CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENE POOL IN SLOVENIA

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ABSTRACT

In Slovenia European beech is autochthonous and the most economically and ecologically important tree species. The paper presents the characteristics of Slovenian beech forests regarding their natural distribution range, diversity of beech forest types and site conditions, sustainable co-nature-based management and gene pool conservation. New information about observed beech injuries and future perspectives of beech forests in the territory of Slovenia according to predicted climate changes are included. The mesic beech-forest vegetation may be adversely affected by changing environmental conditions predicted by the existing climate-change scenarios, and the area of prevailing beech forests is likely to decrease in the future.

Key words: *Fagus sylvatica* L., bukev (in Slovenian), natural distribution, forest types, genetic resources, Slovenia

EUROPEAN BEECH FORESTS DISTRIBUTION IN SLOVENIA

Slovenia belongs to one of the most forested countries in Europe. At the end of 2005 forests covered an area of 1,216,815 ha which represents 60% of the total country. According to Perko (2007), 70% of forests in Slovenia grow on potential beech (44%), fir-beech (15%) or beech-oak (11%) sites. According to palynology data (Culiberg 1994, 1999) the proportion of potential beech sites is probably higher, as records confirm that beech used to be more common in Sub-Mediterranean (Karst) region, where its current infrequency is associated with centuries-long anthropozoogenous influence (Dakskobler 2008).

European beech (*Fagus sylvatica* L.) is among 71 naturally growing trees in Slovenia (Kotar, Brus 1999). The highest area of growing stock has the following tree species: *Fagus sylvatica* L. (32%), *Picea abies* (L.) Karst. (32%), *Abies alba* Mill. (8%) and different species of *Quercus* sp. (7%) (Lesnik, Matijašić 2006).

Beech covers a major part of the forested area of the country and occurs mainly in the montane zone. From the hilly zone, where many mixed forests of sessile oak (*Quercus petraea* /Matt./ Liebl.) and hornbeam (*Carpinus betulus* L.) have been converted to farmland, to montane zone these mixed forests change gradually into forests, in which beech dominates. In the Alpine region, beech grows in mixture with Norway spruce (*Picea abies* /L./ Karst.), and European larch (*Larix decidua* Mill.), while pure beech forests reach up to the higher belt of the dwarf mountain pine zone (*Pinus mugo* Turra) in the Dinarics. In the Dinaric region, the mixed forest of beech and silver fir (*Abies alba* Mill.) is the most wide spread forest community.

In Slovenian forests diverse vegetation patterns have been recognized (Zupančič 1996). The most important beech forests as regards surface area, their size, economic value and protective and biotopic roles are listed below (Dakskobler 2008). Beech forests on acid (dystric) soil are found under the following: acidophilic beech forest with hard fern (*Blechno-Fagetum*), moderately acidophilic beech forest with chestnut (*Castaneo-Fagetum sylvaticae*), and moderately acidophilic beech forest with white wood-rush (*Luzulo-Fagetum*). In the hilly areas and submontane altitudinal belt the following forest communities on calcareous or calcareous-silicate bedrocks are commonly found: submontane beech forest with pyrenees star-of-Bethlehem (*Ornithogalo pyrenaici-Fagetum*), submontane beech forest with hacquetia (*Hacquetio-Fagetum*), beech and sessile oak forest with ivy (*Hedero-Fagetum*), and subpanonic beech forest with vetch (*Vicio oroboidi-Fagetum*). In the montane and altimontane belt the most extended beech forests are montane beech forest in association with dead nettle (*Lamio orvalae-Fagetum*), beech forest with goatsbeard (*Arunco-Fagetum*), the Dinaric montane fir and beech forest (*Omphalodo-Fagetum*), high-montane beech forest with bitter-cress (*Cardamini savensi-Fagetum*), high-montane beech forest with rue-leaved isopyrum (*Isopyro-Fagetum*), and beech forest with hairy alpine-rose (*Rhododendro hirsuti-Fagetum*). On warmer sites in the submontane and montane belt, beech occurs in termophilic beech and hop-hornbeam forest (*Ostryo-Fagetum*) and beech forest with autumn moor grass (*Seslerio autumnalis-Fagetum*). In the altimontane and subalpine belt predominantly in the Alps, beech occurs in the alpine beech forest (*Anemono trifoliae-Fagetum*), fir and beech forests with homogyne (*Homogyno sylvestris-Fagetum*), altimontane beech forest with large white buttercup (*Ranunculo platanifolii-Fagetum*), and subalpine beech forest with holly-fern (*Polysticho lonchitis-Fagetum*).

