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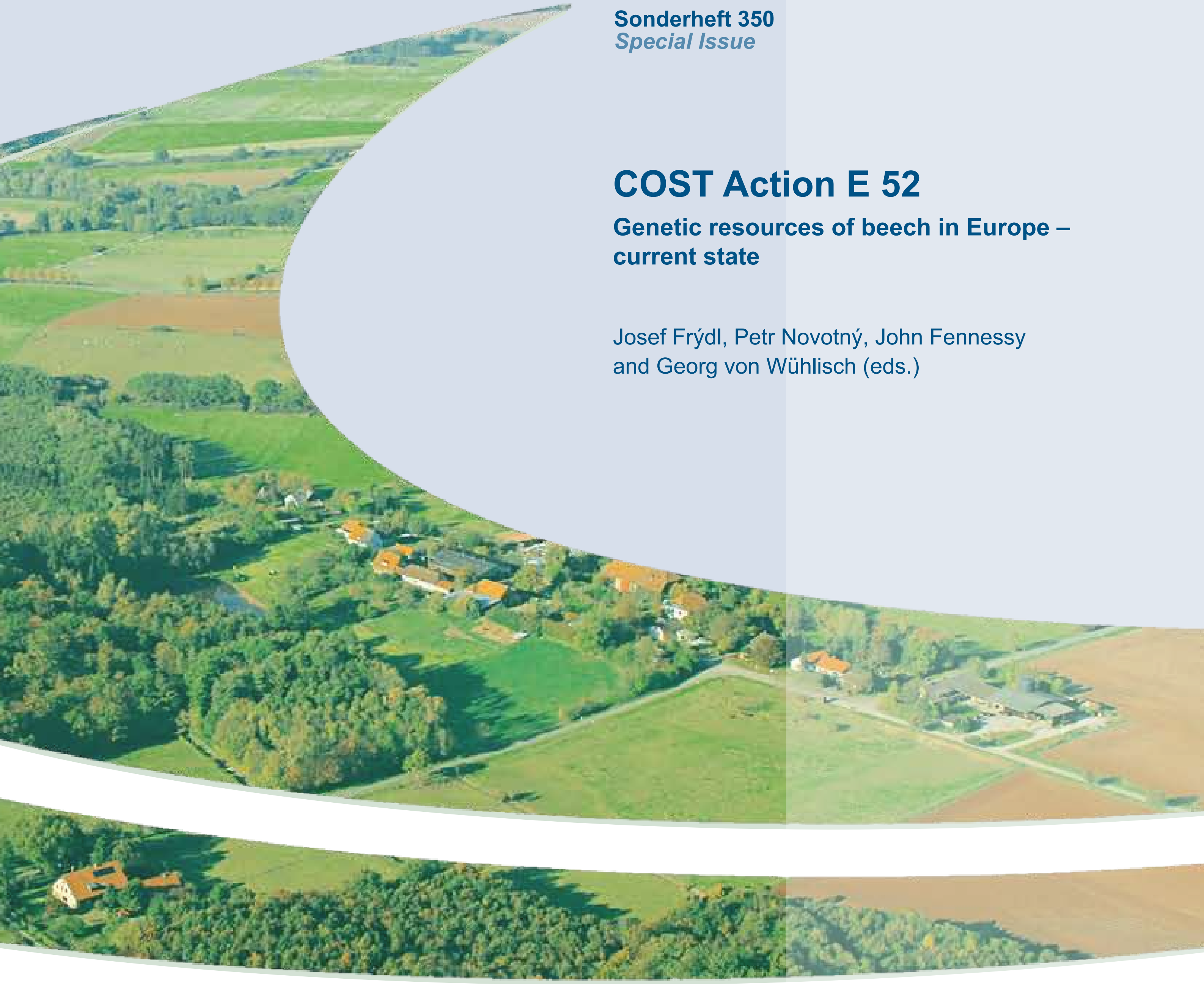
Sonderheft 350
Special Issue

COST Action E 52

Genetic resources of beech in Europe – current state

Josef Frýdl, Petr Novotný, John Fennessy
and Georg von Wühlisch (eds.)



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and Georg von Wühlisch[3] (eds.)

[1] Forestry and Game Management Research Institute, Strnady 136, CZ-156 04 Praha 5-Zbraslav, Czech Republic, E-mail: frydl@vulhm.cz
[2] Research Manager Tree Improvement & Non-wood Forest, COFORD, Department of Agriculture (4W),Kildare Street, Dublin 2, Ireland, E-mail: john.fennessy@coford.ie
[3] Johann Heinrich von Thünen-Institut, Federal Research Institute for Rural Areas, Forestry and Fisheries, Institute for Forest Genetics, Sieker Landstr. 2, D-22927 Großhansdorf, Germany, E-mail: georg.wuehlisch@vti.bund.de

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COST Action E52

Genetic resources of beech in Europe – current state

Implementing output of COST Action E 52 Project

„Evaluation of beech genetic resources for sustainable forestry“

(2006 – 2010)

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Preface

The consideration to prepare a common publication with basic information on European beech genetic resources in European countries was initially proposed during an introductory COST Action E52 Working and Management Committee Meeting (WMCM) in Zvolen, Slovakia (October, 2006) and at that meeting it was agreed in principle by the participants. However, the proposal becomes a firm commitment at the COST Action E52 WMCM in Florence (April, 2008), when the Czech Republic representatives undertook to coordinate the work and so ensured this common publication. Financial assistance from the COST Action E52 resources was approved during COST Action E52 WMCM in Rzesow, Poland (October, 2008). During the COST Action E52 WMCM in Sopron, Hungary (October, 2009) the details on the publication were further developed. The editors convey a special thanks to the initiative of Prof. Ladislav Paule (Slovakia), who suggested that contact should also be made with other countries situated in the original natural distribution area of European beech, including some countries with natural occurrence of oriental beech, and to ask them for their collaboration in the project.

At the end of this four years process, we would like to express our thanks and appreciation to the Communicationes Instituti Forestalis Bohemicae publication staff, especially to Mgr. Eva Krupičková, Klára Šimerová, Šárka Holzbachová, DiS. and Marta Čížková, DiS. for their forbearance and patience in the preparation work of these proceedings.

We would also wish to acknowledge all the authors from the COST Action E52 working group and other authors from various institutions for their timely processing of papers, also to all reviewers for their work and effort which contributed to the completion of this publication at a remarkable level. A special acknowledgment from first two editors belongs to John Fennessy (Ireland) for his support role in the various contributions. Finally we wish to express our grateful thanks to the financial support from the COST Office, too.

Josef Frýdl, Petr Novotný, John Fennessy & Georg von Wühlisch
Editors

Genetic resources of beech in Europe – current state

Introductory Note

European beech (*Fagus sylvatica* L.) is a major and wide-spread forest tree species with a natural occurrence from Scandinavian to Mediterranean countries and ranging from the Atlantic influenced climate in West-Europe to the more continentally influenced regions in Central and South-Central Europe, covering an area of roughly 14 million ha of forest land. Beech is not only of interest for economic reasons. It is also of high ecological and silvicultural value and acts to stabilise forest ecosystems. Beech forests are beneficial for the production of ground water and the regeneration of depleted soils.

Beech is a dominating species in many forest ecosystems. Other species of these ecosystems depend on co-existence with beech. Beech is thus viewed as a flagship species of many ecosystems because they would not exist in this form if beech were not present.

As a widely spread tree species, European beech and its ecosystems will be affected by climate change differently in different regions. Conditions in the north and north-east of the present distribution range will be more favourable for beech and may support further spreading in this region. However, as beech is growing predominantly in the lowlands, where precipitation is anticipated to be reduced, while at the same time evapotranspiration will increase due to higher temperatures, beech stands especially of the southern and south-eastern range of the present distribution will be affected most severely. Migrations of beech populations in the Mediterranean region to higher elevations have already been reported. However, where beech populations already occupy the top of mountain ranges there is no possibility to migrate further by natural means and such populations may disappear unless measures of intentional assisted migration are taken. Before climate change progresses and impacts the ecosystems physically, which is expected to occur in a higher frequency of extreme drought years like 2003, action should be taken.

Due to this concern, COST Action E52 "Evaluation of Beech Genetic Resources for Sustainable Forestry" (http://www.vti.bund.de/de/startseite/institute/fg/forschungsbereiche/herkunfts-und-zuechtungsforschung.html) was implemented and twenty-two European countries as well as Bioversity, Rome, (EUFORGEN-Programme) have agreed to participate. The main objective of this COST Action is to evaluate for the first time jointly 60 field trials located in 19 European countries of the International Beech Provenance Trial established in two series 1995 and 1998 with a total of 200 provenances representing the whole distribution area of beech. This common garden experiment allows predictions of the future distribution range of beech forest ecosystems under the assumption of certain scenarios of climate change, basing on the analysis of the reaction pattern of European Beech populations of defined origin (provenance = progenies of natural beech stands) under changed climate situations in sets of pan European field trials.

The network of forest geneticists created by COST Action E52 including all major countries where European beech occurs, provided the platform to decide about the scope and contents of the present publication, "Communicationes Instituti Forestalis Bohemicae, vol. 25". Covering the whole range of European beech distribution, the present publication with its 29 country reports (including three papers reporting information about 3 million ha of Oriental beech) attempts to give an overview of the present state of the beech forests with respect to their extent of distribution, plant sociological composition, management practices, ongoing research, health state, degree of endangerment, genetic composition of the populations, and conservation strategies of valuable beech genetic resources.

With this publication an earlier publication of 1993: "The scientific basis for the evaluation of the genetic resources of beech – Proceedings of an EC workshop", edited by H.-J. Muhs is updated comprehensively by including reports of more countries, reflecting the changes and progress achieved. For example, air pollution is not harming the beech ecosystems as much as it used to, while concurrently the threat due to climate change has increased. To account for this change differing approaches have been adopted. The high ecological value of beech has been recognised and has led to policies and programmes to convert pure conifer forests into mixed forests with considerable area increases of beech. Additional seed stands have been approved in many countries and artificial regeneration of beech has been implemented increasingly. Silviculture has changed widely. Beech forests are managed progressively more in closed-canopy shelterwood systems where crop trees are selected already at a younger stage and, by giving these more room, an earlier exploitable trunk size is reached. The economic value of beech timber has risen as the demand for wood has increased generally and beech wood can replace many tropical timbers due to its technological properties. Finally, in most countries *in situ* gene conservation stands have been registered and underlie special management practices to maintain a widest possible genetic diversity. The aforementioned manifold changes show that it was highly necessary to give record of them in the present publication, which also gives valuable information of recent inventories in different countries of the total and reduced area covered by beech stands as well as data of the standing volume of beech timber.

It remains to thank all authors providing detailed reports of the state of beech forests in each of their countries. The funding of the printing by the European Science Foundation, Brussels, is gratefully acknowledged. Finally, it is especially appreciated that Josef Frýdl, Petr Novotný and John Fennessy volunteered to undertake the tedious job of editing this publication!

Grosshansdorf, November, 2010
Georg von Wühlisch,
Chairman of COST Action E52

THE STATUS OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN ALBANIA AND ITS GENETIC RESOURCES

Hajri Haska

Forest Directory, Agency of Environment and Forestry, Ministry of Environment, Forest and Water Administration, Tirana, Albania Republic

ABSTRACT

The status of European beech (*Fagus sylvatica* L.) in Albania and its genetic reserve are presented in this paper. Some introductory data for Albania as a country as well as some general data about the forests are provided as well as information about the occurrence of European beech, its distribution in Albanian districts, as well as its occurrence according to nature ecosystems, pure or mixed with other forest species. Beech forests and their age structure as well as production and distribution of volume according to age classes are described in a more detailed way. The descriptions of beech forests and related information where methods for treatment of beech forests are provided. The most important part of this paper is the section which describes genetic reserves of European beech, as well as detailed information on the methods for choosing the reserves and conservation methods. In this section the list of units of European beech nominated as Nature Reserve Integrate (NRI) in Albania is also given, accompanied with some important data as well as a support map with NRI distributions according to districts. The concluding part of this paper gives some data about the health status of European beech forests as well as information about some protected areas selected as bio-monuments.

Key words: Albania, European beech (*Fagus sylvatica* L.), ah, ahishte (in Albanian), distribution, genetic resources, management; ecosystem

SOME GENERAL DATA ON ALBANIA

Albania is a small country located on the Balkan Peninsula, on the south eastern part of Europe, between geographic coordinates 39° 8' and 42° 9' latitude and 19° 16' longitude. With only 28,748 km^2 total surface area, most of the territory is close to the sea and mountains, and as result it has different climatic zones and a well defined vertical vegetation structure.

The climate in Albania is Mediterranean-subtropical and several studies have categorized it in a different way, but the more acceptable is that it identified climatic zones as follow:

(i) *field Mediterranean climate zone*; with mean annual temperature 15 – 16 °C, abundance rainfall during autumn and winter season, meanly rain and very rare snow, annual rainfall 1,000 – 1,200 mm.

(ii) *hilly Mediterranean climate zone*; with mean annual temperature 11 – 12 – 15 °C, abundance rainfall, snow layer 30 – 40 cm.

(iii) *pre-mountain Mediterranean climate zone*; with mean temperature 10 – 11 °C, annual rainfall 900 – 1,000 mm, 40 – 80 cm snow layer.

(iv) *mountain Mediterranean climate zone;* with mean temperature 7 – 10 °C, sometime only 4 – 6 °C, even sometimes descended below zero; maximum annual rainfall 2,000 – 2,500 mm per year, but mean annual rainfall is 1,300 – 1,800 mm.

There are five vegetation types in Albania: (i) Mediterranean vegetation type (macchia Mediterranean); (ii) oak forests; (iii) beach forests; (iv) fir forests; (v) Bosnian and Balkan pine forests.

Extending and strengthening the network of protected area (up to 797 units), as a base for creating an ecologic network of the country, is an important aim and objective of Albanian institutions, and has resulted in extension the surface area of protected areas from 6.4% in June 2005 to 361,401.40 ha or 12.57% of the total country area at the end of 2009.

Administration and management of protected area in Albania is based on Law No. 8906, dated 06.06.2002 "For Protected area", and some related decisions, orders and rules.

After 1990, Albania enacted many important international conventions that have relevance with the protected areas, environment etc. These protected areas, according IUCN categories include:

I. Nature strict reserve/scientific reserve (NStR/ScR); 2 units, 4,800 ha.

II. National parks (N.P.); 14 units; 176,517 ha;

III. Nature monuments (NM); 750 units (more individual trees; usually smaller area); 3,490 ha;

IV. Nature reserve managed (NRM); 22 units; 62,530 ha;

V. Protected landscapes (PL); 5 units; 95,864.4 ha;

VI. Protected area of Nature Resource Managed; 4 units; 95,864.4 ha.

FOREST RESOURCES IN ALBANIA

Approximately 36% of the total surface area of Albania is covered by forests amounting to 1,042,790 ha, with a total standing volume of 75,726,100 m^3, of which 62% is commercial timber and 38% firewood. More of the forest lies at north-east and south-eastern part of Albania.

According to national statistics the current forest situation is as follows:

- High forest: 325,370 ha; coppice forest: 457,598 ha; scrub and other vegetation: 260,190 ha. Some of the main forest species that grow in Albania are as follows (Fig. 1):

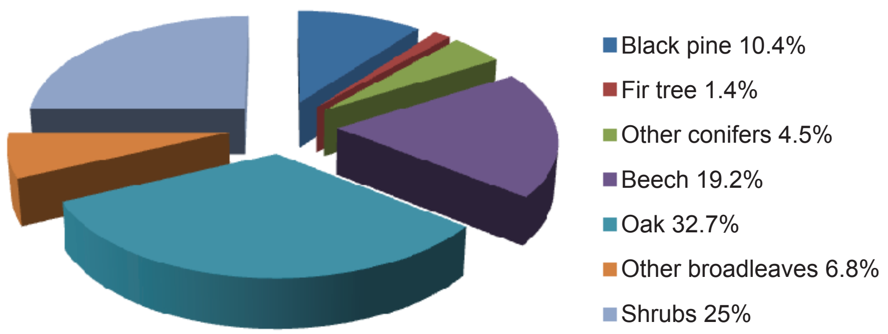

Fig. 1: Proportion (%) of European beech and other main forest trees in Albania (prepared by H. Haska)

- Beech (*Fagus*), 197,093 ha; with total standing volume of 36,441,800 m^3.
- Oak (*Quercus*), 340,770 ha; with total standing volume of 14,635,500 m^3.
- Black pine (*P. nigra* Arnold), 108,620 ha; with total standing volume of 10,170,600 m^3.
- Fir (*Abies*) 15,062 ha; with total standing volume of 3,817,100 m^3.
- Strawberry tree (*Arbutus unedo*), 61,500 ha; with total standing volume of 2,592,000 m^3.
- Hornbeam (*Carpinus*), 92,980 ha; with total standing volume of 2,916,600 m^3, etc.

(Source: Report of State Environment in Albania 2005-2007-2009; Agency of Environment and Forestry)

DISTRIBUTION OF EUROPEAN BEECH IN ALBANIA

Out of a total of 36 districts in Albania, 23 have European beech present from 800 to 2,000 m and even up to 2,400 m altitude (a.s.l.).

The most southern area where European beech is found in Albania lies in Nemerçka mountain, a mountain between Permeti and Gjirokastra districts, in southern Albania with an elevation of 2,489 m (Maja e Drites-Top of Light).

E. beech forests in Albania lie over dusty forest soil while, oak forests over marron soil, whereas scrub in general over calyx marron soils.

Tab. 1: Distribution of E. beech according to districts in Albania – 2007 (ha)

Nr.	District	High forest	Coppice	Total
1	Berat	490	-	490
2	Bulqize	14,120	270	14,390
3	Devoll	810	5,340	6,150
4	Diber	7,840	3,030	10,870
5	Elbasan	5,580	-	5,580
6	Gramsh	5,150	240	5,390
7	Has	2,220	-	2,220
8	Kolonje	2,070	1,040	3,110
9	Korce	5,900	8,320	14,220
10	Kukes	4,390	2,890	7,280
11	Kurbin	90	-	90
12	Librazhd	22,150	-	22,150
13	Malesi e Madhe	21,367	20	21,387
14	Mat	9,610	-	9,610
15	Mirdite	6,510	-	6,510
16	Permet	660	-	660
17	Pogradec	7,980	3,710	11,690
18	Puke	13,380	-	13,380
19	Shkoder	15,080	1,210	16,290
20	Skrapar	2,560	70	2,630
21	Tirane	8,833	20	8,853
22	Tropoje	16,170	70	16,240
23	Kruje	850	-	850
	Total			**200,040 ha**

Fig. 2: Nature monument *"Stone of Billy-Goat"* surrounded by European beech, in National Park "Bredhi i Drenoves", Korca region, Albania (H. Haska)

EUROPEAN BEECH FORESTS AND THEIR AGE STRUCTURE

Forests in Albania have mainly close-to-nature character with dominant uneven aged structure; however in many parts of Albania, very old and overmature stands with low increment can be found. More than 50% of high forests of E. beech are about 100 years old. They are usually in mountainous areas which are hardly accessible due to poor road infrastructure. Those forests are found in some districts such as Tropoje, Librazhd, Malesi e Madhe and Pogradec, and recently have been declared as protected areas. The future role of these areas will be more for nature conservation, recreation and scientific purposes and no longer for wood production.

Intensification of silvicultural activities directed at beech production forests in the future will lead to an improvement of their age structure.

EUROPEAN BEECH FORESTS AND THEIR PRODUCTION POTENTIAL

Forests today have a multifunctional role, however, the main function remains the production of wood, whether as commercial timber or as fire wood, or more recently for biomass which is considered more environmentally friendly.

Forests in Albania can be grouped according to their production as follow:

- Forest with high production, which occupy over 11% of total forest area, and have a annual production of 2.3 m^3/ha.
- Forest with medium production, which occupy over 13% of total forest area, and have a production of 1.8 m^3/ha.
- Forest with low production, which occupy over 76% of total forest area, and have a production of 1.3 m^3/ha.

Fig. 3: Mixed forest of European beech and birch in Dardhe, Korce region, Albania (H. HASKA, 2004)

As it can be seen from the data, it can be concluded that in Albania the predominant forests have low production. Some of the main causes for this can be summarized as follows:

a) Scrub layer in a considerable area of the forest (25% of forest surface), that have very low productivity (1.14 m^3/ha).
b) Over 45% of forest surface with low or medium stocking density.
c) Considerable area of coppice forests (about 31%).
d) Forests at high altitude (up 2,750 m) in the mountains especially on medium and steep slopes, where the site conditions (climatic, pedological) are not favourable for tree growth and productivity.
e) Very old age of some high forests which reduces the annual growth increment.

According to government forest yield figures, forests in Albania have average annual increment values of 1.69 m^3/ha year for high forest, 0.91 m^3/ha for coppice and 1.14 m^3/ha for scrub. Average annual forest increment in Albania is above 1.32 m^3/ha, which is lower than in some of the European countries such as Germany or France, but perhaps higher than some others such as Italy or Greece.

Albanian European beech forests have higher average annual increment than some others species as follows: European beech forests 2.14 m^3/ha, oaks 1.24 m^3/ha, pine 1.45 m^3/ha. However, some species with low surface area have higher increment such as fir with 2.92 m^3/ha, and poplar which has 3.60 m^3/ha.

For many years, the forest strategy and policy of the Albania state has been to increase the productivity of the forests. This has been supported by local community and has been complimented by financial, scientific and technical support from a number of overseas projects, with extra financial support, notably over these last years from the World Bank as well as others financial donations.

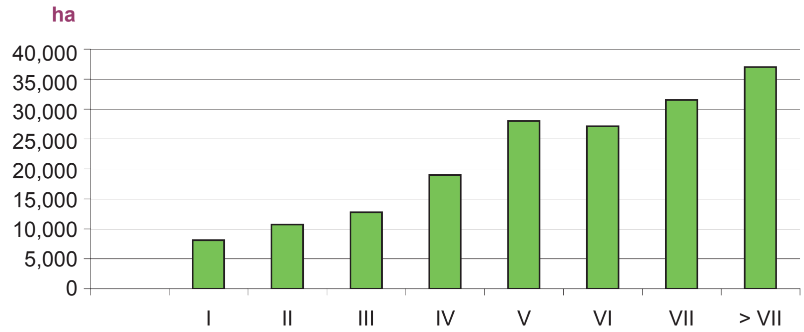

Fig. 4: Distribution of European beech area (high forests) according to age classes (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

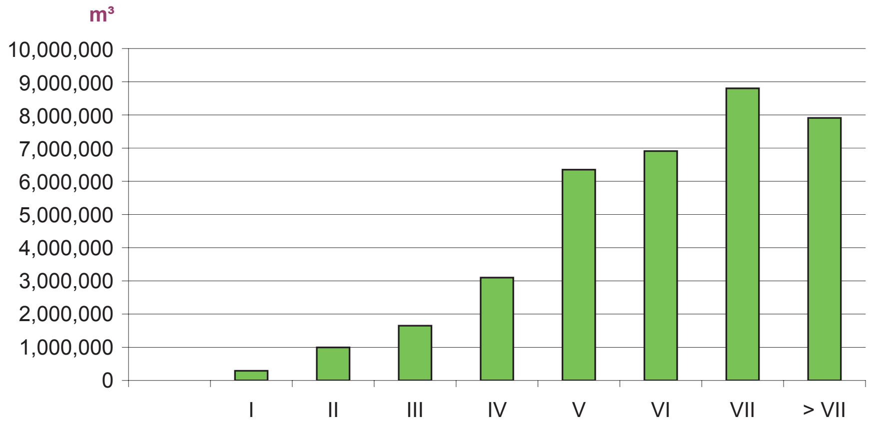

Fig. 5: Distribution of European beech volume (high forest) according to age classes (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

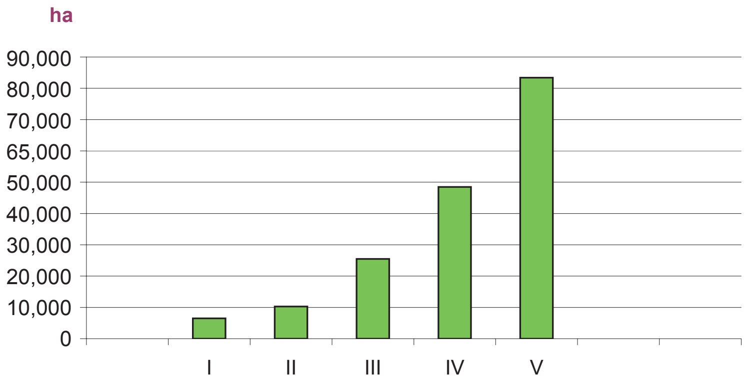

Fig. 6: Distribution of European beech surface (high forest) according to production classis (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

TREATMENT OF BEECH

In forest with a production function there is a need to implement different silvicultural treatments such as cleaning, thinning, and harvesting. Treatment methods for different forest types and different management practices vary according to the purpose of the forest.

In Albanian forests, the practice of successive felling and cutting with clearcuts have proved most successful and have guaranteed forest production continuity as well as the development of regeneration which has protected forest land from erosion.

Experiments with cutting in horizontal and vertical belts or with clearcuts have been also undertaken. These treatment methods with cutting have always been carried out in consideration with specific biological characteristics such as the actual forest stands structure as well as the orographic and climatic conditions where the forest stands are located. So for European beech forests in Albania successive cutting with clearfelling are carried out. Beech usually has good natural regeneration capacity especially in stands over 100 – 120 years.

For forest stands in first production class that are over 80 years of age, it is the practice to manage with three intervention cuttings and in some special cases with only two intervention cuttings. These cuttings are always made with a view to secure new natural regeneration in the forest. Seeds cutting intensity has varied from 25 to 35% of parcel or sub parcel volume. Light cutting intensity and definitive cutting are undertaken in relation to conditions of regeneration and development of seedling after seed cutting. In cases where amount of seedling are high and are distributed in a evenly, then a final cutting to allow light into the stand may be undertaken. Generally the natural regeneration period for beech is five to ten years. Final cutting is applied when seedling have reached 30 – 80 cm high and have a density 3 – 5 seedlings for m^2 with even distribution over the entire surface of the forest stands.

In the mixed forests with beech and conifers (pine, fir), preferences are given to conifers during applied treatment methods, because conifers are considered more valuable.

The data from different studies combined with some general calculations on wood production and presented as the annual harvesting possibility for forests in Albania is estimated at over 1,520,000 m^3, from which 747,000 m^3 are commercial timber and 773,000 m^3 are firewood.

More wood is harvested from beech forests as beech forests cover 43% of total forest. It should also be noted that in general many beech forests are used for the collection of firewood as well as foliage and leaves as fodder for animals, as well as for the collection of non-wood forest products such as mushrooms, medical plants, etc. In the last years, the country also implemented a major improvement in a decentralization process. About 40% of the forests in Albania are now the property of local government to be managed and to produce profit.

GENETIC RESERVES OF EUROPEAN BEECH IN ALBANIA

Two main methods for conservation of genetic resources are used: *in situ* conservation (conservation in natural stands) and *ex situ* conservation.

In situ conservation is realized through Nature strict reserves, National forest parks and Nature bio-monuments, Nature integrated reserve (NRI); while with the second method (*ex situ*), it is achieved through the establishment of gene banks, fields collections, or seedbed gardens. Apart from the above conservation methods other methods have also commenced, such as the conservation of material at very low temperature; *in vitro* conservation; pollen conservation; ADN-s conservation. For many species a gene bank is created near state seed stores or state nursery.

With scientific forest institutions support (Forest and Pasture Research Institute) and Management forest institutions (ex DGFP), such organisations are defining the main forest species in Albania Forest Seeds Stands. These forest seeds stands are generally defined in natural forest areas and sometimes in special cases in afforestation.

In determination of forest seed stands or seeds reserves an acceptable scientific criteria is adhered to such as: adequate size of forest stands, distance from other forest stands. Other tree quality parameters are also taken into account such as – high, diameter, form and quality of individual trunks. Other considerations include a general estimate of forest stand quality and individual tree quality; for example adequate fructification, effect of increasing age, crown form, resistance against diseases and insects, capability to different climate and site conditions, quality of wood production, capability of natural regeneration, high germination potential, seed collection possibility and proximity to seed treatment facility, whether mixed with other forest species and if mixed with some other forest kind with possibility of pollination between them. Other items considered are, number of trees per unit surface area etc.

More care is manifested in identification of "plus" trees, where individual trees chosen are firstly demonstrating phenotypic superiority. Tree with "plus" status can to be superior in one or more characteristics, but will ideally be superior in all characteristics, or at least most of them.

Reproductive criteria that will also be considered include such items as: age of flowering, production quantity of flowers and seeds, flowering periodicity. In relation to wood quality such issues will be considered as basic density, fibres dimensions or resinous oil quality – their quantity, terpens and resin, the last for conifers wood.

For the chosen forest stands and for "plus" tree, other factors which will be taken into consideration will include such characteristics as: resistance against diseases and insect attack, against aridity, animals and other natural and human impacts.

For seeds reserves some others management activity has been made such as; removal of inferior and poor quality trees, undertake thinning which is a very important operation and creates spatial area necessary for flowering and seeds collection; cleaning of ground area for facilitation of prediction control and seed collection; limitation of forest stands for elimination contamination of pollination, as well as and other services such as: paring, fertilize, using of fungicide or insecticide; all these supplementary measures are considered for increasing and conserving production.

In relation with E. beech in Albania, Nature reserve integrate (NRI) are defined in some districts of the country and in total there are approximately 27 units with a surface area exceeding 2,313 ha. These units categorised according to the IUCN criteria are given in Table 2 and are presented according to district (Tab. 3) and their location in Albania can be seen in the map below (Fig. 7).

