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Forests for Future – Multifunctional Forests

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Authors' contributions

This work was carried out in collaboration between both authors. Author LS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AS managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The long periods or rotation cycles of forests production are sources of uncertainty in the predictions of future forest conditions. The rotation cycles of the different types of forests in Europe vary between 30 to 200 years. There is a lot of uncertainty in forecasting the future climate, markets for forest products, as well as the society's requirements from forests. The societal expectation and requirements of forest management have changed dramatically during one rotation cycle of 100 years. They shifted from sole production of timber to the requirements of increasing timber production, as well as for other mainly social functions.

The main aim of this study is to determine what types of forest could satisfy multiple requirements and withstand impacts of potential future threats to their functions under the future uncertainties.

The study shows that such forests should be highly productive multifunctional forests, mixtures of the forests of different primary functions, compatible within the shared space, and resistant to stressors and disturbances. It shows that the best practices for creating such multifunctional forests are considering the optimal spatial arrangement in a complete three-dimensional space, and the system of reforestation establishing mixed forests, such as the in-line and spot planting. The spatial

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arrangement can address conflicts between the maintenance of biodiversity and the timber production. The study presents the results generated from a successfully realized project of real multi-functional forest establishment in the landscape.

Keywords: Forest; future; best practice; multifunctional forest; production; biodiversity.

1. INTRODUCTION

The production period, or rotation cycle, of forests other than the fast-growing species is a main disadvantage in forestry, because it is in most cases longer than a human generation. In the Czech Republic the average rotation cycle is 114 years, which means forests that are now being harvested were created in the beginning of the 20^{th} century, in the era of Austro-Hungarian and Ottoman Empires [1]. Even in the case of the fast-growing plantations, the rotation cycle is considered very long as it varies from 20 to 40 years. The long rotation cycle is a disadvantage in forestry because it is difficult to determine what forests should be planted now to best fit future requirements of forest functions and future climate and markets.

Firstly, we consider the forest functions. During one rotation period (for example 100 years) the requirements of society from forests have changed dramatically; from sole timber production to increased timber production, as well as other functions such as maintenance of biodiversity, recreation, drought and flood control, erosion control etc. On the other hand, the timber production is still extremely important function, because the wood is a renewable resource. However, the question is: what timber? If we talk about the timber production in the future, we must consider the global situation in stock volume of various assortments and market development. The boreal forests of the northern hemisphere could satisfy requirements for pulpwood production and fiber industry, as well as for light construction timber. On the other hand, due to situation in the tropical countries (deforestation, illegal harvest, conversion from rich forest to pure plantations), deficits of quality timber for veneer, furniture, boat construction etc. could be experienced [2,3]. The deficits in satisfying the societal requirements from forests could increase as the societies becomes richer and require more quality goods as a consequence.

Moreover, the preferences of such societies may change towards the demand for new forest functions such as the environmental (biodiversity, erosion, flood and drought control), and the social (game management, recreation, and aesthetic) [4].

The diversification of forest functions, to cover production and by-production would bring more jobs and business opportunities to the local communities, hence potential stabilization of human resources on the landscapes, as well as reversing the migration of people from the countryside to the cities.

In this study, we outline possible establishment of forests that will be best suited to future climate, market and societal requirement, and possess ability to withstand changes in these factors, as well as minimizing the negative effects of future uncertainty.

When establishing forests today we have to consider development of the stock volume, present trends in forest structure development, e.g. preference for simple plantations, climate change, loss of biodiversity as well as growing demand for valuable timber (veneer, furniture, boat construction) all of which will influence future functions of the forests created now.

Evaluation of the current situation and trends shows that multifunctional mixed forests, intentionally created now for future conditions, are the option that can ensure resistant and productive forests which can fulfill all future requirements of forest functions. Such forests would be capable to withstand the impacts of new situations which could arise during their growth cycles, thanks to their composition and structure which are easily modifiable for the changing aims as different assortments and functions are found in one shared space. We show specific practical examples, how such multifunctional forest can be created, based on a realized case study.

2. SELECTION OF TREES

The selection of tree species for the creation of multifunctional forest is determined by the natural conditions such as bedrock, soil, vegetation cover, and microclimate, of the sites where the multifunctional forest is being created. Forest typology, is applied to collectively describe such conditions of the forest habitat. It combines vegetation zonality (elevation zones) from lowland (seashore) to alpine areas with ecological series, which mostly depend on soil types and terrain (undeveloped, stony, rich, acid, alluvial, waterlogged, pseudogleyed, peaty etc.) [5, 6]. The vegetation zonality and ecological series form a grid, cross points of which form groups of forest habitat types. These forest habitat types are known to support specific vegetation communities (forest types) under natural conditions without major disturbance (climax vegetation). Using this system of forest habitat typology we utilize results of long-term natural processes. As there are differences among tree species compositions of the different forest habitat types, the management, as well as the main forest functions would be different. Forest typology is thus a tool enabling to practice forestry that embraces diversity and diversifies types of management across the landscape.

