

Evaluation of the ecological niche of some abundant species of the subfamily Platyninae (Coleoptera, Carabidae) against the background of eight ecological factors

Viktor V. Brygadyrenko

Department of Zoology and Ecology, Oles' Honchar Dnipropetrovsk National University,
pr. Gagarina, 72, 49010 Dnipropetrovsk, Ukraine; e-mail: brigad@ua.fm

Abstract

Brygadyrenko, V. V., 2015. Evaluation of the ecological niche of some abundant species of the subfamily Platyninae (Coleoptera, Carabidae) against the background of eight ecological factors. *Folia Oecologica*, 42: 75–88.

Based on the results of 15 years of research in five regions in the steppe zone of Ukraine we have analysed the relationship between species of the subfamily Platyninae and the eight most significant ecological factors for litter macrofauna in forest ecosystems. In the forests of Ukraine *Calathus ambiguus* (Paykull, 1790) is a typical mesophile, with a slight preference for pine forests. *C. erratus* (C.R. Sahlberg, 1827) is at its most numerous in xeromesophilous moisture conditions with an average abundance of ants. *C. fuscipes* (Goeze, 1777) favours broad-leaved forests with 40–80% tree crown density, a sparse herbaceous layer, and clay soil with high salinity. *C. melanocephalus* (Linnaeus, 1758) is at its most numerous in forests with a deep litter layer with average soil salinity. *Dolichus halensis* (Schaller, 1783) is often found in forests with of low crown density and favours areas with high salinity. *Anchomenus dorsalis* (Pontoppidan, 1763) favours plots with scattered trees, thick grass, mesophilous moisture conditions and low abundance of ants. *Limodromus krynickii* (Sperk, 1835) inhabits forests with a thin litter layer, hygrophilous moisture conditions and soils with low salinity. *Oxypselaphus obscurus* (Herbst, 1784) inhabits moist areas of forests with acid, sandy soil. The methods used in this research allow a quantitative multiple level assessment of the ecological niches of different species of litter invertebrate to be made.

Key words

density of the herbaceous layer cover, ecological niche, litter, moisture, soil salinity, tree crown density

Introduction

The requirements of a species of litter invertebrate regarding level of humidity, light, soil salinity and soil texture are among the basic parameters which determine whether it is present or absent in a given ecosystem (THIELE, 1977). The presence of a species at a particular site means that its environmental requirements are met, that a potential ecological niche is filled (HUTCHINSON, 1957).

The borders between potential ecological niches are harder to research than those between niches which are occupied. The data for laboratory research on the influence of tolerance of species, for example, for a light or temperature regime cannot always be extrapolated for natural habitats (THIELE, 1977). Assessment of potential ecologi-

cal niches in natural ecosystems of a particular climatic zone can only be made by analyzing the abundance of a given invertebrate species across dozens or hundreds of sites (BRYGADYRENKO, 2004, 2006). Up to now, research of this kind has not been conducted for ground beetles.

In the steppe zone of Ukraine over 80% of the territory is given over to agriculture, with forest habitats occupying no more than 10% of the territory (BELGARD, 1971). Forests in this zone are characterized by the extreme phytogenic variety of both natural and cultivated species, with the number of dominant tree species amounting to over 30 (BRYGADYRENKO, 2015). Forest ecosystems in the south of Ukraine are subject to the contrasting, often hostile, conditions of their surrounding environment, and in many cases have a strongly steppe phytocenosis. For

this reason, a detailed study of the distribution of particular ground beetle species in these habitats is a convenient method of conducting research at the maximum level of detail into their potential ecological niches.

In Europe the subfamily Platyninae Bonelli, 1810 (www.faunaeur.org) is represented by the tribes Omphreini, Platynini and Sphodrini. The first of these includes a single genus *Omphreus*, the second by 13 genera (*Agelaea*, *Agonum*, *Anchomenus*, *Atranus*, *Cardiomeria*, *Galaicodytes*, *Limodromus*, *Olisthopus*, *Oxypselaphus*, *Paranchus*, *Platynus*, *Pseudanchomenus* and *Sericoda*), the third by 19 genera (*Amaroschema*, *Gomerina*, *Paraeutrichopus*, *Platyderus*, *Pseudomyas*, *Pseudoplatyderus*, *Calathus*, *Synuchidius*, *Anchomenidius*, *Dolichus*, *Calathidius*, *Hystricosphodrus*, *Laemostenus*, *Licinopsis*, *Pseudotaphoxenus*, *Sphodropsis*, *Sphodrus*, *Taphoxenus* and *Synuchus*). Only 38 species of Platynini and 20 species of Sphodrini inhabit Ukraine, and the variety of species of these subfamilies is much lower in the steppe zone than in the forest-steppe and forest zones (BRYGADYRENKO, 2003a; PUTCHKOV, 2011, 2012).

Species belonging to the ground beetle subfamily Platyninae differ sharply in their ecological preferences, especially with regard to habitat type, moisture, character of the soil, and peculiarities of the plant cover (HŮRKA, 1996; BRYGADYRENKO, 2003a). Some species favour xerophilous ecosystems, though most inhabit mesophilous and hygrophilous habitat types (LINDROTH, 1985). The variety of their habitat requirements, the wide distribution and high abundance of many of these species make the subfamily Platyninae a convenient object for study of ecological niches.

The aim of this research is thus the assessment of the potential ecological niches of 8 species of ground beetle of the Platyninae subfamily, dominant in forests in the steppe zone of Ukraine, measured against the background of 8 ecological factors.

Material and methods

The counting of the ground beetles was conducted in five regions (Dnepropetrovsk, Zaporozhye, Nikolayev, Donetsk and Kharkov) of Ukraine from 2001 to 2014 in natural and planted forests of various types and ages. In this report ground beetles from 836 forest sites are analysed. The same methodology was applied at each site: the soil and vegetational conditions were evaluated and the ground beetles were collected in soil traps; a standard geobotanical description was made (the crown density of the tree layer and the density of the herbaceous layer were measured both as a combined total and also for every plant species separately); the litter depth was measured (taken as the average of ten measurements); the soil texture was noted (clay, loam, sandy loam, sand); the soil humidity was assessed (using indicator species of the herbaceous layer, according to the scale devised for the

steppe zone by BELGARD (1950)); the soil texture was assessed (using indicator species of the herbaceous layer, according to BELGARD's (1950) scale); the abundance of ants was determined (using soil traps). A detailed description of the forest ecosystems of the steppe zone of Ukraine, giving details for different plant species, can be found in BELGARD's (1950, 1971) works on forestry in this zone. A more detailed geobotanical description of the research plots can be found in our earlier publications (BRYGADYRENKO, 2005, 2014, 2015; BRYGADYRENKO and SOLOVJOV, 2007).

The count of ground beetles in the litter was conducted using standard methods: at each site 10 half litre soil traps (with 20% NaCl solution) were placed at least two metres from each other. The traps were checked on average every 5th day (depending on the weather conditions), and, overall, 3–24 collections were made for every sample plot. The abundance of each ground beetle species was calculated from specimens collected per 10 trap-days, subjected to standard ANOVA methods in the package Statistica 8.0. The diagrams (Figs 1–8) show the average number of each species (specimens/10 trap-days), vertical bars denote 95% confidence intervals. Above every graph is shown the factual value of the Fisher criterion for a specified degree of freedom, and also the reliability of differences between different abundance values for the ground beetles. Differences in the abundance of species were considered significant at $p < 0.05$. We considered that insignificant differences at $0.05 < p < 0.10$ represented only a tendency.

Results

Calathus ambiguus (Paykull, 1790), as a eurybiont species, tends to be at its most abundant in xeromesophilous and mesophilous conditions (Fig. 1e), with average abundance of ants (Fig. 1h) and in pine forests (Fig. 1b). Its frequency is 3.7%, average abundance – 0.014 ± 0.101 specimens/10 trap-days and 0.276% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

The abundance of *Calathus erratus* (C.R. Sahlberg, 1827) is significantly greater in xeromesophilous moisture conditions (Fig. 2e), with an average abundance of ants (Fig. 2h). In comparison with *C. ambiguus* (Fig. 1) this species is more xerophilous and favours plots with lower numbers of ants. Its frequency is 3.0%, average abundance – 0.009 ± 0.068 specimens/10 trap-days and 0.169% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

Calathus fuscipes (Goeze, 1777) is a steppe species, frequently found on fields, in anthropogenically transformed ecosystems, where it is numerically dominant in the litter macrofauna. Against the background of 6 of the 8 analysed ecological factors the abundance of *C. fuscipes* varies significantly. It reaches its maximum abundance at

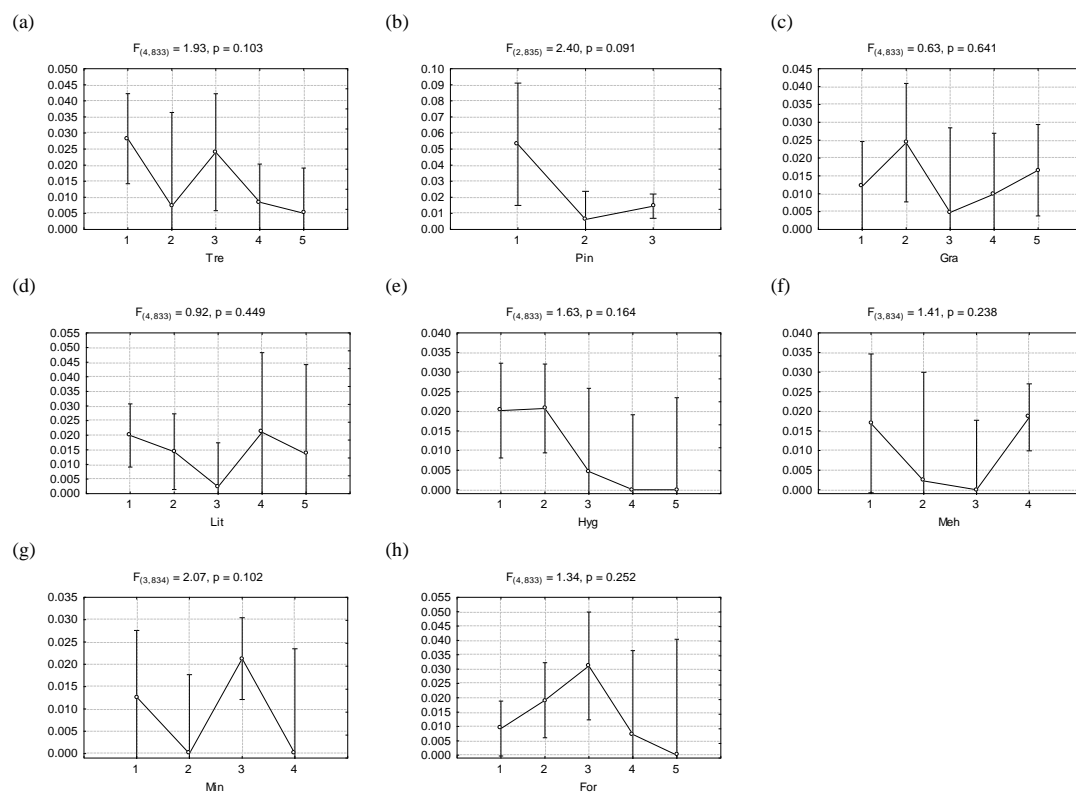


Fig. 1. Influence of conditions in forest ecosystems on *Calathus ambigua* (Paykull, 1790): abscissa Tre – tree crown density (1 – <20%, 2 – 21–40%, 3 – 41–60%, 4 – 61–80%, 5 – >81%); Pin – type of forest ecosystem (1 – pine, 2 – mixed, 3 – broad-leaved forest); Gra – density of herbaceous layer cover (1 – <20%, 2 – 21–40%, 3 – 41–60%, 4 – 61–80%, 5 – >81%); Lit – thickness of the litter (1 – <10 mm, 2 – 11–20, 3 – 21–30, 4 – 31–40, 5 – >41 mm); Hyg – moisture conditions (1 – xeromesophilous, 2 – mesophilous, 3 – hygomesophilous, 4 – mesohygrophilous, 5 – hygrophilous); Meh – soil texture (1 – sandy, 2 – sandy loam, 3 – loam, 4 – clay); Mn – soil salinity (1 – trophotopes AB, B, C, 2 – Dc, Dac, 3 – Dn, 4 – De, E); For – abundance of ants (1 – <4, 2 – 5–16, 3 – 17–64, 4 – 65–256, 5 – >256 specimens/10 trap-days); ordinate – number of ground beetles, specimens/10 trap-days.

sites where tree crown density is 40–80% (Fig. 3a), in broad-leaved forests (Fig. 3b), herbaceous cover density 20–40% (Fig. 3c), the litter layer is 10–40 mm (Fig. 3d), with clay soil (Fig. 3e), in the trophotope Dn (Fig. 3g). A lower abundance was observed (on the level of a tendency) at sites where ants were abundant (over 64 specimens/10 trap-days, Fig. 3h). Its frequency was 11.7%, average abundance – 0.26 ± 1.62 specimens/10 trap-days and 4.95% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

Calathus melanocephalus (Linnaeus, 1758) was significantly more abundant in forests of the steppe zone at sites with a thick litter layer (30–40 mm, Fig. 4d) and with soils of average salinity (Fig. 4g). Other factors analysed influence *C. melanocephalus* only at the level of tendency: abundance was greater in mesohygrophilous and hygrophilous moisture conditions (Fig. 4e) and sites with low numbers of ants (Fig. 4h). Its frequency was 3.8%, average abundance – 0.012 ± 0.083 specimens/10 trap-days and 0.237% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

The abundance of *Dolichus halensis* (Schaller, 1783) was significantly higher at sites with a low tree crown density (Fig. 5a), in trophotope Dn (Fig. 5g). Its abundance was slightly higher (at the level of a tendency) at clay soil sites (Fig. 5f) and low numbers of ants (Fig. 5h). Its frequency was 6.0%, average abundance – 0.080 ± 0.594 specimens/10 trap-days and 1.53% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

The abundance of *Anchomenus dorsalis* (Pontoppidan, 1763) was significantly greatest at forest sites with a low crown density (Fig. 6a), maximum level of herbaceous cover (Fig. 6c), mesophilous moisture conditions (Fig. 6e) and low abundance of ants (<16 specimens/10 trap-days, Fig. 6h). Its frequency was – 1.8%, average abundance – 0.056 ± 1.090 specimens/10 trap-days and 1.08% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

Limodromus krynickii (Sperk, 1835) is a forest meadow species of ground beetle, which in forest ecosystems varies significantly in abundance in relation to 2 of

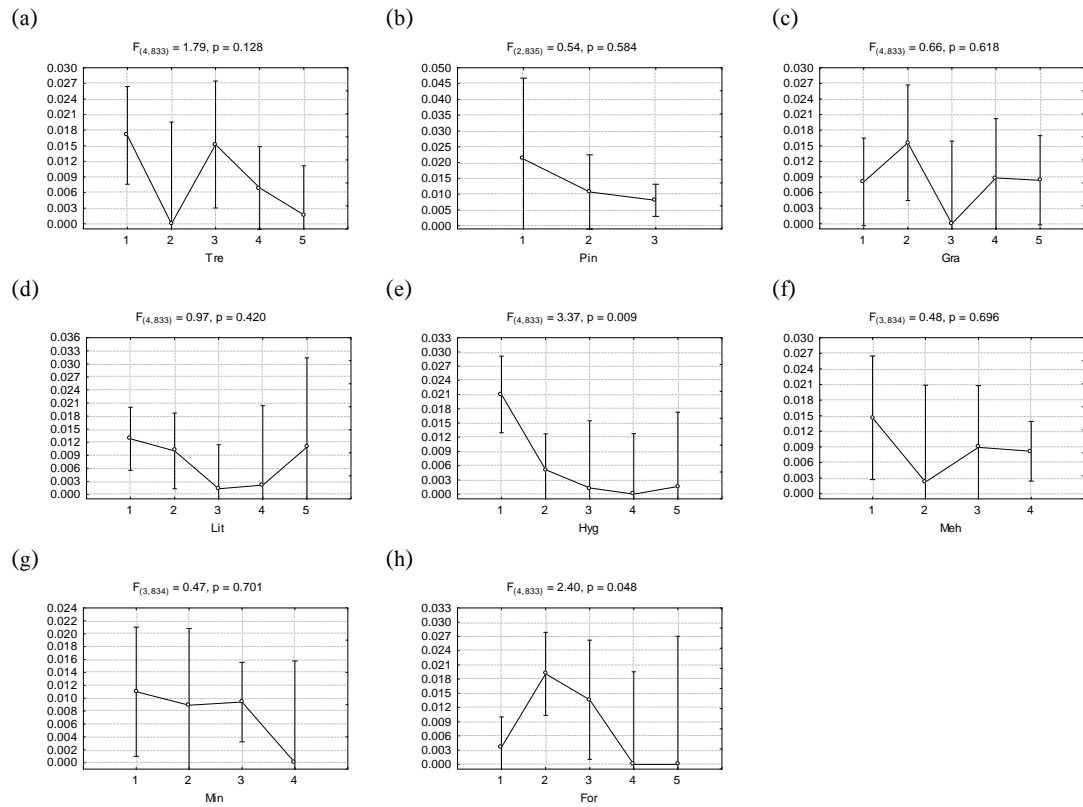


Fig. 2. Influence of forest ecosystem conditions on *Calathus erratus* (C.R. Sahlberg, 1827).
For explanation see key to Fig. 1.

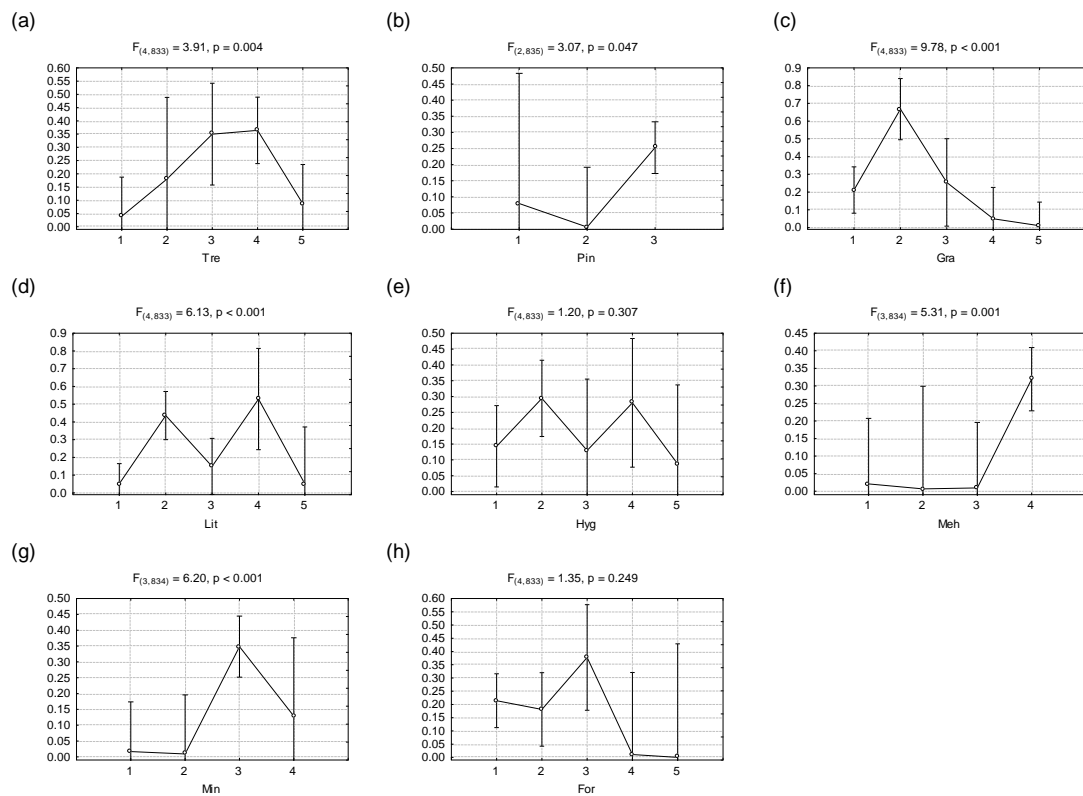


Fig. 3. Influence of forest ecosystem conditions on *Calathus fuscipes* (Goeze, 1777).
For explanation see key to Fig. 1.

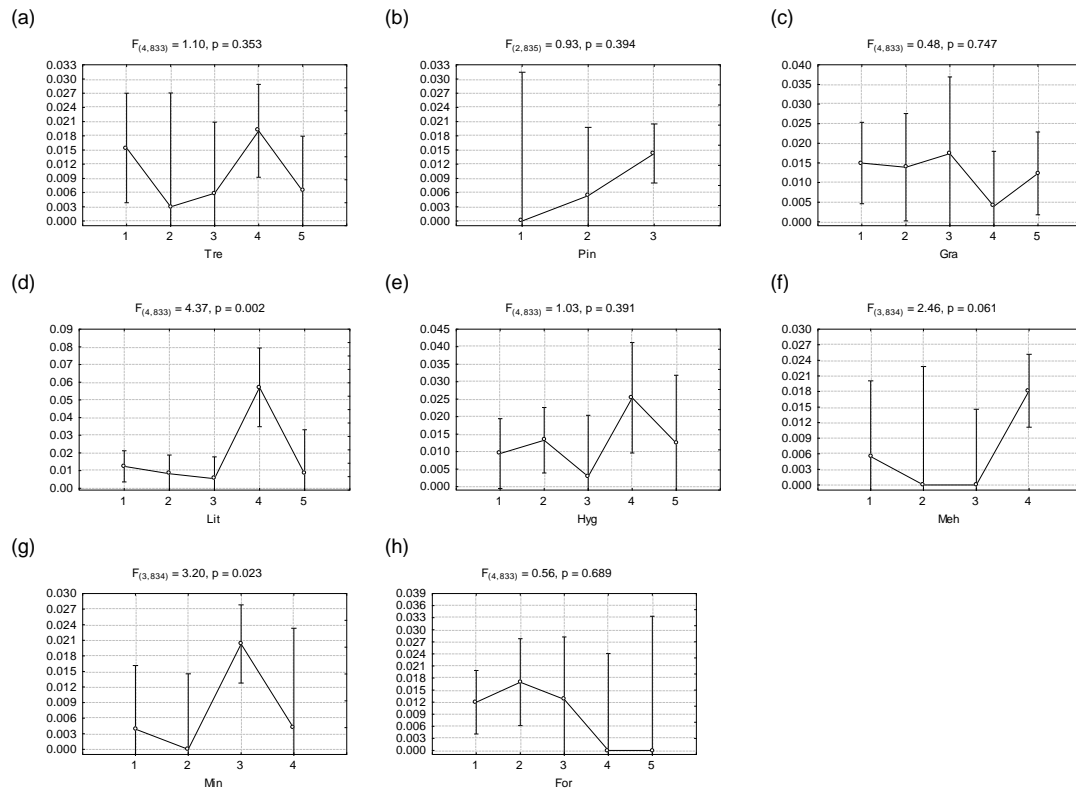


Fig. 4. Influence of forest ecosystem conditions on *Calathus melanocephalus* (Linnaeus, 1758).
For explanation see key to Fig. 1.

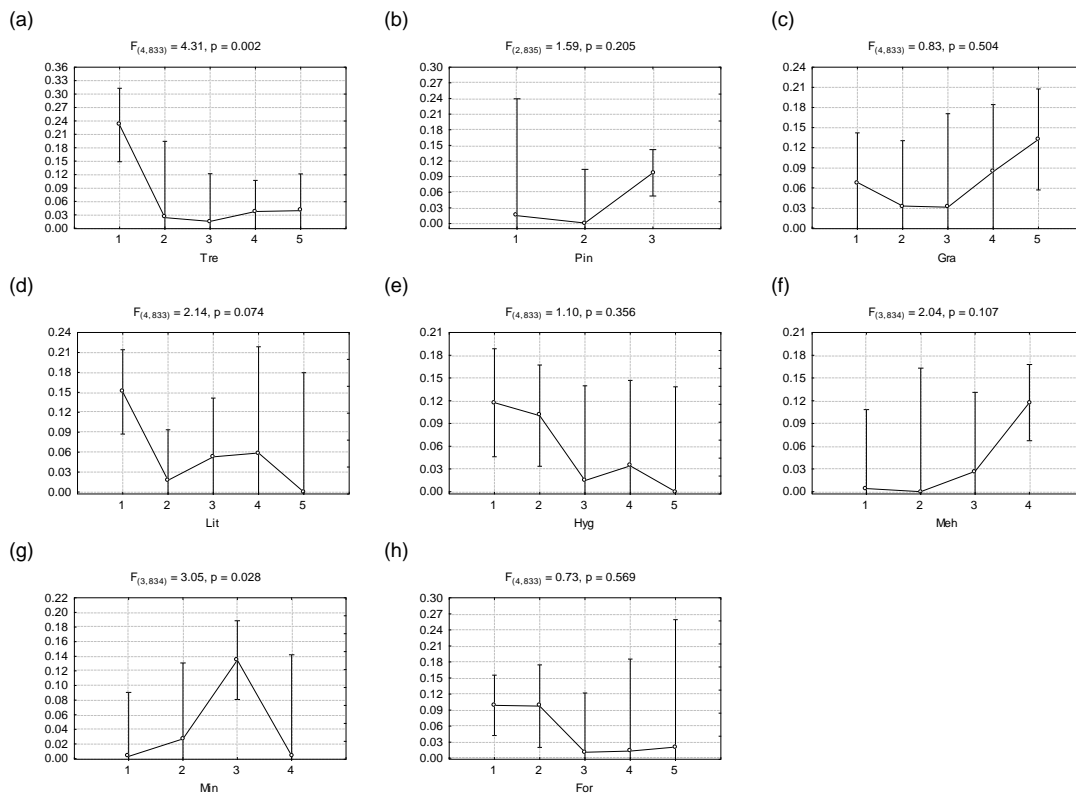


Fig. 5. Influence of forest ecosystem conditions on *Dolichus halensis* (Schaller, 1783).
For explanation see key to Fig. 1.

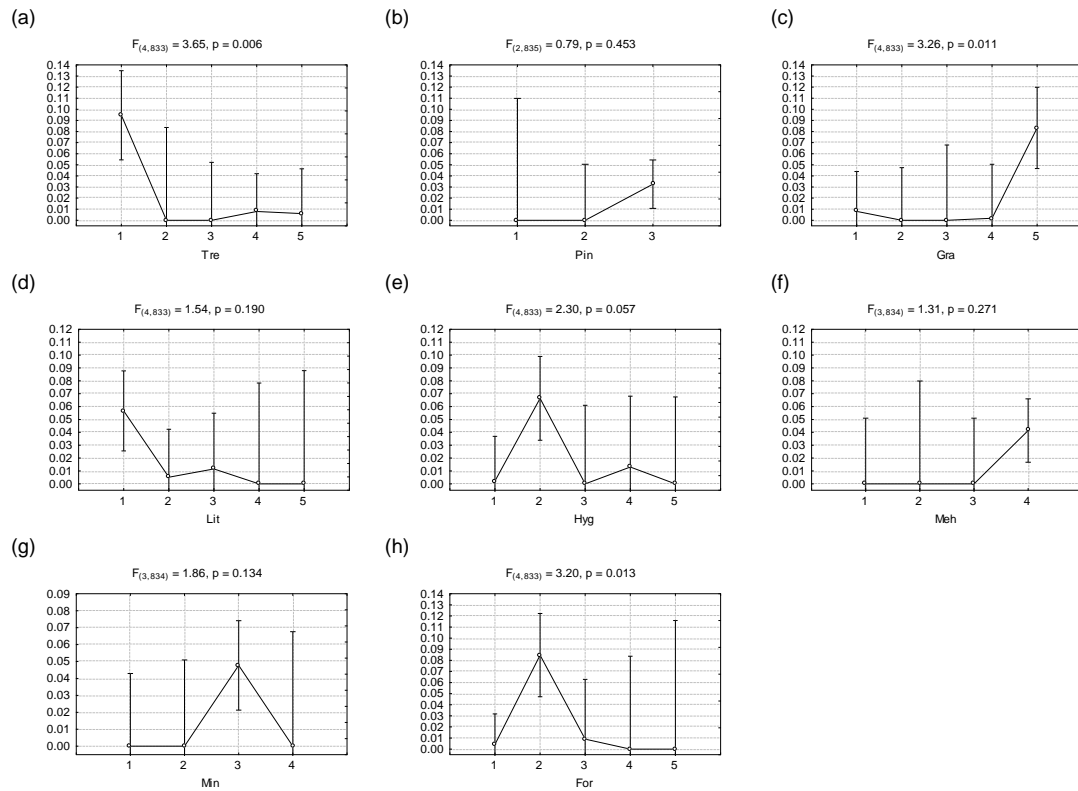


Fig. 6. Influence of forest ecosystem conditions on *Anchomenus dorsalis* (Pontoppidan, 1763).
For explanation see key to Fig. 1.

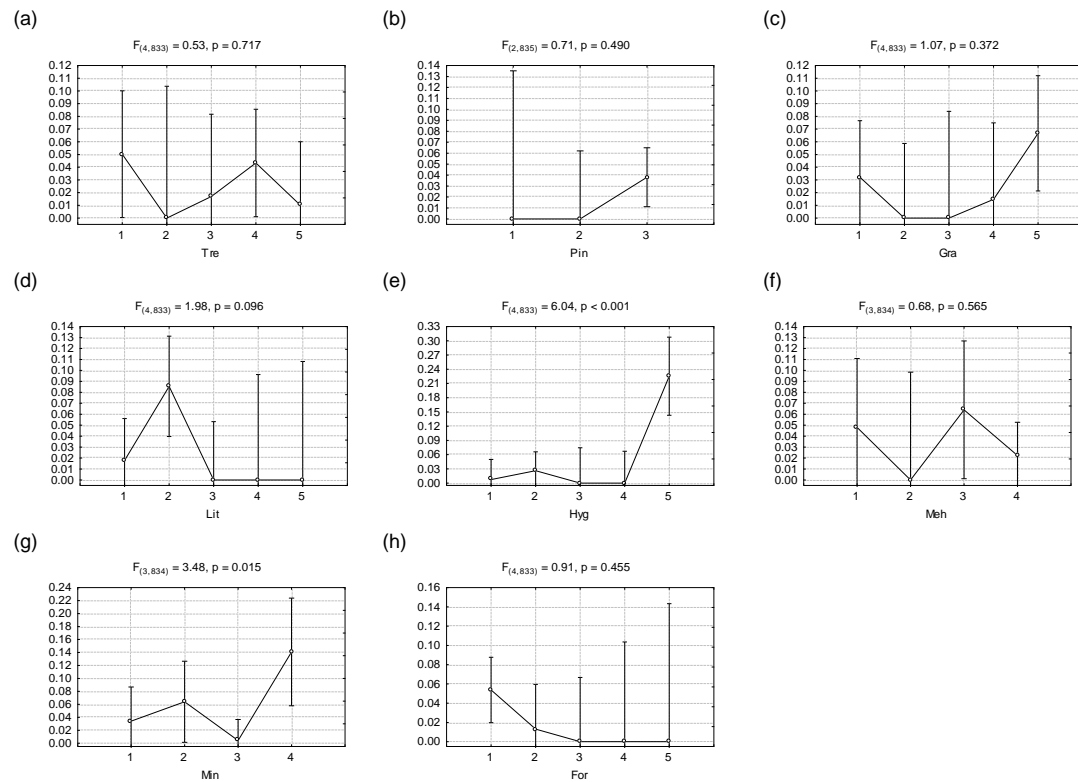


Fig. 7. Influence of forest ecosystem conditions on *Limodromus krynickii* (Sperk, 1835).
For explanation see key to Fig. 1.

