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A SHORT ROTATION COPPICE OF FAST-GROWING TREES, THEIR LANDSCAPE ASPECTS AND BIODIVERSITY

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Abstract

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Biomass should play a dominant role, of about 85%, in the structure of renewable resource utilization by 2030. Biomass is usually used in the form of firewood or wood residues from sawmills, the paper industry and woodworking industries. Other forms, such as straw biomass residues and residues from logging are used less often. If the current trend continues, then short rotation coppice (SRC) of fast-growing trees will be planted on larger areas of agricultural land. The main function of these SRCs in most cases is to produce biomass as biofuel and/or a raw material. The landscape effect of thes,e SRCs has been considered only a by-product of this new form of management. The importance of SRCs for landscape and agricultural practices is one of the conditions for their future development. This article will deal with the landscape functions of SRCs of fast-growing trees and their contributions (benefits) for landscape biodiversity. It will also address the problems of evaluating the biodiversity of the SRCs of fast-growing trees.
This research will answer the question of the stability and functionality of stands as a whole and, at the same time, highlight the role of stands in increasing landscape biodiversity. In this article, research results from the initial years are presented.

Key words: ecological stability, bioindicator, ground-beetle, biodiversity, genus *Carabus*

Introduction

Because human activities over the last decades have devastated the Czech landscape, much effort has been put into landscape protection and revitalization since 1990. The system of financial support and maintenance of non-productive functions of individual segments of the cultural landscape has gradually been improved and extended over the last few years. For instance, the Ministry of Agriculture of the Czech Republic now gives subsidies for mowing meadows that are no longer grazed due to decrease in meat production, and the Ministry of the Environment provides support for the revitalization of waterways to slow run-off.

Plants, and especially woody species produced as energy crops for biomass, can be used to improve the functioning of the landscape, e.g., in various problem areas on the edges of towns, but also in surrounding open landscape. Emphasis is put mainly on the effective use of trees and tree stands for improving the quality of the environment, protecting nature and creating a landscape. The complex of epigeic invertebrates in different parts of the Czech Republic consists of different species characteristic of different biographical areas. Species characteristic of forest ecosystems, which once used to cover most of our country's area, are good indicators of environmental condition changes. With increased revitalization, the total number of species increases, as does the occurrence of species with narrow ecological valency. However, at the same time, their population density and activity decreases. Considering their high level of taxonomy treatment and the extent of knowledge of ecological requirements of each species, the *Carabidae* beetle family is suitable for bioindication of environmental conditions in various habitats (Syrovátka, 2004).

Material and methods

The stands selected for observation of landscape aspects were mainly small experimental plots of the Silva Tarouca Research Institute for Landscape and Ornamental Gardening (VUKOZ, Publ. Res. Inst.) in Průhonice. These plots were established between 1995 and 2000 to test willow and poplar clones for biomass production. Other stands considered were selected SRCs of fast-growing trees, established mainly by farmers or municipalities (e.g., Peklov u Kladna). The significance and effectiveness of SRCs established for production purposes will be evaluated for the fields of landscape creation and protection.

Studying the whole complex of epigeic invertebrates, which would naturally be the best and also the most interesting, is very demanding. The problem is the time requirements and, most importantly the financial requirements caused by the necessary involvement of experts able to correctly identify, not only various beetle species, but also land isopods (*Isopoda*), millipedes (*Diplopoda*), centipedes (*Chilopoda*), spiders (*Araneae*), phalangids (*Opiliones*) and other groups of invertebrates. For this reason, simpler methods that would enable reliable bioindication of environmental condition changes have been sought (Syrovátka, 2004). For bioindication purposes, it is necessary to select a group of invertebrates using the following criteria:

- the group must be sufficiently diversified, so that its representatives would live preferably in all biotopes of the given locality,
- the group must be well identifiable (there has to be an expert able to determine all species in the given area),
- the group must be accessible to qualitative and quantitative assessment (there must be certain assessment criteria for the relevant taxonomy group) http://www.sapard.cz/index.php?clanek=171.

