

EVALUATION OF AUSTRIAN PINE (*PINUS NIGRA*) PLANTATIONS IN HUNGARY WITH RESPECT TO NATURE CONSERVATION – A REVIEW

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Summary: The review deals with the stands of the alien Austrian pine (*Pinus nigra* Arn.) in Hungary, emphasizing the ecological consequences of the afforestation. A short historical overview about the establishment of pine cultures is presented with outlining the distribution of the stands among the major forestry regions of Hungary. The nature conservation and economic problems associated with Austrian pine are summarized, including: the local extinction of the species-rich native flora, the less valuable timber, the rapid physiological decay of trees followed by pathogen epidemics, the insufficient soil amelioration effect, as well as the special vulnerability to forest fires and non-native plant invaders. Applicability of the conifer for land reclamation purposes is also introduced. Finally, we describe some directives and proposals concerning the alteration of Austrian pine plantations to native woody associations complying with the sustainable forest management policy.

Introduction

Opinions declared about the presence of the non-native Austrian pine (*Pinus nigra* Arn.) in Hungary are generally rather biased and contradictory. Foresters usually tend to emphasize the bright side of pine stands (*i.e.* prevention of soil erosion, soil amelioration and soil-shading ability, improved “landscape value”), whereas botanists and ecologists often highlight the harmful effects, including the suppression of the native flora and fauna, low diversity, considerable fire risk and high invasibility. This review is aimed to introduce some consequences associated with the creation of Austrian pine plantations, focusing principally on the ecological and nature conservation problems. In this respect, we summarize the tasks concerning the treatment of the existing pine stands, by which the restoration of the native vegetation is purposed.

Description and plantation of Austrian pine

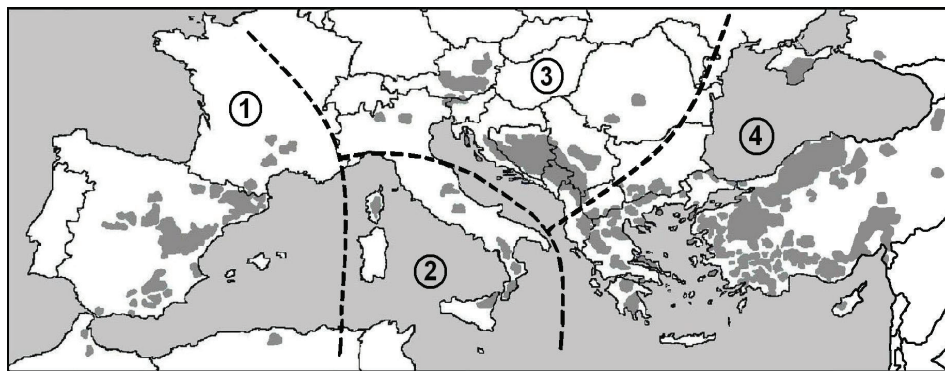
Natural area of Austrian pine stretches from Iberia to Crimea and Taurus Mountains in Asia Minor, through the Alps, the Apennines, Corsica and the Balkans (MEUSEL and JÄGER 1992). As being an Alpine–Mediterranean floristic element, the conifer is alien in Hungary. It is typically the tree of the Mediterranean and continental mountain ranges: the nearest spontaneous occurrences are located in the Vienna Woods, the Croatian Karst and the mountains of the Domogled and the Lower Danube. Austrian pine is well-adapted to very hot and dry habitats, however it shows high tolerance to hard frost, too (BARTHA

1999). The high drought-tolerant (xerophilic) nature is due firstly to the dense horizontal root system extended in deeper soil layer than those of other *Pinus* species (MAGYAR 1960). Secondly, trees growing on leptosols or rendzinas are capable of developing tap roots penetrating deeply into bedrock fissures. It principally grows on calcareous, alkaline soils, but tolerate sufficiently the neutral or faintly acidic conditions (BARTHA 1999). The species has a low nutrient requirement, but is quite sensitive to the high groundwater level.

Due to the mountainous habitat, Austrian pine originally has a discontinuous geographical distribution (Figure 1), that contributed to the evolution of four subspecies showing ecophysiological adaptation to their area (RICHARDSON 1988). Each subspecies has been planted in Hungary, but solely the ssp. *nigra* Arnold occupies great area at present. In its natural habitat, ssp. *nigra* is mostly an associating tree in pubescent oak forests, although it appears in mesophilic forest communities, too.

Figure 1: Natural area of Austrian pine (*Pinus nigra*) subspecies. 1 – *P. nigra* ssp. *salzmannii* Franca; 2 – ssp. *laricio* Maire; 3 – ssp. *nigra* Arnold; 4 – ssp. *pallasiana* Holmboe.

1. ábra: A feketefenyő (*Pinus nigra*) alfajainak természetes elterjedési területe. 1 – *P. nigra* ssp. *salzmannii* Franca; 2 – ssp. *laricio* Maire; 3 – ssp. *nigra* Arnold; 4 – ssp. *pallasiana* Holmboe.