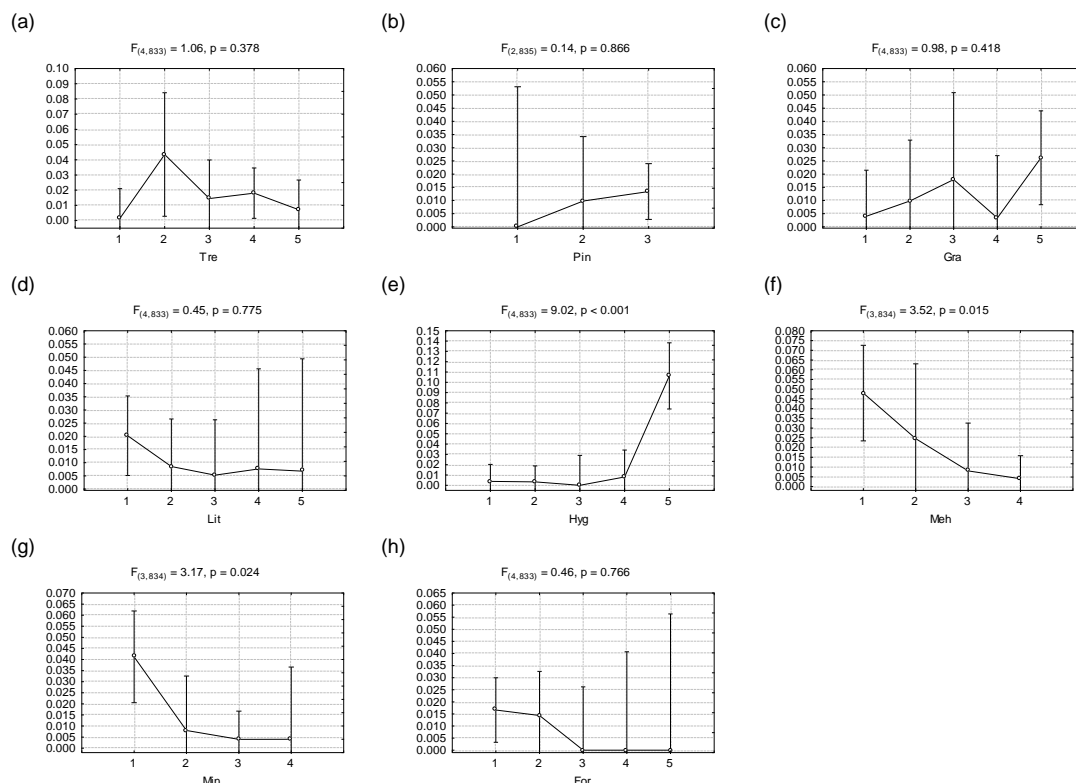


Fig. 8. Influence of forest ecosystem conditions on *Oxytelus obscurus* (Herbst, 1784). For explanation see key to Fig. 1.

the 8 analysed ecological factors. Its abundance reaches its maximum in hygrophilous moisture conditions (Fig. 7e) and in trophotypes De, E (Fig. 7g). It was noted that it tended to be more numerous at sites with a low abundance of ants (Fig. 7h), on plots with a thin litter layer (10–20 mm, Fig. 7d). Its frequency was – 1.2%, average abundance – 0.031 ± 0.358 specimens/10 trap-days and 0.592% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

Oxytelus obscurus (Herbst, 1784) is a hygrophilous forest meadow species of ground beetle, which in the steppe zone significantly varies in abundance in relation to 3 of the 8 ecological factors analysed. Its abundance reaches its maximum in hygrophilous moisture conditions (Fig. 8e), on sandy soils (Fig. 8f), in trophotypes AB, B and C (Fig. 8g). Abundance of ants (Fig. 8h), tree crown density (Fig. 8a) or density of herbaceous cover (Fig. 8c) did not significantly influence the abundance of *O. obscurus*. Its frequency was 1.9%, average abundance – 0.012 ± 0.140 specimens/10 trap-days and 0.237% of the total number of carabid beetles collected in forests of the steppe zone of Ukraine.

According to the results of our research, the abundance of only one of the species studied, *C. ambiguus*, was not significantly influenced by any of the factors (Table 1). The abundance of *C. erratus* was influenced by only one factor, *C. melanocephalus*, *L. krynickii* and *D. halensis* significantly varied in relation to two factors, A.

dorsalis and *O. obscurus* in relation to three factors. The abundance of *C. fuscipes* varied significantly in response to six factors.

Soil salinity influences significantly 5 of the 8 selected ground beetle species belonging to the Platyninae subfamily. Soil moisture and tree crown density influence 3 species. Litter depth, density of herbaceous cover and soil texture influence 2 species. Type of forest ecosystem and abundance of ants influence 1 species (Table 1).

The results of our cluster analysis for the distribution of the species studied on the sample plots show the greatest degree of similarity in the patterns for *C. melanocephalus*, *C. erratus* and *C. ambiguus* (Fig. 9). The lowest degree of similarity in distribution of these species was shown for *O. obscurus*, *L. krynickii* and *D. halensis*. The xerophilous *A. dorsalis* and *C. fuscipes* present a second species cluster showing a low level of distributional similarity.

Discussion

Phylogenetic similarity and ecological adaptability of species in the genus *Calathus*

The genus *Calathus* consists of 177 species classified into 10 subgenera (GAÑÁN et al., 2008). RUIZ et al. (2012) state that the genera *Calathus* and *Dolichus* split at the boundary of the Eocene and Oligocene (about 34 million

Table 1. Relationship between the studied ground beetle species of the subfamily Platyninae and the influence of eight ecological factors in forest ecosystems in the steppe zone of Ukraine (based on the analysis of 836 collections from soil traps)

Species	Tre	Pin	Gra	Lit	Hyg	Meh	Min	For
<i>Calathus ambiguus</i> (Paykull, 1790)	–	–	–	–	–	–	–	–
<i>Calathus erratus</i> (C. R. Sahlberg, 1827)	–	–	–	–	+	–	–	–
<i>Calathus fuscipes</i> (Goeze, 1777)	+	+	+	+	–	+	+	–
<i>Calathus melanocephalus</i> (Linnaeus, 1758)	–	–	–	+	–	–	+	–
<i>Dolichus halensis</i> (Schaller, 1783)	+	–	–	–	–	–	+	–
<i>Anchomenus dorsalis</i> (Pontoppidan, 1763)	+	–	+	–	–	–	–	+
<i>Limodromus krynickii</i> (Sperk, 1835)	–	–	–	–	+	–	+	–
<i>Oxypselaphus obscurus</i> (Herbst, 1784)	–	–	–	–	+	+	+	–

Tre, tree crown density; Pin, type of forest ecosystem; Gra, density of herbaceous layer cover; Lit, thickness of the litter; Hyg, moisture conditions; Meh, soil texture; Min, soil salinity; For, abundance of ants; “+” and “–” – significant ($p < 0.05$) and insignificant ($p > 0.05$) influence of the ecological factor.

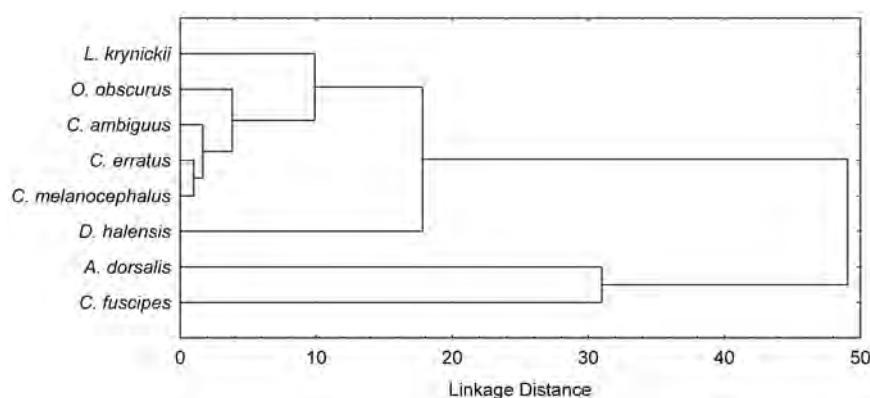


Fig. 9. Results of cluster analysis of the distribution of the ground beetle species studied in forest ecosystems in the steppe zone of Ukraine.

years ago). Following this, one of the youngest groups of the *Calathus* genus appeared, the group of species related to *C. fuscipes*, with the greatest intensity of species development occurring in the mountain ranges of Southern Europe during periods of glaciations, when small populations remained in the southern Pyrenees, the Apennines and the Balkan Peninsula (RUIZ et al., 2009, 2010, 2012). In Central Europe the number of species belonging to the genus *Calathus* is not high, and is dominated by species with a wide range and a fairly high level of ecological adaptability (VERESCHAGINA, 1984).

Study of the biological variety of *Calathus* ground beetles has been conducted most fully in Spain: both from the perspective of territorial distribution in particular areas and that of occupation of ecological niches by particular species (GAÑÁN et al., 2008). NEGRE (1969) was the first to make a detailed analysis of the distribution of *Calathus* species on the Iberian Peninsula, recording 13 species of this genus (the greatest number of species being in the foothills and the mountains of the Pyrenees). In the Iberian Peninsula, there are now known to be 23 species

present, 14 (70%) of which are endemic to the peninsula (GAÑÁN et al., 2008). According to SERRANO (2013) 27 taxa at the level of species and subspecies inhabit Spain. Analysis of the distribution of *Calathus* species on seven of the Canary Islands (colonization and diversification) using Polymerase Chain Reaction Amplification and Sequencing allowed EMERSON et al. (2000) to identify the routes and timing of the colonisation of these islands from continental Europe.

It is well known that various species of this genus are well able to thrive in agricultural landscapes (KROMP, 1999; LANG et al., 1999; MAGURA, 2002; KUTASI et al., 2004). *C. fuscipes*, *C. erratus* and *C. melanocephalus* (SCHWERK and SZYSZKO, 2012) form the dominant ground beetle fauna on abandoned agricultural land in Poland. BŁASZKIEWICZ and SCHWERK (2013), in their research in west Poland (Wałeccki district), an area composed of various forests, agricultural and post-agricultural areas at different stages of succession, found that *C. erratus* composed 3.3%, *C. fuscipes* – 3.9%, *C. melanocephalus* – 1.5% of the Carabid population. Ground beetles of

the genus *Calathus* are one of the faunal components of agroecosystems and are fairly common in eastern Latvia: *C. fuscipes* – 0.26%, *C. erratus* – 0.45%, *C. ambiguus* – 0.44%, *C. melanocephalus* – 0.13% of the Carabid population (BUKEJS and BALALAIKINS, 2008). However, despite sharing an ability to survive in the extreme conditions of agricultural activity, *Calathus* species differ in their range and ecological niches.

C. ambiguus

A West Palaearctic species, ranging to West Siberia and Central Asia (HŮRKA, 1996). In the former Soviet Union *C. ambiguus* is distributed across the whole of its European territory, eastwards to the Altai, the southern limit of its range being in Iran and Afghanistan (VERESCHAGINA, 1984; KRYZHANOVSKIY et al., 1995). PUTCHKOV (2012) mentions that it occurs throughout the territory of Ukraine.

VERESCHAGINA (1984) states that *C. ambiguus* favours open, dry steppe habitat. According to LINDROTH (1985), in Fennoscandia *C. ambiguus* is a “rather stenotopic species, living in open, dry country on sandy or gravelly, sometimes clay-mixed soil with sparse vegetation, notably on southern slopes. Also in agricultural land on sandy fields. The species is often found together with *C. erratus*”. LINDROTH (1974) states that in Great Britain *C. ambiguus* shares the same habitat preference as *C. erratus*, with which it is often associated; also occurring in chalk pits. In the Czech and Slovak Republic *C. ambiguus* is “common in dry and warm unshaded habitats: fields, steppe; lowlands to hills” (HŮRKA, 1996). In Spain *C. ambiguus* is common, occurring in 11 of the 23 regions SERRANO (2013), while it is also included in the fauna of Turkey (KESDEK and YILDIRIM, 2004).

SIGIDA (1993) considers *C. ambiguus* to be a polytopic mesophile, typical of natural steppe areas and pastureland, bairaks (ravine forest) and floodplain forest, salines and areas of high salinity, semi-desert areas, agricultural and urban landscapes. In Moldova *C. ambiguus* is a mesoxerophilic steppe species, not often found in cultivated fields, vineyards and gardens (KARPOVA and MATALIN, 1993). In the Non-Chernozem Area of Russia small numbers of specimens of *C. ambiguus* have been collected from fields sown with winter wheat and maize (SOBOLEVA-DOKUCHAEVA, 1995).

C. erratus

A Eurosiberian species (HŮRKA, 1996). In the former USSR *C. erratus* extends as far as the Primorskiy Krai, ranging in the north beyond the Arctic Circle (VERESCHAGINA, 1984; KRYZHANOVSKIY et al., 1995). PUTCHKOV (2012) states that it occurs throughout Ukraine.

LINDROTH (1985) states that in Fennoscandia *C. erratus* is “xerophilous, usually occurring on dry, sandy or gravelly soil poor in humus and with sparse vegetation. Predominantly in open country, for instance on *Calluna*-

heath, in dunes, and in dry meadows and grassland; also in thin forests. It is frequently encountered on agricultural land on light soil, notably in root crop fields”. LINDROTH (1974) mentions that in Great Britain *C. erratus* occurs on dry, usually sandy ground with sparse vegetation. The northern population of *C. erratus* in Fennoscandia is macropterous, on the shores of the Baltic brachypterous specimens predominate (LINDROTH, 1979). In the Non-Chernozem Area of Russia *C. erratus* inhabits forest ecosystems (SOBOLEVA-DOKUCHAEVA, 1995). In the south of the Baikal region *C. erratus* inhabits mesophilous and steppe type meadows, forest clearings, slopes of ravines, fallow and wasteland (SHILENKOV, 1978). In the Czech Republic and Slovakia *C. erratus* is “common in dry, unshaded habitats: fields, forests, *Calluna*-heath; lowlands to mountains, frequent in hills” (HŮRKA, 1996).

It is rarer in the southern part of its range, being mainly associated with forest ecosystems. SIGIDA (1993) considers *C. erratus* to be a polytopic mesophile, typical of natural steppe areas and pastures, bairak and floodplain forests. *C. erratus* occurs in only one of the 23 regions of Spain researched by SERRANO (2013). It has not been recorded in Moldova (KARPOVA and MATALIN, 1993).

C. fuscipes

A West Palaearctic species, introduced in North America (HŮRKA, 1996). Common across the entire European part of the former USSR, the southern limit of its range is in North Africa and Iran (VERESCHAGINA, 1984; KRYZHANOVSKIY et al., 1995). In Ukraine *C. fuscipes graecus* (Dejean, 1831), (PUTCHKOV, 2012) occurs in the southern subzone of the steppe zone (right bank of the Dnieper, westwards) and in the Crimean peninsula, *C. fuscipes fuscipes* (Goeze, 1777) occurs throughout the rest of Ukraine.

In Fennoscandia according to LINDROTH (1985) *C. fuscipes* is a “eurytopic species, predominantly occurring in open country on rather dry, notably sandy or clay soil more or less rich in humus, e.g. in meadows and grassland; often on cultivated soil and also in light forests”. LINDROTH (1974) states that in Great Britain *C. fuscipes* occurs “in moderately dry meadows and grassland, often on cultivated soil; also in thin forests”. In the Czech and Slovak Republics *C. fuscipes* is “very common, in unshaded, rather dry habitats: meadows, fields, steppe; lowlands to mountains” (HŮRKA, 1996). According to SERRANO (2013) *C. fuscipes* occurs throughout almost all of Spain.

C. fuscipes SIGIDA (1993) is a forest mesophile, occurring in bairak and floodplain forests, agricultural and urban landscapes. In Moldova *C. fuscipes* is a mesophile, belonging to the meadow-field group, being uncommon only on sown perennial grassland (KARPOVA and MATALIN, 1993). According to KLAUSNITZER (1987) *C. fuscipes* is one of the most abundant species of ground beetle in

urban habitats, occurring in the sports stadiums, lawns and airports of Warsaw and Keln; the author considers the species to be a eurytopic mesophile of open ground, dominating on fields. According to KOCOUREK et al. (2013), in the Czech Republic *C. fuscipes* comprised 0.8% of the total of carabid beetles collected from maize fields at the Prague-Ruzyně site (Central Bohemia), and 11.1% of the total of carabid beetles collected at the same time at the Ivanovice na Hane site (Central Moravia). In Hungary, in a lowland oak forest-grassland complex (TÓTHMÉRÉSZ et al., 2014) *C. fuscipes* proved to be one of the most reliable indicators of grassland as opposed to edge and forest ecosystems.

C. melanocephalus

A Palaearctic species, probably introduced in North America (HŮRKA, 1996). *C. melanocephalus* is common all over Europe in lowland habitats and alpine areas up to the middle alpine region (LINDROTH, 1985). VERESCHAGINA (1984) states that in the former USSR *C. melanocephalus* is one of the most abundant and eurybiont species. PUTCHKOV (2012) mentions that it occurs throughout Ukraine. SERRANO (2013) states that *C. melanocephalus* inhabits practically all regions of Spain.

According to LINDROTH (1985), in Fennoscandia *C. melanocephalus* is a “commonly distributed species which usually lives in open country on different kinds of moderately dry ground with sparse vegetation, achieving its greatest abundance on sandy soil. It is a common inhabitant of dry meadows, grassland, dunes and heath; also on agricultural land and in thin forests, mainly of *Pinus*. It is frequent in the fjelds up to the lower alpine region.” The species is nocturnal and its reproductive period is mainly August–September in Scandinavia (NYLUND, 1991). LINDROTH (1974) states that in Great Britain *C. melanocephalus* occurs on all kinds of open moderately dry soil with grass, meadow or weed vegetation.

In the Czech Republic and Slovakia *C. melanocephalus* is “very common, mainly in unshaded or moderately shaded habitats: fields, steppe; lowlands to mountains” (HŮRKA, 1996). *C. melanocephalus* SIGIDA (1993) is a polytopic mesophile, typical of natural steppe areas and pastureland, bairak and floodplain forest, salines and areas of high salinity, and agricultural landscapes. In Moldova *C. melanocephalus* is a mesophile, belonging to the meadow-field group, common on fields in floodplains and dry interfluvies, rare in isolated forest blocks (KARPOVA and MATALIN, 1993). In the Non-Chernozem Area of Russia *C. melanocephalus* comprises on average 2.3% of the total number of ground beetles; on fields of winter wheat – 7.5%, in forest ecosystems – 4.9%, on sown beetroot – 3.6%, clover – 2.4%, barley – 1.1% (SOBOLEVA-DOKUCHAEVA, 1995).

The age structure of *C. melanocephalus* populations can vary in different ecosystems (VAN DIJK, 1972). Some specimens can live longer than usual, which can lead to higher populations in particular ecosystems. The results of laboratory experiments of VAN DIJK (1994) showed that the average number of eggs laid by a female *C. melanocephalus* increased from 50.9 to 73.8 and 142.5 eggs for one female when the beetle’s food consumption was increased from 1 to 2 and 5 mg/day respectively.

Various species in the genus move exclusively on the surface of the soil, for many, for example *C. melanocephalus* (AUKEMA, 1990), short wings are the dominant trait, while long wings are a recessive trait. The expression of genes for long wings could be modified by environmental factors such as temperature and food supply (AUKEMA, 1991). It is possible that prolonged summer migrations account for the presence of small numbers this species in unsuitable habitat.

D. halensis

A Palaearctic species, reaching the southern Kuril Islands, Japan and South China (HŮRKA, 1996). In the former USSR *D. halensis* does not extend as far north as the other species of *Calathus* discussed above; the range of *D. halensis* extends as far east as Primorski Kray (VERESCHAGINA, 1984; KRYZHANOVSKIJ et al., 1995). PUTCHKOV (2012) states that it occurs throughout Ukraine. It is significantly less common in the south of its range: according to SERRANO (2013) *D. halensis* was found only in 2 of Spain’s 23 regions, KESDEK and YILDIRIM (2004) consider *D. halensis* a rare species in Turkey.

The species is highly abundant in the Far East. At nine sites of three forest types selected in order to examine the effects of forest habitat in the Japanese red pine of Naju City, South Korea *D. halensis* comprised 17.4% of the total numbers of ground beetles trapped (Do and JOO, 2013). Do et al. (2014) in their study at Eulsukdo Island landfill (Republic of Korea) found that *D. halensis* comprised 30.8% of over 92,000 ground beetle specimens trapped. Despite these high figures, the abovementioned authors consider this flightless species which breeds in autumn to belong to the group which dominates in grassland and not forest ecosystems.

Research conducted in Busan Metropolitan City (Republic of Korea) showed that in parks *D. halensis* comprised over 40.8% of the total number of ground beetles, at closed landfill sites – 35.5%, in restored urban wetlands – 47.4%, in unmanaged grasslands – 44.1%, in forest parks – 4.1% (Do et al., 2014). At the same time, the species was completely absent from a brown field derelict area, gardens inside the interchange, and urban roadsides (Do et al., 2014). These variations in abundance could be connected either with anthropogenic activity or with natural ecological factors (biotic and abiotic). No attempt was made to distinguish these factors.

In Fennoscandia LINDROTH (1985) mentions that the species occurs “on open, often cultivated fields, usually on clayey soil. It is a common species in agricultural regions of Eastern Europe and is a pronounced steppe element in our fauna.” In the Czech Republic and Slovakia it is “common to sporadic on dry to moderately dry, unshaded habitats: fields; lowlands to hills” (HŮRKA, 1996). SIGIDA (1993) considers *D. halensis* to be a polytopic mesophile, characteristic of natural steppe and pastureland, bairaks and floodplain forest, agricultural and urban landscapes. In Moldova *D. halensis* is a mesophile, belonging to the meadow-field group, abundant on fields in floodplains and dry interfluvials, uncommon in vineyards and nut orchards (KARPOVA and MATALIN, 1993).

A. dorsalis

A West Palaearctic, eurytopic species, reaching eastward to Central Asia (HŮRKA, 1996). The species occurs across almost the entire territory of the former USSR, except for the northern taiga and tundra zones (KRYZHANOVSKIJ et al., 1995). PUTCHKOV (2012) mentions that it occurs throughout Ukraine. SERRANO (2013) states that *A. dorsalis* occurs in 20 of the 23 regions of Spain, KESDEK and YILDIRIM (2004) include it in the fauna of Turkey.

LINDROTH (1974) states that in Great Britain *A. dorsalis* “is the least hygrophilous of all *Agonum*, occurring in open meadows and grassland, usually on gravelly or clayish, often chalky soil. Somewhat local but often abundant; often large aggregations under stones in spring”. In Fennoscandia according to LINDROTH (1985) “the least hygrophilous of all *Agonum*, occurring in open meadows and grassland, usually on gravelly or clayey, often limestone soil. Also on arable land, particularly in winter crops on heavy soil.” In the Czech Republic and Slovakia it is “very common in unshaded, dry to moderately moist habitats; fields, steppe, pastures, edges of small woods; from lowlands to mountains, often gregariously” (HŮRKA, 1996).

In the Caucasus SIGIDA (1993) considers *A. dorsalis* to be a polytopic mesophile, typical of bairak and floodplain forest. In Moldova *A. dorsalis* is a mesophile, belonging to the meadow-field group, occurring infrequently on fields in floodplains and dry interfluvials, in vineyards and cherry orchards, isolated forest blocks (KARPOVA and MATALIN, 1993). In the Non-Chernozem Area of Russia single specimens of *A. dorsalis* were caught in barley crops, winter wheat, beetroot and in forest ecosystems (SOBOLEVA-DOKUCHAEVA, 1995).

A. dorsalis was found by KNAPP and UHNAVA (2014) in drier open areas such as arable fields, meadows, dry grasslands (steppes), and gardens. According to KOCOUREK et al. (2013), *A. dorsalis* comprised 8.7% of the total number of carabid beetles collected from maize fields at the Prague-Ruzyně site (Central Bohemia), and 0.5% at Ivanovice na Hane site (Central Moravia). According to BARANOVSKA et al. (2014), in the Czech Republic *A. dorsalis* occurs in open habitats and is common even in

intensively managed agricultural landscapes. *A. dorsalis* is an important generalist predator feeding on aphids and other arthropod crop pests (WRATTEN and VICKERMAN, 1985; BILDE and TOFT, 1994) and is thus considered a beneficial organism with biocontrol potential.

L. krynickii

A West Palearctic species, ranging from the Elbe River to the Urals and Central Asia (HŮRKA, 1996). In the former Soviet Union the range of *L. krynickii* extends across the European part, eastwards to the Altai (KRYZHANOVSKIJ et al., 1995). In Ukraine PUTCHKOV (2012) states that it occurs in the forest zone, the broad-leaved forest zone and the forest-steppe zone. *L. krynickii* has not been recorded in Moldova (KARPOVA and MATALIN, 1993).

In Fennoscandia according to the data of LINDROTH (1985) the species is very rare in Denmark, and also in Sweden, where it is restricted to the southeast of the country. The species does not occur in Norway or East Fennoscandia. In Europe it is distributed as far as the Elbe and Central Italy in the west, and Leningrad region in the north, extending eastward into Siberia. The species is “decidedly stenotopic, being confined to dark and marshy habitats in mull-rich deciduous forests. The species typically occurs in rich vegetation, e.g. of *Filipendula ulmaria*. The species can be found in litter and undermoss and bark of tree stumps, etc, often together with *A. assimile*.”

HŮRKA (1996) states that it is absent in Bohemia, rare to very rare in Moravia, rare to sporadic in the Slovak Republic, “a local; hygrophilous species of shaded borders of waters with rich vegetation in floodplain forests; lowlands.” In the Caucasus *L. krynickii* according to SIGIDA (1993) is a forest mesophile, occurring in bairak and floodplain forest, agricultural and urban landscapes.

O. obscurus

A Holarctic species (HŮRKA, 1996). It is common in the European part of the former Soviet Union and Western Siberia, extending as far east as Lake Baikal (KRYZHANOVSKIJ et al., 1995). According to PUTCHKOV (2012), in Ukraine it inhabits the forest and forest-steppe zones, and also the Crimean Mountains and their foothills (along with the south-eastern coastal strip). *O. obscurus* has not been recorded in Moldova (KARPOVA and MATALIN, 1993). SERRANO (2013) mentions that *O. obscurus* inhabits only 5 of Spain's 23 regions.

LINDROTH (1974) states that in Great Britain *O. obscurus* occurs “in damp deciduous forests and in densely vegetated marshes, among leaves and mosses”. In Fennoscandia according to LINDROTH (1985) the species occurs “predominantly in deciduous and mixed forests, living in damp, shaded sites among litter and moss. It is particularly numerous in stands of alder and ash in forest swamps, occurring among wet leaves around trees and stumps. Less abundant in peaty woods between pillows

of *Sphagnum*. Also in densely vegetated marshes in open country”.

In the Czech Republic and Slovakia it is “common in floodplain forests and among dense vegetation of edges of marshes and waters, from lowlands to hills” (HŮRKA, 1996). In the Non-Chernozem Area of Russia *O. obscurus* has been recorded (scattered specimens) only in forest ecosystems (SOBOLEVA-DOKUCHAEVA, 1995). In the Caucasus *O. obscurus* SIGIDA (1993) is considered part of the stagnophilous, hygrophilous complex, being a typical inhabitant of marshes and waterlogged, open floodplains. In Hungary, in a lowland oak forest-grassland complex (TÓTHMÉRÉSZ et al., 2014) *O. obscurus* proved to be a highly reliable indicator of edge ecosystems. This ground beetle species swims well, having been observed to survive for up to 22 days on the surface of water (KOLESNIKOV et al., 2012). This feature of its biology enables it to survive in floodplain rivers, far from the banks. Investigations in the north of its range, on Oland island situated in the Baltic Sea, showed that *O. obscurus* is one of the most abundant species of ground beetle, both in forest and meadow habitat (ANDERSEN, 2011). In the steppe zone of Ukraine *O. obscurus* is at its most numerous in broad-leaved forests, in moist, shady areas with a deep litter layer and acid sandy soil.

Fine differences in the habitat preferences of species can be assessed not only by the average value for a species in relation to a specific factor. It is also important to assess the range of tolerance of a species in relation to that particular factor. The presentation of data in this paper in graph form can be used both for comparison of ecological preferences of different species of ground beetle and for assessment of general tolerance of species groups sharing the same ecosystem and for comparisons between ecosystems (BRYGADYRENKO, 2003b).

Adoption of the research methods used for this article allows a clear multiple level assessment to be made of the ecological niches of different species of ground beetle. The results of a quantitative assessment of the ecosystemic preferences of different species can vary under the influence of climatic zone.

Conclusions

In the forests of the steppe zone of Ukraine *C. ambiguus* is a typical mesophile, with a slight preference for pine forests. *C. erratus* is at its most numerous in xeromesophilous moisture conditions with an average abundance of ants. *C. fuscipes* favours broad-leaved forests with 40–80% tree crown density, a sparse herbaceous layer, and clay soil with high salinity. *C. melanocephalus* is at its most numerous in forests with a deep litter layer with average soil salinity. *D. halensis* is often found in forests with of low crown density and favours areas with high salinity. *A. dorsalis* favours plots with scattered trees, thick grass, mesophilous moisture conditions and low abundance

of ants. *L. krynickii* inhabits forests with a thin litter layer, hygrophilous moisture conditions and soils with low salinity. *O. obscurus* inhabits moist areas of forests with acid, sandy soil.

References

- ANDERSEN, J., 2011. Winter quarters of wetland ground beetles (Coleoptera, Carabidae) in South Scandinavia. *Journal of Insect Conservation*, 15: 799–810.
- AUKEMA, B., 1990. Wing-length determination in two wing-dimorphic *Calathus* species (Coleoptera: Carabidae). *Hereditas*, 113: 189–202.
- AUKEMA, B., 1991. Fecundity in relation to wing-morph of three closely related species of the *melanocephalus* group of the genus *Calathus* (Coleoptera: Carabidae). *Oecologia*, 87: 118–126.
- BARANOVSKÁ, E., KNAPP, M., SASKA, P., 2014. The effects of overwintering, sex, year, field identity and vegetation at the boundary of fields on the body condition of *Anchomenus dorsalis* (Coleoptera: Carabidae). *European Journal of Entomology*, 111: 608–614.
- BELGARD, A.L., 1950. *Lesnaja rastitel'nost' jugovostoka USSR* [The forest vegetation of the south-east of the Ukrainian Soviet Socialist Republic]. Kiev: Kiev University Press. 256 p.
- BELGARD, A.L., 1971. *Stepnoe lesovedenie* [Steppe forestry]. Moscow: Lesnaja promyshlennost'. 336 p.
- BILDE, T., TOFT, S., 1994. Prey preference and egg production of the carabid beetle *Agonum dorsale*. *Entomologia Experimentalis et Applicata*, 73: 151–156.
- BLĄSZKIEWICZ, M., SCHWERK, A., 2013. Carabid beetle (Coleoptera: Carabidae) diversity in agricultural and post-agricultural areas in relation to the surrounding habitats. *Baltic Journal of Coleopterology*, 13 (1): 15–26.
- BRYGADYRENKO, V.V., 2003a. Fauna zhuzhelitc (Coleoptera, Carabidae) Dnepropetrovskoj oblasti [Fauna of ground beetles (Coleoptera, Carabidae) of Dnipropetrovsk region]. *Problems of Ecology and Environmental Protection in the Technogenic Region*, 3: 78–88.
- BRYGADYRENKO, V.V., 2003b. Ispol'zovanie topologicheskikh spektrov v zoologicheskoy diagnostike pochv na primere semeystva zhuzhelitc (Coleoptera, Carabidae) [Using topological spectrums in zoological diagnostics of soils with the family Carabidae (Coleoptera) as an example]. *Ecology and Noospherology*, 13 (1): 119–130.
- BRYGADYRENKO, V.V., 2004. Vozdejstvie uslovij sredy na sostav zhivotnogo naselenija podstilki i fitocenozy lesnykh ekosistem stepnoj zony Ukrainy [The influence of environmental conditions on the litter animals and phytocoenosis in the forest ecosystems of the Steppe zone of Ukraine]. *Forestry and Agroforestry*, 106: 77–83.

