Szent István University
PhD School of Environmental Sciences

Evaluation of Austrian pine stands with respect to nature conservation – an ecological approach

book of PhD theses

Imre Cseresnyés

Gödöllő
2013

PhD School

name:	PhD School of Environmental Sciences
field:	Environmental Sciences
director:	Prof. Dr. György Heltai, D.Sc. Head of department Szent István University Faculty of Agricultural and Environmental Sciences Institute of Environmental Sciences Department of Chemistry and Biochemistry

Supervisor:	Dr. Péter Csontos, D.Sc. Scientific advisor Institute for Soil Sciences and Agricultural Chemistry Centre for Agricultural Research Hungarian Academy of Sciences

………………………………….	…………………………………..
Approval of Director	Approval of Supervisor

1. Background and aims

The alien Austrian pine (*Pinus nigra* Arn.) was first introduced in Hungary in the second half of the 19th century. Pine plantations were primarily established in order to prevent the soil erosion in the mountains (mainly on dolomite hills) and to bind the sand drift in the lowlands. Later the wood production became the main goal of the afforestation [TAMÁS 2003]. Despite occupying these forests relatively small areas (3.7% of the total forested lands of Hungary), the species is responsible for some serious nature conservation problems. Most part of the stands was grown in place of species-rich native dolomite vegetations as well as sandy grasslands. Owing to the accumulated litter and the strong shading by the pine canopy, the botanically valuable native flora has been extensively impoverished or locally extinct, thus nowadays these habitats are generally occupied by monodominant *Pinus nigra* stands [BORHIDI 1956, BÓDIS 1993, HORÁNSZKY 1996, CSONTOS et al. 1998]. Low quality timber of Austrian pine has lost its economic importance during the latest decades. Besides this, Hungarian habitats are often suboptimal for the species, resulting in rapidly declining tree vigour in general. For this reason, stands were often damaged by widespread infections of pathogenic fungi and insects, thus the maintaining of these plantations became economically unjustified [KOLTAY 1999]. Large amounts of the resinous needle litter in the dense monocultures [CSERESNYÉS et al. 2006] frequently led to devastating forest fires [GHIMESSY 2003, PAPP 2010]. The low-diversity, fragmented and physiologically weakened plantations have high invasibility that is they offer good opportunities for spreading of invasive species [TÖRÖK et al. 2003]. Propagated invaders intensify the negative effect of Austrian pine on native flora.

Over the last few decades, sustainable forest management has come into general use, displacing the even-aged timber management [VAHID és KÓBORI 2005]. According to the nature conservation requirements, restoration of the native broad-leaved forest or grassland associations in areas covered by Austrian pine plantations is indispensable in Hungary [KESZTHELYI et al. 1995]. Nevertheless, total area of pine stands hasn't decreased considerably and further afforestations are still in progress. Utilizing the small water and nutrient needs of Austrian pine, a part of pine stands was created for biological reclamation of various degraded areas, mainly abandoned open-pit mines.

Objective of our study was to analyze some ecological consequences of the controversial plantation of Austrian pine in order to assist the consideration of the conifer with respect to nature conservation and contribute to the more successful treatment of the existing pine stands. Our investigations were focused on some lesser-known scopes of coniferous stands, *i.e. (1)* fire risk of pine stands, *(2)* soil seed bank of various invasive species in pine plantations and *(3)* coenological study of abandoned open-pit dolomite and bauxite mines reclaimed with Austrian pine.

Aims of the study:

1. Quantification of flammable litter accumulated on pine monocultures at various age classes and slope aspects; measurement of litter mass in pine stands mixed with broad-leaved trees.
2. Evaluation of fire risk in pure and mixed pine stands at various age classes by using McArthur's empirical fire danger model: investigation of the probability of combustion and fire propagation under different meteorological, topographical and drought conditions.
3. Comparison of the outputs of McArthur's model with experimental laboratory results known from the scientific literature in order to prove the authenticity of our results and the applicability of the model for European pine stands.
4. Investigation of the persistent soil seed bank of the widely invasive black locust (*Robinia pseudoacacia* L.) and common milkweed (*Asclepias syriaca* L.) as well as the locally invasive honey locust (*Gleditsia triacanthos* L.) in Austrian pine stands.
5. Based on seed bank study, consideration the potential danger of the plant invaders to the restoration of native flora or to other planned area utilization.
6. Coenological study of abandoned dolomite and bauxite quarries reclaimed with Austrian pine; assessment of the naturalness of the herb-layer vegetation developed in the restoration areas.
7. Examination of the differences between the flora of the studied abandoned quarries and the vegetation *(1)* is the potential climax association of the area (*Cotino–Quercetum pubescentis* or *Quercetum petraeae–cerris*) or *(2)* developed through regenerative succession in a similar habitat (after burning or clear-cutting the forest formerly covered the area); investigation of the influence of Austrian pine on regenerative succession.
8. Based on the results obtained, consideration the presence of Austrian pine in Hungary and making proposals in relation to the treatment of existing pine stands and the prospective plantation of the species.

