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ASSESSMENT OF MANAGEMENT STRATEGY FOR HARDWOOD FLOODPLAIN FOREST ECOSYSTEM IN PROTECTED AREA

Jaroslav Simon[1], Ivo Machar[2]

[1] Department of Forest Management, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

[2] Department of Biology, Faculty of Education, Palacky University, Žižkovo nám. 5, 771 40 Olomouc, Czech Republic

Abstract

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The floodplain forests of lowland rivers in the temperate zone of Europe are an important biota refuges in the cultural landscape. Most of these forest ecosystems are included to the national systems of protected areas and ecological networks. The paper deals with innovative method for assessment of management strategy for hardwood floodplain forest ecosystems. The presented method is based on a combination of results from historical research with the application of growth simulation model. This method enables to predict a future development of the forest ecosystem studied and assess the forest management strategy. This can be a useful tool for correction of management plan of protected area. The method was applied in study site Vrapac National Reserve within the Morava River basin (Litovelske Pomoravi Protected Landscape Area, Czech Republic).

Keywords: forest history, forest management, management plan, management strategy, nature reserve

1 INTRODUCTION

The basic tools for maintaining forest biodiversity include sustainable forest management practice (ANGELSTAM *et al.*, 2004, SEYMOUR and HUNTER, 1999). It is based on an ecosystem approach (GRUMBINE, 1994; YAFFEE, 1999) that is optimally applied on the landscape scale of the integrated catchment area (EISELTOVÁ, BIGGS, 1995). The landscape-ecological backbone of the catchment area is the river alluvium of the main watershed recipient (HASLAM, 2008). Key ecosystems of the European alluvial plains of lowland rivers are represented by floodplain forests, which are important biota refuges in the cultural landscape (KLIMO *et al.*, 2008). The floodplain forests support ecological functions of lowland rivers as bio-corridors (FOPPEN, REIJNEN, 1998). For biodiversity of floodplain forests along lowland rivers, the hierarchical level of beta-diversity is important (PRACH *et al.*, 1996), conditioned by the existence of dynamic fluvial successional series of floodplain habitats (MACHAR, PECHANEC, 2011). However, the fluvial dynamics in floodplains of lowland rivers in the European temperate zone is significantly influenced by anthropogenic land use, because the floodplains are a zone of ancient oekoumene (POLÁČEK, 1999). Changes of water regime of river alluvium were the most important impacts of man to floodplain forests ecosystems in history (DÉCAMPS *et al.*, 1988). Habitats of European hardwood floodplain forests are even considered to be an indirect result of anthropogenic land-use of the landscape (PENKA *et al.*, 1991; ŘEHOŘEK, 2008) despite the fact that their biodiversity is extremely high (MADĚRA, 2001). Current forest management in floodplain forests is based on special silvicultural methods (MATIĆ *et al.*, 2008). The last surviving remnants of European hardwood floodplain forests in natural state are usually territorially protected within systems of national protected areas and form the basis of the Natura 2000 network (JONGMAN, 1995). In order to strictly protect hardwood floodplain forests within the protected areas and national parks in Europe, a so-called non-intervention management (based on leaving the forest ecosystem to spontaneous development) is generally applied (SCHNITZLER-LENOBLE, CARBIENER, 2007). In protected areas of large size (thousands of hectares, such as the Donau-Auen National Park in Austria or Letea Forest Natural Monument in the Danube delta), such non-intervention management of the floodplain forest ecosystem is undoubtedly well-founded (DISTER, 2007). Nevertheless, a vast majority of today's small-scale reserves of European hardwood floodplain forest situated along lowland rivers are the former game preserves or grazing forests (MEZERA, 1956) and current non-intervention management of these protected areas can lead to significant changes in the structure of the overall character of the forest ecosystem (UNAR, ŠAMONIL, 2008; VRŠKA *et al.*, 2006). Regarding the European habitats of hardwood floodplain forests along lowland rivers, which are classified as sites of European importance of the Natura 2000 network, it is therefore necessary to look for optimal management strategies for maintaining the biodiversity of these dynamic forest ecosystems (e.g. OSZLÁNYI, 2000). This management strategy is a set of principles from which types of care of forest areas with special protection statute are derived (VILLARD, JONSSON, 2009).

The main objective of this paper is to present a method for assessment the ecosystem management strategy for hardwood floodplain forests of lowland rivers in protected areas under ecological conditions of the European temperate zone. The proposed method is based on a combination of historical research of the floodplain forest ecosystem with the application of growth simulation model in order to predict the future development of the forest ecosystem studied. The method was applied in the Vrapac study site within the Morava River basin, situated in the eastern part of the Czech Republic.

2 MATERIALS AND METHODS

2.1 Study site

The Vrapač study site (Fig. 1) is located 2 km west of the town of Litovel at an altitude of 236 m. The organism mapping quadrate is 6268, coordinates 17°02´ E, 49°42´ N. The whole study site is a national nature reserve (MONTÁGOVÁ, 1999) and core zone of Protected Landscape Area Litovelske Pomoravi (MACHAR *et al.*, 2009). The forest ecosystem at the study site is a complex of mature forest stands composed of geobiocoene type *Ulmi-fraxineta carpini superiora* (MACHAR, 2008a). The Vrapac study site is classified as a hardwood floodplain forest of lowland rivers in the Natura 2000 classification of habitats (CHYTRÝ *et al.*, 2010). The border of the study site is delineated in accordance with the border of the national nature reserve. For more detailed description of this nature reserve and its biota, see MACHAR, RYBKA (1994). The Morava River, forming the northern border of the study site, creates the so-called anastomosis river system (KIRCHNER, IVAN, 1999).