- BRYGADYRENKO, V.V., 2005. Ekologicheskie aspekty vzaimodejstvija murav'ev (Hymenoptera, Formicidae) s podstilochnymi bespozvonochnymi v uslovijah stepnyh lesov [Environmental aspects of the interaction of ants (Hymenoptera, Formicidae) with litter invertebrates in steppe forest]. *Question of Steppe Forestry and Forest Land Reclamation*, 9: 181–192.
- BRYGADYRENKO, V.V., 2006. Vozmozhnosti ispol'zovaniya napochvennyh bespozvonochnyh dlya indikacii gradaciy uvlazhneniya edafotopa v lesnyh ekosistemah [The possibility of using soil invertebrates to indicate soil moisture gradations in forest ecosystems]. *Visnyk of Dnipropetrovsk University. Biology, Ecology*, 14: 21–26.
- BRYGADYRENKO, V.V., 2014. Influence of soil moisture on litter invertebrate community structure of pine forests of the steppe zone of Ukraine. *Folia Oecologica*, 41: 8–16.
- BRYGADYRENKO, V.V., 2015. Vplyv umov zvolozhennja ta mineralizacii g'runtovogo rozchynu na strukturu pidstylkovoi mezofauny shyrokolistjanyh lisiv stepovoi zony Ukrai'ny [Influence of moisture conditions and soil salinity on structure of litter macrofauna of the deciduous forests of Ukraine steppe zone]. *Visnyk of Dnipropetrovsk University. Biology, Ecology*, 23: 50–65.
- BRYGADYRENKO, V.V., SOLOVJOV, S.V., 2007. Vplyv pervynnogo g'runtoutvorennja u zaplavnyh lisah Dniprovs'ko-Oril's'kogo pryrodnoho zapovidnyka na strukturu gerpetobiju [Effect of initial soil in floodplain forests of the Dnieper-Oril's'ke Nature Reserve on the community structure of litter invertebrates]. *Pynannia Bioidycii ta Ecologii*, 12 (1): 34–45.
- BUKEJS, A., BALALAIKINS, M., 2008. Ground beetles (Coleoptera: Carabidae) of wheat agrocenosis in Latvia. *Acta Zoologica Lituanica*, 18: 134–138.
- DO, Y., JOO, G.J., 2013. The effect of fragmentation and intensive management on carabid beetles in coniferous forest. *Applied Ecology and Environmental Research*, 11: 451–461.
- DO, Y., KIM, J.Y., KIM, G.-Y., JOO, G.-J., 2014. Importance of closed landfills as green space in urbanized areas: Ecological assessment using carabid beetles. *Landscape and Ecological Engineering*, 10: 277–284.
- DO, Y., LINEMAN, M., JOO, G.-J., 2014. Carabid beetles in green infrastructures: The importance of management practices for improving the biodiversity in a metropolitan city. *Urban Ecosystems*, 17 (3): 661–673.
- EMERSON, B.C., OROMI, P., HEWITT, G.M., 2000. Interpreting colonization of the Calathus (Coleoptera: Carabidae) on the Canary Islands and Madeira through the application of the parametric bootstrap. *Evolution*, 54: 2081–2090.
- GAÑÁN, I., BASELGA, A., NOVOA, F., 2008. Diversity patterns in Iberian Calathus (Coleoptera, Carabidae: Harpalinae): Species turnover shows a story overlooked by species richness. *Environmental Entomology*, 37: 1488–1497.
- HŮRKA, K., 1996. *Carabidae of the Czech and Slovak Republics*. Zlín, Czech Republic: Kabourek. 565 p.
- HUTCHINSON, G.E., 1957. Concluding remarks. *Cold Spring Harbor Symposia on Quantitative Biology*, 22: 415–427.
- KARPOVA, E.V., MATALIN, A.V., 1993. Annotirovannyj spisok zhuzhelic (Coleoptera, Carabidae) juga Moldovy [An annotated check list of carabids (Coleoptera, Carabidae) of Moldova]. *Entomologičeskoe Obozrenie*, 72: 570–585.
- KESDEK, M., YILDIRIM, E., 2004. Contribution to the knowledge of Carabidae fauna of Turkey. Part 2 Platynini (Coleoptera, Carabidae). *Linzer Biologische Beiträge*, 36 (1): 527–533.
- KLAUSNITZER, B., 1987. *Ökologie der Großstadtf fauna*. Jena: VEB Gustav Fischer Verlag. 246 p.
- KNAPP, M., UHNAVA, K., 2014. Body size and nutrition intake effects on fecundity and overwintering success in Anchomenus dorsalis (Coleoptera: Carabidae). *Journal of Insect Science*, 14 (240): DOI: 10.1093/jisesa/ieu102
- KOCOUREK, F., SASKA, P., ŘEZÁČ, M., 2013. Diversity of carabid beetles (Coleoptera: Carabidae) under three different control strategies against European corn borer in maize. *Plant Protection Science*, 49: 146–153.
- KOLESNIKOV, F.N., KARAMYAN, A.N., HOBACK, W.W., 2012. Survival of ground beetles (Coleoptera: Carabidae) submerged during floods: Field and laboratory studies. *European Journal of Entomology*, 109: 71–76.
- KROMP, B., 1999. Carabid beetles in sustainable agriculture: A review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems and Environment*, 74 (1–3): 187–228.
- KRYZHANOVSKIJ, O.L., BELOUSOV, I.A., KABAK, I.I., KATAEV, B.M., MAKAROV, K.V., SHILENKOV, V.G., 1995. *A checklist of the ground-beetles of Russia and adjacent lands (Insecta, Coleoptera, Carabidae)*. Sofia: Pensoft Publishers. 271 p.
- KUTASI, C., MARKÓ, V., BALOG, A., 2004. Species composition of carabid (Coleoptera: Carabidae) communities in apple and pear orchards in Hungary. *Acta Phytopathologica et Entomologica Hungarica*, 39 (1–3): 71–89.
- LANG, A., FILSER, J., HENSCHER, J.R., 1999. Predation by ground beetles and wolf spiders on herbivorous insects in a maize crop. *Agriculture, Ecosystems and Environment*, 72 (2): 189–199.
- LINDROTH, C.H., 1974. *Coleoptera, Carabidae. Handbooks for the identification of British insects*. Vol. 4, part 2. London: Royal Entomological Society. 148 p.
- LINDROTH, C.H., 1979. The theory of glacial refugia. In ERWIN, T.L., BALL, G.E., WHITEHEAD, D.R., HALPERN, A.E. (eds). *Carabid beetles*. The Hague: Dr. W. Junk bv Publishers, p. 385–394.

- LINDROTH, C.H., 1986. The Carabidae (Coleoptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica*, 15 (2): 233–497.
- MAGURA, T., 2002. Carabids and forest edge: Spatial pattern and edge effect. *Forest Ecology and Management*, 157 (1–3): 23–37.
- NEGRE, J., 1969. Los grandes Calathus de la Península Ibérica. *Miscellània Zoològica*, 2 (4): 7–32.
- NYLUND, L., 1991. Metabolic rates of *Calathus melanocephalus* (L.) (Coleoptera, Carabidae) from alpine and lowland habitats (Jeloy and Finse, Norway) and Drenthe, the Netherlands. *Comparative Biochemistry and Physiology*, 100A (4): 853–862.
- PUTCHKOV, A.V., 2011. Ground beetles of the Ukraine (Coleoptera, Carabidae). *ZooKeys*, 100: 503–515.
- PUTCHKOV, A.V., 2012. Faunisticheskij obzor karaboidnyh zhukov (Coleoptera, Caraboidea) Ukrainy [A review of the caraboid-beetles (Coleoptera, Caraboidea) of Ukraine]. *Ukrai'ns'kyj Entomologichnyj Zhurnal*, 2 (5): 3–44.
- RUIZ, C., BJARTE, J., SERRANO, J., 2009. Molecular phylogeny of the tribe Sphodrini (Coleoptera: Carabidae) based on mitochondrial and nuclear markers. *Molecular Phylogenetics and Evolution*, 50: 59–73.
- RUIZ, C., JORDAL, B.H., EMERSON, B.C., WILL, K.W., SERRANO, J., 2010. Phylogeny of the subtribe Calathina (Coleoptera: Carabidae: Sphodrini) in the Holarctic region based on nuclear and mitochondrial markers. *Molecular Phylogenetics and Evolution*, 55: 358–371.
- RUIZ, C., BJARTE, J.H., SERRANO, J., 2012. Diversification of subgenus *Calathus* (Coleoptera: Carabidae) in the Mediterranean region – glacial refugia and taxon pulses. *Journal of Biogeography*, 39: 1791–1805.
- SCHWERK, A., SZYSZKO, J. 2012. Variation in epigeic carabid fauna (Coleoptera: Carabidae) on differently-treated post-agricultural land. *Baltic Journal of Coleopterology*, 12 (1): 39–48.
- SERRANO, J., 2013. *New catalogue of the family Carabidae of the Iberian Peninsula (Coleoptera)*. Murcia: Ediciones Universidad de Murcia. 192 p.
- SHILENKOV, V.G., 1978. Osobennosti biologii massovyh vidov zhuzhelic (Coleoptera, Carabidae) fauny juzhnogo Pribajkal'ja [Peculiarities of biology of abundant ground-beetles (Coleoptera, Carabidae) in the south of the Baikal region]. *Entomologičeskoe Obozrenie*, 57 (2): 290–301.
- SIGIDA, S.I., 1993. Landshaftno-biotopicheskoe raspredelenie i jekologicheskaja karakteristika zhuzhelic (Coleoptera, Carabidae) Predkavkaz'ja i severnyh sklonov Central'nogo Kavkaza [Landscape and biotopic distribution and ecological characteristic of carabids (Coleoptera, Carabidae) of Ciscaucasia and northern slopes of the Central Caucasus]. *Entomologičeskoe Obozrenie*, 72 (1): 11–38.
- SOBOLEVA-DOKUCHAEVA, I.I., 1995. Osobennosti formirovaniya fauny zhuzhelic (Coleoptera, Carabidae) agrocenozov Nechernozem'ja pri kontakte s lesum [Peculiarities of formation of ground-beetles fauna (Coleoptera, Carabidae) in agrocoenoses neighbouring forests in the non-Chernozem area]. *Entomologičeskoe Obozrenie*, 74 (3): 551–567.
- THIELE, H.U., 1977. *Carabid beetles in their environments*. Berlin: Springer-Verlag. 369 p.
- TÓTHMÉRÉSZ, B., NAGY, D.D., MIZSER, S., BOGYÓ, D., MAGURA, T., 2014. Edge effects on ground-dwelling beetles (Carabidae and Staphylinidae) in oak forest-forest edge-grassland habitats in Hungary. *European Journal of Entomology*, 111 (5): 686–691.
- VAN DIJK, T.S., 1972. The significance of the diversity in age composition of *Calathus melanocephalus* L. (Col., Carabidae) in space and time at Schiermonnikoog. *Oecologia*, 10: 111–136.
- VAN DIJK, T.S., 1994. On the relationship between food, reproduction and survival of two carabid beetles: *Calathus melanocephalus* and *Pterostichus versicolor*. *Ecological Entomology*, 19: 263–270.
- VERESCHAGINA, T.N., 1984. Zhuzhelicy roda *Calathus* Bon. (Coleoptera, Carabidae) fauny SSSR [Carabids of the genus *Calathus* Bon. (Coleoptera, Carabidae) of the fauna of the USSR]. *Entomologičeskoe Obozrenie*, 63 (4): 751–766.
- WRATTEN, E.S.D., VICKERMAN, G.P., 1985. Foraging by the carabid *Agonum dorsale* in the field. *Ecological Entomology*, 10: 181–189.

Received August 13, 2015

Accepted October 9, 2015

Comparison of the andosols properties of forest and meadow ecosystems on the neovolcanic rocks of the Central Slovakia

Michal Hudec^{1,2}, Filip Tulis², Melánia Feszterová^{1*}, Juraj Hreško²

¹Department of Chemistry, Faculty of Natural Sciences, Constantine the Philosopher University,
Tr. A. Hlinku 1, 949 74 Nitra, Slovak Republic

²Department of Ecology and Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher
University, Tr. A. Hlinku 1, 949 74 Nitra, Slovak Republic

Abstract

HUDEC, M., TULIS, F., FESZTEROVÁ, M., HREŠKO, J., 2015. Comparison of the andosols properties of forest and meadow ecosystems on the neovolcanic rocks of the Central Slovakia. *Folia Oecologica*, 42: 89–102.

The aim of the paper was to describe the chemical and physical characteristics of the mixed forest soils and to compare their characteristics with meadow soils (mowed and xerothermic) situated at selected volcanic mountains of Central Slovakia. The andosols analysed were taken from the Kremnické and the Štiavnické mountains. The chemical and physical characteristics of andosols have been monitored. It was proved that in the mixed forests there is a constant input of fresh organic matter which affects the content of total organic carbon (TOC) and keeps it at a steady level. The highest value variability of TOC among seasons and the highest average value of TOC were proved to be in xerothermic meadows ($8.93 \pm 4.49\%$). The land use has a statistically significant impact on the differences between the values of active pH ($F = 7.5001$, $p = 0.001$) and exchangeable soil reaction ($F = 18.8866$, $p = 0.000$). Total nitrogen (N_T) was affected by land use and was decreasing from xerothermic meadows to mixed forests ($p < 0.001$) in linear dependence similar to the TOC content ($F = 11.7573$, $p = 0.000$). The value variabilities of cation exchange capacity (CEC) and basic cation (S) between soils of mixed forest and mowed and xerothermic meadows were statistically significant. The content of TOC negatively correlated with the sand fraction (soils of the mixed forest and xerothermic meadow) and the clay fraction (soils of monitored ecosystems).

Key words

andosols, ecosystem, Kremnické and Štiavnické mountains, season, soil properties

Introduction

Andosols represent a unique body of soil types in Slovakia that is part of the national heritage. Moreover, they are part of European volcanic soils (JURÁNI and BALKOVIČ, 2007). The genesis of andic properties and characteristics is determined by the natural soil-forming factors in the following order: rock-time-climate-relief-vegetation (BALKOVIČ, 2002). The soils formed

from volcanic materials, which contain a large amount of soil organic carbon (SOC) due to their stabilization, belong to mineral soils (ARMAS-HERRERA, 2012; MORA et al., 2014). Andosols have a specific morphology and specific physical and chemical properties (NOVAK et al., 2010). Andosols are soils with a large structural development and stability of aggregates. Their properties have a significant role in their high infiltration rate. However, they are affected by environmental changes,

*Corresponding author:
e-mail: mfeszterova@gmail.com

especially those related to changes of land use (NERIS et al., 2012). The land use in practice can have a permanent effect on the distribution of nutrients in soil, and it can affect the natural recovery of the ecosystem at the end of the land use (LAL, 2000; ALEKSANDROWICZ-TRZCIŃSKA, 2005; SAKBAEVA et al., 2012; GÖMÖRY et al., 2015). Generally, the soils used for agriculture are not similar in terms of the chemical, physical and biological characteristics compared to forest soils (MAŁECKA and HILSZCZAŃSKA, 2014).

It is important to monitor not only the changes in the land management and landscape cover, but also the content of soil organic matter. It has ecological and environmental consequences (SLEPETIENĖ et al., 2010; HUDEC and HREŠKO, 2012). Soil organic matter (SOM) is a determining factor of soil quality (RYAN, 1998; GÄRDENÄS et al., 2011; OSTROWSKA and PORĘBSKA, 2012). It has an important role in the soils of each ecosystem (KALISZ et al., 2010). It affects the chemical and physical properties of soil, such as the formation of stable aggregates, water retention, cation exchange capacity, nutrient content as well as nitrogen and carbon content (KONONOVA, 1966). ARROUAYS et al. (2001) and NAVARRETE et al. (2010) reported that the carbon cycle, biodiversity and soil fertility are influenced by land management, landscape cover and agriculture. In forest management, the soil has an important role, especially in the production of plant biomass. Sand density affects its structure, and can lead to changes of biomorphological characteristics (PACH et al., 2001), changes of biomass allocation (JAGODZIŃSKI and OLEKSYN, 2009a) and it can modify the retention of nutrients in biomass and soil (JAGODZIŃSKI and OLEKSYN, 2009b; MAŁECKA and HILSZCZAŃSKA, 2014). Soil organic matter is very important to all soil processes that have an impact on crop production and the environment (RYAN et al., 2008). The soil carbon losses from soil cause the reduction of organic matter, fertility, ability to retain water and frequent local dryness (BIERKENS et al., 2008).

In recent years, the number of changes in the country has been increasing, which represents a risk for accumulation of carbon in the forest in terms of time and area. The type of vegetation cover of non-cultivated land is a factor that affects the organic carbon content of soil (LIU et al., 2010). Soil organic components are important factors of forest health and productivity (JURGENSEN et al., 1997). The losses of forest cover affect the decrease of the SOC which occurs in advance of complete deforestation when degraded forests are transformed into pasture, cropland and eroded areas (COVALEDA et al., 2011).

The aim of this study was to observe changes of the chemical and physical characteristics of the andosols soil type. Soil samples were collected from selected ecosystems (mixed forest, meadows: mowed and xerothermic) in different seasons (autumn, spring) during 2011–2013.

Material and methods

The study was located in Kremnické and Štiavnické mountains (Fig. 1). Kremnické and Štiavnické mountains are volcanic mountains that are located in Central Slovakia. It is part of the West Carpathians province, sub-province Inner Western Carpathians and the Slovak Central Mountains. It is important to define the correct position with respect to individual monitoring points for the sampling of soil. Soil samples were collected by a probe (10 sampling sites = 10 open borrow pits) from a depth of about 1 m in autumn of 2011, 2012 and spring of 2012, 2013. An open probe is used for determination of soil characteristics such as soil profile description, its depth, the stratigraphy (arrangement of genetic horizons) and morphological characteristics. A soil sample was taken from each sampling area (5×5 m) in a total of ten different locations (Table 1).

The sampling area was divided into regular grids. This provides a balanced surface covering of the land being surveyed and contributes to the achievement of objective results (NOZDROVICKÝ, 2008). The soil samples were taken from the terrestrial organogenic horizon Ol (0–5 cm), Aau horizon (5–35 cm) and from Bva cambic andosols horizon (35–60 cm). Andosols were identified according to IUSS Working Group WRB (2006), on the basis of the dark-coloured, deep, fluffy, melanic, andic (Aa) horizon. Allophanes and grain size of soils were not evaluated.

Soil was air-dried at room temperature and sieved (<2 mm), and a sample was taken using standard procedures. Visible plant remnants were removed by hand. Soil reaction was determined in distilled water as active soil reaction ($\text{pH}_{\text{H}_2\text{O}}$) and in a solution of 1 mol L^{-1} KCl as exchange soil reaction (pH_{KCl}). The ratio of soil and solution was 1 : 2.5 (VAN REEUWIJK, 2002). Total organic carbon (TOC) was measured using the Tjurin method modified by Nikitina according to ORLOV and GRIŠINA (1981). The content of humic substances (HS), as well as the HA : FA ratio was determined by group composition of humic substances using the Belčíková-Kononová method (KONONOVÁ AND BELČIKOVÁ, 1962). Humic substances were extracted into a 0.1 mol L^{-1} solution of sodium pyrophosphate adjusted to $\text{pH} = 13$ with 1 mol L^{-1} sodium hydroxide and the samples were left for infusion for 24 hours at room temperature. To separate fulvic acids (FA) from humic acids (HA), the solution was centrifuged (10,000 rpm) and the precipitate containing HA was dissolved with sodium hydroxide. The total nitrogen (N_T) was determined by the Kjeldahl method (BREMNER, 1960), inorganic nitrogen (N_in) as the sum of ammonium (N-NH_4^+) and nitrate (N-NO_3^-), while nitrogen was determined by the colour method (RADOV et al., 1985). Cation exchangeable capacity ($\text{CEC} = \text{H} + \text{S}$), base saturation ($\text{V} = \text{S} / \text{CEC} \times 100$), hydrolytic acidity (H) and sum of basic cations (S) were measured according to JACKSON (2005). Silt, sand and

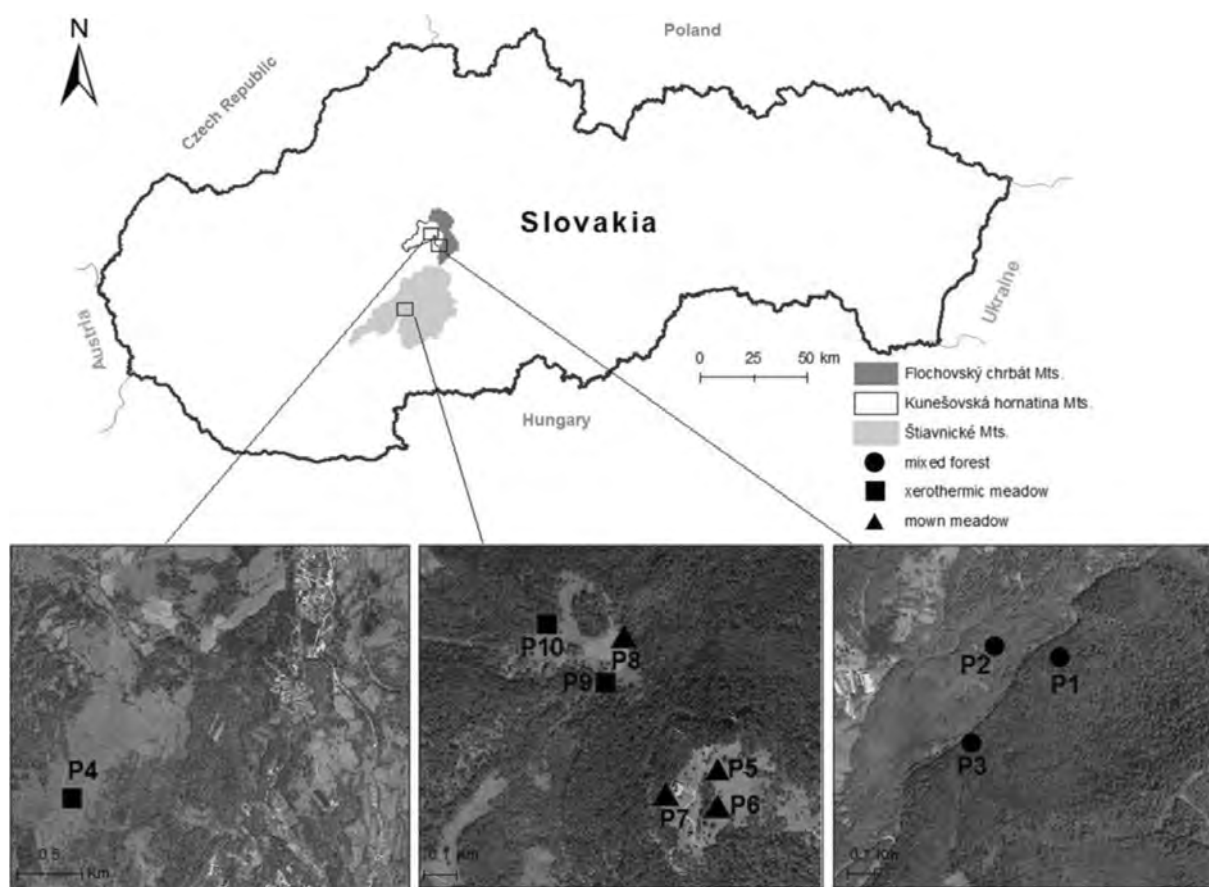


Fig. 1. Localization of the andosols soil type.

Table 1. Characteristics of monitoring places of soil samples

Localization of andosols	Altitude (m o. s.)	Exploitation	Slope exposure	Slope of relief	Outflow conditions	Geomorphological division	
P1	678	Mixed forest	NW	$\geq 25^\circ$	Strong outflow	Fločovský chrbát Mts.	Kremnické mountains
P2	637	Mixed forest	SE	$\geq 25^\circ$	Strong outflow		
P3	558	Mixed forest	NW	$\geq 25^\circ$	Strong outflow		
P4	944	Xerothermic meadow	S	$12^\circ-17^\circ$	Poor outflow	Kunešovská hornatina Mts.	
P5	1,002	Mown meadow	SE	$12^\circ-17^\circ$	Moderately strong outflow		
P6	974	Mown meadow	SE	$12^\circ-17^\circ$	Poor outflow		
P7	998	Mown meadow	S	$7^\circ-12^\circ$	Poor outflow	Sitnianska vrchovina Mts.	Štiavnické mountains
P8	911	Mown meadow	E	$7^\circ-12^\circ$	Moderately strong outflow		
P9	891	Xerothermic meadow	SW	$\geq 25^\circ$	Strong outflow		
P10	895	Xerothermic meadow	SE	$12^\circ-17^\circ$	Poor outflow		

E, east; NW, north-west; S, south; SE, south-east.

clay fractions were determined using the pipette method (VAN REEUWIJK, 2002). The results are shown in the tables by averages from a depth of 0–60 cm.

The measured data was statistically processed using the software Statistics 8, a statistics program using parametric tests. The two-way ANOVA with interaction was used to compare the chemical and physicochemical properties of soil in terms of different seasons and ecosystems, with separation by means of Tukey's HSD test. To determine the correlation relationships between chemical parameters, we used Spearman's test of serial correlation.

Phytocenological research was realized during the years 2013 and 2014 based on the methods developed by the Zurich-Montpellier school (BRAUN-BLANQUET, 1964) using the new BRAUN-BLANQUET 9-member ordinal scale of coverage (VAN DER MAAR, 1978). Bryophytes and lichens were not described. The sampling and described area was 5×5 m. Phytocenological records were saved in database software called Turboveg (HENNEKENS and SCHAMINÉE, 2001) and subsequently exported into the software JUICE (TICHÝ, 2002). For the classification of the entries, Twinspan (HILL, 1979) was also used in the software JUICE (TICHÝ, 2002) and the formally defined syntaxes in the work of JANIŠOVÁ et al. (2007). The names of taxa are listed according to the work of MARHOLD (1998). Syntax nomenclature is given by JAROLÍMEK et al. (2008).

- P1 – mixed forest, beech-spruce-hornbeam forest (age 150 years; cover crop; stand 285 B) 50% *Abies alba*, 45% *Fagus sylvatica*, 5% *Acer pseudoplatanus*
- P2 – mixed forest, beech-spruce-hornbeam forest (age 140 years; cover crop; stand 347 B) 90% *Fagus sylvatica*, 10% *Abies alba*
- P3 – mixed forest, beech-spruce-hornbeam forest (age 55 years; cover crop; stand 283 B) 70% *Fagus sylvatica*, 10% *Acer pseudoplatanus*, 10% *Abies alba*, 10% *Picea abies*
- P4 – acid loving mesophilic meadow e.g. *Arrhenatherion elatioris*, mowed
- P5 – mesophilic meadow e.g. *Arrhenatherion elatioris*
- P6 – coppice with transient character, where the species overlap mesophilic meadows e.g. *Arrhenatherion elatioris* and sub-xerophylic lawns for example *Bromion erecti*
- P7 – mesophilic meadow e.g. *Arrhenatherion elatioris*
- P8 – mesophilic meadow e.g. *Arrhenatherion elatioris*
- P9 – coppice with transient character, in which the elements of thermophilic hems grow, for example *Geranion sanguinei*, sub-xerophylic lawns for example *Bromion erecti*, or species of mesophilic meadows e.g. *Arrhenatherion elatioris*, mowed
- P10 – ecotonic ecosystem e.g. *Geranion sanguinei*, mowed

Results and discussion

The chemical and physical characteristics of soils under different land uses are shown in Tables 2a–c. The highest average value of total organic carbon (TOC) was detected on xerothermic meadows ($8.93 \pm 4.94\%$) in autumn 2011, with the highest values of difference in this land use situation (Fig. 2). The lowest difference in terms of TOC values, between the periods in which soil was sampled, was detected in mixed forest (Fig. 2). The content of TOC in the mown meadow soil showed increasing values during the entire period from autumn 2011 to autumn 2012. In the spring of 2013, there was a decrease of TOC content from $7.42 \pm 6.01\%$ to $5.15 \pm 3.00\%$. The TOC content in the soils of the mixed forest and the xerothermic meadow decreased in spring 2013 but not in the same season in 2012.

The TOC content in soil was influenced not only by land use. According to MARTELLOTTI (2010), climate affects plant growth and yield, and it mediates decomposition rates, thus impacting on the quantity and rate of C cycling. Management practices will alter this balance by affecting the system's productivity, and the speed of residue and soil organic matter decomposition. The TOC content of forest soils is lower than that of other land use types. It is said that the enrichment of afforested soils by organic substrates in the form of compost and mining residues on the one hand improves the fertility of the poor soils, but on the other hand it stimulates beneficial microbial processes in the environment, increases the proportion of antagonists and also the resistance to infection in the roots of a young forest ecosystem (KWAŚNA et al., 2000, 2001).

The central European forestry has started an ecologically-oriented conversion of spruce monocultures to broadleaf and mixed forests (GALKA et al., 2014). We monitored the soils of a mixed forest of beech-spruce-hornbeam. With regard to the seasonal impact (autumn/spring), we did not detect statistically significant differences in TOC content ($F = 2.8697$, $p = 0.095$). According to ISLAM and WEIL (2000), the total C (TOC) levels tended to be higher in reforested and grassland sites, but the variability was not high enough. Even GÜNDOĞAN et al. (2011) did not detect statistically significant differences in TOC between grassland, forest and arable land. MUTSOTSO and MUYA (2008) also detected a higher TOC content on natural grassland, as well as on natural forest. Changes in TOC content were influenced by different factors and had divergent behaviour depending on the type of habitat and the stand density. In forests, the dynamics of the density are dependent on the species, the quality of the locality (in terms of soil), and other factors (SOCHA

Table 2a. Mixed forest – average values of soil chemical properties (mean value \pm standard deviation)

Chemical properties		2011	2012		2013
		Autumn	Spring	Autumn	Spring
TOC		4.91 \pm 1.86	4.30 \pm 2.06	3.99 \pm 1.59	3.91 \pm 1.84
pH _{H2O}	(%)	5.82 \pm 0.46	5.97 \pm 0.28	6.14 \pm 0.07	5.93 \pm 0.35
pH _{KCl}		4.73 \pm 0.30	5.06 \pm 0.40	4.68 \pm 0.09	4.84 \pm 0.47
N-NH ₄ ⁺		13.03 \pm 3.38	19.75 \pm 4.27	16.70 \pm 3.21	14.23 \pm 3.33
N-NO ₃ ⁻	(mg kg ⁻¹)	8.07 \pm 2.15	9.13 \pm 2.58	8.57 \pm 1.84	9.03 \pm 1.48
N _{in}		21.10 \pm 4.59	28.88 \pm 6.82	25.27 \pm 4.75	23.27 \pm 4.68
N _T		4.13 \pm 1.92	3.43 \pm 2.12	2.90 \pm 1.44	3.12 \pm 1.82
HS		4.45 \pm 0.85	3.67 \pm 1.07	3.60 \pm 0.89	3.27 \pm 0.60
HA	(%)	1.95 \pm 0.45	1.56 \pm 0.41	1.65 \pm 0.39	1.47 \pm 0.32
FA		2.49 \pm 0.43	2.11 \pm 0.68	1.95 \pm 0.50	1.80 \pm 0.29
HA : FA		0.78 \pm 0.10	0.76 \pm 0.12	0.85 \pm 0.03	0.82 \pm 0.07
C : N		12.51 \pm 1.48	13.92 \pm 2.63	14.45 \pm 2.00	14.48 \pm 1.77
H		14.30 \pm 1.59	13.24 \pm 1.34	13.32 \pm 1.30	12.95 \pm 1.33
S	(cmol kg ⁻¹)	10.57 \pm 3.97	9.85 \pm 2.87	9.10 \pm 1.54	7.85 \pm 0.85
CEC		24.87 \pm 2.53	23.12 \pm 1.67	22.42 \pm 1.71	20.80 \pm 1.43
V	(%)	41.33 \pm 11.91	41.95 \pm 9.81	40.48 \pm 5.39	37.80 \pm 3.74

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; N-NH₄⁺, ammonium nitrogen; N-NO₃⁻, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

Table 2b. Mown meadow – average values of soil chemical properties (mean value \pm standard deviation)

Chemical properties		2011	2012		2013
		Autumn	Spring	Autumn	Spring
TOC		2.85 \pm 1.59	4.65 \pm 2.99	7.42 \pm 6.01	5.15 \pm 3.00
pH _{H2O}	(%)	5.77 \pm 0.49	5.41 \pm 0.10	5.75 \pm 0.29	5.66 \pm 0.21
pH _{KCl}		4.46 \pm 0.22	4.48 \pm 0.10	4.49 \pm 0.19	4.48 \pm 0.32
N-NH ₄ ⁺		9.80 \pm 7.25	52.88 \pm 24.37	27.62 \pm 6.09	42.35 \pm 23.18
N-NO ₃ ⁻	(mg kg ⁻¹)	4.92 \pm 0.68	7.63 \pm 1.79	8.37 \pm 2.86	8.98 \pm 1.80
N _{in}		14.72 \pm 7.66	60.52 \pm 25.65	35.98 \pm 6.57	51.33 \pm 24.06
N _T		3.25 \pm 1.88	5.20 \pm 3.70	11.73 \pm 9.04	5.72 \pm 2.80
HS		3.05 \pm 0.90	3.12 \pm 1.40	3.32 \pm 1.23	2.38 \pm 1.41
HA	(%)	1.15 \pm 0.30	1.03 \pm 0.35	1.24 \pm 0.43	0.57 \pm 0.36
FA		1.90 \pm 0.65	2.90 \pm 1.08	2.09 \pm 0.85	1.81 \pm 1.08
HA : FA		0.71 \pm 0.37	0.77 \pm 0.58	0.73 \pm 0.35	0.63 \pm 0.51
C : N		9.68 \pm 1.91	9.72 \pm 1.50	7.70 \pm 3.12	8.94 \pm 1.89
H		6.57 \pm 1.83	5.27 \pm 0.66	3.63 \pm 0.64	4.09 \pm 0.75
S	(cmol kg ⁻¹)	7.22 \pm 1.61	5.92 \pm 0.86	5.53 \pm 1.48	4.83 \pm 0.65
CEC		13.78 \pm 3.39	11.18 \pm 1.36	9.17 \pm 1.96	8.92 \pm 1.38
V	(%)	52.70 \pm 2.92	52.81 \pm 3.25	59.97 \pm 4.05	54.31 \pm 1.75

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; N-NH₄⁺, ammonium nitrogen; N-NO₃⁻, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

Table 2c. Xerothermic meadow – average values of soil chemical properties (mean value \pm standard deviation)