Tab. 2: E. beech Nature Reserve Integrate units (NRI) in Albania according to IUCN category

Nr.	Species	Surface (ha)	Nr.	Surface according to IUCN category (ha)						
				I	II	III	IV	V	VI	VII
1	European beech	2,313	27		424		1,889			

Tab. 3: European beech Nature Reserve Integrate (NRI) in Albania

Nr.	District	Forest	Surface (ha)	Parcel	Altitude (m a.s.l.)	Age (years)
I	Berat	Tomorr (National Park)	30	9a	870-1,050	110
II	Bulqize	Liqeni i Zi	57	4a-22b	1,300-1,725	80-120
III	Devoll	Perparimaj	81	85, 86, 87, 88	1,300-1,650	70-110
IV	Diber	Lure (National Park)	300	1-32	850-1,750	100-180
		Zhuri i Pllahut	34	32a		
V	Has	Tej Drinini Bardhe	80	140, 141	1,110-1,340	110-115
VI	Kolonje	Orgocke	50	60, 69	1,500	160
VII	Librazhd	Qarrishte	124	96-112	1,150-1,750	90-180
		Rrajce	77	64a, 65a	1,600-1,650	120-155
		Dardhe-Xhyre	112	28a, 29b	1,350-1,450	80-135
		Lepush	25	69ab, 70a	1,150-1,670	180-190
		Stravaj	42	20, 21a	1,210-1,543	200
VIII	Mat	Qaf Shtame-Kete	86	24, 34-35	900-1,700	125-170
		Isuf Emin Plloci	20	23, 24	1,400-1,600	90-160
IX	M.Madhe	Lugina e Vermoshit	74	53a, 53b	1,250-1,700	170
		Fusher Zeze	20	39b	1,500-1,650	160-170
		Thethi (National Park)	50	4	1,518	150
X	Pogradec	Bishnice	43	17a	1,604-1,854	190
		Guri i Nikes	72	8, 9	1,050-1,220	100-110
XI	Puke	Iballe	48	35, 36a	745	80
XII	Shkoder	Cukal	500	1-20	1,350-1,735	135-180
XIII	Tirane	Dajt (National Park)	74	36, 37	1,400	130
		Bize	47	95, 96, 97, 98	1,277-1,490	140-170
XIV	Tropoje	Curraj i Eperm	40	97a	900-1,160	130
		Nikaj Mertur	75	10, 11a	800-1,400	105
		Lumi i Gashit	30	89b	1,600	130
		Çerem – Dragobi	122	87, 88, 89	1,350-1,950	90-120
TOTAL			2,313			

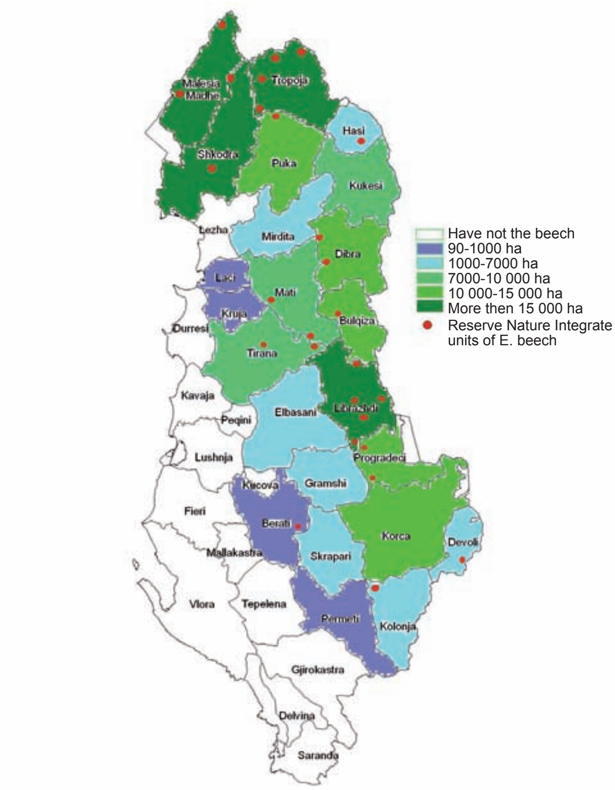

Fig. 7: Distribution of European beech and Nature Reserve Integrate units (NRI) in Albania according to districts (prepared by H. Haska)

THE DATA ABOUT HEALTH CONDITION OF EUROPEAN BEECH IN RECENT YEARS IN ALBANIA

Albania has for many years been monitoring the health of its forests which has been undertaken by a number of scientific institutions. For the entire country a national network with 299 permanent sample plots has been created. The method used was applied firstly from the Germany and later adapted by the European Commission.

The monitoring process took place in the districts with the highest forest production potential such as Puka, Kukës, Mat, Shkodra, Tirana, Librazhd, Pogradec, Korça, Përmet, Berat, Vlora, Dibra, and Kolonja. In the period 2005 – 2007, data on the forest health status were collected at country level in order to evaluate the parameters and determine the needle and leaf fall, the level of tree discolouration, pests, illnesses and other factors, with the final objective to control the situation as regards forest health and give recommendations for improving the health of the forest.

The monitored species are black pine, fir, beech, oak, etc.

Below are some data for forests including E. beech forests, data collected over recent years.

Tab. 4: Percentage of defoliation according to category (average 2005-2007)

Category	Percentage of leaf loss according to category				
	0-10% (0)	11-25% (1)	26-60% (2)	61-99% (3)	100% (4)
Leaf loss (%)	63.3	30.0	5.2	1.1	-

Tab. 5: Percentage of discoloration according to category (average 2005-2007)

Category	Percentage leaf discolouration according to category				
	0-10% (0)	11-25% (1)	26-60% (2)	61-99% (3)	100% (4)
Leaf discolouration level (%)	48.1	38.6	12.0	0.9	0.4

The most problematic pests for beech: (*Mikiola fagi* Hartig), Librazhd, Kolonja; (*Rhynchaenus fagi* L.), Korça, Puka; (*Phyllaphis fagi* L.), at national level; (*Cryptococcus fagisuga* Lindinger).

Some the main diseases in beech (*Fagus sylvatica*): (*Nectia dittisima*), in all ancient beech woods; (*Phytophthora fagi*), Shkodra, Kukës; (*Fomes fomentarius*), Librazhd (unused areas).

Tab. 6: Level of damage by the main pests (%) according to category for European beech

Category	**Level of damage**					**I.D. (%)**
	0-10% (0)	11-20% (1)	21-50% (2)	51-90% (3)	91-100% (4)	
Beech (*F. sylvatica*)	61.3	33.2	4.0	1.5	-	13.7

Pests which cause a high level of damage in the leaf are the *Tortrix viridana* L. 17%, *Saperda charcharis* L. 22% and *Ceratostomella ulmi* 19%.

Tab. 7: Level of damage by the main diseases in European beech

Category	**Level of damage**					**I.D. (%)**
	0-10% (0)	11-20% (1)	21-50% (2)	51-90% (3)	91-100% (4)	
Beech (*F. sylvatica*)	80.3	16.0	2.2	1.5	-	**10.5**

The disease causing a high intensity of damage in the leaf species is *Cryphonectria parasitica*.

Tab. 8: Percentage of damage according to causes in the tree species of broadleaved forests

Type of damage	**Percentage of damaged trees according to causes**							
	Pest	Disease	Grazing and overgrazing	Climatic factors	Pedology factors	Fires	Unknown causes	**Total (%)**
Leaf	4.3	4.6	1.7	2.3	1.5	2.7	1.2	**18.3**

Degree of damage according to causes is at an average value of 18.9%, while for the conifers it is 19.2% and for the broadleaved species is 18.3%. The highest levels are found in other broadleaved species such as oak, hornbeam and box, where a considerable area of these species is suffering from water deficit due to the high and prolonged temperatures.

Discoloration: This is the basic indicator of the complex factors which are reflected in the change of colour through to the dying of the leaves. Referring to the classification according to category, it is obvious that this indicator has a notable increase in the second and third categories (26 – 60% and 61-99% with respective values of 15.42 and 1.48%), compared to last years (in the category 26 – 90% it was 9.79% while in category 61 – 99% it was 0.98%) .

The pest with the highest intensity in the leaf species is: *Tortrix viridana* L. 17.0%, *Saperda charcharis* L. 22.0% and *Ceratostomella* at the poplar and elm-trees 19.0%.

The disease causing a high intensity of damage in the leaf species is *Cryphonectria parasitica* 25.3%. Degree of damage according to causes is at an average value of 18.9%, while for the conifers it is 19.2% and for the broadleaved species it is 18.3%.

In future, with better coordination between all stakeholders working in forestry, such as the specialists of the FSD, communes, others entities that work in forests and cooperate with observing and signalling staff are to be allocated and share some important monitoring duties.

PROTECTED AREA AND SOME EUROPEAN BEECH BIO-MONUMENTS IN ALBANIA

Many of protected areas are covered by European beech, mainly pure but also mixed with others forest species. Greatest evidence of this is in the national parks, where European beech is one of the main forest trees as follows:

“Shebenik-Jabllanica” national park which was approved in 2008 with a surface area of 33,928 ha and is 80 km from the capital Tirana.

National park “Mali I Dajtit”, was extended with a large surface area added last year and is also very near to Tirana. This national park has a very rich flora that includes Mediterranean shrubs (*Arbutus unedo*), oaks and at high altitude beech forest pure and mixed with conifers.

“Thethi” national park is another park in the Albania Alps, where beech created pure or mixed forest stands; this is 70 – 75 km distant from Shkodra city.

National park “Lura” in Dibra district, 55 km from Peshkopi city, 30 km from Kurbnesh and 70 km from Burrel city. This area has many pure and mixed stands of beech with conifers such as Bosnian and Balkan.

“Lugina e Valbones” national park lies in Tropoja district, 25 km from Barjam Curri city and is part of the Albanian Alps. Some parts of this area has virgin forests where beech grows pure and mixed with others species such as Norway spruce (*Picea abies*) which is the only area of Norway spruce growing in Albania.

“Zall Gjocaj” national park, Mati district, 40 km from Burrel city, has a high level of biodiversity and some part with virgin forests which are covered by different forest trees pure or in mixture such as beech, black pine, fir, Bosnian pine, ash, maple etc.

“Qaf Shtame” national park, in Kruja district 25 km distant from Kruja city, is another very beautiful place where beech and black pine grow together.

“Tomorri” national park in Berati district 30 – 40 km distant from Berati city is covered by forest composed of beech and Bosnian pine, and others forest species, pure or mixed.

“Prespa” national park in Korça district, about 25 km from Korca city is a cross-border park between Greece, Macedonia and Albania. In the lower parts oak grows while in the more productive parts oak grows with beech, both pure or in mixed stands.

“Bredhi i Drenoves” national park also in Korça district, 10 km from Korca city, has very beautiful forests composed of *Abies borisii-regis* mixed with maple, ash, black pine can be found and in some cases with beech.

“Llogara” national park in Vlora district in the southern part of Albania where beech grow very rare at higher altititude.

In Albania are designated some nature monuments, and these are approved by the government and are included in the national heritage. A nature monument is a natural object with one or more unique values; scientific, historic, religions, ecologic, cultural, esthetics, didactics, touristic – these are habitats for rare species as well as endemic, threatened or important species. To facility their study, nature monuments are divided into three categories: geo-monuments, hydro-monuments and bio-monuments. Albania has recognised a number of bio-monuments (around 308), some of which contains European beech.

BIO-MONUMENTS WITH EUROPEAN BEECH IN ALBANIA ACCORDING TO DISTRICTS

Gramshi district – Ahishta e Rovjes; Librazhdi district – Pylli i Stravajt, Druri i Bizges, Ahet e Fushe Gurrës, Pylli i Barkmadhit Kostenje; Korçe district – Ahishtja e Protopapes Opar, Ahishtet e Bofnjes; Devolli district – Ahishtja e Shenkostandinit, Pylli i Shen Thanasit, Ahishtja e Bradvices; Diber district – Ahu i Blliçes, Boroviku i Beguinecit, Krasta e Pocestit; Hasi district – Ahishtja e Liqenit te Kuq; Tropoje district – Ahishtja Gurra e Hasan Gashit (Mertur), Ahishtja e Vranices; Malesia e Madhe district – Ahu i Greçes (Mrizi i Greçes), Mrizi (ahu) i Pleshtit (Boge); Skrapari district – Ahishtja e Leshnjes; Ahishtja e Symizes, Ahishtja e Lirzes.

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Reviewed

Contact:
Prof. Dr. Hajri Haska
Director of Forest Directory
Agency of Environment and Forestry; Ministry of Environment, Forest and Water Administration
Rruga: "Halil Bega", Nr: 23, Tirane, Albania
e-mail: haskahajri@yahoo.com

CURRENT STATE OF ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY) IN ARMENIA

HASMIK GHALACHYAN[1] – ANDRANIK GHULIJANYAN[2,3]

[1] Plant Resources Management Division, Bioresources Management Agency, Ministry of Nature Protection of the Republic of Armenia, Government Building 3, Republic Square, 375010 Yerevan, Armenia

[2] "Forest Research and Experimental Centre" State Non-Commercial organization

[3] Ministry of Nature Protection of the Republic of Armenia, Government Building 3, Republic Square, 375010 Yerevan, Armenia

ABSTRACT

This paper presents the current state of oriental beech (*Fagus orientalis* LIPSKY) in Armenia. It is the dominant tree species in 82.2% of the national forest area. Research shows that in Armenia oriental beech prefers to grow in the northern part of the country. From an economic viewpoint, the species provides a valuable wood resource which is widely used for the manufacture of furniture, as well as for carpentry and in the construction of buildings. Oriental beech is also an excellent park tree, with several ornamental garden forms. Furthermore, the paper describes the current state of the oriental beech gene pool and its preservation in the framework of the Armenian conservation programme. It includes information on the current state of forestry research on oriental beech and related activities.

Key words: oriental beech (*Fagus orientalis* LIPSKY), Բոխի արևելյան, դաժի (in Armenian), oriental beach distribution, oriental beech ecology, preservation and conservation of oriental beech gene pool, genetically conditioned variability, research experiments

INTRODUCTION

The Republic of Armenia is located on the verge of Southern Caucasus and Asia Minor, occupying about 10% of the north-eastern part of the Armenian plateau and is situated between 35° 50‘ – 40° 15‘ of the northern latitude and 43° 27‘ – 46° 37‘ of the eastern longitude. Armenia borders Georgia in the north, Azerbaijan in the east, Iran in the south and Turkey in the west.

Armenia is a typical mountainous country with a complex geographical structure. The total area of the country is 29,740 km^2. The highest peak is Mount Aragatz (4,090 m above sea level) and the lowest is along the banks of Debed River (375 m). Relative altitude fluctuates from 1,500 to 3,700 m. The average altitude of the territory is 1,850 m. Such broad altitudinal variation results in a great diversity of climate and landscape.

Water resources in the country are quite limited. The largest lake is Lake Sevan which is a natural source of drinking water for the region. Rivers are small and shallow.

Armenia is characterized by a mountainous continental climate with a peculiarity for its dryness. Average highest annual temperature is 14 °C, and the lowest is -2.7 °C. The highest average temperature is observed in July – August in the Ararat valley and pre-mountain zone which is in the range of 24 – 26 °C; in mountain zones it is in the range of 15 – 20 °C; in high altitude regions it varies from 10 to 15 °C and even lower.

Average lowest temperature in January fluctuates between -18.9 and -3.1 °C. The annual precipitation range is from 600 to 1,000 mm. High altitude zoning is demonstrably obvious. In winter long-lasting snow cover exists above 1,300 m (according to the National Report on the State of Plant Genetic Resources in Armenia, 2008).

ORIENTAL BEECH DISTRIBUTION IN THE REPUBLIC OF ARMENIA

Generally, oriental beech natural occurrence is in Western Europe (Eastern Balkan Peninsula), Crimea, Caucasus, Asia Minor (North), Iran (North).

Oriental beech is a common species and a third century typical relict. The scientist Tumajanov (1971) has shown the Holocene expansion of that species from the Kakheti to the northern side of the Big Mountain Range (Georgia). It is possible that during this time a habitat transformation has taken

Fig. 1: Stand of oriental beech showing large-trunks (A. Ghulijanyan, 2009)

place and the species has extended its range in the other direction to the south – Little Caucasus, and turned into large beech forests which are a common occurrence when old relict species become acclimatized and the result is an enlargement of their natural habitat area. Oriental beech is a good example of this.

Despite the negative human impact on the forest ecosystem, oriental beech shows a strong sustainability and shows a much better sustainability than Georgian oak species. Georgian oak is one of the main constituents of Armenian forests. Description of oriental beech forests in Northern Armenia is given in Tables 1 and 2.

As a result of intensive unregulated forest removal, many of oriental beech stands have been seriously damaged. The natural regeneration recovery is slow and generally unsatisfactory and urgent reafforestation activities are needed in those parts of the distribution area (Fig. 1, 2).

The main part of the mesophilic forest ecosystem of Armenia can be considered as relict. A number of former relict plant species have now become acclimatized in forest ecosystems. There are both very common and rare tree species and grass among these plants. For example, *Betula*, *Tilia*, *Lonicera*, *Euonymus*, *Pyrola*, *Cornus mas*, *Carpinus betulus*, *Rhus coriaria*, *Tamus communis*, *Juglans regia*, *Platanus orientalis*, *Zelcova carpinifolia*, *Atropa bella-donna* species are considered relict species of Armenian forests.

Oriental beech grove dominance is found in 82.2% of the forest area, accounting for 77,970 ha while 83.2% of general resource or 17,074,059 m^3 are distributed in the northern part. In the same location

Fig. 2: Regrowth of coppiced stump of oriental beech (A. Ghulijanyan, 2009)

Fig. 3: Leaves of oriental beech (http://www.cirrusimage.com/tree_Oriental_Beech.htm)

Table 1: Changes of the areas with dominance of oriental beech and Georgian oak distribution according to height above sea level and scope declivity level

The dominating tree species	The level of scope declivity	Sea level height [m]						
		Up to 800 meters	800-1,200	1,200-1,600	1,600-1,800	1,800-2,000	2,000 and higher	Total
Oriental beech	Up to 10	5.2	363.0	514.6	92.4	9.5		984.7
	11-20	9.3	1,886.0	7,744.4	2,450.0	445.8	19.5	12,555
	21-30	51.5	7,244.8	29,034.9	13,634.6	5,992.4	214.7	56,172.9
	31-40	80.6	3,510.6	10,965.5	5,603.8	1,650.5	126.0	21,937
	41 and higher	8.6	569.2	1,861.1	623.7	141.8	4.0	3,208.4
	Total	155.2	13,573.6	50,020.5	22,404.5	8,240.0	364.2	94,858
Georgian oak	Up to 10	34.7	235.3	395.5	158.5	23.4		847.4
	11-20	57.2	1,620.4	5,708.8	2,070.7	132.6	17.0	9,606.7
	21-30	233.4	7,029.0	15,853.2	8,036.1	4,473.7	505.9	36,131.3
	31-40	146.4	3,715.5	6,357.6	3,175.0	1,380.0	342.6	15,117.1
	41 and higher	16.8	665.3	1,099.7	249.7	40.9		2,072.4
	Total	488.5	13,265.5	29,414.8	13,690.0	6,050.6	865.5	63,774.9

29.9% of Georgian oak is distributed over an area of 19,087 ha and accounts for 24.5% of the forest resource with 2,381,310 m^3.

In the southern part of the country the data for the species are as follows: oriental beech – 12.2% of the forest with an area of 11,611 ha and a volume representing 11.5% of the total and amounting to 2,366,404 m^3 while Georgian oak accounts for 62.8% of the area or 40,033 ha and representing 63.3% of the volume which is equivalent to 510,513 m^3.

Experience shows that in Armenia oriental beech prefer to grow on the northern parts of the country while Georgian oak grows better in the southern part of the country.

The above data show the differences between oriental beech and Georgian oak forests, due to ecological needs, altitude and humidity preferences.

In the northern areas of the country where oriental beech prefer to grow, the mountains are higher than in the southern parts of the country, where mountains are much lower and where Georgian oak prefers to grow.

Table 2: The change of resource indexes of oriental beech and Georgian oak according to sea level height and scope diclivity level

The dominating tree species	The level of scope declivity	The sea level height [m]							1 ha average resource (m)
		Up to 800 meters	800-1,200	1,200-1,600	1,600-1,800	1,800-2,000	2,000 and higher	Total	
Oriental beech	Up to 10	1,200	47,190	76,050	10,900	1,560		136,900	139.0
	11-20	1,710	339,500	1,455,740	433,650	62,800	3,600	2,297,000	183.0
	21-30	10,790	1,499,800	7,454,970	2,990,000	1,205,000	35,420	12,111,480	215.4
	31-40	12,100	827,500	1,560,470	1,277,000	328,800	20,950	5,111,320	233.0
	41 and higher	2,920	165,490	511,060	158,610	29,370	520	867,970	217.8
	Total	28,720	2,879,480	11,058,290	4,870,060	1,627,530	60,490	20,524,670	216.4
	1 ha, average resource (m^3)	185.0	212.1	220.6	217.1	197.5	166.1	216.4	
Georgian oak	Up to 10	2,270	27,900	40,690	12,680	1,450		91,290	107.7
	11-20	4,440	186,500	395,290	236,500	13,800	910	1,223,470	127.3
	21-30	20,740	802,960	2,635,120	1,075,520	552,620	48,000	4,642,430	128.4
	31-40	9,490	428,000	769,860	400,500	148,000	10,810	1,866,340	123.5
	41 and higher	2,250	70,280	136,890	31,380	2,630		243,430	117.5
	Total	39,190	1,515,640	3,977,850	1,756,580	718,500	59,720	8,066,960	126.5
	1 ha, average resource (m^3)	80.2	114.3	135.2	128.3	118.7	69.0	126.5	

The Georgian oak forests prefer the south-western and south-eastern sides, where they account for 16,780 ha (26.3%) and 17,451 ha (27.4%), and together with the northern areas amount to 19,087 ha (29.9%) (Tab. 1).

As mentioned above, forest ecosystems have been extensively changed over the last ten years.

The reason of this is the change in the main forest distribution areas and distribution of forest species. Another reason for these changes is the structure and the habitat of these species.

Table 3: Dynamic changes of areas covered with forests and resources according to forest forming species

Main treespecies	The year of forest establishment	Total		1 ha average resource [m^3]
		Square [ha]	Resource [m^3]	
Oriental beech	1966	90,236.1	14,652,090	162.4
	1978	92,784.0	16,763,000	180.7
	1988	93,596.0	21,611,300	230.9
	2006	94,858.0	20,524,670	216.4
Georgian oak	1966	47,064.7	4,830,400	102.6
	1978	52,040.5	5,791,120	11.3
	1988	54,002.0	7,267,750	134.6
	2006	63,774.9	8,066,960	126.7
Hornbeam	1966	27,068.4	2,876,200	106.3
	1978	26,275.4	3,140,380	119.5
	1988	26,783.0	3,826,730	142.9
	2006	31,507.9	3,979,370	126.3
Pine-tree	1966	1,621.4	181,330	111.8
	1978	4,431.0	276,000	62.3
	1988	6,529.9	456,000	69.8
	2006	7,139.3	590,895	82.8
Oriental hornbeam	1966	6,686.4	319,020	47.7
	1978	6,127.0	325,500	53.1
	1988	6,132.0	385,900	62.9
	2006	13,304.3	534,890	40.2
Other species	1966	8,047.4	593,260	73.7
	1978	10,069.1	838,070	82.5
	1988	11,053.1	1,060,720	95.7
	2006	10,969.6	874,035	79.6
Total forest covered area	1966	180,724.4	23,452,300	129.8
	1978	191,822.0	27,134,080	141.4
	1988	198,096.0	34,608,400	174.7
	2006	221,554.0	34,570,820	156.0

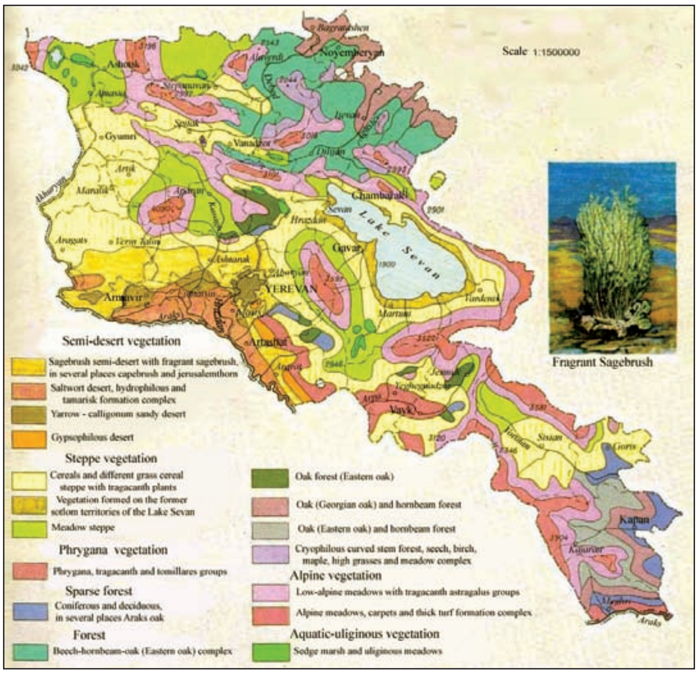

Fig. 4: Botanic map of the Republic of Armenia (http://www.armstat.am/file/article/marz_07_e_7.pdf)

ECOLOGY OF ORIENTAL BEECH

Mesophyte. Very shade tolerant. One of essential forest-forming trees. Usually grows with other broadleaved or coniferous trees but may form pure stands. Generally dominates on northern slopes in wet valleys. Demands warmth, high soil fertility and wetness, as well as air humidity. Thrives on fertile, brown forest soils. Forms best stands of all ages at the altitude 700 to 1,200 m. In the Caucasus, attains 2,200-2,300 m, to form subalpine elfin woodlands (Chukhina 2003).

USE AND ECONOMIC VALUE

Technical, ornamental. Provides valuable wood which is widely used for furniture (bentwood „Viennese“ furniture), as well as construction and carpentry (parquetry). Excellent park tree, with significant ornamental garden forms. Nut bearing trees cultivated in Armenia include walnut (*Juglans regia*), hazel (*Corylus avellana*, *C. colurna*) and chestnut (*Castanea sativa*). People also use the fruits of beech (*Fagus orientalis*). Wild species of almond (*Amygdalus nairica*, *A. fenzliana*, *A. urartu*) and pistachio (*Pistacia mutica*) are also grown in the country.

The unique forest of Mtnadzor gorge is considered a fine example of natural indigenous forests. Here the primary targets for conservation are oak, hornbeam and oak-hornbeam forests, as well as rare plant communities, such as yew (*Taxus baccata*). Here also is found the only small oriental beech grove in the south of Armenia along with a plane grove (*Platanus orientalis*) (Chukhina 2003).