2. Materials and methods

2.1. Evaluation of fire risk in Austrian pine stands

Fire risk investigation was carried out in Austrian pine plantations standing on dolomite hills of Budai Mts. It was the first application of McArthur's empirical model for fire risk prediction in European coniferous stands. The Australian model was developed on the strength of field study of more than 800 forest fires devastated eucalypt forests and on the basis of fuel-burning experiments [NOBLE et al. 1980]. Its subsequent, revised forms were applicable for other broad-leaved and coniferous forests. Several study [*e.g.* PASTOR et al. 2003] suggested the adoption possibilities of this practical and simple model for European pine stands with emphasizing, that verification of the obtained results are needed. By knowing the air temperature, relative humidity, wind speed, amount of fuel, drought factor and degree of slope, the model predicts the probability of combustion (Fire Danger Index = FDI), flame height, spotting distance and rate of spread (*Fig. 1*). The value of drought factor was derived from the Byram–Keetch Drought Index (BKDI), the amount of last precipitation and the days since last rain.

For modeling fire risk, knowledge of the amount of fuel and drought factor was needed first of all. Amount of fuel was measured in five replicates of 2 m by 2 m quadrats in different pine stands represented four age classes (20–40, 40–60, 60–80 and above 80 years) and three exposure types (north, south and plateau). According to McArthur's model the fire behaviour depends on the amount of litter only with a diameter of less than 6 mm (*fine fuel*). Therefore, three litter fractions were collected from the quadrats: *1)* needles (including twigs with diameter less than 6 mm); *2)* branches (including twigs with diameter above 6 mm); and *3)* cones. Dry weights of the fractions were determined (kg/ha) for each sampling stands. By application of meteorological data, daily values and annual trends of both the BKDI and the drought factor were calculated for the 1985–2009 period [KEETCH and BYRAM 1968]. Drought factor calculation highlighted the seasons are crucial in view of fire hazard.

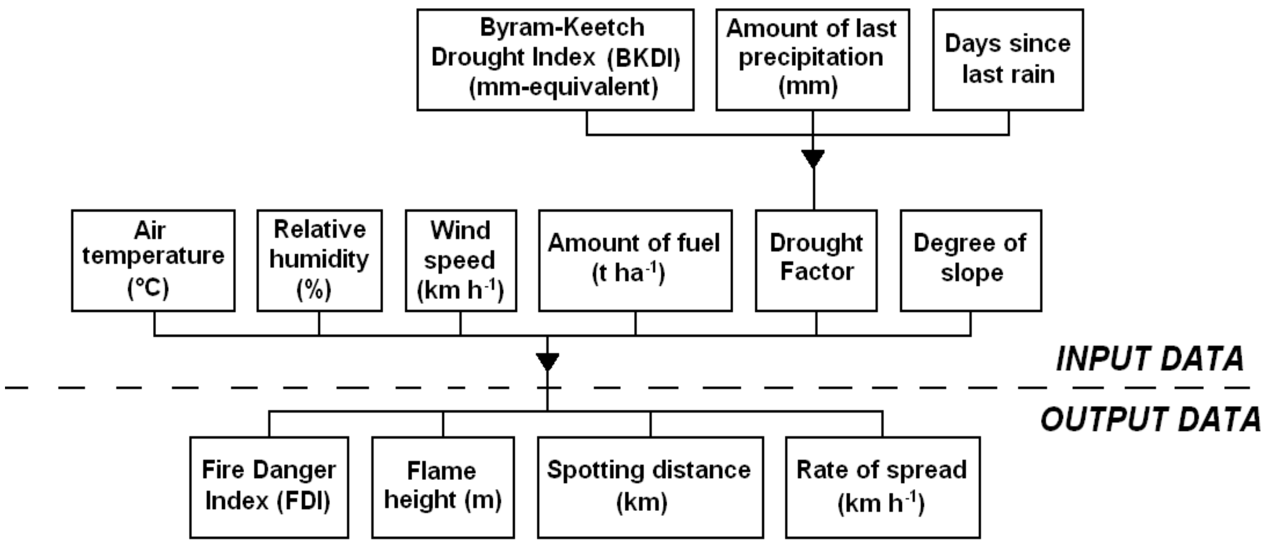

Figure 1:
Schematic diagram of McArthur's fire danger model

Based on the measured litter mass and the calculated drought factor, fire risk and fire behaviour under various meteorological and topographical conditions can be modeled. In this case, one input parameter among six (*Fig. 1*) was changed within an appointed interval (while the other five parameters were kept constant) and its result on the four outgrowths of the model (FDI, flame height, spotting distance, rate of spread) was examined. In order to prove the authenticity of our results and the applicability of McArthur's model for European pine stands, we compared the outputs of the model with experimental laboratory results originated from the scientific literature.