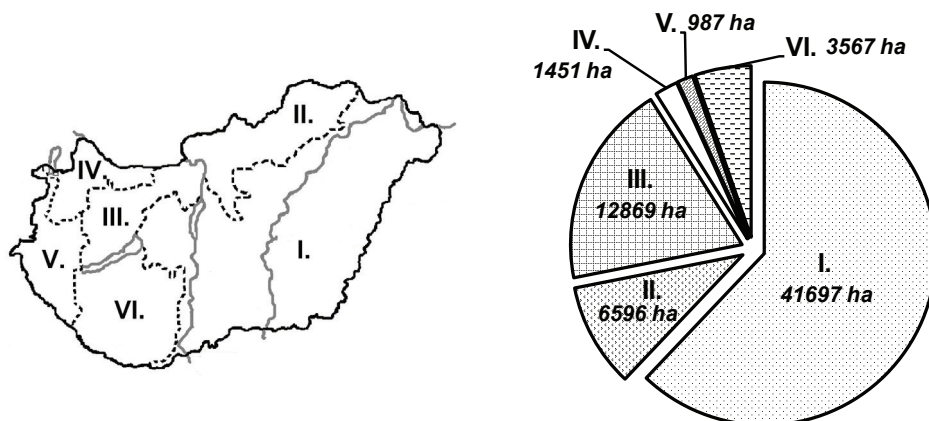
Austrian pine plantations were first established in Hungary in the second half of the 19th century for soil preservation and landscape protection purposes (TAMÁS 2001a, 2003). It was necessary to prevent the soil erosion in the mountains (particularly on dolomite slopes) and to bind the sand drift in the lowlands. Dolomite areas are naturally very sensitive to soil erosion; in addition, their serious degradation has been intensified and extended by considerable anthropogenic impacts such as deforestation and overgrazing. Tree and shrub recovery was artificially suppressed on pastures in favour of herb vegetation. Later on the most part of grazing lands were abandoned, and a country-wide afforestation program commenced in the mid-20th century. Afforestation of various uncultivated lands – unfortunately including the botanically valuable dolomite grasslands – became a general governmental policy. Austrian pine seemed to be a reasonable tree for this purpose, as the species was successfully applied much earlier for reforestation on eroded karst hills. The dense root system and the high interception ability of pine crown can considerably protect the soil surface against the erosion caused by downpours (TOPÍĆ et al. 2008). Both for this reason and because of the broad environmental tolerance, Austrian pine was widely planted for soil preservation on degraded slopes in South

Europe, Asia Minor and North Africa (PAUSAS et al. 2004, BARČIĆ et al. 2006, GILS et al. 2010). Positive experiences gave an impulse to afforestation in Hungary, multiplying the area of pine stands in two decades.

The major part (64%) of Austrian pine stands is situated in the sandy areas of Great Plain and Small Plain in Hungary (Figure 2). The binding of sandy soils in the lowlands was already suggested in the second half of the 18th century, when deforestation and overgrazing induced damaging sand-drift formation (MAGYAR 1960). At the beginning, only black locust (*Robinia pseudoacacia* L.) and black poplar (*Populus nigra* L.) stands were created; the application of Austrian pine and Scots pine (*Pinus sylvestris* L.) became general by the end of the 19th century. The reason was that the climate of Hungarian plains was first declared unfit for Austrian pine owing to some failed cultivation attempt. Further on, Austrian pine was considered as an excellent sand-binding tree due to its dense root system. Moreover, good soil amelioration, soil-shading and weed suppressing ability was assigned to needle litter densely accumulated (MAGYAR 1960). As a result of governmental afforestation programs, the area of Austrian pine monocultures increased considerably in sandy plains.

Figure 2: Area distribution of Austrian pine (*Pinus nigra*) stands among the main Hungarian forestry regions (based on NFCSO 2013). I. – Great Plain; II. – North-Hungarian Mountains; III. – Transdanubian Mountains; IV. – Small Plain; V. – Western Transdanubia; VI. – Southern Transdanubia.

2. ábra: A feketefenyő (*Pinus nigra*) állományainak területi megoszlása erdőgazdasági tájcsoportok tekintetében (forrás: NÉBIH 2013). I. – Alföld; II. – Északi-középhegység; III. – Dunántúli-középhegység; IV. – Kisalföld; V. – Nyugat-Dunántúl; VI. – Dél-Dunántúl.



Based on data furnished by the Hungarian Forest Management Inventory of the National Food Chain Safety Office (NFCSO hereafter), Austrian pine stands occupy 67167 hectares in area at present, representing 3.7% ratio of the total forested lands in Hungary (NFCSO 2013). According to the main Hungarian forestry regions, the highest part (62.1%) of plantations is found in the Great Plain, 19.2% of area is situated in the Transdanubian Mountains (chiefly on limestone and dolomite bedrock) and 9.8% in the North-Hungarian Mountains. Remaining part is divided among Western and Southern Transdanubia and the Small Plain (Figure 2). Pine cultures take the place of sandy grasslands, limestone and dolomite rock grasslands and various xerotherm oak forest associations in general (BARTHA and MÁTYÁS 1995).