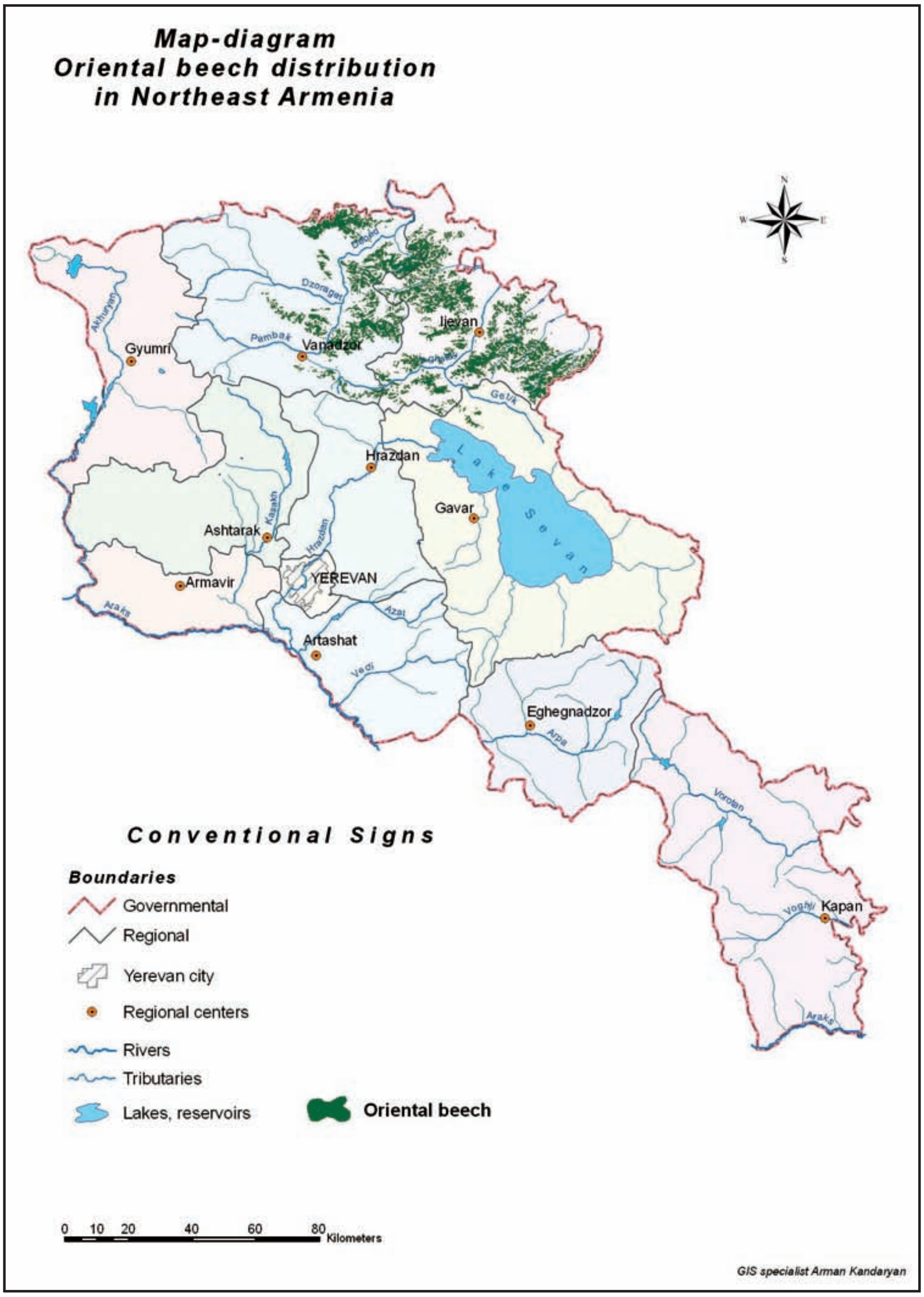

Fig. 5: Map of oriental beech distribution in northeastern Armenia

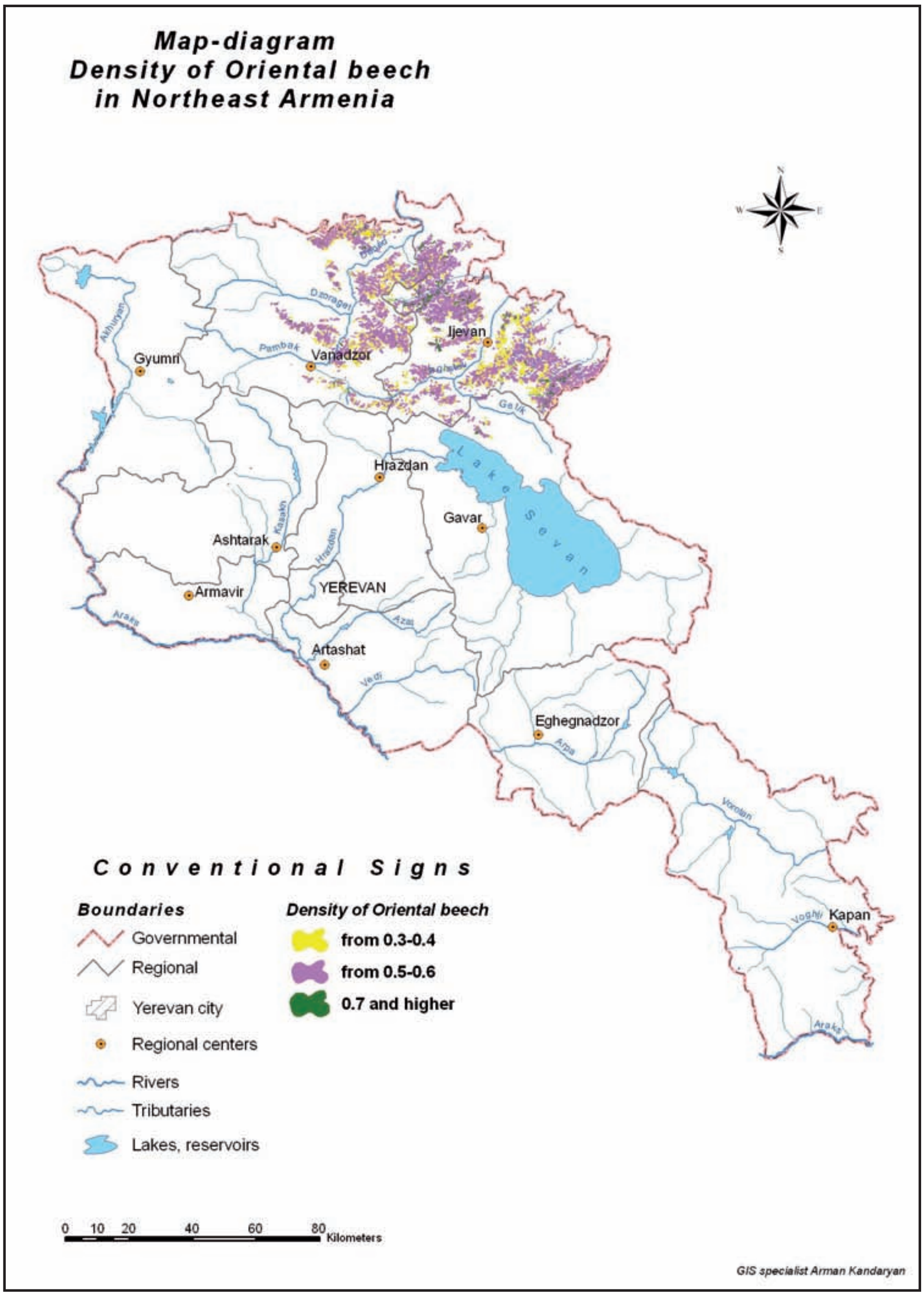

Fig. 6: Map of oriental beech density in northeastern Armenia

PESTS, DISEASES AND ABIOTIC IMPACTS

To-date some 43 insect species are considered to be associated with oriental beech as a host tree in neighboring Iran, the majority of which are not very host specific bark and wood borers (Adeli, Soleimani 1976). A similar situation is found in Armenia.

According to Avagyan (2009), the National Forest Policy and Strategy (2004) and The Forest National Programme (2005) include issues on climate change risks. The following activities related to climate change as envisaged in these programmes: assessment of forest vulnerability as a result of forecasted climate change; development of measures aimed at increasing forest adaptability; efficient use of international financing mechanisms in the forest sector (as envisaged by Kyoto Protocol) for implementation of afforestation/reforestation projects by using Clean Development Mechanism based on forest ecosystems capacity to absorb carbon; assessment of the damage caused to forests by pests and diseases and application of integrated methods to control pests and diseases spread in the forests and the forest maintenance improvement programme.

ORIENTAL BEECH GENE POOL PRESERVATION AND CONSERVATION

A network of specially protected areas was first established in Armenia in 1958 to protect ecosystems, habitats and rare, endemic and threatened species (http://www.cac-biodiversity.org/arm/arm_natreserves.htm).

There are currently five State Reserves, 22 State Reservations and one National Park registered, which together cover around 311,000 ha, or 10% of the surface of the country. Around 60% of Armenian species are represented within the protected area network; however there is a bias towards forest habitats, and a need to expand the system to include better representation of other ecosystems.

As for oriental beech, there are several nature reserves managed for this species, in Armenia, as e.g. the Dilijan reserve (Khanjyan 2004). This nature reserve is managed by "Hayantar" State Enterprise (under the authority of the Ministry of Nature Protection). "Dilijan" National Park is situated in the north of Armenia, in one of most picturesque areas (established in 1958, area: 27,995 ha). The main subjects of protection are beech and oak forests that also include some pines (*Pinus kochianus*), as well as the shady yew grove of Hakhnabad with impressive *Taxus baccata* trees. While the National Park doesn't present the whole diversity of the flora of northern Armenia, it has over 1,000 species of plants in an area of 28,000 ha. The main wood and bush types are oak (*Quercus iberica*), beech (*Fagus orientalis*), different types of hornbeam (*Carpinus caucasicus*, *C. orientalis*), as well as ash, some types of lime tree, maple, caprifoil, spindle tree and others (*Fraxinus*, *Tilia*, *Acer*, *Lonicera*, *Euonymus*). Numerous plants like rare Job`s-tears (*Lychnis flos-cuculi*), different orchids, and fritillaria (Orchidaceae, *Fritillaria*) are included in the Red Book.

Another nature reserve, in which management is directed to other species as well as to the oriental beech gene pool preservation and conservation, is the Shikakhogh reserve, managed by "Hayantar" State Enterprise (under the authority of the Ministry of Nature Protection). It was established in 1958. The Shikakhogh Reserve is situated in the northern slopes of the Meghri ridge that protects the area from hot air masses from the Iranian Plateau, while the high Zangezur range stretches from north to south and slows humid air from the Caspian Sea. Due to the mild climate and numerous close gorges not only single representatives, but whole communities and islands of tertiary flora have survived here such as yew grove (*Taxus baccata*), along with the only beech grove in southern Armenia as well as ivy, persimmon, plane and walnut, *Fagus orientalis*, *Hedera helix*, *Diospyrus caucasicus*, *Platanus orientalis*, *Juglans regia*, *Periploca graeca* etc. The main part of the reserve is occupied by broadleaf trees – generally oak and oak/hornbeam forests – that occupy the middle area of the vegetation belt at altitudes of 1,000-2,200 m above the sea.

FOREST RESEARCH

In the Asian region, numerous research experiments have been established aimed at studying oriental beech influence and behaviour, such as a study undertaken to establish the effects of harvesting impact on the herbaceous understory, of the forest floor and top soil properties as well as the effects of extraction practices on a beech stand (Murat, Makineci, Yilmaz 2005). In this study, the impact of extraction work on the access roads have been carried out for many years and the likely effects of man, animal and mechanical interactions in the beech stand have been examined.

Numerous other studies on the genetical characteristics of oriental beech have also been undertaken, e.g. research aimed at the clarification of the unique *Fagus sylvatica-orientalis* complex or two distinct species undertaken by studying the sequence of the trnL-trnF region of chloroplast DNA (cpDNA). Twenty-nine *Fagus sylvatica* and twenty-two *Fagus orientalis* populations have been sampled to better delineate the systematic position of the genus *Fagus*, *Fagus taurica* Popl., *Fagus moesiaca* Czecz., *Fagus grandijblia* Ehrh., *Fagus crenata* Bl., *Fagus japonica* BI., and *Fagus hayatae* Palibin were also considered (Vettori et al. 2004).

In 2002, there was an assessment on the adverse effects of human impact on biodiversity in Armenia's premier wilderness areas – the Khosrov Reserve and Gndasar Mt./Noravank Canyon (Khorozyan 2002). The report from this experimental study derives from the field project generously supported by The Whitley Laing Foundation for International Nature Conservation/Rufford Small Grant program which was implemented over four months in the summer-autumn of 2002. The aim of this project was to assess the status and distribution of adverse human activities in the areas of both Khosrov Reserve and Gndasar Mt./Noravank Canyon and predict their actual or potential impact on biodiversity. Among the results of this research, for example in the Khosrov Reserve, in site conditions studies it has been established that through out the canyon bottom with streams flowing alongside, this sparse forest transforms to the dense "jungles" or true woods of oak (*Quercus macranthera*), oriental beech (*Fagus orientalis*), crooked and thorny berry trees and shrubs like buckthorn (*Rhamnus pallasii*), dog rose (*Rosa canina*), hawthorn (*Crataegus calycina*), wayfaring tree (*Viburnum lantana*), etc.

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Reviewed

Contacts:

Dr. Hasmik Ghalachyan

Plant Resources Management Division, Bioresources Management Agency, Ministry of Nature Protection of the Republic of Armenia

Government Building 3, Republic Square, 375010 Yerevan, Armenia

e-mail: hasmikghalachyan@yahoo.com
hasmikgrigan@yahoo.com

CURRENT STATE OF THE EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENE-POOL IN AUSTRIA

Raphael Klumpp[1] – Herfried Steiner[2] – Eduard Hochbichler[1]

[1] Institute of Silviculture, Department of Forest- and Soil Sciences, University of Natural Resources and Applied Life Sciences Vienna, Peter Jordan Str. 82, 1190 Vienna, Austria

[2] Department of Forest Inventory, Unit of Natural Forest Reserves and Nature Conservation, BFW Austria, Hauptstr. 7, A-1140 Vienna, Austria

ABSTRACT

The current state of European beech (*Fagus sylvatica* L.) in Austria is presented in this paper as well as information on the present distribution of beech and on its actual representation in forest stands and plant communities. The historical as well as the contemporary status of beech in Austrian forestry is also outlined.

Key words: European beech (*Fagus sylvatica*), Buche, Rotbuche (in German), distribution, silviculture, gene-pool, forest history, forest genetic resources, Austria

THE CURRENT DISTRIBUTION OF EUROPEAN BEECH IN AUSTRIA

European beech is the most common broadleaved tree species in Austria, covering an area of 323,000 ha which represents 9.6% of the Austrian forests. Beech was recorded up to a maximum elevation of 2,050 m a. s. l. during the national inventory of 2002 (Englisch 2006). Beech is usually found in Austria at elevations from 150 m a. s. l. up to 1,500 m a. s. l. throughout the northern foothills of the Alpine mountains and up to 1,550 m a. s. l. in the southern foothills. More than 70% of the trees are to be found at an elevation between 300 and 900 m a. s. l. and only 6% can be found between 1,200 and 1,500 m a. s. l. (Schadauer, Büchsenmeister, Schodterer 2006). Rendzina soils on substrates rich in carbonates are most frequently occupied by beech.

Being a tree species of the montane forest communities, the species occurs mainly in beech dominated forests as well as in the spruce-fir-beech and the maple-ash-forests. As a mixed species it can be found in oak-hornbeam as well as in spruce-fir communities and hence it is spread over a total area of 1.5 million ha or 50% of all Austrian forests (Schadauer, Büchsenmeister, Schodterer 2006). In most cases, beech cover is less than 10% of the area and pure stands where beech cover is more than 80% are scarcely found. However, the "Viennese Forest" west of Vienna and the "Kobernausser Forest" in Upper Austria are two regions well known for their pure beech stands.

As a result of intensive forestry practice during the last two centuries, beech forms pure beech stands only on 28% of the potential beech forest sites, while artificial spruce stands can be found on 45% of this area. The most important forest community, the spruce-fir-beech type with an extension of more than 1.1 million ha is even covered by 72% of anthropogenic spruce forests. This anthropogenic driven development is influenced by climate fluctuations: a natural dynamic in beech regeneration was reported by Polaczek (1954) who observed a better success of beech regeneration after several warm years and vice versa a better spruce regeneration after cold years. Thus it is not surprising, that the area covered by beech increased by 14,000 ha during the "warm" decade between 1992 and 2002.

Beech forestry practice varies between Austrian regions and differs according to regional challenges and the individual objectives of the owner. High quality wood production is the main objective for pure and mixed beech stands, sometimes including larch and spruce on good sites, as well as for mixed stands with spruce and fir on medium sites. Recreation and special forest functions dominate forestry in those forests, which are close to urban areas.

The structure of ownership differs among Austrian regions: large land owners are to be found in the east of Austria and small farmers in the west, while in contrast, the two famous forest regions "Viennese Forest" and "Kobernausser Forest" are owned extensively by the Austrian Federal Forest Stock Corporation (ÖBF AG).

CONSIDERABLE BEECH DISEASES AND PESTS

There are quite a number of pests and insects as well as fungi associated with *Fagus sylvatica* as host and their impact has been mostly underestimated by practitioners (Tomiczek, Perny, Cech 2006). The latest synoptical publications on the situation of beech pests in Austria document the presence of several pests of no economic importance in most of the cases (Tomiczek et al. 2009, 2010). Some examples of pests important for Austrian beech stands are cited below.

Out of the group of insects occurring on the stem or on the bark of beech, *Cryptococcus fagisuga* created a problem for 60 ha of beech stands in 2008 but only for 10 ha in 2010. The beetle *Agrilus viridis* is still present at a potentially dangerous level and the processing of dead beech trees for fuel wood instead of removing the dead tree in time from the forest is problematic in this respect. Amongst the bark beetles, *Taphorychus bicolor* can be observed in many regions of Austria since 2003. *Trypodendron domesticum* is one of the most important timber beetles in Austria, which may cause dieback of beech saplings (Tomiczek et al. 2009, 2010).

An increased activity of *Phytophtora* species was recorded during recent years, where *P. cambivora* was observed most frequently. Furthermore the fungus *Apiognomonia errabunda* resulted in brownish leaves of Upper Austrian beech stands in spring 2008 and in Lower Austria in spring 2009 (Tomiczek et al. 2009, 2010).

HISTORY, FOREST MANAGEMENT AND GENERAL THREATS

Beech was among the last tree species that conquered the Eastern Alps after the last glacial period. The first pollen records date from the period around 5,400 B.C. but the widest expansion was reached 5,000 years later, when beech dominated the forests together with fir and spruce (Kral 1994). Despite early anthropogenic influences, the forest composition of large forest areas was still close to nature at the time of 1000 AD, when beech had a distribution of 20% and was the most common broadleaved tree species (Kral 1994). Beech was cultivated as a fruit tree during the middle age. However, when fuelwood and construction timber became more economically valuable, the percentage of beech was consequently reduced to roughly half of its natural distribution (see above), in particular as beech timber was not transportable by the historical logistic system of water channels.

Huge clearcuts were practiced to provide timber in historical times. At present, the natural regeneration of beech stands dominates as a silvicultural technique in Austria. The classical method is shelterwood cutting of an area between one to three hectares (preparation cutting, seed cutting, several release cuttings and the final cut). The final cut is undertaken, if the regeneration covers most of the area of the stand and the height of young plants reaches 30 to 60 cm (Fig. 1).

Fig. 1: Beech recruitment during the final stage of shelter cut (S. Spinka, 2010)

The treatment goal for the young stand phase is to achieve a dense, homogenous thicket with a high number of well-formed trees at adequate spacing. Sometimes weeding (reducing competitive shrub and tree species) is necessary. The cleaning of the young stands, processed at a height frame of three to six (ten) metres top height, should eliminate wolf trees (forked dominant and co-dominant trees; negative selection). Generally, there are discussions amongst practitioners about the necessity of treatments (intensity, type) in this early stand phase. Therefore treatments are neglected in most of the young stands in Austria. The choice of crop trees as well as the selective thinning, starts at a top height of fifteen to eighteen metres (branch free bottom log of eight to twelve metres) and is already current practice in Austria (Fig. 2). In the second half of the rotation cycle, repeated increment thinning is obligatory up to 20 years before starting the shelterwood cutting.

Over the last two decades alternate silvicultural methods (shelterwood group selection system, target diameter harvesting concept) were discussed and also practised in few Austrian forest enterprises. The main topic of the discussion is the quality development of the stands, in particular of the young stands, which grow up from shelterwood group regeneration.

Fig. 2: Selected target trees in a beech stand of the Viennese Forest (S. Spinka, 2010)

Despite the fact, that two thirds of all young forest stands in Austria originate from natural regeneration (Schodterer 2004), beech transplants are used for the restoration of secondary coniferous stands (see above), where mother trees are not found in sufficient number. The reproductive material for this need must be imported to an extent of 44% (period 1997 – 2006; Anonymous 2008). In 2010, 254 beech forest stands covering an area of 1,556 ha have been approved for seed procurement according to Austrian legislation (Anonymous 2010). The responsible federal forest office BFW targets to increase the area of approved seed stands by an extra 1,745 ha considering the different plant communities and forest ecoregions of Austria (Anonymous 2010).

During the decade from 1997 to 2006, 57 seed harvests were carried out, in 39 stands which resulted in the collection of 2,834 kg of viable seeds (Anonymous 2008). In general, no seed harvest was possible for four years out of ten and a seed harvest of more than 1,000 kg was realized only in 2001 and 2003, respectively (Anonymous 2008). These numbers clearly demonstrate the demands of the market. Since beech is a stand forming tree species abundantly occurring throughout Austria, no seed orchards (*ex situ* units) have been established. In order to meet future requirements for timber production under the climate change constraint, the installation of suitable beech plus tree seed orchards should be discussed for Austria.

The human impact on the *Fagus sylvatica* gene pool in Austria, caused by historical forest exploitation and alteration of forest communities is obvious, but a quantification impossible. Provenance research is urgently needed, in order to define suitable provenances for the restoration of the potential beech forest communities. The possible effects of the ongoing climate change process (Lexer et al. 2001) should be considered when designing those provenance tests in order to define provenances with special conformity or genetic adaptability.

GENE RESERVES AND NATURE RESERVES IN AUSTRIA

Beech forest ecosystems are included in the Austrian programme of gene conservation forests (Geburek, Müller 2006, Konrad, Litschauer, Geburek 2007). These *in situ* gene conservation units have been established in order to conserve genetic resources of regional importance. The Austrian system of forest ecoregions serves as filter at a landscape level for identifying valuable forest stands. The forest authority and the "Austrian Research and Training Centre for Forests" (BFW) select valuable beech stands but the final decision is made in a voluntary manner together with the respective forest enterprise. Subsidies are provided to the owners to compensate special efforts and increased silvicultural management costs. These forests are managed specifically to foster natural regeneration. In this way the natural selection dynamics and adaptive potential of the species are preserved. Today, 106 gene conservation forests with a total area of 3,269.8 ha have been established (Tab. 1).

Tab. 1: Gene conservation forests containing beech as a main or a secondary tree species

Forest type	Number of gene conservation forests	Area (ha)
spruce-fir-beech forest	78	2,819.5
beech forest	26	447.8
sycamore maple-beech forest	2	2.5
Total	**106**	**3,269.8**

The "Austrian Nature Reserve Programme" is a method for protecting valuable forest ecosystems and was initiated as a consequence of the ministerial conference process Ministerial Conference for the Protection of Forests in Europe (MCPFE) in 1993 (Frank, Mueller 2003). Beech as well as spruce-fir-beech forests are of particular relevance for the nature reserve programme, as those forest communities are to be found all over the Austrian forest ecoregions.

The number of existing reserves is given in Table 2 as well as the number of reserves which needs to be established in future in order to cover the Austrian forest communities in a representative way. The success of the "Austrian Nature Reserve Programme" clearly demonstrates the commitment of the forest owners. Thus the future of the programme depends only on the political provision of funds.

Both programmes (the nature reserves and the gene reserves) are valuable methods for preserving the Austrian gene pool of European beech, which complement each other. The nature reserves warrant natural dynamics without active forest management and the gene reserves encourage individual management measures for the respective reserves. Both strategies should be continued in order to meet the challenge of global warming.

FOREST RESEARCH

Fagus sylvatica traditionally has not been the among the main target species in Austrian forest genetics, which may be explained by the dominating economic interest in Norway spruce. Within the Austrian forest monitoring programme, the forest tree fertility, pollen and seed release of beech

Tab. 2: Compilation of different associations of Austrian (sycamore-) beech and spruce-fir-beech forests according to Willner (2007) and their respective representation in the "Nature Reserve Programme" throughout the 22 Austrian forest ecoregions

Forest type	*Association*	Number of reserves	To be established (missing)
beech forests			
	Athyrio distentifolii-Fagetum	0	2
	Carici albae-Fagetum	1	1
	Castaneo-Fagetum	0	2
	Cyclamini-Fagetum	4	6
	Galio odorati-Fagetum	9	7
	Hacquetio-Fagetum	0	2
	Helleboro nigri-Fagetum	1	4
	Lamio orvalae-Fagetum	2	2
	Melampyro-Fagetum	6	8
	Mercuriali-Fagetum	7	5
	Ostryo-Fagetum	2	2
	Taxo-Fagetum	0	1
high montane sycamore - beech forests			
	Saxifrago rotundifoliae-Fagetum	5	4
spruce-fir-beech forests			
	Adenostylo glabrae-Fagetum	5	3
	Anemono trifoliae-Fagetum	2	1
	Calamagrostio villosae-Fagetum	1	6
	Cardamino trifoliae-Fagetum	4	5
	Dentario pentaphylli-Fagetum	1	0
	Isopyro-Fagetum	0	2
	Lonicero alpigenae-Fagetum	1	1
	Luzulo-Fagetum	7	8
	Poo stiriacae-Fagetum	1	0
	Σ	59	72

has been observed for more than 24 years (Litschauer, Konrad 2006). Relatively recent activities were initiated dealing with provenance research and genetic diversity in the species. The project DYNABEECH (2001 – 2004) aimed to assess the impacts of silvicultural regimes on genetic and ecological diversity (Buiteveld et al. 2007). Also the latest international research projects on molecular markers as well as the first international beech provenance test (COST Action E52) involved Austrian research activities (e. g. Comps et al. 1998, Magri et al. 2006). In addition to the international beech provenance trial, a similar national trial has been established in 1995 using a large number of Austrian provenances.

The latest findings can be interpreted in a way that suggests that the glacial refuge of the Austrian beech population may have been in the Balkan Peninsula (Magri et al. 2006). The long-term monitoring of beech flowering and seed production exhibited a more frequent seed production in the south of Austria compared to the north. Moreover, a trend for a better seed harvest as consequence of sufficient precipitation has also been observed together with a subsequently increasing population of seed insects (Litschauer, Konrad 2006)

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Contacts:

Ass. Prof. Dr. Raphael Th. Klumpp
Universität für Bodenkultur, Institut für Waldbau
Peter Jordan Str. 82, A-1190 Wien, Austria
tel.: +431 47654 4063
e-mail: raphael.klumpp@boku.ac.at

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

Patrick Mertens[1] – Elodie Bay[1] – Bart De Cuyper[2]

[1] Département de l'Etude du Milieu Naturel et Agricole, Direction du Milieu Forestier, Avenue Maréchal Juin, 23, B-5030 Gembloux, Belgique/Belgium

[2] Research Institute for Nature and Forest, Gaverstraat 4, B-9500 Geraardsbergen, Belgium

ABSTRACT

Walloon forests cover approximately 555,000 ha with 7,6% beech stands ("hêtre" in French, *Fagus sylvatica* L. in Latin) which represents 7% of forests. It is the second most important broadleaved species after oak, with a wood volume of 10,000,000 m³. It is a native species of the Walloon Region.

Forests in Flanders cover about 150,000 ha, having an afforestation index of 11%. The most important tree species are poplar (45,000 ha) and pedunculate oak (30,000 ha) while beech occupies the third place, covering 21,000 ha.

Key words: *Fagus sylvatica* L., beech, hêtre (in Belgian), Wallon Region, Flemish Region, gene-pool, genetic resources, current status

EUROPEAN BEECH DISTRIBUTION IN BELGIUM

Wallon Region

Five provenance regions were defined according to natural delineations (Fig. 1). Beech is potentially well adapted to the whole Walloon Region. However, 70% of beech forests are located in Ardenne and 15% in Gaume regions. Half of the beech forests is found at higher altitudes greater than 400 m, and more than 75% grows on slope of at least 5° (IPRFW 2000)[1].

Flemish Region

As beech naturally occurs on loamy and sandy-loamy soils, its area in Flanders covers the provenance regions "Brabant District West" and the southern part of "Brabant District East" (Fig. 1).

CHARACTERISTICS AND FOREST MANAGEMENT

Wallon Region

Beech forests cover 42,000 ha in the Walloon region. 89% of those stands are composed of beech, and considered as pure; oaks complete the stand composition. Average basal area of those stands is

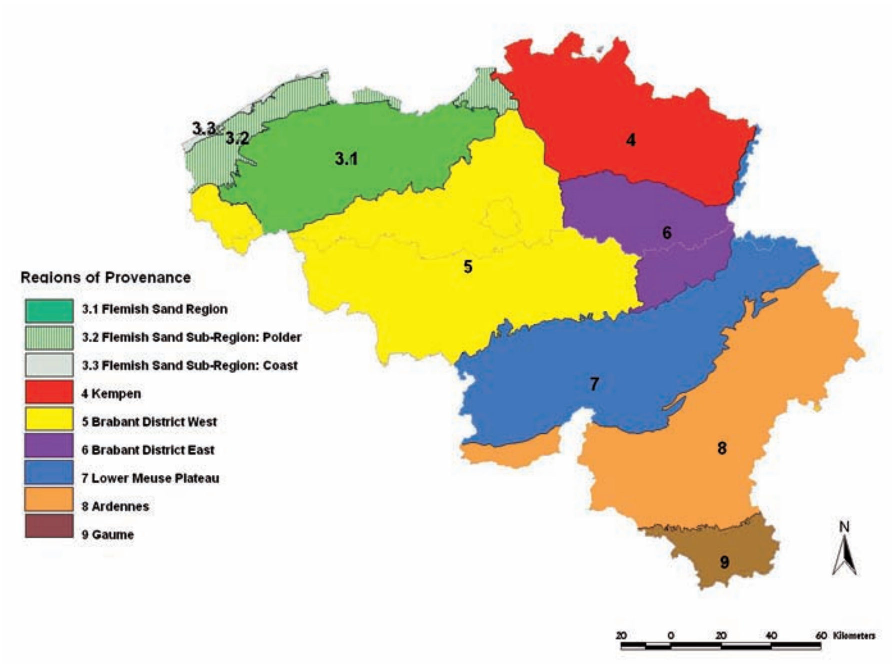

Fig. 1: Provenances regions in Belgium (Vander Mijnsbrugge et al. 2004[2], Orvert 2008[3])

20 m².ha^{-1}. Natural regeneration, revealed by the presence of seedling, thickets or saplings, is observed in 44% of the beech forest area. More than four out of five regenerated trees are beech. There is a contrast in the regeneration, depending on the altitude: under 450 m, the distribution of stem circumferences indicates a multi-storied high forest, while over 450 m there is a clear lack of regeneration (IPRFW 2000)[1]. Even in the case of natural regeneration which was commonly used for regeneration, artificial plantations have become more and more frequent since the 1980s. Reproductive material used mainly comes from Walloon Region. There are five selected seed stands in the region.

Plantation establishment and some crop development works of beech (as well as other species) are encouraged by economic initiatives of the Walloon Region (DGRNE 1997)[4].

Flemish Region

As beech is mostly found together with oak in mixed stands, pure beech stands cover only 4,250 ha. The average volume and basal area amount to 480 m³.ha^{-1} and 33 m².ha^{-1} respectively.

The main beech forest is the Forest of Soignes (Sonian Forest, see Fig. 3), located near Brussels, covering 4,420 ha of which 56% are located in Flanders. Beech constitutes the main species and it accounts for 80% of the basal area. The only Flemish seed stand, covering 1,453 ha, is located in this forest.

BEECH DISEASES AND PESTS

Wallon Region

The Walloon beech forest was subjected to a severe insect attack by bark beetles beginning in autumn 1999 and located throughout the Ardennes area and to a lesser extent in Gaume. The main factor that had increased insect pressure seems to be an intense and unusual cold period in November 1998. Beech bark had been badly injured, allowing xylophagous insects a wide entrance door. The preceded relative warm period could explain why bark was not acclimatized for frost. The bark beetles involved were *Trypodendron domesticum* Er. and *Trypodendron signatum* Er. Injuries caused by insects were also colonized by fungi. Moreover, ethanol produced by injured tissues attracted more and more bark beetles. As a result, 11% of beech were infested in 2001 and 5% in 2002 (these numbers do not take into account damaged trees removed earlier). It was estimated that a volume of 2,000,000 m^3 of beech wood has been damaged between 1999 and 2005 (Huart, Rondeux 2001, Huart et al. 2003)[5,6]. Currently, less attacks by bark beetles were observed, however beech has still the highest rate of defoliation in Wallonia (Laurent, Lecomte 2006)[7].