Based on these criteria, the *Carabidae* family was selected. The family is represented by a relatively high number of species in most types of ecosystems. Bionomy of individual species, which enables them to colonize biotopes in various development stages, is well known, and European species of the *Carabidae* family are relatively easily and reliably identified (Bezděk, 2001).

To determine the level of adaptation and relict character, *Carabidae* fauna of the Czech Republic has been divided into three groups according to Hůrka et al. (1996):

- **group R** with narrowest ecological valency, showing relict character in the present; these are rare and endangered species of natural, not too damaged ecosystems,
- **group A** with more adaptable species, inhabiting more or less natural biotopes or biotopes near natural condition, also occurring on secondary, well regenerated biotopes, especially near their original areas,
- **group E** of eurytopic species, which often have no specific requirements about the character and quality of the environment; species of unstable, changing biotopes; these inhabit heavily human-affected, i.e., damaged landscapes; the group includes expansion species currently proliferating in such unstable environments.

As early as 2001, a transect reaching into three associations has been marked out on the experimental plantation: an agricultural meadow (a meadow poor in species), a stand of short rotation coppice and a part of the forest complex of Průhonice park. Research at the Peklov site focused on monitoring the *Carabus* species in stands with various rotation periods. The length of the rotation period is caused by the different site conditions.

On each biotope, traps were laid 10 m apart and numbered in increasing order from the meadow to the forest. Ground traps, plastic bottles with the tops cut off (height approx. 20 cm, diameter 8 cm), were inserted into the ground. These were filled with concentrated formaldehyde solution (approx. 150 ml) and covered with aluminium sheet roofs to prevent, at least to some extent, intrusion of various vertebrates and overfilling of the traps with rainwater, as well as drying up.

The traps were installed from early spring to autumn, when the experiment ended. Traps were emptied monthly. Each time, their contents were poured into a bowl, separated to remove large vegetable remains, and then poured into bottles. In the laboratory, after washing the bottle contents with water, the material was sorted according to major groups: carabid beetles, spiders and phalangids, isopods, millipedes and centipedes.

From the complex of carabid beetles, *Carabus* species were selected, and the number of individuals was determined for all groups.

Results

SRCs of fast-growing trees can have a positive effect on their surroundings from an environmental point of view by e.g., increasing biodiversity, enhancing the food chain, creating biocorridors for the migration of fauna, increasing the small water cycle in the landscape and subsequent cooling, and revitalization of agricultural soils.

Trees can root in compacted soil layers, thus loosening and aerating these soils. At the same time, trees use excess nutrients, lowering the amount that flows into underground waters. Tree litter often further increases low humus levels, thus significantly improving the physical properties of the soil (Simanov, Čížek, 2004). The spectra of environmental factors improved by SRCs has in many ways a positive effect on the livability, management, and ecological stability of the landscape area, the disturbance of which can lead to economic losses. The favorable effect that SRCs have on soil, humidity and microclimate conditions is significant – grassland conditions in intensively used agricultural landscapes can change into forest conditions, characterized especially by the renewal of the function of the so-called short or closed water cycle (Pokorný, 1997; Ripl, 1995; Ripl et al., 1996). This function influences the character of the individual biotopes, the possible development of various biocoenoses and the renewal of species variety and communities (biodiversity) of the landscape.

In SRCs with closed canopies (from the 3rd–4th year), temperature and humidity conditions are similar to those found in permanent greenery or forest stands, i.e., welcome sites that provide new niches for a wide variety of species (small animals, birds and insects). The low management intensity of SRCs (harvest every 3–6 years), in comparison to conventional plant production or orchards, adds to the attractiveness of this new element in the landscape structure.

The argument that these stands also fulfill the function of refugia, biocorridors and interactive elements of the Land System of Ecological Stability (USES in Czech) may be correct in areas with intensely used landscapes, but this has not been verified in Czech conditions. The results of the above-cited authors and from other research suggest that SRC may function as interactive elements of USES and possibly also as anthropic conditional biocenters (Löw et al., 1995), but explicit proof of this is needed for Czech conditions (Weger et al., 2002).