Quantification of litter mass and evaluation of fire risk was also executed in pine stands mixed with native broad-leaved trees to a various ratio (6–79%) to show the effect of mixing on litter mass and fire risk.

2.2. Seed bank examination of invasive plants

Soil seed bank of the invasive black locust, honey locust and common milkweed was studied in Austrian pine plantations standing in sandy soil areas (Small Hungarian Plain, Gödöllő Hills and Csévharaszt) by sampling of two soil layers (0–6 cm and 6–12 cm). Seeds were separated by sieving then mechanically scarified (except for common milkweed) and germinated. The mean seed bank density (seed/m^2) of each examined pine stand was calculated. Seedling bank of honey locust was determined as well. We analyzed the relationship between the seed bank density of black locust and honey locust and the age (basal area) of trees. As for common milkweed, the correlation between seed bank density and density of common milkweed plants was investigated.

2.3. Coenological study of abandoned dolomite and bauxite quarries reclaimed with Austrian pine

We carried out coenological studies in three abandoned dolomite (Keszthelyi Mts.: Balatongyörök, Vonyarcvashegy, Gyenesdiás) and three bauxite (Gerecse Mts.: Nagyegyháza; Bakony Mts.: Szőc, Sáska) quarries had reclaimed through planting of Austrian pine. Percentage cover of each species of understory vegetation was estimated three times in five replicates of 10 m by 10 m permanent quadrats in each study area. Cover of Austrian pine as well as total species number, cover and Shannon-diversity of herb layer was determined respecting each quadrat and sample area. We studied (in each quadrat separately) the effect of pine cover on species number, diversity and cover of herb layer vegetation. We assigned three ecological attributes *i.e.* Raunkiaer life-form, social behaviour type and phytosociological group [BORHIDI 1993] to the species. Based on the percentage cover of species and their ecological attributes, group distributions was calculated for characterizing the vegetation of the study sites. Group distributions were statistically compared by performing homogeneity tests. The quasi-mean naturalness value of vegetation was calculated at each sampling site, regarding to the group distribution of social behaviour types and the naturalness values of constituting species [BORHIDI 1993].

We also analyzed the influence of pine cover on group distributions of Raunkiaer life-form, social behaviour type and phytosociological group. In this case, all of the surveyed 30 quadrats were sorted into three groups (n = 10) on the basis of their percentage pine-cover (low: 10–30%; medium: 40–65%; high: 70–90%), then group distributions of the studied ecological attributes were calculated for these quadrat groups and were compared statistically with homogeneity test.

For revealing better the effect of Austrian pine on the understory vegetation, we examined the differences and similarities between the flora of the studied abandoned quarries and the vegetation *(1)* is the potential climax association of the area or *(2)* developed through regenerative succession in a similar habitat without influence of Austrian pine. Identification of the potential vegetation type was founded upon partly the maps (M = 1:28800) of the First (1780–1784) and the Second (1819–1869) Military Mapping Survey of Hungary, partly the habitat conditions and the observations of the vegetation surrounded the sampling areas. *Cotino–Quercetum pubescentis* association in dolomite quarries and *Quercetum petraeae–cerris* association in bauxite quarries were determined as potential vegetation types of the sampling areas. Based on coenological data published in literature [SZODFRIDT and TALLÓS 1964, FEKETE 1966] and unpublished data from BARINA, we created the group distributions (Raunkiaer life-form, social behaviour type and phytosociological group) of these natural vegetation types and compared them with the spectra derived from our data collected in the reclaimed quarries. Similar comparative analyses were performed by using coenological data had fixed in vegetations developed through regenerative succession. Latter data are originated from dolomite rock grassland regenerated after burning of an Austrian pine stand [TAMÁS and CSONTOS 2006] and from the herb-layer vegetation regenerated following the clear-cutting of sessile oak – Turkey oak forests [CSONTOS 1996]. Besides the comparison of group distributions, we paid attention to studying the differences of species-pools of the vegetations.

3. Results and discussion

3.1. Fire risk in Austrian pine stands

Mass of litter accumulated in pure Austrian pine stands proved to be independent of exposure but showed age-dependent changes. After a significant increase, the amount of needle litter culminated in age class 60–80 years (17560 kg/ha) then decreased significantly in older stands. As for branch and cone litter, similar trends were detected, but the changes were significant only for the increase of branch litter mass. The reduced amount of litter in the oldest stands is very likely a consequence of the decreasing productivity. This phenomenon is mostly caused by the physiological decadence of pine trees and by nutrient limitation attributable to the accumulation of litter and woody biomass [GOWER et al. 1996]. Due to the low decomposition rate of needle, the amount of flammable litter accumulated in Austrian pine stands many times exceeds the litter quantity of the native forest or grassland vegetations [JÁRÓ 1958, MOLNÁR 1975], thus the coniferous plantations (especially the age class 60–80 years) are subjected to an increased fire risk.