2.2.1 Sources of historical research of the forest ecosystem in the study site

Published own data from detailed historical researches of the study site Vrapac were used in the purpose of this article (MACHAR, 2008b; MACHAR, 2008c).

2.2.2 Prediction of the future forest ecosystem development

Prediction of the future development of the forest ecosystem in the Vrapac study site was made using SIBYLA growth simulator (FABRIKA, ĎURSKÝ, 2006) in its modification for the nature conditions of the Czech Republic depending on the climatic model (SIMON, 2007).

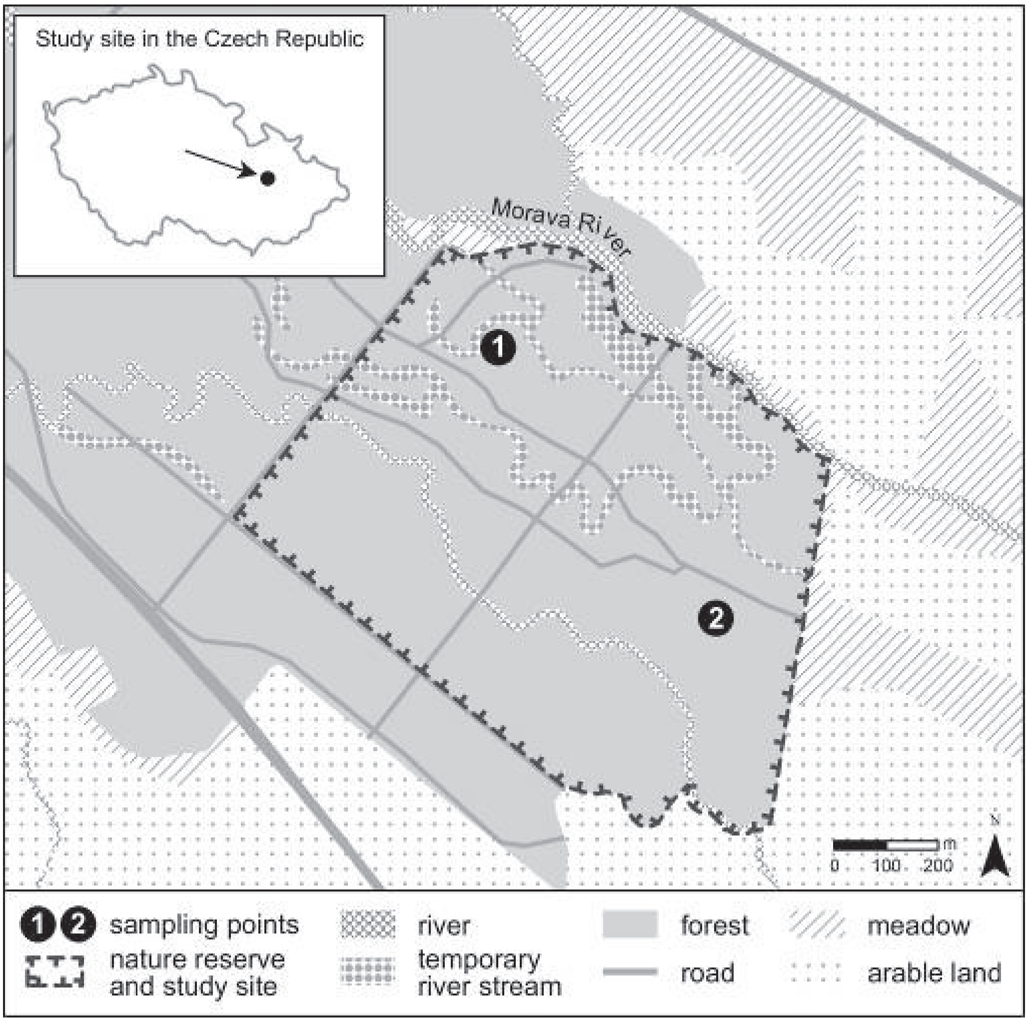
Field part of analyses targeted on assessment of the development of the state of the forest was carried out in the period of 2000–2001 and 2006–2007. The realistic values of biometrical quantities entering growth simulations were derived for the first time period. Two sampling plots (Fig. 1) were analysed that were different in the expected management strategy:

- No. 1 – forest stand No. 771 A 15/8 (management strategy I – non impact regime, natural succession of forest ecosystem – according to the actual management plan).
- No. 2 – forest stand No. 768 E 13 (management strategy II – the contiguous area with reduced management regime – use of special management measures based on selection cutting system).

Determining criteria for the area selection for biometrical analyses were as follows:

- Level of approach of the expected natural composition of the stands (oak 50, ash 30, elm 10, maple 10, alder) enabling its achievement by the use of a special management.
- Approaching the stage of maturity in both, ecological understanding and economic meaning by the area of management strategy II (level of regeneration in connection with the enforceable legislation).