The other criteria used in the selection of the tree species are desired quality and quantity of the timber, non-timber products (fruit), tree species competitiveness, allelopathy and capacity to fulfill other non-productive functions. The exotic tree species (non-native in the given environment) can be used, but only as an admixed tree species, and their share of the composition of a multifunctional forest should not exceed 20%.

3. SPATIAL ARRANGEMENT

Spatial arrangement refers to the use of space in vertical structure of stands to maximize the use of the available space and light, as well as to horizontal structure, where forest stands are divided into sub-sections, possibly fulfilling different functions, but all forming a complete stand of forest edges, alleys, standards etc. [7]. A similar arrangement of horizontal structures could be applied in the special form of agroforestry called silvo-pastoral systems, where the tree component forms the integral part which provides the productive and non-productive functions not provided by the treeless pastures, fulfilling other functions such as the provision of fodder (leaves, fruits), shade for livestock, erosion control, production for herders (timber, fruits, bark), biodiversity,and amenities [8,9]. The spatial arrangement of the vertical structure can be the pure one-story plantation, or the mixed rich-structured multistoried stand, where there is a better utilization of space above and below the main crown canopy, as illustrated in Figure 1.

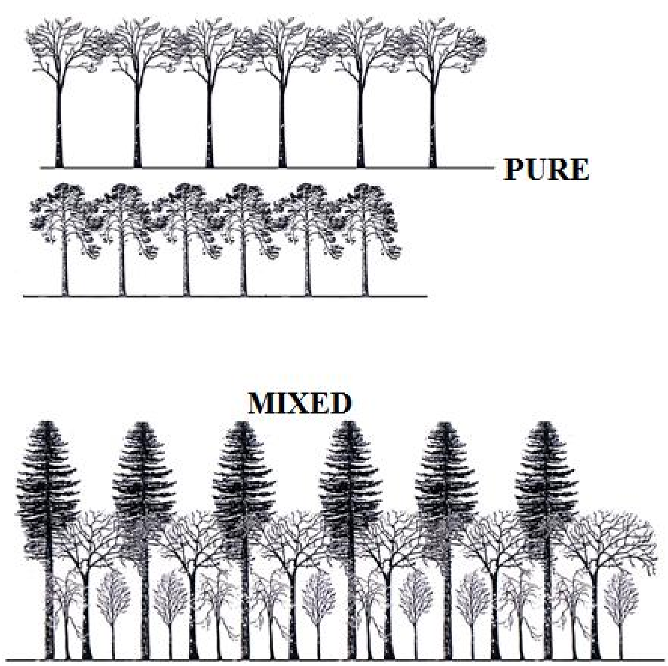

Figure 1. Different forms of space fulfilling in pure and in the mixed richer-structured commercial forest plantations

The creation of the rich-structured stands requires a selection of tree species that differ in their ecological requirements, i.e. occupy a different space in some direction of their ecological niche such as the sun-demanding and the shade-tolerant tree species. Furthermore, the different growth patterns of the tree species can be utilized in creating stands, where the two-storied structure is only temporary. A fast-growing and slow-growing tree species can be planted in a mixture, or the system of coppice-with-standards is used where a part of the stand is regenerated from sprouts and the other part from seeds as illustrated on Figure 2 [10].

The diversified spatial arrangement, i.e. the placement of trees in three-dimensional space in such a way that they better utilize the space, offers a variety in production, and it can also shorten the production time for certain assortments to some extent. Moreover, in terms of ecological demands, such systems are advantageous for the tree species growing better in the shade, by offering protection during the early stages of their growth, as well as for the production of special assortments such as the big trees with relatively long branchless stems, due to the improvement of their self-pruning process when growing in shady environments.

Spatial arrangement patterns that support vertical and horizontal heterogeneity also play the role in the maintenance of biodiversity in multifunctional forests where the timber production is one of their most important functions, and the biodiversity representing coexistence of dead wood with veteran old trees could also be maintained. The sections of forest which are less important for the quality timber production such us forest edges and alleys along lines in the forests (roads, rides, streams etc.) [11] can be targeted for other functions.