Nature conservation and forest management problems

The widespread establishment of Austrian pine stands has led to grave nature conservation problems. Thousands of hectares of plantation have been created on the botanically valuable dolomite slopes in the mountains and on the similarly species-rich sandy grasslands on the plains. Harmful effect of the afforestation on native vegetation was investigated in dolomite areas in most cases. Since natural open and closed dolomite rock grasslands and xerotherm oak forests often show a remarkable coexistential variety, as well as preserve numerous endemic species and pro- and interglacial relicts, they belong to habitats undoubtedly deserving strict protection (ZÓLYOMI 1958, CSONTOS and LÓKÖS 1992, BARTHA et al. 1998). As opposed to the original area, where Austrian pine occurs just as an associating tree or forms sparse forests mixed with deciduous woody species, the Hungarian plantations are monodominant and became densely-closed quickly due to the neglected forestry thinning. Austrian pine showed broad adaptation to the ecological conditions of the habitats of native grassland associations. The strong shading caused by the closed canopy resulted in the impoverishment or local extinction of numerous light-demanding plant species grown in rock grasslands, deteriorating the formerly balanced vegetation texture (BORHIDI 1956, BÓDIS 1993, BARTHA et al. 2004). Apart from the shading, the competition of pine roots and the accumulated needle litter contributed to the extinction of the native flora as well, leading to the formation of *nudum* pine monocultures with missing herb-layer (HORÁNSZKY 1996, JÁRÓ 1996). Floral devastation induced by pine stand establishment was also observed in sandy grasslands on the plains. In the latter habitats, development of a high-coverage but species-poor shrub layer constituted by disturbance-tolerant and alien species is a common phenomena (BORHIDI 1956). Afforestation with Austrian pine exerted an unfavourable influence on indigenous fauna, too. Species number and diversity of animal communities found in pine plantations tend to be considerably smaller than those of found in the neighbouring native grassland or forest vegetation, probably attributable to the inadequate food supply and the absence of microhabitats (NAGY 1996, TÖRÖK and TÓTH 1996).

The nature conservation damage due to Austrian pine is aggravated by the invasive behaviour of the conifer. Additionally, the species is classified as a transformer invader that changes the character, condition, form or nature of the ecosystems occupied (TÖRÖK et al. 2003). Austrian pine seedlings can settle in grasses, contributing to the spontaneous spreading of pine stands established in dolomite areas, and threaten the surrounding indigenous grassland communities (UDVARDY 1998, MIHÓK 1999, TAMÁS 2001b). Potential of Austrian pine for renewal from seed was also observed on sandy lowlands, particularly in deep-lying places with more favourable microclimate (LACZAY 1981, LEEGE and MURPHY 2000).

Over the harmful nature conservation impact, the rationality of the establishment and maintenance of Austrian pine stands is contestable in respect of forest economy as well. Austrian pine's timber has a less versatile applicability as opposed to Scots pine because of the high resin content and knotted trunk (MOLNÁR and BARISKA 2002). The thick resin ducts and the frequent occurrence of sapwood diseases bring about insufficient mechanical properties and strongly restrict the industrial usability. Logging is generally uneconomical on the steep hillsides owing to the difficult mechanization.

Austrian pine exhibits ecophysiological adaptation to the Mediterranean climate. Consequently, Hungarian habitats are usually rather suboptimal for the species because of the poor nutrient supply and the inadequate amount and temporal distribution of the precipitation. The negative effect of the suboptimal habitat conditions together with the plantation of pine trees in monoculture form resulted inevitably in the decay of stands within 2–3 decades (KOLTAY 1999, SZILASI 2013). More than a half of the 20–40 years old Austrian pine stands is injured; nearly 20% of them are economically unreasonable to maintain. Both the wind fellings and the branch breakages under early-winter and early-spring damp snow show an increasing tendency. Water need of Austrian pine is significantly higher in autumn than those of other pines adapted to continental climate (e.g. Scots pine), therefore it is very sensitive to autumn drought prevailing fairly often in Hungary (LENGYEL 1964, JÁRÓ 1996). The species tolerates poorly the temperature anomalies in winter: owing to the absence of winter dormancy, a sudden rise in temperature can strongly increase the canopy transpiration, leading to an immediate shoot drying (particularly if the soil is still frozen). The considerable increase in vernal activity makes the species very sensitive to spring cold recurrence and water shortage. The insufficient water supply provokes a decline in physiological status of trees, moreover their resistance decreases by the strongly inhibited resin production. Therefore, widespread and severe epidemics of various pathogens generally occur in coniferous cultures in years following the drought period (LENGYEL 1961, KOLTAY 1999). During the last fifty years, the phenomena was expansively observed on several occasions mainly in Austrian pine stands but sometimes in Scots pine plantations as well (CSILLAG 2006, KOLTAY et al. 2013). Infections – expressing in red canopy and intense needle falling – were attributable to dangerous fungal pathogens (e.g. *Cenangium ferruginosum*, *Cyclaneusma minus*, *Diplodia pinea*, *Mycosphaerella pini*, *Sclerophoma pithyophila*) appeared just recently or well-known long before in Hungary (KOLTAY 1990, 1997, 2003, CSILLAG 2006, SZILASI 2013). In Austrian pine plantations standing on the sandy lowlands, *Heterobasidion annosum* (syn. *Fomes annosus*) also causes serious problem. The fungus injures the sapwood, propagating from tree to tree through the root contacts in dense monocultures (PAGONY 1980, LACZAY 1981). Regarding insects, the damages of pine-tree lappet (*Dendrolimus pini*), six-toothed pine bark beetle (*Ips sexdentatus*), pine shoot beetle (*Myelophilus piniperda*) and *Pissodes notatus* may become serious (AMBRUS and CSÓKA 1989, HORVÁTH 1993, KOLTAY 1999). Propagation of pathogens is not promoted exclusively by the weakened physiological status of trees. The pine monocultures with species-poor or totally absent herb-layer vegetation form very unfavourable habitats for the most parasites and natural enemies of the pathogens, contributing to their invasion (AMBRUS and CSÓKA 1989).