Drought conditions showed considerable variability between years. In regard to the studied 25-year period (1985–2009), BKDI changes by a characteristic annual trend: the index is uniformly low from January to March, thereafter increases continuously till the end of August and finally it decreases till January. Consequently, August and September can be regarded the crucial months from the point of view of fire events. Annual trend of drought factor is similar to the change of BKDI. The mean value of drought factor is 7 in summer, but during a permanent drought the factor can be maintaining the highest possible value (10) for a long time. In a dry year, serious fire risk is generally expected not only in August and September but also in spring and in the late autumn.

McArthur's model predicted that in a summer day (characterized by average weather conditions for the season) a *very high* fire risk (FDI = 24) can be expected in the Austrian pine stands. In the most fire hazardous 60–80-year old stands, near 10 m flame height, 1.5 km spotting distance and – as for a 30° upslope fire – 4.3 km/h rate of spread was calculated. Wind speed is the most important factor in the rate of spread: a strong wind (about 60 km/h) is able to increase the FDI to the *extreme* class. Considerable fire risk is realized principally in windy and low-humidity summer days. By comparison of our results with literature data we concluded, that McArthur's model describes the relation of litter mass, meteorological and drought conditions and degree of slope with fire risk and fire behaviour in like manner as other widely used fire danger models [VIEGAS 1998]. Our factual outcomes also correspond to the published results of litter-burning experiments [SANTONI and BALBI 1998, MORANDINI et al. 2001, MORVAN and DUPUY 2001]. The obtained results proved the applicability of McArthur's model for prediction of fire risk and fire behaviour for European coniferous stands, but the verification of the results may be needed.

In the mixed stands, the amount of accumulated litter decreased linearly with the increasing proportion (basal area ratio) of broad-leaved trees (at 50% ratio of broad-leaved trees the litter mass reduced by 30% in comparison with the pure pine stand), resulting in a decreased fire hazard. Additionally, water loss is significantly slower in the mixed litter than in needles [SONG et al. 2010], thus in mixed forests smaller drought factor exists in general than in pure Austrian pine stands, contributing to the further reduction of fire risk.

3.2. Seed bank of invasive plants

Soil seed bank of all the studied invasive species (black locust, honey locust and common milkweed) was revealed in Austrian pine stands. Seeds of black locust were found in both sampled soil layer. Higher germination rate was detected in the lower

(95.6%) than in the upper soil layer (93.1%). Most probably this resulted *(1)* partly from the favourable environmental conditions for seed survival associated with deep burial and *(2)* partly from the higher decomposition rate of non-viable seeds in the deeper soil layer [FENNER and THOMPSON 2005]. Black locust developed considerable seed bank: its density ranged from 640 to 2285 seeds/m^2 in the studied pine plantations; the mean value was about 1400 seeds/m^2. Total density of the seed bank and also the seed bank ratio of the lower soil layer increased with tree age. These findings can be interpreted by *(1)* the growing seed production of elderly trees, *(2)* the long-term accumulation of dormant seeds and *(3)* the time-consuming character of seed burial into the soil [MASAKA et al. 2010]. Seed bank of honey locust was also present in both sampled soil layers with 1168 seeds/m^2 mean density and with higher germination rate in the lower soil layer (98.2%) than in the upper one (96.5%). No correlation was found between the seed bank density and the basal area of trees, presumably as a consequence of the generally high yearly or multi-year fluctuation in seed production observed at honey locust [MARCO and PÁEZ 2000]. In the pine stands we also detected the seedling bank of honey locust (1.44 seedlings/m^2) which often plays an important role in the invasion of the species. Seed bank of common milkweed was found only in the upper soil layer with 73 seeds/m^2 mean density and 15% germination rate. The low germination rate is due to the common germination of the most part of the viable seeds occurred in the first spring after seed rain [CSONTOS 2001]. Positive linear correlation was showed between the seed bank density and the density of common milkweed plants.

After burning or clear-cutting of coniferous stands or in parallel with the physiological decadence of trees, renewal and spreading of invaders is expected from the soil seed bank. The germination of buried seeds can be continued for decades, strongly inhibiting the restoration of the native flora or the other planned area utilization. Nowadays, honey locust may present only local problems, but the invasion of black locust and common milkweed has already become country-wide. Pine stands in sandy areas forms “*stepping stone*” habitats for common milkweed, promoting the spread of the invader toward other grasslands or agricultural areas.