Forest stands of all listed communities are part of the habitat types in EU Community interest (Habitat Directive 1992). Surface distribution of beech communities in Slovenia can be found in two vegetation maps in scale 1: 100,000 (Košir et al. 1974, 2003), and in scale 1:400,000 (Čarni et al. 2002).

CHARACTERISTICS AND FOREST MANAGEMENT

European beech in Slovenia grows and forms communities in all phytogeographical regions (Wraber 1969), on all terrain positions and slope orientations, on calcareous, silicate and mixed calcareous-silicate bedrock. It occurs on different soil types: lithosols, regosols, rendzinas, rankers, brown soils on limestones and dolomites, eutric and distric brown soils, lessivé soils, podzols, semipodzols and pseudogleys (Urbančič et al. 2005), from hills (150 m a. s. l.) to the subalpine belt (1,650 m a. s. l.) (Dakskobler 2008).

According to the international soil classification (WRB 2006) different soil groups with soil subunits were determined on beech sites. Fir-beech forests and beech forests on carbonate parent material (as limestones, dolomites, marls, flyschs etc.) mostly overgrow Leptosols, Phaeozems, Cambisols and/or Luvisols with eutric to calcaric properties. For beech-oak forests Luvisols on limestones and dolomites are characteristic. Acidophilic beech forests mostly cover Leptosols, Umbrisols, Cambisols, Alisols and/or Acrisols with dystric properties developed on non-carbonate parent material.

Special beech sites can be rarely found also on folic Histosols (high mountains), Regosols (eroding areas, unconsolided material), Podzols (bases poor siliceous parent material, in areas with high precipitations) or Planosols (on clayey sites).

In the Alpine and Dinaric high mountain belt (alpine vegetation belt), in cold air pools (frost hollows), in lowlands on hydromorphic soil, and on steep, stony, rocky or explicitly sunny and warm sites in

the Sub-Mediterranean and in the hinterland, the climatic and soil conditions are mainly unsuitable for beech.

Forests as a renewable natural resource with their multiple roles are ranked among the country natural wealth. Forestry is traditionally co-nature-based and oriented in sustainable and multifunctional management regardless of the ownership. Clearcuts are forbidden since 1947. Natural regeneration is promoted wherever possible. Renewal work with care for forest young components is carried out on 10,000 – 12,000 ha per annum. If seedlings are used, they should originate from known seed sources in Slovenian forests and from adequate tree species and provenances. Replanting with sowing and seedlings is carried out annually on ca 500 ha, mainly for implementation of the long-term ecological improvement (conversion) from spruce monocultures growing in natural beech or beech-silver fir sites to broadleaved forests. To achieve the conversion, a combination of natural and artificial regeneration starting as advanced planting is preferred (Diaci 2006). On average 130,000 beech seedlings from local provenances are planted annually. Tree seeds and seedlings are collected from officially approved selected seed stands or from the source identified seed stands in the Slovenian forests.

Managements regimes in beech forests are carried out with regard to the site, stand conditions and silviculture technique used (irregular shelterwood system, single tree selection system or group selection system). In managed beech forests only small-scale regeneration practices are applied. The regeneration is usually induced through diffuse opening in the canopy layer. The total growing stock for beech in 2005 was 95,486,453 m^3 (SFS, 2006). Beech is present in 89% (> 1 million ha) of total forested area. In 73% of the area (851,333 ha) its presence in growing stock is more than 5%. Annual harvesting of beech in 2005 was 795,470 m^3, representing 66.1% of total yearly felling of broadleaved tree species in Slovenia and 24.6% of total amount of all trees harvested. Long-term monitoring revealed a 15.8% average level of defoliation of beech in the years 1993 – 2005.