Foresters frequently mention that the decomposition of the ample needle litter of Austrian pine has notable capability for soil amelioration. However, comprehensive investigations have not shown any considerable alteration in the chemical composition, acidity and organic matter content of soil under Austrian pine stands (HALBRITTER et al. 2003). Conversely, researches carried out in dolomite area revealed lower spatial heterogeneity in the upper soil layer of pine plantation compared to those of native grassland vegetation. The phenomenon is presumably responsible for the uniformization of microhabitats, contributing to the impoverishment of the vegetation (that was formerly

attributed mainly to canopy shading). Austrian pine's litter exhibits slow decomposition rate due to the high initial C/N ratio, thus tends to accumulate in large quantities on the soil surface (JÁRÓ 1996, CSERESNYÉS et al. 2006, CSONTOS et al. 2007). Substances released from litter are able to inhibit the germination and growing of various indigenous plant species, additionally the rapid desiccation of the resinous needle produces high fire risk in the coniferous stands (BORHIDI 1956, CSERESNYÉS et al. 2011).

Fire risk in pine stands

Wildfires are considered to be the important part of natural disturbance pattern in numerous vegetation types worldwide, playing key role in preservation and renewal of the ecosystems, as well as in maintenance of their diversity and productivity (LICHTMAN 1998, BOWMAN and MURPHY 2010). However, in parallel with the growing human population and expansive land use, the frequency and extent of forest fires show continuous and powerful increase for already hundreds of years, but particularly during the last few decades (MILLÁN et al. 1998, NIKLASSON and GRANSTRÖM 2000, VALOR et al. 2013). This unfavourable tendency is observable not only in the Mediterranean areas are well-known for frequent fire events (VIEGAS 1998, BOBOULOS and PURVIS 2009), but also occurs in the continental woodlands of Central Europe (ZUMBRUNNEN et al. 2011), and even in the Eurasian and North American boreal pine forests (ZACKRISSON 1977, JOHNSON and LARSEN 1991).

According to studies executed in different Central European countries, the 80–95% of forest fires broken out in the last decades is attributable either to human negligence or purposive lighting (VIEGAS et al. 1999, FULÉ et al. 2008, ZUMBRUNNEN et al. 2011). Anthropogenic fires show similar ratio in Hungary. Based on long-term (1950–1992) data evaluation, 65% of wildfires were verified to originate from humans (composed of 47% and 17% due to negligence and intention, respectively), but further 23% were very likely caused by human activities (GELETA 1995, GHIMESSY 1995).

Hungary is situated in the warm temperate zone that is the third in order among climatic regions regarding fire risk only surpassed by the Mediterranean and the wet subtropical areas (BUSSAY 1995, TAMÁS 2001a). Annual number of forest fires ranged from 500 to 600 in the country during last years with 4700, 2400 and 2600 hectares in area burnt in total in 2007, 2008 and 2009, respectively (PAPP 2010). Extension of forest fires rarely exceeds 50 hectares, with the area of 5.9 hectares on the average (NFCSO 2013).

The probability of wildfire initiation and the fire propagation are determined jointly by the amount and characteristics of flammable organic matter, the existing meteorological factors and the topographical conditions (MILLÁN et al. 1998). Fire risk exists at any given time, in a given place if the thermal energy potentially released from the burning fuel is higher than that required to evaporate the moisture from the comburent (GHIMESSY 1995). The amount of flammable organic substances available in forest ecosystems many times exceeds the mass accumulated in nonforest vegetation types (PRÉCSÉNYI 1971, MOLNÁR 1975), strongly increasing the fire risk in forests situated in areas with periodical water shortage. There is no considerable litter accumulation in deciduous forest associations in Hungary, because the leaf litter is decomposed almost entirely within 1–3 years (PAPP 1972, TÓTH 1985). Accordingly, the litter mass generally remains under 6–8 t/ha in the

native forest vegetations (TÓTH and PAPP 1973). However, decomposition of needle litter is much slower as a consequence of different chemical composition (FIORETTO et al. 1998), so it tends to accumulate (JÁRÓ 1996, KAVVADIAS et al. 2001). Field studies completed in Austrian pine monocultures in Hungary showed that the amount of flammable litter varied with stand age with reaching its maximum value of 18–20 t/ha in stands between 60 and 80 years (CSERESNYÉS et al. 2006). Though lower litter masses were determined in younger and older stands, but the amount exceeded 12 t/ha in general.

Owing to the high comburent availability, the planted Austrian pine stands in Hungary are more endangered by fires than both the grasslands (occupied the area prior to afforestation) and the native broad-leaved forest of the country. Paleobotanical researches in North America verified that devastating wildfires occurred more frequently in forests of eastern white pine (*Pinus strobus* L.) than in neighbouring broad-leaved woodlands during the last thousands of years (CLARK et al. 1996). In several regions of South Europe, planted *Pinus* (*P. nigra* in particular) stands are considered as the most inflammable vegetation type (FERNÁNDEZ et al. 1997, CHRISTOPOULOU et al. 2013). Fire threat in artificial Austrian pine stands is enhanced by additional risk factors. Firstly, the quantity of flammable litter is much higher in the dense, even-aged monocultures than in native coniferous forests, leading to an increasing intensity and spreading rate of surface fires (FERNANDES et al. 2008). Secondly, the dense pine canopy forms a continuous, highly inflammable crown layer, affording possibility of evolving a crown fire that is very difficult to control. Thirdly, the high rainfall interception loss by canopy promotes the rapid litter desiccation; moreover the great terpenoid content and the good air penetrability contribute to the enhanced inflammability of needle litter and the acceleration of fire propagation (ZHAO et al. 2012). These facts are jointly and severally liable for the considerably high flame temperature and fire intensity responsible for the difficult fire control and serious ecosystem damage (GILS et al. 2010).