Flemish Region

In Flanders, diseases and pests do not constitute a major problem. Infections by *Nectria ditissima* and *N. coccinea* and attacks by *Rhynchaenus fagi* and *Apiognomonia errabunda* are recorded only occasionally.

EUROPEAN BEECH GENE POOL PRESERVATION AND CONSERVATION ON NATIONAL LEVEL

For the last ten years, a major effort has been made to increase the number of seed stands of different hardwood species. Today, the results are sufficient for beech to meet the regeneration needs of foresters. Nevertheless, these selections are not directly linked to a general conservation purpose but are mainly done to ensure good timber production potential for the future.

More specifically, the concept of forest reserves has been developed since 1973. Currently, eight forest reserves with a total area of 244 ha have been registered. They generally comprise special ecological sites including beech and oaks.

Conservation *ex situ* was also undertaken using provenance/progeny trials. In the 1950s, different tests were established to study genetic variability in beech at different levels (individual, population, ecological type, provenance). These tests, mainly limited to Belgian populations, completed by observations in natural forests, show an important variability between populations for different characteristics such as flushing, morphology of leaves and growth. In addition, Belgium took part in an international provenance trial in 1988 establishing one site in Paliseul where 74 provenances were compared. These different trials should give more basic information to elaborate a complete long-term conservation program (Jacques, De Cuyper 2003)[8].

Fig. 3: Regenerated stand by clumps in Forêt de Soignes (P. MERTENS, 2009)

Fig. 2: Regenerated stand by trees in Southern Belgium (N. LEMOINE, 2002)

ECOLOGY

There are two main ecological types where beech forest is found: Atlantic and continental. Those are also subdivided according to the pH of soil. Soil and plant associations of the different ecological types are presented in Table 1 (SIBW 2008)[9].

Tab. 1: Characteristics of ecological type associated with beech forest in Wallonia

Ecological type	Trophic feature	Texture feature	Canopy layer	Shrub layer	Herb layer
Atlantic:					
– acidophilic	oligotrophic	sandy to silty-gravel	beech, sessile oak, pedunculate oak, silver birch, rowan	hornbeam, sycamore, hazel, holly, alder, buckthorn	Germanders Bilberry Ferns
– neutrophilic	meso-eutrophic	brown leached	beech, sessile oak, pedunculate oak, ash, maples	hornbeam, hazel, field maple, elder	Anemones Yellow deadnettle hyacinths Lesser celandine Nettle
Continental:					
– acidophilic	oligotrophic	silty gravel, sandy loam, silty sand	beech, sessile oak, sycamore, hornbeam	beech, hornbeam, hazel	Haircap moss Wood-rush Bilberry Bracken fern Hair grass
– neutrophilic	meso-eutrophic	loam, silty sand and pebbly sandstone	beech, sessile oak, ash, maples	hornbeam, hazel, red elder, guelder rose, hawthorn	Woodruff Yellow deadnettle Wood anemone

In the Atlantic type, the neutral soils are more frequent than in continental.

FOREST RESEARCH

In the Walloon Region, the main interest in forest research is to observe phenology and phenotypic plasticity of the main broadleaved species (and notably beech), in order to assess consequences of potential climatic changes, as faced nowadays. This assessment will be achieved firstly by a state of the art of adaptation of current forest tree population, realized under greenhouse conditions. Secondly, evaluation of phenology will be conducted under different regional situations, considering soil temperature at root level.

As for the Flemish Region, on the one hand, research concerning beech focuses on the problems with natural regeneration and measures for its enhancement. On the other hand, new and more accurate tariff tables have been constructed.

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Contacts:

Ir. Patrick Mertens, Ir. Bart De Cuyper
Département de l'Etude du Milieu Naturel et Agricole, Direction du Milieu Forestier
Avenue Maréchal Juin, 23, B-5030 Gembloux, Belgique/Belgium
e-mail: patrick.mertens@spw.wallonie.be, bart.decuyper@inbo.be

AN OVERVIEW OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN BOSNIA AND HERZEGOVINA

Dalibor Ballian

University of Sarajevo, Faculty of Forestry, Zagrebačka 20, 71000 Sarajevo, Bosnia and Herzegovina

ABSTRACT

This work presents the status of beech in Bosnia and Herzegovina. Beech (*Fagus sylvatica* L.) is one of the most important forests tree species in Bosnia and Herzegovina, both from the economic and from ecological point of view. The area of beech forests extends to 665,000 ha, out of which 318,000 ha are occupied by coppice beechwoods (Matić et al. 1971). This paper provides the most important information on the range of this species, conservation of genetic resources, methods of management and its importance for productive forestry.

Key words: European beech (*Fagus sylvatica* L.), common beech, bukva (in Bosnian) distribution, genetic resources, Bosnia and Herzegovina, forestry research

EUROPEAN BEECH DISTRIBUTION IN THE BOSNIA AND HERZEGOVINA

The beech (bukva) (*Fagus sylvatica* L.) shows very good horizontal and vertical distribution in Bosnia and Herzegovina. It grows, in combination with sessile oak (*Fagetum submontanum*), in the lowest forest zones, at higher elevations it can be found in hills, where it forms pure stands (*Fagetum montanum*), and finally in mountain areas, mixed with common fir or with both fir and spruce, forming our most important community of mixed beech and fir forests (*Abieti fagetum*).

The forests growing in the Central Dinarides are very specific; over a very small area there is a broad variety of climate, edaphic, orographic and other factors which all have direct influence on the differentiation of various ecotypes (Stefanović 1977, Stefanović et al. 1983).

According to Fukarek (1970), beech occupies the largest part of forest land in Bosnia and Herzegovina (Fig. 1). If a wide zone in the Western Bosnia and the entire lower Herzegovina with thermophilous sub-Mediterranean vegetation as well as the belt of lowlands and hilly terrain in the North and Northeast Bosnia occupied by hygrophilous and moderately thermophilous sub-Pannonian formations are not considered, the spread of beech is the unique feature of the entire remaining area.

Of course, deeply cut river valleys, karst fields and mountain's summits must be excluded from this area, as beech is rare here. In almost all river valleys, usually the southern slopes from the bottom to

Fig. 1: Distribution of European beech (*Fagus sylvatica* L.) in Bosnia and Herzegovina

the top are occupied by oak forests, whereas beech grows exclusively in depressions or along wet banks of creeks, while northern slopes are almost completely occupied by beech with few exceptions.

First, it is necessary to distinguish between the range of pure beech forests and the range of beech as a species. The extension of beechwoods in Bosnia and Herzegovina is significantly narrower compared with the range of beech alone which, be it single trees or groups, grows in forests composed of oak and hornbeam, or, on the other hand, ascends followed by mountain pine (*Pinus mugo* Turra s. l.) far above the upper forest's limit. Therefore, on the lower distribution limit, beech can be found growing scattered or in mixed stands composed of deciduous trees such as European hornbeam (*Carpinus betulus* L.), field maple (*Acer campestre* L.), sessile oak (*Quercus petraea* (Matt.) Lieblein), lime and some other species. Often beech appears mixed with xerophilous species, such as hop hornbeam (*Ostrya carpinifolia* Scop.), manna ash (*Fraxinus ornus* L.), wild service tree (*Sorbus torminalis* (L.) Crantz), European cornel (*Cornus mas* L.) and others.

Condition of beech at the lower border of its range largely depends on the character of the site. Beech usually occupies fresher, better protected and moister depressions or north-oriented slopes, while on dry and open slopes (often facing west and south) it is unable to compete with oak and other thermophilous species. It is not a rare case that in shadowed places (e. g. river valleys) beech grows at lower altitudes than oak (as a sort of inversion), even it moves from the northern slopes to the opposite south-oriented slopes.

Survival and growth of beech at low altitudes in Bosnia greatly depend on the orientation of a particular river valley. If the river valley is extended from the north to the south (as it is the case of the biggest rivers Una, Vrbas, Bosna and Drina), then the beech line is significantly distant from the valley. If the river valley is oriented from the east to the west, beech descends from the northern slopes to the valley itself, and even is able to cross it. Hence, the extent of the lower beech line depends on ecological conditions of the stand which, under these conditions, are significantly determined by the terrain form and shape.

Beech reaches its upper distribution limit only in some of the western and southern Bosnian and Herzegovinian mountains with an altitude above 1,900 m. Summits of these mountains are overgrown by the stands of mountain pine, where beech occupies favourable locations (north-oriented slopes) and individually can ascend up to 1,800 m. In addition to the mountain Plješevice located on the border with Croatia, this is the case of the following Bosnian mountains: Klekovača, Dinara (Troglav), Kamešnica, Šator, Vitoroga, Golija, Kujača, Cincar, Malovan, Raduša, Vran, Vranica, Bjelašnica, Treskavica, Jahorina, Zelengora, Maglić (Vučevo) and Ljubišnja, in Herzegovina parts of Bjelašnica (Krvavac), Visočica, followed by mountains Prenj, Čvrsnica and Velež. On the other hills and mountains, beech does not reach its upper limit, so either pure submontane beechwoods or mixed fir-spruce-beech forests cover the highest locations.

The attached map of the beech range shows that Bosnia and Herzegovina is crossed by two important vegetation and geographical range lines, forming internal limits of beech distribution within its own range. One is the border of steppe (in a wider sense) or thermophilous and hydrophilous zone vegetation of the oak forests of Pannonia; the other is the border of evergreen and thermophilous Euro-Mediterranean vegetation of the Adriatic area.

CHARACTERISTICS AND FOREST MANAGEMENT

Beech is one of the most important forest trees in Bosnia and Herzegovina, viewed both from the economic and ecological aspects. The forest cover of Bosnia and Herzegovina represents 2,710,000 ha of forests and forest land, covering approximately 53% of its territory (Stojanović et al. 1986). High forests represent 1,266,000 ha, low forests, stumps and coppices 918,000 ha. Moreover, there are bare lands and glades of 390,000 ha suitable for afforestation, and 130,000 ha of arid soils. Of the overall forest area, pure beechwoods represent 660,000 ha, of which there are 345,000 ha of high and 318,000 ha of low forests (Matić et al. 1971). In addition, beech is found in mixed forests composed of beech and fir or beech, fir and spruce mixture at an area of 565,000 ha. In that way, the total area of forests containing beech is 1,225,000 ha. Out of that, 93% are natural or semi-natural forests, which is significant in comparison with the European average where the proportion of natural or/and semi-natural forests is rather low. Based on this, Matić, Pintarić, Drinić (1969) elaborated guidelines for management, however, they were subjected to many changes.

Beech forests in Bosnia and Herzegovina have different characteristics, but the specific feature of beech forests in central Bosnia is that an important area of pure beech forests are of secondary origin (Beus 1984). They were created from mixed beech and fir stands or beech-fir-spruce mixture through human activities already during medieval times and as such represent a transitional stage of vegetation. In addition to natural forests making significant portion, there are seven relatively well-preserved primeval forests with a high concentration of beech: Ravna vala on the Mountain Bjelašnica, Janj, Lom, Mačen do, Trstionica and Plješevica, as well as the most important European prime Peručica. Many scientific studies have been undertaken here, among them works by Drinić (1956), Fukarek (1962, 1964a, b), Stefanović (1970, 1988), Pintarić (1978, 1997), Leibundgut (1982), later, research was conducted in the prime forest Janj and Lom (Maunaga et al. 2001), Trstionica (Ballian, Mikić 2002). All the prime forests are mixed, with a great proportion of beech. Prime forest Mačen occupies a special place, and has hosted research on beech structure (Mešković 2007).

When presenting a review on the systems of management of beech forests in Bosnia and Herzegovina, the following basic facts must be taken into account: in spite of a common primeval-forest origin (they were all primeval forests until 90 – 100 years) beech stands in Bosnia and Herzegovina do not have similar structural composition. According to Bozalo (1991) there are great differences in density, growth and structure between different stands but also within an individual stand. Most frequently there is a regular network of patches in the stand composed of two even-aged layers; the upper layer is composed of rare older trees and lower layer is formed of offspring, heterogeneous in every way. Between them, there are often patches without undergrowth with only a few old trees or insufficiently regenerated patches without old trees. On average, the quality of these beech trees is very poor, but again there are differences between as well as within the stands in this respect.

Considering the described composition and structural build of beech stands, management systems based on clearcuts or shelterwood cutting have never been applied. In the area of the Krivaja river, clearcutting was implemented on larger areas for some time, and also on smaller areas in the central Bosnia, aiming at replacing beech by coniferous forests, but it did not bring good results. The negative effects of this activity are visible up to the present because it resulted in highly degraded stands occupying highly productive soils.

As the selection cutting, which was the most common method in beech forests, was not an acceptable solution, there were more attempts to work out a better-suited way of management within some already established management systems. This is why Pintarić (1991) promoted combined natural regeneration.

This focused on satisfying three demands: 1) to increase permanently the amount and quality of crop, 2) to maximize the use of mechanization in the manipulation of forests assortments and 3) to preserve and improve other permanent commonly useful functions of beech forests.

Bozalo (1991) and Pintarić (1991, 2000), based on the actual situation and the structural composition of beech forests in Bosnia and Herzegovina, natural and working conditions, and biological and ecological characteristics of beech, found a solution in the system of management by selected group cuttings in stands. The advantages of this system compared to clearcuttings on larger areas, classical shelterwood and selection cutting, concerning the regeneration of stands, increasing crops and improving quality, are all well known. This management system is also advantageous regarding other public-benefit functions of beech forests. In other words, within this management system there was a need to develop ways of work that would allow for higher use of mechanization in wood-manipulating operations, but also use of knowledge in genetics and breeding.

Coppice beech forests were managed exclusively by clearcutting, aiming at conversion into coniferous forests, but Pintarić (1986) advocated tending to improve the structure of beech stand. Consequently, during the last five years, a system of management by selection was developed (Matić 1985) and implemented in stands in the age category 40 – 60 years, with a small financial gain (Koričić 2004). Based on this system, smaller stands in western Bosnia have been converted into high forests over several years. The experiences with artificial planting of beech forests are unsatisfactory because beech plants are produced occasionally in small amounts as plant production requires seed crops, which are very rare. This is one of major factors causing a lack of experiences with artificial planting of beech and implementation of improving measures. On several occasions, there were attempts of seeding beech stands, but it was done sporadically and on a smaller scale.

PRESERVATION AND CONSERVATION OF GENETIC RESOURCES OF EUROPEAN BEECH

The area of Dinarides is very specific both by its terrain shape and its climate and this is the main reason why it represents an important center of vegetation diversity. Therefore, many experts suggested that forests trees in the Dinarides area show higher levels of genetic variability compared with the north. This applies also to beech, as confirmed by research conducted by Gömöry et al. (1999) and Brus (1999), which showed that a high variability is characteristic not for central Europe but the Balkans, and especially for Bosnia and Herzegovina.

As beech gained in importance in Bosnia and Herzegovina during the last fifteen years, there were attempts to extend the sources of reproductive material, seed bases. Thirteen seed stands were

Fig. 2: A typical beech forests in eastern Bosnia, Mt. Konjuh (*Fagetum montanum*)

established aimed at seed production, and at present they are considered to be important for the conservation of the autochthonous gene pool. Special activities were carried out in declaring protected beech forests, usually located in protected areas around water sources. In this way several stands in Bosnia and Herzegovina were declared to be protected. However, in relation to the protection of the gene pool, prime forests are of special interest, since beech plays a special role in their structure and because all prime forests belong to forest communities of beech-fir forests (*Abieti fagetum*) which are under permanent protection.

FOREST RESEARCH

In the past, research on beech was not a matter of high importance because beech had been considered a weed species until twenty years ago. Lately, but still with rather late when compared to developments in Europe, efforts were made in establishing research on the genetic structure of this valuable species. An experiment with twenty two European provenances was launched within the COST Action E52. The experiment was located on a typically degraded beech stand near Kakanj in Central Bosnia. Current research is directed towards the molecular-genetic research on beech, in cooperation with foreign laboratories. At present the results are partially complete; there are ongoing isoenzymatic analyses that will provide us with new information on the genetic structure of beech originated from the Central Dinarides, and there are plans for conducting comprehensive morphological research.

Fig. 3: Beech forest on the Mt. Šator (*Fagetum subalpinum* s.l.)

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Reviewed

Contacts:

Prof. Dalibor Ballian, DSc.
University of Sarajevo, Faculty of Forestry
Zagrebačka 20, 71000 Sarajevo,
Bosnia and Herzegovina
e-mail: balliand@bih.net.ba

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) AND ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY) GENE-POOL IN BULGARIA

ALEXANDER H. ALEXANDROV – ALYOSHA DAKOV

Forest Research Institute – Sofia, Bulgarian Academy of Sciences
132 St. Kliment Ohridski blvd., Sofia 1756, Bulgaria

ABSTRACT

European beech (*Fagus sylvatica* L.) distribution in Bulgaria is presented, incl. a map, general characteristics of beech forests: areas, ecology, species composition of stands, ecological, morphological and phenotypic beech forms, health status, regeneration and silvicultural practices, harvested wood, as well as gene pool conservation and research. Briefly data are presented on oriental beech (*Fagus orientalis* LIPSKY).

Key words: European beech, obiknoven buk (in Bulgarian), oriental beech, iztochen buk (in Bulgarian), gene-preservation, in situ conservation

INTRODUCTION

Some beech populations in southeastern Europe survived during the Quaternary due to their distribution in areas without glaciations. At present *Fagus sylvatica* L. and *Fagus orientalis* LIPSKY are species with primary forestry importance for Bulgaria due to their wide natural distribution, important environmental functions and valuable timber. The wide range of European beech determines its large ecological, morphological and phenological variability according to the altitude, forming the upper forest limit in some mountains. The good beech seed yields in the country are defined in the management directions relying mainly on the natural regeneration and only in unfavourable conditions – on afforestation. During the last years the investigation interest in beech increases at national and at Paneuropean level.

DISTRIBUTION

European beech (*Fagus sylvatica* L.)

The natural distribution of this species covers Stara planina (Balkan range), Sredna gora, the Rhodopes, Rila Mt., Pirin Mt., Belasitsa Mt., Osogovo Mt. and Vitosha Mt. (Fig. 1). It is distributed from 100 – 200 m a. s. l. up to 1,800 m although tree groups and solitaires could be found outside these limits. The lowest populations of European beech are located at 150 m in Bozhuritsa Locality, Vidin region – north-west Bulgaria and at 200 – 300 m in Ludogorie – north-east Bulgaria.

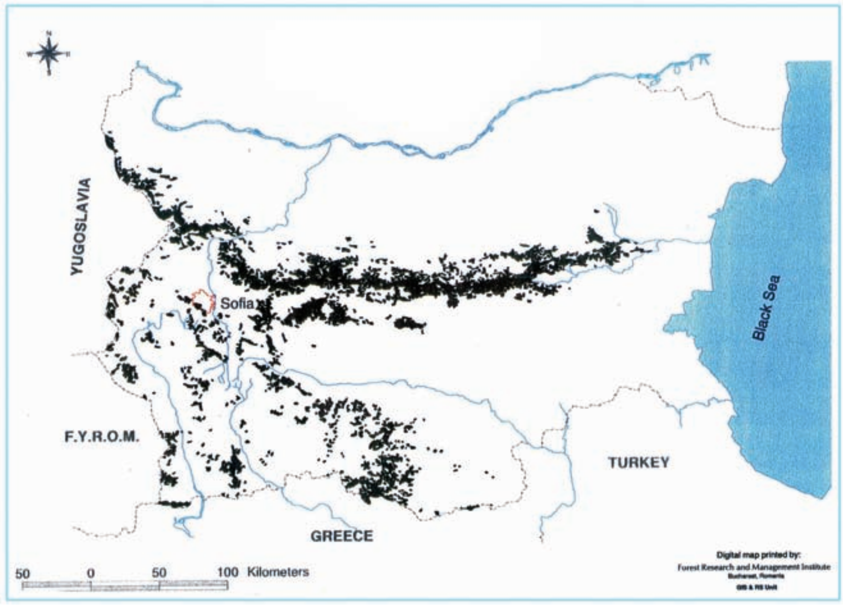

Fig. 1: Natural distribution of *Fagus sylvatica* in Bulgaria

Oriental beech (*Fagus orientalis* Lipsky)

The natural distribution of oriental beech is in the eastern part of Balkan peninsula, Asia Minor, Crimea, the Caucasus and Iran, in Crimea being located from the sea level up to 2,300 m above sea level (Delkov 1988). The taxonomic status of *Fagus orientalis* Lipsky is uncertain according to Greuter et Burdet (1981), Tutin (1993), Denk et al. (2002) who tend to accept it as subspecies of *Fagus sylvatica* L. The discrimination between both beeches by means of biochemical markers is considered by Busov (1995), Gailing et von Wuehlisch (2004).

In Bulgaria oriental beech is distributed in the Strandzha Mt., in parts of Eastern Rhodopes and Eastern Stara planina (Eastern Balkan range), where on west it reaches Vurbitsa pass and on east – to Obzor and Dvoynitsa river (Fig. 2). At an altitude above 700 m it is substituted usually by European beech.

GENERAL CHARACTERISTICS

Beech forests occupy the second place – 18.7% of the forest area in the country, after the oak ones (36.1%). Totally the beech forests cover 685,150 ha, of which 416,570 ha are high-stem. The growing stock is 189,267,500 m^3 or 30.1% of Bulgarian forests, while the high-stem beech forests comprise 114,535,110 m^3 with annual increment of 4.06 m^3/ha (Kostov, Rafailova 2009).

The human activity during the last 30 – 40 years led to about 20% increasing of beech growing stock as well as to increasing of the relative part of the coppice beech forests.

Fig. 2: Map of natural range of *Fagus orientalis* L. in Bulgaria

Fagus sylvatica L. forms both large pure stands and mixed ones with some deciduous species such as hornbeam, sycamore, durmast oak, Norway maple, Balkan maple, limes, common ash, silver birch, aspen, rowan, wild service tree and bird cherry. In the higher parts of the mountains it mixes with coniferous species as Norway spruce and silver fir, rarely with Scots pine and Macedonian pine. Large European beech forests occur in the mountain belt on north slopes and on fresh to wet rich soils. The mixed hornbeam-beech stands are about 100,000 ha, 70,000 ha of them being in the Balkan range.

The most productive are the mixed stands of European beech, Norway spruce and silver fir, which in Parangalitsa reserve of the Rila Mt. at 1,400 m reach growing stock of 1,600 m^3/ha.

During the last decade a process of beech area extension to higher altitudes has been observed as a result of climatic changes and limited pasture.

Oriental beech as a Pontic species is a colonizer in the Strandzha Mt., where it forms mixed stands usually on north exposures. The species most frequently concomitant are evergreen shrubs as *Rhododendron ponticum* L., *Laurocerasus officinalis* Roem. and *Ilex colchica* Pojark. In East Balkan range *Fagus orientalis* occurs in deep defiles and on north exposures up to 550 m a. s. l. In the mixed stands it grows with *Carpinus betulus* L. and more limited with *Tilia tomentosa* Moench., *Acer pseudoplatanus* L. and other deciduous species.

The ecological conditions in the wide altitudinal range of *Fagus sylvatica* L. distribution in Bulgaria determine the presence of the following ecotypes (Dobrinov, Doykov, Gagov 1982, Alexandrov 1990):

1. Pre-mountain and hilly-plain ecotype. It is located from 150 – 200 m up to 500 – 600 m in the hilly parts of north Bulgaria and Predbalkan, respectively, in the region of Vidin and Shumen plateau at 350 – 400 m. The hilly-plain ecotype is characterized with longer vegetation period and some xerophyte features as thick cuticle and pubescent leaves.
2. Low-mountain type. It is located in the altitudinal range from 500 – 600 m to 800 – 900 m where it forms pure and mixed stands with *Quercus petraea* Liebl., *Carpinus betulus* L., *Tilia* spp., *Acer pseudoplatanus* L., *Fraxinus excelsior* L., etc.
3. Middle-mountain ecotype. Its distribution is from 900 – 1,000 m to 1,300 – 1,400 m. It has the most qualitative stems, fast growth and highest wood productivity. Some individuals reach up to 40 m height, and the growing stock of stands – up to 800 – 900 m^3/ha.
4. High-mountain ecotype. It is located at an altitude of more than 1,400 m and reaches up to 1,700 – 1,800 m, where, in some areas in Balkan range, the Pirin Mt. and Osogovo Mt. forms the upper boarder of the forest. The growth is slow, and the stems are of lower quality.

According to the branching habit of stem there are:
1. single-stem form;
2 forked form which could bifurcate once, twice, etc.;
3. bunch-form.

According to the bark cracking there are described:
1. smooth-bark form;
2. with small bark fissures;
3. f. *fraxinoides*; 4. f. *quercoides*.

According to the bark colour there are pale-bark and dark-bark (lead-coloured) forms.

In general the individuals with fissured bark are of slower growth, stem benching and less resistance.

According to the direction of beech wood fibres there are twist fibre and straight-fibre forms, which are inherited (Dobrinov, Doykov, Gagov 1982). The twist fibres are non-desirable characteristics and this is the reason why these individuals are removed during thinnings.

The polymorphism according to the size and form of the leaves covers the following forms:
1. f. *grandifolia*; 2. f. *parvifolia*; 3. f. *rotundifolia*; 4. f. *carpinifolia*; 5. f. *quercifolia*. The last one is suggested to be a bud mutation.

As about the phenology the most discernable are the early- and late-flushing forms with 2 – 3-week difference of the phenophases. The late-flushing form, similarly to the oak, is of straight-stem, with small tapering, narrow crown, finer branches, fast growing, better quality timber and more resistant to diseases and pests. The early-flushing form is the most frequently bench-stem one.

From tree breeding point of view the most valuable are the individuals with monopodial or high forked stem, smooth silver-grey bark, narrow pyramidal or conic crown, fine branches and late-flushing.

The ornamental forms with pyramidal crown (f. *pyramidalis*) or with pendulous branches (f. *pendula*) and according to the leaf colouring are applied for gardening: dark red (f. *purpurea*), multicoloured and three-coloured – white leaves with green spots and pink edges.

The health status of beech forests is good and they are of high vitality. It is determined by the site conditions, incl. climatic and pedologic, insects and fungal background, the age of the stand and management. In general, beech forests are weakly attacked by insect pests.

20-year investigations of International Co-operative Programme 'Forests' indicate that in comparison with other main tree species in the country the state of European beech is the best one (MEW, MAF, UF, FRI, 2006).

The following diseases are of significant practical importance: wood rots, caused by wood-destroying fungi Basidiomycetes, as well as stem and branch canker, caused by the fungus *Necrotia ditissima*.

Some abiotic factors such as windbreaks and ice breaks, although rarely, cause significant damages. In November 2007, about 500,000 m^3 wood mass, mainly from pre-mature stands (60 – 80 years old) were broken and fell due to windbreaks and ice breaks in Balkan range beech forests (the State Forestry Etropole, Botevgrad and Vitinia) within the altitudinal range of 700 – 800 m up to 1,100 – 1,200 m.

The felling with preliminary natural regeneration is the basic management way of forests in Bulgaria especially during the first half of the 20th century (Vachovski, Dimitrov 2003).

In the pure beech stands shelterwood felling and group-selection system are usually applied, the number of the phases and their duration depending on the regeneration.

In the mixed beech stands, especially with species with contrast ecological requirements, as those by beech, fir and spruce, the single tree selection system is the most suitable.

The clearcutting in the high-stem forests has been forbidden by Forestry Law since 1992.

When the regeneration with beech at some site conditions is missing or is insufficient and no additional natural regeneration is expected, only afforestation with beech seedlings is reliable and applied during the last 3 – 4 decades. The area afforested with beech reached 2,652 ha in 1987 and after that followed a significant reduction of afforestation with this species – 1,467 ha (1990), 309 ha (1994), 121 ha (2000), 74 ha (2005).

The production of beech seedlings – 1,250,000 in the year 2000, 5,070,000 (2002), 2,000,000 (2008) – is realized most frequently in a traditional way – in open nurseries or in temporary nurseries under the canopy of beech stands preliminary thinned to density of 30%.

Beech timber production reached 2,990,000 m^3 (139.2% of the growth) in 1960, after that decreased to 2,267,000 m^3 (110.4% of the annual increment) in 1970, to 1,175,000 m^3 (77.5%) in 1980, to 775,000 m^3 (61.1%) in 1990 (Garelkov et al. 1995). During the period 2000 – 2005 the average wood harvesting of beech was about 1,100,000 m^3 of which 810,000 m^3 in high-stem beech stands, 250,000 m^3 in coppice and 40,000 m^3 in reconstructed beech stands, the ratio of the main fellings being 64% (Kostov, Rafailova 2009).

GENE-POOL CONSERVATION

The most reliable method for conservation of beech gene pool is *in situ*. It includes genetic resources of genus *Fagus* in the three national parks – Central Balkan, Pirin and Rila, in seven natural parks, in reserves, and all approved seed production stands.

The total area of *in situ* gene conservation of European beech was 41,724 ha or 6.1% of genus *Fagus* area in the year 2005, mentioning a significant increasing in comparison with the year 2000, when it was 32,759 ha, while of the oriental beech it was 5,882.3 ha (2005), insignificantly changed from 5,819.1 ha (2000) (Alexandrov, Pandeva 2007).

Of all forest tree species in the country the largest area of *in situ* conservation represents the genus *Fagus* – totally 47,606 ha (32.8%), i. e. 6.9% of beech territory.

European beech occurs in the tree composition of 44 reserves in the following mountains: the Balkan range, Sredna gora, Vitosha, Rila, Pirin, Slavianka, Osogovo and the Rhodopes at altitudinal range of 330 m (Vulchi gorge) up to 1,740 m (Shabanitsa). The average age varies from 60 years at Vrachanski karst to 270 in Shabanitsa. Some of the reserves as Steneto, Boatin, Dzhendem and Tsarichina comprise valuable beech genetic fund.