The forest edge is an abrupt transition between two relatively homogenous ecosystems, at least one of which is a forest. We can distinguish different types of edges in forests such as the boundary between harvested and standing sections, and the boundary between forests and non-forest ecosystems (agricultural land, water bodies). In this study forest, an edge was defined as the boundary between forests and other open landscape patterns, mainly agricultural land. These forest edges, at least in Europe, are more stable than the forest edges created by forest harvesting.

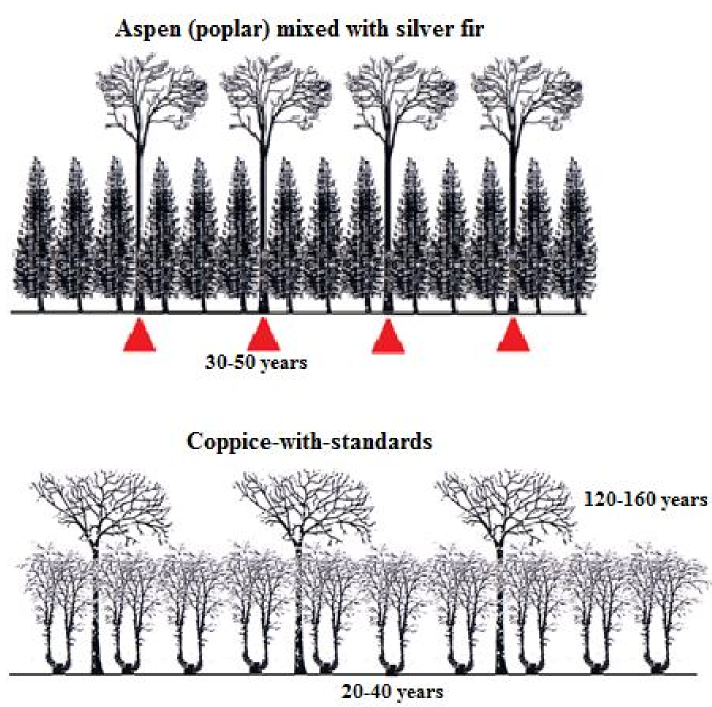

Figure 2. Temporal two-storied forests with different rotation cycles

Forest edges are the most appreciated parts of forests because in comparison with the forest interior, they have higher biodiversity, as well as high static stability, resistance to wind-throws and capacity to retain more moisture from rain and fogs, and to collect pollutants such as NH_4, NO_3 and SO_4 [12].

An important issue in understanding how to work with the forest edges is to know where the thresholds between the forest edges and the forest interiors are. Forest edges are narrower in the managed than in the unmanaged forests, and vary from 5 to 25 meters. In the riparian forests of the eastern region of the Czech Republic, the width of the forest edge is 8 meters, based on the differences of the mensurational variables of the forest edge and of the forest interior. This study proposes that those 8 meters, indicating distance from the line separating forests from other cultures into the forest interior, the forest edge should be excluded from intensive forest management carried out for the development of interior of the stand. It should also be left intact when the harvesting of remaining stands is carried out. Moreover, the intensive management of forest interior may contribute to the maintenance of biodiversity of forest edge, because some of the wildlife dependent on the veteran trees requires sun-exposed trunks. Therefore, when the operations of the final harvesting and the intensive permanent management of the forest interior are carried out, the retention of sun-exposed trunks in the forest edge for biodiversity purposes is important, as illustrated in Figure 3 [11].

Situation would be different for the veteran trees sourced from standards or reserved trees in the forest interior. Here, if their crowns are left to grow in the absence of competition from the neighbors, the dimensions of their crowns would differ from the crowns of the trees growing in dense forests. The latest study conducted in the riparian and upland forests in the eastern region of the Czech Republic revealed that the average projection of oak crowns was 348 m^2 in riparian forests and 200 m^2 in upland forests, and 333 m^2 for ash crowns in riparian forests [13]. It means that the loss of productive land from the veteran trees sourced from standards or reserved trees in the forest interior is higher than its loss from forest edges, because in riparian forests only 3 standards take 1/10 of the productive forest land. Consequently, it means that their placement within the spatial arrangement of the stand should reduce the loss of productive forest land to minimum. Moreover, there are such sections of the forests, where maintenance of the big veteran trees does not cause considerable loss of productive forest land, for example in alleys along lines in the forest such as forest roads, rides, narrow streams and narrow power lines.