3.3. Vegetation of abandoned dolomite and bauxite quarries reclaimed with Austrian pine

Great differences were observable among the vegetations developed in both the abandoned dolomite and bauxite quarries; the variety was reflected in the dominant species and the Shannon-diversity as well as in the significant differences found among the examined group distributions (Raunkiaer life-form, social behaviour type and phytosociological group). Afforestation in the three dolomite quarries happened almost at the same time (21–24 years before coenological study). In the sample area of Balatongyörök and Vonyarcvashegy, the flora was dominated by the species of natural dolomite vegetations, while the covers of the disturbance-tolerant, indigenous ruderal and alien competitors were low. Thus, these vegetations were characterized by relatively high naturalness values. In the forest stand of Gyenesdiás, ruderal species (mainly *Calamagrostis epigeios* and *Solidago gigantea*) prevailed over the natural ones therefore the naturalness value of the vegetation was much lower than in the other stands. Varieties among the vegetations could be due to the dissimilar propagule sources as well as to the different human disturbances. Abandoned bauxite quarries were afforested 6, 15 and 20 years before study consequently we could regard them as a successional chronoseries. Disturbance-tolerant species (*C. epigeios* and *S. gigantea*) were dominant in the herb layer of the youngest stand (Szőc), became subdominant in the middle-aged plantation (Nagyegyháza) and represented low cover ratio in the oldest pine stand (Sáska). In parallel with the descending cover of disturbance-tolerant species, cover ratio of species of the natural flora increased gradually, resulting in the higher diversity and naturalness value of the vegetation.

The increasing canopy cover of Austrian pine reduced the species number and total cover of the herb layer and for dolomite quarries, a decreasing diversity was detectable as well. We also observed the disappearance of several plant species from the highly pine-covered quadrats. Interestingly, the species has small naturalness value (*i.e.* ruderal competitors and alien invaders) displaced from the dense part of the coniferous stands much rather than the more valuable species of the potential vegetation, leading to the increased naturalness of the flora. As for bauxite quarries, relative cover of the natural oak-forest's species is higher in quadrats are strongly covered by Austrian pine. A presumable explanation of this observation is that the closed-canopies areas are chiefly found in the older pine plantations (mainly in Sáska), where more time was available in the colonization of forest species.

The floras in the reclaimed open-pit mines are significantly differed both from the potential vegetation type of the areas and from the associations developed through regenerative succession followed a forest fire or clear-cutting in a similar habitat. The vegetation of the reclaimed dolomite quarries has lower naturalness than has the native *Cotino–Quercetum pubescentis* association. In our study sites, relative abundance of disturbance-tolerant and indifferent species (mainly of the indigenous and alien ruderal competitors) is higher, but the ratio of natural dolomite species (mainly of the specialists) is smaller than in the potential vegetation. Most part of the botanically valuable and generally protected dolomite species is absent from the reclaimed areas. As for bauxite quarries, comparative evaluation showed similar differences than for dolomite sites. Proportion of the ruderal plants is higher, but the relative cover of natural forest species is much smaller in the flora of the reclaimed bauxite quarries than in the native sessile oak – Turkey oak forests. Similar differences are observable in case of comparing the flora of the bauxite quarries with the same-age stage of regenerative succession of sessile oak – Turkey oak forests. Supplantation of weeds and ruderal species as well as spreading of natural competitors and specialist is slower under the pine canopy; geophyte of oak forests and the protected species are absent even from the herb layer of the oldest Austrian pine stand. Lack of the appropriate propagule sources in the reclamation area are probably contributed to the unfavourable influence of Austrian pine exerting on the regenerative succession. In order to quite realize the consequences of Austrian pine application, long-term ecological monitoring of the reclamation areas would be needed with involving unforested control sites.

4. New scientific results

1. Amounts of needle, branch and cone litter were quantified in Austrian pine monocultures represented different age classes and exposure types. The litter fractions showed their maximum quantities in age class 60–80 years. Amount of flammable litter is considerably higher in Austrian pine stands than in native forest or grassland associations, thus the coniferous plantations are subjected to an increased fire risk. We verified that in pine stands mixed with native broad-leaved trees, the mass of accumulated litter decreased linearly with the increasing proportion of broad-leaved trees, resulting in a considerable reduction of fire risk.
2. Expectable drought condition of flammable litter was quantified by the Byram–Keetch Drought Index (BKDI) and drought factor. Based on the annual trend of drought conditions we showed that August and September are the most crucial months from the point of view of fire events. We proved that McArthur’s empirical fire danger model is adequate to the prediction of fire risk and fire behaviour in Austrian pine plantations.
3. We provided factual information on fire risk (Fire Danger Index, flame height, spotting distance, rate of spread) of Austrian pine stands under various meteorological, topographical and drought conditions.
4. Persistent soil seed bank of the invasive black locust, honey locust and common milkweed was showed in Austrian pine stands. For black locust, total density of the seed bank and also the seed bank ratio of the lower soil layer increased with the age (basal area) of trees. For common milkweed, the seed bank density increased with the density of common milkweed plants.
5. By revealing their seed banks, we called the attention to the potential danger of the invasive species found in pine plantations: after burning or clear-cutting of coniferous stands or in parallel with the physiological decadence of pine trees, quick renewal and spreading of the invaders from the soil seed bank is expected, strongly inhibiting the restoration of the native flora or the other planned area utilization.
6. Based on coenological study executed in abandoned open-pit dolomite and bauxite quarries reclaimed with Austrian pine we founded that the increasing canopy cover of Austrian pine reduced the species number, the total cover and the Shannon-diversity of the herb-layer vegetation. We showed that the flora of the reclaimed areas had considerably lower naturalness than had *(1)* the potential climax association of the areas (*Cotino–Quercetum pubescentis* or *Quercetum petraeae–cerris*) or *(2)* the vegetation developed through regenerative succession in similar habitats (after burning or clear-cutting the forest formerly covered the area) without reclamation with Austrian pine.