Oriental beech appears in 6 reserves, out of which five are in Strandzha Mt. (Lopushna, Silkossia, Sredoka, Tissovitsa and Vitanovo) and one in Eastern Balkan range (Kirov dol) at altitudinal range from 190 m up to 480 m. The average age is from 100 years for Vitanovo to 150 years for Kirov dol (Turok et al. 2000).

The *in situ* gene conservation involves also the virgin forests, of which 75% are in the protected territories. Within the total area of virgin forests in Bulgaria of 103,356 ha or 2.9% of the total forest area of the country, beech virgin forests cover 32,338 ha or 31.3% of the virgin forests (Veen, Raev 2006).

The seed stands of *Fagus sylvatica* L. are on 12,550 ha and of *Fagus orientalis* Lipsky – 740.3 ha, which together present about 2% of genus *Fagus* area; they are sufficient enough for seed production purposes of these species in the country. They represent valuable autochtonous populations that could be used for export of beech seeds to other European countries.

RESEARCH

Investigations of beech forests being done for several decades in Bulgaria resulted in publishing of three books as follows: Marinov, Nedyalkov, Naumov (1961), Garelkov, Turlakov (1978) and Garelkov et al. (1995). They deal with biology and ecology of the beech, its distribution, typology of beech forests, structure, growth and productivity of beech ecosystems, its management, afforestation, diseases and pests, and prognoses for the future of beech forests.

On the base of long-term investigations Dobrinov, Doykov, Gagov (1982) published "Forest genetic fund in Bulgaria" in which, among the deciduous species, the first place is dedicated to beech (*Fagus* spp.).

In the field of breeding and forest plantations of beech two Ph.D. theses (Garelkova 1980, Botev 1988) were defended, and one, on variability and selection of *Fagus sylvatica* L. in the Central Balkan (Dakov 2010), is under preparation.

During the last 1 – 2 decades a few population genetic surveys in beech were carried out in the Balkans, including some Bulgarian populations. The presence of rare alleles in the Rhodopes Mountains populations was found out proving their autochthonous nature and refugia origin at glaciation time (Hazler et al. 1997). Polygenesis and genetic differentiation of beech on the Balkan peninsula reveal the taxanomical status of its populations (Gömöry et al. 1999).

Under the auspices of the International Plant Genetic Resources Institute (IPGRI 1998) a project was realized on "Genetic resources of broadleaved forest tree species in Southeastern Europe" with participation of Bulgaria, Romania and Moldova. The project investigation on the genetic resources of *Fagus* spp. were published in a brochure of Turok et al. (2000).

During the period 1995 – 2009, planned into phases I, II, III of European Forest Genetic Resources Programme (EUROFGEN), investigations of the economically most important species in Europe were realized, grouped into 5 networks, *Fagus* spp. was included sequentially in the following networks: Social Broadleaves, Temperate Oaks and Beech, Stand-forming Broadleaves. A paper on the genetic resources of Bulgarian Social Broadleaves including those of European and oriental beech was published by Alexandrov et al. (1999) in an EUFORGEN edition.

Within the programme COST (European Cooperation in the Field of Scientific and Technical Research) including a project COST Action E52 "Evaluation of beech genetic resources for sustainable forestry" (2006 – 2010) articles on survival, growth and ecophysiology of 49 beech provenances from 20 European countries were published by Alexandrov, Pandeva, Dakov (2006), Velinova, Naydenova, Dakov (2008, 2010).

The beech genetic resources of the Balkans and in particular of Bulgaria are valuable resource for the European forestry, especially for the South and Southeast Europe, where they could be used in suitable sites. The studied provenances at different ecological conditions via the programme COST Action E-52 give opportunity for selection of the most suitable ones for the expected climate changes.

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Contacts:

Prof. Alexander H. Alexandrov, DSc.
Forest Research Institute
Sofia, Bulgarian Academy of Sciences
132 St. Kliment Ohridski blvd., Sofia 1756, Bulgaria
e-mail: forestin@bas.bg

CURRENT STATUS OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENETIC RESOURCES IN CROATIA

Mladen Ivanković[1] – Saša Bogdan[2] – Joso Gračan[3] – Ivan Pilaš[4]

[1] Croatian Forest Research Institute, Division for Genetics, Tree Breeding and Forest Seed Husbandry, Cvjetno naselje 41, 10450 Jastrebarsko, Croatia
[2] University of Zagreb, Faculty of Forestry, Department of Forest Genetics, Dendrology and Botany, Svetošimunska 25, 10000 Zagreb, Croatia
[3] Hrvoja Macanovića 43, 10000 Zagreb, Croatia
[4] Croatian Forest Research Institute, Division for Ecology and Silviculture, Cvjetno naselje 41, 10450 Jastrebarsko, Croatia

ABSTRACT

This paper presents general data on European beech genetic resources in Croatia and provides an overview of forest genetics research activities. In the first part, the paper deals with the horizontal and vertical distribution range of the species and its habitat characteristics. Basic information on forest management, seed zonation as well as general information about threats to genetic resources follows. Finally, a review on conservation efforts, including the development of *in situ* and *ex situ* conservation units as well as research work on provenance testing are presented.

Key words: beech, distribution range, habitat, conservation, provenances, research

DISTRIBUTION AND HABITAT

The European beech (Croatian names: obična bukva, bukva prosta, bukva šumska, buk, bukva) is one of the most important forest tree species of the Republic of Croatia. Pure or mixed beech stands constitute quite stable ecosystems, and are mostly naturally regenerated. It is the most common tree species in Croatia, where it accounts for 47% of the forest area (Vukelić, Rauš 1998) and forms 45% of total wood growing stock. According to Klepac (1986), pure beech stands occupy an area of 200,000 ha, mixed stands with sessile oak and hornbeam accounting for 700,000 ha while mixed stands of beech, silver fir and Norway spruce occupy an area of 200,000 ha. It is considered as one of the most vital forest tree species in Croatia, since pure and mixed stands are not significantly damaged by pests, diseases and air pollution (Glavaš, Harapin, Hrašovec 1992, Potočić, Seletković 2000).

The European beech woodland appears in many types of forest communities and is widespread both horizontally and vertically. In the lowlands it occurs as a secondary species in forests of pedunculate oak and common hornbeam. Its share in the low hills increases and reaches its culmination and the highest commercial value in the highlands up to 800 m, where it forms climatozonal communities in which it has distinct dominance. Above this area it occurs in mixed stands with silver fir. Horizontally, the para-Mediterranean vegetation zone occurs in the Dinaric Alps that extend along the Adriatic coast, while in the continental part northward of the Dinaric Alps, the features of the Illyrian vegetation zone decrease and those of the Central European vegetation zone of acidophilic forests increase (Vukelić, Baričević 2003).

In the lowlands, the species can be found at minimum altitude of 100 m above sea level, where it is the secondary species in stands of pedunculate oak and hornbeam (Matić, Oršanić, Anić 2003). In the mountains of central Croatia and mountains between the Sava and Drava rivers, it can be found mainly on the northern slopes between 350 and 750 m a. s. l., within pure or mixed stands with sessile oak, hornbeam and sweet chestnut. In the area of Gorski Kotar the species reaches 700 m a. s. l. in pure stands, while at higher altitudes it is in mixed stands with silver fir. In the Dinaric Alps it can be found up to 1,500 m a. s. l. European beech also grows at altitudes above 200 m on the slopes of the Dinaric Alps along the northern Adriatic coast (Učka, Senjska Draga), where it forms so-called para-Mediterranean vegetation zone (Matić, Oršanić, Anić 2003).

Beech forests are under the influence of almost all climatic types occurring in Croatia, according to Köppen's classification. It favours areas influenced by moderately warm summers, high precipitation (between 716 and 2,523 mm) and shorter winters, as well as with mean annual air temperatures between 7 and 10 °C. The distribution range of the species in Croatia can be divided in four distinctive climatic regions. The first region is situated in the eastern Pannonian part of Croatia, which is characterized by a moderately warm rainy climate (climate type *Cfwb"x"*). The second region is situated in the western Pannonian part (climate type *Cfwbx"*). In comparison with the previous one, this type is characterized by somewhat higher annual precipitation which ranges from 806 to 1,255 mm. The other two climate types occur west and south-west from the Karlovac-Topusko line. Those are type *Cfwbx"* (a moderately warm rainy climate, but with somewhat higher annual precipitation than in the western Pannonian region) and *Dfsbx"* (boreal climate). The boreal climate type influence areas above 1,200 m a. s. l. In this region, the driest part of the year occours in the warm season. Precipitation is marked by two maximums, one in early spring and one in the late autumn. Mean annual precipitation ranges between 1,106 and 2,523 mm. The mean annual air temperatures range between 3.9 and 10.0 °C, dependent on the altitude. The region is characterized by significant temperature extremes where absolute temperature fluctuations rise to 66.5 °C. Frost is a frequent phenomenon, with late spring frosts often occurring even in late June. The beech forests in the area of Lika and Gorski Kotar mostly grow on indented terrain and permeable soil substrates with numerous different microclimatic conditions which is a typical characteristic of this region (Seletković, Tikvić 2003).

In the lowland region the occurrence of beech is linked exclusively to micro-elevations out of the reach of floodwaters, with deep gleyic hydromorphic soils (fluvisols and planosols) or terrestic (automorphic) soils (eutric cambisols and luvisols). In general, from the hilly to the subalpine zone, pure beech stands or mixed oak-beech and beech-fir stands are usually found on different automorphic, very rarely hydromorphic soil types. Within its range in Croatia, beech is completely absent from sites with extreme edaphic conditions (dry and shallow soils on dry terrains and sunny expositions, positions with stagnant groundwater in the rhizosphere (Pernar, Bakšić 2003).

FOREST MANAGEMENT

Most beech forests in Croatia are managed as even-aged forest stands. They are usually regenerated naturally by the shelterwood method. Natural regeneration results from seeds from the mature trees standing in the regenerating area. However, problems with natural regeneration arise in stands with disturbed structure, where canopy openings give rise to invasion of weeds which impair normal regeneration. That is why seed and nursery raised stock have increased in importance due to interventions needed in the stands undergoing a regeneration phase. Interventions constitute measure of artificial regeneration in normal beech stands on the basis of inadequate natural regeneration, or a tending measure in the adequate stocking of insufficiently regenerated areas. Seeds and seedling are also frequently used in uneven-aged beech-fir stands, in which increasing fir dieback creates gaps, as well as in the conversion of deciduous and coniferous forest of other species established in potential beech sites (Matić, Oršanić, Anić 2003). In those cases and according to the law on forest reproductive material, seeds and seedlings should originate from the same provenance region, respecting altitudinal distribution types.

The regeneration of beech stands is based on the shelterwood method consisting of three to five cuts (so-called: preparatory cut, seed cut, one or two additional cuts and the final clearfell). Regenerating cuts are applied on smaller or larger areas and regeneration periods range from 10 to 20 years.

The selective cut method has been applied for regeneration of mixed stands of European beech and silver fir in the mountain zone of the Dinaric region (Matić, Skenderović 1993, Matić, Oršanić, Anić 2003).

SEED ZONE DELINEATION AND FOREST REPRODUCTIVE MATERIAL LEGISLATION

The first seed zonation of European beech forests in Croatia was made in the 1950s (Šafar 1958), and afterwards by the Department for Control of Forest Seeds in 1963 (Gradečki, Poštenjak, Regent 1990). Another zonation was made in the 1990s (Gračan et al. 1995, 1999).

In 2008, a new seed delineation was made according to the regulations on provenance regions of economically important forest tree species, made under the Law on Forest Reproductive Material (Official Gazette 2005). The European beech forests are delineated in four provenance regions and eleven seed units (Fig. 1).

2.2. Provenance region of mountain beech forests (300 – 800 m a. s. l.)
2.2.1. Dilj and Psunj seed unit
2.2.2. Zagorie and Bilogorie seed unit
2.2.3. Žumberak and Pokuplie and Banovina seed unit
2.3. Provenance region of Pannonian beech and fir forests (800 – 1,000 m a. s. l.)
2.3.1. Papuk seed unit
2.3.2. Slieme seed unit
2.3.3 Zagorie seed unit
3.3. Provenance region of Dinaric beech and fir forests (700 – 1,200 m a. s. l.)
3.3.1. Gorski kotar seed unit
3.3.2. Kapela and Velebit seed unit
3.4. Provenance region of coastal beech forests (800 – 1,000 m a. s. l.)
3.4.1. Istra seed unit
3.4.2. Velebit and Dinara seed unit
3.4.3. Mosor and Biokovo seed unit

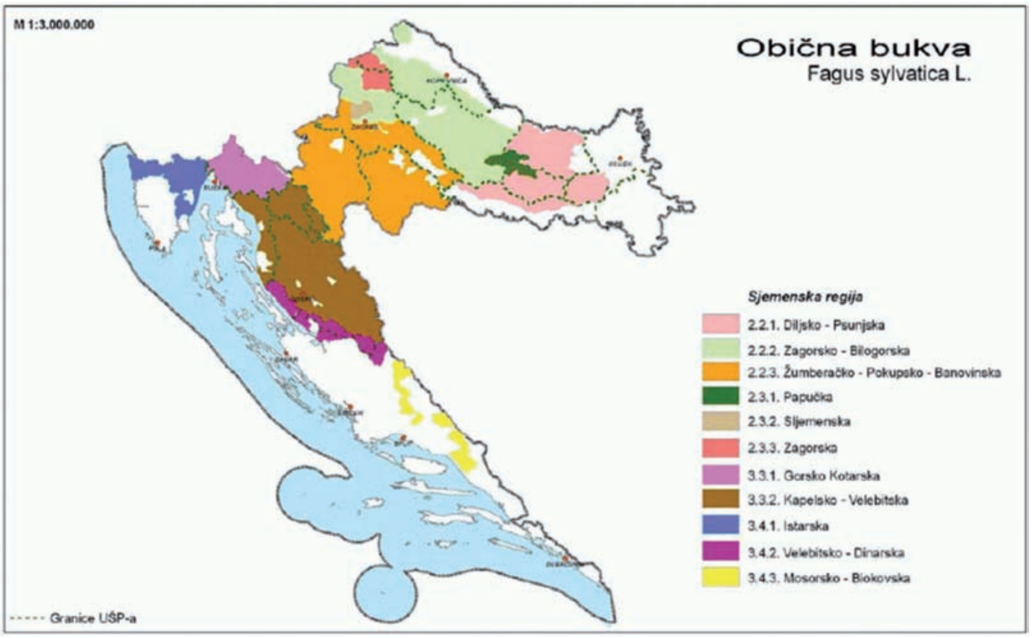

Fig. 1: Provenace regions and seed units of the European beech (NN 107/08)

THREATS TO THE GENETIC RESOURCES

European beech is considered as the most vital tree species in Croatia. To date, there have not been any significant damages in the beech stands caused by diseases or insects. Compared to other economically important tree species, European beech shows better resistance to forest decline. Defoliation status of the beech in Croatia for the period 1987 – 2001 showed that severe damage varied between 4.2% and 11.9%, which was lower than in the rest of Europe (Potočić, Seletković 2000). No continuity was found in the deterioration of the condition of the beech in any of the damage classes. It fluctuated, depending on the strength of diverse unfavourable ecological and biological factors. In other tree species, such as silver fir, pedunculate oak, sessile oak, Aleppo pine, black pine and others, the condition was significantly worse in all damage classes (Prpić et al. 2003).

However, the assessment of beech defoliation from 1999 to 2001, showed considerable differences between various areas. A particularly high percentage of significantly defoliated trees was found in the area of Zagreb (39.4%) and Požega (20%) cities. Local differences could be explained by air pollution caused by industries and traffic. Also, significant beech defoliation was found along the busiest tourist roads (Prpić et al. 2003).

Decrease of mean precipitation and severe droughts have been frequently recorded since 1990. Droughts are most dangerous for the beech in lowland and hilly areas, while higher altitudes are less exposed due to higher relative air moisture (Harapin 2003).

Beech has been under strong anthropogenic influence for a long time. It has been used for fuelwood, building material, charcoal, and other purposes. Sometimes, intensive cuttings have resulted in dry soil, dry-topped crowns and tree and stand dieback. Beech, as a sciophyte, is very sensitive if its bark is directly exposed to the sun. Poor management practice in some beech forests or large infrastructural changes (highways, canals, retentions, etc.) resulted in forest gaps, soil dehydration, bark sun scorch, physiological weakening and tree dieback and decline of beech stands over large areas (Harapin 2003).

CONSERVATION AND FOREST GENETICS RESEARCH

Considering *in situ* conservation measures, beech as one of the most valuable forest species, can be commonly found in four national parks (Plitvice Lakes, Risnjak, Paklenica and Northern Velebit), four nature parks (Velebit, Medvednica, Biokovo and Papuk), two nature reserves (Bijele stijene and Samarske stijene).

Additionally there are 15 seed stands which occupy a total area of 568 hectares, as well as 12 stands which serve as conservation units with the total area of 1,088 hectares. As a result of *ex situ* conservation efforts, two provenance trials were established, which occupy a total area of four ha. The beech forests protected within national parks, nature parks, reserves or seed stands are managed in a natural and sustainable way. It means that management is directed toward promotion of biodiversity and its self-regeneration capacity in the protected areas.

The first research on the European beech provenance variation in Croatia started in the early 1990s when the Croatian Forestry Institute participated in the international project "Assessment of beech genetic resources for adequate use in sustainable forest management" (Gračan, Ivanković 2001, von Wuehlisch 2007). The first provenance trial was established in 1995 in the region of the Forest Office Bjelovar. Unfortunately, severe drought and damage by rodents led to a high plant mortality in the trial. During the spring of 1998 a second international provenance trial was established in the region of the Forest Office Kutina (trial "Kutinska Garjevica"). The trial was established with 15 indigenous and 21 exotic provenances originating from other parts of Europe. At the same time, another provenance trial which comprised only indigenous provenances was established in the region of the Forest Office Duboka. A third provenance trial was established during the spring 2007 on Medvednica mountain, close to the city of Zagreb (Fig. 2). Both trials are included in the COST Action E52 "Evaluation of Beech Genetic Resources for Sustainable Forestry".

Assessments of height growth and survival in the field trial "Kutinska Garjevica" began soon after its establishment. The results of those assessments in 1998, 1999 and 2000, show that average survival rate were 76.0% (1998), 60.7% (1999) and 58.1% (2000). The provenance P 59 (Pidkamin, Ukraine) had the highest survival percentage of 96.0% (1998), 95.3% (1999) and 94.7% (2000), while the lowest survival percentage was shown by provenance P 67 (Bilowo) from Poland: 47.0% (1998), 30.1% (1999) and 24.6% (2000).

Survival of indigenous provenances, namely P 13 (Samobor), P 14 (Pisarovina) and P 10 (Ivanjska) was also high, just below provenance P 59. All provenances from Croatia had a survival rate higher than the average for the trial. Survival of Croatian provenances ranged from 83.3% (P 13) to 64.7% (P 2 Sjeverni Dilj and P 7 Bjelovar Bilogora). Provenances from Slovenia also had higher than average survival rate (58.1%). Mean trial heights were 40.7 cm (1998), 46.6 cm (1999) and 70.1 cm (2000).

Fig. 2: International beech provenance trial Medvednica from the series 2007

The highest average height in year 2000 had provenance P 5 (Sjeverna Babja gora 110.6 cm), P 12 (Vurberg, Slovenia 107.0 cm) and P 14 (Gračec Lučelnica 104.0 cm). The lowest mean heights were observed in provenances P 64 (Nižbor, Czech Republic 40.9 cm), P 23 (Torup, Sweden 41.1 cm), P 67 (Bilowo, Poland 41.5 cm) and P 21 (Grasten, Denmark 41.6 cm).

On the basis of conducted research work and by comparing common provenances in the Croatian and Slovenian trial, it was observed that some provenances showed phenotype stability under different site conditions, while on the other hand, some provenances showed specific adaptability to environmental conditions which prevailed in the two trials. Typical provenances that showed specific adaptability and quite unstable mean phenotypic values were P 13 (Soignes from Belgium), P 14 (Aarnink from the Netherlands), P 46 (Domažlice from the Czech Republic) and P 67 (Bilowo from Poland) (Ivanković, Bogdan, Božič 2008).

It should be noted that studies undertaken on growth traits and flushing phenology in Croatian provenance trials of the European beech indicate ecotypic pattern of genetic diversity (Jazbec et al. 2007, Ivankovic, Bogdan, Božič 2008) which coincides with some other results (Comps et al. 1991, Paule 1995, Gömöry, Hynek, Paule 1998, Chmura, Rożkowski 2002).

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Reviewed

Contacts:

Dr. sc. Mladen Ivanković, Dr. sc. Sasa Bogdan
Croatian Forest Research Institute, Division for Genetics, Tree Breeding and Forest Seed Husbandry
Cvjetno naselje 41, 10450 Jastrebarsko, Croatia
e-mail: mladeni@sumins.hr, sasa.bogdan@zg.htnet.hr

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENETIC RESOURCES CONSERVATION IN THE CZECH REPUBLIC

Petr Novotný – Josef Frýdl

Forestry And Game Management Research Institute

Strnady 136, 156 04 Praha 5-Zbraslav, Czech Republic

ABSTRACT

The paper describes the current state of European beech (*Fagus sylvatica* L.) in the Czech Republic. It provides information on the horizontal and vertical distribution of the species, together with data on its actual representation in forest stands, plant communities and on the site conditions, in which it occurs. While in the past E. beech natural composition in the Czech Republic forests was 3,170,000 ha or 40.2% of the current total area of the Czech Republic, the present composition of the species is very different, with just 182,048 ha, or approximately 7.0% of the present area of forests in the Czech Republic. The reasons for this are that most beech stands were harvested for glass manufacturing and for charcoal production. Another factor is that in the past some mixed beech stands were replaced by Norway spruce monocultures. However, at present the area of European beech has increased and this is reflected in a higher proportion of this species in the present tree species composition. As well as information on the E. beech gene pool preservation and conservation programme, there is also information on E. beech current *in situ* and *ex situ* gene conservation activities. The current state of forestry research on beech and other related activities are also described.

Key words: European beech (*Fagus sylvatica* L.), buk lesní (in Czech), distribution, gene-pool current state, Czech Republic, forestry research

EUROPEAN BEECH DISTRIBUTION IN THE CZECH REPUBLIC

Forest land covers 2,660,734 ha in the Czech Republic out of a total area of 7,886,519 ha. The composition of forest tree species has considerably changed in the past two and a half centuries as a result of intensive forest management. Replacement plantations of coniferous tree species have also been recommended since the 18th century.

While the natural species composition included beech (40.2%), oaks (19.4%), fir (19.8%), spruce (11.2%) and pine (3.4%), the present species composition is rather different. The proportions of spruce (52.4%) and pine (17.0%) are higher. Oaks (6.8%), beech (7.0%) and fir (< 1%) are under-represented with regard to the original species distributions (Report about Forest State and Management of the Czech Republic in 2008). Most beech stands were harvested and the wood was used in glass manufacturing as well as for charcoal production. Mixed beech stands were replaced by Norway spruce monocultures and oak stands by pure pine stands.

European beech is distributed almost over the entire Czech Republic, with a concentration in the mesophyticum and oreophyticum regions. A small population of European beech is recognized in the thermophyticum, while in the regions that have been utilised for agriculture this species is missing. European beech is the most important broadleaved species in the Czech Republic, from an economic point of view. Its occurrence is recorded from about 300 to 1,000 m a. s. l., mainly from the supracolline to the mountainous level, however it rarely occurs on northern slopes especially on limestone at the colline level. The minimum elevation limit of this species is in the locality of Dúbrava at Hodonín (South Moravia, altitude 220 m), and the valley of the Labe river close to Hřensko (North Bohemia, altitude ca 120 m – inversion site). According to Koblížek (1990), the altitudinal maximum of European beech is recorded in a rocky area close to the Black Lake locality of the Šumava Mts. (South Bohemia, altitude 1,240 m), as well as on the southern slopes of the Krkonoše Mts. (Eastern Bohemia, altitude 1,200 m), and the locality of Velká Kotlina in the Hrubý Jeseník Mts. (North Moravia, altitude 1,250 m). The centre of European beech distribution is recorded as in the beech forest vegetation level, where this species formed pure stands in the past. At lower levels, where European beech forms mixtures with oak, this species grows mostly on northern slopes or inversion sites with higher soil humidity. European beech does not grow in floodplain forests. Where European beech occurs at higher elevations, it forms mixed stands with Norway spruce and silver fir.

In the Bohemia region, extensive mixed stands of European beech have remained in the Šumava Mts. (South Bohemia, altitude 650 – 1,000 m), considerable remnants of beech woods are recorded in the Český les (Bohemian Forest) Mts., as well as the Novohradské hory Mts. and the Blanský les (Blanský Forest) Mts., (e. g. localities called Královský hvozd, Boubín, Žofínský prales). European beech occurrences at lower altitudes are recorded in the Krušné hory (Ore Mts. – 400 – 700 m a. s. l.) and the Lužické hory (Lusatian Mts.). In the Jizerské hory Mts., Krkonoše (Giant Mts.) and Orlické hory Mts., the occurrence of European beech is rare (average upper distribution limits is about 900 m in these localities). Larger occurrence of European beech is recorded in sub-mountainous regions of the above mentioned mountains. Similarly European beech occurrence is recorded in the Králický Sněžník Mts. and Jeseníky Mts. Remains of original beech woods are located around Českomoravská vrchovina (Bohemian-Moravian Highland) (e. g. in localities of Žákova hora, Křemešník), and in other areas (Železné hory Mts., Blaník Mt., Kostelec nad Černými lesy region, Císařský les /Císařský Forest/, Drahanská vrchovina Highland, Oderské vrchy Highland). In addition, European beech occurrence is recorded in the Brdská vrchovina Highland and in the locality of Hřebeny, in very poor site conditions. Greater representations of European beech are recorded both in the Doupovské hory Mts. and in České středohoří Middle Mts., and is probably as a result of local nutrient basaltic base sites.

In the Moravian region, European beech is abundant in the areas of the Chřiby Highland, Malé Karpaty Mts. and Bílé Karpaty (White Carpathians) Mts. In the Beskydy (Beskids) Mts., European beech was largely artificially replaced by Norway spruce. Considerable remains of autochthonous beech woods are located in natural reserves, such as Mionší National Nature Reserve and Salajka National Nature Reserve, including natural reserves managed both at the Radhošť Mt. and Kelečský Javorník Mts. (Úradníček 2004).

CHARACTERISTICS AND FOREST MANAGEMENT

The territory of the Czech Republic is divided into 41 Natural Forest Regions, delimited by geographic, geomorphologic and climatic conditions (Plíva, Žlábek 1986). Ecological conditions affect the representation and formation of regional populations which are adapted to local conditions. There are nine forest altitudinal zones (FAZ) in the Czech Republic. Beech occurs naturally from FAZ 2 to 7. Beech stands survived in extremely steep areas, where it was impossible to carry out artificial regeneration with spruce. At these locations beech also regenerates naturally.

European beech distribution map in the Czech Republic are published in Čermák et al. (1955), Götz (1966), Moravec, Neuhäusl (1976), Slavík (1990), Neuhäuslová et al. (1998). The actual distribution range of European beech in the Czech Republic according to the National Forest Inventory is presented in Figure 1.

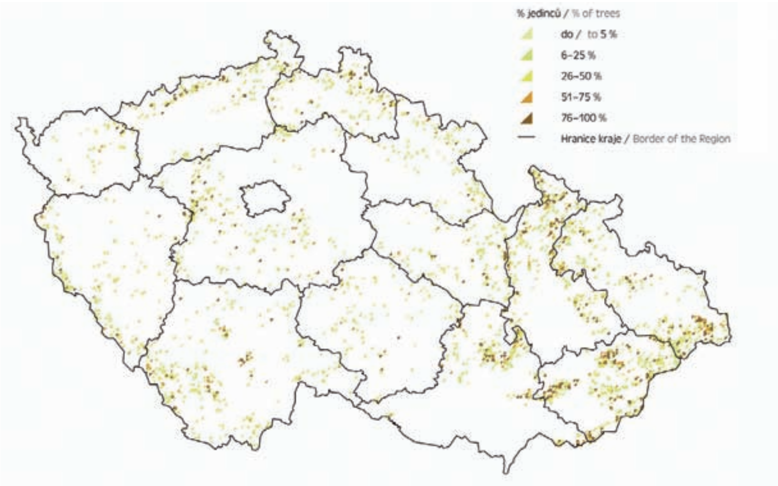

Fig. 1: Present distribution range of European beech in the Czech Republic (Source ÚHÚL: Národní inventarizace lesů v České republice 2001 – 2004)

In the Czech Republic, European beech is represented in three associations: Herb-rich woodlands (*Eu-Fagenion* Oberdorfer 1957 em. Tüxen in Oberdorfer et Tüxen 1958) – beech, silver fir-beech and lime-beech climax or subclimax woodlands (*Fagus sylvatica, Abies alba, Tilia cordata, T. platyphyllo*s) with frequent herbs or grasses, on siliceous brown forest soils (brown earths, cambisoils) in the submontane and montane levels. Calcicolous beech woodland (*Cephalanthero-Fagenion* Tüxen in Tüxen et Oberdorfer 1957) – beech woodland (*Fagus sylvatica*) on rendzina soils on substrates rich in carbonates or with an admixture of $CaCO_3$, mostly in the submontane or montane, rarely colline, levels. Acidophilous beech and silver fir woodland (*Luzulo-Fagion* Lohmeyer et Tüxen in Tüxen 1954) – mesophilous species-poor beech and silver fir woodland on oligotrophic siliceous soils, mostly in the submontane to supramontane levels, and waterlogged oak-beech woodland on pseudogleys at lower elevations in north-eastern Moravia (Neuhäuslová et al. 1998).

European beech wood is often characterized by "red heart", however, it is possible to obtain valuable assortments from higher parts of stem, while affected parts are usually processed for firewood or cellulose (Úradníček et al. 2001).