Chemical properties		2011	2012		2013
		Autumn	Spring	Autumn	Spring
TOC		8.93 \pm 4.94	5.27 \pm 2.20	7.43 \pm 3.86	4.14 \pm 3.28
pH _{H2O}	(%)	5.26 \pm 0.90	5.15 \pm 0.36	5.70 \pm 0.36	5.61 \pm 0.40
pH _{KCl}		4.04 \pm 0.33	3.96 \pm 0.22	4.21 \pm 0.32	4.47 \pm 0.34
N-NH ₄ ⁺		26.30 \pm 21.64	69.80 \pm 36.76	34.63 \pm 16.64	51.10 \pm 33.47
N-NO ₃ ⁻	(mg kg ⁻¹)	6.83 \pm 4.50	5.65 \pm 1.34	7.48 \pm 1.27	7.17 \pm 2.10
N _{in}		33.13 \pm 24.83	75.45 \pm 37.79	42.11 \pm 17.43	58.27 \pm 35.44
N _T		16.54 \pm 8.90	9.03 \pm 3.08	13.13 \pm 5.54	5.80 \pm 4.70
HS		4.50 \pm 2.27	4.62 \pm 1.63	4.21 \pm 3.03	3.01 \pm 2.30
HA	(%)	0.82 \pm 0.53	1.45 \pm 0.34	0.82 \pm 0.53	0.80 \pm 0.67
FA		3.68 \pm 1.88	3.17 \pm 1.30	3.39 \pm 3.33	2.21 \pm 1.64
HA : FA		0.31 \pm 0.23	0.50 \pm 0.10	0.59 \pm 0.37	0.76 \pm 0.51
C : N		5.22 \pm 0.67	5.72 \pm 0.54	5.52 \pm 0.79	8.84 \pm 3.03
H		5.10 \pm 0.89	3.80 \pm 0.54	3.55 \pm 1.17	3.77 \pm 0.99
S	(cmol kg ⁻¹)	7.25 \pm 1.42	5.28 \pm 0.84	4.68 \pm 1.13	4.98 \pm 1.21
CEC		12.35 \pm 2.19	9.08 \pm 1.36	8.23 \pm 2.23	8.74 \pm 2.12
V	(%)	59.50 \pm 2.92	58.08 \pm 1.44	57.48 \pm 4.05	57.20 \pm 3.92

TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; N-NH₄⁺, ammonium nitrogen; N-NO₃⁻, nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

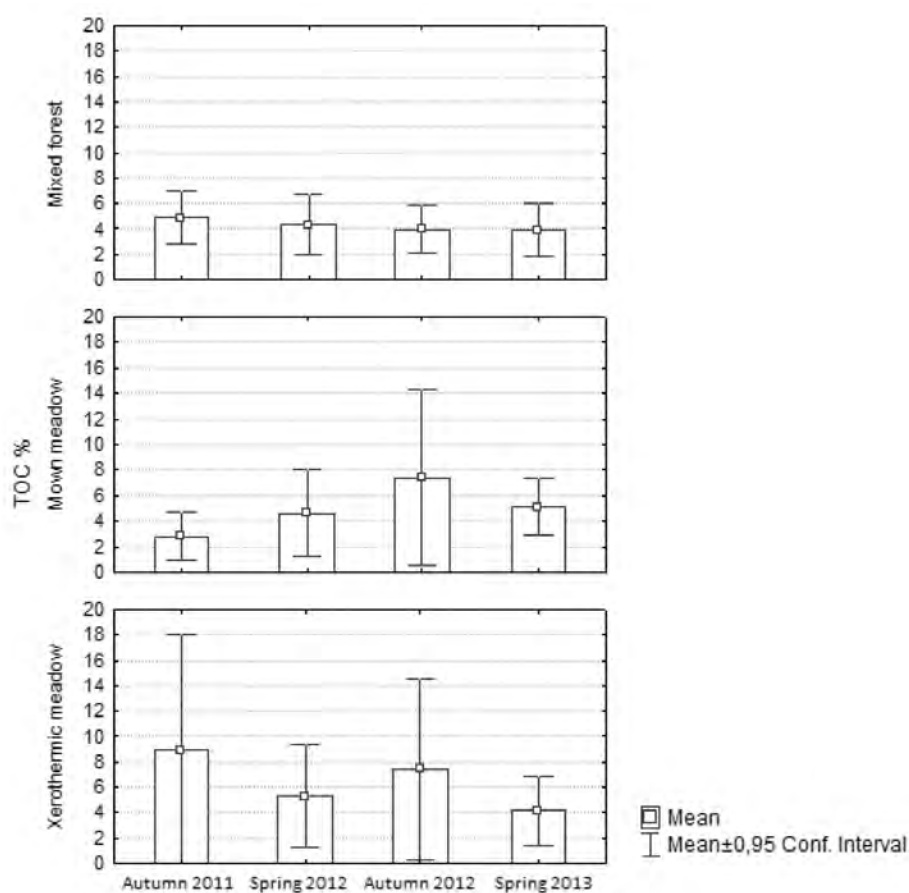


Fig. 2. Variability of TOC (total organic carbon) depending on the land use in different years.

and ZASADA, 2014). The highest variability in terms of values between seasons was detected in the case of xerothermic meadows (Table 3), probably because of the fresh organic substance supply during the whole year.

Land use had a statistically significant impact on difference in active values ($F = 7.5001$, $p = 0.001$) and exchange soil reaction ($F = 18.8866$, $p = 0.000$) (Table 4). According to ISLAM and WEIL (2000), the pH values of the natural forest, reforested land, grassland and cultivated soils, varied significantly. A drop in pH values was also indicative of the process of soil transformation (KALISZ et al., 2010). GÜNDOĞAN et al. (2011) detected statistically significant differences in the values of active soil reaction between grassland, forest and arable land, while grassland had significantly higher pH than both forest and arable lands ($p < 0.05$). The drop in soil acidity and the nitrogen deposition in the context of contemporary climate change will limit the silvicultural function of forest communities (JANÍK et al., 2014). The soils of xerothermic and mown meadows on the neovolcanic rocks of central Slovakia were significantly more acidic than that of the mixed forest ($p < 0.05$), probably because of the highest average TOC content in the soil, and eventually because of the high content of basic cations in the soil of the mixed forest.

The content of ammonia nitrogen (N-NH_4^+), originating during the biological decomposition of organic samples in soil, was influenced not only by different types of ecosystem, but also by the season ($F = 13.2885$, $p = 0.001$) (Table 4).

Total nitrogen (N_T) was affected by the land use and decreased from xerothermic meadows to the mixed

forests ($p < 0.001$) following a pattern similar to that shown by TOC ($F = 11.7573$, $p = 0.000$). Soil organic C and N have been proposed as useful indicators of soil quality (ARSHAD and COEN, 1992). A statistically significant difference in the values of N_T was also detected between individual seasons ($p < 0.01$) ($F = 8.0201$, $p = 0.006$). This was probably associated with a different rate of mineralization of the plant material fallout, and the intensity of nutrient uptake by plants (BIELIŃSKA et al., 2008). Mutual interaction of factors of the land use and seasonal differences also affect the content of N_T ($Z = 3.5117$, $p = 0.035$). ISLAM and WEIL (2000) did not detect any statistically significant difference in N_T content between ecosystems (natural forest, reforested land, grassland, cultivated land). The impact between total C and N depends on the type of ecosystem ($F = 46.753$, $p = 0.000$) on the importance level $\alpha = 0.001$, which does not correlate with the ISLAM and WEIL (2000) results, but partially correlates with the results of WRÓBEL et al. (2012). A positive correlation was found between the total nitrogen and inorganic nitrogen content but this was not statistically significant ($r = 0.428$). In the soil of mixed forests, we found a positive correlation between total nitrogen and inorganic nitrogen ($r = 0.618$) at a significance level of $\alpha = 0.05$. A correlation between total and inorganic nitrogen in the soil of the mown meadow ($r = 0.274$, $p = 0.158$) and the xerothermic meadow ($r = 0.311$, $p = 0.170$) was not found. Using the variance analysis, we found statistically significant differences in the content of inorganic nitrogen for different ecosystems ($F = 7.3197$, $p = 0.0013$) (Table 4).

Table 3. Mineral fraction composition of the studied andosols soil types

		Mixed forest		
Structure		Sand (%)	Clay (%)	Silt (%)
2011	Autumn	45.83 ± 7.21	19.59 ± 4.97	34.48 ± 7.99
	Spring	45.83 ± 3.03	18.90 ± 2.83	35.27 ± 2.65
2012	Autumn	50.13 ± 4.65	17.98 ± 3.29	31.88 ± 7.40
	Spring	48.73 ± 3.17	13.77 ± 4.00	37.50 ± 5.84
		Mown meadow		
2011	Autumn	39.22 ± 8.43	30.85 ± 3.77	29.93 ± 8.66
	Spring	36.72 ± 8.47	32.97 ± 6.45	30.30 ± 6.87
2012	Autumn	38.07 ± 9.17	33.57 ± 4.96	28.37 ± 11.17
	Spring	27.40 ± 5.88	33.75 ± 8.61	38.85 ± 7.28
		Xerothermic meadow		
2011	Autumn	44.30 ± 6.08	13.13 ± 3.14	42.58 ± 4.45
	Spring	39.23 ± 5.93	10.40 ± 6.13	50.38 ± 1.54
2012	Autumn	44.63 ± 7.49	15.98 ± 7.37	39.40 ± 3.23
	Spring	34.56 ± 11.85	27.66 ± 18.45	40.96 ± 19.30

Sand – mineral particles of ϕ 2,000–50 μm ; Clay – mineral particles of $\phi < 2 \mu\text{m}$; Silt – mineral particles of ϕ 50–2 μm .

Table 4. Variance analysis of soil chemical characteristics depending on the land use and season with the mutual interaction

	Effect	Test statistics	Significant level
TOC	Seasons	2.8697	0.094904
	Ecosystem	1.9329	0.152717
	Seasons-Ecosystem	1.7632	0.179355
pH _{H2O}	Seasons	0.5990	0.441695
	Ecosystem	7.5001	0.001150**
	Seasons-Ecosystem	0.3258	0.723118
pH _{KCl}	Seasons	3.4283	0.068496
	Ecosystem	18.8866	0.000000***
	Seasons-Ecosystem	0.8907	0.415154
N-NH ₄ ⁺	Seasons	13.2885	0.000522***
	Ecosystem	9.3602	0.000260***
	Seasons-Ecosystem	2.6964	0.074767
N-NO ₃ ⁻	Seasons	1.5472	0.217884
	Ecosystem	3.1105	0.051075
	Seasons-Ecosystem	1.2948	0.280725
N _{in}	Seasons	12.8053	0.000648***
	Ecosystem	7.3197	0.001333**
	Seasons-Ecosystem	2.4611	0.093025
N _T	Seasons	8.0201	0.006103**
	Ecosystem	1.7573	0.000042***
	Seasons-Ecosystem	3.5117	0.035454*
HS	Seasons	2.5397	0.115723
	Ecosystem	2.5041	0.089374
	Seasons-Ecosystem	0.0620	0.939957
HA	Seasons	2.4587	0.121585
	Ecosystem	16.7532	0.000001***
	Seasons-Ecosystem	2.3766	0.100650
FA	Seasons	1.9624	0.165871
	Ecosystem	3.9019	0.024949*
	Seasons-Ecosystem	0.7402	0.480893
H	Seasons	3.1800	0.079093
	Ecosystem	318.4540	0.000000***
	Seasons-Ecosystem	0.0200	0.980594
S	Seasons	4.3164	0.041582*
	Ecosystem	26.1312	0.000000***
	Seasons-Ecosystem	0.0223	0.977990
CEC	Seasons	6.8150	0.011145*
	Ecosystem	191.3430	0.000000***
	Seasons-Ecosystem	0.0170	0.982678
V	Seasons	0.9270	0.339140
	Ecosystem	56.4080	0.000000***
	Seasons-Ecosystem	0.1990	0.819754
Sand	Seasons	6.6883	0.011884*
	Ecosystem	2.8143	0.067049
	Seasons-Ecosystem	2.8211	0.066629

Table 4. Variance analysis of soil chemical characteristics depending on the land use and season with the mutual interaction – continued

	Effect	Test statistics	Significant level
Clay	Seasons	2.7144	0.104129
	Ecosystem	1.1524	0.322073
	Seasons-Ecosystem	1.1436	0.324798
Silt	Seasons	3.0175	0.086967
	Ecosystem	2.7779	0.069340
	Seasons-Ecosystem	2.7664	0.070084
Texture	Seasons	1.6000	0.212172
	Ecosystem	12.5000	0.000025***
	Seasons-Ecosystem	3.7000	0.029227*

Significant differences at *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

TOC, total organic carbon; pH_{H_2O} , active soil reaction; pH_{KCl} , exchange soil reaction; $N-NH_4^+$, ammonium nitrogen; $N-NO_3^-$, nitrate nitrogen; N_{in} , inorganic nitrogen; N_T , total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

The mineralization of organic carbon compounds was also demonstrated by the C : N ratio (KALISZ et al., 2010; MAŁECKA and HILSZCZAŃSKA, 2014). The C : N ratio dropped from about 13 : 15 in the mixed forest to below 8 : 10 in the mown meadow and 5 : 9 in the xerothermic meadow (Table 2). The C : N ratio showed a negative correlation with the inorganic nitrogen ($r = -0.321$) for all types of landscape with a significance level of $\alpha = 0.05$. Soils with a lower C : N ratio have a greater potential to decompose organic material and to release plant nutrients (N, P, K, etc.) into the soil environment (KOÇYIGIT and RICE, 2004). Mineralization is a primarily biological process that converts organic N in decomposing litter to inorganic N in the form of NH_4^+ (PAUL and CLARK, 1996). It can provide up to 75% of the mineral N input in forest soil (BERENDSE et al., 1989). As for decomposition in general, pH, moisture, temperature, and in particular, soil C and N concentrations, and the C : N ratio of the litter material, seem to have the strongest influence on the mineralization rates (ANDERSSON et al., 2002; BOOTH et al., 2005). When decomposing substrates with a high C : N ratio, microorganisms will retain more inorganic N (mainly as NH_4^+) during decomposition, thus reducing the availability of this N pool to plants. Conversely, if the C : N ratio of the substrate is lower than that of the decomposers, microorganisms will increase the size of the mineralized N pool in the soil (BELYAZID et al., 2013).

Even though that difference in TOC content is not impacted by land use, there is a statistically significant difference between individual humic fractions, in terms of humic acid (HA) ($F = 16.7532$, $p = 0.000$) and fulvic acid (FA) ($F = 3.9019$, $p = 0.025$). The connection between HA : FA was not detected as being influenced by land use ($F = 1.0016$, $p = 0.372$). Connexion of

HA : FA in andosols represented values averaging 0.700. In KOBZA's (2008) opinion with regard to andosols, there is a high humic content and, despite its quality, there is a relatively low HA : FA < 1. However, little information is available on the impact of different methods of application in terms of HS on nutrient status, especially in the soil and climate conditions of the temperate zone (OSVALDE et al., 2012).

The soil of a forest ecosystem (mixed forest) has been based on the detected values (cations exchangeable capacity and the sum of basic cations) to the soil with the highest sorption capacity (Tables 2a–c). Variability in terms of the values of CEC and S between a forest ecosystem (mixed forest) and a meadow ecosystem (mown and xerothermic meadows) was statistically significant (Table 4). Hydrolytic acidity was positively correlated to humic substances (humic acid and fulvic acid) in the forest ecosystem.

The sand (36.28 %) and silt (40.07 %) are dominant in the case of grain size of the andosol soil (Table 3). According to KOBZA (2008), the fraction 0.002–0.05 mm (silt) and 0.05–2 mm (sand) dominates in the whole soil profile. According to COVALEDA et al. (2011) the determination of particle-size fractions is useful in studying the effect of land use change on soil carbon stocks, but few studies have been carried out to determine the effect of forest cover depletion on particle-size fractions, and even less so in volcanic soils. Based on our results, land use did not have a statistically significant influence on grain soil structure, which does not agree with the argument of AGOUME and BIRANG (2009), who state that land-use systems significantly affect the clay, silt and sand fractions. The organic matter content of the soil is in positive correlation with the clay fraction (BOSATTA and AGREN, 1997). In our case, TOC was negatively correlated to sand fraction in the

soil of the mixed forest ($r = -0.408$, $p < 0.05$), and in soil of the xerothermic meadow. Within all observed and examined ecosystems, we detected a negative correlation between TOC and clay fraction ($r = -0.230$, $p < 0.05$). TOBIAŠOVÁ et al. (2012) and PAN et al. (2013) detected a negative correlation between TOC and sand

fraction, and a positive correlation between silt and clay fractions. The TOC of grassland (mown and xerothermic meadows) was positively correlated with N_T ($r = 0.960$, $p < 0.05$), which is comparable to the argument of PAN et al. (2013). In the case of mown meadows, with the help of correlation analysis between the

Table 5. The correlation between the parameters of carbon and nitrogen, and parameters of sorption complex, soil reaction and soil fractions

	Ecosystems	pH _{H2O}	pH _{KCl}	H	S	CEC	V	Sand	Clay	Silt	Texture
TOC	MF	0.305	0.567*	0.379	–	–	–	–	–0.015	0.327	–0.178
	MM	–	0.222	–0.067	0.170	0.331	0.269	–0.025	–0.257	0.318	0.153
	XM	–	–	0.296	0.225	0.263	–0.235	–	–0.314	–0.213	–0.154
HS	MF	0.138	0.162	0.529*	–0.331	–0.058	–	–	–0.124	0.401	–0.323
	MM	–	0.083	0.224	0.265	0.255	–0.033	–0.228	–	–0.009	0.191
	XM	–	–	–0.046	–0.037	–0.042	–0.035	–	–0.344	–0.335	–0.181
HA	MF	0.145	0.072	0.568*	–0.374	–0.084	–	–0.357	–0.194	0.407*	–0.299
	MM	–0.206	0.008	0.345	0.483*	0.432*	0.066	–0.367	–	–0.111	0.193
	XM	–	–	0.170	0.035	0.095	–0.385	–	–0.323	–0.360	–0.133
FA	MF	0.126	0.224	0.474*	–0.282	–0.035	–	–	–0.065	0.377	–0.326
	MM	–	0.111	0.146	0.137	0.148	–0.076	–0.140	–	0.040	0.172
	XM	–0.401	–	–0.101	–0.052	–0.075	0.071	–0.431	–0.299	–0.278	–0.168
N-NH ₄ ⁺	MF	0.556*	0.721*	0.147	–	–	–0.366	–0.332	0.162	0.153	–0.264
	MM	–0.364	0.211	–0.065	–0.145	–0.109	–0.146	0.230	–0.205	0.140	0.031
	XM	–	–0.252	0.162	0.066	0.109	–0.272	–0.333	–0.233	0.133	0.223
N-NO ₃ [–]	MF	0.384	0.582*	–0.001	–0.367	–	–0.276	–	0.046	0.288	–0.199
	MM	0.000	–0.146	–0.366	–0.325	–0.362	0.216	0.332	0.063	0.068	0.055
	XM	–0.322	–0.298	–0.056	–0.165	–0.123	–0.244	–0.220	–0.170	0.046	0.160
N _{in}	MF	0.541*	0.730*	0.107	–	–	–0.364	–0.385	0.134	0.212	–0.262
	MM	–0.344	0.185	–0.097	–0.169	–0.138	–0.117	0.250	–0.188	0.139	0.035
	XM	–	–0.264	0.151	0.050	0.096	–0.280	–0.336	–0.237	0.131	0.226
N _T	MF	0.288	0.559*	0.374	–	–0.403	–	–	0.002	0.315	–0.175
	MM	–0.333	0.227	–0.151	0.114	–0.022	0.347	–0.102	–0.209	0.303	0.149
	XM	–	–	0.250	0.203	0.230	–0.185	–	–0.309	–0.317	–0.241
HA:FA	MF	0.085	–0.327	0.150	–0.105	–0.030	–0.142	0.222	–0.237	–0.012	0.098
	MM	0.530*	0.204	–0.050	0.014	–0.019	0.110	0.149	0.283	0.088	–0.132
	XM	0.417	0.317	–	–0.385	–0.434	0.306	0.917*	0.563*	–0.222	–0.230
C : N	MF	–0.256	–	–0.397	0.446*	0.275	0.487*	0.321	–0.030	–0.227	0.097
	MM	0.443*	0.112	0.155	0.094	0.131	–0.127	0.047	–0.020	–0.225	–0.062
	XM	0.303	0.532*	–0.366	–0.238	–0.301	0.369	0.845*	0.558*	0.294	0.241

Significant differences at * $p < 0.05$.

MF, mixed forest; MM, mown meadow; XM, xerothermic meadow; TOC, total organic carbon; pH_{H2O}, active soil reaction; pH_{KCl}, exchange soil reaction; N-NH₄⁺, ammonium nitrogen; N-NO₃[–], nitrate nitrogen; N_{in}, inorganic nitrogen; N_T, total nitrogen; HS, humic substance; HA, humic acid; FA, fulvic acid; H, hydrolytic acidity; S, basic cation; CEC, cation exchange capacity; V, base saturation.

parameters of carbon and nitrogen and the parameters of sorption complex, soil reaction and fractions on the different ecosystems, we detected a negative influence of the clay fraction on the content of humic substances (Table 5). The clay fraction was negatively correlated with humic acids ($r = -0.550$, $p < 0.05$) and also with fulvic acids ($r = -0.440$, $p < 0.05$).

Conclusions

The highest average TOC and basic cations content were in the soil of the mixed forest. The xerothermic and mown meadows were more acidic ($p < 0.05$) than the soil of the mixed forest. In our case, the land use did not influence the TOC values ($F = 1.933$, $p = 0.153$). Humic substances are typical products of humifical transformations. The process of humification is contingent on a whole line of environmental and ecological factors. Locality, soil type, slope relief, season, climate, altitude and also the use of ground cover have a huge impact on the whole process. Statistically significant differences between the monitored ecosystems were found in terms of the humic acid ($F = 16.753$, $p = 0.000$) and the fulvic acid content ($F = 3.9019$, $p = 0.025$). One of the reasons for the creation of humic substances are different herbal and zoological remainders entering the humification process. Humic acids are present in all herbs, soils and animals, and they are a natural part of the food chain, and undertake unchangeable tasks during the transformation of lifeless substances into nutriment. In the mixed forest soil we determined the minimal differences in the TOC content during the monitoring period 2011–2013 (spring, autumn). This is thanks to the regular supply of organic matter in the forest soil from the root system and logging residues.

In the soil of the mixed forest, we found a positive correlation between total nitrogen and inorganic nitrogen ($r = 0.618$) at a significance level of $\alpha = 0.05$. A significant correlation between total and inorganic nitrogen in the soil of the mown meadow ($r = 0.274$, $p = 0.158$) and the xerothermic meadow ($r = 0.311$, $p = 0.170$) was not found. The most important transformations of nitrogen in soil relate to the biological N fixation, which positively affects the forest ecosystem. Nitrogen is bound directly into the soil through the roots.

The forest ecosystem has an important role in the carbon cycle through the transformation of inorganic carbon to organic carbon as well as in the process of accumulation that consists of sequestration, humification and decomposition, which lead to the formation of carbon stocks in the deeper layers of the soil.

Acknowledgement

This work was co-funded by European Community in the frame of project No. 26220220180: Building Research Centre „AgroBioTech” and by the University Grant Agency (Grant No. VIII/10/2015).

References

- AGOUME, V., BIRANG, A.M., 2009. Impact of land-use systems on some physical and chemical soil properties of an oxisol in the humid forest zone of Southern Cameroon. *Tropicultura*, 27: 15–20.
- ALEKSANDROWICZ-TRZCIŃSKA, M., 2005. Stan mikoryz sosny zwyczajnej w uprawie założonej na gruncie porolnym [Mycorrhizae condition of Scots pine in cultivation founded on the basis porolnym]. *Sylvan*, 149: 42–49.
- ANDERSSON, P., BERGGREN, D., NILSSON, I., 2002. Indices for nitrogen status and nitrate leaching from Norway spruce (*Picea abies* (L.) Karst.) stands in Sweden. *Forest Ecology and Management*, 157: 39–53.
- ARMAS-HERRERA, C.M., MORA, J.L., ARBELO, C.D., RODRÍGUEZ-RODRÍGUEZ, A., 2012. Interannual variations of soil organic carbon fractions in unmanaged volcanic soils (Canary Islands, Spain). *Ecology and Evolution*, 2: 2374–2386.
- ARROUAYS, D., DESLAIS, W., BADEAU, V., 2001. The carbon content of top soil and its geographical distribution in France. *Soil Use and Management*, 17: 7–11.
- ARSHAD, M.A., COEN, G.M., 1992. Characterization of soil quality: Physical and chemical criteria. *American Journal of Alternative Agriculture*, 7: 25–31.
- BALKOVIČ, J. 2002. *Soils with andic properties in chosen Slovakian mountains*. PhD thesis. Bratislava: Comenius University in Bratislava, Slovakia. 144 p.
- BELYAZID, U.J., BELYAZID, S., AKSELSSON, C., 2013. *Nitrogen in boreal forest ecosystems – The influence of climate change, nitrogen fertilization, whole-tree harvest and stump harvest on the nitrogen cycle. A report from Belyazid Consulting & Communication*. Appendix to the report Effects of climate change, nitrogen fertilization, whole-tree harvesting and stump harvesting on boreal forest ecosystems – A review of current knowledge and evaluation of how these factors may influence the possibilities to reach the Swedish environmental objectives. 48 p. [cit. 2015-06-30]. <http://belyazid.com/doks/Nitrogencycling.pdf>
- BERENDSE, F., BOBBINK, R., ROUWENHORST, G., 1989. A comparative study on nutrient cycling in wet heath-

- land ecosystems. II. Litter decomposition and nutrient mineralization. *Oecologia*, 78: 338–348.
- BIELIŃSKA, E.J., MOCEK-PLÓCINIĄK, A., KACZMAREK, Z., 2008. Eco-chemical forest soil indices from a forest fire. *Polish Journal of Environmental Studies*, 17: 665–671.
- BIERKENS, M.F.P., DOLMAN, A.J., TROCH, P.A., 2008. *Climate and the hydrological cycle*. IAHS special publications 8. Wallingford, UK: IAHS Press. 344 p.
- BOOTH, M.S., STARK, J.M., RASTETTER, E., 2005. Controls on nitrogen cycling in terrestrial ecosystems: A synthetic analysis of literature data. *Ecological Monographs*, 75: 139–157.
- BOSATTA, E., Ågren, G.I., 1997. Theoretical analyses of soil texture effects on organic matter dynamics. *Soil Biology and Biochemistry*, 29: 1633–1638.
- BRAUN-BLANQUET, J., 1964. *Pflanzensoziologie. Grundsätze der Vegetationskunde*. Wien; New York: Springer-Verlag. 866 p.
- BREMNER, J.M., 1960. Determination of nitrogen in soil by Kjeldahl method. *Journal of Agricultural Science*, 55: 1–23.
- BRONICK, C.J., LAL, R., 2005. Soil structure and management: a review. *Geoderma*, 124 (1–2): 3–22.
- COVALEDA, S., GALLARDO, J.F., GARCÍA, OLIVA, F., KIRCHMANN, H., PRAT, C., BRAVO, M., ETCHEVERS, J.D., 2011. Land-use effects on the distribution of soil organic carbon within particle-size fractions of volcanic soils in the Transmexican Volcanic Belt (Mexico). *Soil Use and Management*, 27: 186–194.
- GALKA, B., LABAZ, B., BOGACZ, A., BOJKO, O., KABALA, C., 2014. Conversion of Norway spruce forests will reduce organic carbon pools in the mountain soils of SW Poland. *Geoderma*, 213: 287–295.
- GÄRDENÄS, A.I., ÅGREN, G.I., BIRD, J.A., CLARHOLM, M., HALLIN, S., INESON, P., KÄTTERER, T., KNICKER, H., NILSSON, S.I., NÄSHOLM, T., OGLE, S., PUSTIAN, K., PERSSON, T., STENDHAHL, J., 2011. Knowledge gaps in soil carbon and nitrogen interactions – from molecular to global scale. *Soil Biology and Biochemistry*, 43: 702–717.
- GÖMÖRY, D., PAULE, L., LONGAUER, R., 2015. Geografické trendy genetickej premenlivosti lesných drevín v Karpatoch [Geographic trends of genetic variety of forest trees in Carpathian Mountains]. In LUKÁČIK, I., SARVAŠOVÁ, I. (eds). *Dendroflóra strednej Európy – využitie poznatkov vo výskume, vzdelávaní a praxi*. Zvolen: Technická univerzita vo Zvolene, 2015, p. 19–29.
- GÜNDOĞAN, R., ÖZYURT, H., AKAY, A.E., 2011. The effects of land use on properties of soils developed over ophiolites in Turkey. *International Journal of Forest, Soil and Erosion*, 1: 36–42.
- HILL, M.O., 1979. *TWINSPAN. A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes*. Ithaca: Cornell University. 90 p.
- HENNEKENS, S.M., SCHAMINÉE, J.H.J., 2001. Turboveg, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science*, 12: 589–591.
- HUDEC, M., HREŠKO, J., 2012. Obsah humusu na pôdach kamenných miest Kremnických vrchov [The content of humus on rocky soils Kremnické vrchy Mts]. *Ekologické štúdie*, 3 (2): 20–27.
- ISLAM, K.R., WEIL, R.R., 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. *Agriculture, Ecosystems and Environment*, 79: 9–16.
- IUSS WORKING GROUP WRB, 2006. *World reference base for soil resources*. 2nd ed. World soil resources report, no. 103. Rome: FAO. 132 p.
- JACKSON, M.L., 2005. *Soil chemical analysis. Advanced course. A manual of methods useful for instruction and research in soil chemistry, physical chemistry of soil, soil fertility and soil genesis*. Madison: University of Wisconsin – Madison Libraries. 930 p.
- JAGODZIŃSKI, A., OLEKSYN, J., 2009a. Ekologiczne konsekwencje hodowli drzew w różnym zagęszczeniu. I. Wzrost i rozwój drzewostanu [Ecological consequences of breeding trees in varying densities I. Growth and development of the stand]. *Sylvan*, 153: 75–85.
- JAGODZIŃSKI, A., OLEKSYN, J., 2009b. Ekologiczne konsekwencje hodowli drzew w różnym zagęszczeniu. II. Produkcja i alokacja biomasy, retencja biogenów [Ecological consequences of silviculture at variable stand densities. II. Biomass production and allocation, nutrient retention]. *Sylvan*, 153: 147–157.
- JANÍK, R., BUBLINEC, E., DUBOVÁ, M., 2014. Space-time patterns of soil pH and conductivity in submountain beech ecosystems in the West Carpathians. *Folia Oecologica*, 41: 141–145.
- JANIŠOVÁ, M., HÁJKOVÁ, P., HEGEDŮŠOVÁ, K., HRIVNÁK, R., KLIMENT, J., MICHÁLKOVÁ, D., RUŽIČKOVÁ, H., ŘEZNIČKOVÁ, M., TICHÝ, L., ŠKODOVÁ, I., UHLIAROVÁ, E., UJHÁZY, K., ZALIBEROVÁ, M., 2007. *Travinno-bylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov* [Grassland vegetation of Slovak Republic – electronic expert system for identification of syntaxa]. Bratislava: Botanický ústav SAV. 263 p.
- JAROLÍMEK, I., ŠIBÍK, J., HEGEDŮŠOVÁ, K., JANIŠOVÁ, M., KLIMENT, J., KUČERA, P., MÁJEKOVÁ, K., MICHÁLKOVÁ, D., SADLOŇOVÁ, J., ŠIBÍKOVÁ, J., ŠKODOVÁ, I., UHLÍŘOVÁ, J., UJHÁZY, K., UJHÁZYOVÁ, M., VALACHOVIČ, M., ZALIBEROVÁ, M., 2008. A list of vegetation units of Slovakia. In JAROLÍMEK, I., ŠIBÍK, J. (eds). *Diagnostic, constant and dominant species of the higher vegetation units of Slovakia*. Bratislava: Veda, p. 295–329.
- JURÁNI, B., BALKOVIČ, J., 2007. *Soil of volcanic regions in Slovakia. Soils of volcanic regions in Europe*. Berlin: Springer, p. 82–102.