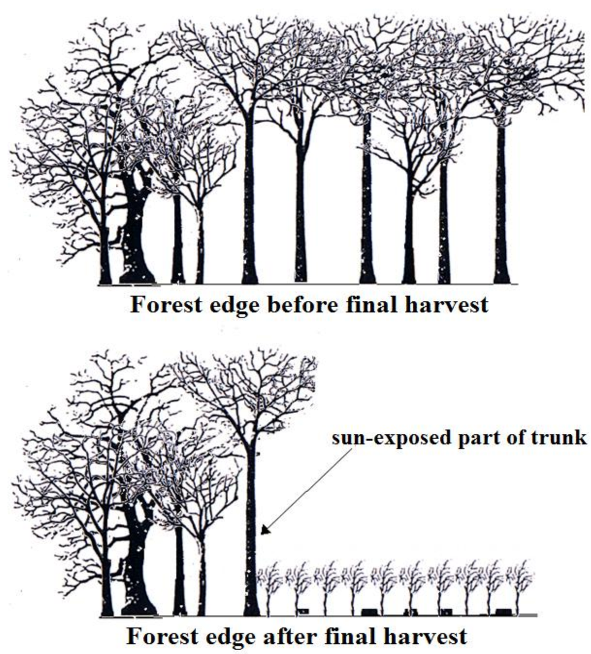

Figure 3. Forest edge before and after the final harvesting of forest's interior

4. LINE AND SPOT PLANTING

Selection of planting methods to create line and spot planting systems, aims to create individually mixed forests, which utilize the space as much as possible without compromising the performances of their assigned functions. Evaluation of a line planting method used in regenerating the past stand, and the results of its application in our present regeneration of forests and afforestation, enabled this study to establish and confirm best practices for the line planting.

The results generated from evaluation of the production and development of one stand, located in the upland rich sites of the Czech Republic, revealed the broad opportunities inherent in the mixed stands, as well as in the changing of their managing practices for adaptation in response to the destabilizing influence of changing natural and socio-economic situations [14,15].

The stand was planted on abandoned farmland in the year 1891. The afforestation was carried out in lines. The first line was formed by beech (*Fagus sylvatica*), the second and third line by spruce (*Picea abies*) respectively, and the fourth line by larch (*Larix decidua*) and oak (*Quercus petraea*). The tree species composition at the time of planting was: spruce 50%, beech 25%, larch and oak 25% and others +. The proportions of the tree species which made-up the composition of the present stand are spruce 1%, beech 96%, larch 3% and others + (Figure 4). Although the stand was regenerated in a wide spacing (1,8 x 0,9 m), the beech reached outstanding dimensions (Tab. 1), and its quality was highly profitable [14].

During the development cycle of the stand, some previously unknown advantages of this practice of individually mixed tree species in lines became apparent. The practice revealed improvement of timber utilization, especially the softwood, whose rotation cycle is shorter than the rotation cycle of the hardwood. Softwoods were the first to be harvested through intermediate cuts. It also revealed improvement of timber quality for all tree species. In this mixed stand, the improvement was stronger for beech and spruce compared to the other pure stands. These stands can thus maintain their competitiveness in the timber market, thanks to enhanced diversity of assortments and potentially higher resilience to the changes in the operating environment, as well as the timber and other markets it was created for.

Another important fact is that this practice also increased the success of the natural regeneration. Once the main softwood component has been harvested, the stand has lower stocking, and therefore creates conditions suitable to natural regeneration process. In this case the last intermediate cut is actually the first stage of shelter wood cutting [16].

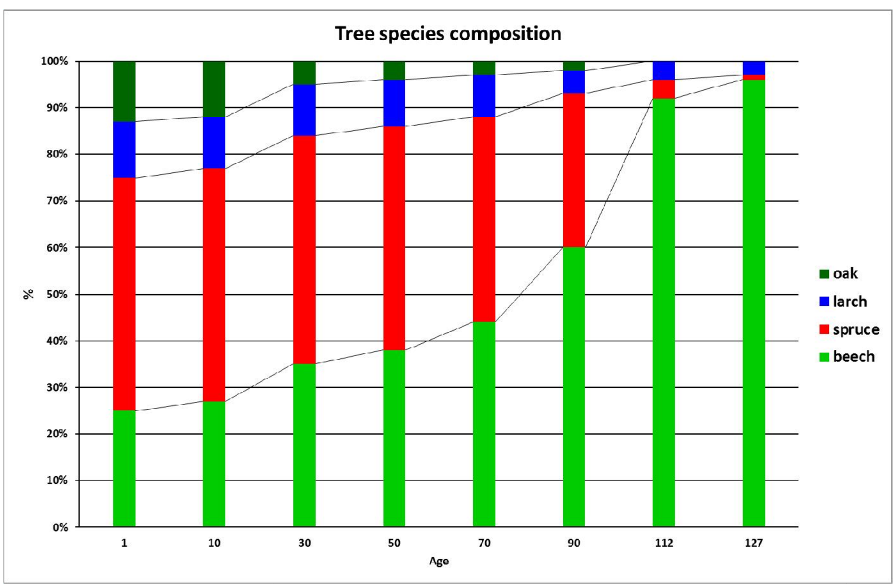

Figure 4. Development of the trees species composition

The spot planting is a line planting modified mainly for regeneration or creation of the silvo-pastoral system of agroforestry on farmlands. It is founded on the combinations of the tree species which form large crowns and relatively long branchless trunks for fruit and timber production and the tree species suitable for coppicing illustrated on Figure 5.

