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Multifunctional Forests - A Case Study of Windbreak System Regeneration

***Lubomir SALEK[1], Lubomir TIPMANN[1], Hedvika PSOTOVA[2]**
[1] Faculty of Forestry and Wood Sciences, Czech University of Life Sciences in Prague, Kamycka 129, 16521 Prague 6 – Suchdol, Czech Republic
[2] ArvitaP Ltd. – landscape architecture company, Příčná 1541, Otrokovice, Czech Republic
*Corresponding author: lubomir.salek@seznam.cz

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Abstract

The study solves the problems with creation of multifunctional forest using the example of windbreak system establishment and completing. The requirements of eight interest groups from local residents are collected and individual tree species are evaluated according to their ability to fulfill the required functions. The appropriate tree species are chosen the management of planting and development is given. The selected major tree species is lime (*Tilia cordata*) because it belongs to the tree species whose characteristics correspond to the required function the best. As the goal is mixed two-storied windbreaks with the width of 20 m line planting is used for mixing three species and forming suitable structure and roof-shape of windbreak cross-section.

Key words: Windbreak, multifunctional forest, erosion control, interest group, management

Çok İşlevli Ormanlar-Rüzgar Kıran Sistemlerinin Yeniden Oluşturulması Üzerine Bir Çalışma

Özet

Bu çalışma, rüzgar kıran sistemlerin kurulma ve tamamlanma örneğinden yola çıkarak, çok işlevli ormanların oluşturulmasında ortaya çıkan problemleri çözmektedir. Yerel halk içerisinden seçilen sekiz çıkar grubuna mensup kişilerin gereksinimleri belirlenmiş ve bu gereksinim duyulan işlevleri karşılayabilme yeterliliklerine göre özel ağaç türleri değerlendirilmiştir. Uygun ağaç türleri seçilmiş ve bu türlerin dikim yöntemleri ve gelişimleri gösterilmiştir. Seçilen en önemli ağaç türü, gereksinim duyulan işlevleri en iyi karşılayacak özelliklere sahip olan, ıhlamur ağacı (*Tilia cordata*) olmuştur. Üç türü karıştırmak ve rüzgar kıran profilinin uygun yapısını ve çatı-şeklini oluşturmak için, 20 metre enindeki bir hat üzerinde dikimin yapıldığı iki-katlı rüzgar kıranlar kullanılmıştır.

Anahtar Kelimeler: Rüzgarkıran, çok-işlevli orman, erozyon kontrolü, çıkar grubu, yönetim

Introduction

Nowadays the role of forests is shifted from source of timber to the other functions. However the timber production remains important part because wood is one of the renewable materials in the world. Therefore the effort should be concentrated on the forests which maintain more than one function and moreover, the functions should be in balance. Other possibility also exists, a part of forest is determined only for timber production as a timber plantation and a rest is only for by-production purposes. However, the multifunctional forest seems to be better solution because it enables the survival of organisms linked with forests on larger area, efficiency of maximum of forest functions on larger area as well as job opportunities for local residents joined with utilize of natural resources. On the other hand multifunctional mixed forest undoubtedly needs more sophisticated management than fast-growing pure plantation.

Windbreaks form model example of multifunctional forest in landscape because they fulfill more functions than only wind erosion control (Brandle *et al.*, 2004; Evrendilek and Ertekin, 2002). Although their design in the landscape is strictly according to the preponderant direction and velocity of dangerous winds, their species composition and structure can be modified also in favor of other forest functions. David and Rhyner (1999) introduce that in Wisconsin the most common species forming the upper stratum in conifer windbreaks are red pine (*Pinus resinosa*), white pine (*P. strobus*) and jack pine (*P. banksiana*) while northern pin oak (*Quercus ellipsoidalis*), bur oak (*Q. macrocarpa*) and boxelder (*Acer* *negundo*) are the most abundant in the hardwood barriers. In both types, the most common species occurring in the lower stratum are cherries (*Prunus* ssp.) and hazelnuts (*Corylus* ssp.). These tree species are valued also for their timber, fruits and forming shelters for wildlife. Hagen (1976) reveals that windbreaks should be at least 20 feet (6 m) tall for providing of sheltered area with the width equal to ten times of the windbreak height. He also mentioned that windbreaks indirectly influenced wind erosion because in many areas windbreaks trap snow which increases soil moisture and prevents freeze-drying of the surface-soil clods. Foereid *et al.* (2002) introduced results in the research of Danish coppice willow windbreaks where microclimate was modified at a distance up to 4-7 times the windbreak height from the windbreak. Bird *et al*. (2007) investigated efficiency of windbreak structure on shelter characteristics and confirmed that effective shelter is best obtained by establishing tall, dense windbreaks.