- JURGENSEN, M.F., HARVEY, A.E., GRAHAM, R.T., PAGE-DUMROESE, D.S., TONN, J. R., LARSEN, M.J., JAIN, T.B., 1997. Impacts of timber harvesting on soil organic matter, nitrogen, productivity, and health of Inland Northwest Forests. *Forest Science*, 43 (2): 234–251.
- KALISZ, B., LACHACZ, B., GLAZEWSKI, R., 2010. Transformation of some organic matter components in organic soils exposed to drainage. *Turkish Journal of Agriculture and Forestry*, 34: 245–256.
- KOBZA, J., 2008. Poznámky ku genéze andozemných pôd a problém ich klasifikácie [Notes to genesis of andosols and the problems of their classification]. In *Vedecké práce Výskumného ústavu pôdoznanectva a ochrany pôdy č. 30*. Bratislava: Výskumý ústav pôdoznanectva a ochrany pôdy, p. 55–61.
- KOÇYIGIT, R., RICE, Ch.W., 2004. Carbon dynamics in tallgrass prairie and wheat ecosystems. *Turkish Journal of Agriculture and Forestry*, 28: 141–153.
- KONONOVA, M.M., 1966. *Soil organic matter. Its nature, its role in soil formation and in soil fertility*. London: Pergamon Press. 544 p.
- KONONOVA, M.M., BELČIKOVA, N.P., 1962. Uskorenyje metody opredelenija sostava gumusa mineralnyh počv [Simplified methods of humus determination in mineral soils]. *Počvovedenije*, 10: 75–87.
- KWAŚNA, H., BRZESKI, M.W., SIEROTA, Z., 2001. Mikroorganizmy środowiska glebowego odłogujących gruntów porolnych – zmiany w zbiorowiskach grzybów i nicieni po dodaniu trocin iglastych [Microorganisms of soil environment fallow former farmland – changes in the communities of fungi and nematodes after adding sawdust conifers]. In DAHM, H., POKOJSKA, A. (red.). *Drobnoustroje środowiska glebowego – aspekty fizjologiczne, biochemiczne, genetyczne*. Toruń: Wyd. A. Marszałek, p. 57–66.
- KWAŚNA, H., SIEROTA, Z., BATEMAN, G.L., 2000. Fungal communities in fallow soil before and after amending with pine sawdust. *Applied Soil Ecology*, 14: 177–182.
- LAL, R., 2000. Soil management in developing countries. *Soil Science*, 165: 57–72.
- LIU, X.L., HE, Y. Q., ZHANG, H.L., SCHRODER, J.K., LI, C.L., ZHOU, J., ZHANG, Z.Y., 2010. Impact of land use and soil fertility on distributions of soil aggregate fractions and some nutrients. *Pedosphere*, 20: 666–673.
- MAŁECKA, M., HILSZCZAŃSKA, D., 2014. Changes in ectomycorrhizal structure of Scots pine growing on abandoned farmland soil enriched with organic substrates. *Sylvan*, 158: 243–250.
- MARHOLD, K., HINDÁK, F., 1998. *Zoznam nižších a vyšších rastlín Slovenska* [Checklist of non-vascular and vascular plants of Slovakia]. Bratislava: Veda. 687 p.
- MARTELLOTTA, A., 2010. *The impact of long-term tillage, crop rotation and N application on soil carbon sequestration*. Theses, dissertations and student research in agronomy and horticulture. Lincoln: University of Nebraska. [94 p.] [cit. 2015-05-30]. <http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1022&context=agronhortdiss>
- MORA, J.L., GUERRA, J.A., ARMAS-HERRERA, C.M., ARBELO, C.D., RODRÍGUEZ- RODRÍGUEZ, A., 2014. Storage and depth distribution of organic carbon in volcanic soils as affected by environmental and pedological factors. *Catena*, 123: 163–175.
- MUTSOTSO, B., MUYA, E.M., 2008. Characteristics of below-ground biodiversity sites in Kenya: Their constraints, interventions and emerging issues. *Tropical and Subtropical Agroecosystems: An International Multidisciplinary Journal*, p. 991–1003.
- NAVARRETE, I.A., TSUTSUKI, K., NAVARRETE, R.A., 2010. Humus composition and the structural characteristics of humic substances in soils under different land use in Leyte, Philippines. *Soil Science and Plant Nutrition*, 56: 289–296.
- NERIS, J., JIMÉNEZ, C., FUENTES, G., MORILLAS, G., TEJEDOR, M., 2012. Vegetation and land-use effects on soil properties and water infiltration of Andisols in Tenerife (Canary Islands, Spain). *Catena*, 98: 55–62.
- NOVÁK, P., KHEL, T., VOPRAVIL, J., LAGOV, J., 2010. Do andosols occur in the Czech Republic? *Soil and Water Research*, 5: 161–171.
- NOZDROVICKÝ, L., RATAJ, V., GALAMBOŠOVÁ, J., KOLÁŘOVÁ, K., MACÁK, M., HALVA, J., TUČEK, J., KOREŇ, M., SMREČEK, R., 2008. *Presné pôdohospodárstvo: implementácia s podporou informačných technológií a techniky* [The precision agriculture: the implementation of information technology support and technology]. Nitra: Slovenská poľnohospodárska univerzita. 168 p.
- ORLOV, D., GRIŠINA, L.A., 1981. *Praktikum po chemiji gumusa* [Chemical book of exercises for humus analyzing]. Moscow: Izdatel'stvo Moskovskovo universiteta. 124 p.
- OSTROWSKA, A., PORĘBSKA, G., 2012. Assessment of TOC-SOM and SOM-TOC conversion in forest soil. *Polish Journal of Environmental Studies*, 21: 1767–1775.
- OSVALDE, A., KARLSONS, A., ČEKSTERE, G., MAŁECKA, S., 2012. Effect of humic substances on nutrient status and yield of onion (*Allium cepa* L.) in field conditions. *Proceedings of the Latvian Academy of Sciences*, 66 (4/5): 192–199.
- PACH, M., BARTKOWICZ, L., SKOCZEŃ, W., 2001. Charakterystyka cech biomorfologicznych świerka w borze górno-głowym Pilska w zależności od budowy i struktury drzewostanów [Characteristics of bio-morphological features of spruce in high mountain spruce forest in the Pilsko depending on the structure of the forest stands]. *Sylvan*, 145: 23–37.
- PAN, CH., ZHAO, H., ZHAO, X., HAN, H., WANG, Y., LI, J., 2013. Biophysical properties as determinants for

- soil organic carbon and total nitrogen in grassland salinization. *PLoS One*, 8 (1): e54827.
- PAUL, E. A., CLARK, F.E., 1996. *Soil microbiology and biochemistry*. 2nd ed. San Diego, USA: Academic Press. 340 p.
- RADOV, A.C., PUSTOV, I.V., KOROLEV, A.V., 1985. *Praktikum po agrochimiji* [Agro-chemical book of exercises]. Moskva: Agropromizdat.
- RYAN, J., 1998. Changes in organic carbon in long-term rotation and tillage trials in northern Syria. In LAL, R., KIMBLE J.M., FOLLET, J.M., STEWART, R.F. (eds). *Management of carbon sequestration in soil*. Advances in soil science. New York: CRC Press, p. 285–296.
- RYAN, J., MASRI, S., IBRIKÇI, H., SINGH, M., PALA, M., HARRIS, H.C., 2008. Implications of cereal-based crop rotations, nitrogen fertilization, and stubble grazing on soil organic matter in a Mediterranean-type environment. *Turkish Journal of Agriculture and Forestry*, 32: 289–297.
- SAKBAEVA, Z., ACOSTA-MARTÍNEZ, V., MOORE-KUCERA, J., HUDNALL, W., NURIDIN, K., 2012. Interactions of soil order and land use management on soil properties in the Kukart watershed, Kyrgyzstan. *Applied and Environmental Soil Science*, 12: Article ID 130941.
- ŠLEPETIENĖ, A., ŠLEPETYS J., LIAUDANSKIENĖ I., 2010. Chemical composition of differently used Terric Histosols. *Zemdirbystė-Agriculture*, 97 (2): 25–32.
- SOCHA, J., ZASADA, M., 2014. Zagęszczenie i dynamika procesu wydzielania drzew w młodocianych drzewostanach brzoźowych na gruntach porolnych [Stand density and self-thinning dynamics in young birch stands on post-agricultural land]. *Sylwan*, 158: 340–351.
- TICHÝ, L., 2002. Juice, software for vegetation classification. *Journal of Vegetation Science*, 13: 451–453.
- TOBIÁŠOVÁ, E., DEBSKA, B., BANACH-SZOTT, M., 2012. Influence of particle size distribution of soil on quantity and quality of soil organic matter. *Acta Fytotechnica et Zootechnica*, 1: 13–18.
- VAN DER MAAREL, E., 1979 Transformation of cover-abundance values in phytosociology and its effects on community similarity. *Vegetatio*, 39: 97–114.
- VAN REEUWIJK, L.P., 2002. (ed.). *Producers for soil analysis*. Technical Paper (International Soil Reference and Information Centre), no. 9. Wageningen: International Soil Reference and Information Centre [cit. 2015-06-12]. http://www.isric.org/isric/web-docs/docs/ISRIC_TechPap09_2002.pdf
- WRÓBEL, M., GREGORCZYK, A., WRÓBEL, J., 2012. The effect of chemical soil properties on weed infestation structure in willow (*Salix L.*) short-rotation coppice. *Polish Journal of Environmental Studies*, 21: 1893–1899.

Received July 16, 2015

Accepted November 19, 2015

Impact of weather and habitat on the occurrence of centipedes, millipedes and terrestrial isopods in mountain spruce forests

Martin Lazorík, Emanuel Kula*

Department of Forest Protection and Game Management, Faculty of Forestry and Wood Technology,
Mendel University Brno, Zemědělská 3, 613 00 Brno, Czech Republic

Abstract

LAZORÍK, M., KULA, E., 2015. Impact of weather and habitat on the occurrence of centipedes, millipedes and terrestrial isopods in mountain spruce forests. *Folia Oecologica*, 42: 103–112.

Microclimatic factors (air temperature, soil temperature and moisture in the Ah and B horizons) were determined using AMET weather stations and VIRRIB sensors on four sites in the Moravian-Silesian Beskids (Czech Republic) in 2007–2014. Simultaneously, pitfall traps were installed to monitor epigeic activity of myriapoda (Diplopoda and Chilopoda) and terrestrial isopods (Oniscidea). No statistically significant relationship was found between the occurrence of epigeic macrofauna and the microclimate of the studied forest stands. A linear curve was fitted to the data, demonstrating an increase in air temperature by 2.9 °C and a decrease in moisture by 4.49% over the eight years of monitoring. In this period, the catch of the studied groups of macrofauna decreased while the diversity of the monitored communities increased. Increasing temperature led to the occurrence of synanthropic species *Porcellio scaber* and the decline of montane centipede species such as *Lithobius tenebrosus* and *Lithobius borealis*.

Keywords

Chilopoda, Diplopoda, forest soil, moisture, Moravian-Silesian Beskids Mts, Oniscidea, temperature

Introduction

In the past few decades, the course of weather has been regarded as a factor of the environment which is undergoing global change affecting the ecosystems. These changes are quantified on the basis of direct measurement of climatic factors and indirectly through the response of fauna and flora. The influence of climate on soil fauna was monitored through myriapods and terrestrial isopods, which are known to react sensitively to developing site conditions – both to changes in temperature and decreasing moisture (AUERBACH, 1949; FRÜND, 1987; BLOWER, 1951; LEWIS, 1981). The abundance and diversity of edaphic zoocenosis depends on soil moisture content as affected by thick-

ness of the surface humus (JABIN, 2008) or by snow cover depth (TEMPLER et al., 2012). It is presumed that the rising temperature may not only increase the abundance of invertebrates but also extend their distribution area and the ability to reproduce (RODENHOUSE et al., 2009; LADANYI and HORVATH, 2010). The influence of snow cover on the centipede community in the permafrost conditions of the northern parts of the USA was described by TEMPLER et al. (2012). Myriapods are confirmed to have a wide temperature tolerance (0–32 °C) (PFLEIDERER-GRUBER, 1986), allowing the representatives of centipedes to remain at the temperature –3 °C for the period of 7 days (LAVY and VERHOEF, 1996). Some species require low temperature limits to develop larval stages (between –6 and +3 °C) (TOPP, 1994). Low snow

*Corresponding author:
e-mail: kula@mendelu.cz

depth or late arrival of snow cause freezing of the upper soil layers, which can induce changes in the quantity of edaphic macrofauna (BALE and HAYWARD, 2010). Changes in the quantity of edaphic macrofauna may be related to deviations in the amount of carbon and its cycle or the nutrient content in forest soils, since the majority of its representatives significantly contribute to the decomposition of organic matter (TEMPLER et al., 2012). Invertebrates increase the degree of decomposition (SEASTEDT and CROSSLEY, 1983; HÄTTENSCHWILER and GASSER, 2005; WALL et al., 2008; ROUFED et al., 2010) and mineralisation (VERHOEF and BRUSSAARD, 1990) and stimulate microbial respiration (HANLON and ANDERSON, 1979; KANEDA and KANEKO, 2008).

Using long-term measurements of microclimatic data and simultaneous monitoring of the epigeic part of soil macrofauna in four sites located in forest stands with different site conditions, we tested some hypotheses of the effect of weather on soil fauna via statistical methods.

Questions to be solved: (*) Is it possible to use the basic linear trend evident from the climatic data for 2007–2014 for simple determination of increase or decrease in temperature and moisture in the studied soil environment?

(*) Is there any correlation between the catch rate of epigeic macrofauna and the climatic factors?

(*) What impact do climatic factors have on the course of temperature and moisture in the soil environment in complex with other factors of the environment?

Material and methods

Study area and sites

In the northeastern part of the Czech Republic in the Moravian-Silesian Beskids (1,160 km²), permanent research areas were set up in the Smrk and Kněhyně massifs and along the Čeladenka mountain river. A specific feature of the area is the homogenous, moderately rich bedrock consisting of sandstones and slates of the external flysch and the Magura flysch. On the abnormally thick layer of weathered parent material, there are soils with a trophic range from oligo-basic (Cryptopodsols and Podsols) to eu-mesobasic soils (Cambisols, Ranker) and with a hydric range from soils without hydromorphic influence to soils permanently affected by water (Histosol). Steep slopes (14–15° on average) predominate and the whole area is under the influence of high precipitation (>1,000 mm). The climate and the soil types present strongly affect the hydrological situation of the area (the average outflow rate 20–30 m³ s⁻¹). The climate is characterised by average annual precipitation of 690–934 mm, mean annual temperature of 2.6 °C, temperature minimum in January (–6.1 °C) and maximum in July (11.7 °C), with absolute temperature minimum –30.9 °C and absolute temperature

maximum 29.5 °C (Lysá hora weather station of CHMI, 1,323 m asl).

The Pěkná forest site (49°29′01.9″N; 18°21′23.0″E) is characterised by a two-storey forest stand, with the upper layer consisting of Norway spruce of 98 yrs and with 95% canopy closure. The understorey consists of six-year-old beech (80%) and of four-year-old fir (20%). The studied area is located below a forest road on a gentle mountain ridge in the central part of the Smrk massif that reaches the maximum altitude of 1,276 m asl. The soil environment is characterised by Haplic Podsols with mor humus form, the height of the soil profile is 70 cm. The parent rock is flysch fine-grained muscovite sandstone (Table 1).

The Stolová ridge site (49°30′31.7″N; 18°19′24.3″E) is located on a steep mountain ridge above the Korabský stream, which continues across the territory of the Malá Stolová mountain (1,009 m asl). The forest stand consists of 88% spruce with admixed beech, larch and birch aged 89 with full canopy closure. The soil environment is characterised by Leptosols with moder humus form, with the soil profile reaching 80 cm in depth. The parent rock is flysch sandstone with 10–30% of the area covered by boulders forming a talus field (Table 1).

The Čeladenka valley site (49°29′55.2″N; 18°20′26.1″E) represents the alluvium of the main stream “Čeladenka”, where the vegetation consists of single-storey forest stand with spruce aged 70 yrs. The site gets flooded sporadically, after prolonged rainfall (2011). The soil is characterised by Fluvisols with moder humus form, with the soil profile reaching 80 cm in depth. The parent rock consists of alluvial sediment currently reaching up to 4 m above the water level in the stream (Table 1).

The Skalka mound site (49°31′38.5″N; 18°23′12.9″E) is located on an isolated conical elevation reaching 613 m asl and situated in the main valley of the mountain massif. The forest stand is formed of spruce monoculture aged 95 yrs. The soil environment is characterised by Leptosols with mor humus form, with the soil profile reaching 60 cm in depth. The parent rock is flysch quartziferous sandstone with 50–70% of the area covered by boulders forming a talus field (Table 1).

Sampling of epigeic macrofauna

Epigeic macrofauna was captured using five pitfall traps per site (4,000 ml glasses, 263 mm height, 93 mm hole diameter, covered by a tin roof, 4% solution of formaldehyde) situated in a line within each stand with 10 m spacing. After installation of the traps (1 May), the catch was monitored at six-week intervals for seven successive seasons (15 June, 31 July, 15 September and 28 October, from 2007 to 2013). On each of the dates, a mixed sample was obtained by combining specimen from all five traps on the site. The sample was preserved

Table 1. Environmental factors characterising the model sites in 2007–2014

Environmental factor		Pěkná forest	Stolová ridge	Čeladenka valley	Skala mound
Temperature air	°C	7.2	7.9	8.2	8.6
Temp. max	°C	30.6	30.4	34.1	32.1
Temp. min	°C	−21.0	−31.5	−15.9	−17.8
Temp. soil 1	°C	6.62	7.07	7.61	8.23
Temp. soil 1_max	°C	17.1	22.5	15.8	16.3
Temp. soil 1_min	°C	−1.4	−3.6	−0.4	−0.3
Temp. soil 2	°C	6.74	7.06	7.86	8.61
Temp. soil 2_max	°C	18.4	16.6	17.0	19.9
Temp. soil 2_min	°C	−2.3	−3.6	−1.6	−2.4
Moisture 1	%	26.85	14.26	26.62	21.35
Moisture 1_max	%	38.1	27.5	49.2	36.4
Moisture 1_min	%	15.2	5.5	12.6	6.1
Moisture 2	%	24.74	20.27	21.16	17.09
Moisture 2_max	%	41.7	25.5	42.6	26.5
Moisture 2_min	%	10.6	6.8	12.9	6.4
Exposition		E	E	NE	SE
Depth of sensors HA	cm	10	15	12	20
Depth of sensors HB	cm	25	40	18	30
Altitude	m	880	800	560	600
Type of soil		Haplic Podzols	Leptosols	Fluvisols	Leptosols
Skeleton	%	29.2	53.7	11.7	54.6
Trees		Norway spruce			

in 75% ethanol. Subsequently, it was processed in a laboratory where the representatives of myriapods and isopods were determined to the species level. For the analysis of the effect of climate, total annual sums of specimen trapped at each site were used.

Seasonal activity of the myriapoda and terrestrial isopod communities was evaluated for each of the seasons studied. The diversity was expressed by the Shannon–Weaver index for individual seasonal phases (spring 1 May–15 June, summer 16 June–31 July, late summer 1 August–15 September, autumn 1 October–31 November).

Microclimatic factors

Air temperature was measured by a PRO V2 temperature sensor placed under a shade and installed onto a shaded side of a tree trunk at the height of 2 m above ground (Fig. 1), at a distance of 20 cm from the trunk. To measure soil temperature, two sensors were used which were inserted into the centre of the monitored soil layer (Ah – horizon 1 and B – horizon 2) after exposing the soil profile. The sensors were covered with sifted soil to eliminate contact with stones (Fig. 1). The depth of the individual sensors ranged between 10 and 50 cm. The sensors (air temp., TEPH1, TEPH2) were

connected to a MetoUNI datalogger where the measured values were recorded at hourly intervals.

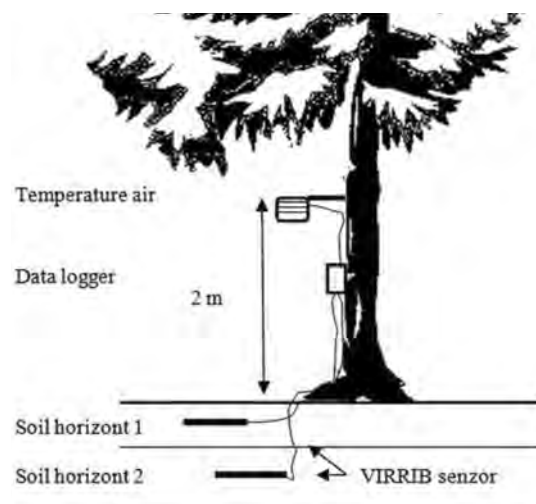


Fig. 1. Technical implementation of installation of AMET weather station with air temperature, soil temperature and soil moisture measurement.

Soil moisture was determined by measuring the resistance of soil by a Virrib sensor (Amet Velké Bí-

lovice) of the weather station. One moisture sensor was located in the centre of the organomineral topsoil (Ah horizon), the other one in the centre of the subsoil layer (B horizon) (Fig. 1). The measurement allows to determine the volumetric soil moisture content in the range 5–50%. The values were recorded by the datalogger at 60 minute intervals (4/2007–10/2014). Volumetric soil moisture represents the ratio between the water content in soil and the total volume of the measured soil.

Average daily values were determined as arithmetic averages from a set of 24 measurements over the course of one day for the measured quantities (air temp., TEPH1, TEPH2, Moist1, Moist2). From a network of 30 stations, four representative areas were selected (based on integrity of measurement and site conditions).

Data analysis

ALA Connect software allowed download of the measured data from the weather station. Daily averages from the individual sensors were processed in Excel. Mutual correlation between the measured temperatures, soil moisture and capture rate of individual representatives of millipedes, centipedes and terrestrial isopods in pitfall traps was tested. To determine the trends in the obtained data, linear regression was used. Statistically significant similarity of the environmental data with the occurrence of macrofauna representatives was sought based on a correlation matrix.

Seasonality of the macrofauna occurrence was evaluated via one-way ANOVA based on the degree of variance. A hypothesis on the inequality of variance in individual monitored sites was expressed via STATISTICA 10.0 software. The Shannon-Weaver diversity index, calculated for each site and season separately, was used to describe the population. Due to the statistically significant variance, a multiple comparison Tukey's HSD test of homogenous groups was performed. The result was estimation of the variability of variance in individual sites and the differentiation of groups with different values of soil moisture.

The significance of the individual environmental factors was compared via principal component analysis (PCA). The basic principle of the analysis is substitution of the original variables by a set of new (hypothetical) variables summarising variance of the original variables. The new variables are called the principal components and are a linear combination of the original variables. The principal components are determined via sequential search for the highest variability with the highest explanation of variance. The result of the PCA is a matrix of covariance coefficients with the determination of eigenvalues and the associated eigenvectors of the matrix (HARUŠTIAKOVÁ et al., 2012). We have analysed environmental variables associated with the microclimate of the soil environment (air temp.,

TEPH1, TEPH2, Moist1, Moist2, exposition, altitude, ToS, Skel., aspect).

The influence of two sets of variables was tested. The matrix of independent variables of ecological data – environmental variables (air temp., TEPH1, TEPH2, Moist1, Moist2, exposition, altitude, ToS, Skel., aspect) and the matrix of dependent variables represented by species captured in pitfall traps. A canonical correspondence analysis (CCA) was applied which uses multidimensional regression to determine the linear combination of variables that best explain the inertia of the ordination scores obtained from the dependent variables (LEPŠ and ŠMILAUER, 2003). The testing of hypotheses in CCA was performed using the strength of the permutation test. The statistics were carried out in CANOCO for Windows 4.5 software which allows for the analysis of test strength using the Monte-Carlo permutation test with 999 repetitions. The test strength testing with the individual environmental variables was done using a “forward selection” function, where the first eigenvalue is compared with the appropriate statistic obtained from random permutations of the data. The result of the CCA is an ordination diagram in which the species and samples are indicated by individual points (HARUŠTIAKOVÁ et al., 2012).

Abbreviations: Air temp., air temperature measured at 2 m above the ground; TEPH1, soil temperature in the central depth of Ah horizons; TEPH2, soil temperature in the central depth of B horizons; Moist1, volumetric soil moisture in the central depth of Ah horizons; Moist2, volumetric soil moisture in the central depth of B horizons; Exposition, exposition of the research area; Altitude, height above sea level; ToS, type of soil according to WRB, 2006 (The World Reference Base for Soil Resources); Skel., percentage content of soil skeleton in the topsoil with particle size of >2 mm; Aspect, seasonal occurrence of the captured species; SW, Shannon-Weaver diversity index.

Results

Climatic factors 2007–2014

During the reporting period, the mean air temperature was 7.97 °C, the difference between the lowest and the highest situated study site being 1.4 °C. The lowest temperature (–31.5 °C) was measured at the Stolová ridge site (20 December 2009, 21:00), after previous eight days of frost with subsequent slight warming. The highest temperature (34.1 °C) was measured at the Čeladenka valley site (8 August 2013, 14:00) during 10 days of warm weather in late July/early August (Table 1). The soil temperature in topsoil (Ah horizon) did not fluctuate as widely when compared to air temperature. The mean soil temperature of 6.62–8.23 °C was 0.6–0.83 °C higher than the average air temperature.

The lowest temperature in the topsoil was measured at the Stolová ridge site along with the lowest air temperature. The highest soil temperature (22.5 °C) was determined at the Stolová ridge site (15 July 2010, 16:00). The mean soil temperature (6.74–8.61 °C) in the subsoil (B horizon) was higher by 0.12–0.38 °C when compared to the topsoil (Ah). The lowest temperature ranged between –3.6 and –1.6 °C [Pěkná forest –2.3 °C (8 March 2011), Stolová ridge –3.6 °C (23 February 2011), Čeladenka valley –1.6 °C (8 March 2011) and Skalka mound –2.4 °C (26 February 2011)]. The highest temperatures in the subsoil (B) were within the range of 19.9 and 16.6 °C.

The sites differed significantly by their maximum values of volumetric soil moisture (27.5–49.2%) from the measured average volumetric soil moisture (14.26–26.85%). The highest value was recorded at the Čeladenka valley site (49.2%, 24 June 2014). During the studied seven-year period, the mean annual air temperature increased by 2.9 °C.

Influence of weather on soil macrofauna

Mutual comparison allowed to calculate a correlation matrix for the individual sites to define the relationship between air temperature, soil temperature, soil moisture and the capture rate of macrofauna in pitfall traps. A correlation between air and soil temperature was confirmed ($r = 0.923$ to $r = 0.991$). With increasing temperature, soil moisture decreased. Fitting of the individual curves of weather development and capture rate of macrofauna did not reveal a statistically significant relationship to the course of temperature. Visual comparison revealed a slight similarity in the development of soil moisture and increase in the occurrence of macrofauna, but with a partial time delay after the period of increased moisture. Only at the Čeladenka valley site, there was a correlation between the captured macrofauna and air temperature ($r = 0.437$, Table 2) and soil temperature in the topsoil (Ah) layer ($r = 0.416$) and the subsoil (B) layer ($r = 0.397$).

Seasonality effect

Due to the course of weather throughout the year, when the changing temperature delineates a curve similar

to a sinusoid, an influence of the seasonal aspect on the development of soil macrofauna population was found. The variance of occurrence of a species was analysed by one-way ANOVA where the hypothesis of equality of variance in mean values of the basic dataset was rejected by a test criterion ($F = 6.3675$ and $p = 0.00051$, Fig. 2). Using a Tukey's HSD test of multiple comparisons, a statistically significant difference was detected in the Summer set. Species diversity was determined in parallel (Shannon-Weaver index) for the population captured in spring ($SW = 1.853$), summer ($SW = 2.213$), late summer ($SW = 2.113$) and autumn ($SW = 2.156$). The highest species diversity was detected in the summer season.

The effect of environmental variables

The determination of the effect of individual environmental variables was performed via PCA which was explained using four canonical axes. Based on the fact that axis 1 explained 79.33% of the variance in the original data matrix, we can consider only the first component. Axis 2 explained 8.72% of the variance, followed by axis 3 with 7.21% and axis 4 with 4.74% of the variance of the original data. From the values of explained variance from the correlation matrix it follows that the important components are altitude ($r = 0.389$) and type of soil ($r = 0.304$). Another significant component was soil moisture, where the moisture in the subsoil (B horizon) was more significant ($r = 0.229$) than in the topsoil (Ah horizon) ($r = 0.153$). Soil and air temperature reached only very low values of explained variance.

The relationship between the representation of the captured centipede, millipede and terrestrial isopod species in the samples and the environmental variables was analysed using canonical correspondence analysis. In the ordination space, the first canonical axis explained 12.9% of total variability (Fig. 3), which was statistically significant ($F = 2.185$, $p = 0.001$), since the first axis was very well correlated with the environmental data ($r = 0.829$). In our case, the first canonical axis can be interpreted as a gradient of the site, from eastern exposition ($r = 0.608$) with skeleton content ($r = 0.457$) and slightly higher air temperature ($r = 0.180$) to the site with lower altitude ($r = -0.579$), more favourable fluvisol conditions ($r = -0.518$) and higher soil moisture

Table 2. Correlation coefficients between the environmental factors and the occurrence of macrofauna

Variable	Pěkná forest	Stolová ridge	Čeladenka valley	Skalka mound
Temperature	–0.0692	0.1906	0.4372	0.1326
Temp. soil 1	–0.0337	0.2791	0.4159	0.1161
Temp. soil 2	–0.0387	0.3244	0.3968	0.1289
Moisture 1	0.0635	–0.2220	–0.0343	0.0892
Moisture 2	0.0289	–0.1006	–0.2089	0.0663

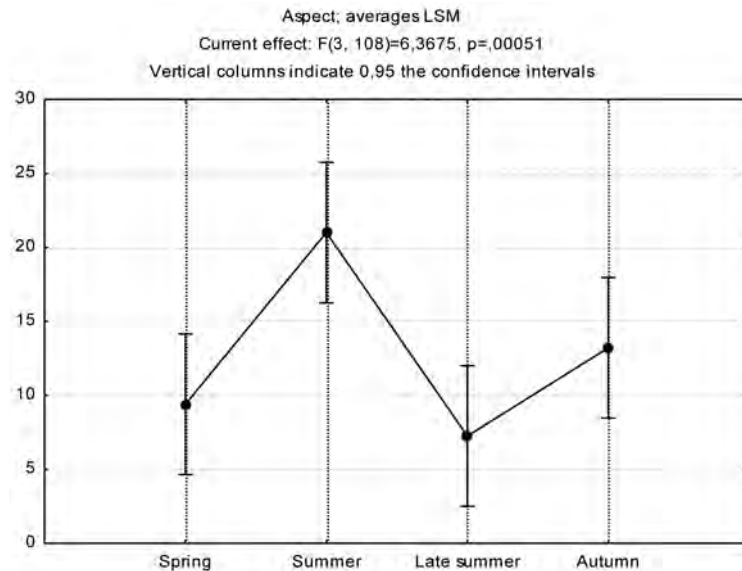


Fig. 2. Significance of congruence of median variance of the basic set of samples expressed via the seasonal aspect factor.

($r = -0.382$). The gradient of the second canonical axis best characterises correlations with the soil moisture ($r = 0.396$) and the type of soil ($r = 0.377$) variables. The selected environmental variables explain 22.24% of the total inertia of species data. The environmental variables which significantly influence the variability of animal communities were determined via forward selection, the most significant variables being exposition, altitude and type of soil while temperature, moisture and seasonality were of reduced significance (Table 3).

As regards the studied species of the Chilopoda group, they occur more frequently on sites with lower content of skeleton and good hydrologic regime in medium and higher positions (Fig. 3). As regards the relation to temperature, Chilopoda are more resistant to lower temperatures and do not suffer from frost. In

contrast, Diplopoda occurred in medium and lower altitudes on soils with higher content of humus and higher temperatures as well as with a good hydric regime (Fig. 3). The Isopoda were more frequent on sites with southeastern exposure with soil type Leptosols and with boulders on the surface. This site was characterized by warm climate but good hydric conditions (Fig. 3).