SRCs begin to fulfill the landscape function soon after their establishment; from the second vegetation season, the stands reach 1.5 m in height and significantly and mainly positively affect their surrounding environment. Establishing SRCs of fast-growing trees is one of the most suitable ways to renew the small water cycle and thus revitalize the landscape functions that were disturbed during historical large-scale clearcuts and ploughing. SRCs protect soils from evaporation, contribute to the stabilization of runoff and stabilize the local climate.

The ecological stability of SRCs is a frequently discussed question. Are SRCs resistant to biotic and abiotic damages? One way to increase the resistance of SRCs is to establish mixed stands, using not only a mixture of species, but also of clones. If clones with similar growth parameters are chosen, then the establishment of mixed stands is possible without negatively affecting yield in comparison to one-clone monocultures.

Other tree species e.g., alder (*Alnus*) and hazelnut (*Corylus*) have also been proven to be suitable for production of multifunctional stands of fast-growing trees. It is assumed that these species would be used as a supplement in SRCs or to establish SRCs where high yields are not the main goal. Rosehip (*Rosa canina*), for instance, can also be used as a hedge around SRCs. Rosehips, known nesting and hiding places for many insect-eating birds and small animals could be left unharvested even in the SRC harvest year.

Landscape function

The most often cited significance of SRCs is the set of landscape creation functions. This is mainly due to the marked growth and habit of willows and poplars that have been part of the visual character of the Czech cultural landscape for over a century. The reasons for planting willows and poplars in landscape are listed below according to the significance for the landscape function including a short description of the side effects on the landscape:

- Stands planted on stream/riverbanks: quick reinforcement of banks against water erosion, quick production of biomass (for burning) in areas with optimal conditions, creation of biocorridors and natural borders in the landscape, esthetic effect. They are known for their role in regulating runoff and mineral nutrient flows and resulting floods. They are less known for their role along the water flow as a corridor in which terrestrial plants and animals can spread. Some species use the moist alluvial soils to spread (Anonymous, 2004).
- Forest stands in polders: dammed polders that are able to catch most flood waves. Poplars and willows cannot only withstand 1–2 months of flooding of their root systems, but in this state can reach normal biomass production rates.

- Biological melioration (drying) of wet areas using SRCs is a natural and not economically demanding measure in which excess water is used to produce biomass.
- Biological protection: when zones of vegetation are planted along highways and roads to function as biological filters to capture lead and other substances (gas and solid particles from vehicles) that accumulate in plants.
- Windbreaks: limits the drying out of soils, lowers wind erosion and damage to agricultural produce, landscape partitioning, increases biodiversity of the agricultural landscape, creation of biocorridors and forest communities in forestless agricultural areas.
- Plantations (for energy crops, for basket weavers): provide more than protection, increase biodiversity of the agricultural landscape, provide cover and food for small animals and nesting places for birds.
- Waste lands/soils: greening of spoil heaps and waterlogged sites in anthropogenic areas (Mottl, Štěrba, 1975; Mottl, 1989; Mottl et al., 1992).
- Accompanying linear structures: poplars and mainly their cultivars were planted along main roads already in the Austro-Hungarian Empire, thus becoming an important element of the Czech landscape; in this case their function is mainly aesthetic (Mottl, Štěrba, 1975; Mottl, 1989).
- Solitaires in the landscape: Only rarely can remnants of original native species from natural sprouting be found. Usually these are from several allochtonous species and hybrids between them (Mottl, Štěrba, 1975; Mottl, 1989).
- Greening of urban areas, around fishponds, along streams: female powder clones and cultivars of poplars that do not produce "down" (small seeds wrapped in fluff) or weeping willow cultivars and cultivars with colored leaves (Mottl, Štěrba, 1975; Mottl, 1989; Šimíček, 1992).

