

Too high management intensity (sidedress, sheep pen, reclamation) on plots or their surrounding area, brings about degradation of vegetation communities. Decline of species richness and disturbance of habitats is caused by machining, over-abundance of nutrients, and by spreading invasive species.

On the base of vegetation and succession investigation, we came to the conclusion that, the most optimal using for preservation and improving landscape biodiversity, is sustainable using of grassland by grazing or mowing of middle intensity, as well as maintaining and creating new remnants of hedgerow to a certain extent, till the grassland is not replaced by a forest. Although forests are considered the most stable habitats, from the point of nature conservation view, the decline of species richness and biodiversity of landscape is noticed, as well as environmental conditions for many endangered species of birds, reptiles and insects, typical for non-forest habitats, are modified.

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References

Ellenberg, H., 1974: Zeigewerte des Gefä pflanzen Mitteleuropas. Scripta Geobotanica, 9, Göttingen, 97 pp.

Halada, Ľ., 1998: Landscape ecological assessment of vegetation (in Slovak). PhD thesis. ÚKE SAV, Branch Nitra, 111 pp.

Hennekens, S.M., 1996: TURBO(VEG). Software package for input, processing and presentation of phytosociological data. IBN-DLO, Wageningen University of Lancaster.

Hennekens, S.M., 2001: Turboweg for Windows. Web site at http:/www.alterra.nl/ onderzoek/producten/websites/turboweg/.

Herben, T., Münzbergová, Z., 2001: Geobotanical data processing in examples. Part I. Species composition data (in Czech). Prírodovědecká fakulta, Karlova Univerzita, Praha, 91 pp.

Križová, E., 1995: Succession – theoretical issues (in Slovak). In Križová, E., Ujházy, K., (eds), Secondary succession. Workshop proceedings. LF TU, Zvolen, p. 7–13.

Lepš, J., Šmilauer, P., 1999: Multivariate analysis of ecological data. Faculty of Biological Sciences, University of South Bohemia, České Budejovice, 110 pp.

Maglocký, Š, 2002: Potential natural vegetation. In Landscape Atlas of the Slovak Republic. 1st ed. Ministry of Environment of the Slovak Republic, Bratislava, Slovak Environmental Agency, Banská Bystrica, p. 114–115.

Michalko, J., Magic, D., Berta, J., Rybníček, K., Rybníčková E., 1987: Geobotanical map of C.S.S.R. Veda, Bratislava, 168 pp.

Moravec, J. et al., 1994: Phytocenology (in Czech). Academia Praha, 403 pp.

Sláviková, D., 1998: Importance of grassland in the creation of agrarian landscape and possibility of sustainable development (in Slovak). In Izakovičová, Z., Velebný, V., (eds), Theory and praxis of agricultural landscape. Workshop proceedings. Únia krajinných ekológov Slovenska, Bratislava, p. 87–94.

ter Braak, C.J.F., 1988: CANOCO – a FORTRAN program for canonical community ordination by (partial) (detrended) (canonical) correspondence analysis, principal components analysis and redundancy analysis (version 2.1.), Technical Report LWA-88-02, GLW, Wageningen, 95 pp.

ter Braak, C.J.F., 1990: Update notes: CANOCO version 3.10. agricultural Mathematics Group, Wageningen, 35 pp.

ter Braak, C.J.F., Šmilauer, P., 1998: CANOCO Reference Manual and User's Guide to Canoco for Windows. Software for Canonical Community Ordination (version 4), Centre for Biometry Wageningen and Microcomputer Power (Ithaca NY, USA), 352 pp.

Tichý, L., 2001: JUICE 4.1. Software User's Guide. Department of Botany, Masaryk University, Brno, 44 pp.

Ujházy, K., 2003: Secondary succession of abandoned meadows and pastures in Poľana locality (in Slovak). TU Zvolen, Vedecké štúdie 7/2003/A, 103 pp.

VUPU, 1989: Soil map of Dolný Kubín district. M 1 : 5000, VÚPÚ Bratislava.