Statistical data also support the serious fire threat of the coniferous plantations in Hungary. Approximately 25% of forest area burnt annually in Hungary is represented by Austrian pine and Scots pine stands altogether (GHIMESSY 1991), although the two conifers constitute only 11.1% of the total forested lands of the country (NFCISO 2013). In the droughty years of 1993 and 1994, more than a half of the forest area burnt in Pilis Mts. was formed by Austrian pine monocultures (ZAMBÓ 1995). Austrian pine stands growing on the extremely dry sandy plains of Central Hungary are registered to be endangered by fires above all (NFCISO 2013). In our country, August and September can be regarded the crucial months from the point of view of fire events, when serious danger of fire is generally expected even in years featured by ordinary temperature and rainfall conditions (CSERESNYÉS et al. 2011). However, the fire-risk period may range from spring to late autumn during a dry year. As for Austrian pine cultures standing on the steep dolomite slopes, the rate of fire propagation can be accelerated by slope effect (additionally, fire-fighting is very strenuous in hilly terrain).

Forest fires cause natural and economic damages, such as biomass destruction, air pollution and fire-related soil erosion above all (AGÓCS 1995, BUSSAY 1995). High-intensity fires induce significant physicochemical changes in soil properties (particularly in the upper layer subjected to high temperature), including the increased pH, the reduced organic matter and organic acid content, the decreased cation exchange capacity and ratio of Ca-humates, the degradation of clay minerals and the enhanced mobilization of

toxic heavy metals and compounds (FERNÁNDEZ et al. 1997). In consequence, the adverse alterations culminate in the reduced puffer capacity, the inhibited water and heat transfer, structure deterioration and soil erosion. Pine stands are often injured seriously by fire even in case when crown fire is not evolved. The reason is that the upward heat flux from burning litter induces intense crown transpiration, leading to rapid canopy desiccation and almost total needle loss (GHIMESSY 2003). Pine stem is generally damaged by a low-intensity surface fire. The viscosity of Austrian pine's resin decreases considerably even with a slight temperature rising, the resin obstructs the phloem vessels and thus eventually causes the decay of root system part beneath them (GHIMESSY 1995). Root death reduces the water and nutrient uptake and also makes the stand more susceptible to wind felling. Fire damages the cambium structure, ensuring rich substratum for various fungal and other pathogens (GHIMESSY 2003). It is an important nature conservation problem, that forest fires are frequently followed by the colonization or recovery of invasive plant species.

Spreading of plant invaders in Austrian pine stands

At present, 3% of the Hungarian flora (nearly 100 species) belongs to the adventive floristic elements. A part of them became plant invader due to their aggressive propagation and threaten to the ecological balance in natural and seminatural associations (BOTTA-DUKÁT 2004). Changes in land use taken place during the last 25 years, including the fragmentation and partition of arable fields, the reduced soil tillage, the decreased herbicide application and the afforestation with exotic trees promoted the rapid spreading of invaders (TÖRÖK et al. 2003).

Different plant communities possess different resistance to plant invasion. The species-rich and high-diversity associations with strong interspecific interactions show lower invasibility (ALPERT et al. 2000). Susceptibility to invasions is enhanced by various factors, such as small species pool, low diversity, small intensity of competition, fragmentation and altered disturbance regimes.

Coniferous forests have lower diversity and smaller coverage in their shrub- and herb-layer in general than have broad-leaved forests, thus they are more susceptible to invasions (MANDRYK and WEIN 2006). Moreover, a significant part of Austrian pine plantations found in Hungary forms *nudum* type monoculture without herbs and shrubs. These stands are often fragmented, disturbed by humans and contain physiologically weakened trees, therefore they are regarded as "associations" having the highest invasibility (TÖRÖK et al. 2003). Nowadays in Hungary, stands of exotic trees are occupying roughly the half of the total forested lands (NFC SO 2013), playing key role in spreading of numerous alien species. Colonization of several woody invaders, including *Ailanthus altissima* (Mill.) Swingle, *Celtis occidentalis* L., *Elaeagnus angustifolia* L., *Gleditsia triacanthos* L., *Padus serotina* (Ehrh.) Borkh. and *Robinia pseudoacacia* L., as well as non-native herbaceous plants such as *Asclepias syriaca* L., *Conyza canadensis* (L.) Cronqu., *Phytolacca americana* L. and *Solidago gigantea* Ait. is widely observed in Austrian pine plantations (UDVARDY 1998, VARGA 2003, BAGI 2004, BALOGH et al. 2004, BOTTA-DUKÁT and DANCZA 2004, BARTHA et al. 2006, CSILLAG 2006).

From among invasive plants, species are capable of forming long-term persistent seed

bank in the soil can pose potentially major threat to the ecosystems. The high-density persistent soil seed banks of the phanerophyte black locust and the geophyte common milkweed (*Asclepias syriaca* L.) were revealed in Austrian pine stands (CSERESNYÉS and CSONTOS 2012b, CSERESNYÉS 2013). Black locust trees often show good vigour even under closed Austrian pine canopy (MAGYAR 1960), but a gap opening or a forest fire present them good opportunity to propagate more intensely (AGÓCS 1995, CSILLAG 2006, GILS et al. 2010). The nitrogen-fixing species can supplement soil nitrogen stores and increases the rates of nitrogen cycling and availability, facilitating the spread of undesirable nitrophilous weeds and other exotic species (TOBISCH et al. 2003, RICE et al. 2004).