This study proposes a planting pattern in squares of 3x3 m where the distance between the two adjacent saplings is 1 m, as illustrated in Figure 5. There would be four saplings of oak (beech, pine, chestnut etc.) in the center of the spot, and saplings of lime (*Tilia* sp.) or hornbeam (*Carpinus* sp.) would form the borders of the spot. The total number of saplings in one spot is 16.

Future development along the desired pathway is dependent on the appropriate continuous management. The management has to assure that tree species in the center are taller than the lime trees. If the lime grows faster, which is likely, its terminal shoot has to be cut to reduce its vertical growth. The purpose of the lime in the mixture is to promote self-pruning of species inside the cluster, not to overtop and shade them. When the trees in the center reach a diameter between 20 and 30 cm, the lime and gradually some individuals of central trees can be removed, in order to achieve the final number of one or two individuals in the spot. Subsequently sprouting, lime shoots can provide supplementary source of fodder for the livestock or wild animals and thus enhance the fodder production in a wood pasture [17].

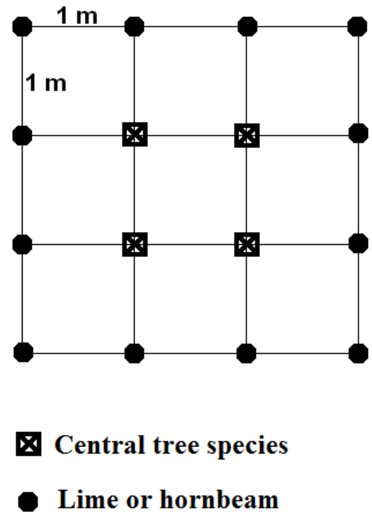

Figure 5. Planting pattern for spot planting

Table 1. Development of basic mensurational data in the stand arisen from line planting

			Age 90 years		
Tree species	**Number of trees**	**DBH (cm)**	**Mean height (m)**	**Basal area (m^2)**	**Volume (m^3)**
beech	147	42	33	20,5	344
spruce	71	34	32	6,7	93
larch	30	32	31	2,4	32
Sa	**248**			**29,6**	**469**
			Age 112 years		
Tree species	**Number of trees**	**DBH (cm)**	**Mean height (m)**	**Basal area (m^2)**	**Volume (m^3)**
beech	99	57	37	26	492
spruce	9	54	36	1,9	28
larch	8	50	40	1,5	25
Sa	**116**			**29,4**	**545**
			Age 127 years		
Tree species	**Number of trees**	**DBH (cm)**	**Mean height (m)**	**Basal area (m^2)**	**Volume (m^3)**
beech	110	62	42	32,8	764
spruce	4	54	43	0,9	17
larch	2	59	44	0,5	9
Sa				**34,2**	**790**

5. CONCLUSION

The creation and management of forests that are to fulfill multiple functions is more difficult and complex in the multifunctional mixed forests than in the pure forest plantations. The mixed forests however offer more benefits in the long term. Their higher diversity ensures better stability for the uncertain conditions of the future environments, and distant future markets. The systems of multifunctional forestry are applicable in the tropical, subtropical, as well as in the temperate conditions.

Line planting enables relatively easy and simple planting of the number of seedlings calculated for a project. The benefits can easily be quantified, especially for the timber production. For the case study described above, first timber harvest from the poplars, a fast-growing tree species, could be carried out at the end of a rotation cycle of 20 years.

The inclusion of the fast growing tree species in the creation of the mixed stands helps to persuade local residents that the mixed stands will bring relatively fast (in comparison with other forest tree species) production and other benefits. Mixed forests are important because they enable utilization of synergistic effect when two or more species growing together are able to produce a result not obtainable independently and/or larger than the sum of the two species. The typical example is planting of windbreaks on agricultural land, where mixed multistoried forest shows better efficiency in required functions than only monoculture [18].

Furthermore, when the local residents see the mixed forests delivering their benefits including jobs and renewable raw material right at the beginning and throughout their production cycles, they are much more likely to protect them, and voluntarily take care of them, hence help mitigate conflicts between the ecological and the economical functions of the forests.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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