Based on the monitored *Carabus* species in individual SRC stands, Table 1 shows that in the third year of the stand's existence, suitable conditions for species that inhabit more-or-less natural or close to natural biotopes already exist.

When comparing the monitored species from various biotopes (see Fig. 1), it is evident that SRC stands can create transient sites important especially for the spread of species into agricultural landscapes. The occurrence of the monitored indicators was compared for three biotopes: meadow, forest, and SRC stands. The same species were found in SRC stands as in the forest, but with fewer individuals present. None of the monitored species were found in the meadow.

T a b l e 1. Occurrence of monitored species in stands with various rotation periods in 2006 and 2007.

Rotation period (years)	*Carabus nemoralis*	*Carabus hortensis*	*Abax parallelepipedus*
1	12	0	4
3	39	18	28
6	81	7	16

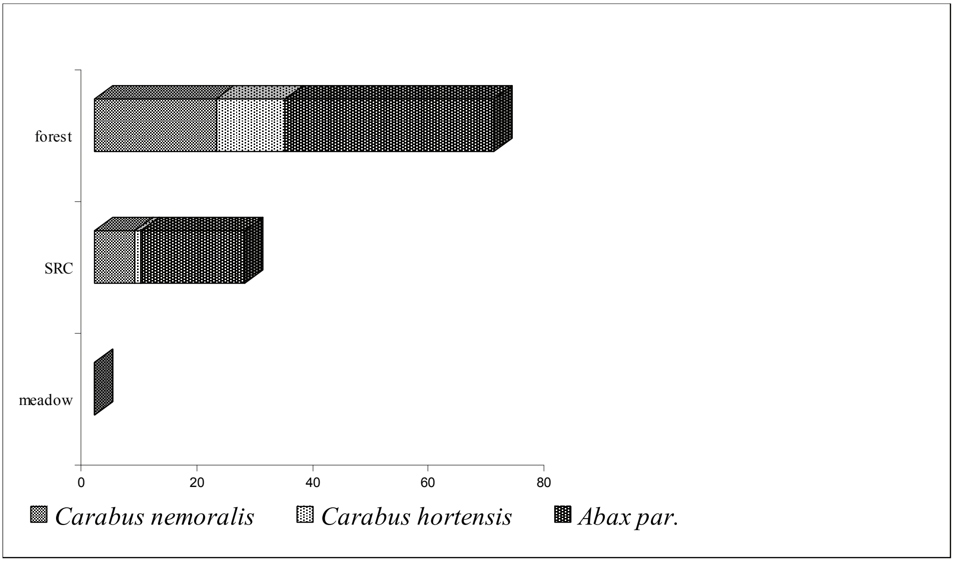

Fig. 1. Comparison of *Carabus* genus occurence in three monitored biotopes, in 2006, 2007.

Discussion

One substantial phenomena of the previous Czech landscape development was that arable land was extended to unsuitable sites. With this, the historic balance of forests, fields and land resources that plays a significant role in the functioning of the whole agrosystem was disturbed. Forests were more-or-less untouched with their share remaining around 36% of the overall territory. The share of meadows and pastures significantly decreased to enable the creation of ploughed fields. Many agricultural areas have 100% ploughed lands. Of the overall area of agricultural lands in the Czech Republic, approximately 40% are in lowlands, which traditionally have advantageous conditions for agricultural use. The remaining part of the land is more-or-less fragmented, hilly to mountainous, and the conditions for management are less favourable.

On average throughout the Czech Republic, 72% of land defined as agricultural is ploughed. This is accompanied by lower ecological stability of many areas and wind and water erosion. Today 54% of arable land is threatened, which is causing, among other things, substantially lower yields. We cannot forget to include the inherently altered cycle of nutrients in the soil, the decrease of organic content (to a critical 1%), allogenic substances, the affected quality of underground and surface waters, the compaction of subsoil layers, the frequent inconsiderate and insensitive reclamation of water-logged soils, etc. Last but not least, the aesthetics of the landscape, its livability, and its permeability suffers greatly.