Discussion

Weather course

Climatic factors were measured under a mature spruce stand. Therefore, the general patterns of temperature and moisture course in a forest ecosystem must

Table 3. Environmental variables driving animal communities: percentages of explained variability, significance and inclusion in manual forward selection (FW). CCA ordination of log-transformed and body size-weighted data

Variable	Variability explained (%)	F	P	FW selection
Exposition	18.34	7.471	0.001	+
Altitude	16.91	6.887	0.001	+
Type of soil	15.36	6.254	0.001	+
Skeleton	11.95	4.867	0.001	+
Moist 2	11.82	4.812	0.001	+
Temp. air	6.63	2.700	0.001	+
Moist 1	6.09	2.482	0.005	+
TEPH2	4.85	1.974	0.008	
Aspect	4.81	1.960	0.117	
TEPH1	3.24	1.319	0.197	

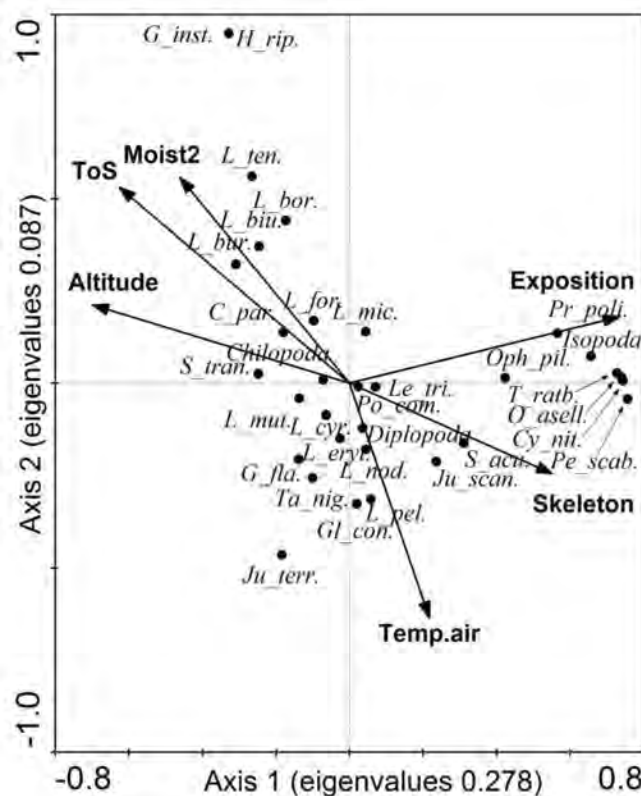


Fig. 3. Effectiveness of environmental variables depending on the capture rate, substantiated by canonical correspondence analysis in the ordinance diagram.

be characterised. Temperature stratification of the atmosphere in the forest stand changes throughout the day and the season. Due to the broken surface of the stand, the effect of air flow is subdued and absorption of photoactive radiation affects the temperature in the stand (ARYA, 2001). Total moisture of the stand also increases due to soil moisture as well as moisture released during transpiration of plants when compared to open areas (forest-free areas) (HAYASHI, 1983; HURTALOVÁ et al., 2003). Based on the measured climatic factors, we can assert an increase of the average temperature at the local scale by up to 2.9 °C over the period of seven years, which is in accordance with the generally reported global trend of warming (WARDLE et al., 2004; TEMPLER et al., 2012). As expected, when comparing the air temperature and soil temperature in both soil horizons, a positive correlation was demonstrated, even though the amplitude in soil temperature was smaller than in air temperature. This was the case especially in winter seasons when the continuous snow layer acts as thermal insulation. Soil moisture content changed inversely proportional to the course of air temperature. Therefore, over the course of the study, an increase in average air temperature was detected, followed logically by a decrease in moisture of the soil environment. The increase in temperature led to a gradual increase in the occurrence of synanthropic species of soil macrofauna

Porcellio scaber. *Porcellio scaber* is a species with wide ecological valence occurring in sites under anthropogenic influence (TUF and TUFOVÁ, 2008). Simultaneously, a decreased occurrence of the species inhabiting montane and submontane areas (*Lithobius tenebrosus*, *Lithobius borealis*) was observed. *Lithobius tenebrosus* has been described as a species associated with trunks of coniferous trees (SCHATZMANN, 1990; TAJOVSKÝ, 2001; KULA and LAZORÍK 2014). *Lithobius borealis* is a species typical of montane and submontane spruce stands linked to tree bark (SUMMERS and UETZ, 1979; SPELDA, 1999; BLACKBURN et al., 2002; KULA and LAZORÍK, 2014).

Effects of microclimatic factors on macrofauna

The effects of weather on the occurrence of macrofauna communities are reported on by AUERBACH (1949, 1951) and FRÜND (1987). Positive relationship to moisture has been established for representatives of centipedes, millipedes and especially terrestrial isopods based on the understanding of their morphology, mainly their epicuticle structure (LEWIS, 1981; HOPKIN and READ, 1992; WIRKNER and PASS, 2002). If the top wax layer of the epicuticle is noticeably missing (BLOWER, 1951; MEAD-BRIGGS, 1956) and the breathing spiracula are not sufficiently formed, evaporation increases (LEWIS,

1963; CURRY, 1974). Our results are in agreement with a number of studies which demonstrate a relationship between invertebrates and sites with increased soil moisture (ALBERT, 1983; FRÜND, 1987; CLOUDSLEY-THOMPSON and CRAWFORD, 1970; JABIN, 2008).

For centipedes in the temperate zone, a very wide temperature valence and tolerance was reported (ALBERT, 1983). *Lithobius forficatus* showed activity in a temperature range between 0–32 °C (PFLEIDERER-GRUBER, 1986), and even survived frost of –3 °C for one week without any damage (LAVY and VERHOEF, 1996). Temperature tolerance is confirmed by results of laboratory breeding (JABIN, 2008), where the abundance of centipedes did not correlate with temperature data. Since no temperature threshold of activity has been defined for individual centipede species, a sum of effective temperatures could not be used. Therefore, their activity was assessed only as a sum of the numbers of their occurrences at a site in the reference growing season. The seasonal aspect was observed, which defined the summer period (June–July) as the most appropriate for the activity of centipedes, since it also features the highest rainfall. Extreme temperatures have no effect on the abundance of macroarthropods (JABIN, 2008). It was found out that millipedes (DAVID et al., 1996), isopods (TANAKA and UDAGAWA, 1993) and rove beetles (TOPP, 1978) can survive hypothermia at the temperature between –4 and –5 °C. In our study sites, soil freezing down to a depth of 12 cm was detected only in 2011 when no snow cover formed even at higher elevations. Therefore, an increased mortality in soil arthropods cannot be ruled out, since snow cover fulfils an insulating function (BALE, 1991). Certain limited level of activity of macroarthropods cannot be excluded even under the snow cover.

To demonstrate the impact of climatic factors, we used the principal component analysis (PCA), where the basic environmental factors affecting soil environment were monitored. Based on a correlation matrix with verification of the regression analysis test using the Monte-Carlo test, it was found out that the factor of the type and location of the soil environment has a more significant effect than the climatic factors. We can conclude that microclimatic factors do not have a statistically significant influence on the distribution of the individual soil macrofauna species. Exposition, altitude, type of soil and soil skeleton content, i.e. factors determining the quality of the soil were confirmed to be important factors. It follows from the data that the occurrence of species is closely related to the quality of the environment and not to the temperature or moisture. It should be stressed that the presented results are of a smaller scale i.e. represent a regional assessment. At the global scale, significantly higher abundances were found in warmer areas compared to colder areas (BLACKBURN et al., 2002).

Conclusions

A direct effect of microclimatic factors of the soil environment (temperature, moisture) on the dynamics of the communities of centipedes, millipedes and terrestrial isopods in mountain spruce forests has not been proven.

Nevertheless, an indirect effect of environmental factors, such as exposition, altitude and soil skeleton content was found. An increase in average air temperature by +2.9 °C and decrease in soil moisture by –4.49% may be a cause for the decline in montane and submontane species (*Lithobius borealis*, *Lithobius tenebrosus*) and an increase in the numbers of synanthropes (*Porcellio scaber*, *Ophiulus pilosus*) with wide ecological valence at the expense of relict species.

Acknowledgements

This study was supported by the Ministry of Education of the Czech Republic (VZ MSM 6215648902) and by the Netex, Ltd., Děčín, Nadace ČEZ, Co., Prague, Lafarge cement, Co, in Čížkovice.

References

- ALBERT, A.M., 1983. Characteristics of two populations of Lithobiidae (Chilopoda) determined in the laboratory and their relevance with regard to their ecological role as predators. *Zoologischer Anzeiger*, 34: 214–226.
- ARYA, P.S., 2001. *Introduction to micrometeorology*. N.Y.: Academic Press. 420 p.
- AUERBACH, S.I., 1949. A preliminary ecological study on certain deciduous forest centipedes. *American Midland Naturalist*, 42: 220–227.
- AUERBACH, S.I., 1951. The centipedes of the Chicago area with special reference to their ecology. *Ecological Monograph*, 21: 97–124.
- BALE, J.S. 1991. Insects at low temperatures: a predictable relationship? *Functional Ecology*, 5: 291–298.
- BALE, J.S., HAYWARD, S.A.L., 2010. Insect overwintering in a changing climate. *Journal of Experimental Biology*, 213: 980–994.
- BLACKBURN, J., FARROW, M., WALLACE, A., 2002. Factors influencing the distribution, abundance and diversity of geophilomorph and lithobiomorph centipedes. *Journal of Zoology*, 256: 221–232.
- BLOWER, J.G., 1951. A comparative study of the chilopod and diplopod cuticle. *Quarterly Journal of Microscopical Science*, 92: 142–161.
- CLOUDSLEY-THOMPSON, I.L., CRAWFORD, E.S., 1970. Water and temperature relations, and diurnal

- rhythms of scolopendromorph centipedes. *Entomologia Experimentalis et Applicata*, 13: 187–193.
- CURRY, A., 1974. The spiracle structure and resistance to desiccation of centipedes. *Symposium of the Zoological Society London*, 32: 365–382.
- DAVID, I.F., CELERIER, M.L., VANNIER, G., 1996. Overwintering with a low level of cold-hardiness in a temperate millipede *Polydesmus angustus*. *Acta Oecologia*, 17: 393–404.
- FRÜND, H.C., 1987. Räumliche Verteilung und Koexistenz der Chilopoden in einem Buchen-Altbestand. *Pedobiologia*, 30: 19–29.
- HANLON, R.D.G., ANDERSON, J.M., 1979. The effects of collembolan grazing on microbial activity in decomposing leaf litter. *Oecologia*, 38: 93–99.
- HARUŠTIAKOVÁ, D., JARKOVSKÝ, J., LITNEROVÁ, S., DUŠEK, L., 2012. Vicerovměrné statistické metody v biologii [Multivariate statistical methods in biology]. Brno: Akademické nakladatelství CERM. 110 p.
- HAYASHI, Y., 1983. *Aerodynamical properties of air layer affected by vegetation*. Environmental Research Center papers, 3. Ibaraki (Japan): Environmental Research Centre, University of Tsukuba. 54 p.
- HÄTTENSCHWILER, S., GASSER, P., 2005. Soil animals alter plant litter diversity effects on decomposition. *Proceedings of the National Academy Sciences*, 5: 1519–1524.
- HOPKIN, S.P., READ, H., 1992. *The biology of millipedes*. Oxford, New York, Tokyo: Oxford University Press, 231p.
- HURTALOVÁ, J., MATĚJKA, F., JANOUŠ, D., ROŽNOVSKÝ, J., 2003. Influence of a spruce forest stand on the flowing and air temperature and moisture vertical stratification. In ROŽNOVSKÝ, J., LITSCHMANN, T. (eds). *Seminář Mikroklima porostů*. Brno, 26. března 2003, p. 66–79.
- JABIN, M., 2008. *Influence of environmental factors on the distribution pattern of centipedes (Chilopoda) and other soil arthropods in temperate deciduous forests*. Göttingen: Cuvillier Verlag. 128 p.
- KANEDA, S., KANEKO, N., 2008. Collembolans feeding on soil affect carbon and nitrogen mineralization by their influence on microbial and nematode activities. *Biology and Fertility Soils*, 44: 435–442.
- KULA, E., LAZORÍK, M., 2014. Chilopoda v korunové a kmenové fauně lesních dřevin [Chilopoda in crown and stem fauna of forest trees]. *Zprávy Lesnického Výzkumu*, 59: 175–183.
- LADANYI, M., HORVATH, L., 2010. A review of the potential climate change impact on insect populations – general and agricultural aspects. *Applied Ecology Environmental Research*, 8: 143–152.
- LAVY, D., VERHOEF, H.A., 1996. Spatiotemporal variation in body composition and cold tolerance of soil arthropods. *Pedobiologia*, 40: 529–540.
- LEPŠ, J., ŠMILAUER, P., 2003. *Multivariate analysis of ecological data using CANOCO*. London: Cambridge University Press. 282 p.
- LEWIS, J.G.E., 1963. On the spiracle structure and resistance to desiccation of four species of geophilomorph centipedes. *Entomologia Experimentalis et Applicata*, 6: 89–94.
- LEWIS, J.G.E., 1981. *The biology of centipedes*. Cambridge: Cambridge University Press. 488 p.
- MEAD-BRIGGS, A.R., 1956. The effect of temperature upon the permeability to water of arthropod cuticles. *Journal of Experimental Biology*, 33: 737–749.
- PFLEIDERER-GRUBER, M., 1986. *Ökophysiologische Studien an Chilopoda in Tirol*. Innsbruck: O.K. Druck. 84 p.
- RODENHOUSE, N.L., CHRISTENSON, L.M., PARRY, D., GREEN, L.E., 2009. Climate change effects on native fauna of northeastern forests. *Canadian Journal of Forest Research*, 39: 249–263.
- ROUFED, S., HANDA, I.T., DAVID, J.F., HÄTTENSCHWILER, S., 2010. The importance of biotic factors in predicting global change effects on decomposition of temperate forest leaf litter. *Oecologia*, 163: 247–256.
- SCHATZMANN, E., 1990. Weighting of habitat types for estimation of habitat overlap – application to a collection of swiss centipedes. In MINELLI A. (ed.). *Proceedings of 7th international congress of myriapodology*. Vittorio Veneto, Italy, 1987. Leiden: Brill, p. 299–309.
- SEASTEDT, T.R., CROSSLEY, D.A., 1983. Nutrients in forest litter treated with naphthalene and simulated throughfall: a field microcosm study. *Soil Biology and Biochemistry*, 15: 159–165.
- SPELDA, J., 1999. Ökologische Differenzierung südwestdeutscher Steinläufer (Chilopoda: Lithobiida). *Verhandlungen der Gesellschaft für Ökologie*, 29: 389–395.
- SUMMERS, G., UETZ, G.W., 1979. Microhabitats of woodland centipedes in a streamside forest. *American Midland Naturalist*, 102: 346–352.
- TAJOVSKÝ, K., 2001. Colonization of colliery spoil heaps by millipedes (Diplopoda) and terrestrial isopods (Oniscidea) in the Sokolov region, Czech Republic. *Restoration Ecology*, 9: 365–369.
- TANAKA, K., UDAGAWA, T., 1993. Cold adaptation of the terrestrial isopod, *Porcellio scaber*, to subnivean environments. *Journal of Comparative Physiology B*, 163: 439–444.
- TEMPLER, P.H., SCHILLER, A.F., FULLER, N.W., SOCI, A.M., DRAKE, J.E., KUNZ, T.H., 2012. Impact of a reduced winter snowpack on litter arthropod abundance and diversity in a northern hardwood forest ecosystem. *Biology and Fertility of Soils*, 48: 413–424.

- TOPP, W. 1994. Seasonal time partitioning and polymorphism in the developmental cycles of sympatric Staphylinoidea (Coleoptera) living in an unstable environment. In DANKS, H.V. (ed.). *Insect life-cycle polymorphism*. Dordrecht: Kluwer, p. 277–312.
- TUF, I.H., TUFOVÁ, J., 2008. Proposal of ecological classification of centipede, millipede and terrestrial isopod faunas for evaluation of habitat quality in Czech Republic. *Časopis Slezišského Muzea Opava* (A), 57: 37–44.
- VERHOEF, H.A., BRUSSAARD, L., 1990. Decomposition and nitrogen mineralization in natural and agro-ecosystems: the contribution of soil animals. *Biogeochemistry*, 11: 175–211.
- WALL, D.H., BRADFORD, M.A., ST. JOHN, M.G., TROFYMOW, J.A., BEHAN-PELLETIER, V.M., BIGNELL, D.E., DANGERFIELD, J.M., PARTON, W.J., RUSEK, J., VOIGT, W., WOLTERS, V., GARDEL, H.Z., AYUKE, F.O., BASHFORD, R., BELJAKOVA, O.I., BOHLEN, P.J., BRAUMAN, A., HENSCHER, J.R., JOHNSON, D.L., JONES, T.H., KOVÁŘOVÁ, M., KRANABETTER, J.M., KUTNY, L., LIN, K.-C., MARYATI, M., MASSE, D., POKARZHEVSKII, A., RAHMAN, H., SABARA, M.G., SALAMON, J.-A., SWIFT, M.J., VARELA, A., VASCONCELOS, H.L., WHITE, D., ZOU, X., 2008. Global decomposition experiment shows soil animal impacts on decomposition are climate-dependent. *Global Change Biology*, 14: 2661–2677.
- WARDLE, D.A., BARDGETT, R.D., KLIRONOMOS, J.N., SETIHA, H., VAN DER PUTTEN, W.H., WALL, D.H., 2004. Ecological linkages between aboveground and belowground biota. *Science*, 304: 1629–633.
- WIRKNER, C.S., PASS, G., 2002. The circulatory system in Chilopoda: functional morphology and phylogenetic aspect. *Acta Zoologica*, 83, 193–202.

Received November 19, 2015

Accepted February 3, 2016

Perception of land consolidation by land owners: a case study

Zlatica Muchová^{1*}, Jaroslav Bažík¹, František Petrovič², Juraj Hreško²,
Lubomír Konc¹, Peter Michal¹

¹Department of Landscape Planning and Ground Design, Horticulture and Landscape Engineering Faculty, Slovak University of Agriculture in Nitra, Hospodárska 7, 949 76 Nitra, Slovak Republic

²Department of Ecology and Environmental Sciences, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 949 01 Nitra, Slovak Republic

Abstract

MUCHOVÁ, Z., BAŽÍK, J., PETROVIČ, F., HREŠKO, J., KONC, L., MICHAL, P., 2015. Perception of land consolidation by land owners: a case study. *Folia Oecologica*, 42: 113–121.

Land consolidation in Slovak Republic is claimed to be negatively perceived, although, there is no empirical evidence of this. This is used by administration to interfere with land consolidation. Based on owners' opinion in cadastral area of Malý Báb, where land consolidation was carried out, we show that a positive view on land consolidation prevails (almost 80%). Groups of respondents with inclination to a negative perception (e.g. the seniors with bad experiences in the past, ignorant juniors) were identified, problematic areas (e.g. communication, mistrust, contributions to environmental measures) and lack of information (e.g. people with a lower education and juniors) highlighted. It seems that a positive attitude on land consolidation could be achieved with well-informed owners, provided their views and concerns will be respected.

Keywords

environmental measures, land consolidation, land fragmentation, owners' perception

Introduction

Fragmentation, unresolved ownership relations, and environmental issues characterize situation (not only) in Slovakia, see e.g. JUSKOVÁ et al. (2015). According to various sources, one of the most widespread tools for solving these problems is land consolidation. FAO (2004, 2008) defines land consolidation as a term used broadly to describe measures for adjusting property rights structure through co-ordination between owners and users. Land consolidation involves re-allocation of parcels to remove fragmentation effects but the term goes well beyond these actions. Land consolidation has been associated with broad economic and so-

cial reforms from the time of its earliest applications. HARTVIGSEN (2015) shows, that land consolidation is more than an outcome of normal land market transactions agreed between a few private landowners. Land consolidation is carried out through a project and connected with a certain geographical area (project area). Land consolidation outcome is the result of a planning process, facilitated by land professionals along with active involvement of landowners and other stakeholders in the project area. Reallotment plan, as a result of planning process, displays land parcels layout and connected ownership after a land consolidation project. THOMAS (2006) defines land consolidation as one of the most important elements in helping to solve the structural

*Corresponding author:
e-mail: zlatica.muchova@uniag.sk

problems of agriculture and agricultural production. International consultants recommend land consolidation procedures as a “secret weapon” for economic growth and shared wealth. Generally most of the definitions present land consolidation as a tool for solving 1) land readjustment (land use, ownership and other rights) and 2) spatial physical planning (roads, landscape and soil). Recently, authors especially highlight multi-functions of land consolidation, specifically comprehensive reallocation of (rural) land while addressing environmental issues.

First projects in Slovakia were aimed only at land readjustment to eliminate land fragmentation as defined by e.g. DEMETRIOU (2012). Over time, land consolidation in Slovakia adopted a multidisciplinary approach as defined by e.g. LISEC et al. (2014). They indicated that main aims of land consolidation are plots structure, road infrastructure improvements and that land consolidation is an important tool for agricultural and rural development. Also JÜRGENSON et al. (2010) consider land consolidations as tools of land management which can reduce land fragmentation and other disturbing factors of land use. Land consolidation is an excellent instrument to implement rural development projects with multiple purposes and goals, in a single land consolidation project. According to PAŠAKARNIS et al. (2013) land consolidation can even minimize the inequality between rural and urban areas, if the improvements include agricultural production, better housing, employment, infrastructure, education, health services, environment, cultural opportunities etc.

Land consolidation means (BLAŽEK et al., 2014; HAVLÍČEK et al., 2014; IVANOVÁ et al., 2013; LI et al., 2014; LIGA et al., 2014; MURGAŠ, 2009; TARASOVIČOVÁ et al., 2013) introduction of land arrangement changes of a certain territory, in order to create an integrated soil management according to the needs of individual landowners, in addition to the social demands on the landscape, environmental and construction issues. LOUWSMA et al. (2014) emphasize land consolidation as being an improvement of distribution of agricultural plots, water management and infrastructure. To improve the structure of rural areas, land consolidation is aimed at creation of a functional and attractive rural environment, in which it is pleasant to work, live and recreate for residents and visitors alike. Land consolidation arranges land plots spatially and functionally, consolidates or splits them up to provide conditions for effective management by landowners. Besides that, it also enables environmental improvement, soil conservation, water management and increasing ecological stability (KADLEC et al., 2014; DUMBROVSKÝ et al., 2004). Land consolidation refers to a series of activities, which deal with improvement of productivity and working conditions in rural areas, production of reconstruction plans for rural settlement, and improving rural life (LONG, 2014). If land consolidation is implemented in a comprehensive way, it could support environmental protec-

tion and management of natural resources. JÜRGENSON (2010), OLAH and BOLTÍŽIAR (2009), ŠPULEROVÁ et al. (2011) summarized, that land consolidation can solve land use conflicts for example in the infrastructure, nature, environment and furthermore it can cover public demands of land, sustainable land management and improve general livelihood in rural areas. Land consolidation can be used to make agriculture and forestry more competitive, can help to improve access to plots, can support environmental management and sustainable development in rural areas.

Despite their obvious benefits, land consolidations in Slovakia struggle with public recognition as a useful tool that works for individuals, communities, state, environment, improves possibilities for managing land market as well as tax collection. THOMAS (2006) reminds that many people are surprised/disappointed if after finishing initial projects some of the expected gains do not materialize. Land consolidation procedures can be successfully carried out, only if decisions to take such measures are an outcome of attentive diagnosis and comprehensive analysis, with precisely-defined goals. Careful attention must be paid when using special instruments for specific structural conditions. It is agreed by many authors, that land consolidation is dependent on political, socio-economic and environmental demands of particular countries or regions.

Land consolidation projects may be justifiably criticized for a lack of feedback from potential participants (PODHRÁZSKÁ et al., 2015), who are directly affected (with major consequences). It is possible to determine an appropriate strategy and tactic for further positive development (and public perception) of land consolidation by focusing on the views of residents and owners themselves.

Authors of this contribution aimed at collecting empirical evidence on participants' opinion/perception of landscape consolidation and derivation of some implications. Our goal is to find the main target groups of population in terms of age, education and gender, on which it will be appropriate to focus education and promotion regarding land consolidation. Based on a survey, we try to identify the most negative attitudes and (perceived) problems that may result in rejecting the entire process. Suggestions are also discussed, how to positively influence the public for supporting full-scale implementation of comprehensive land consolidations.

Material and methods

Research of satisfaction and opinion about land consolidation was carried out in Malý Báb cadastral area, where a land consolidation project was completed (Fig. 1). Table 1 shows some details about this land consolidation project. The cadastral area is located in the western part of Slovakia.

Table 1. Basic information about land consolidation project in the case study area

Malý Báb	
Start	1. 6. 2005
End	28. 12. 2011
Duration	6 years
Area (ha)	879
Number of ownership relations	7,673

For a better understanding of the whole land consolidation process timeline, Table 2 shows time requirements for individual stages. This project lasted for 6 years and 3 months, costing 347,289 EUR. Table 3 shows ownership parameters of the area.

Data on landscape consolidation perception was obtained by interviews using a standard questionnaire

with 15 questions. Interviewers were prepared to explain any uncertainties. Questions were formulated as confirmatory (i.e. respondent either confirms – YES, or does not confirm – NO) and binary (YES/NO – 1/0). 60 questionnaires in the cadastral area of Malý Báb were collected.

Survey questions were divided into three categories:

- 1st category of questions aims at finding out if respondent had heard of land consolidations and if he/she had been an active participant in the project. If the answer is YES, interviewer asks questions from the 2nd category. If the answer is NO, interviewer asks/answers questions from the 3rd category.
- 2nd category of questions dealt with a specific information to determine positive and negative opinion of respondents about the entire process of land consolidation.



Fig. 1. Demonstration of initial ownership relations (A) compared to the new reallocation plan (B).

Table 2. Timetable for land consolidation project

Stage name	Date
Decision about regulation of land consolidation	1. 6. 2005
Geodetic grid	30. 7. 2005
Decision of land consolidation area	31. 10. 2005
Planimetric mapping	31. 10. 2006
Elevation mapping	31. 10. 2006
Land valuation	31. 7. 2007
Initial state registry	31. 7. 2007
Local territorial system of ecological stability	31. 7. 2007
General principles for functional territorial organization	31. 5. 2008
Principles of reallocation of new plots	31. 1. 2009
Proposal for common and public facilities and measures	30. 9. 2009
Reallocation plan in the form of placement and marking plan	30. 9. 2010
Implementation of land consolidation project	30. 4. 2011
Updating documentation on new mapping and geodetic plan	30. 9. 2011
Registration in the Land Registry	28. 12. 2011

Table 3. Basic information about ownership before and after the land consolidation project in the case study area

	Number of ownership relations	Number of parcels	Average number of co-owners per parcel	Average number of parcel per owner	Average area per parcel (ha)
Before the project	7,673	1,600	4.80	7.85	0.55
After the project	2,867	1,336	2.15	2.93	0.65

- 3rd category of questions collects parametric information: EDUCATION, AGE and GENDER. Based on this information, we attempted to find dependencies.

Questionnaire

QAR. Have you heard of land consolidation?

- YES [1]
- NO [0] (If the answer is NO, interviewer goes on to question Qx1R about education).

QBR. Do you perceive land consolidation as positive?

- YES [1]
- NO [0]

QCR. Have you been an active participant of land consolidation before?

- YES [1]
- NO [0]

QDR. Do you feel that land consolidation helped you with something?

- YES [1]
- NO [0]

QER. Have the procedures of land consolidation project been sufficiently explained to you?

- YES [1]
- NO [0]

QFR. Do you have now a better overview of your ownership/property than before the land consolidation project?

- YES [1]
- NO [0]

QGR. Do you know the location of your parcels now?

- YES [1]
- NO [0]

QHR. Have new parcels been discovered during the land consolidation project you were unaware of?

- YES [1]
- NO [0]

QIR. Do you have information about environmental aspects of the land consolidation project?

- YES [1]
- NO [0]

QJR. Do you agree with the contribution for common facilities and measures?

- YES [1]
- NO [0]

QKR. Do you evaluate the approach of planners and other participants (mayor, deputies, authorities, etc.)

positively?

- YES [1]
- NO [0]

QLR. Based on your experience, would you agree (again) with the initiation of a project in your cadastral area?

- YES [1]
- NO [0]

Qx1R. Have you completed (technical) university (bachelor, master, engineer)?

- YES [2] (It is treated as higher education.)
- NO [1] (It is treated as secondary and lower education.)

Qx2R. Age of respondent (determined by interviewer!)

- Lower [1] (obviously junior)
- Middle [2] (“productive age”)
- Higher [3] (obviously senior)

Qx3R. Gender (determined by interviewer!)

- Male [2]
- Female [1]

For the collected data evaluation, conventional methods of descriptive statistics and multivariate methods were used (cluster analysis for identification of similar groups of respondents). To study connections of responses based on parameters GENDER (1 – female, 2 – male), AGE (1 – juniors /18–24 years/, 2 – middle age /25–64 years, “productive age”/, 3 – seniors /above 65 years/) and EDUCATION (1 – without higher education, 2 – higher education) analysis of contingency tables with chi-square test ($p\text{-value} < 0.05$) was used (<http://cran.r-project.org>).

Results

In Malý Báb cadastral area (Table 4) positive responses prevailed in questions QAR “Have you heard of land consolidation?” (90%), QBR “Do you perceive land consolidation as positive?” (77%), QDR “Do you feel that land consolidation helped you with something?” (57%), QFR “Do you have a better overview of your ownership/property than before the land consolidation project?” (65%), QGR “Do you know the location of your parcels now?” (82%) and QLR “Based on your experience, would you agree (again) with the initiation of a project in your cadastral area?” (57%). Questions QDR (57%), QFR (65%) and QLR (57%) were answered positively, but there was a high number of

Table 4. Summary percentages of responses to the questions asked in the survey without regard to the education, age and gender. Questions are listed in Material and methods

Responses	QAR (%)	QBR (%)	QCR (%)	QDR (%)	QER (%)	QFR (%)	QGR (%)	QHR (%)	QIR (%)	QJR (%)	QKR (%)	QLR (%)
YES	90.00	76.67	48.33	56.67	46.67	65.00	81.67	33.33	26.67	41.67	48.33	56.67
NO	10.00	23.33	51.67	43.33	53.33	35.00	18.33	66.67	73.33	58.33	51.67	43.33

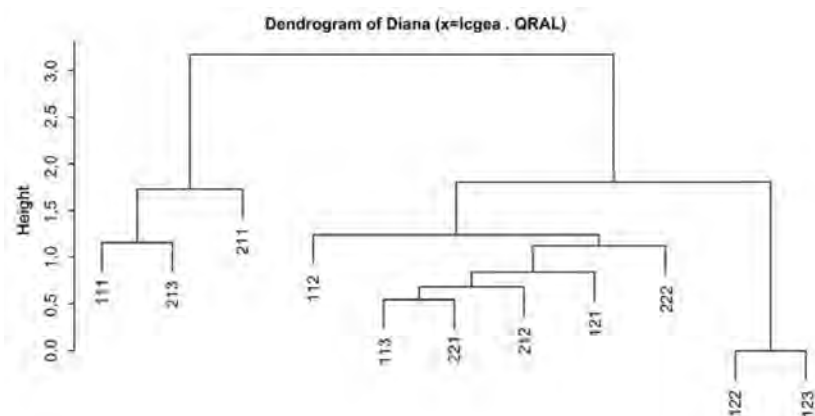


Fig. 2. Dendrogram – Diana (agglomerative clustering) for all available (nonempty) gender (1 or 2); education (1 or 2); age (1, 2 or 3) groups with regard to questions A to L responses.

negative answers. Negative answers were recorded in questions QCR “Have you been an active participant of land consolidation before?” (52%), QER “Have the procedures of land consolidation project been sufficiently explained to you?” (53%), QHR “Have new parcels been discovered during the land consolidation project you were unaware of?” (67%), QIR “Do you have information about environmental aspects of the land consolidation project?” (74%), QJR “Do you agree with the contribution for common facilities and measures?” (68%) and QKR “Do you evaluate the approach of the planner and other participants (mayor, deputies, authorities, etc.) positively?” (52%), but with a rather high number of positive answers. It can be concluded that respondents answered 50% of the questions positively and 50% of the questions negatively, an equal ratio.

Dendrogram (Fig. 2) shows similarity of responses in groups which are arranged by gender, education and

age. The first number in the three-digit code means: 1 – female, 2 – male; second number: 1 – lower education, 2 – higher education; third number: 1 – junior, 2 – middle age, 3 – senior.

Splitting the tree at the height of 2.0 leaves us with two groups. The smaller one on the left consists of young females and males without higher education and older males without higher education (which are surprisingly closer to the young females than males). The large group has three prominent subgroups. Productive and senior females with higher education on the right, productive females without higher education on the left and the rest of the combinations in between.

We attempted to find answers’ dependency on gender (Table 5), education (Table 6) and age (Table 7), based on the outputs of contingency tables (chi-square with $p\text{-value} < 0.05$).