7. Reclaimed areas were characterized by alien plant invaders and indigenous ruderal competitors, while the most part of the species of natural dolomite vegetations (including constant and protected plants) were generally rare or absent from the abandoned mines. The characteristic succession processes (supplantation of weeds and ruderal species as well as propagation of natural competitors) is slower or partial under the pine canopy.
8. We could conclude the inhibiting effect of Austrian pine on the natural (regenerative) succession, but in order to clearly realize the ecological consequences of pine application, long-term monitoring of the reclamation areas would be needed with involving unforested control sites.

5. Suggestions

In areas covered by Austrian pine, regeneration of the native forest or grassland vegetation should be aimed. For habitat restoration, it is worth utilizing the natural regeneration ability of the native plant association and promoting the natural succession. In habitats are suitable for maintaining forest vegetations, pine plantations should be gradually changed through mixed stands into pure native broad-leaved forests. This alteration lessens the fire risk: the decreased fuel mass and the slower litter dehydration result in the smaller probability of fire ignition as well as the decreased intensity and spreading rate of fire, furthermore ceases the hazard of crown fire initiation. In terms of fire risk, we have to pay more attention to the 60–80-year-old, dense pine stands (high amount of fuel), the plantations standing on the steep slopes of dolomite hills (rapid fire propagation and difficult fire-fighting), as well as stands situated in nature reserves or close to inhabited area or highly protected natural value. In the large and continuous pine stands, forming and maintenance of fire-traces are much needed. In the most fire hazardous months of August and September (particularly in hot, windy and low-humidity days) strict inspection is essential so that fire ban will be observed. The fire ban should be expanded to the wide strip of agricultural and other areas surrounding the Austrian pine stands.

For forest management, good care should be taken in pine plantations are invaded by alien plant species, especially in case the invader has ability to form a persistent soil seed bank. Since the removal of seeds from the soil is practically unrealizable, release of the area from the invasive species may be extremely difficult. These invaders have to be removed from the pine stands as soon as possible in order to prevent the further accumulation of dormant seeds in the soil or to deplete at least partially the seed bank have already developed. Strong renewal of black locust and honey locust from the seed bank and seedling bank is particularly expected after forest fires. Control of common milkweed is very important in pine stands through which the invader is able to occupy further agricultural and grassland areas. Investigation of other invasive plant species is a timely task from the point of view of soil seed bank formation.

Replacing of Austrian pine stands planted for land reclamation purposes are also needed. The native flora of the degraded dolomite areas could be restored mainly by promoting the natural regenerative succession. In habitats of sessile oak – Turkey oak forests, forestry plantation of indigenous stand-forming and accompanying trees may also reasonable over the selective thinning of pines. Partial or total removal of alien invaders and other aggressive competitors (e.g. *Calamagrostis epigeios*) is essential for the successful land reclamation. Regenerative succession may be facilitated with an expertly planned active propagule addition to the reclaimed area. For the further land reclamations, application of Austrian pine should be entirely neglected or restricted only to steep scarps are highly exposed to soil erosion. The elimination of anthropogenic disturbances (e.g. landfilling, motor traffic) could prevent somewhat the deterioration of the vegetation's naturalness.

References

BÓDIS, J. (1993): Degradation of dolomite grassland communities due to *Pinus nigra* plantation. I. Textural changes [in Hungarian]. *Botanikai Közlemények* 80(2): 129–139.

BORHIDI, A. (1956): Feketefenyveseink társulási viszonyai. *Botanikai Közlemények* 46(3–4): 275–285.

BORHIDI, A. (1993): Social behaviour types of the Hungarian flora, its naturalness and relative ecological indicator values. Janus Pannonius University, Pécs, 93 p.