Another useful property of windbreaks is that they trap parts of the suspended dust particles blown into them. Honda (1974) found that individual plants trapped 35 to 80 percent of the dust. Consequently, if typically species trap 50 % of the dust three rows in a windbreak would presumably trap 88 % of the dust.

Windbreaks influenced the visual appearance of agricultural land, too. According to the survey in Iowa, USA, majority of respondents preferred groups of trees planted in straight rows. Most of them (74%) preferred field windbreaks consisting of tree and shrubs, whereas 69% preferred windbreaks in which conifers were mixed with hardwood (Grala *et al*., 2010).

Windbreaks form environment for animals whose life is associated with trees and shrubs, especially for birds. According to the research made in Quebec, no difference was found in bird abundance, diversity and richness between two types of windbreaks, one of them composed of tall trees and second one of shrubs (Bernier-Leduc *et al*., 2009). Hess and Bay (2000) analyzed habitat suitability for wildlife including breeding birds, small mammals and deer in windbreaks in Nebraska, USA. Their results indicate that increasing area of individual windbreaks is the most effective way to improve their value as wildlife habitat.

A project of creation and management of multifunctional forest is given in this study as a case study explaining reasons for it and process of planning of windbreak system establishment and completing.

Study area and present situation

The east part of the Czech Republic is one of the most threatened parts in the country by wind erosion. Dry high winds blowing mainly from east and south-east directions were bringing about high rate of soil erosion. The situation was aggravated in sixties and seventies in the last century because of the big change in land tenure. During the process of establishment of agricultural cooperatives organized by Communist regime the small fields with various crop were reunited into large fields with uniform cultivation. The rate of wind erosion increased into incredible scale. The strongest dust storm in the year 1972 blown away 193 m^3 per ha which represents 2 cm of top soil on agricultural land. In addition, the soil particles were deposited into drifts two meters high (Švehlík, 1998). The problem threatening the agriculture and rural development in the area was solved by establishment of windbreak system formed by poplars whose fast growth enabled the efficiency of system as soon as possible.

The largest windbreak system was established next to the village Sucha Loz (coordinates 48°57'42,43'' N; 17°42'47,38'' E; average altitude 350 m).

Unfortunately after establishing no care was executed and windbreaks are left their own course. The present situation is that the windbreaks are close to their natural disintegration and their efficiency quickly declines (Vacek *et al*., 2009). Moreover, the system is not completed which was manifested mainly in winters with higher amount of snow precipitations. Winds blowing to the village formed high snow drifts and municipality had to spend high amount of money from the budget for removal of snow from streets and pavements (village mayor, verbally). Therefore the establishment and completing of windbreak system must be created.

The system of windbreaks is located mainly on rich deep soils, soil types are typical cambisol, pseudogleyed cambisol and haplic luvisols according to the system of the World Reference Base for Soil Resources (Němeček, 2001). As the new windbreaks will be wider (width 20 m) a part of them will be located on former agricultural land where anthrosols are found. The recommended width of windbreaks (20 m) corresponds with the required function according to the domestic reports (Vacek, Simon et al, 2009) as well as the international (David and Rhyner, 1999, Hess and Bay, 2000)

Methods

According to the demands and needs of interest groups (Table 1) the new windbreak must be multifunctional and the functions must be in action as soon as possible. These requirements influence the selection of appropriate tree species and management of planting and tending.