According to the Report about forest state and management of the Czech Republic in 2008, the average quality of tested seeds of European beech was described as having the following characteristics: 70% viability of pure seeds and 69% germination. The stock of seed and raw seed registered in the Seed Production Plant at Týniště nad Orlicí was 17,688 kg of pure seed and 5,764 kg of raw seed. Artificial regeneration of European beech recorded in recent years are as follows: 3,386 ha (2000), 2,908 ha (2001), 3,143 ha (2002), 3,032 ha (2003), 3,406 ha (2004), 3,275 ha (2005), 3,433 ha (2006), 3,625 ha (2007) and 3,865 ha (2008).

According to the long-term monitoring of forest condition, average defoliation of European beech in stands older than 60 years was 22.5% in the period 1991 – 2006. Within this period, mean defoliation decreased in 1998 to the lowest level (14.6%), then increased slightly, and there has been only a minor change from 2000 to date.

In 2008, average prices of beech round wood in the Czech Republic were as follows: Assortments of logs of the 1st class = 3,877 CZK (ca 152 €)/m^3, 2nd class = 2,829 CZK (ca 111 €/m^3), 3rd A/B class = 1,762 CZK (ca 69 €/m^3); 3rd C class = 1,389 CZK (ca 55 €/m^3); 3rd D class = 1,111 CZK (ca 44 €/m^3) and pulpwood of the 5th class = 908 CZK (ca 36 €/m^3).

For current legislative rules in the Czech Republic, there is a valid Forest Act no. 289/1995 Gaz. together with several executive decrees of the Ministry of Agriculture, implementing this act. Marketing of forest reproductive material is regulated by Act no. 149/2003 Gaz. and its executive decrees.

The following basic materials of European beech had been registered in the Czech Republic up to 31. 12. 2009 (www.uhul.cz):

- Category identified (seed source – 9 trees; 756 stands of phenotype class C /23,045.38 ha/; 27 stands of phenotype class B /252.78 ha/; 1 stand of phenotype class A /7.38 ha/).
- Category selected (692 certified stands of phenotype class B /10,740.29 ha/; 637 certified stands of phenotype class A /2,613.50 ha/).
- Category qualified (7 seed orchards /9.69 ha/; 287 plus trees).

In the Czech Republic 107 European beech genetic conservation units (60,073.27 ha) have been registered. These measures are aimed at the preservation and conservation of European beech gene pool.

EUROPEAN BEECH GENE POOL PRESERVATION AND CONSERVATION

As already mentioned, the proportion of European beech has decreased from an original 40.2% to a current level of 7.0% as a consequence of forest management over the past 200 years (Report about forest state and management of the Czech Republic in 2008). However, regeneration of European beech has been steadily increasing and this is reflected in the higher portion of this species in overall tree species composition (Tab. 1). Mean age of beech forest stands has also been increasing up to 2000 (73 years), which implied total aging of European beech population in the Czech Republic. However current data show that an increase of mean age has stopped (70 years in 2008). The plan to increase the proportion of European beech in the Czech Republic to 18% is now evident, but it will be necessary to pay attention to additional artificial regeneration, despite increasing natural regeneration. The origin of reproductive material to be used for artificial regeneration has to meet requirements of related national (Ministry of Agricultural Decree no. 139/2004 Gaz.; Fig. 2) and international legislative rules on reproductive material zoning.

Tab. 1: European beech proportion and mean age in forest stands of the Czech Republic

	1950	1970	1980	1990	2000	2008
%	4.5	5.0	5.3	5.4	6.0	7.0
ha	102,243	129,158	135,988	140,130	154,791	182,048
yrs	66	67	69	71	73	70

Report about forest state and management of the Czech Republic in 2006
Report about forest state and management of the Czech Republic in 2008

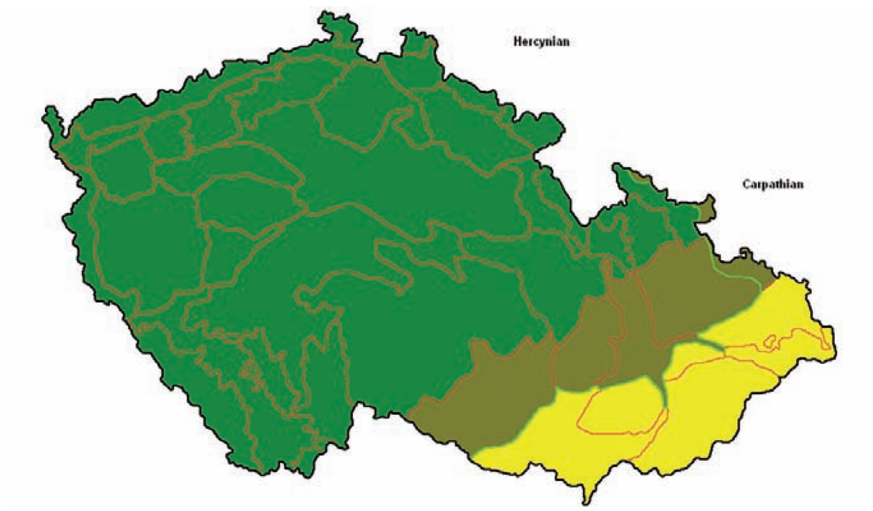

Fig. 2: General delimitation of areas with approved horizontal transfer of European beech reproduction material in the Czech Republic; according to current legislation

CURRENT GENETIC CONSERVATION ACTIVITIES *IN SITU* AND *EX SITU*

Passive gene conservation of beech populations *in situ* has taken the form of nature reserves. The gene conservation units are considered an active way of gene conservation and reproduction. These units are groups of stands with a minimum area of 100 ha. Here natural regeneration of target species is obligatory. If natural regeneration is not successful, it is possible to use a reproductive material coming from these units for their artificial regeneration. Guidelines for the management of individual gene conservation units are elaborated by the FGMRI Strnady (Novotný, Frýdl, Čáp 2008).

The most important *ex situ* conservation activities are grafting and establishment of clonal archives and seed orchards. Up to now, one clone archive of beech, covering seven altitudinal forest vegetation belts, was established for the most polluted areas of Krušné hory (Ore Mts.). The establishment of special plantations for obtaining secondary cuttings is another method of *ex situ* conservation. Besides, some beech genetic resources have been conserved within the existing seed banks and tissue culture banks.

FOREST RESEARCH

Provenance research of European beech in the Czech Republic over the past 38 years revealed numerous valuable findings on height growth characteristics of various subpopulations in various site conditions of research provenance plots, that have been established and examined, to-date. These research plots are of long-term character, and continue to provide importance results with increasing age.

Two maps are presented (Fig. 3 and 4) with examples of locations of beech forestry research in the Czech Republic. This type of research is very important for the management of genetic resources in the Czech Republic.

Current research projects present possibilities for solution of problems with European beech in the Czech Republic. FGMRI Strnady, Department of Forest Tree Biology and Breeding. has been carrying out the national research project QF4025 "Applications of the results of the European beech (*Fagus sylvatica* L.) genetically conditioned variability verifying for the gene resources protection and reproduction and for this species increasing in the forest stands of the Czech Republic". This project was financed by the Ministry of Agriculture of the Czech Republic through the National Agency for Agricultural Research. This project started at the 1st February 2004 and finished 31st December 2007.

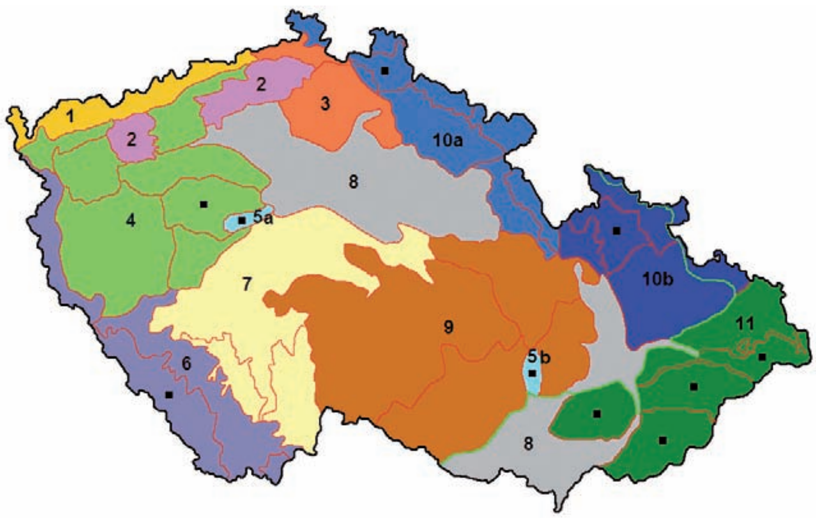

Fig. 3: Delineation of the proposed seed zones for European beech in the Czech Republic (According to Hynek 2000)

The main purpose of the project was to realize breeding measures, directed to the protection and reproduction of European beech gene resources and to contribute to creating conditions for saving and increasing proportion of this species in the forest stands. Evaluation of the provenance plots series 1972, 1984, 1995 and 1998 provided additional information about the variability of beech, mainly about viability and production potential of individual beech populations. This information will be used for streamlining of seed harvesting from the certified forest stands and for the purpose of seed zoning. The positively verified subpopulations have been used as the basic material for autovegetative propagation with the aim to create a set of trees grown especially for production of cuttings. The actual findings from provenance research of European beech are mentioned e. g. in the papers of Novotný (2006), Novotný et al. (2007), Novotný, Frýdl (2010), Novotný, Frýdl, Čáp (2010).

Current international COST Action E52 "Evaluation of Beech Genetic Resources for Sustainable Forestry" and national research project COST MŠMT OC08009 "Participation of the Czech Republic in evaluating European beech (*Fagus sylvatica* L.) provenances with the aim to judge their utilization in forestry regarding expected climatic changes" provide another possibility for continuation and extension of research activities aimed at European beech in the Czech Republic.

Another national research project COST MŠMT OC08022 „Ecophysiology of beech proveniences and their sensitivity to growth environments" contributes to scientific investigation of beech ecophysilogy and adaptation capabilities under the conditions of expected climate change. Some results of this research were published (Košvancová 2009, Košvancová-Zitová 2009)

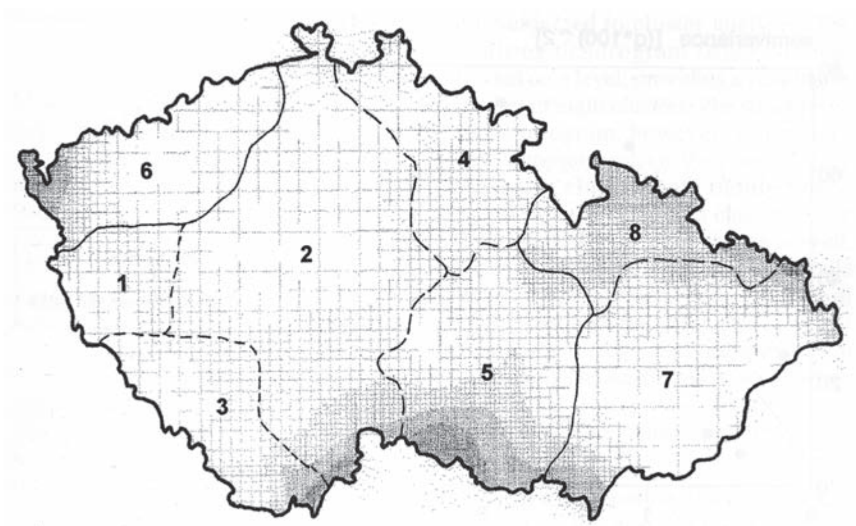

Fig. 4: Delineation of proposed seed zones for European beech in the Czech Republic based on isozyme gene markers (Gömöry, Hynek, Paule 1998)

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Contacts:

Ing. Petr Novotný, Ph.D., Ing. Josef Frýdl, CSc.
Forestry and Game Management Research Institute
Strnady 136, 156 04 Praha 5-Zbraslav, Czech Republic
tel.: +420 257 892 228, +420 257 892 271
e-mail: pnovotny@vulhm.cz, frydl@vulhm.cz

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN DENMARK

Jon K. Hansen

Forest & Landscape Denmark, Hørsholm Kongevej 11, DK-2970 Hørsholm

ABSTRACT

European beech (*Fagus sylvatica*), is the most important broadleaved species as regards forest area and production. The species today covers 13% (69,000 ha) of the forest area in Denmark and 31% of the total area with broadleaved species in Denmark. The species is mainly growing on more fertile moraine soils in east Denmark, but is used more frequently in west Denmark as well as on poorer sandy soils. The health status of the species has improved since the mid-1990s, when it was poor, probably due to drought. The species is mainly naturally regenerated. Provenance experiments have revealed only small differences between Danish provenances in growth, but these experiments have also revealed that it is possible to improve stem straightness especially using specific provenances from Switzerland or Slovakia. However, these provenances are also more prone to late frost in the spring due to earlier bud burst than Danish provenances.

Key words: European beech (*Fagus sylvatica* L.), bøg (in Danish), distribution, provenance research

EUROPEAN BEECH DISTRIBUTION IN DENMARK

European beech is the most important broadleaved species covering 13% of the total forest area and 31% of total area with broadleaved species in 2006 (Nord-Larsen et al. 2008). The species is mainly distributed to the eastern Isles of Denmark and eastern parts of Jutland characterized by more fertile soils such as clayey and sandy moraine in contrast to the western part of Jutland with sandy soils. In 2006, the percentage of the total forest cover with beech was 8% in Jutland and 24% at the Isles and the total area 71,614 ha (Nord-Larsen et al. 2008).

HEALTH STATUS

Defoliation recorded in sample plots from 1988 to 2006 showed a steady decrease in leaf loss after a period in the mid-1990s with larger leaf loss possibly associated with drought and large mast years (Thomsen et al. 2008). Health status as measured by degree of defoliation is possibly associated with precipitation in the growing season as seen in the period 1989 – 2006 (Thomsen et al. 2008).

FOREST MANAGEMENT

European beech in Denmark is mostly growing in even aged monocultures, perhaps with a few trees of ash (*Fraxinus excelsior*) and sycamore (*Acer pseudoplatanus*). The species is both planted and naturally regenerated. Additionally, beech is the constituent part in the understorey of oak forests. The management regime might change to natural regeneration in smaller plots combined with mixtures with other species to ease natural regeneration (Larsen 2005). Planting of beech is subsidized by the state when planted in existing conifer forest and as afforestation.

In 2005 the harvest of beech was 224,700 m^3, 60,400 m^3 of which were used for logs and veneer and the remaining for fire wood (Statistics Denmark 2007).

GENETIC RESOURCES

Beech in Denmark is largely naturally regenerated. From 2001 – 2006 the average annual seed harvest and import of seed was 13.9 tons. The annual seed harvest from approved Danish stands of Danish origin was 7.5 tons and the annual seed harvest from approved Danish stands of any origin 11.7 tons, while the annual import was 2.2 tons (Bastrup-Birk et al. 2008). Danish seed sources should be approved (Bekendtgørelse om skovfrø og planter 2007). The total area with approved seed stands, i. e. in the category of selected resources is 485 ha. The country is considered as one seed zone concerning beech.

The Forest and Nature Agency has recently approved a number of beech stands of known local origin around the country. These stands will serve as gene conservation stands and restrictions will be made concerning planting of beech in surrounding stands (units) (Ditlevsen, pers. comm.).

Provenance field trials have only shown small differences between Danish provenances as regards growth and stem form and actually only statistical certain differences as regards growth. Provenance field trials with European provenances have revealed larger differences as regards the percentage of trees with straight stems and timing of bud burst (e. g. Hansen et al. 2003). Especially the Swiss provenance Sihlwald has shown to be superior as regards stem straightness and two approved Danish seed stands are of this origin. The use of this species, however, should be restricted to areas less prone to late frost since the buds of this provenance (like Slovak provenances) burst early.

RESEARCH PROJECTS

Research topics focussing on beech are dealing with natural regeneration, nutrient leaching, and carbon sequestration in near natural managed forests and with the development of individual tree growth models.

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Contacts:

Jon Kehlet Hansen, Ph.D.
Forest & Landscape Denmark
Hørsholm Kongevej 11
DK-2970 Hørsholm
tel.: +45 3533 1635
e-mail: jkh@life.ku.dk

EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN FRANCE

Alexis Ducousso

Genetic team, UMR BIOGECO, INRA

69 route d'Arcachon, 33612 CESTAS cedex

ABSTRACT

European beech is the third most important forest species in France after pedunculate oak (*Quercus robur*) and sessile oak (*Quercus petraea*). It covers an area of 1,392 millions hectares (public forests: 773,000 ha and private forests: 619,000 ha) which represents 9.3% of the forest cover (IFN 2008). The public forests represent 26% of the forest area but public ownership amounts to 55% of the beech forests. The main beech forests are located in the plains of the north-east and in the mountains (Vosges, Jura, Alps, Massif Central and Pyrenees) but it has an important position in the plain of the north west (Normandy and Picardy) (Fig. 1). It is present in the Mediterranean region at mountainous level (Corsica, Luberon, Ventoux, Lure, Verdon, etc.). Marginal populations are found on the plain of the south-west (Roquefort, Ciron valley, etc.) and in the Mediterranean region (Cagnes sur Mer, Massane, Valbonne, Sainte Baume, etc). The beech forests are slowly expending. The standing volume is $260*10^6$ m^3 (11%) and the annual production is $8.4*10^6$ m^3 per year (8%). The individual number is $884*10^6 + 50*10^6$. With such a distribution, beech is subjected to various climatic and soil conditions.

Key words: European beech (*Fagus sylvatica* L.), hêtre (in French), genetic resources, research

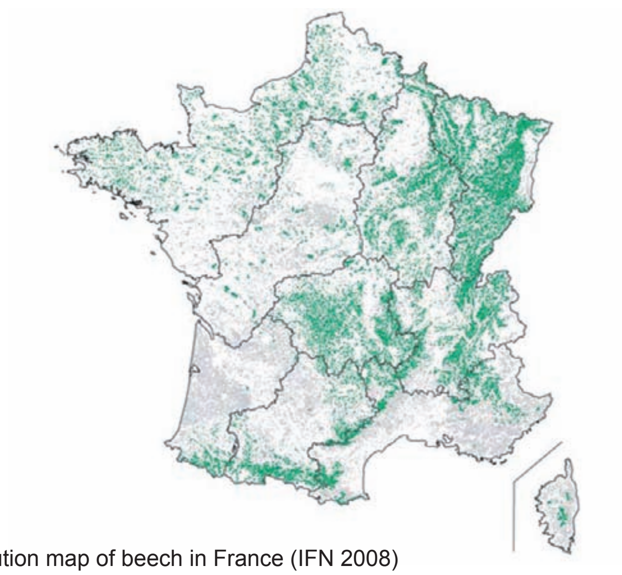

Fig. 1: Distribution map of beech in France (IFN 2008)

CHARACTERISTICS AND FOREST MANAGEMENT

Beech is found in different types of forests, the most common are beech and oak-beech forests in the plains (*Carpino betuli-Fagenalia* and *Quercelia roboris*), beech and fir-beech forests in the mountains (*Fagenalia sylvaticae* and *Acerion pseudoplatani*).

The main silvicultural management is high forest (65%) followed by high forest with standard (26%) and coppice (9%) (Tab. 1).

Tab. 1: Silvicultural management for the beech forests in France

Silviculture	Surface	%
High forest	904,800 ha	65
High forest with standard	361,920 ha	26
Coppice	125,280 ha	9

The wood prices (Tab. 2) range from 3 €/m^3 to more than 175 €/m^3 therefore quality is a high priority but the best qualities (A and B) represent only 16.4% (Tab. 3). Several factors account for this low percentage: high forests are too dense, pathological problems, defaults like nodes, etc.

Tab. 2: Beech wood prices in France in June 2008 (Anonymous 2008)

Quality	Length (m)	Diameter (cm)	Wood price (€/m^3)
A	3	55 and more	175 and more
B	3	50 and more	35 – 123
B	2.5	45 and more	72 – 110
C	3	45 and more	30 – 40
C	2	35 and more	15 – 25
C	1.5	35 and more	16 – 20
D	1.8	30 and more	12 – 17
D	1.5	30 and more	3 – 7

Tab. 3: Volume and price of beech wood sold in Lorraine according to quality during the period 1994 – 1996 (Bastien, Hein, Chavane 2005)

Quality	Percentage	Price
A	0.6	323 €/m^3
B	15.8	168 €/m^3
C	48.1	81 €/m^3
D	35.5	38 €/m^3

In order to increase the production of wood of good quality, silvicultural norms are evolving. The foresters are reducing cycle and density and are trying to promote mixed stand (up to 20%) with maple, oak, fir, wild cherry, wild service tree, etc.

GENETIC RESOURCES MANAGEMENT IN FRANCE

Natural regeneration is of high priority but plantations are still common. The number of commercialized beech seedlings produced is decreasing: 1,774,000 seedlings in 2008, 2,553,000 in 2005 and 4,714,000 in 1998. Beech is the most affected species by this phenomenon. It has several putative origins: (i) high priority for natural regeneration, (ii) fall of plantation density, (iii) cost of beech plantations, (iv) risk with climatic changes and (v) global decrease of artificial regeneration in France.

In France, we have only 'selected' seed stands for forest reproductive material. France is divided in 16 provenance regions and has 169 selected beech seed stands. They cover a surface area of 7,716.9 ha (Tab. 4).

Tab. 4: Beech provenances regions in France

Provenance region		Selected stands		Beech surface (%)
Code	Name	Number	Surface area (ha)	
FSY 101	Massif Armoricain	4	147.7	8
FSY 102	Nord	19	2,886.0	10
FSY 201	Nord-Est	70	3,010.0	19
FSY 202	Vallée de la Saône	0	0	6
FSY 301	Charentes	1	6.8	1
FSY 401	Massif Central nord (low altitude)	11	289.1	11
FSY 402	Massif Central nord (high altitude)	7	115.1	11
FSY 403	Massif Central sud	18	341.6	12
FSY 501	Jura	18	371.0	17
FSY 502	Préalpes du Nord	2	19.1	17
FSY 503	Alpes Internes nord	0	0	8
FSY 601	Pyrénées occidentales	7	160. 5	12
FSY 602	Pyrénées centrales	10	293.0	45
FSY 633	Pyrénées orientales	2	77.0	16
FSY 751	Région méditerranéenne	0	0	7
FSY 800	Corse	0	0	10
TOTAL		169	7,716.9	11

The delineation of the provenance regions (Fig. 2) was carried out according to:

- Genetic data for the following provenances regions (Comps et al. 1987, Vernier, Teissier du Cros 1996, Magri et al. 2006): Nord (FSY102), Nord East (FSY201) and Pyrenees (FSY601, FSY602 and FSY603);
- Soil conditions (Tessier Du Cros, Lepoutre 1983) for Massif Armoricain (FSY101), Charentes (FSY301) and North East (FSY201) ;
- Climatic conditions for Massif Central (FSY401, FSY402 and FSY403);
- Soil and climatic conditions: Jura (FSY501) and Alps (FSY502 and FSY503).

GENE CONSERVATION OF EUROPEAN BEECH IN FRANCE

At the end of the 1980s several threats to beech genetic resources were identified:

- Generalization of exchanges of forest reproductive material and plantation for regeneration
- Impact of silviculture
- Several episodes of decay
- Climatic changes

Facing these threats, a programme of gene conservation was launched in 1986. This *in situ* network was the first with the fir (*Abies alba*). It includes 26 genetic conservation units (GCU) (Fig. 3). These GCU are representatives of the differences of the main provenances regions and marginal conditions. The GCU cover a surface of 4,446.7 ha (Tab. 5). Six populations are considered as marginal because five are in the Mediterranean region and one on extreme condition for altitude and soil. One GCU, NF of Verzy, has a peculiar phenotype because the trees are crooked. It is dwarf beech (*Fagus sylvatica* var. *tortuosa*).

Tab. 5: List of the 29 GCU in France with their location and particularities

Forest	Region	Core zone	Buffer zone	Remarks
Aigoual	Languedoc-Roussillon	13.8	110	marginal population
Aubusson	Auvergne	10	102	
Baïgorry	Aquitaine	7.5	146.4	
Beaulieu	Champagne-Ardennes	8.7	112.3	
Boucheville	Languedoc-Roussillon	19.9	187.7	
Brotonne	Normandy	25.8	140.2	
Châtillon	Burgundy	10.4	154.7	
Chizé	Poitou-Charentes	12.6	183.9	
Colettes	Auvergne	8.7	96.9	
Coscione	Corse	40	34	marginal population
Ecouves	Normandy	13.6	143.4	
Filsis	Alsace	10	230.5	
Fougères	Brittany	10.3	151.5	
Gar Cagire	Midi-Pyrénées	10	151.5	
Gérardmer	Lorraine	15.2	82.7	marginal population
Haye	Lorraine	16.2	218.7	
Issaux	Aquitaine	11.6	95.0	
Léoncel	Rhône-Alpes	10.1	118	
Luchon	Midi-Pyrénées	4	48.6	
Lure	Provences-Alpes-Côte d'Azur	5	255.4	marginal population
Luxueil	Franche Conté	8.1	226.9	
Montagne Noire	Midi-Pyrénées	8.5	169.7	
Moussaou	Midi-Pyrénées	34.2	181.1	
Retz	Picardy	7	180.5	
Sainte Baume	Provences-Alpes-Côte d'Azur	14.1	124.2	marginal population
Valbonne	Languedoc-Roussillon	23.3	118.9	marginal population
Verrières du Grosbois	Franche-Comté	5	175	
Verzy	Champagne-Ardennes	33.3	0	dwarf beech
Wingen	Alsace	11.5	92.6	
		408.4	4,032.3	

Fig. 2: Beech provenance region limits in France (white zones: no seed harvesting; dashed zone: provenance region without registered stands; dotted blue: two provenances regions according to altitude)

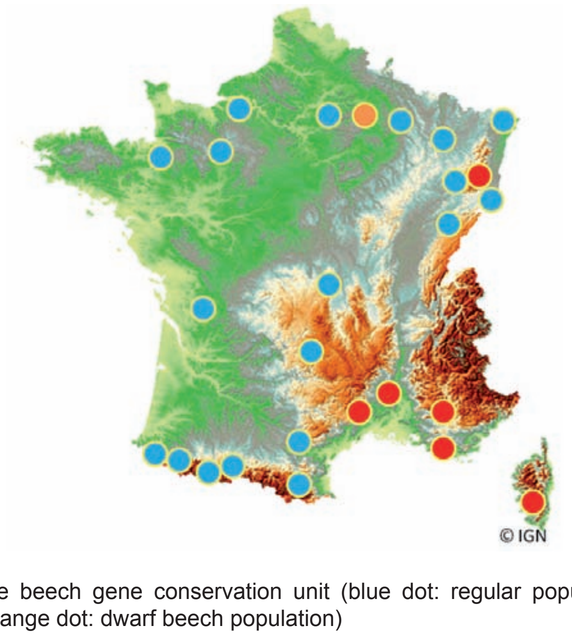

Fig. 3: Location of the beech gene conservation unit (blue dot: regular population; red dot: marginal populations; orange dot: dwarf beech population)

FOREST RESEARCH

The beech research programme started during the 1970s. This programme has different aims: ecology, ecophysiology, pathology and genetic diversity organization. The genetic programme focuses on three objectives: adaptation to climate changes, management and conservation of genetic resources. The first provenance test was established in 1979 and the last one in 1994 (Tab. 6). Among the 12 provenance tests only three of them are international that means sister plantations exist in different European countries and tested populations covered a large part of the natural range. All these international tests are located in the National Forest of Lyons (West France), the younger one is included in the COST Action E52. One progeny test was planted in 1999 in the National Forest of Hayes (North East France).

Tab. 6: List of the provenance and progeny tests, location, tested material and individual number (*: IUFRO test; +: test included in the COST Action E52)

Forest name	Region	Plantation years	Provenance number (countries)	Surface (ha)	Individuals
			Provenances tests		
Ecouves	Normandy	1979	16 (16 F)	0,50	1,540
Sommedieue	Lorraine	1979	14 (13 F + 1 RO)	0,46	1,100
Arfons	Midi Pyrénées	1979	15 (14 F + 1 B)	0,32	1,400
Ligny en Barrois	Lorraine	1983	32 (29 F + 1 B + 2 NL)	0,19	1,345
Plachet	Champagne-Ardennes	1982	30 (27 F + 1 B + 2 NL)	0,33	1,345
Ormancey	Champagne-Ardennes	1982	22 (20 F + 1 B + 1 NL)	0,16	689
Guimont	Limousin	1981	34 F	0,50	2,520
Retz	Picardy	1982	30 (24 F + 3 NL+ 3 RO)	0,27	1,356
Lyons	Normandy	1982	49 (39 F + 4 B + 3 NL + 1 CH + 4 RO)	0,34	2,200
Lyons*	Normandy	1986	24 (6 F + 2 NL + 1 DK + 14 D + 1 TU)	0,67	6,700
Lyons*	Normandy	1987	61 (3 F + 2 E + 18 D + 1 NL + 15 CZ + 2 HU + 8 RO + 1 B + 4 H + 3 GB + 3 PL + 1 YU)	1,44	14,400
Lyons*+	Normandy	1994	49 (1 E + 4 F + 34 D + 1 I + 2 CZ + 1 PL + 5 SK + 1 RO)	1,50	7,500
			Progenies tests		
Haye *	Lorraine	1999	77 progenies from NF Hayes	1,61	4,285

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Contacts:

Dr. Alexis Ducousso
Genetic team, UMR BIOGECO, INRA
69 route d'Arcachon, 33612 CESTAS cedex, France
e-mail: alexis.ducousso@pierroton.inra.fr

ORIENTAL BEECH IN GEORGIA – PRESENT STATE AND CONSERVATION PRIORITIES

Tengiz Urushadze[1] – Zurab Manvelidze[2] – Lasha Dolidze[1] – Irina Tvauri[1]

[1] Vasil Gulisashvili Forest Institute, 0186, Mindeli str. 7, Tbilisi, Georgia

[2] Shota Rustaveli State University, Institute of Biodiversity, 6010, Ninoshvili str. 35, Batumi, Georgia

ABSTRACT

This article discusses the current state of oriental beech forests (*Fagus orientalis* Lipsky) in Georgia, based on data from the last (2000) inventory of the state forests. It describes the distribution of forests according to altitude and steepness of slopes, as well as according to main functional divisions. The main characteristics of biodiversity of beech forests at the ecosystem level as well as the main wood species are considered together with the quantification of the supply of timber. Spatial and age structure of stands of virgin forests are presented according to height and diameter and other peculiarities of the main biological stages of formation and development of these natural characteristics. The main principles of forestry management and conservation priorities according to different categories of forests are also considered.