CSERESNYÉS, I., CSONTOS, P., BÓZSING, E. (2006): Stand age influence on litter mass of *Pinus nigra* plantations on dolomite hills in Hungary. *Canadian Journal of Botany* 84(3): 363–370.

CSONTOS, P. (1996): Regeneration succession of sessile oak – Turkey oak forests: processes in the herb layer [in Hungarian]. Scientia Kiadó, Budapest, 122 p.

CSONTOS, P., TAMÁS, J., KALAPOS, T. (1998): A magbank szerepe a dolomitnövényzet regenerálódásában korábban feketefenyvessel borított területeken. *In:* CSONTOS, P. (szerk.): *Sziklagyepek szünbotanikai kutatása*, pp. 183–196. Scientia Kiadó, Budapest.

CSONTOS, P. (2001): Seed longevity of Scotch thistle (*Onopordum acanthium* L.) and common milkweed (*Asclepias syriaca* L.) [in Hungarian]. *Acta Agronomica Óváriensis* 43(2): 83–92.

FEKETE, G. (1966): Der xerotherme Flaumeichen-Buschwald des nördlichen Bakony-Gebirges. *Annales Historico-naturales Musei Nationalis Hungarici* 58: 207–221.

FENNER, M., THOMPSON, K. (2005): The ecology of seeds. Cambridge University Press, Cambridge, 260 p.

GHIMESSY, L. (2003): Az erdőtűz-kárról. *Erdészeti Lapok* 138(3): 81–82.

GOWER, S. T., MCMURTRIE, R. E., MURTY, D. (1996): Aboveground net primary production decline with stand age: potential causes. *Trends in Ecology and Evolution* 11(9): 378–382.

HORÁNSZKY, A. (1996): Studies on the „Kis- és Nagy-Szénás" protected area relating to phytosociology, forest management and nature conservancy questions [in Hungarian]. *Természetvédelmi Közlemények* 3–4: 5–19.

JÁRÓ, Z. (1958): Alommennyiségek a magyar erdők egyes típusaiban. *Erdészettudományi Közlemények* 1: 151–160.

KEETCH, J. J., BYRAM, G. M. (1968): A drought index for forest fire control. USDA Forest Service Research Paper SE-38. USDA Southeastern Forest Experiment Station, Asheville, NC, 32 p.

KESZTHELYI, I., CSAPODY, I., HALUPA, L. (1995): Irányelvek a természetvédelem alatt álló erdők kezelésére. A KTM Természetvédelmi Hivatalának Tanulmánykötetei 3., Budapest, 251 p.

KOLTAY, A. (1999): A hazai fenyőállományok egészségi állapota. *Erdészeti Lapok* 134(1): 15–16.

MARCO, D. E., PÁEZ, S. A. (2000): Invasion of *Gleditsia triacanthos* in *Lithraea ternifolia* montane forests of central Argentina. *Environmental Management* 26(4): 409–419.

MASAKA, K., YAMADA, K., KOYAMA, Y., SATO, H., KON, H., TORITA, H. (2010): Changes in size of soil seed bank in *Robinia pseudoacacia* L. (Leguminosae), an exotic tall tree species in Japan: Impacts of stand growth and apicultural utilization. *Forest Ecology and Management* 260(5): 780–786.

MOLNÁR, E. (1975): A survey of studies on grassland production in Hungary. *Acta Botanica Hungarica* 21(1–2): 91–101.

MORANDINI, F., SANTONI, P. A., BALBI, J. H. (2001): The contribution of radiant heat transfer to laboratory-scale fire spread under the influences of wind and slope. *Fire Safety Journal* 36(6): 519–543.

MORVAN, D., DUPUY, J. L. (2001): Modeling of fire spread through a forest fuel bed using a multiphase formulation. *Combustion and Flame* 127(1–2): 1981–1994.

NOBLE, I. R., BARY, G. A. V., GILL, A. M. (1980): McArthur's fire-danger meters expressed as equations. *Australian Journal of Ecology* 5: 201–203.

PAPP, M. (2010): Megnövekedett hazánkban az erdőtüzek gyakorisága. *Az Európai Unió Agrárgazdasága* 15(3): 4–5.

PASTOR, E., ZÁRATE, L., PLANAS, E., ARNALDOS, J. (2003): Mathematical models and calculation systems for the study of wildland fire behaviour. *Progress in Energy and Combustion Science* 29(2): 139–153.

SANTONI, P. A., BALBI, J. H. (1998): Modelling of two-dimensional flame spread across a sloping fuel bed. *Fire Safety Journal* 31(3): 201–225.

SONG, F., FAN, X., SONG, R. (2010): Review of mixed forest litter decomposition researches. *Acta Ecologica Sinica* 30(4): 221–225.

SZODFRIDT, I., TALLÓS, P. (1964): A felsőnyírádi erdő cseres–tölgyesei. *Veszprém Megyei Múzeumok Közleményei* 2: 423–435.