In the 1990's in Hungary, total or partial restoration of the native vegetation types was begun in areas covered by Austrian pine stands, primarily in nature reserves (KESZTHELYI et al. 1995). Following the clear-cut of coniferous stands, the recolonization of indigenous species from surrounding native forests and grasslands is generally slow, even if the appropriate propagule sources are available in the adjacent areas (MATLACK 1994, CSONTOS et al. 1996, RYDGREN et al. 1998). Under these circumstances, the local soil seed bank receives an essential role in the regeneration of the native vegetation. In soil of Austrian pine stands, the seed bank of native species (that existed prior to the afforestation by pine) became impoverished; its density and richness declined steadily because of their short-term persistent seeds (CSONTOS et al. 1996, 1997, AUGUSTO et al. 2001, MATUS et al. 2003). Consequently, the diverse natural seed bank could be replaced gradually by the high-density persistent seed bank of non-indigenous species (CSERESNYÉS and CSONTOS 2012b). Seed germination of the invaders (black locust in particular) can be continued even for decades, inhibiting strongly the restoration of the native flora after the removal of the Austrian pine stand. Contributing to the renewal from the soil seed bank, the effective vegetative propagation, such as root sprouting also promotes the rapid spread of the adventives, especially after local disturbances. Thus eventually, it can happen that an area just cleared from Austrian pine is occupied by another non-natives (and invaders at that) in place of the natural vegetation required, which would be a rather unacceptable result. In consequence, both before and during the replacement of pine stands the utmost care should be given to prevent the spreading of plant invaders in order to achieve a successful habitat restoration. The risk of excessive propagation for several invasive species is particularly enhanced by wildfires, because a certain increase in temperature is able to break the physical dormancy of their soil-buried seeds, provoking vigorous germination (AULD and DENHAM 2006). The undesirable phenomenon cannot be left out of account in Austrian pine plantations are more vulnerable to forest fires.

Role of Austrian pine in land reclamation

Austrian pine is widely used for forestry reclamation in devastated lands. In many countries of Central and South Europe, the species is planted for this purpose both in monoculture and in mixture with other coniferous or broad-leaved trees (KAVVADIAS et al. 2001, MUDRÁK et al. 2010, MILETIĆ et al. 2011). Its extensive application started in the 1950's in Hungary. First a number of abandoned sand pits and waste rock dumps related to coal mining were experimentally afforested between 1955 and 1957 in the territory of Pilis Mts. and Budai Mts. Based on forestry reports summarizing the observations,

Austrian pine and black locust were the two most efficacious reclamation woody species among others in these cases (FEJÉR 1960, 1963). Austrian pine also proved to be a good choice in forestry reclamation projects carried out in pits and waste rock dumps in coal-mining district of the South Mecsek Mts. (KASSAI 1963, SZERÉMY 1981). Pure and broad-leaved mixed Austrian pine plantations were created in waste rock areas of Tatabánya coal-mining district in the 1970's to mitigate the soil erosion and air pollution (CSICSAI 1986), and large stands were grown on dried slurry reservoirs of the thermal plant of Pécs town as well (PAPP 1982). Successful forestry restorations were completed by cultivating Austrian pine, black locust and silver berry (*Elaeagnus angustifolia* L.) in mixture on coal ash and red sludge reservoirs in the Transdanubian Mts. (HORVÁTH 2002) as well as on city landfills of Budapest (BARANYI 1986). Primarily Austrian pine and Scots pine were applied during one of the greatest land reclamation program in Hungary, when 257 hectares of devastated area in the Iharkút–Németbánya open-pit bauxite mining district (Central Transdanubia) was technically reclaimed then revegetated in several stages between 1976 and 2006 (KÁROLY et al. 2006).

The good applicability of Austrian pine for land reclamation is presumably related to its wide habitat tolerance. The cover substrate deposited through the technical reclamation is generally characterized by physical and chemical conditions are very improper for plant cultivation, such as low nutrient supply and organic matter content, extremely high or low pH, as well as high spatial heterogeneity in texture and subsequently in water-holding and water-conducting capacity (SZEGI 1985, JOCHIMSEN 2001). Materials of waste rocks, but particularly the power plant slags and red sludges usually contain high level of mobile and easily mobilizable toxic heavy metals and compounds, such as sulphides (VICZIÁN 2004, LIU et al. 2011). Austrian pine is quite tolerant to dry and nutrient-poor soils, additionally trees can be easily settled by seed sowing or sapling planting (ZAGAS et al. 2010). The species exhibits intensive early root expansion, even under unfavourable environmental conditions. Root morphology is well adapted to physical soil properties, thus enables the species to keep up more efficient water and nutrient uptake rate and higher biomass production compared to black locust and Scots pine (RICHARDSON 1998, BAUMANN et al. 2006). Though the soil amelioration effect of the conifer proved to be unsatisfactory in many cases, the dense root system, the quick canopy closure and the intensive litter formation markedly reduce soil erosion (FILCHEVA et al. 2000, MILETIĆ et al. 2011). Similarly to some other *Pinus* species, Austrian pine has evolved a tolerance to the high concentration of toxic metals (*i.e.* Al, As, Cd, Cu, Sb, Sn, W) and pyrite in soil (JOHANSSON et al. 2005, PRATAS et al. 2005, PARRAGA-AGUADO et al. 2013). Heavy metals uptaken by pine roots tend to be translocated and accumulated in old, preferably lignified stem tissues and older needles to avoid their toxicity in young tissues and organs possessing higher metabolic activity. Owing to the stress avoidance strategy, Austrian pine can be used as a responsive bioindicator even under low heavy metal contamination levels, but may be suitable for phytostabilization and phytoextraction (CSONTOS et al. 2012).