In 2008 the prices of non coniferous roundwood in Slovenia (fco. forest road) were for sawlogs (beech) 63.60 EUR/m^3, pulpwood, round and split 32.56 EUR/m^3, other industrial roundwood 37.32 EUR/m^3, wood fuel 32.60 EUR/m^3 (Statistical Office of the Republic of Slovenia; http://www.stat.si).

Legislation in regards to forestry includes the Forest Act (UL RS, no. 30/93, 13/98, 56/99, 67/02, 110/02, 112/06, 115/06, 110/07) and the Act on Forest Reproductive Material (ULRS, no. 58/02, 85/02), which was based on the Directive on the marketing of forest reproductive material (1999/105/EC). Supporting documents: three regulations, 19 rules and two other legally documents are valid (http://www.mkgp.gov.si).

BEECH DISEASES AND PESTS

In Slovenia, sanitary felling of beech comprised 1,021,000 m^3 in the period 1995 – 2006, which represents 9.9% of all sanitary felling and 3.1% of total felling in this period (Timber, ZGS). The highest percentage in the sanitary felling of beech was due to sleet damages (46%), forest operation damages (18.8%), wind throw (14.2%) and snow (11.5%). Diseases of beech were the cause of 4.6% of sanitary felling while other damages (pests, game, pollution, unknown reasons) were the cause of 4.9% of sanitary felling.

In the last few years different symptoms of beech injuries and dieback were observed locally in Slovenian forests. With expected climate change harmful biotic factors are expected to intensify and extend over wider areas (Jurc 2007, Ogris, Jurc, Jurc 2008). Stands suffering from extreme dry and hot weather were more susceptible to *Armillaria* spp. and unusual cases of fast mycelial

spread in the cambial zone of seemingly healthy beech trees were observed. *Fomes fomentarius* (L.) J. J. Kickx, *Ganoderma* spp., and *Kretzschmaria deusta* (Hoffm.) P. M. D. Martin were frequent invaders of sun-burnt portions of the bark. Oportunistic pathogens as *Nectria coccinea* (Pers.) Fr., *Neonectria ditissima* (Tul. & C. Tul.) Samuels & Rossman and *Nectria cinnabarina* (Tode) Fr.) which are the cause of cankers and branch dieback appeared in a wider extent. In central part of Slovenia infrequent symptoms of *Phytophthora* infections occurred. Isolates in pure cultures were identified as *Phytophthora cambivora* (Petri) Buisman and *P. citricola* Sawada. At the edge of the beech area in Slovenia (E & W parts of the country) cases of massive top dieback of mature beech trees were observed. Bark of the trees was necrotized and some necrosis extended downwards to mid stem heights. On the dead bark numerous stromata of *Biscogniauxia nummularia* (Bull.) Kuntze developed. The trees were occasionally also attacked by beech bark beetle, *Taphrorychus bicolor* Herbst and beech splendour beetle, *Agrilus viridis* L., which, in these cases, were secondary pests. Some stands of beech showed attack of ambrosia beetle *Xyloterus domesticus* L. Although the number of entrance holes on a single trunk could be small, the sourrounding bark dies out in large oval necrosis. Wood degrading fungi spread relatively fast in wounded trunks causing rapid deterioration of their value. In recent years some outbreaks of leaf disease caused by endophytic fungus *Apiognomonia errabunda* (Roberge ex Desm.) Höhn. were also detected. The populations of primary pests reducing leaf tissues (*Rhynchaenus fagi* L.), or sucking on leaves and bark (*Cryptococcus fagisuga* Lindiger, *Phyllaphis fagi* L.), have expanded in recent years, causing considerable defoliation, browning of leaves and weakening of the trees.