The analyses themselves were performed on stabilised square areas (100 × 100 m). The tree stock was inventoried from the width of 5 cm at the height of 1.3 m. Individuals were placed in to a rectangular system of coordinates; the following values and parameters were measured and valuated – width and perimeter of the tree trunk at the height of 1.3 m, the height of the tree, the height of green tree top setting, and the social position.



1: *Study site Vrapac*

3 RESULTS

3.1 History of the floodplain forest ecosystem management in the Vrapac study site

Since Neolithic times, the floodplain forests in the Morava River floodplain were exposed to impact by man, primarily because of its location in the middle of an intensively agriculturally farmed landscape. Of course, the fundamental influence on floodplain forests can be attributed to the deforestation of foothill and mountain locations within the Morava River catchment area in the Early Middle Ages for the purposes of territorial colonization. The drainage area deforestation led to destabilization of the flow in the river and caused the phenomenon of regular (annual) spring floods. This flooding process is linked to strong sedimentation of flood loams (OPRAVIL, 1983).

Approximately in the middle of the 18th century, the major part of the floodplain area, where the Vrapac National Nature Reserve is located, consisted of meadows with single standing trees and smaller areas of coppice forest. The meadows that were presumably intensively used for grazing were gradually turned into forests, so that in the 18th century, the forest became the prevailing landscape matrix. Till 1872, the floodplain forests were managed as a coppice-with-standards with a rotation period of coppice of 40 years; with the seed trees of oak and less frequently, also other trees. From 1872 on, the composite forest was purposely turned into high forest. During the artificial regeneration, the oak (*Quercus robur*) has been purposely preferred as the main commercial species. The present richly structured stands of the floodplain forest in the Vrapac study site are a result of intensive forestry activities and much credit is to be given to the foresters for having preserved it in the present state. Although the Morava River that forms the northern border of the reserve is not regulated by technical means, it is very strongly anthropogenically influenced, as are the dynamics of the whole river system in the floodplain of the Vrapac study site (MACHAR, 2008b).

I: *Current state of forest stands in the sampling plots in the Vrapac study site*

Plot	Storey	Age (years)	Density (%)	Species Representation (%)	Mean Height (m)	Mean Breast Height Diameter (cm)	Number of trees on 1 ha (ind)	Note
No. 1 771 A 15/8 Management Strategy I	(16)	(159)	40	ash - 70	34	57	565	Storey separation is formal and corresponds with silvicultural practice
				oak - 25	31	68		
				sycamore - 5	32	53		
	(9)	(89)	(80)	oak - 40	28	34		
				ash - 20	30	35		
				lime - 20	27	32		
				alder - 13	27	32		
				sycamore - 5	28	32		
				hornbeam - 7	28	29		
	(2)	(5–15)	80	lime - 90	0	8		
				ash - 5	6	5		
				maple - 5	6	5		
No. 2 768 E 13 Management Strategy II	14	134 (5–15)	90	oak - 60	28	49	320	Understorey of lime is not included in the 1st and 7th age group
				ash - 15	29	47		
				lime - 15	26	37		
				hornbeam - 5	24	37		
				sycamore - 5	28	43		
				maple - 1	28	42		

3.2 Current state of forest ecosystem in study site

Silvicultural description of the forest stands created based on the enforceable forest management plan with specifications of updating is shown in Table I. This table shows the base of information input for the growth simulations of forest stands.