TAMÁS, J. (2003): The history of Austrian pine plantations in Hungary. *Acta Botanica Croatica* 62(2): 147–158.

TAMÁS, J., CSONTOS, P. (2006): Dolomitterületek vizsgálata a Budai-hegységben – milyen a növényzet erdőtűz után 10 évvel? *In:* KALAPOS, T. (szerk.): *Jelez a flóra és a vegetáció. A 80 éves Simon Tibort köszöntjük*, pp. 105–115. Scientia Kiadó, Budapest.

TÖRÖK, K., BOTTA-DUKÁT, Z., DANCZA, I., NÉMETH, I., KISS, J., MIHÁLY, B., MAGYAR, D. (2003): Invasion gateways and corridors in the Carpathian Basin: biological invasions in Hungary. *Biological Invasions* 5(4): 349–356.

VAHID, Y., KÓBORI, J. (2005): Nemzeti Erdőprogram és az EU-csatlakozás. *Erdészeti Lapok* 140(12): 354–356.

VIEGAS, D. X. (1998): Weather, fuel status and fire occurrence: predicting large forest fires. *In*: MORENO, J. M. (ed.): *Large forest fires*, pp. 1–30. Backhuys Publishers, Leiden.

Publications in PhD topic

Articles in journals with IF:

Cseresnyés, I., Csontos, P., Bózsing, E. (2006): Stand age influence on litter mass of *Pinus nigra* plantations on dolomite hills in Hungary. *Canadian Journal of Botany* 84(3): 363–370. [IF: 0.985] doi:10.1139/B06-003

Csontos, P., Bózsing, E., **Cseresnyés, I.**, Penksza, K. (2009): Reproductive potential of the alien species *Asclepias syriaca* (Asclepiadaceae) in the rural landscape. *Polish Journal of Ecology* 57(2): 383–388. [IF: 0.433]

Cseresnyés, I., Szécsy, O., Csontos, P. (2011): Fire risk of Austrian pine (*Pinus nigra*) plantations under various temperature and wind conditions. *Acta Botanica Croatica* 70(2): 157–166. [IF: 0.702] doi:10.2478/v10184-010-0022-5

Cseresnyés, I., Csontos, P. (2012): Soil seed bank of the invasive *Robinia pseudoacacia* in planted *Pinus nigra* stands. *Acta Botanica Croatica* 71(2): 249–260. [IF: 0.702] doi:10.2478/v10184-011-0065-2

Articles in other journals (in Hungarian with English abstract):

Cseresnyés, I., Bózsing, E., Csontos, P. (2003): Quantitative analyses of the litter under Austrian pine stands planted on dolomite hills. *Természetvédelmi Közlemények* 10: 37–49.

Cseresnyés, I., Csontos, P. (2004): Analysis of fire-risk conditions in *Pinus nigra* stands by using McArthur's model. *Tájökológiai lapok* 2(2): 231–252.

Bózsing, E., **Cseresnyés, I.** (2006): Reproductive biological studies of *Asclepias syriaca* L. stands in Pest County, Hungary. *Természetvédelmi Közlemények* 12: 179–186.

Cseresnyés, I., Csontos, P. (2006): Change in drought conditions of *Pinus nigra* stands in Hungary. *Tájökológiai Lapok* 4(2): 255–268.

Cseresnyés, I. (2010): Seed bank of the invasive black locust (*Robinia pseudoacacia* L.) in the soil of planted Austrian pine stands. *Botanikai Közlemények* 97(1–2): 59–68.

Cseresnyés, I., Csontos, P. (2012): Vegetations of abandoned open-pit bauxite mines reclaimed with Austrian pine – A nature conservation assessment. *Tájökológiai Lapok* 10(2): 315–340.

Book chapters (in Hungarian):

Cseresnyés, I., Csontos, P., Bózsing, E. (2007): Dolomitra telepített feketefenyvesek avartömegének vizsgálata. *In*: Csontos, P. (szerk.): *Feketefenyvesek ökológiai kutatása*. Scientia Kiadó, Budapest, pp: 31–42. (ISBN 963-8326-38-7)

Cseresnyés, I., Csontos, P. (2007): A feketefenyvesek szárazsági viszonyainak változása. *In*: Csontos, P. (szerk.): *Feketefenyvesek ökológiai kutatása*. Scientia Kiadó, Budapest, pp: 43–56. (ISBN 963-8326-38-7)

Csontos, P., **Cseresnyés, I.** (2007): Feketefenyvesek tűzveszélyességi viszonyainak elemzése. *In*: Csontos, P. (szerk.): *Feketefenyvesek ökológiai kutatása*. Scientia Kiadó, Budapest, pp: 57–79. (ISBN 963-8326-38-7)