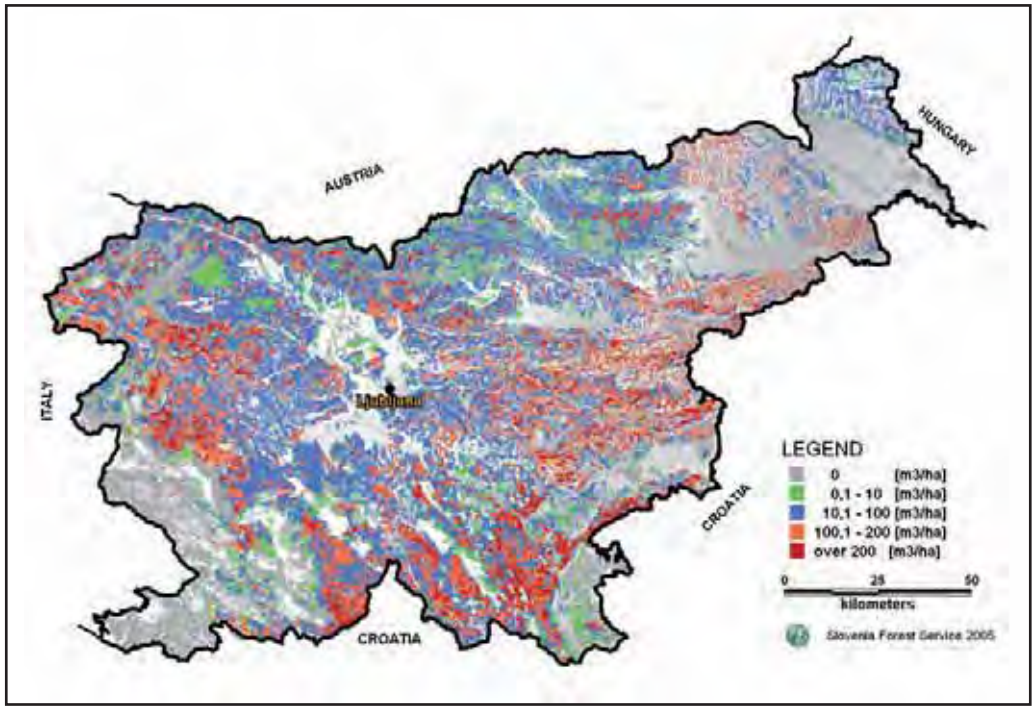

Fig. 1: Present distribution of beech (*Fagus sylvatica* L.) in Slovenia according to its share in growing stock (SFS, Pisek 2005)

EUROPEAN BEECH GENE POOL PRESERVATION AND CONSERVATION ON NATIONAL LEVEL

After the primary succession in the postglacial period, the larger part of the Slovenian territory was overgrown by forests, above all by beech and fir-beech forests (Šercelj 1996). Results of genetic analysis of European beech populations in Central and South Eastern Europe using isoenzymes as gene markers have shown the existence of genetic differences between provenances of beech from north-western part of the investigated area and provenances of beech from eastern part of the Balkan Peninsula (Brus 1999, Brus, Horvat-Marolt, Paule 1999). The obtained results supported the hypothesis that during the ice ages the European beech was present in microrefugia at the South Eastern periphery of the Alps and on the territory of today's Slovenia (Brus, Horvat-Marolt, Paule 2000, Brus 2008a). Findings were confirmed by the Magri et al. (2006) study which analyzed large palaeobotanical and genetical data of common beech in Europe. The territory of today's Slovenia was one of the main source areas for the post-glacial development of beech and supposedly the most important glacial refugia for its re-colonization in Europe (Magri et al. 2006, Brus 2008b). Development of beech forests allowed a possibility that European beech in the territory of present day Slovenia passed the way of genotypic specialization which resulted in locally adapted races or ecotypes.

Conservation of locally adapted races is ensured by approved forest seed objects, through protection of natural parks, natural monuments, and forest reserves (virgin forests). In the network of 173 virgin forest reserves which was established in the 1970s on suitable sites (Mlinšek 1980), beech is the dominant species in 62% with high share in its growing stock (Smolej et al. 1998). However conservation of forest genetic resources in Slovenia is traditionally an integral part of close-to-nature and sustainable forest management and linked to the Forest Act (1993). In order to mitigate the impacts of climate changes on forests and to enhance their sustainability with promotion of dynamic genetic processes for adaptation to changing environmental conditions, collection and use of forest beech reproductive material is strictly implemented through the Act on Forest Reproductive Material (ULRS, no. 58/02, 85/02) and the Rules on requirements and approval procedure of basic forest reproductive material (FRM) in the categories "source identified" and "selected" and Slovenian national list of basic material (ULRS, no. 91/03). The main criteria for approval of seed sources for multifunctional forestry are autochthony, effective population size, adaptation to site conditions, health status and resistance, uniformity, isolation of the stand, age and development stage of population, volume production, quality of wood and the form and growth habit. European beech seed sources which are approved in category "selected" need to be at least 5 ha in extent, to contain 70 phenotypically acceptable fructifying trees, and up to 20% of phenotypically less favourable trees (Kraigher, Pučko, Božič 2004).