Nevertheless, the establishment of Austrian pine stands for the purpose of area restoration is a rather exceptionable procedure if ecological and nature conservation aspects are considered. Coenological survey of abandoned dolomite and bauxite quarries formerly revegetated with Austrian pine monoculture indicated a decreasing species number, coverage and diversity of the herb-layer vegetation along with the increasing

cover of pine canopy (CSERESNYÉS and CSONTOS 2012a, CSERESNYÉS 2013). Presence of pine stands is observed to impede the regeneration succession of the herb layer: the repression of weeds and the spreading of species belonging to the native flora take place more slowly or just partially under Austrian pine stands as opposed to that happens through the spontaneous revegetation in a similar habitat without reforestation. Recolonization of the constant and accompanying species typical of the surrounding areas does not occur in most cases in the post-mining pine stands, and the geophytes and the botanically valuable and protected plants are also absent in general, even many decades after forestry reclamation (CSERESNYÉS 2013). In several cases, indigenous disturbance-tolerant species and alien invaders become predominated in the reclaimed areas for a long time.

Replacement of Austrian pine stands by native vegetation – directives and proposals

In the years past there has been an increasing attention to forested lands by the public: the improving attitude to nature conservation and the strengthening social expectations demand the notable alteration of the goals and objectives of forest management worldwide. The conception of the multifunctional forest management was established by the 1970's, declaring the simultaneous maintenance of the economic, soil-defensive and social welfare functions of forests. According to the sustainable forest management policy (SFMP), all kinds of forest and forest ecosystems should be treated and utilized with preserving or enhancing their biodiversity, productivity and regeneration capacity, as well as ensuring the long-term maintenance of their ecological, economic and social functions jointly (based on the definition of the Second Ministerial Conference on the Protection of Forests in Europe, Helsinki, 1993). Hungarian National Forest Strategy and Forest Programme (2001), founded on the objective of SFMP, also assumes the priority of nature conservation respects in the course of silvicultural operations (MÉSZÁROS et al. 2003, VAHID and KÓBORI 2005). Establishment and keeping of exotic tree monocultures such as Austrian pine plantations do obviously not correspond to nature conservation principles (BUNDITY 1995, KESZTHELYI et al. 1995).

Many benefits are attributed to the replacement of monodominant pine stands by native forest associations, including: increased litter decomposition rate, reduced soil acidification, balanced nutrient turnover (without nutrient deficiency), higher species diversity and ecological integrity, reduced sensitivity to weather anomalies (*i.e.* storm, drought) and pest outbreaks (HARTLEY 2002, PORTÉ et al. 2004). In the Hungarian areas covered by pine cultures, restoration of the natural or seminatural forest and grassland vegetation is desirable. Spontaneous regeneration of species constituting the original associations should be promoted within coniferous stands by opening canopy gaps (selective pine thinning) or by artificial planting of native broad-leaved trees and shrubs. In this manner, more stable ecosystems with higher resistance to environmental variables can be formed, which additionally meet much better the requirements of nature conservation and goals of silviculture (HORVÁTH 1993, BARTHA 2003).

Directives concerning the treatment of all forest types including Austrian pine stands situated in nature reserves are summarized by KESZTHELYI et al. (1995). According to that, strictly protected areas have to be entirely exempted from Austrian pine as soon as

possible. In other preserves, Austrian pine is possibly kept in stands mixed with broad-leaved trees of 50% cover ratio at least, but solely in extremely dry and very dry habitats; while places with better water supply must be intended for maintaining forests of natives only. Forestry planting of *Quercus cerris* L., *Q. petraea* (Matt.) Liebl., *Q. pubescens* Willd. and *Fraxinus ornus* L. in the mountainous regions, and application of *Populus alba* L. or *P. × canescens* (Ait.) Sm. in the sandy lowlands is suggested to form mixed forests (KESZTHELYI et al. 1995). Forests consisting of indigenous trees mentioned above must be restored in strictly protected areas. Austrian pine can be partially or fully removed from the stands chiefly by selective thinning or by small-scale (<1 hectare) clear-cutting in certain cases.

Many studies dealing with the treatment of Austrian pine plantations focused mainly on stands occupying dolomite areas, emphasizing that the natural regeneration ability of the native dolomite vegetation should be utilized. According to CSONTOS et al. (1996) and HORÁNSZKY (1996), spontaneous regeneration can be facilitated by cutting out of Austrian pine in plots or in network, followed by the enlargement and connection of clearings after the partial recovery of grassland vegetation. Austrian pine cultures are observed to have lower biotic potential than have native forest and shrub associations: pine stands growing in place of xerotherm oak forests get gradually thinner in general, contemporaneously with the spontaneous recolonization of numerous indigenous woody species (e.g. *Fraxinus ornus* L., *Cotinus coggygria* Scop., *Quercus pubescens* Willd., *Q. cerris* L.) in the area (BÓDIS 1993, JÁRÓ 1996). Studies from Central and Western Europe also suggested the promotion of the spontaneous succession during the alteration of alien coniferous stands to native flora, accentuating that selective pine thinning have to be followed by repeated silvicultural interventions, such as the removal of undesirable shrubs for mitigating the competitive interactions (OBERLECHNER and VACIK 2003, JONÁŠOVÁ et al. 2006).