Statistically significant dependency on gender was found in responses to QFR “Do you have a better over-

Table 5. Summary percentages of responses to the questions asked in the survey with regard to the gender. Questions are listed in Material and methods. Statistically significant response dependency on gender is denoted by the + sign next to the particular response

Responses	QAR (%)	QBR (%)	QCR (%)	QDR (%)	QER (%)	QFR+ (%)	QGR (%)	QHR (%)	QIR (%)	QJR+ (%)	QKR (%)	QLR (%)	Gender
YES	96.55	79.31	58.62	62.07	55.17	79.31	86.21	41.38	31.03	58.62	58.62	62.07	1
NO	3.45	20.69	41.38	37.93	44.83	20.69	13.79	58.62	68.97	41.38	41.38	37.93	1
YES	83.87	74.19	38.71	51.61	38.71	51.61	77.42	25.81	22.58	25.81	38.71	51.61	2
NO	16.13	25.81	61.29	48.39	61.29	48.39	22.58	74.19	77.42	74.19	61.29	48.39	2

Table 6. Summary percentages of responses to the questions asked in the survey with regard to education. Questions are listed in Material and methods. Statistically significant response dependency on education is denoted by the + sign next to the particular response

Responses	QAR (%)	QBR (%)	QCR (%)	QDR (%)	QER (%)	QFR (%)	QGR (%)	QHR (%)	QIR (%)	QJR (%)	QKR (%)	QLR+ (%)	Education
YES	86.05	69.77	46.51	51.16	44.19	60.47	76.74	34.88	23.26	34.88	44.19	46.51	1
NO	13.95	30.23	53.49	48.84	55.81	39.53	23.26	65.12	76.74	65.12	55.81	53.49	1
YES	100.00	94.12	52.94	70.59	52.94	76.47	94.12	29.41	35.29	58.82	58.82	82.35	2
NO	0.00	5.88	47.06	29.41	47.06	23.53	5.88	70.59	64.71	41.18	41.18	17.65	2

Table 7. Summary percentages of responses to the questions asked in the survey with regard to age. Questions are listed in Material and methods. Statistically significant response dependency on age is denoted by the + sign next to the particular response

Responses	QAR (%)	QBR+ (%)	QCR (%)	QDR (%)	QER (%)	QFR (%)	QGR (%)	QHR (%)	QIR (%)	QJR (%)	QKR+ (%)	QLR+ (%)	Age
YES	85.71	78.57	35.71	64.29	42.86	64.29	85.71	35.71	21.43	50.00	50.00	57.14	1
NO	14.29	21.43	64.29	35.71	57.14	35.71	14.29	64.29	78.57	50.00	50.00	42.86	1
YES	90.00	95.00	45.00	60.00	60.00	75.00	85.00	25.00	20.00	40.00	70.00	80.00	2
NO	10.00	5.00	55.00	40.00	40.00	25.00	15.00	75.00	80.00	60.00	30.00	20.00	2
YES	92.31	61.54	57.69	50.00	38.46	57.69	76.92	38.46	34.62	38.46	30.77	38.46	3
NO	7.69	38.46	42.31	50.00	61.54	42.31	23.08	61.54	65.38	61.54	69.23	61.54	3

view of your ownership/property than before the land consolidation project?” and QJR “Do you agree with the contribution for common facilities and measures?”, dependency on education in question QLR “Based on your experience, would you agree (again) with the initiation of a project in your cadastral area?” and dependency on age in questions QBR “Do you perceive land consolidation as positive?”, QKR “Do you evaluate the approach of the planner and other participants (mayor, deputies, authorities, etc.) positively?” and QLR again.

Discussion

Based on responses it can be clearly concluded that respondents are aware of the existence of land consolidation and most perceive it positively. They are also aware of irregularities and chaos in property rights because they experience (d) this phenomenon in various areas of life. They perceive naturally the fact that it would be appropriate to make some amendments. Due to lack of information, however, they cannot consider whether the proposed method of solution through the land consolidation is suitable and natural human fear of the unknown manifests itself.

After the project they are clearly better informed about the location of their parcels. Unfortunately, only at the end of the project, the participants are able to fully perceive the benefits of land consolidation. This is based on the fact that they can easily compare, without any complicated explanation, the state of their owner-

ship before and after the project.

Contributions to the common facilities and measures are perceived negatively, since the participants of land consolidation provide “free of charge” a certain percentage of their property and they cannot (are unable to) verify whether any value and benefits will reach them.

A land consolidation project provides an additional review of existing ownership relations, which may, in certain cases, notify owners about new property. In the majority of cases, plots “lost” due to historical development have not been discovered mirroring the quality of the land evidence.

Environmental aspects were not explained sufficiently. Due to detachment from the ownership in the past, perception of a need to protect the natural environment, awareness of the aesthetic and staging potential of rural area is absent. We expect the situation to improve with a change of generations, because ecology and environment are gaining weight with time in the whole European Union. Landscape should be consolidated and maintained so as to be attractive for living, recreation, business, investment and be sustainable.

Facts and implications from our survey highlighted some groups of respondents. Well-educated respondents of “productive” age consider land consolidation as an appropriate tool for handling a large range of issues related to ownership and rural development. This result was expected. Based on the age of respondents, we can assume that most of them are owners of certain land area possibly through an inheritance, purchase or

other legal act. Farm managements are also members of this group. Their education enables them a potential management of the property for a benefit (private/business use, selling, leasing).

Alternatively, seniors (males in particular) with a lower education show a negative view of some aspects of land consolidation. We assumed the opposite. We believed that this group would have the greatest interest in land consolidation. In this group, experience prevails over knowledge. They remember the injustices that landowners suffered during forced collectivization. Based on these experiences, in many cases, they reject any manipulation of land ownership, land transfers and contribution of land for common facilities and measures. They do not fully understand the land evaluation criteria, the difference to a market price in particular.

In our opinion the key are juniors under 24 years, who expressed lack of knowledge, lack of information, insecurity and particular ignorance to the process. A small subgroup already owns the land. Some of them are economically active. Unfortunately, many of them follow the passive-consumerist lifestyle of the modern age.

If processes of land consolidations are to be successful, promotion needs to target groups that reject or don't have any interest in land consolidation and clearly show that benefits dominate over eventual disadvantages (e.g. by visualization and "success stories").

Using comparison of base demographics of the case study area and the Slovakia (Table 8) we can try to estimate the evolution of public perception of landscape consolidations.

Available data shows, that in Slovakia, "productive" age represents 69% of the population and higher education has 20% of the population. Let us assume that "productive" age population perceives land consolidation positively, by a vast majority, while maybe 2/3 of seniors perceive land consolidation negatively. It can be expected that the group of seniors will contain more and more educated/well-informed ("pro land consolidation") people on the basis of natural regrouping of population in the "productive" age amongst seniors (and by interaction/communication between generations) thus shifting the perception. Positive differences

between the situation before and after a land consolidation should be explained to juniors, who will eventually become the economically active population. They will gradually acquire the ownership of the land. Relevant campaigns, journals, advertising, promotional materials are available which can be aimed at specific target groups. The process can be made more attractive to them using examples of realizations that can promote their interests such as cycling, relaxation areas, playgrounds etc.

Conclusions

Efforts to obtain empirical evidence about land owners' perception of land consolidation and analysis of collected data showed the following key findings. Awareness about land consolidation is high (90% on average), positive perception also (77%). They are considered helpful/useful in some way (57%) and seen as contributing to a better overview of ownership (65%). A majority (57%) would even agree with additional land consolidation. Among issues with a negative perception can be mentioned the contribution to the common facilities and measures (42%), a lack of information about ecological aspects (27%) and land consolidation as a whole (47%). Also the participants do not feel that new plots have been discovered that they were unaware of (33%). As essential groups, we consider respondents of higher education in "productive" age (they perceived land consolidation as a tool for consolidation of the country), seniors of lower education (much more conservative than we expected, prominent lack of trust based on bad experiences in the past is shown, by males in particular) and juniors (group with a lack of information, lack of knowledge or even ignorance). We think that addressing problematic groups of respondents/population, especially juniors, is important, so they can be educated about land consolidation. Natural demographic development should strengthen positive opinion/support for implementation of land consolidation among seniors. Information campaigns should focus on juniors, who will soon be economically active, so

Table 8. Base demographics of the case study area and the Slovak Republic

Parameter	Description		Parameter representation (%)	
			c. a. Malý Báb	Slovakia
Gender	1	Female	48	48
	2	Male	52	52
Age	1	18–24 years – juniors	23	15
	2	25–64 years	33	69
	3	Above 65 years – seniors	44	16
Education	1	Without education and secondary	72	80
	2	University education	28	20

they can make decisions about their interests/quality of life (i.e. “not only” ownership but also “nice” country, “healthier” environment, opportunities for relaxing...). Seniors’ concerns can be mitigated by better communication with examples of successful completion of land consolidation (including common facilities and measures and environmental impact). In this way, positive pressure on the administration could be established, for greater extent of land consolidations in Slovakia. Also any proposed measures should be implemented in accordance with the needs for landscape development, ecological stability, quality of life of citizens and the following generations.

Acknowledgements

Results obtained in the research projects VEGA no. 1/0574/13 and KEGA no. 025UKF-4/2015 have been used in this paper.

References

- BLAŽEK, V., HÁJEK, V., LIČÍK, L., NIŽNANSKY, B., POPKOVÁ, K., ŠMÍDA, J., 2014. Urban places and spaces from point of view of the three different methods using old maps and plans (on the example of the urban space in the Liberec town). *International multidisciplinary scientific geoconference Surveying geology and mining ecology management, SGEM*, 3, 2: 1039–1046.
- DEMETRIOU, D., 2012. *The development of an integrated planning and decision Support system (IPDSS) for land consolidation*. PhD thesis. Garstang North: University of Leeds, School of Geography. 353 p.
- DUMBROVSKÝ, M., MEZERA, J., STRÍTECKÝ, L., 2004. *Metodický návod pro vypracování návrhů pozemkových úprav* [Methodical instructions for the draft of land consolidation]. Brno: Českomoravská komora pro pozemkové úpravy. 190 p.
- FAO, 2004. *Operations manual for land consolidation pilot projects in Central and Eastern Europe*. FAO Land tenures manuals 1. Rome: Food and Agriculture Organization of the United Nations. 69 p.
- FAO, 2008. *Opportunities to mainstream land consolidation in rural development programmes of the European Union*. FAO land tenure policy series 2. Rome: Food and Agriculture Organization of the United Nations. 58 p.
- HARTVIGSEN, M., 2015. *Experiences with land consolidation and land banking in Central and Eastern Europe after 1989*. Rome: Food and Agriculture Organization of the United Nations. 128 p.
- HAVLÍČEK, M., PAVELKOVÁ, R., FRAJER, J., SKOKANOVÁ, H., 2014. The long-term development of water bodies in the context of land use: The case of the Jovka and Trkmanka river basins (Czech Republic). *Moravian Geographical Reports*, 22 (4): 39–50.
- JÜRGENSON, E., HASS, H., MAASIKAMÄE, S., 2010. The impact of land fund characteristics on the land reform results in Estonian rural municipalities. *Lžūu Mokslo Darbai*, 86: 65–70.
- IVANOVÁ, M., MICHAELI, E., BOLTŽIAR, M., 2013. Analýza zmien priestorovej štruktúry krajiny pokrývky územia severne od vodnej nádrže Zemplínska šírava. *Geografický Časopis*, 65: 235–250.
- JUSKOVÁ, K., MUCHOVÁ, Z., POCHOP, M., 2015. Stav pozemkových úprav v České republice a Slovenské republice aneb “Když dva dělají totéž, není to vždy totéž”. *Geodetický a Kartografický Obzor*, 61: 72–81.
- KADLEC, V., ŽÍŽALA, D., NOVOTNÝ, I., HEŘMANOVSKÁ, D., KAPÍČKA, J., TOPPL, M., 2014. Land consolidations as an effective instrument in soil conservation. *Ekológia (Bratislava)*, 33: 188–200.
- LI, Y., LIU, Y., LONG, H., CUI, W., 2014. Community-based rural residential land consolidation and allocation can help to revitalize hollowed villages in traditional agricultural areas of China: evidence from Dancheng County, Henan Province. *Land Use Policy*, 39: 188–198.
- LIGA, J., PETROVIČ, F., BOLTŽIAR, M., 2014. Land cover changes in Slovakia 1990–2006 related to the distance from industrial areas and economic development. *Geografický Časopis*, 66: 3–20.
- LISEC, A., PRIMOŽIČ, T., FERLAN, M., ŠUMRADA, R., DROBNE, S., 2014. Landowners’ perception of land consolidation and their satisfaction with the results – Slovenian experiences. *Land Use Policy*, 38: 550–563.
- LONG, H., 2014. Land consolidation: an indispensable way of spatial restructuring in rural China. *Journal of Geographical Sciences*, 24: 211–225.
- LOUWSMA, M., VAN BEEK, M., HOEVE, B., 2014. A new approach participatory land consolidation. *XV International FIG congress, Engaging the challenges – enhancing the relevance, Kuala Lumpur, Malaysia, 16–21 June 2014*. 10 p. [cit. 2015-10-3]. https://www.fig.net/resources/proceedings/fig_proceedings/fig2014/papers/ts02d/TS02D_louwsma_van_beek_et_al_7020_abs.pdf
- MURGAŠ, F., 2009. Quality of life and its spatial differentiation in districts of Slovakia. *Geografický Časopis*, 61: 121–138.
- OLAH, B., BOLTŽIAR, M., 2009. Land use changes within the Slovak biosphere reserves zones. *Ekológia (Bratislava)*, 28: 127–151.
- PAŠAKARNIS, G., MORLEY, D., MALIENE, V., 2013. Rural development and challenges establishing sustainable land use in Eastern European countries. *Land Use Policy*, 30: 703–710.
- PODHRÁZSKÁ, J., VAISHAR, A., TOMAN, F., KNOTEK, J., ŠEVELOVÁ, M., STONAWSKÁ, K., VASYLCHENKO, A.,

- KARÁSEK, P., 2015. Evaluation of land consolidation process by rural stakeholders. *European Countryside*, 7 (3): 144–155.
- R DEVELOPMENT CORE TEAM, 2015. *R: a language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing [cit. 2015-11-12]. <http://www.r-project.org/>
- ŠPULEROVÁ, J., DOBROVODSKÁ, M., LIESKOVSKÝ, J., BAČA, A., HALABUK, A., KOHÚT, F., MOJSES, M., KENDERESSY, P., PISCOVÁ, V., BARANČOK, P., GERHÁTOVÁ, K., KRAJČÍ, J., BOLTIŽIAR, M., 2011. Inventory and classification of historical structures of the agricultural landscape in Slovakia. *Ekológia (Bratislava)*, 30: 157–170.
- TARASOVIČOVÁ, Z., SAKSA, M., BLAŽÍK, T., FALŤAN, V., 2013. Changes in agricultural land use in the context of ongoing transformational processes in Slovakia. *Agriculture*, 59 (2): 49–64.
- THOMAS, J., 2006. What's on regarding land consolidation in Europe? *Proceedings of the XXIII International FIG congress 2006, Shaping the change, Munich, 8–13 October 2006*. 16 p. [cit. 2015-10-31]. https://www.fig.net/resources/proceedings/fig_proceedings/fig2006/papers/ts80/ts80_03_thomas_0311.pdf

Received December 18, 2015

Accepted February 1, 2016

The influence of age on the functional effect of forest stands with simplified spatial structure

Jiří Schneider^{1*}, Ilja Vyskot¹, Radka Redlichová²

Faculty of Regional Development and International Studies, Mendel University in Brno, Tř. Generála Píky
2005/7, 613 00 Brno, Czech Republic

¹Department of Environmentalistic and Natural Resources, ²Department of Regional and Business Economics

Abstract

SCHNEIDER, J., VYSKOT, I., REDLICHOVÁ, R., 2015. The influence of age on the functional effect of forest stands with simplified spatial structure. *Folia Oecologica*, 42: 122–129.

The aim of this article is to present research on the relationship between forest stand age and its functional effect. Forest ecosystem (forest stand) age together with its stocking and health condition is specified as criterion characterizing forest stand (with simplified structure) actual stage, dynamics and functional effect on a base of realized analysis of wide spatial and time forest stand parameters data set. The criterion “forest ecosystem development phases” is used for forest age structure expression. It represents the percentage of forest stand age from a predicated period of its existence – rotation period. There were realized development dynamics analyses of particular forest functions and actual functional effects; forest stand age weight development as a reducing criterion for different forest stand conditions and model real effect of the forest functions development for chosen stand types. Research was carried out at the state enterprise Lesy ČR, s.p., organization unit Židlochovice. The results present a synergistic effect of functional reduction criterion on the real effect of forest stand functions. Simultaneously, the higher the forest stand age, the higher the importance of the forest stand condition and stocking.

Key words

function-reducing criteria, forest functions, forest stands age, real effect of forest functions, rotation period

Introduction

An increasing number of authors are concerned with the evaluation of forest functions on the base of parametric quantification at the present time. The reason is primarily the requirement of forest functions value quantification as the primary presumption of objective poly-functional forest management.

The processes and functions are not the end services directly used by people. They are only the biological, chemical and physical interactions among ecosystem units (features, attributes) (BOYD and BANZHAF,

2006; KLINE, 2007). Although, e.g. KLINE (2007) presents on the example of forests ecosystems that the forest utilities come from social-utility outcomes of ecosystem functions. These functions are produced by the attributes and conditions of forest landscapes. Kline's statement (2007) is in accordance with VYSKOT et al. (2003) that the forests functions are produced primarily without human interventions (VYSKOT et al., 2003). Only on the basis of the functions abilities and effects quantification it is possible to define the end services for the public (KLINE, 2007).

*Corresponding author:
e-mail: jiris1712@gmail.com

PHUA and MINOWA (2000) introduce the next example of ecosystem approach. The authors define the Environmental functions of the tropical forest in Kinabalu Park as biodiversity conservation and, soil and water conservation functions, including landslide, flood and drought prevention functions. Biodiversity indexes such as Fisher's alpha index and Shannon-Wiener index, Annual Rainfall, Soil Depth, Geology, Topography and Slope are used as determination criteria.

Except for the terms "forest functions" and "ecosystem forest services", the terms "non-timber forest products (NTFP)", "non-wood forest products (NWFP)", and "non-timber value (NTV)" are used in professional literature (e.g. SCARPA et al., 2000). SCARPA et al. (2000) has calculated the non-timber value (NTV) in the forests in the state of Maine (USA) using the FIA database (Forest Inventory and Analysis). According to SCARPA et al. (2000) the NTV is affected by three categories of variables: ecological attributes of the area, physical (geographical) location and socioeconomic context. From the FIA database four variables were used – the stand index SITE, the distance of forests from the water element DWATR, the slope of the land SLOPE and the distance from the transport network DROADS. As a main characteristic of the forests having impact on their functional effects the species and spatial structure of the forests were set.

The forests' functions in the ecosystem approach of VYSKOT et al. (2003, 2013) stem from the forest ecosystem existence itself. This is based on the existence of single material elements as well as energy-material flows and information flows among them and their mutual influence. This influence is present in the forest ecosystem as well as between this ecosystem and its surroundings. As an example, the influence of the forest on the micro-climate characteristics dynamics could be used, e.g. the development of the air temperature or the relative air humidity during the day in the forest is less dynamic than compared to open space (e.g. SCHNEIDER et al., 2011). Likewise, the role of protective forest belts and their spatial structure on the air flow is well known (e.g. LAMPARTOVÁ et al., 2015; BRANDLE et al., 2004; STŘEDA et al., 2007; PERI et al., 2002). The next forest function that is described by many authors, is the ability of the forest with differentiate species composition, age structure and stand structure to fix carbon (e.g. SCHNEIDER et al., 2015; MUUKKONEN, 2007; CIENCIALA et al., 2006; ZHANG, 2009 etc.). The impact of the forests on the hydrological regime and run-off conditions in the catchment area is also important. The changes of the spatial structure (extreme cases of states of calamity) of the forest have an impact on the partial components of the water balance. By this the moisture conditions or the total character of the run-off are affected (e.g. HLÁSNY et al. 2013, 2015).

Comprehensive overview of the forest functional effects are presented e.g. by ČABOUN et al. (2010), who in principle and systematically describe the impact of the trees and forests on single ecosystem processes. These are then aggregated into functional groups – edaphic, atmospheric, hydric, lithic, phytobiotic, zoobiotic, microbiotic and anthropic. TUTKA et al. (2009) states the example of these functions' structuring on market and non-market. This is the step bonding the forests' functions and ecosystem services.

The aim of the paper was to find out, if there is any influence of the forests' age on the ability of the function production, and if so, by what way. The theoretical model according to VYSKOT et al. (2003, 2013) was verified on the development trend of the real forests.

Material and methods

Methodological basis of this work is the original method; The Quantification and Quantitative Evaluation of the Societal Forests Function (VYSKOT et al., 2003, 2013) (next only "Method"). This method claims that forest ecosystem influence to the environment is defined by its all-society functions (VYSKOT et al., 2003) – bio-production, ecological-stabilization, hydric-water management, edaphic-soil conservation, social-recreation and sanitary-hygienic. These forest functions are evaluated on two levels. The first level is called the real potential of the forests functions. This is given by the biotope parameters which present functional-determination criteria. The real potential of the forests functions represents the potential of the forest functional ability. This is the maximal reachable forest function production, which the given forest is able to reach in a given area.

The second level is given by the actual state of the forest. This is described through the functional-reduction criteria affecting the real effect of the forest functions. These criteria are set separately for structurally differentiated (rich) forests and stands with the simplified space structure.

The recent state (as well as the functional affects) of the structurally differentiated forests determine the functional-reduction criteria: a) the frequency distribution of the breast-height diameters; b) the height differentiation of the forest; c) the horizontal distribution of the wood and d) health condition.

These criteria could also be used for the forest with simplified space stand structure. The value of a–c criteria would be however, more or less constant. That is why the criteria of age, stocking and health condition are used for these types of forests. On the other hand, it is clear, that the criteria of age and stocking lose their sense of widely structured forests with very differenti-

ated age structure on the same area. Therefore, the only universally used functional-reduction criterion is the forests health condition.

Solving the steps of forest age influence to real functional effect of forest stand consists in a) quantification and evaluation of forests potential functional ability – real potential of forest functions (RP_{f}), b) quantification and evaluation of forests actual functional effects – real effect of forest functions (RE_{f}), c) analysis of age development influence in conditions of Forest Enterprise Zidlochovice (Forest of the Czech Republic Company).

Function-reducing criteria determination

Forest stand status is determined by tree species composition, stand age and spatial structure parameters and influenced by actual health disposition. Tree species composition is a direct determinant of potential functional ability of concrete forest ecosystem and is defined for the long term. It is the constant criterion for actual functional effect of the forest ecosystem evaluation.

Three suitable usable criteria for characterizing the dynamic effects of forest ecosystems were obtained by wide analysis of chronological and spatial forest stand parameters:

- Forest stand age (stand development stage)
- Stocking
- Health condition.

Their suitability and practical utility is defined by the following qualities:

- Reflect important natural processes and anthropic interventions in forest ecosystems
- Their value defines actual forest ecosystem status
- Their full value defines optimal forest ecosystem status
- Integration in legislation standards for forest stand status valuation
- Easy availability, measurability and verification.

If the value of the function-reducing criterion decreases, the effect of the forest ecosystem to fill its function decreases too – real potential of forest functions is reduced to real effect of forest functions.

Criterion “forest stand age” (forest ecosystem development stage) is used for the expression of age. The forest ecosystem development stage represents the percentage of forest stand age from a predicated period of its existence – rotation period (Table 1). The rotation period represents the frame production period of the forest management unit (rotation period limits are recommended under legislation). These parameters usage supports their utilization for forest stands with a different age of felling maturity (VYSKOT et al., 2003).

Table 1. Function-reducing criterion of forest stand age (forest ecosystem development stage). Source VYSKOT et al., 2003

Forest ecosystem development stage	% of rotation period
Unstocked area	0
Non-established young plantation, regeneration	to 7
Established young plantation, young growth	8–15
Small pole stage	16–25
Pole stage	26–40
Large-diameter stage of smaller dimension	41–60
Large-diameter stage	61–80
Mature stands	80+

Functional effectiveness depending on reducing criteria

Particular function-reducing criteria specifically influence the real effects of forest functions value (recent functional effects). The actual functional effects of forest ecosystem determination on the basis of functional-reduction criteria result from current scientific knowledge and results of parameters forest stand age (Table 2), stocking and health status research. Functional effects level = real effect of forest functions value = percentage of real potential of forest functions fulfilling (VYSKOT et al., 2003).

Function-reducing synergy criteria

With regards to mutual cohesion and dependence of ecosystem processes in the forest ecosystem it can be claimed that function-reducing criteria take effects to real effect of forest functions value synergistically. Ecosystem relations are not constant in time. They change and dynamically transform depending on forest stand status. Real effect of forest functions resulting value is influenced by significance of separated functional-reduction criteria. The significance of function-reducing criteria was determined on the base of analysis of databases and scientific results of forest stand age, stocking and health status research.

Analysis of the real effect of forest functions development dynamics and dependence on time

Given scientific announcement presents part of the long-term research of forest stand age influence to the

Table 2. Real effects of forest functions in relation to forest stand age. Source VYSKOT et al., 2003

Forest ecosystem development stages (% of rotation period)	Forest function						
	Bio-production	Ecological-stabilization		Hydric water management	Edaphic soil conservation	Social-recreation	Sanitary-hygienic
0	0	10	100	10	10	10	10
to 7	10	10	100	30	10	10	10
8–15	10	10	100	50	10	10	10
16–25	10	30	70	70	30	30	30
26–40	30	50	50	100	50	50	50
41–60	50	70	30	100	70	70	70
61–80	70	100	10	100	100	100	100
80+	100	100	10	90	100	100	100

real effect of forest functions on an example of stand type C5 – pure oak stand type within the forest site type 1S1 – hornbeam-oak wood on sands with Narrow-leaved meadow-grass. Forest stand age is expressed by forest ecosystem development phases (in percentage of the rotation period). Data sets present an actual functional effect trend for different health status of forest stands. Damage degree 0 characterizes normal health status (healthy forest stand), for comparison there is also shown a trend under damage degree IIIB – dead forest stand. The value of stocking is 9–10 (full stocking); the value occurring over a prevailing part of the rotation period.

The overall development of the real effect, modeled on the existing forests (chosen forests groups) comes from the data of the forest management plan. The meaning of the stand group choice is the simulation of the RE_{fi} development of the given forest during its life cycle using real variables. The choice of the stand group of the given stand type has followed the below mentioned rules from the point of view of particular functional reduction criteria and further characteristics:

- The age reduction criterion – all the presented age stages are represented (resp. % of the rotation); the same rotation.
- The stocking reduction criterion – the chosen represented value for the given age interval.
- The health condition reduction criterion – the represented value for the given age interval is used.
- Further characteristics – the same forest type is calculated as well as the similar area and position in the forest complex.

The dynamics of the real effect development is shown in two ways. The first consists of the expression of the functional value levels. By these levels the real

potential is qualified. If the real effect RE_{fi} equals e.g. 1 it means that, under the Czech Republic conditions, the actual functional effects of the solved forest are very low. The second way is the percentage expression of RE_{fi} . The value (%) shows to what extend the actual functional effects (RE_{fi}) fulfill the total ability of the forest (real potential RP_{fi}).

Results

Forest stand age influence to topical functional effect of forest ecosystem is presented by the example of forest stand type C5 – pure oak stand type in the forest site type 1S1 – hornbeam-oak wood on sands with Narrow-leaved meadow-grass. Real effects of forest function are valuated for all groups of all-society functions – bio-production, ecological-stabilization, hydric-water management, edaphic-soil conservation, social-recreation and sanitary-hygienic. They are expressed in percentage of real potentials of forest functions and also in value grades 0–6 (Table 3).

The development trend of real effect is shown by an example of the sanitary-hygienic function.

The trend of development of the real effect of the sanitary-hygienic function has identical behavior as the real effect of the social-recreation function. This fact confirms the mentioned functions cohesion. Thanks to higher real potential the real effects of the sanitary-hygienic function obtain higher values in value degrees.

The stand age also involves the influence of two functional-reduction criteria on the real effect of the forests. Figure 1 presents the synergistic influence with the health condition. The mutual relation of stocking and age is shown in Fig. 2. There are evidently more signifi-

Table 3. The values of real potentials of forest functions (RP_n), functionally reducing criteria and real effects (RE_n) for selected stand type C5 – oak monoculture (the forest site type 1S1 – hornbeam-oak wood on sands with Narrow-leaved meadow-grass, Forest Administration Valtice)

Rotation period: 120				RP_n :											
Criterion				Real effect (in %)						Real effect (reduced real potential)					
Age	Stocking	Health condition	% rotation	BP	ES	HV	EP	SR	SH	BP	ES	HV	EP	SR	SH
1	0	1	1	20	25.5	36	21	16.5	15.5	0.8	0.8	1.1	0.6	0.5	0.6
25	10	1	21	23.5	44	76	44	35.5	37	0.9	1.3	2.3	1.3	1.1	1.5
27	10	1	23	28	58	79	51	41	44	1.1	1.7	2.4	1.5	1.2	1.8
31	10	1	26	44	70	100	65	57	60	1.8	2.1	3.0	2.0	1.7	2.4
38	10	1	32	44	70	100	65	57	60	1.8	2.1	3.0	2.0	1.7	2.4
51	10	1	43	65	85	100	85	76	85	3.3	2.6	2.0	2.6	2.3	3.4
64	9	1	53	65	85	100	85	76	85	2.6	2.6	3.0	2.6	2.3	3.4
73	9	1	61	79	100	100	100	94	100	3.2	3.0	3.0	3.0	2.8	4.0
74	9	1	62	86.5	100	100	100	91	100	3.5	3.0	3.0	3.0	2.7	4.0
91	9	1	76	86.5	100	100	100	91	100	3.46	3.0	3.0	3.0	2.73	4.0
105	9	1	88	100	100	97	100	91	100	4.0	3.0	2.91	3.0	2.73	4.0
118	9	1	98	100	100	97	100	91	100	4.0	3.0	2.9	3.0	2.7	4.0

Forest function: BP, bio-production; ES, ecological-stabilization; HV, hydric-water management; EP, edaphic-soil conservation; SR, social-recreation, SH, sanitary-hygienic.

cant differences in the real effects of young forests than compared to the adult stands, caused by stocking.

The dynamics of the real effect of the societal forest functions are presented on the example of the forests groups of the forest type C5 – oak monoculture. Real effects are expressed in percent of the real forest function potential (Fig. 3) and also a reduced potential in absolute values 0–6 (Fig. 4). From the evaluation of both charts it is evident that the complex view of actual forest functional effects' development is convenient to use in both ways of expression. The connectors' course in Fig. 3 involves crucially the value level of the real potential of the particular functions, e.g. with high real potential (e.g. RP_{nSH} – value level $F_v = 4$) is the real ef-

fect of young forests (in age of 30 % rotation) on the value level of 3 (average). Figure 4 indicates how quick are actual functional effects (real effect) near the potential functional availability (real potential).

Discussion

The individual works identify the influence of age on the partial ecosystem components and processes and their dynamics. The production ratios, expressed like growth increments, are the traditional object of the long-run forest research (e.g. ASSMANN, 1970). LEHTONEN et al. (2004) investigate the influence of the forest age on

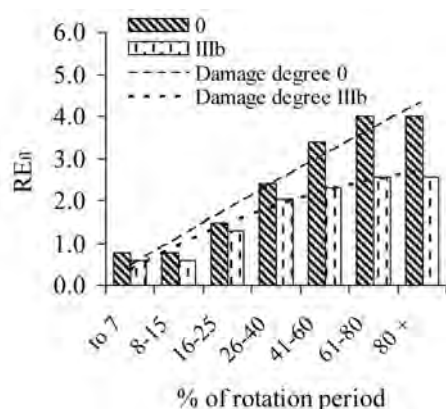


Fig. 1. Trend of real effect of sanitary-hygienic function development of forest stands with stocking 9–10.

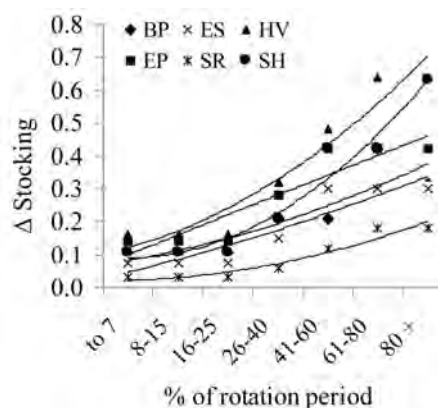


Fig. 2. Difference development of real effect of forest function in forest stand with full stocking and stocking 3 and less. For explanation see key to Table 3.

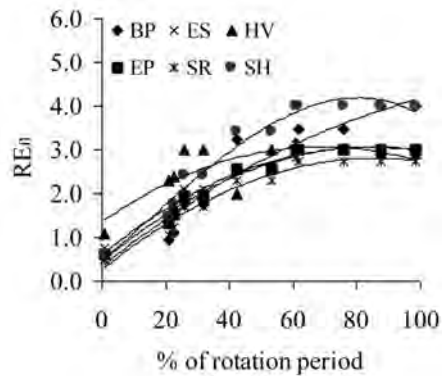


Fig. 3. The development trend of the real effect of forest stands modelled on existing stand type C5 – oak monoculture (the forest site type 1S1 – hornbeam-oak wood on sands with Narrow-leaved meadow-grass, Forest Administration Valtice) – the value expression 0–6. For explanation see key to Table 3.