3.3 Prediction of the future development of floodplain forest ecosystem in the Vrapac study site

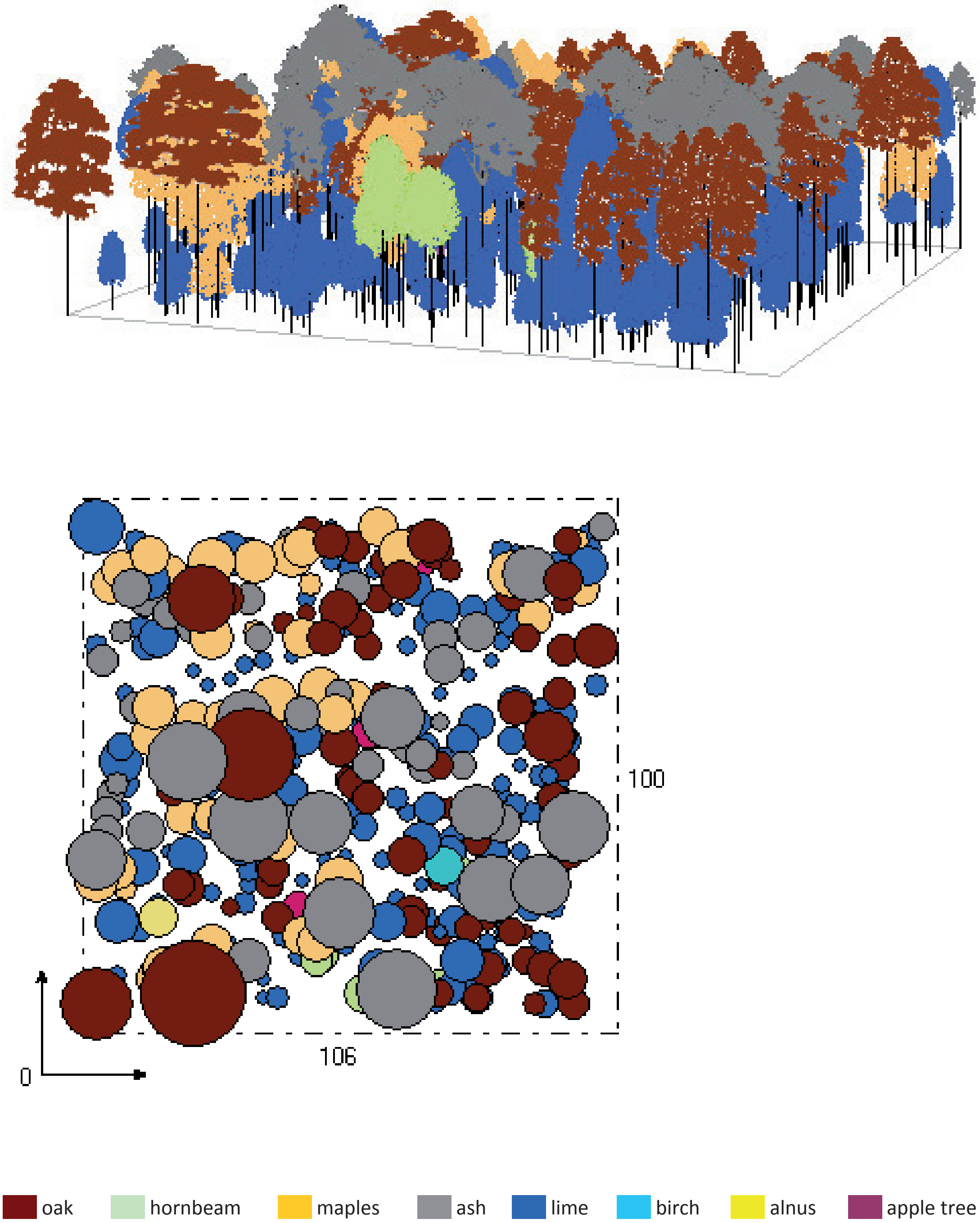
The results of the simulations performed on the analysed sampling plot No.1 are not necessary to be seen and valuated from the stand species composition change point of view because the proposed non-impact regime does not set the maintenance of an actual final image of the forest but the ensuring of natural dynamics. It is possible to say that based on the simulations (Fig. 2–3) the trend of gradual succession of the existing stand heads towards its homogenisation.

The largest individuals of oak (*Quercus robur*) gradually disappear from the top stand level, in the stand level ash (*Fraxinus excelsior*) starts to assert itself into the dominant position, oak subsides and gradual ingrow of lime (*Tilia cordata*) into the main storey is without a doubt, the increase of its proportion at the stage of maturing. A new connected stand forms which will further limit the possible natural regeneration of oak. Character of the stand will gradually approach the image of existing economic forests established in artificial way with the difference of the significant lime part occurrence that is usually reduced during the stand tending of commercial stands.

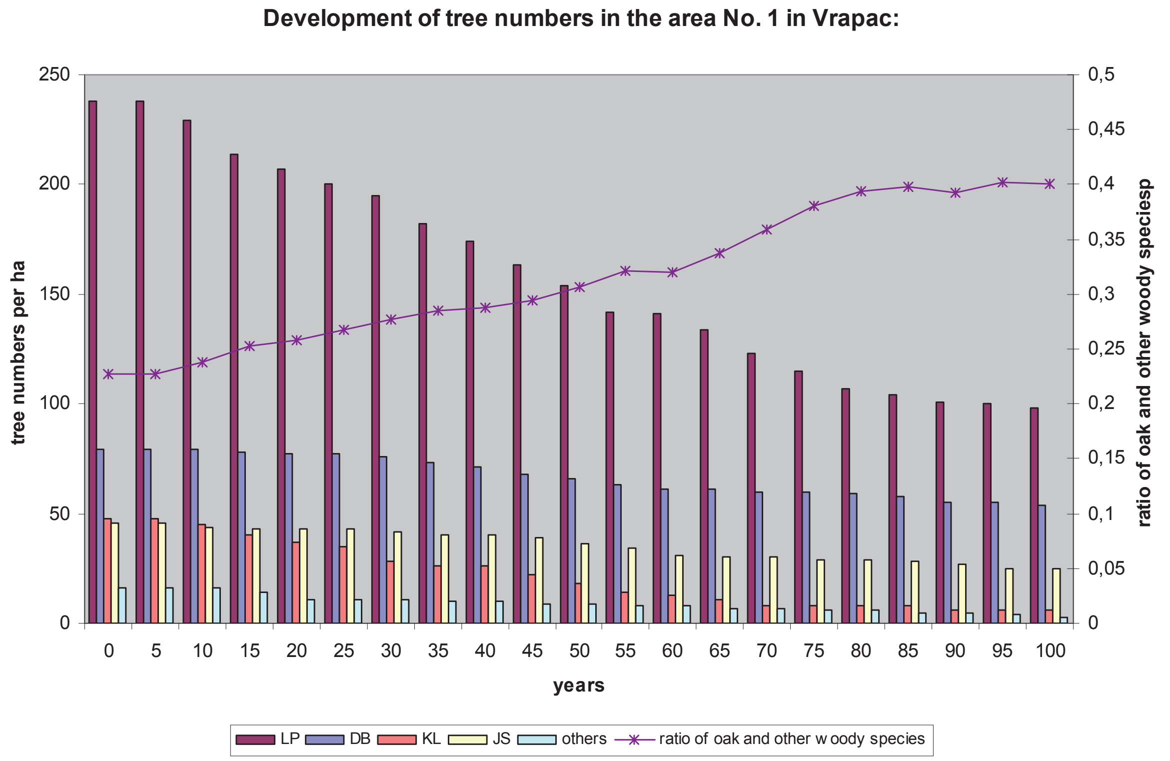
The increase of *Acer platanoides* fraction is the forest stand composition, eventually the occurrence of elm (*Ulmus carpinifolia*) in the valuable fraction, does not seem to be very probable. The explicit state seems to be realistic, based on valuation of the simulations, in the time horizon of 50 to 100 years under the condition that the lowest stand storey will be formed by lime and ash in dominant form. Fraction of lime in the top storey will gradually decrease.