Key words: Georgia Republic, beech, აღმოსავლეთის წიფელი (in Georgian), biodiversity, forest management

ORIENTAL BEECH DISTRIBUTION IN THE REPUBLIC OF GEORGIA

Based on its forests, Georgia is the richest country in the entire ecoregion of the Caucasus, included in the World Wildlife Fund (WWF) list of 200 ecoregions, which are distinguished by richness of species, endemism, taxonomic uniqueness and characteristics of peculiarities of origination and rarity of habitats (WWF & IUCN 1994, Williams et al. 2006, WWF Global 200 Ecoregions). The Caucasus is also one of 34 "hot-spots" of biodiversity, identified on the world globe, which are characterized by greatest biological diversity and richness of endangered land ecosystems (WWF 1998).

The total area of Georgia is 6.95 million ha and of this, the total area of forests is 2,988,000 ha while the territory covered with high forest is 2,767,300 ha. The high percentage of forests at 39.1% is heighlighted in comparision with other countries in the Caucasus at 27%. The total supply of wood amounts to 453 million m^3, with an annual national increment of 4.6 – 4.8 million m^3. Average wood supply from one hectare is 157.8 m^3 and annual additional supply of the wood on one hectare forms 1.8 m^3 (Materials of the forests arrangement of the Republic of Georgia 1990 – 1995, Gigauri 1980).

According to Gigauri (2000) the forests of Georgia are divided into mountain and lowland forests according to geographic conditions. Mountain forests occupy 98% of the area while only 2% is occupied by lowland forests. Forests are located on steep and gentle slopes. Forests area is decreasing along the lower part of mountain slopes and in the west of Georgia up to 500 – 600 m a.s.l., in the east of Georgia up to 700 – 800 m a.s.l. and also in the sub Alpine region up to 1,800 – 2,500 m a.s.l. At heigh mountain levels and on steep slopes there are areas still covered with high forests in a natural state and not damaged by farming activity. 7.3% of the forests are situated at 500 m a.s.l. while 19.5% are at 501 – 1,000 m a.s.l. A further 35.5% are between 1,001 – 1,500 m a.s.l. while 37.7% are over 1,501 m a.s.l. Thus almost ¾ (73.2%) of forests are located at 1,001 m a.s.l. and higher.

The greatest part of the forests (78.0%) are located on steep slopes from 21° to 35° and steeper, while (36° and more) are slopes in mountains. Such an unequal distribution of forests according to vertical zonation and steepness of slope defines the wide spectre of their biodiversity (Tab. 1).

Tab. 1: Distribution of areas covered with forest according to elevation (m a.s.l.) and slope inclination (°)

Elevation		Slope	
(m a.s.l.)	%	(°)	%
0 – 250	3.9	0 – 10	5.5
251 – 500	3.4	11 – 15	6.8
501 – 1,000	19.5	16 – 20	9.7
1,001 – 1,250	16.8	21 – 25	16.6
1,251 – 1,500	18.7	26 – 30	18.2
1,501 – 1,750	17.8	31 – 35	19.6
1,751 – 2,000	12.9	36 – 40	15.2
>2,001	7.0	41 and above	8.4

According to the main functional aims the forest of Georgia can be divided in the following way:

Reserve forest (protected territories): 495,900 ha (16.6%)

State farming forest fund: 2,492,100 ha (83.6%)

Among them:

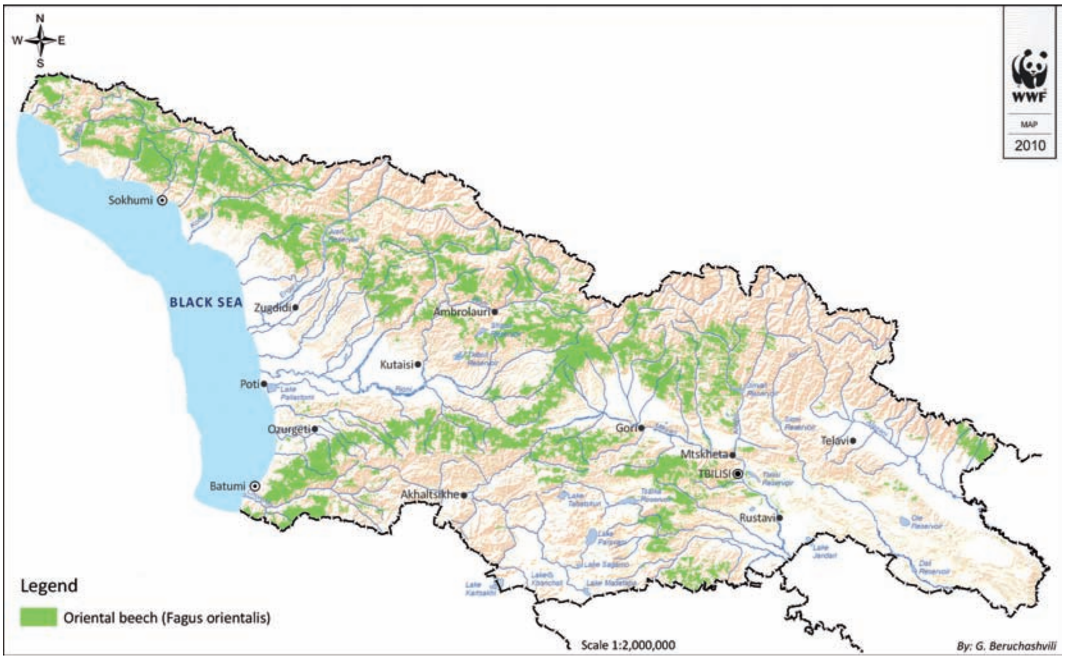
- forests of green zone – 265,700 ha;
- forests of resort zone – 890,600 ha;
- soil-protective water regulation forests – 1,335,800 ha;
- total: 2,988,000 ha (100%)

The species composition of Georgian forests is very diverse. About 400 species of trees and bushes grow naturally in these forests. Each one is an inseparable part of the ecosystem as a whole and encompasses its own microcenosis, which are linked in 123 botanical genera and 56 families. Included in their number are 153 species of trees, 202 species of bush, 29 species of sub-shrubs, and 11 species of liana.

Richness of endemic woody plants is a characteristic of the diversity of the dendroflora, including 61 endemic species of Georgia and 43 of the Caucasus. The occurrence of pure and mixed stands points to the biological diversity of these forests, diversity of forest ecosystems and the complex structure.

The Georgian forests are very diverse from the point of view of biological, genetical and economical importance and are presented as stands of valuable woody species. Based on the data of Gigauri (2000), the broadleaved forests in Georgia occupy 83.6% of all forests and their supply of wood accounts for 251.3 million m^3. The stands of hardwood species occupy 70.5% of broadleaved forests and their supply of wood accounts for 290.3 million m^3. This includes the following:

The largest territories of Georgia's forests are occupied by oriental beech at 42.5% and with a volume of wood of 224.7 mil. m^3 (see map).



- Oak (*Quercus iberica* Stev, *Q. macranthera* F. et M., *Q. imeretina* Stev, *Q. longipes* Stev and etc.) at 10.5%, and with a volume of wood of 23.6 mil. m^3;
- Hornbeam (*Carpinus caucasica* Grossh) stands at 9.9% with a volume of wood of 24.7 mil. m^3;
- Chestnut (*Castanea sativa* Mill.) stands at 3.8% and with a volume of wood of 12.7 mil. m^3.

The softwood species group form 10.8% and the total volume of wood at 20 million m^3 and include:

Alnus barbata C.A.M., *A. incana* (L.) Moench at 7.2% with a volume of wood of 13.8 mil. m^3;

Betula verrucosa, *B. litwinowi* A. Doluch at 2.7%, with a volume of wood which is 3.5 mil. m^3;

Populus alba L., *P. tremula* L., *P. nigra* L. at 0.6%, with a volume of wood 1.4 mil. m^3.

Coniferous forests occupy 16.4% of all forests and the volume of wood of this forest category is 121.9 mil. m^3 and include:

- Pine (*Pinus Sosnowskyi* Nakai) group at 4.4% of the area covered with forests and providing a volume of wood of 14.6 mil. m^3;
- spruce (*Picea orientalis* Link) group at 5.0% and providing a volume of wood of 32.4 mil. m^3;
- *Abies nordmanniana* (Stev) Spach group at 6.9% and providing a volume of wood of 74.7 mil. m^3 (Fig. 1).

Georgia's forests contain an increasing wood resource in such valuable species as:

yew (*Taxus baccata*), oak (*Quercus macranthera*, *Quercus imeretina*), ash (*Fraxinus excelsior*), zelkova (*Zelkowa carpinofolia*), box (*Buxus colchica*), linden (*Tilia caucasica*), maples (*Acer campestre*, *A. Trautvetteri* and other), pear (*Pyrus caucasica*) and many more.

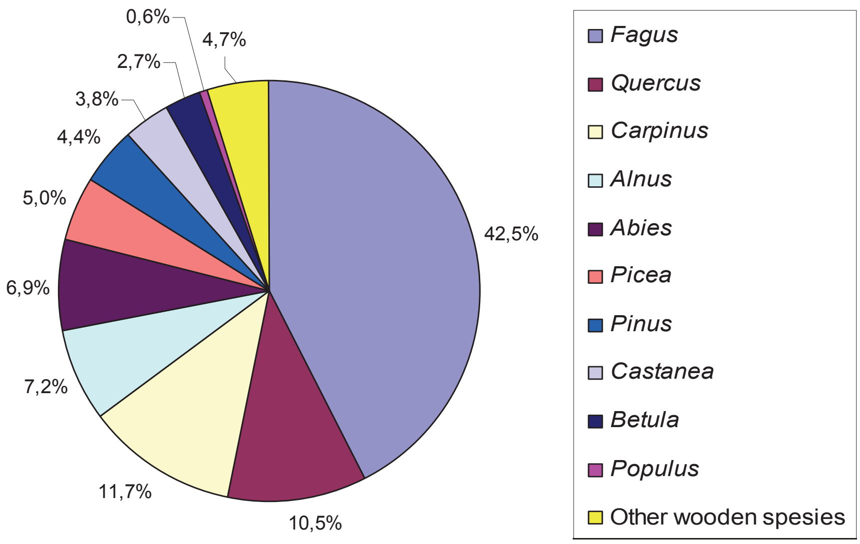


Fig. 1: Distribution of areas covered with forest according to main wood species (%)

Georgia has an abundantly large area of forests which provide a substantial supply of wood of species including: birch (*Betula medwedewii*), oak (*Quercus pontica*), buckthorn (*Rhamnus imeretina*), wing nut (*Pterocarya ptherocarpa*), blueberry (*Vaccinium arctostaphylos*), laurel (*Laurus nobilis*), azalea (*Rhododendron ungerni*, *R. ponticum*), *Epigaea gaultherioides*, *Osmanthus decorus*, tree strawberry (*Arbutus andrachne*), persimmon (*Diospyros lotus*), bladder nut (*Staphylea pinnata*), *S. colchica*, juniper (*Juniperus foetidissima*), apricot (*Prunus laurocerasus*) and others.

Oriental beech in Georgia is characterized by a distinct zonal distribution, while solitary old age (300 – 400 years) specimen trees (Photo 1, 2) are located directly on the shore of the Black Sea, and are found up to an upper boundary of the subalpine belt at an altitude of 2,200 m and over. The forest belt is formed from 800(1,000) m to 1,500(1,600) m (Gulisashvili 1974).

The virgin beech forests of indigenous origin are found mainly on slopes with large inclines and in inaccessible mountain ravines and on slopes managed as protected areas. Because the main beech forests are located mainly on hillside slopes, near populated areas and close to the Black sea, natural forest ecosystems are frequently replaced with anthropogenic formations – agro-ecosystems.

Over long periods, the beech forests in Georgia have undergone the anthropogenic stress due to high demand for valuable timber (mainly parquet assortment) and fuel wood. As a result conditions of stability of species' diversity and main forest-taxation characteristics of virgin beech forests remained in a fragmented form and retained importance from the point of view of implementation of sustainable forestry policy. Particularly, in fulfillment of protective-ecological functions (soil-protection, water-protection, water regulation), as well as supply of the population with wood raw material and fuel wood as well as other non-timber forest resources.

CHARACTERISTICS AND FOREST MANAGEMENT

The principles of protection, sustainable development and management of the forests of Georgia are based on the Constitution of Georgia (web-site: www.parlamet.ge), the Declaration "On Principles of Sustainable Development of Forests" of the UN International Conference on Environment and Development in Rio de Janeiro, 1992 and on the principles, established by Article 5 of the law of Georgia (web-site: http://aarhus.ge/uploaded files/ ee5a802ed 8f 21815 f48f182 cce57edfe. pdf) "On Protection of Environment"; the principle of preservation of biological diversity is one of the most important of these.

Photo 1, 2: *Fagus orientalis* Lipsky (Z. Manvelidze)

In Georgia, typological analysis of forest flora has special significance for sustainable management of forestry from the point of view of observance of principles of sustainable forest management and preservation of sustainability of separate parameters of biological diversity (Makhatadze 1962, Japaridze 2003).

According to typological point of view *Fagetum* of Georgia can be said to be studied widely. Studies have been undertaken by the following: Gulisashvili (1964), Dolukhanov (1968), Tumajanov (1938), Makhatadze (1965), Svanidze, Abuladze, Parjanadze (1978), Svanidze (2001), Kvachakidze (1992, 2001), Bakhsoliani (2002), Manvelidze, Memiadze, Gorgiladze (2004), Dolidze (2006) and others.

The phytocenological spectrum of Georgian beech forests over time has been significantly determined by orographic, climatic, soil and anthropogenic factors (Kvachakidze 2001). In the beech forests of

Georgia 52 associations (forest types) are recognised while in the beech forests of the state forest fund, regulation on felling must be justified from the forestry and environmental points of view and is mainly based on characteristics of the specific types of beech forests (Gulisashvili 1964):

Beech forests with rhododendron sub-forest (*Fagetum rhododendrosum*): Beech forests of this type are found in Western Georgia in shady damp parts of the mountains as well as in Eastern Georgia. These stands are highly productive.

Beech forests with cherry laurel sub-forest (*Fagetum laurocerasosum*): They are spread in damp valleys of Western Georgia on steep slopes of all exposures. Vegetation includes azalea, ilex, Caucasian bilberry etc., which are mixed together with cherry laurel in the subforest.

Beech forest with dead surface (*Fagetum nudum*): This is sufficiently wide type of forest, and is found mainly in the form of high-density stands. Beech forests of this type are presented in the lower and upper belts of the distribution of beech forests:

Beech forests with dead surface in the lower belt are spread on the northern mountain slopes of mean inclination at the altitudes 600 – 800 m. In this type of beech forest due to the high density of canopy, natural regeneration is very limited.

Beech forests with dead surface in the middle belt are spread within the altitudes at 1,000 – 1,200 m, mainly on slopes of north-eastern exposures. The natural regeneration of beech by seed in these stands of high density is unsatisfactory.

Beech forests with star grass cover (*Fagetum asperulosum*): They are found mainly within the altitudes 800 – 1,500 – 1,700 m. This is very wide spread type of forest and may be of two sub-types.

Beech forests with star grass cover at the middle belt are found within the altitudes 1,000 – 1,400 m. Natural regeneration (by seeds) is satisfactory. Productivity of stands is high (growth class I-II). Here grass cover is relatively sparse.

Beech forests with star grass cover of the upper belt are found at altitudes 1,500 – 1,800 m, mainly on the northern exposures of mean (15 – 20°) inclination. Hornbeam and lime are mixed with beech and here a sub-forest is seldom found. Grass cover is weakly developed.

Beech forests with fescue grass cover (*Fagetum festucosum*): Vertical distribution of this type of beech forest according to height may be divided into three belts, in particular:

Beech forests with fescue grass cover of the lower belt. This type is found at the altitudes 1,000 – 1,300 m, on steep southern mountain slopes. Associated species are hornbeam, common maple, lime etc. which are mixed with beech in these stands. Here the sub-forest is less developed. These stands are of high productivity (growth class I-II).

Beech forests with fescue grass cover of the middle belt are found at altitudes of 1,300 – 1,500 m, on the slopes of southern and northern (less) exposed sites. The different ages of the stands determine their biodiversity.

Beech forests with fescue grass cover of the upper belt are found at 1,600 – 1,800 m, on the steep slopes (inclination 21 – 35°). These stands are mainly of beech with Nordmann fir and eastern spruce and are mixed with it in Western Georgia. Natural regeneration in medium density beech forests of this type is satisfactory.

One of the main determining features of biological diversity of Georgian beech forests is their distribution according to the density of stands.

Stands of medium density (0.5 – 0.7) mainly dominate in Georgian beech forests. It is noteworthy that low-density stands occupy sufficiently large areas and the area of high-density stands have significantly decreased. This is caused mainly by economic interference by man in the natural processes. Incorrect use of exploitation regulations of beech forests in separate regions has resulted in felling of high-density productive stands, or have resulted in significant decrease of density of these stands. As a result, these stands have suffered significant reduction of productivity and indices of marketable value of the stands (Fig. 2).

In Georgia all age group of beech forests are represented (Gigauri 2004) (Fig. 3)

- Young groups occupy 6.3% of all forests area and the wood supply represents 1.5%
- Middle aged groups occupy 32.9% of forest areas and the supply of the wood represents 21.8%
- Matured groups occupy 17.9% of forest area and the supply of wood represents 17.1%;

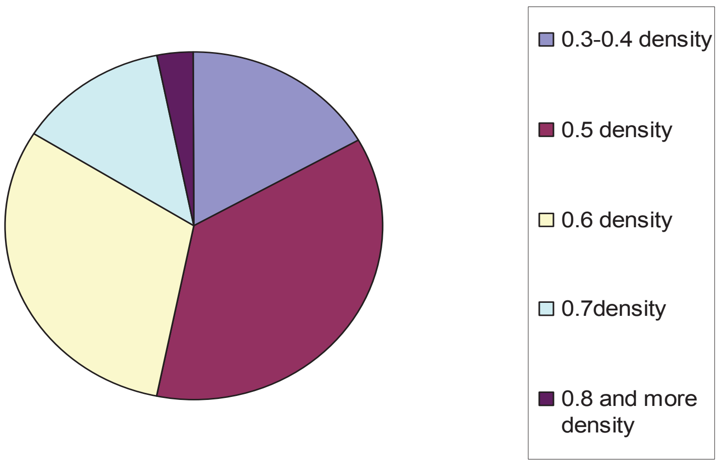


Fig. 2. Distribution of areas covered with beeches according to frequency

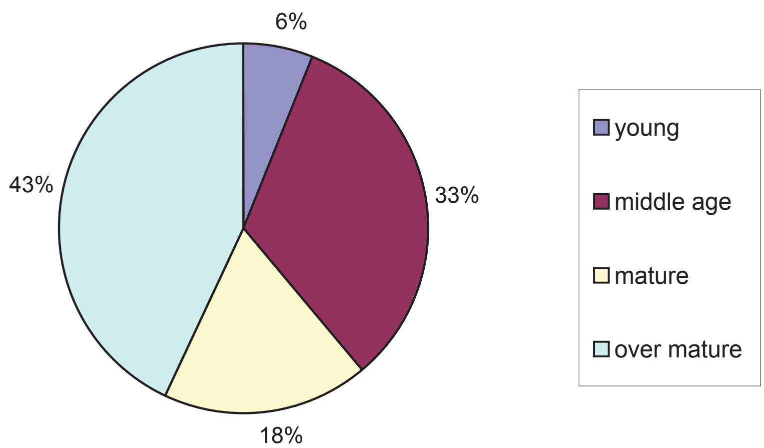


Fig. 3. Distribution of areas of beech forest according to groups of different ages

– Matured and over-aged groups account for 42.9% of the forest area and the supply of wood is 59.6%.

Beech forests of Georgia are characterized by high indicator levels of productivity (Fig. 4) particularly:

– High productivity (I-II class quality) groups occupy 21% of all forests;
– Average productivity groups (III class quality) – 44.9% of forests;
– Low productivity groups (IV class quality) – 24.9% of forests;
– Very low (V-Va class quality) productivity groups – 9.2% of forests.

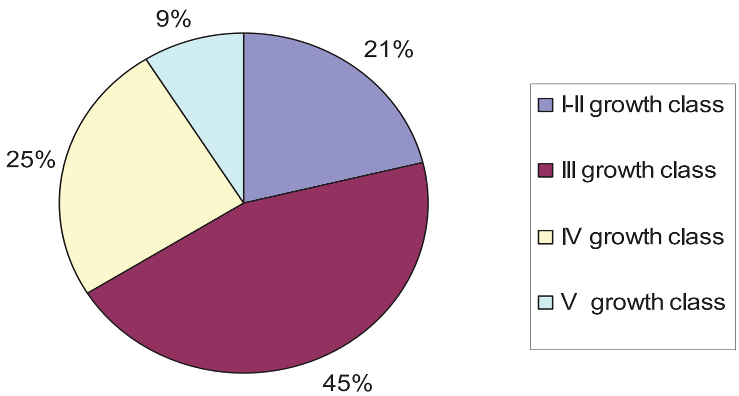


Fig. 4: Distribution of areas covered with beech forest according to quality classes

One important determinant of biological diversity of forests in Georgia, like other countries, is the dynamics of accumulation of biomass over a period of time. An individual beech tree or an entire stand accumulates a certain amount of biomass at various stages of growth and development under the influences of external factors (soil, climate, relief etc.) and due to their biological characteristics.

Based on data by Gigauri, Dzebisashvili (1990), of the main species forming the forests of Georgia, oriental beech occupies one of the leading places after eastern spruce and fir, according to the index of accumulation of biomass by a tree of one and the same diameter, and at 100 cm diameter, its total volume on average contributes 16.71 m^3 (Tab. 2).

Tab. 2: Dynamics of accumulation of biological mass of beech according to thickness stages

Thickness stage (cm)	Average height (m)	Volume of wood biomass (m^3) among them			
		Stem	Crown wood	Green mass of crown	Total
20	24.0	0.34	0.08	0.03	0.45
60	37.5	4.52	0.97	0.31	5.80
100	42.0	13.80	2.44	0.47	16.71
140	44.0	27.79	3.81	0.53	32.13
160	45.5	37.33	4.67	0.71	42.71

In separate regions of Georgia virgin forest stands still remain with an area of approximately 566,000 ha, of which 396,300 ha are of virgin beech forests.

These beech forests are similar to the virgin forests of fir and spruce, are characterized by different age structures and are distinguished by a high variability of age. Trees of almost all age groups, from seedlings to large-sized trees that are at maturity are present in the same stand. This high variability of age is also present within each grade of diameter and the difference between ages sometimes vary over several hundreds years.

In Georgia the virgin forests with beech are found as stands of composite structure, mainly vertically distributed, multilayered and with different levels of height and diameter.

In such stands, the distribution of trees in different levels of height and diameter is non uniform and is characterized by several maximums ("peaks") and the series of distribution in the entire stand is asymmetrical. For example, in the virgin fir and beech forests the distribution of numbers of trees on aggregative grades of diameter is as follows:

43.5% of the number of trees in grade category of diameter up to 20 cm.

30.2% of the number of trees in grade category of diameter range 24 – 40 cm.

11.3% of the number of trees in grade category of diameter range 44 – 60 cm.

04.4% of the number of trees in grade category of diameter range 64 – 80 cm.

03.6% of the number of trees in grade category of diameter range 84 – 100 cm.

02.6% of the number of trees in grade category of diameter range 104 – 120 cm.

01.8% of the number of trees in grade category of diameter range 124 – 140 cm.

01.2% of the number of trees in grade category of diameter range 144 – 160 cm.

00.9% of the number of trees in grade category of diameter range 164 – 180 cm.

00.7% of the number of trees in grade category of diameter range 184 – 200 cm.

Furthermore, in natural stands can be found many virgin forests with beech, where trees of phenomenal diameter (2.0 – 2.5 m) and height (50 – 60 – 65 m) are not unusual.

Thanks to the environmental conditions (soil, climate) which are optimal for growth and development of forests, the virgin forests of Georgia, especially in the western part, are represented mainly by high productivity stands. In this connection the pure and mixed beech stands of Abkhazeti and Zemo Svaneti are especially distinguished where supply of wood per ha is frequently 1,000 – 1,200 m^3, and in separate virgin forest areas can reach 1,600 – 1,800 m^3 with annual increment of 20 – 25 m^3. These forests are indeed monuments of nature not made by hands. The virgin fir and beech forests are unmatched by productivity index in the other countries of Europe and possibly Asia.

In stands formed of beech and, according to the peculiarities of vertical distribution of trees in space these may be categorised in four layers, while in pure beech forests – three layers (Fig. 5).

The stands of virgin beech forests of Georgia – pure and mixed, of different ages, with different diameter structure – are recognized as classical examples of a high index of biological diversity.

In stands of composite structure on the same slope, as well as in adjoining area, the whole spectrum of biodiversity, the whole natural patchwork is presented – the system of stand roots, grass canopy and biological stages within one cycle of development of the stand.

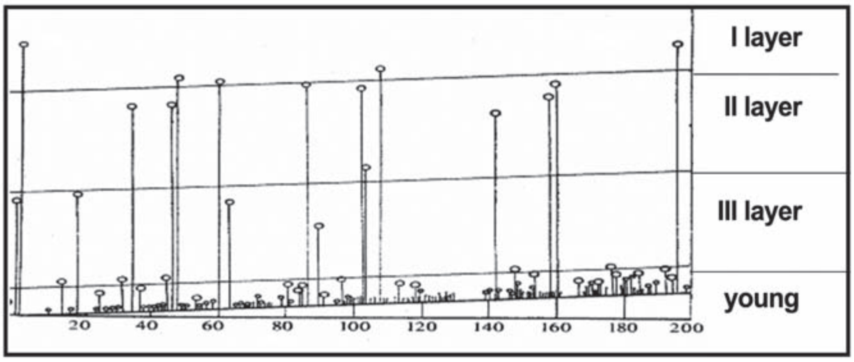


Fig. 5. Scheme of structure at height of beech group (according to GIGAURI 1980)

During the life of one generation (500 – 600 years) beech forest will pass the main biological stages of development:

1. Teenage stage (age 40 – 60);
2. Development stage of young forest (age 41 – 100);
3. Development stage of the middle and matured parts of the group (101 – 160);
4. Maturity stage of the group (age from 161 to 240 – 250). Trees reach large size;
5. Stage when trees of the upper part of the canopy get old and when they begin to die gradually (age from 250 to 350 – 360);
6. Primary stage of dying of the earlier generation or natural maturity of the forest (from 360 to 500 – 600 – 800).

The main principles of forest management in various categories of forests in Georgia are:

In protection forests, national parks and on protected areas of various categories the regime of forestry is determined by preservation, protection and improvement of the entire complex of natural conditions (today 14 state reserves, 8 national parks, 12 game reserves, 14 natural monuments and 2 protected landscape function in Georgia) (web-site: http://dpa.gov.ge/).

In green zone forests, the forestry management aims at the formation of valuable forest stands – healthy, high productive and of aesthetical valuable that will promote improvement of sanitary hygienic conditions of the urban-industrial environment and secure the remainder of the population and adequately protect their health status.

In the forests of such importance, the main regulations of forestry are determined by improvement of sanitary, hygienic and aesthetical conditions of the forests.

In the mountain forests the protection of soil and water through regulation are important functions and here the purpose of forestry is the conservation and strengthening of soil protection, water preservation and other water control functions. Here, the main function is to avoid erosion and protect the permanent health status of rivers and streams. Besides protective and other functions but due to their high productivity, these forests also have a function of timber production. These protective and exploitation functions of the forests supplement each other. However, forest exploitation requirements are always subordinate to the protective functions of forests (Cutting Rules in Georgian Forests, 2000).

The main requirement of beech forestry in Georgia is that stands always are characterized by different age structures and contain a variable range of diameter that together with other factors provide various assortment of timber.

EASTERN BEECH GENE POOL PRESERVATION AND CONSERVATION IN THE REPUBLIC OF GEORGIA

As already mentioned, the age structure of virgin beech forests in Georgia is sufficiently differentiated and as such are characterized by different ages. In their overall numbers young and middle age stands occupy almost 40% of the total forests.

In the virgin stands at the same location, as well as in adjoining territory, the whole spectrum of biodiversity is presented by an entire natural patchwork. In particular, the system of below ground area – the roots of a stand, the grass canopy, other biological stages of development in time of a stand but within the life of one generation: young growth (shoot), the under canopy area, stands composed of average age variables, maturing stand, mature stand, old stands and stands remaining standing to over maturity and finally dying and dead trees. Each of these in this very intricate natural system, occupies its own ecological niche; they influence each other and exist in a close mutual dependence that establishes reliable prospects from the point of view of preservation and conservation of the gene pool of oriental beech.

For the protection and conservation of beech forests and subject to economic activity, it should be noted, that in Georgia selection of ecologically justified and acceptable regulations combined with methods of wood harvesting and correct determination of annual quantities of forest products, are and will continue to be the central issue of science and practice.

Based on long-term scientific research and practical experience, in the mountain forests of Georgia these rules and methods of determination of wood harvest and annual cut of forest products have been in use for a long time, and contribute to the conservation and strengthening of the social-environmental functions (soil protective, water regulation, climate regulation etc.).