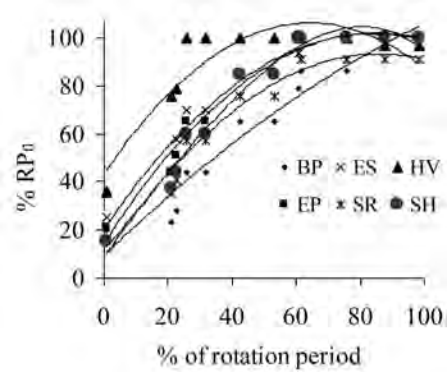


Fig. 4. The development trend of the real effect of forest stands modelled on existing stand type C5 – oak monoculture (the forest site type 1S1 – hornbeam-oak wood on sands with Narrow-leaved meadow-grass, Forest Administration Valtice) – the percentage expression from 0 to 100 % of the real potential of forest function (RP_0). For explanation see key to Table 3.

the biomass expansion factors (BEFs) for Scots pine, Norway spruce and birch. According to this study BEFs (biomass component/stem volume) change as a stand ages, especially in Norway spruce stands (LEHTONEN et al., 2004). The influence of the age of the hydric functions was presented e.g. by VERTESSY et al. (2001). They have investigated relations between stand age and catchment water balance in mountain ash forests. They measured leaf area index (LAI), sapwood area index (SAI) and various water balance components in several mountain ash stands, ranging in age between 5 and 240 years. They have demonstrated that old-growth mountain ash forests yield significantly more water than young regrowth forests of the same species because of lower evapotranspiration. They have estimated the difference in evapotranspiration for 15 and 240-year-old forests to be 460 mm per year for sites with 1,800 mm annual rainfall (VERTESSY et al., 2001). CSERESNYÉS et al. (2006) recognized stand age influence on litter mass. They found a significant increase with age detected through the age classes of 21–40, 41–60, and 61–80 years, and then a significant decrease occurred in stands above 80 years for the needle litter. In case of branch litter, the age-dependent increase was again significant to its maximum quantity, but the decrease in old stands proved to be insignificant (CSERESNYÉS et al., 2006).

Their research is an example of the analysis of the influence of the forest age on the pedogenetic functions. The above mentioned works confirmed the trends of the age impact on the single forest functions. Other publications (e.g. WANG et al., 2013), confirm the forest age in not only the determining indicator but it operates in accordance with other factors like the forest type.

Conclusions

Ecosystem services have become a mainstream concept for the expression of values assigned by people to various functions of ecosystems (BENNETT et al., 2015). This conception respects the principles of ecosystem functions, like the ecological provisioning base. The age of the forest is one of the detail criterion influencing the quantitative and qualitative effects and abilities of the forests to produce the ecosystem functions.

The criterion forest stand age is in affinity with the rotation period of the forest stand. It is given by the definition of criterion, when forest physical age was not ideal valuable criterion for tree species with different physiological and economical maturity. The influence of criterion forest stand age is the highest from all function-reduction criteria. It is given especially by the wide extent of criterion values. Every forest stand obtains values 0–100% of age of the rotation period in standard ecosystem conditions, but its stocking usually varies between 8 and 10, and health status is characterized as slightly damaged forest stand.

The importance of criterion stocking and health status increases for the older forest ecosystems and for the youngest forest age classes their importance is very low.

The trend of real effects of forest functions has for particular functions mostly an exponential character. Development of real effect marginal values is a very important descriptive parameter. This parameter determines the level of all society forest functions influence by the criterion forest stand age.

Comparable results obtained within forest management or forest mensuration are available especially

for bio-production forest functions. Concerning other forest functions, the influence of forest stand age on functional effectiveness is not yet investigated relevantly.

Criterion forest stand age loses importance when the forests are richly structured. This can be substituted for example by the graph of DBH (diameter breast-high) frequency.

The real functional effect of the forests with simplified spatial stand structure arising from the model is, mainly in the first half of rotation, significantly dependent on age. Its wage is for all functions between 0.8 (09)–0.6. In the second half of rotation the weight of health condition is increasing as well as stocking (VYSKOT et al., 2003). The structurally differentiated forests health condition stays as the crucial functional-reduction criterion. The age (age differentiated forests) and stocking lose importance. These criteria are replaced by the spread of the thickness classes and tree stratification.

Acknowledgements

The position of the forests functions in the system of ecosystem services evaluation is solved by the authors within the project EHP-CZ02-OV-1-032-2015 “Raising awareness and publicity of the importance of forest functions in the landscape and near-natural watercourses in urban areas as a part of basin ecosystem services”. This project has been supported by a grant from Ireland, Lichtenstein and Norway. The final synthesis of the partial problems and the processing of the paper was done within the project of Internal Grant Agency of Faculty of Regional Development and International Studies No 16/2015 – The chosen environmental tools as the regional development factors.

References

- ASSMANN, E., 1970. *The principles of forest yield study. Studies in the organic production, structure, increment and yield of forest stands*. Oxford: Pergamon Press. 506 p.
- BENNETT, E.M., CRAMER, W., BEGOSSI, A., CUNDILL, G., DÍAZ, S., EGOH, B.N., GEIJZENDORFFER, I.R., KRUG, C.B., LAVOREL, S., LAZOS, E., LEBEL, L., MARTÍN-LÓPEZ, B., MEYFROIDT, P., MOONEY, H.A., NEL, J.L., PASCUAL, U., PAYET, K., HARGUINDEGUY, N.P., PETERSON, G.D., PRIEUR-RICHARD, A.H., REYERS, B., ROEBELING, P., SEPPELT, R., SOLAN, M., TSCHAKERT, P., TSCHARNTKE, T., TURNER, B.L., VERBURG, P.H., VIGLIZZO, E.F., WHITE, P.C.L., WOODWARD, G., 2015. Linking biodiversity, ecosystem services, and human well-being: three challenges for designing research for sustainability. *Current Opinion in Environmental Sustainability*, 14: 76–85.
- BOYD, J., BANZHAF, S., 2006. *What are ecosystem services? The need for standardized environmental accounting units*. Discussion Paper RFF-DP-06-02. Washington, DC: Resources for the future. 26 p.
- BRANDLE, J.R., HODGES, L., ZHOU X.H., 2004. Windbreaks in North American agricultural systems. *Agroforestry Systems*, 61, 65–78. DOI: 10.1023/B:AGFO.0000028990.31801.62.
- CSERESNYÉS, I., CSONTOS, P., BÓZSING, E., 2006. Stand age influence on litter mass of *Pinus nigra* plantations on dolomite hills in Hungary. *Botany*, 84: 363–370.
- CIENCIALA, E., HENŽLÍK, V., ZATLOUKAL, V., 2006. Assessment of carbon stock change in forests – adopting IPPC LULUCF Good practice guidance in the Czech Republic. *Lesnícky Časopis – Forestry Journal*, 52: 17–28.
- ČABOUN, V., TUTKA, J., MORAVČÍK, M., KOVALČÍK, M., SARVAŠOVÁ, Z., SCHWARZ, M., ZEMKO, M., 2010. *Uplatňovanie funkcií lesa v krajine* [The application of forest functions in the landscape]. Zvolen: Národné lesnícke centrum. 285 p.
- HLÁSNY, T., SITKOVÁ, Z., BARKA, I., 2013. Regional assessment of forest effects on watershed hydrology: Slovakia as a case study. *Journal of Forest Science*, 59: 405–415.
- HLÁSNY, T., KOČICKÝ, D., MARETTA, M., SITKOVÁ, Z., BARKA, I., KONÔPKA, M., HLAVATÁ, H., 2015. Effect of deforestation on watershed water balance: hydrological modeling-based approach. *Lesnícky časopis – Forestry Journal*, 61: 89–100.
- KLINE, J. D., 2007. *Defining an economics research program to describe and evaluate ecosystem services*. General Technical Report PNW-GTR-700. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 46 p.
- LAMPARTOVÁ, I., SCHNEIDER, J., VYSKOT, I., RAJNOCH, M., LITSCHMANN, T., 2015. Impact of protective shelterbelt microclimate characteristics. *Ekológia (Bratislava)*, 34: 101–110.
- LEHTONEN, A., MÄKIPÄÄ, R., HEIKKINEN, J., SIEVÄNEN, R., LISKI, J., 2004. Biomass expansion factors (BEFs) for Scots pine, Norway spruce and birch according to stand age for boreal forests. *Forest Ecology and Management*, 188: 211–224.
- MUUKKONEN, P., 2007. Generalized allometric volume and biomass equations for some tree species in Europe. *European Journal of Forest Research*, 126: 157–166.
- PERI, P.L., BLOOMBERG, M., 2002. Windbreaks in southern Patagonia, Argentina: a review of research on growth models, windspeed reduction, and effects on crops. *Agroforestry Systems*, 56: 129–144.

- PHUA, M.H., MINOWA, M., 2000. Evaluation of environmental functions of tropical forest in Kinabalu Park, Sabah, Malaysia using GIS and remote sensing techniques: implications to forest conservation planning. *Journal of Forest Research*, 5: 123–131.
- SCARPA, R., BUONGIORNO, J., HSEU, J.-S., ABT, K. L., 2000. Assessing the non-timber value of forests: a revealed-preference, Hedonic Model. *Journal of Forest Economics*, 6:2 2000 [cit. 2016-10-18]. http://www.srs.fs.usda.gov/pubs/ja/ja_scarpa002.pdf
- SCHNEIDER, J., HOLUŠOVÁ, K., RYCHTÁŘ, J., VYSKOT, I., LAMPARTOVÁ, I., 2015. Carbon storage in beech stands on the Chřiby uplands. *Ekológia (Bratislava)*, 34: 26–38.
- SCHNEIDER, J., LITSCHAMNN, T., REBROŠOVÁ, K., ŠKRDLA, J., VYSKOT, I., 2011. Measurement of microclimatic characteristics in model beech stands in the Chřiby highlands in 2008–2010. In *Mikroklima a mezoklima krajinných struktur a antropogenního prostředí*. Praha: Česká bioklimatologická společnost, p. 113–122.
- STŘEDA, T., ROŽNOVSKÝ, J., POKLADNÍKOVÁ, H., 2007. Vliv různých typů lesních pásů na proudění vzduchu [Influence of different types of forest belts on air flow]. In ROŽNOVSKÝ, J., LITSCHMANN, T., VYSKOT, I. (eds). *Klima lesa. Sborník referátů z mezinárodní vědecké konference, Křtiny 11.–12. 4. 2007*. Praha: Česká bioklimatologická společnost, p. 32–43.
- TUTKA, J., VILČEK, J., KOVALČÍK, M., 2009. Oceňovanie verejnoprospešných funkcií lesných a poľnohospodárskych ekosystémov a služieb odvetví [Valuation of public functions of forest and agricultural ecosystems and the sector services]. In KOVALČÍK, M. (ed.). *Aktuálne otázky ekonomiky lesného hospodárstva Slovenskej republiky. Recenzovaný zborník z odborného seminára, Zvolen 21.–22. október 2009*. Zvolen: Národné lesnícke centrum, p. 79–88.
- VERTESSY, R. A., WATSON, F. G., SHARON, K. O., 2001. Factors determining relations between stand age and catchment water balance in mountain ash forests. *Forest Ecology and Management*, 143: 13–26.
- VYSKOT, I., et al., 2003. *Quantification and evaluation of forest functions on the example of the Czech Republic*. Prague: Ministry of Environment of the Czech Republic. 218 p.
- VYSKOT, I., SCHNEIDER, J., KLIMÁNEK, M., HOLUŠOVÁ, K., KOZUMPLÍKOVÁ, A., 2013. *Metodika ekologického a ekonomického hodnocení celospolečenských funkcí variantně strukturních typů lesů* [Methodology of ecological and economic evaluation of social functions of alternatively structural forests]. Certifikovaná metodika. Brno: Mendel University in Brno. 83 p.
- VYSKOT, I., SCHNEIDER, J., KOZUMPLÍKOVÁ, A., (2016). Dynamics of functional effect of forest stands within ecosystem services problematics. *Zprávy Lesnického Výzkumu*, (in press).
- WANG, W., ZENG, W., CHEN, W., YANG, Y., ZENG, H., 2013. Effects of forest age on soil autotrophic and heterotrophic respiration differ between evergreen and deciduous forests. *PloS One*, 8: e80937.
- ZHANG, X., ZHAO, Y., ASHTON, M.S., 2009. Methods of measuring carbon in forests. In TYRELL, M.A., ASHTON, M.S., SPALDING, D., GENTRY, B. (eds). *Forests and carbon: a synthesis of science, management, and policy for carbon sequestration in forests*. Yale F&ES Publication Series, Report number 23. Yale School of Forestry & Environmental Studies, p. 183–221.

Received December 3, 2015

Accepted February 4, 2016

Short communication

Winter occurrence of diprionid larvae (Hymenoptera, Symphyta) on pines in Central Europe: an effect of global warming?

Miroslava Šebestová¹, Milada Holecová^{1*}, Katarína Hollá¹, Anna Šestáková²

¹Department of Zoology, Faculty of Natural Sciences, Comenius University in Bratislava, Mlynská dolina, Ilkovičova 6, 842 15 Bratislava, Slovak Republic

²The Western Slovakian Museum, Múzejné námestie 3, 918 09 Trnava, Slovak Republic

Abstract

ŠEBESTOVÁ, M., HOLECOVÁ, M., HOLLÁ, K., ŠESTÁKOVÁ, A., 2015. Winter occurrence of diprionid larvae (Hymenoptera, Symphyta) on pines in Central Europe: an effect of global warming? *Folia Oecologica*, 42: 130–133.

During two winter seasons (2013–2014 and 2014–2015), we collected insects from branches of Scotch pine trees in the Borská nížina lowland (western Slovakia) using beating method. Four hymenopteran species in the larval stage were recorded in December 2013: *Diprion similis* (Hartig, 1834), *Gilpinia frutetorum* (Fabricius, 1793), *Gilpinia pallida* (Klug, 1812) and *Gilpinia variegata* (Hartig, 1834). The occurrence of diprionid larvae in the non-growing season has not been so far reported from Central Europe and may be a result of global warming.

Keywords

Diprionidae, *Pinus sylvestris*, sandy soils, Scotch pine, Slovak Republic, winter activity

Introduction

Diprionid sawflies (Symphyta: Diprionidae) are primitive Hymenoptera with holarctic distribution (VIITASAAARI, 2002). In Europe and North America, their larvae feed on needles of various conifers. Some species undergo an unpredictable outbreak and hence might be responsible for considerable damages in Europe (BEAUDOIN et al., 1994; VIITASAAARI, 2002).

Depending on climatic conditions and altitude, diprionid sawflies may have one or two generations per year (VIITASAAARI, 2002). As a rule, bivoltine populations of pine feeding diprionids occur in lowlands of Central Europe. Their larvae feed preferably on the Scotch pine from May till October (LORENZ and KRAUS,

1957; PSCHORN-WALCHER, 1982). Sawflies of the family Diprionidae endure adverse conditions (e.g. winter) in diapause, typically in the eonymph stage localized inside cocoons. These can be found on twigs and understorey or in forest litter. *Neodiprion sertifer* (Geoffroy, 1785) represents an exception since it overwinters as eggs on twigs. Diapause also helps synchronize reproduction and development with suitable climatic conditions (PSCHORN-WALCHER, 1982; KNERER, 1983; BEAUDOIN et al., 1994; VIITASAAARI, 2002).

There are only few data about overwintering larvae of phyllophagous insects dwelling on branches of coniferous trees (e.g. DVOŘÁČKOVÁ and KULFAN, 2009; PARÁK et al., 2015; KULFAN et al., in press).

*Corresponding author:
e-mail: holecova@fns.uniba.sk

Material and methods

The study of diprionid sawflies was carried out in Scotch pine forests of different age and structure, growing on the sandy soils in the Záhorská nížina lowland, western Slovakia (Table 1). The eight investigated study plots belong to the biotope of managed pine forests and seminative pine-oak forests. The area is warm with moderately dry climate and mild winters, whereby the average temperature in January is usually above -3°C . The average annual temperature is 9°C , and annual rainfall about 550 mm (LAPIN et al., 2002). Study plots were visited during December 2013–March 2014 and December 2014–March 2015. Sawfly larvae were sampled monthly by beating from Scotch pine branches at heights of 1–3 m above the ground, using a beating tray with a diameter of 1 m. One sample consisted of larvae that had dropped into the beating tray from a total of 20 branches which were 1 m long each. In total, ten samples (200 branches) were taken. The larvae were preserved in 70% ethanol and examined in the laboratory, using a stereomicroscope Leica EZ4. Identification of sawfly larvae was made according to LORENZ and KRAUS (1957) and VIITASARI and VARAMA (1987). The voucher specimens of all sawfly species detected in the present study are deposited in the collection of the first author.

Results and discussion

Twenty-three diprionid larvae were collected during the first winter season in December 2013 (Table 2). Despite the comparatively low average temperature on several

sampling days in December 2013, i.e. the temperature did not rise above 0°C , all larvae were active during most of the time (for further details, see Table 2). Over the winter season from December 2014 to March 2015 no larvae were obtained.

This unusual finding of active diprionid larvae in winter has not been yet reported from Central Europe (LORENZ and KRAUS, 1957; PSCHORN-WALCHER, 1982; HELLRIGL, 1996). According to PSCHORN-WALCHER (1982), a partial third generation of *Diprion pini* occasionally emerge in the United States, but months of its occurrence were not specified.

In our material, the recorded larvae very likely belong to the second generation that did not complete their development. It is well known that the length of the larval feeding period depends on temperature (PSCHORN-WALCHER, 1982; BEAUDOIN et al., 1994; VIITASARI, 2002). Both years 2013 and 2014 were distinctly warmer in their first half (until August) than the long-term average (Fig. 1), which might be the reason for the prolonged occurrence of larvae. During the warmer autumn 2014, larvae of the last naturally occurring seasonal wave (the autumnal larvae) could complete their development and reached the dormant eonymph stage. In contrast to the year 2014, the colder weather from September to December 2013 (Fig. 1) might have caused the prolonged development of the autumnal larvae, and hence, some of them were present on pine twigs even in December. Another possibility is that global climatic changes and thus warmer climate throughout the year enabled an extra late emergence of diprionids which larvae did not achieve the dormant eonymph. Although larvae did not complete their de-

Table 1. Study plot characteristics

Location	Study plot	GPS coordinates	Altitude m a.s.l.	Study plot characteristics
Lakšárska Nová Ves	1	48°34'56,85"N 17°10'33,41"E	222	About 25-year old pines free growing on sand dunes that gradually reach the adjacent stand about 100-year old.
	2	48°34'54,46"N 17°10'34,56"E	218	About 10-year old pines forming a dense forest stand close to a canopied stand.
	3	48°34' 51,43"N 17°10'22,78"E	218	About 25-year old pines forming a forest stand wall adjacent to a meadow.
	4	48°34'55,81"N 17°9'52,23"E	218	About 15-year old pines forming a dense, strongly canopied forest stand.
Studienka	5	48°32' 25,65"N 17°8'29,88"E	218	About 100-year old pines forming a stand with grassy undergrowth and surrounded by a meadow.
	6	48°32'16,49"N 17° 8'15,03"E	218	About 15-year old pines growing in irregular clusters with grassy undergrowth.
Pernek	7	48°23'16,5"N 17°6'10,7"E	203	About 8-year old scotch pines forming a strongly canopied forest stand without grassy undergrowth.
Moravský Svätý Ján	8	48°33'52,4"N 16°59' 54,1"E	159	About 10-year old pines forming a canopied forest stand wall.

Table 2. The number of collected diprionid larvae at eight study plots (SP 1–SP 8) in the Borská nížina lowland, western Slovakia, and average daily temperature on the sampling days (as measured by the meteorological station in Moravský Svätý Ján)

	Study plot								Occurrence of larval stages in months according to LORENZ and KRAUS (1957) and PSCHORN-WALCHER (1982)
	SP 1	SP 2	SP 3	SP 4	SP 5	SP 6	SP 7	SP 8	
Sampling day	19.xii. 2013	19.xii. 2013	17.xii. 2013	16.xii. 2013	12.xii. 2013	12.xii. 2013	28.xii. 2013	30.xii. 2013	
Average daily temperature	−0.7 °C	−0.7 °C	−0.2 °C	0.2 °C	0.3 °C	0.3 °C	7.7 °C	2.7 °C	
<i>Diprion similis</i>	2	1	2	2		1	1		v. and ix.
<i>Gilpinia frutetorum</i>	1				2		1	1	v.–vi. and viii.–ix.
<i>Gilpinia pallida</i>	1				1	5	1		vi.–x.
<i>Gilpinia variegata</i>							1		v.–vi. and viii.

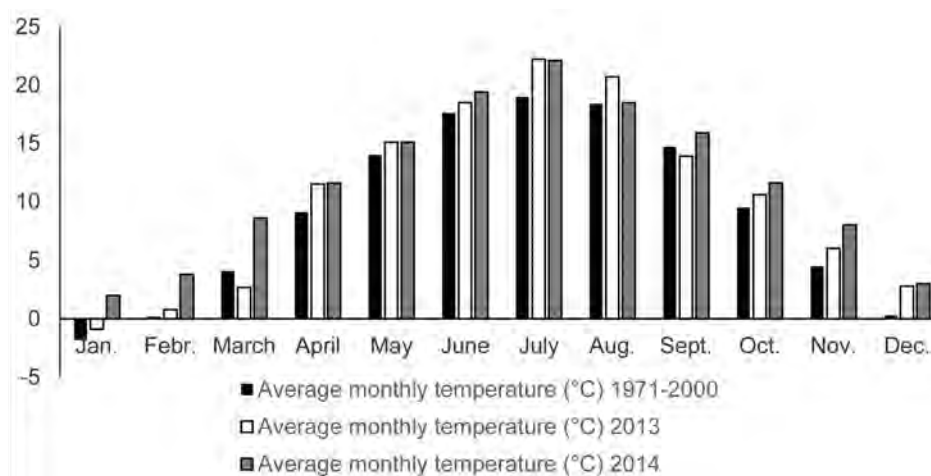


Fig. 1. Long-term average monthly temperatures (1971–2000) and average monthly temperatures in 2013 and 2014 (according to the measurements of the meteorological station in Kuchyňa).

velopment, they could serve as a food source for insectivorous animals in lowland Scotch pine forests during mild winters.

Acknowledgements

We would like to thank Peter Vďačný, Ján Kulfan and two anonymous reviewers for critical comments to the manuscript. We are also grateful to Oľga Šimková for the linguistic correction of the text. The study was supported by VEGA (Scientific Grant Agency of the Ministry of Education and the Slovak Academy of Sciences), grant numbers 1/0066/13 and 2/0035/13.

References

- BEAUDOIN, L., GERI, C., ALLAIS, J. P., GOUSSARD, F., 1994. Influence of consanguinity on the sex-ratio and diapause of *Diprion similis* L. (Hymenoptera, Diprionidae) populations. *Journal of Applied Entomology*, 188: 267–280.

- DVOŘÁČKOVÁ, K., KULFAN, J., 2009. Caterpillars overwintering on spruce roost near their food. *Folia Oecologica*, 36: 75–78.
- HELLRIGL, K., 1996. *Forstschädliche Kiefernblattwespen in Südtirol (Hym., Symphyta, Pamphiliidae, Diprionidae). Eiablage, Diapauseverhalten, Voltinismus*. Schriftenreihe für wissenschaftliche Studien, Landesabteilung Forstwirtschaft der Autonomen Provinz Bozen, no. 3. Bozen: Autonome Provinz, Abt. Forstwirtschaft. 90 p.
- KNERER, G., 1983. Diapause strategies in diprionid sawflies. *Naturwissenschaften* 70 (4): 203–205.
- KULFAN, J., DVOŘÁČKOVÁ, K., ZACH, P., PARÁK, M., SVITOK, M., (2016). Distribution of lepidopteran larvae on Norway spruce: Effects of slope and crown aspect. *Environmental Entomology*, (in press).
- LAPIN, M., FAŠKO, P., MELO, M., ŠTASTNÝ, P., TOMLAIN, J., 2002. Klimatické oblasti [Climatic regions]. In *Atlas krajiny Slovenskej republiky*. Bratislava: Ministerstvo životného prostredia Slovenskej republiky; Banská Bystrica: Slovenská agentúra životného prostredia, p. 95.

- LORENZ, H., KRAUS, M., 1957. *Die Larvalsystematik der Blattwespen (Tenthredinoidea und Megalodontoidea)*. Abhandlungen zur Larvasystematic der Insekten Nr. 1. Berlin: Akademie-Verlag. 339 p.
- PARÁK, M., KULFAN, J., ZACH, P., 2015. Are the moth larvae able to withstand tree fall caused by wind storm? *Annals of Forest Research*, 58: 185–190.
- PSCHORN-WALCHER, H., 1982. Unterordnung Symphyta, Pflanzenwespen. In SCHWENKE, W. (ed.). *Die Forstschädlinge Europas 4. Hautflügler und Zweiflügler*. Hamburg, Berlin: Parey, p. 1–234.
- VIITASAARI, M., VARAMA, M., 1987. *Sahapistiaiset 4. Havupistiäiset (Diprionidae) Julkaisuja 10* [Sawflies 4. Conifer sawflies (Diprionidae) Report 10]. Helsinki: Department of Agricultural and Forest Zoology, University of Helsinki. 79 p.
- VIITASAARI, M., 2002. *Sawflies (Hymenoptera, Symphyta). I. A review of the suborder, the western Palearctic taxa of Xyleoidea and Pamphilioidea*. Helsinki: Tremex Press. 516 p.

Received December 15, 2015

Accepted February 5, 2016

Instructions for authors

Folia Oecologica is an international journal devoted to publishing peer-reviewed articles covering all aspects of both theoretical and applied ecology and related interdisciplinary fields (nature conservation, forestry, agriculture, ecological economics etc.). The journal publishes full-text papers, short communications and review articles. All submitted manuscripts are reviewed by two independent reviewers.

Manuscript layout

The manuscripts (MS) should be written in English, well-arranged, not exceeding a maximum extent of 20 pages, including tables and figures. The authors are responsible for the quality of the text, MS written in poor English will be returned. Please send an electronic version of the MS (an e-mail attachment) as a Microsoft Word file (DOC, or RTF format, A4 format, font Times New Roman, size 12, 1.5 lines, standard margins 2.5 cm on each edge of the page) together with all figures and tables (each on a separate sheet) to the editorial office. Avoid hyphenation, do not define the styles and paragraphs. Do not use either spacing or tabulator for beginning a paragraph. The authors are requested to submit MS that have not been, nor will be, published elsewhere. This fact should be explicitly stated in a covering letter, which authors send alongside with the MS.

An original scientific paper should comprise: 1. The title. 2. The author's (authors') name: full first name and family name. 3. Address: complete address and E-mail address of corresponding author. 4. Abstract: in one paragraph, without references to tables, figures and literature, not exceeding 15 lines (900 characters). 5. Key words (maximum 6). 6. Introduction. 7. Material and methods. 8. Results. 9. Discussion (or Results and discussion). 10. Conclusions (optional). 11. Acknowledgement. 12. References. Names of chapters and names of subchapters must be written after omission of two lines and one line, respectively, in bold font and aligned to the left edge.

In the manuscripts, it is necessary to use SI symbols. Non-integer numbers should be provided with a decimal point, (e.g. 1.7, not a 1,7), the thousands (with exception of years) are separated with a comma: 5,600. The variables in mathematical formulae and expressions should be written in *italics*, the symbols for functions and constants in the normal font, the matrices in bold capitals, the vectors in bold small letters. The SI units – recommended rules of writing: 10%, 10 °C, 10 µL, 5–15 mg g⁻¹, kg m⁻¹ s⁻², 1,200 m asl, Pa, mol. The components of numerical expressions should be separated by spaces, e.g., p. 5–15, 19–23 July 2009, y = x + 1, p < 0.05. Latin names of genera, species, sub-species and varieties are written in *italics*, the name of the author of the description (or his abbreviation) normally: e.g. *Lymantria dispar* (Linnaeus, 1758), *Lymantria dispar* (L.), *Abies cephalonica* Loud. var. *graeca* (Fraas) Liu. The names of cultivars are written normally, e.g. *Olea europea* L. cv. Chalkidikis. Taxon and syntaxon names are written in *italics*. All the tables and figures must be referred to in the text: Table 1, Tables 2–4, Figs 2–4.

References

Literature citations

The literature cited in the text should conform to the following patterns: one author – FUNKE (1971) or (FUNKE, 1971), two authors – SOKAL and ROHLF (1995) or (SOKAL and ROHLF, 1995), three and more authors – ALSTAD et al. (1982) or (ALSTAD et al., 1982). More than one work written by the same author is to be distinguished with small letters appended after the year: NOVÁK (1950a, 1950b).

Reference list

The list of literature cited in the text of article (ordered alphabetically and according to the publication year) is placed on the last page. Latin names of genera, species and sub-species cited in the list of references are to be written in standard type. The titles of each article must be cited in the original language appended by an English translation (in square brackets). Titles in languages not using the Latin alphabet should be transliterated keeping with the British Standard 2979 (in the case of the Cyrillic e.g. ж = zh, x = kh, ц = ts, ч = ch, ш = sh, щ = shch, ю = yu, я = ya).

Work in a periodical

SHAROV, A.A., LIEBHOLD, A.M., RAVLIN, F.W., 1995. Prediction of gypsy moth (Lepidoptera: Lymantriidae) mating success from pheromone trap counts. *Environmental Entomology*, 24: 1239–1244.

EIBERLE, K., NIGG, H., 1984. Zur Ermittlung und Beurteilung der Verbissbelastung. *Forstwissenschaftliches Centralblatt*, 103: 97–110.

Book

SZUJECKI, A., 1983. *Ekologia owadów leśnych* [Ecology of forest insects]. Warszawa: Państwowe Wydawnictwo Naukowe. 604 p.

MILLER, J.R., MILLER, T.A. (eds), 1986. *Insect-plant interactions*. New York: Springer-Verlag. 342 p.

Book series

NYBOM, H., RUMPUNEN, K. (eds), 2005. *Proceedings of the 1st international rose hip conference. Gümüşhane, Turkey, September 7–10, 2004*. Acta Horticulturae, 690. Leuven: International Society for Horticultural Science. 301 p.

Work published in a book or in a proceedings

BASSET, Y., SPRINGATE, N.D., ABERLENC, H.P., DELVARE, G., 1997. A review of methods for sampling arthropods in tree canopies. In STORK, N.E., ADIS, J., DIDHAM, R.K. (eds). *Canopy arthropods*. London: Chapman & Hall, p. 27–52.

CIBEREJ, J., KOVÁČ, G., BILÁ, A., 1999. Faktory ovplyvňujúce početný stav kamzíka vrchovského v TANAP-e [Factors influencing game populations in chamois (*Rupicapra rupicapra* L.) in the High Tatra National Park]. In KOREŇ, M. (ed.). *Päťdesiat rokov starostlivosti o lesy TANAP-u. Zborník referátov z konferencie*. Poprad: Marmota Press, p. 111–116.

Dissertation

CHROMOVÁ, L., 2002. *Pôdne a vegetačné zmeny lesných spoločenstiev okolia obce Brusno (Veporské vrchy)* [Changes in soils and vegetation of forest communities of the Brusno village (the Veporské Mts)]. PhD thesis. Bratislava: Comenius University, Faculty of Natural Sciences. 122 p.

Web source

WOODWARD, J.L.W., 1999. *Effect of fungicide treatment to control shot-hole disease of cherry laurel*. Centre for Applied Nursery Research [cit. 2011-10-12]. <http://www.canr.org/98013.pdf>

Tables

The tables should be prepared in Word, without vertical grid lines, and submitted on separate A4-sized pages, not included into the text. Use the Times Roman font and the font size 9. Table width should be of one or two text columns (77 and 160 mm) or 235 mm. The tables are to be numbered, each after other, with Arabic numerals (Table 1, Table 2...). The numbering and captioning should be placed over the table (aligned left), commentaries, if any, under the table. The text in the captions should always begin with a capital letter and should be centralised. The abbreviations of measured units should be given in round brackets. The tables must be self-explicable. Avoid doubling the information in tables and figures.

Figures

Submitted are only high-quality figures in black, in one of the following formats: jpg, png, tif, xls, each on a separate A4 sheet. Avoid three-dimensional graphs, if possible. Please use only shade lining, not shading. The lines must be sharp and the written text must be distinctly readable also after the diminution. Use the Arial font. The font size should not exceed 11, the recommended size is 9. The text in the captions should always begin with a capital letter and should be centralised. We prefer figures to be in the width of 77, 160 or 235 mm. Figures itself and legends within larger figures should not be framed. Figure parts should be identified by lowercase roman letter (a), (b), (c), etc. The figures must be self-explicable with readable legend and symbols, without necessity to seek explanations in the text of the MS.

Off-prints

Each author and co-authors will obtain one electronic copy of the published paper.

Editorial office

Institute of Forest Ecology SAS, Centre of Scientific Information – Library, Štúrova 2, 960 53 Zvolen, Slovak Republic, e-mail: knizuel@savzv.sk Manuscripts should be sent to the editorial office. Folia Oecologica is accessible at <http://www.savzv.sk/editorial-activity/>