Overproduction in conventional agriculture, the exhaustibility of fossil fuel sources and the actual ecological problems in environmental protection are currently priorities in management and research in developed countries, including the Czech Republic. Phytoenergetics can solve all three groups of the above-mentioned problems.

The characteristics of the individual landscape functions of SRCs is dependent on the specific landscape structure, the method and intensity of use, the management methods, settlement patterns, and the state and placement of natural elements and sources of pollution and devastation. The effectiveness of SRCs can be increased, above all, by the rational selection of sites before SRC establishment, the adjustment of the shape of the stand, the expansion of the species composition, the modification of farming management and supplemental technical elements or the linking of existing landscape elements to attain the desired effect.

SRCs with closed canopies are able to cool the landscape by means of their photosynthetic mechanisms. Thus, a belt of these stands can function as insulation against overheating of the earth's surface, which is one of the reasons for extreme climate changes. This cooling landscape mechanism was limited by deforestation and landscape changes – large-scale agriculture with grain crops.

Among the effective instruments that enables the integration of SRCs in the protection and landscape creation process is the enveloping of SRCs with other plants. Only native species should be used as hedges, but they do not have to be willows and poplars. An expanded species composition can be used. Hedges around SRCs are effective instruments that enable the positive integration of SRCs in the functional landscape system and can even partially be a local substitute for permanent greenery. This effect can further affect species and spatial composition that stems from the concrete conditions and site characteristics.

Currently the option of multi-species composition is used only exceptionally, because of the work difficulty and expense of establishing stands. To date there is no experience with the harvesting of these hedges. It is assumed that they would not be harvested as often as the SRCs.

The main goals for establishing test sites with hedges around SRC's are to select suitable tree species and their combinations, to evaluate suitable planting technology, and the possibility of using them especially for biological and aesthetic functions. On the basis of three years of experience, it is possible to say that if we look at rooting and survival, woody species, such as *Viburnum opulus*, *Rhamnus cathartica*, *Fraxinus exscelsior*, *Corylus avellana*, *Cornus mas* are very suitable species. Rosehip (*Rosa canina*) can also be used.

Fast-growing trees have been used to create greenery and for biological re-cultivation of anthropogenic soils. The possibility of planting directly in non-enriched soils, the fast growth and the early fulfillment of ecological and other functions of permanent greenery in the landscape are among the benefits of establishing SRCs. In terms of soils, leaf litter improves the soil parameters and tree roots improve the soil layers up to 10 m deep. Heavy-metal decontamination of soils is a relatively new use for SRCs. Willows and poplars can accumulate heavy metals.

SRCs have been used e.g., in Sweden for tertiary wastewater treatment. Several 10–75 ha willow stands of this type have been established since 1997. SRCs are watered with the so-called tertiary effluent, which is wastewater cleaned in a classical two-step wastewater treatment plant. This effluent obtains the remnants of nutrients (nitrogen and phosphorous) and sometimes traces of heavy metals (copper, zinc and cadmium). Swedish researchers have been dealing the most with this research topic; they have been observing the efficiency of the SRCs of willows for cleaning wastewater, and the fertilizer effect for biomass production. After 7 years of research, the following data on average was collected: the irrigation period for 10 May to 20 October with application of 730–770 mm.m^2/year and with nutrient content of N-P-K/72–10–85 kg/ha/year (Hasselgern, 1998; Larsson et al., 2003). The European research project "Biomass Short Rotation Coppice Irrigated and Fertilised with Municipal Wastewater" also addressed this issue. Experimental plots were established in Sweden, Greece, France and Northern Ireland. The results of this research clearly indicate the positive effect of irrigating with municipal wastewater on biomass yields from willow plantations (Ripl, 1995).

Ulrich et al. (2004) presumed that poplar stands do not particularly improve or support the diversity of carabids in Poland. Allegro, Sciaky (2003) also claimed that the carabid communities and populations are very unstable in poplar plantations in the northern Italian agricultural landscape. Our research results to date rebut this claim, which may have been based on a very uniform landscape, strongly affected by agriculture and with different abiotic conditions in Poland and Italy.