Results of simulations of forest stands succession in sampling plot No. 2 for the regime of natural regeneration (Fig. 4–5) show a very similar trend with a very similar target image of the forest. This is not surprising considering the fact that the main difference between the two areas is the occurrence of the top storey with dominant oak at the mature stage and expected destruction in the time horizon of approximately 50 years.

Considering the fact that it is a locality with expected use of special management, the target image of the forest is possible to be influenced in the direction of actual state of the forest stands in the plot No. 1 and to fulfil the fundamentals of dynamic conservation of forest ecosystem. Basic management measure can then be aimed to the reduction of lime in all storeys and creation of bio groups of target composition woody species.



2: *Simulation model of the forest stand based on is actual state in the sampling plot No. 1 (Woody species: Dub – Quercus robur, Habr – Carpinus betulus, Javory – Acer sp., Jasan – Fraxinus excelsior, Lípa – Tilia sp., Bříza – Betula sp., Olše – Alnus glutinosa, Jabloň – Malus sylvestris)*



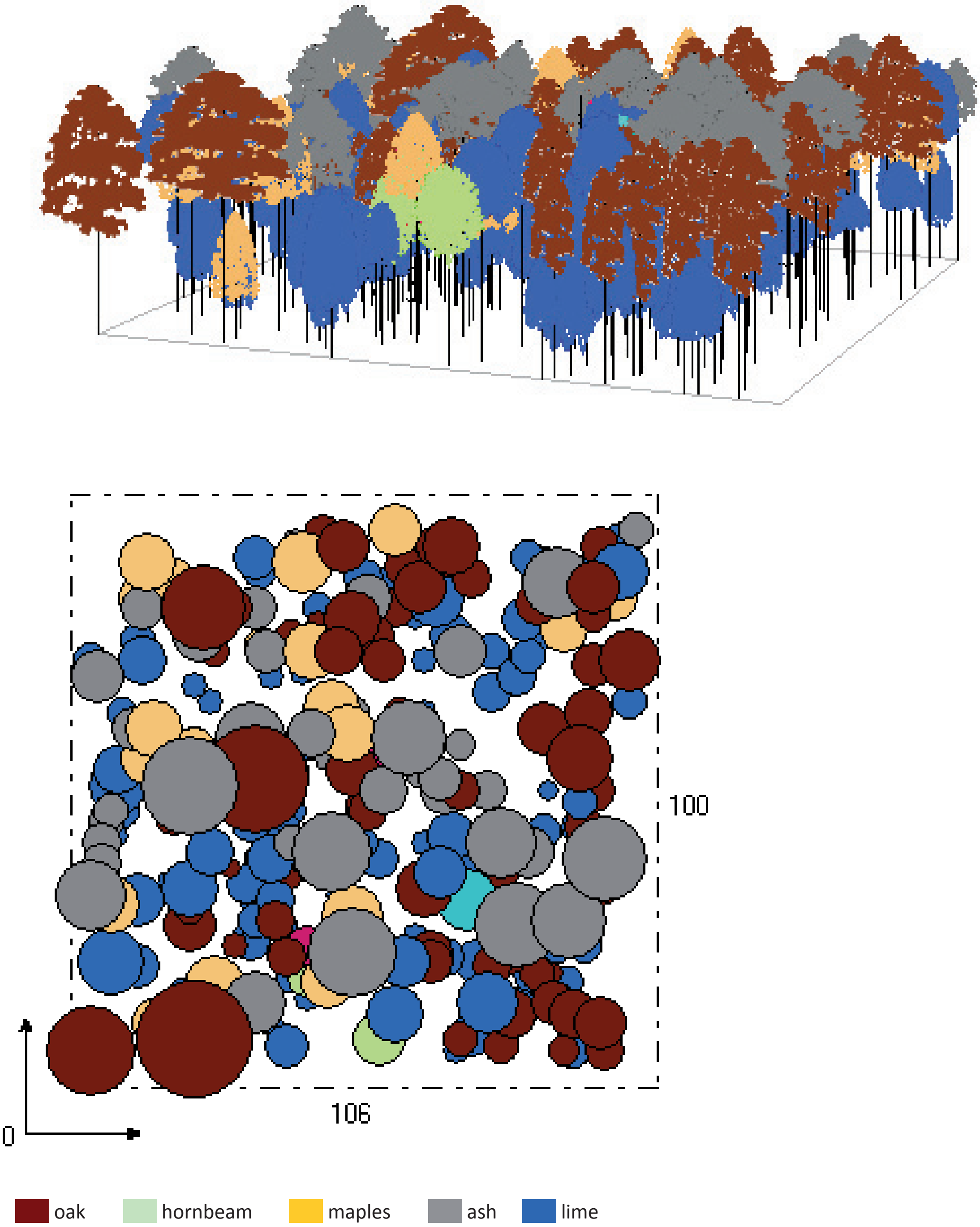
3: *Development of tree numbers and development of the oak fraction comparing to other woody species for the time horizon of the simulation of 100 years in the sampling plot No. 1*