Table 1. Forest functions and interest groups

Interest group	Forest function	Note	Criteria
Municipality, foresters	Timber production	Quantity as well as quality	Mixed stands, intensive tending for quality purposes, admixed fast growing tree species
Conservationists	Nature protection and enhancement of biodiversity	The area is a part of Landscape Protected Area	Site suitable tree species, mixed stands, trees with hollows
Farmers, municipality	Erosion control including snowdrift control		Efficiency as soon as possible, durability, evergreen forest edge
Hunters	Game management	Source of fodder, shelters for wildlife	Tree species for browsing, bushes, understory
Farmers	Soil improvement of adjacent agricultural land		Amount of forest litter – humus content in soil
Farmers, municipality	Water retention (flood control)		Loose forest soil, dense root system on stream banks
Villagers (women)	Aesthetic visual impacts	Aesthetic functions in all year seasons	Mixing of evergreen species with deciduous, colorful stands, trees with blossoms, colored leaves in autumn
Beekeepers	Fodder for bees	Pollen and nectar in early spring and continually during a year	

The choice of tree species comes from the criteria (Table 2). Each forest tree species which occurs or is planted in the given area fulfils the criteria in certain level. The fulfillment is divided into 4 grades:

0 – no fulfillment
1 – weak fulfillment
2 – middle fulfillment
3 – high fulfillment

If the criteria and tree species are put to the table (table 2) and in their intersection the grades are placed, their sum (arithmetic average of individual criteria within one function) shows the most appropriate tree species (Table 3).

However, only the sum does not create an optimal mixture. Certain tree species maintain a required function which is not kept by others and therefore those tree species would not be suitable from other purposes. But in this case those tree species must be included to the final mixture.

Furthermore, the windbreak system is not placed on uniform natural conditions. It is located on loamy rich soil and pseudogleyed (waterlogged) soil as well as on various altitudes (from 294 to 406 m). Therefore the mixture in individual windbreaks is modified according to the given natural conditions (soil, vegetation belt).

Table 2. Grades of function fulfillment

	Quality timber production	Quantity timber production	Edible fruits	Honey production	Soil improving	Windbreak function in winter (control snow drift)	Windbreak function in summer	Flood control function - stream banks	water management (retention)	Game management (tree species for browsing)	Game management (fruits)	Game management (shelter)	Aesthetic	Nature protection - biodiversity	Nature protection - biodiversity (tree hollow forming)	Nature protection - site appropriate	Fruits for birds
number of columns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Robinia pseudoacacia	1	3	0	3	0	1	2	1	1	0	0	1	2	0	0	0	0
Picea abies	2	3	0	1	0	3	2	1	3	0	0	3	1	1	1	0	1
Betula pendula	1	2	0	0	2	1	2	2	3	0	0	1	3	1	1	1	0
Larix decidua	3	2	0	0	1	1	2	1	2	0	0	1	3	1	0	0	1
Populus nigra	2	3	0	0	2	1	1	2	2	0	0	1	2	2	2	2	0
Fraxinus angustifolia	3	2	0	0	3	1	3	3	2	0	0	1	2	1	1	0	1
Carpinus betulus	1	1	0	0	3	1	3	3	2	0	0	2	2	2	1	3	2
Juglans regia	3	3	2	0	2	1	2	2	2	0	0	1	2	0	0	0	0
Pseudotsuga menziesii	2	3	0	0	1	3	3	2	3	0	0	3	2	0	0	0	1
Salix alba	1	3	0	2	2	1	2	3	2	1	0	2	1	1	2	2	0
Alnus glutinosa	1	2	0	2	3	1	3	3	3	0	0	2	1	2	1	2	1
Fraxinus excelsior	3	2	0	0	3	1	3	2	2	0	0	1	2	1	0	3	1
Pinus sylvestris	2	2	0	1	0	3	3	1	3	0	0	2	2	3	0	1	1
Ulmus minor	3	1	0	0	3	1	2	2	2	0	0	2	2	3	0	3	1
Acer campestre	1	1	0	2	3	1	3	2	2	0	0	3	2	2	0	2	1
Quercus cerris	1	1	0	0	2	1	2	2	2	0	3	2	2	3	3	0	2
Acer platanoides	1	2	0	2	3	1	3	2	2	0	0	2	2	2	1	1	1
Populus alba	1	3	0	0	2	1	1	2	2	0	0	1	3	3	2	2	0
Populus tremula	1	3	0	0	2	1	1	2	2	3	0	2	2	2	2	2	0
shrubs	0	0	1	2	2	1	1	2	2	1	1	3	2	3	0	3	2
Sorbus aucuparia	1	2	0	2	3	1	2	2	2	0	1	3	2	1	0	1	3
Ulmus laevis	2	2	0	0	3	1	2	3	2	0	0	2	3	3	0	1	1
Quercus petraea	2	2	0	0	2	1	3	1	1	0	3	2	2	3	1	3	2
Coryllus avelana	1	1	3	2	3	1	1	2	3	0	1	3	1	3	0	2	2
Ulmus glabra	3	2	0	0	3	1	3	2	2	0	0	2	3	3	0	1	1
Abies alba	2	3	0	2	1	3	3	2	3	0	0	3	2	2	0	1	1
Salix caprea	1	1	0	3	3	1	2	3	2	3	0	3	2	3	0	2	0
Fagus sylvatica	2	2	2	0	2	1	3	2	1	0	3	2	2	1	1	2	2
Sorbus torminalis	3	2	0	2	3	1	3	2	2	0	0	2	2	2	0	3	2
Aesculum ippocastanum	1	2	0	2	3	1	1	2	2	0	3	1	3	3	3	0	0
Acer pseudoplatanus	3	2	0	2	3	1	3	2	2	0	0	2	3	2	1	1	1
Quecus robur	3	2	0	0	2	1	3	3	1	0	3	2	2	3	2	3	2
Tilia cordata	2	2	0	3	3	1	3	3	2	1	0	2	3	3	1	3	2
Malus sylvestris	1	1	2	2	3	1	3	2	2	2	3	2	2	3	2	3	3
Cerasus avium	3	2	2	2	3	1	3	2	2	0	0	2	3	3	1	3	3
Pyrus pyraster	2	1	2	2	3	1	3	2	2	0	3	2	3	3	1	3	3