Settlement of broad-leaved trees in pine plantations makes the forest still less vulnerable to wildfires. Mixed litter is characterized by greater water holding capacity and slower desiccation rate as compared with pure needle litter, reducing the litter dryness and risk of fire subsequently. The amount of accumulated flammable litter becomes smaller in mixed stands (by 30% at 50:50% cover ratio), leading to a further reduction in spreading rate and intensity of fires (CSERESNYÉS 2013). Furthermore, the breaking continuity of pine canopy decreases considerably the probability of crown fire initiation: beneath 50% pine cover ratio just local crown fire outbreaks are expected (VIEGAS 1998). During the most fire hazardous periods of years, strict inspection is essential in Austrian pine stands so that fire ban will be observed. In addition, fire ban should be expanded to the wide strip of agricultural or other areas surrounding the pine plantations (fires reach pine forests from adjoining fields in many cases). We have to pay more attention to stands situated in nature reserves or close to inhabited area or protected natural value. Non-public roads traversing pine stands are worth closing to motor traffic by placing barriers to minimize the likelihood of anthropogenic fire ignition. Fire control in large and continuous pine cultures can be effectively supported by forming and maintenance of fire-trace networks.

Special care should be taken in course of forest management in pine plantations are invaded by alien plant species. Release of the area from exotic plant invaders with long-term persistent soil seed bank may be extremely difficult. Root- and stem-sprouting of woody invaders (e.g. *Robinia pseudoacacia* L., *Ailanthus altissima* (Mill.) Swingle, *Acer negundo* L.) can be efficaciously inhibited by stump grubbing and chemical treatment

(VARGA and SZIDONYA 2002), but the removal of seed bank from the soil is practically unfeasible. This is why the formation of the invaders' soil seed bank has to be prevented anyway. Apart from the age and designation of Austrian pine plantation, avoidance and suppression of seed bank forming non-natives is essential in all stands in order to forestall the further accumulation of dormant seeds or to deplete at least partially the seed bank have already built up.

Austrian pine cultures serving for land reclamation should be also converted into native plant associations principally by facilitating the natural regeneration (HODAČOVÁ and PRACH 2003), as described above. Contemporaneously with selective pine thinning, repeated planting of indigenous stand-forming (*Quercus cerris* L., *Q. petraea* (Matt.) Liebl) and accompanying trees (e.g. *Acer campestre* L., *Carpinus betulus* L., *Fraxinus ornus* L., *Tilia cordata* Mill.) may be reasonable. Partial or total removal of alien invaders and other aggressive competitors (*Calamagrostis epigeios* (L.) Roth in particular) is essential for ensuring the regeneration succession (MUDRÁK et al. 2010, HÁZI et al. 2011). Revegetation is strongly influenced by propagule availability in a given area (MATLACK 1994), thus an active propagule addition planned and carried out by experts can be important a couple of years after forestry reclamation. Since Austrian pine has an obstructive effect on regeneration succession, further establishment of pine stands can be reasonable just in spoil areas where the unfavourable habitat conditions (soil water holding capacity or nutrient supplying ability) make impossible the application of other tree species (CSERESNYÉS and CSONTOS 2012a). In other cases, erosion-prevention ability of the conifer has to be utilized, and its plantation (possibly mixed with native broad-leaved trees or shrubs) should be restricted solely to steep scarps are highly exposed to soil water erosion.

We can conclude, that Austrian pine stands – have been established earlier or planned to create in future – must not be treated as cultures will be maintained for decades. Although these plantations can be provisionally important in some places as protective forests to prevent erosion hazard and air pollution, but their presence is decidedly harmful elsewhere. In areas occupied by Austrian pine, the locally native vegetation type should be restored at the earliest convenience with consideration of directives and suggestions described in this study.

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FEKETEFENYŐ (PINUS NIGRA) ÁLLOMÁNYOK TERMÉSZETVÉDELMI MEGÍTÉLÉSE – SZEMLE

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Kulcsszavak: tájidegen fafaj, erdőtüz, invazív fajok, rekultiváció, természetvédelem, *Pinus nigra*, fenntartható erdőgazdálkodás

Összefoglalás: A szemle a Magyarországon tájidegen feketefenyő (*Pinus nigra* Arn.) állományaival foglalkozik, kihangsúlyozva a fenyőtelepítés természetvédelmi szempontból káros következményeit. Rövid történeti áttekintést követően ismerteti a feketefenyő-állományok – erdőgazdasági tájcsoportok szerinti – területi megoszlását. Ezt követően tárgyalja a faj megthonosításával kapcsolatba hozható természetvédelmi és erdőgazdasági problémákat, különös tekintettel a természetes flóra lokális kipusztítására, a csekély értékű faanyagra, az állományok gyors fiziológiai leromlására és számos kártevő elszaporodására, a nem kielégítő talajjavító hatásra, valamint a monokultúrák erdőtüzek és invazív növényfajok általi sebezhetőségére. Külön fejezet ismerteti a feketefenyő rekultivációs célú hasznosításának kérdéseit. A tanulmány végül a feketefenyvesek természetes növénytársulásokká alakítását célzó irányelveket és javaslatokat foglalja össze, főként a fenntartható erdőgazdálkodással összefüggésben.