4 DISCUSSION

Assessment of management strategy for hardwood floodplain forest ecosystem in study site Vrapac

The importance of forest ecosystems as permanently renewable natural resources is irreplaceable (FLOYD *et al.*, 2001,). More and more, however, we see that emphasis is put on forest ecosystem functions (STARR, 2009) including biodiversity protection (HOOPER *et al.*, 2009) and carbon metabolisms (EDWARDS *et al.*, 2009). Among others, the conservation of forest ecosystem biodiversity requires special management strategies for forest areas with a special protection statute (NORTON, 1999). The methodology for assessment of management plans in protected areas used in the Czech Republic (SVÁTEK, BUČEK, 2005) allows quick acquisition of updated information about the status of a particular protected area. However, this methodology does not contain any instructions for detailed assessment of the forest management effectiveness regarding the protected areas in the long term perspective (AUSDEN, 2007). At the same time, numerous discussions about forest management effectiveness with regard to specially protected areas in forested landscapes emphasize the importance of natural disturbance regimes (ANGELSTAM, 1996) and refer to the absence of special methods for assessing the effectiveness of different types of management of protected areas (ALEXANDER, 2008; HOCKINGS *et al.*, 2000) depending on management categories (IUCN, 1994). It is a problem especially with respect to the need for justifying the use of considerable financial resources expended by both the national nature conservation and forest owners on special management of forest protected areas with special protection statute such as Natura 2000 sites (EUROPEAN COMMUNITIES, 2002; IDLE, BINES, 2005).

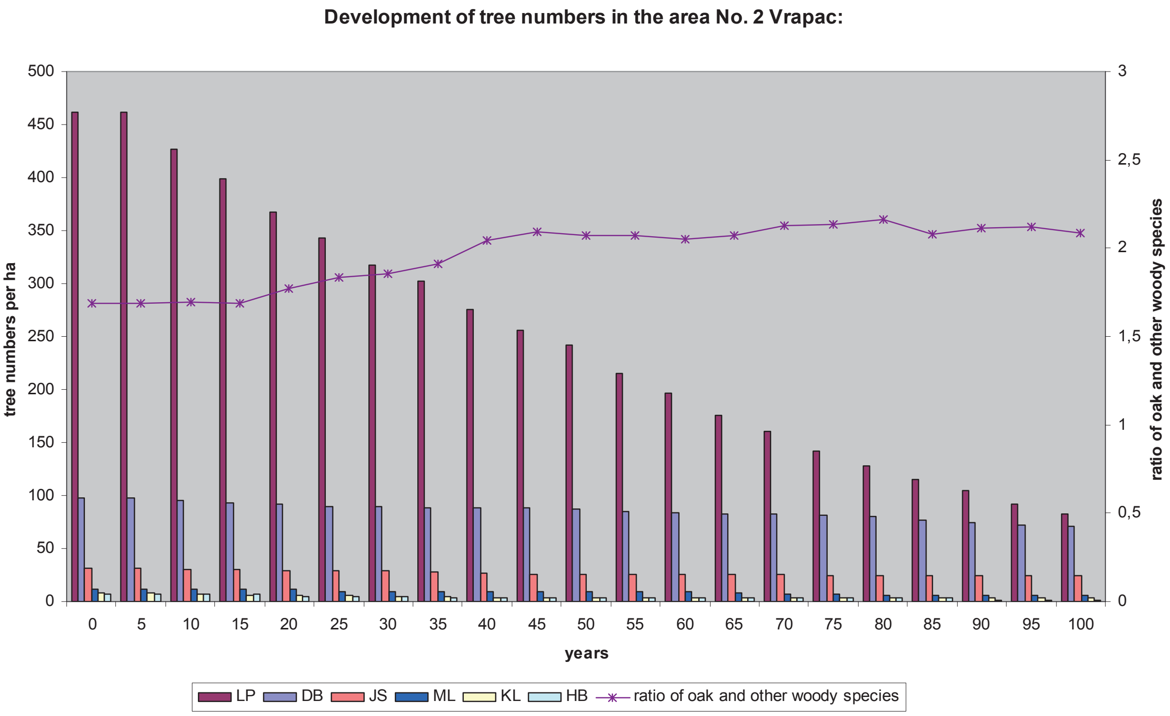
The method in this paper is based on linking of results from history research of the forest ecosystem with the growth simulation model of the ecosystem. Historical analyse of the floodplain forest ecosystem in the Vrapac study site showed that the most important turning point in the development of the hardwood floodplain forest ecosystem during the 20th century was the change in the forest management method, i.e. the transition from coppice-with-standards forest system to high forest silviculture. A similar situation is known from other European regions: In England, the majority of small-scale private woods (up to 5 ha) were managed as coppice-with-standards forests roughly in the period from 1450 till 1850; the forest management then changed into a high forest regime (ROTHERMAN, JONES, 2000). In Germany and France, the sprouting management (coppice forest) has historically been an almost extinct way of forest management for more than 50 years (with rare exceptions), although many forest stands still show signs of the former coppice regime (OSTERMANN, REIF, 2000). The current