Table 3. Evaluation of tree species per functions

	Timber production	Non-timber production	Erosion control	Game management	Aesthetic	Biodiversity	Sum
average from columns	1-2	3-4	5-9	10-12	13	14-17	
Robinia pseudoacacia	2.00	1.50	1.00	0.33	2.00	0.00	6.83
Picea abies	2.50	0.50	1.80	1.00	1.00	0.75	7.55
Betula pendula	1.50	0.00	2.00	0.33	3.00	0.75	7.58
Larix decidua	2.50	0.00	1.40	0.33	3.00	0.50	7.73
Populus nigra	2.50	0.00	1.60	0.33	2.00	1.50	7.93
Fraxinus angustifolia	2.50	0.00	2.40	0.33	2.00	0.75	7.98
Carpinus betulus	1.00	0.00	2.40	0.67	2.00	2.00	8.07
Juglans regia	3.00	1.00	1.80	0.33	2.00	0.00	8.13
Pseudotsuga menziesii	2.50	0.00	2.40	1.00	2.00	0.25	8.15
Salix alba	2.00	1.00	2.00	1.00	1.00	1.25	8.25
Alnus glutinosa	1.50	1.00	2.60	0.67	1.00	1.50	8.27
Fraxinus excelsior	2.50	0.00	2.20	0.33	2.00	1.25	8.28
Pinus sylvestris	2.00	0.50	2.00	0.67	2.00	1.25	8.42
Ulmus minor	2.00	0.00	2.00	0.67	2.00	1.75	8.42
Acer campestre	1.00	1.00	2.20	1.00	2.00	1.25	8.45
Quercus cerris	1.00	0.00	1.80	1.67	2.00	2.00	8.47
Acer platanoides	1.50	1.00	2.20	0.67	2.00	1.25	8.62
Populus alba	2.00	0.00	1.60	0.33	3.00	1.75	8.68
Populus tremula	2.00	0.00	1.60	1.67	2.00	1.50	8.77
shrubs	0.00	1.50	1.60	1.67	2.00	2.00	8.77
Sorbus aucuparia	1.50	1.00	2.00	1.33	2.00	1.25	9.08
Ulmus laevis	2.00	0.00	2.20	0.67	3.00	1.25	9.12
Quercus petraea	2.00	0.00	1.60	1.67	2.00	2.25	9.52
Coryllus avelana	1.00	2.50	2.00	1.33	1.00	1.75	9.58
Ulmus glabra	2.50	0.00	2.20	0.67	3.00	1.25	9.62
Abies alba	2.50	1.00	2.40	1.00	2.00	1.00	9.90
Salix caprea	1.00	1.50	2.20	2.00	2.00	1.25	9.95
Fagus sylvatica	2.00	1.00	1.80	1.67	2.00	1.50	9.97
Sorbus torminalis	2.50	1.00	2.20	0.67	2.00	1.75	10.12
Aesculum hippocastanum	1.50	1.00	1.80	1.33	3.00	1.50	10.13
Acer pseudoplatanus	2.50	1.00	2.20	0.67	3.00	1.25	10.62
Quecus robur	2.50	0.00	2.00	1.67	2.00	2.50	10.67
Tilia cordata	2.00	1.50	2.40	1.00	3.00	2.25	12.15
Malus sylvestris	1.00	2.00	2.20	2.33	2.00	2.75	12.28
Cerasus avium	2.50	2.00	2.20	0.67	3.00	2.50	12.87
Pyrus pyraster	1.50	2.00	2.20	1.67	3.00	2.50	12.87