The national list of basic forest reproductive material in Slovenia is established and published by the Slovenian Forestry Institute (SFI) each year in the official gazette and on SFI web page. As for current state of European beech basic material (seed sources) for reproductive material in Slovenia, to 01/01/2009 (Kraigher et al. 2009) the following basic material sources have been registered: in the category "source identified" 269 ha (7 seed stands from 3 regions of provenance); in the category "selected" 504 ha (20 seed stands from 7 regions of provenance); whereas four seed stands have been notified out of the total area of 203 ha as European beech dynamic "gene conservation units", of all stands classified under category "selected sources".

Fig. 2: Rajhenavski Rog forest reserve in Kočevje Region is overgrown by Dinaric fir-beech forest (Photo: L. Kutnar)

Fig. 3: Natural regeneration of mountain beech forest on the Gorjanci Mountain near Novo Mesto Region after application of selective thinning treatment (Photo: L. Kutnar)

BEECH DOMINATED FOREST SOIL ECOSYSTEM RESEARCH

Beech dominated forests are important regarding biodiversity both above- and below-ground. The Slovenian Forestry Institute research team in cooperation with several national and international institutions studied the below-ground aspect of beech dominated forests recently, starting from the basic analyses of fine root growth and their importance for soil structure and carbon dynamics (Kraigher et al. 2007, Železnik et al. 2007, 2009, Grebenc, Štupar, Kraigher 2007) to the applied studies of rhizosphere symbionts diversity. The influence of ozone (Grebenc, Kraigher 2007a, b) and small canopy gap (Grebenc 2005, Grebenc et al. 2009) were proven to influence the below-ground components. Several biodiversity analyses were performed in various groups of beech forests soil organisms including ectomycorrhizal fungi (Grebenc 2005, Grebenc et al. 2009), litter decomposing fungi (Bajc et al., in prep.), eubacteria (Grebenc, Bajc, Kraigher 2009, Kraigher et al., in prep.) and pedofauna (Grebenc, Bajc, Kraigher 2009, Grgič et al., in prep.) all indicating a high biodiversity under moderate anthropogenic influence, pronounced differences among sites and within repetitions at sites, and also a general shortage of knowledge on below-ground components in temperate beech forests. Studies represented parts of national and international (EU) projects covering different forest management systems applied in the country, from virgin forests, managed forests, to remediation sites and the international beech provenance trial.

FUTURE PERSPECTIVES OF BEECH FORESTS

Predicted climate changes could cause significant changes in the beech forest distribution. The change of forest vegetation pattern, driven by expected climate changes, has been studied recently (Kutnar, Kobler 2007, Kutnar et al. 2009). Based on the three different climate scenarios, the trend scenario, the hot-and-dry scenario, and the wet-and-less-hot scenario, the simulations showed that the spatial pattern of forest vegetation types would be altered significantly under impacts of predicted changes. In the following decades the vegetation type of major part of forest sites might change. Due to the predicted climate warming, the share of thermophilous forests might increase from the present 14% to range between 21% (wet-less-hot scenario) and 71% (hot-dry scenario). The share of thermophilous forests, which are economically less interesting and more fire-prone, will increase significantly by replacing mesic beech forests. From ecological-, nature-conservation- and forest-management points of view, the predicted decrease of the share of Dinaric fir-beech forest (*Omphalodo-Fagetum*) is especially important (Kutnar, Kobler 2007, Kutnar et al. 2009). Taking into account the most pessimistic hot-dry scenario, and assuming the actual ecological niche of this forest would not change in the future, this forest type might disappear completely from the territory of Slovenia by the end of the 21st century.

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