4: *Simulation model of the forest stand based on is actual state in the sampling plot No. 2 (Woody species: Dub – Quercus robur, Habr – Carpinus betulus, Javory – Acer sp., Jasan – Fraxinus excelsior, Lípa – Tilia sp.)*

state of coppice and coppice-with-standards in the Czech Republic was summarized by KNEIFL *et al.* (2011). At present, the nature conservation authorities are concerned about forests of coppice origin because their importance for biodiversity has long been known (FULLER, WARREN, 1992). Regarding the hardwood floodplain forest habitats, the management principles for forest areas included in the Natura 2000 network in the Czech Republic (VIEWEGH *et al.*, 2003) consider the silvicultural system of coppice-with-standards as one possible way of management.

According to MÍCHAL (1998), coppice-with-standards was ecologically very stable and created favourable conditions for maintaining forest biodiversity. But, in general, managed coppice contains little dead wood, and is therefore unlikely to support specialised saproxylic species (KIRBY,



5: *Development of tree numbers and development of the oak fraction comparing to other woody species for the time horizon of the simulation of 100 years in the sampling plot No. 2*

1992). The management of stands in the form of coppice-with-standards was naturally subject to the economic interests of the forest owner (HONNAY *et al.*, 2004). The original character of the former coppice-with-standards in the Vrapac study site is somewhat obscured by more or less spontaneous development of the forest ecosystems during the past 60 years, when the forest management insisted on converting the vegetation indirectly into the high forest silvicultural form. The nature conservation in the area currently supports the forms of management based on spontaneous ecosystem development (SERVUS, 2008) that further leads to the loss of the original character of a coppice-with-standards.

Based on applying the simulation model, the forest ecosystem in the study site Vrapac can be included into the "decay phase" within the model of small development cycle of deciduous forest in the European temperate zone (THOMAS and PACKHAM, 2007). The simulation modelling of the forest ecosystem future development in the study site Vrapac showed that the non-intervention forest management will lead to the gradual deepening of stand differentiation and stocking reduction together with the emergence of cleared areas. Natural recovery of the forest ecosystem in these open areas can be expected only if the pressure of herbivores on the natural regeneration is eliminated.

A crucial decision for sustainable floodplain forest ecosystem protection in the Vrapac study site involves setting conservation objectives based on defining the subject of conservation in the locality. Undoubtedly, the subject of conservation is the ecosystem of hardwood floodplain forest within the relevant targets of Natura 2000 network. The main conservation target is then a matter of long-term maintaining of the biodiversity and continual development of the forest ecosystem (KADAVÝ *et al.*, 2011).

In view of these findings, the following basic strategies can be considered for the management of forest ecosystem in the Vrapac study site:

A. Return to historical forms of management (i.e. to coppice-with-standards). This type of management – in the opinion of the authors of this paper – however, is de facto excluded, because the upper stand storey (trees of seed origin) is approaching the limit of physical survival and the beginning of future decay, and any real possibility of regeneration of an already over-mature lower storey (of coppice origin) at the age of almost 90 years through back to coppice management is more than questionable, moreover in the background of strong game grazing in study site.

B. Non-intervention management of the forest ecosystem according to the principles by VACEK (2003). Nevertheless, as shown by the growth simulation model above, such non-intervention forest management would gradually lead, not only to complete eradication of the coppice-with-standards forest character, but also to a mosaic-like decay of vegetation. In the case of the permanent impact of herbivores, natural regeneration of the tree layer, and therefore also the continuous development of the forest ecosystem, would not be possible. In the future, non-intervention forest management will necessarily lead to a significant change in the species composition of the ecosystem tree component. The long-term non-intervention forest management probably will result in a total disappearance of the oak from the ecosystem (MATULA *et al.*, 2012), which would completely change the today's character of a natural habitat of hardwood floodplain forest in the frame of catalogue of habitats in Natura 2000 network (defined predominantly by a specific species composition, see CHYTRÝ *et al.*, 2010).