Results (management)

According to the method of choice of tree species, their interaction, future management, growth ability and accessibility of seedlings in forest nurseries these tree species were selected:

- Main tree species: *Quercus petraea, Quercus robur, Fagus sylvatica, Tilia cordata, Salix caprea, Populus nigra, Pinus sylvestris, Fraxinus excelsior,* shrubs
- Admixed tree species: *Cerasus avium, Pyrus pyraster, Aesculum hippocastanum, Ulmus laevis, Ulmus glabra, Corrylus avellana, Populus alba, Carpinus betulus, Larix decidua*

The most abundant tree species will be lime (*Tilia cordata*) whose characteristics are optimal for fulfillment of required function. The decomposition of its leaves is very quick and positively influences the humus content in forest soils as well as in adjacent agricultural soils. It is shade-tolerant tree species forming lower story of stands and due to its ability of sprouting the next regeneration can be vegetative (future cost saving).

The management of planting forming the mixed forest is solved as line planting which enables the organization of planting as simple as possible (Figure 1). The shrub species are planted in groups and their spread in the edges of windbreaks (ecotones) is supposed naturally. The main goal for the cross section structure is forming the roof-shape of windbreaks (Figure 2) and at least two storied stands where the edges of windbreaks will be branched along the whole tree height and partly covered by leaves (needles) during winter. It is reason for existence of pine (*Pinus silvestris*) in the edge of windbreaks. Moreover, at the edge of the windbreaks poplars as very fast-growing tree species will be planted. The reason is the management because poplars as fast-growing tree species will show the borders of windbreaks in the landscape and enable their functions as quickly as possible. The timber production will be also reached quickly and during the windbreak development the poplars will be removed and their cutting in winter is practically harmless because they will be cut in direction to the agricultural fields.