From the research done in the Czech Republic, it is evident that the surrounding biotopes and the means of stand management are important for the developing invertebrate fauna in SRC stands. It is advisable to limit ploughing between rows and to leave a layer of residuals in the plantations. Hedges also play a role in increasing the number of invertebrates by enabling migration from surrounding areas and by providing cover during harvest times, e.g., in the year after harvest. Hence, it is advisable to establish plantations with various rotation periods.

Conclusion

Woody species grown as energy crops can be used to improve the functioning of the landscape e.g., to improve various problem localities on edges of towns and in the open countryside. Mainly, the effective characteristics of these woody species and stands should be used to improve the environment, protect nature and create landscapes.

It can be said that, in comparison to 2001, the ecological conditions of the experimental SRCs of VÚKOZ, Publ. Res. Inst in Michovka have improved and significantly differ from the meadow communities. The improvement of soil humidity conditions has obviously played a significant role in this. Leaving the soils be (limited tilling between rows) and creating leaf fall and litter have had favourable effects on the soils. From the current observation of experimental SRCs, it is obvious that the stands positively affect their surrounding landscape and the human environment e.g., by increasing biodiversity, stabilizing the water regime, cooling the soil surface and increasing the diversity of intensively managed landscapes.

The initial hypothesis of the present study stated that the soil of woody SRC plantations shaded and covered with leaf debris, should be suitable for gradual propagation of forest species, some of which display a tendency to migrate into the plantation. Species *Carabus hortensis* and *Carabus nemoralis* are classified (Hůrka et al., 1996) as a group species inhabiting more-or-less natural habitats or habitats near natural condition. They also occur on secondary, well-regenerated biotopes. This group especially includes the species typical of forest stands. Evidently, the propagation of these species to the SRC plantation biocoenose indicates favourable development aimed at the establishment of stable conditions. For SRC stands, it is necessary to consider their specific manner of management. SRC stands are harvested several times during their existence. When a part of the stand is cleared, an increase in species diversity may manifest itself (Syrovátka, 2004). Increased diversity of carabid species after clearing is usually explained as a consequence of more favourable microclimatic conditions for species of open sites and sites generally, and by increased species diversity of vegetation on the clearings, which affects the carabid associations both directly (more food for herbivore species) and indirectly (more herbivorous invertebrates as food for raptatory carabids) (Dedek, 2006). It is also necessary to consider ploughing between lines or prevention of ploughing and plant debris formation, which contributes to the differentiation of vertical distribution of carabids, as well as to the prevention of interspecies competition (Boháč et al., 1995). Carabid occurrence depends on many abiotic and biotic factors, namely humidity, vegetation character, temperature, geological substrate, migration ability of species, predation and human influence. Other authors (Syrovátka et al., 1999) have shown that in case of favourable changes in soil or vegetation and humidity conditions, important positive changes of composition of this invertebrate complex may take place rather quickly.

This idea, including the results obtained to date, indicates that SRC stands do not promise establishing conditions for the existence of real forest associations, but rather of specifically much more diverse transition associations.

Maintaining and increasing landscape biodiversity should be one of the priorities of nature conservation. In consequence of intense landscape utilization and cultivation, ecosystem degradation and a decrease in biological diversity occur. Similar temperature and humidity conditions are established inside SRC stands with closed canopies (in 3^{rd}–4^{th} year), such as in permanent vegetation stands or in forest stands that are proved to be desirable sites and new niches for a broad assortment of animals, such as small game, birds and insects. The low intensity of management of these new landscape structure elements, compared to conventional plant production or fruit orchards, also contribute to their attractiveness.

This article has focused only on the *Carabidae* family (a narrow group), but a complex study dedicated to the presence of other invertebrates, mammals and birds in SRC areas would also be an important and interesting contribution.

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