C. Forest management that is specifically aimed at a gradual creation of a richly-structured forest ecosystem with the maximum possible respect for the ecosystem's natural dynamics and disturbances (FRELICH, 2002) such as fluvial processes during floods and beaver populations activities along river. In the opinion of the authors of this paper, this type of management strategy is the most suitable and long-sustainable ecosystem management strategy for the studied ecosystems of hardwood floodplain forest in the Vrapac study site.

This ecosystem management strategy should include two basic groups of measures:

C.1 Management measures in the short-term period (protection of natural regeneration in the areas of spontaneously emerging stand glades, e.g. by fencing in order to prevent any access of large herbivores; in selected areas of several spontaneously arising glades, it is necessary to consider their active surface extension in order to create local regeneration areas suitable for artificial regeneration of the photophilous oaks; leaving all dead standing trees as well as fallen trees in the vegetation outside the fenced regeneration areas to increase the amount of decaying wood in the forest ecosystem).

C.2 Management measures in the long-term period (respecting factors of natural floodplain forest dynamics such as erosion and accumulative effects of water flow during floods, as well as the influence of beaver populations on the emergence of "beaver meadows" along watercourses).

CONCLUSION

The floodplain forests of lowland rivers in the temperate zone of Europe are often considered as ancient woodlands (FULLER, 1995). Detailed study of the history of floodplain forest ecosystem in the Vrapac study site (MACHAR, 2008b; 2008c) showed that the floodplain forest Vrapac is not ancient woodland. Today's generically and spatially diverse forest ecosystem in the Vrapac site, currently protected in the status of a National Nature Reserve and considered as one of the best natural examples of floodplain forest in the Czech Republic (ŠAFÁŘ, 2003), was created artificially by establishing a forest on former meadows in the late 18th century.

The results of the growth simulations of forest ecosystem using SILVA growth simulator carried out for two sampling plots in Vrapac study site showed almost consistently that the trend of gradual evolution of the existing richly diversified stands of floodplain forest gradually leads probably to its homogenization in the future. Within the mode of non-intervention management, the mightiest individuals of oak *(Quercus robur)* gradually disappear from the highest layer of the forest ecosystem, and ash *(Fraxinus excelsior)* begins to dominate in the main vegetation level while lime *(Tilia cordata)* starts to grow into it. This will result in a closed stand that will limit the potential natural regeneration of oak. The character of the vegetation will gradually approach the current production forests established through artificial regeneration; the only difference will be the presence of the lime stand component which is usually reduced in the cultivation of commercial forests. Increased proportion of maple *(Acer platanoides)* in the vegetation composition or the occurrence of elm *(Ulmus carpinifolia)* in an assessable representation does not seem to be very likely. This described prediction for the stand condition relates to the time horizon of 50–100 years of non-intervention management. Within the long-term perspective, the non-intervention management of floodplain forest probably leads to an increase in the proportion of dead wood in the ecosystem which is finally reflected in the biodiversity of organisms linked to various forms of rotting wood and decaying old trees. Nevertheless, the results of growth simulations in the Vrapac study site show that the non-intervention management regime in the habitat of hardwood floodplain forest leads to homogenization of species composition of the ecosystem woody component. It is significant that the non-intervention regime gradually changes the character of hardwood floodplain forest ecosystem to the form known from the commercial forests of today – the main stand level contains increasingly less common oak, a tree species to which a significant part of biodiversity of this type of forest ecosystem.

The method of assessing the forest ecosystem management strategy presented in this article is based on linking of historical analysis and prediction of the future ecosystem development using the growth simulation model. The results obtained by using this method in the Vrapac study site can be related to its current management strategy (e.g. Management Plan for national nature reserve). These findings are useful not only as a key basis for optimizing the forest ecosystem management strategies in the Vrapac study site but, when generalized, they could be also useful in developing management strategies for other ecosystems of hardwood floodplain forests of lowland rivers in the temperate zone of Europe.

SUMMARY

Maintaining of biodiversity of forest ecosystems usually requires special management strategies regarding the conservation targets. Habitats of European hardwood floodplain forests are considered as important biota refugees in the landscape, because their biodiversity is extremely high. Current forest management in floodplain forests is based on special silvicultural methods or – in nature reserves – often on non-intervention management. The method of assessing the forest ecosystem management strategy presented in this article is based on linking of historical analysis and prediction of the future ecosystem development using the growth simulation model.

Historical analyse of the floodplain forest ecosystem in the Vrapac study site showed that the most important turning point in the development of the hardwood floodplain forest ecosystem during the 20th century was the change in the forest management method, i.e. the transition from coppice-with-standards forest system to high forest silviculture.

The simulation modelling of the forest ecosystem future development in the study site Vrapac showed that the non-intervention forest management will lead to the gradual deepening of stand differentiation and stocking reduction together with the emergence of cleared areas. Natural recovery of the forest ecosystem in these open areas can be expected only if the pressure of herbivores on the natural regeneration is eliminated.

The results obtained by using this method in the Vrapac study site can be related to its current management strategy (e.g. Management Plan for national nature reserve). These findings are useful not only as a key basis for optimizing the forest ecosystem management strategies in the Vrapac study site but, when generalized, they could be also useful in developing management strategies for other ecosystems of hardwood floodplain forests of lowland rivers in the temperate zone of Europe.

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Contact information

Ivo Machar: ivo.machar@upol.cz