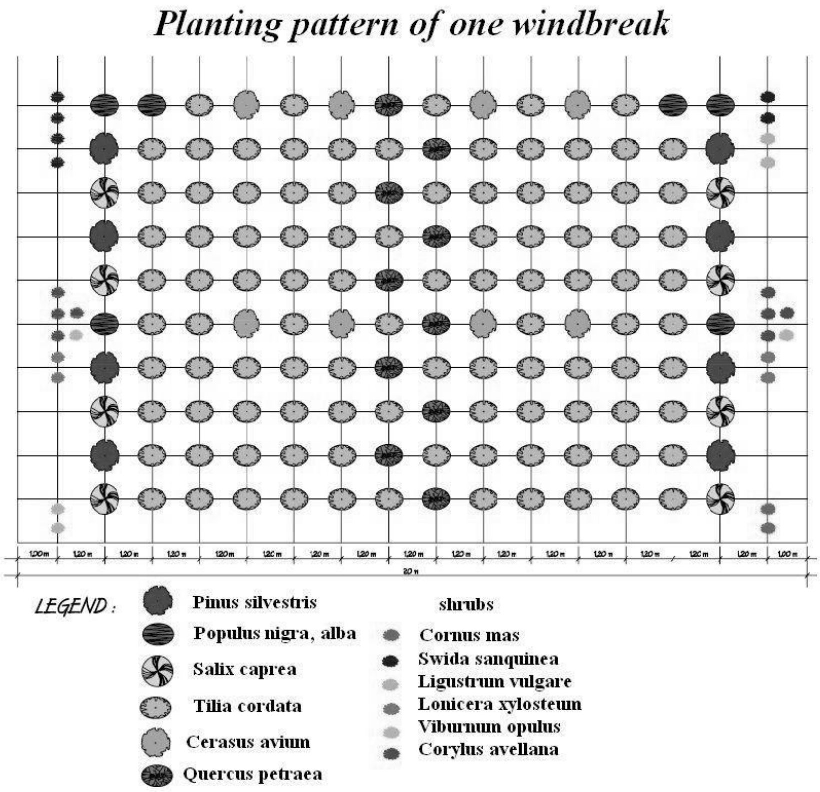

Figure 1: Example of planting pattern of one windbreak

Management of tending and development is based on removal of individuals which either do not meet the criteria for full fulfillment of function or their role in stands is at an end. Ending is concerned mainly to the fast growing tree species, in our case to poplars. Therefore the tree species composition will be gradually changed during the stand development in favor of long-lived tree species. Regarding the long-rotation cycle (100 - 160 years according to the major tree species) tending will not be restricted only to the younger stage but they will be carried out to the final spatial structure which is supposed in age of 80-120 years.

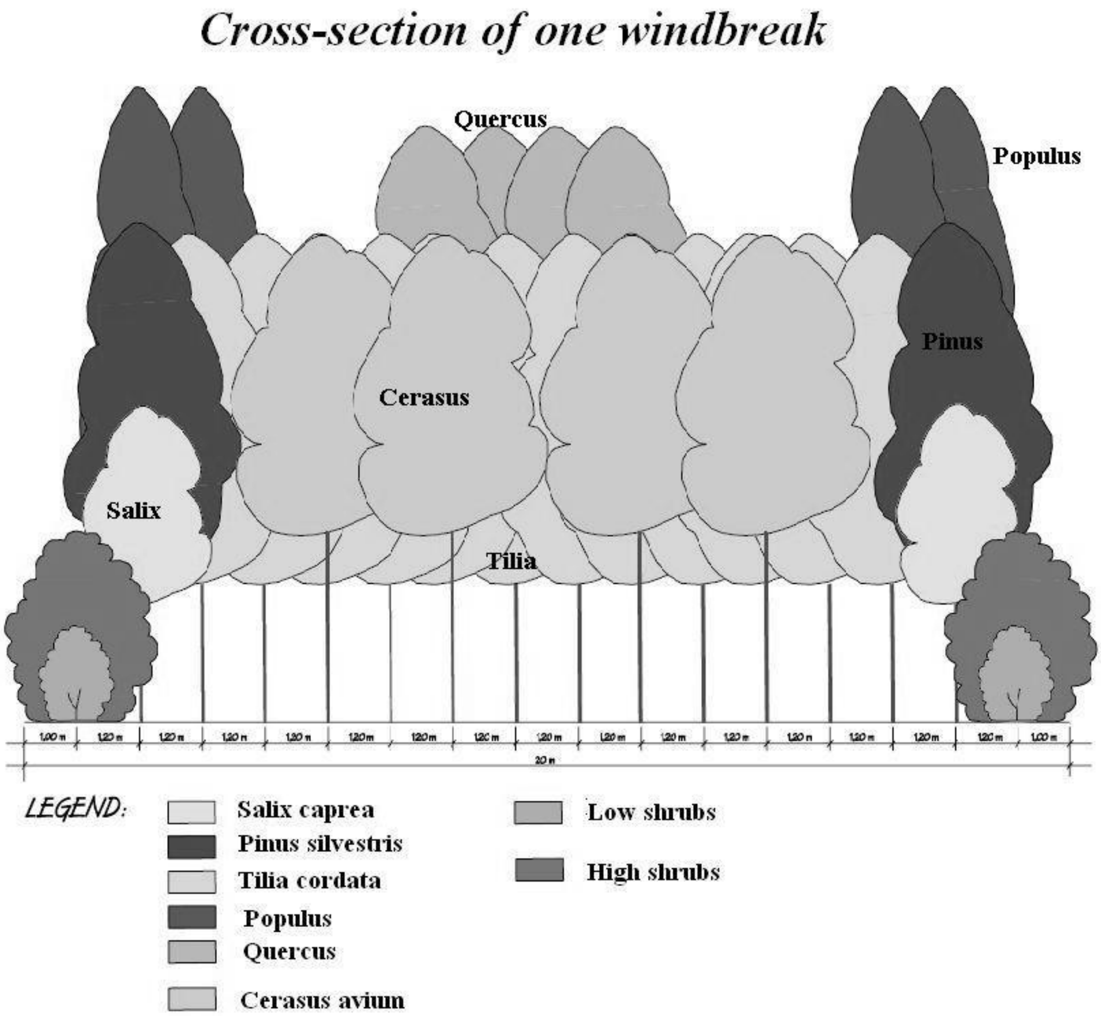

Figure 2: Cross-section of one windbreak

Windbreaks are generally solved as two storied stand with edges formed by bushes, low trees and evergreen trees. Generally forming two storied stands means that the shade-tolerant tree species are mixed with light-demanding tree species. The lower story helps forming the appropriate shape of stems of upper story tree species, their self-pruning and quality of timber production. Moreover, lime assures the functions of erosion control. Nonetheless, during the development it can happen, especially in younger age that a shade-tolerant tree species performs more vigorous growth than light demander and holds it down. In that case it is needed to press the shade-tolerant tree species to lower story simply by cutting of terminal shoot.

For instance, there is a model showing tending in three phases during the young stage of development:

1. Supposed in the age of 10 years. The intervention is focused to the reduction of number of lime. In case lime forms overtopping trees their terminal shoots will be cut.
2. This intervention is supposed in age between 15 and 20 years. The aim is strong reduction of poplars, namely *Populus nigra*. Poplars were cut in direction to the agricultural land (in winter) in order to avoid damages of other trees. As the windbreaks should be semi-permeable the tending is also focused to the reduction of pine (*Pinus silvestris*) and lime (*Tilia cordata*). Several individuals of poplars will be left growing as a source

of reproductive material or for amenity purposes (big trees).

3. Third intervention (age between 25-30 years) is again aimed to the reduction of lime and slightly to reduction of oak. Firstly diseased or damaged trees will be removed and trees with inappropriate shape of stem in order to get the maximum of quality timber.

Tending interventions will accompany the development of windbreaks generally to their age of 80 years aiming achievement of optimal level of all functions. Shrubs and goat willow (*Salix caprea*) will be left for natural development and the natural spread of shrubs at the edges of the windbreaks is supposed.

Conclusion

The case study shows the method aimed to establishment of mixed multifunctional forests where the functions are balanced and the needs and demands of interest groups are more or less respected. Line planting enables relatively easy and simple planting according to the project as well as the calculation of seedling number. Benefits, especially the benefits from timber production can be calculated, too. In our case first timber harvest appears after 20 years from production of fast-growing trees species (poplars). Just planting of fast growing tree species helps to persuade the villagers that the mixed stands will bring relatively immediate (in comparison with other forest tree species) production and function (wind erosion control).

The evaluation of forest function per tree species can be naturally changed according to the natural conditions and needs of local residents or other interest groups. The important fact is that the mixed forests enable the use of synergic effect when two or more things functioning together are able to produce a result not independently obtainable.

In addition, if the local residents practically see that the efficiency of functions of forest belts in the landscape appears from the beginning and the belts will bring job opportunities for them and sources of renewable raw material then they will protect them and take care of them. Thus ecological functions can be joined with economical functions of forests.

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