Based on this, wood harvesting and timber utilization are required to satisfy the following requirements:

1. Preservation and widening of biological sustainability and diversity of forest ecosystems;
2. Firm observance of all requirements of permanent or constant utilization of timber, growing and formation of purposeful high productive forests;
3. On mountain slopes – preservation and strengthening of soil and water protective role and other associated social and environmental functions;
4. Avoidance of occurrence and development of erosion and generally other adverse natural phenomena;
5. Improvement of appropriate environmental conditions for natural regeneration of tree species, valuable from the biological, forestry, economical or other point of view, and of their biological communities;
6. Increase of productivity and quality indices of forests with timely use of trees assigned for felling and their utilization before deterioration of the wood technical properties.

Thus, in the forests of Georgia use of timber, in the first place, is the process of preservation and protection of the biological-ecological-natural properties of the forest, and not for forestry-industrial purposes.

CURRENT GENETIC CONSERVATION ACTIVITIES *IN SITU* AND *EX SITU*

A genetic resources inventory of several species in Georgian broadleaves forest was carried out based on the international (IPGRI) project "Plant Genetic Resources Development programme for South-East Europe - Preservation of Broadleaved Forests Genetic Resources". Sample plots areas were established and after their detailed description was recorded plus stands and plus trees were registered. The location and detailed taxation-forestry characterization of the plus trees was also identified and described.

Each tree was numbered and characterized.

During the 2004-2005 reporting period 13 forest units and 23 forest unit subdivision of genetic reserves were registered, and 40 temporary sample plots have been established. 217 plus trees were described and information obtained and entered into the data base in Mtskheta, Akhmeta, Tianeti, Dmanisii, Kaspi, Dusheti, Telavi, Kvareli and Tetriwkaro regions.

The priority of protection and conservation of the gene pool of the Georgian forest ecosystems especially in beech forests, which occupy almost half of the territory of the countries forests is determined by its connection with the commitments of Georgia to the international convention "on biological diversity" (The Convention on Biological Diversity, 1992, web-site: http://www.cbd.int) and the government priorities, determined by the strategy and action plan of Georgia on biodiversity (web-site: http://www.nacres.org/pdf/bsap_ge.pdf; Resolution of Government Georgia #27, 2005.19.02. (web-site: http://www.garemo. itdc.ge/ storage/ assets/ bsapge.pdf).

In situ conservation of species and their habitats firstly requires firm observance of the principles of sustainable nature management, in particular, the harmonization of environmental, economical and social factors.

Based on the above principles, endemic, relic and rare plant species of local flora, and groups of living organisms, formed by their prevalence, distinguished by structural, functional, geographical, environmental and other characteristic features, which in nature are presented by ecosystems of high conservation values, groups of phytocenoses and the main and secondary types (associations) of phytocenoses, are subject to conservation of ecosystem and species diversity in the first place.

The success of measures for *in situ* conservation of species and ecosystem diversity demands protection of ecosystems of high conservation value through effective management.

In this connection and taking into account the unique biological diversity and tourist recreation resources of Georgia, territorial protection of nature and development of tourism related to it must be considered as one of the highest priorities. Successful implementation of this activity requires regulation of the process of spatial arrangement (development of infrastructure, taking into account cultural heritage and requirements of environment protection), as well formation of modern effective protected areas.

In the scope of the 2005 – 2010 program on *ex-situ* conservation of habitats and species established by the strategy and action plan of biodiversity of Georgia (web-site: http://www.nacres.org/pdf/bsap_ge.pdf; Rezolution of Georgia government #27, 2005.19.02. web-site: http://www.garemo. itdc.ge/ storage /assets/ bsapge.pdf certain results are achieved from the point of view of identification and determination of the ways of conservation of important places of biodiversity outside the protected areas. In particular, under the financial and methodological support of the biodiversity conservation foundation the research fulfilled in 2009 within the project, have identified "wildlife monuments", ("Launching the Conservation of Georgia's Natural Monuments") (http://www.nacres.org.), in which the objects of high conservation value in the ecosystems of beech forests are included.

The first logical step for resolution of the problem of the *ex-situ* conservation of species diversity is a formation of a living collection and seed banks in botanical gardens, protected areas and in the areas attached to education or scientific research centers.

FOREST RESEARCH

Currently the Vasil Gulisashvili Forest Institute performs the administration of the project "Afforestation and optimization of harvested Beech stands in Adjara for supporting sustainable development" The project goal is to study the existing situation of the ecosystems in the beech forest areas of the Adjara region affected by felling activities; study the influence of these ecosystems on the protective ecological functions and devise science-based measures for the recovery of the forest ecosystems.

In order to address the problems of sustainable management of forest resources in accordance with the strategy and action plan of Georgia on biodiversity (web-site: http://www.nacres.org/pdf/bsap_ge.pdf), the following strategic principles must be taken into account:

- The ecosystems of virgin forests are substantial and important for the preservation of the general functional state of the forests;
- Sustainable utilization and management of forest ecosystems must make possible the preservation of their main environmental processes, biological diversity, fertility and renewable capacity;
- Complete inventory of forest resources is essential for sustainable management of forest resources;
- Sustainable utilization and management of Georgian forests must contribute in the preservation of local and global ecosystems;
- The conditions are to be considered, which damage or cause deterioration to the general functional state of Georgian forests;
- The fundamental environmental functions of Georgian mountain forests must be considered;
- Considerable part of Georgian mountain forests are to be preserved in a more or less virgin state and respectively they are to be considered as the resources of international importance;
- It should be taken into account that sustainable utilization and preservation of forest resources and their flora and fauna may be provided by coordination of the national policy and international efforts.

The above requirements are the main purpose and tasks for development of forestry based on the principles of sustainable development and are as follows:

- Elaborating, implementation and analysis of demonstration projects for estimation of new and traditional forms of management of forest resources;
- Providing of moratorium on timber logging in old forest stands and forests of high conservation value and implementation of priority principles for the protection of stands of such type of forests;
- Use of methods of planning of land utilization and zoning in management of these forest resources;

- Elaborating and implementation of programs of restoration and reforestation of forest lands acceptable from the environmental and social points of view, in order to increase forested areas and restore forest types, which were significantly degraded or totally destroyed;
- Forest plantations are not to be created at the expense of natural forests or other natural ecosystems;
- The areas and forest types are to be established, where the forest of natural origin disappeared and where restoration and reconstruction of forest stands is necessary; development of optimal technical and economical assessment of methods of restoration and reconstruction of forest stands.

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Reviewed

Contacts:

Dr. Irina Tvauri
Forest Institute
0186, Mindeli str. 7, Tbilisi, Georgia
e- mail: itvauri@yahoo.com

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) FORESTS IN GERMANY

Georg von Wühlisch[1] – Hans J. Muhs[2]

[1] Institute for Forest Genetics, Sieker Landstrasse 2, D-22927 Grosshansdorf, Germany
[2] Schimmelmannstrasse 37, D-22926 Ahrensburg, Germany

ABSTRACT

The situation of beech forests in Germany is presented with special consideration of the genetic constitution and conservation of the genetic resources. The occurrence of beech has been influenced by man starting already in Neolithic times, resulting in an area of now 1.565 million ha (reduced area). Beech occupies a broad spectrum of ecological niches, some with a high genetic diversity. A national plan for conserving the genetic resources of all tree species has been developed. A close-to-nature silvicultural concept is being followed aiming at multiple forest functions and uses. Beech forests have suffered in the years following the drought during the summer of 2003, but on the whole the beech forests are highly productive and years of seed production are more frequent. The economics of beech silviculture improved in recent years due to diversification of the uses.

Key words: beech forests, European beech, Buche (in German), distribution, ecology, biodiversity, silviculture, regeneration, economics, conservation, research

DISTRIBUTION OF EUROPEAN BEECH IN GERMANY

Beech has migrated into Central Europe together with fir and spruce only in a late stage of the remigration process after the Ice Age. There it was favoured by the agricultural system of the Neolithic people, which cleared the forest composed of oak, ash, hazel, elm, and other deciduous trees. After they had abandoned these areas, beech was more successful in colonizing these areas. Thus the anthropogenic influence was severe and had a lasting effect on the distribution of beech, explaining its widespread occurrence (Küster 1998). Beech in Central Europe when compared to regions of South-Eastern Europe is able to migrate into the low lands and to adapt to the moist sub-Atlantic climate.

Beech occurs potentially all over Germany, except in the regions close to the coast of the North Sea (marsh and peat soils), the dry sites (loess and sandy soils) mainly in East-Germany, the upper Rhine valley and the high elevation above 1,600 (north slopes) or 1,800 (south slopes) of the Alps. Hofman, Anders, Matthes (2000) estimated this area to be 50.8% (potentially natural vegetation) for the East-German Federal States, where beech would play a dominant role. It would occupy the rich, loamy sites close to the Baltic Sea and the low-mountain regions in the southern part, while in the West-German Federal States the occurrence is scattered according to local site conditions, but the potential proportion of beech forest is about the same.

After the clearing of vast forest areas for agricultural purposes in the medieval period, the human influence on beech forests was detrimental for two reasons. The total forest area was reduced to about 30%, in some regions even far less and the species composition of the forests was simultaneously reduced from about 50% beech down to less than the present 15%. Moreover, beech was replaced by faster growing conifers or its viability was reduced due to continued coppicing. This led to a critical situation some 250 years ago; thereafter regular forest management was introduced based on the principles of sustainability.

Updated area figures are given in the Second National Forest Inventory (Federal Ministry 2002): Total forest area is 11.075 million ha (public owned 33.3%, corporate bodies 19.5% and private and to be privatised 47.2%), thereof 1.565 million ha (14.8%) are covered by beech (reduced area). Most beech forests (80%) are located in south-west and central parts of Germany mainly in Baden-Württemberg, Rhineland-Palatinate, Saarland, Hesse, part of Bavaria and the southern parts of Lower Saxony and North Rhine-Westphalia.

Changes in the 15 years from the first (1987) to the second (2002) inventory are remarkable: the increase in total forest area by afforestation is 135,288 ha or about 9,020 ha/year. Moreover about 81,754 ha or 5,450 ha/year of mainly conifer forest were replaced by broadleaved forest tree species. Thus, both figures result in a considerable change in species composition. Beech is leading with an increase of about 1.9 percent (from 12.9 to 14.8% of the total forest area), the other deciduous tree species together increase by 2.9% in area, and Douglas fir and silver fir by about 0.6%, while Norway spruce, Scots pine and larch show a loss of 5.4% in total area.

ECOLOGY AND BIODIVERSITY

Beech prefers mild winters and a sub-Atlantic climate with sufficient rainfall, reaching at least a yearly minimum precipitation of 500 to 600 mm. It is sensitive to late frost and hard winter frost and has low tolerance to drought and a high water table. Although beech can grow on a wide range of different soils with low to high pH-values, it is found most frequently on limestone derived rich soils. Beech has been in the past and is still expanding its range under natural condition because of its pronounced competitiveness (Hofmann, Anders, Matthes 2000).

In Germany, there are four main forest communities with beech as forest cover: *Luzulo-Fagetum* in hilly to mountainous regions often in mixture with oaks, silver fir and Norway spruce depending on altitude and covering 734,000 ha; *Deschampsio-Fagetum* in the northern low lands sometimes mixed with oaks and covering 53,000 ha; *Galio odorati-Fagetum* from the low lands to the Alps on neutral to acid soils sometimes mixed with common ash and sycamore maple and covering 427,000 ha and *Hordelymo-Fagetum* widely distributed on neutral to carbonate rich soils and covering 277,000 ha. Beech is not coppiced any more in Germany, all coppiced stands have been converted to high forest. Most of the beech forest is natural (60%) or managed close to nature (22.5%), while forests of other tree species have only low percentages of this type of management, e. g. oak forests (5.3% natural and 41.5% close to nature), Norway spruce (5.6% respectively 21.8%) and Scots pine (5.0% respectively 10.2%) (Federal Ministry 2002).

A great advantage of beech ecosystems is their ability to catch ground water because of their low evaporation rate, smooth bark favouring an effective stem flow, leafless time for more than half a year. All these factors result in high percolation rates in beech forests, which are higher than in any other forest species or grassland. The annual seepage will supply up to 40% of the precipitation to the ground water in optimal cases. Thus, beech forests are increasingly favoured in water catchment areas.

Beech forest ecosystems in Central Europe appear to be poor in species biodiversity compared to oak forest ecosystems. As beech is able to grow and dominate on a variety of sites, the composition of flora and fauna species varies with site conditions, of which the poorest are on acidic soils in the low land, the richest on calcareous soils in the mountainous regions. To capture as much of the diversity for nature conservation as possible, a network of beech forests in national parks and forest nature reserves (most are unmanaged over the last 30 years) has been established, including National Park Jasmund, Müritz, Grumsin (Schorfheide-Chorin), Hainich, Eifel and Kellerwald-Edersee, which are some prominent ones. There are 716 such natural forest reserves distributed all over Germany and covering 31,167 ha. The richness in terms of biodiversity is ascertained by a survey undertaken at different places, which show for example that the number of 96 strictly monophagous insects specialized on beech is high but fairly low compared to 298 depending on oak. However, if the total number of species of all different habitats is considered, the number of animals adds up to 6,716 of which 1,792 are beech forest specialists and the number of plants comprises 4,320 of which 1,169 are specialized on beech forests (Janssen 2008). Thus, the contribution to the natural heritage of the forests is evident due to their high biodiversity.

PESTS, DISEASES AND ABIOTIC IMPACTS

Beech suffers from a complex disease, which is not yet fully analysed. Obviously an aphid (*Cryptococcus fagisuga*) and *Nectria* fungi started to attack the trees, followed by beech bark beetles (*Trypodendron domesticum* and *Hylocoetus dermestoides*). In the late phase fungi like *Fomes fomentarius* and other fungi causing white rottenness are damaging the trees until they die off. This complex disease has already been described in the west of Germany (Eifel, Hunsrück and Saarland) years ago and is still expanding. Besides this, the small beech bark beetle (*Taphrorychus bicolor*) has damaged the cambium after heavy storms in south-west Germany. Browsing by deer is critical; during the time of regeneration and protective fencing is necessary.

Air pollution was still heavily affecting beech, much more than the conifers as shown by the crown defoliation, although the main pollutants (SO_2, NO_x) have decreased substantially during the past years, except for NH_3 and O_3, the last one of which continued to be the most critical for the forest. Especially beech suffered from crown defoliation with a drastic increase of damaged trees from 30% (2003) to 55% (2004). This could be explained by the drought in 2003 and a heavy seed crop in 2004 because a positive correlation between crown defoliation and the intensity of seed production was found (BMVEL 2003, 2004).

SILVICULTURE AND MANAGEMENT

After the periods of heavy overuse of the forests during the past centuries, which continued up to the middle of the last century and also devastated large areas of beech forests, it was necessary to find a better way to protect and use the forests. The old credo of sustainable management first put into practice by Hannß Carl von Carlowitz in the 18th century was revived and extended to include also aspects of ecology, nature protection and genetics beside the original economical aspect. Hence, clearcuts of the stands even with low acreage are avoided, uneven aged stands are well accepted, and natural regeneration is preferred wherever it is advantageous. This is the case when the quality and the origin of the stand to be regenerated are sufficiently adapted to the prevailing site conditions. If the prerequisites for the natural regeneration are not given or the regeneration fails, for instance in case of lack of seed crop, low number of beech trees per stand or insufficient preparation of soil, then seed or plants raised thereof or wildlings (young wild grown seedlings) taken from adjacent stands can be used to interplant and fill gaps in the stand to be regenerated. It is accepted practice to intervene during the development of the stand by early promotion of selected trees. Thinning measures are supporting this strategy, which is aiming at a high proportion of best quality stems in the stand for harvest. Felling is done at intervals in congruence with the development of the stand by optimizing increment and quality of timber. Dead wood is left in the stand in order to enhancing biodiversity.

As a result, these principles of "modern" silviculture can be described briefly as close to nature silviculture of the beech forest for multiple uses. Close to nature silviculture supports different functions of the forest like wood production, production of ground water in water catchment areas, preservation of biodiversity, protection of various kinds, as well as allowing multiple uses for instance for wild life and hunting, recreation, and a place of culture and experience of aesthetic, historical and mystical aspects. Since the 1980s silviculture has been gradually modernized in Germany, which caused a radical change in the management not only of the beech forests, but primarily for these affecting all beech forests (forest conversion phase). It was the main characteristic of modern silviculture to comply with the natural processes as much as possible. Shortly after the introduction of modern silviculture it turned out to be essential for a successful and competitive forest management (Janssen 2008).

Forest policy was encouraged to manage all forests with the aim to structure and to mix the stands with broadleaved tree species, to let the trees grow for a longer time, thus increasing the age, the standing volume and the increment. This management was extremely successful: The total standing volume for all forests increased up to 3,380 million m^3, which is the highest in Europe followed by Sweden and France. For beech, the total standing volume grew by 25.8% within 15 years up to 583 million m^3 (about 17.3% of the total) or 323 m^3/ha. Most of the standing volume exists in stands older than 120 years (37%) followed by stands between 80 and 120 years (35%). The mean annual increment during a 15 year period (1987 – 2002) of all beech forest was 11.74 m^3/ha, higher than in the past. Additionally, stand structure and management system have the advantage that the stands gain a higher stability and value in terms of ecology and biodiversity, support the wood industry with high quality timber continuously and cost efficiently, and increase the carbon sequestration (Federal Ministry 2002).

For future planning, the BMVEL (2005) investigated how much wood would be available for the period 2003 – 2042, by group of species, wood classification system, and region. The increment estimate, including all species on the total national forest area reaches 60 million m^3/year of usable wood (stem wood and industrial wood) in the first years and will increase to 70 million m^3/year by 2042. For beech wood the corresponding figures are 10.8 million m^3/year for 2003, then the increment will rise up to more than 12.7 million in the years between 2008 – 2012 and drop slowly again down to 10.8 million. However, generally the supply of beech wood will be sustainable in the years to come.

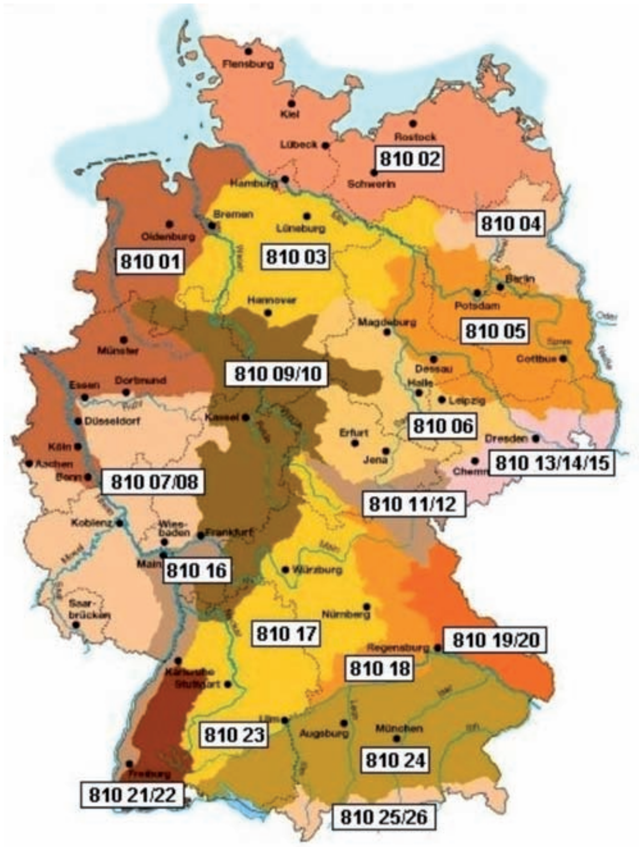

Fig. 1: The 26 regions of provenance of European beech in Germany

Legend: The registration code and common name are given below. The numbers in brackets refer to the ecological units [(http://fgrdeu.genres.de) according to the German Law on Forest Reproductive Material Moving in Trade Forstvermehrungsgutgesetz (FoVG), Legal Ordinance on Regions of Provenance (Herkunftsgebietsverordnung, *Fagus sylvatica*), and regions of provenance (Herkunftsgebiete):

810 01 Niedersächsischer Küstenraum und Rheinisch-Westfälische Bucht (03)
810 02 Ostsee-Küstenraum (01, 02)
810 03 Heide und Altmark (04, 05)
810 04 Nordostbrandenburgisches Tiefland (06)
810 05 Märkisch-Lausitzer Tiefland (10, 11)
810 06 Mitteldeutsches Tief- und Hügelland (09, 14, 16)
810 07 Rheinisches und Saarpfälzer Bergland, kolline Stufe (12 bis 400 m, 20 und 29 bis 500 m)
810 08 Rheinisches und Saarpfälzer Bergland, montane Stufe (12 über 400 m, 20 und 29 über 500 m)
810 09 Harz, Weser- und Hessisches Bergland, kolline Stufe (07 und 08 bis 400 m, 21, 22 und 31 bis 500 m)
810 10 Harz, Weser- und Hessisches Bergland, montane Stufe (07 und 08 über 400 m, 21, 22 und 31 über 500 m)
810 11 Thüringer Wald, Fichtelgebirge und Vogtland, kolline Stufe (15 und 25 bis 600 m, 13, 26 und 27 bis 700 m)
810 12 Thüringer Wald, Fichtelgebirge und Vogtland, montane Stufe (15 und 25 über 600 m, 13, 26 und 27 über 700 m)
810 13 Erzgebirge mit Vorland, kolline Stufe (17, 18 und 19 bis 500 m)
810 14 Erzgebirge mit Vorland, montane Stufe (17, 18 und 19 von 500 bis 700 m)
810 15 Erzgebirge mit Vorland, hochmontane Stufe (17, 18 und 19 über 700 m)
810 16 Oberrheingraben (30)
810 17 Württembergisch-Fränkisches Hügelland (23, 24, 32, 33, 34 und 39)
810 18 Fränkische Alb (35)
810 19 Bayerischer und Oberpfälzer Wald, submontane Stufe (28, 36 und 37 bis 800 m)
810 20 Bayerischer und Oberpfälzer Wald, montane Stufe (28, 36 und 37 über 800 m)
810 21 Schwarzwald, submontane Stufe (38 bis 900 m)
810 22 Schwarzwald, hochmontane Stufe (38 über 900 m)
810 23 Schwäbische Alb (40 und 41)
810 24 Alpenvorland (42, 43, 44, 45)
810 25 Alpen, submontane Stufe (46 bis 900 m)
810 26 Alpen, hochmontane Stufe (46 über 900 m)

REGENERATION AND SEED PROCUREMENT

Due to the prevailing natural regeneration of beech up to the 1970s, planting was not common. But when the forest policy aimed at increasing the area of broadleaved tree species within their potential natural range by conversion of the coniferous forest, mostly seed of beech was required for planting. Consequently seed was collected in own stands or imported mainly from South-East Europe in case of lack of seed crops in Central Europe.

Meanwhile the self-supply has improved not only for technical reasons, but also due to more frequent crop years since the 1990s when large quantities could be collected (see below).

According to the national law on forest reproductive material (FoVG 2002), seed stands had to be approved and regions of provenances had to be delineated (Fig. 1). The delineation is based on ecological units (Ökologische Grundeinheiten). The entire land area of the Federal Republic has been divided into areas of uniform ecological conditions: 46 ecological units in total. A number of similar and adjacent ecological units are combined to form a region of provenance. There are 26 regions of provenance throughout the Federal territory comprising some 14,181 seed stands for collecting seed to be marketed in the category "selected" covering a total area of 81,315 ha, of which 71,049 ha are autochthonous (87%). Additional 30 stands with acreage of 244 ha are approved for collecting seed to be marketed in the category "tested" (BLE 1999). Seed collection and plant establishment are carried out by private seed dealer and nurseries mainly. There are public agencies, which run seed kilns and some small nurseries, because most of the approved basic material is owned by the states (59%), but they sell by far the largest quantities of seed to private nurseries.

ECONOMICS

Beech wood is mostly used for fire wood and pulp. This market is still expanding since the middle of the last century. In the past decades a trend could be observed towards a diversification of the uses. The industry developed new techniques and new products using beech wood. This was possible, because it could rely on the sustainable supply of beech wood of high quality, especially of sawn timber and veneer. With the new uses, beech wood became more valuable and its price rose.

As shown above, the standing volume of beech wood is high, especially in stands of high age class. Thus, a total of 10 million m³/year was harvested, of which about 7.4 million m³/year was used for industry (pulp, paper, chipboard) or domestic fuel and 2.6 million m³/year as sawn timber for a variety of uses for instance for furniture, wooden strips, plates and toys, construction, parquet floor, stairs, for joiner and carpenter and the packaging industry.

More beech wood is exported than imported. In 2006 the export of beech raw wood reached annually about 1,010 thousand m³ and for sawn timber 384 thousand m³. The figures for import are 37 thousand m³ raw wood and 56 thousand m³ sawn timber. Main countries importing beech raw wood were Sweden, China, Austria, Italy, and Denmark, and those importing sawn timber were China, U.S.A., Poland, Spain, and The Netherlands. This market offers further opportunities for expansion.

The prices for harvested stem wood reached about 90 to 120 €/m³ and for industrial wood between 23 and 30 €/m³ in the years 1995 to 2006. On average the forwarding cost to the forest roadside amounted to 26 €/m³, the corresponding prices came up to 48 €/m³ for unsorted beech wood. Thus the earnings for the forest owner from the sale of the wood was 22 €/m³. The total income of beech forest owner has been calculated to about 260,000 €/1,000 ha and year, this includes also the earnings from other uses, primarily hunting leases, while the expenditures summed up to about 240,000 €/1,000 ha and year. Four jobs can be created in the forestry sector (two employees and two as service providers) permanently and additional four jobs in the wood industry and saw mills to process the wood from 1,000 ha. Besides these positive economics other valuable contributions of the beech forest to the total balance like the ecological and social functions should not be forgotten (Janssen 2002).

CONSERVATION

In 1987 (revised in 2000) a national concept for the conservation and sustainable use of forest genetic resources in the Federal Republic of Germany was elaborated and a working group (Bund-Länder-Arbeitsgruppe) was established coordinating all activities for evaluation of genetic resources and *in situ* and *ex situ* conservation measures as well as research in this field. Meanwhile the major forest tree species have been intensively dealt with and the minor forest tree and shrub species got more attention and special topics like monitoring, source identification, documentation and cooperation with international bodies gain importance.

In recent years beech nuts have been collected in approved stands: 184,815 kg (2004), 11 kg (2005), 196,640 kg (2006), and 43,185 kg (2007). Besides the approved basic material for beech (see above), special gene conservation units have been identified. Either they are stands (184 stands covering 1,496 ha) or single trees (193) *in situ* and one stand (1.0 ha) *ex situ*. Beech nuts have also been stored as special objects to be conserved; there are 65 seed lots stored together with 44,857 kg of seed as of May 2008. All special objects to be conserved have a unique status; they are registered and get special treatments, if necessary.

In the 1990s a data base was established containing all information about important plant genetic resources, including forest genetic resources, which is available on the website (http://www.genres.de/genres_eng/fgr/fgr_index.htm). The database serves as a national centre providing data and useful information for interested users, in the near future it will also be linked with the information systems EUFGIS (EUFORGEN) and REFORGEN (FAO).

Since 2004 a concept for genetic monitoring of forest tree species in the Federal Republic of Germany is available on the website (http://www.genres.de/genres_eng/fgr/fgr_mon.htm) and (http://www.genres.de/genres_eng/fgr/fgr_rah.htm). Beech has been chosen for a conservation pilot study; the first results show a high variation within stands and also differences among stands from different regions as shown by isozyme and DNA marker analyses. A second project includes beech and wild cherry as species to be monitored. Beside many other characters such as genetic markers are also studied to measure differences between old trees, naturally regenerated young trees and seed of the same old trees. Changes in the genetic structure may give evidence for disturbances in the transmission from one generation to the next one. So far no such evidence has been found (BLE 2009).

RESEARCH

Some research topics in the field of genetic variation, genetic resources, provenances, genetic monitoring, genetic differentiation and diseases of beech, which have been conducted in the past five years or are still under investigation (BLE 2009) may be mentioned below:

Three studies are under way to analyse, assess and correlate the resistance or tolerance to drought in populations of beech. This is particularly of interest in the eastern part of its distribution, where the rainfall is at its lower limit for beech. Additional studies of wood anatomy and chlorophyll-a-fluorescence are also integrated into these studies. Some studies are dealing with the genetic structure in regenerated populations, the influence of thinning on the genetic structure, and the variation in stands. Genetic monitoring occupies a large part of research, in particular the long-term monitoring in cooperation with the environmental monitoring of the Level II plots, which have been established during an EU-wide project. Distinction between seed lots by using stable isotopes or between *Fagus sylvatica* and *F. orientalis* by nuclear marker has been successful. In an older provenance trial it could be shown that economic value, e. g. straight stem form and fine branching, is influenced by the provenance. Over recent years the COST Action E52 is focussing on a joint evaluation of the international beech provenance trials. Furthermore the complex disease of beech occurring in western parts of Germany is being investigated more intensively.

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Reviewed

Contacts:
Dr. Georg von Wühlisch
Institute for Forest Genetics
Sieker Landstrasse 2, D-22927 Grosshansdorf, Germany
e- mail: georg.wuehlisch@vti.bund.de

THE EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN GREAT BRITAIN: ECOLOGICAL STATUS, SILVICULTURE AND MANAGEMENT OF GENETIC RESOURCES

Scott McG. Wilson

Consultant Forester and Forest Ecologist,
3 Thorngrove Crescent, Aberdeen AB15 7FH, Scotland, UK

ABSTRACT

This paper presents information about the current status of the European beech (*Fagus sylvatica* L.) in Great Britain. Beech is a native species in southern parts of Great Britain where it can be found in three natural beech woodland types (calcareous, mesotrophic and acid). Beech has also been established in plantations throughout many parts of Great Britain over the past 400 years, and is the third most abundant timber hardwood after oak and ash. A variety of silvicultural approaches has been adopted in beech woodlands, although low timber prices and landscape/nature conservation priorities in recent years have reduced the intensity of stand management. A major proportion of the British beech resource is in old stands under low-intervention management. Important examples of natural beech woodland are protected within designated conservation sites (equivalent to forest reserves in Europe). A network of selected seed stands for beech is maintained throughout Great Britain, but much beech reproductive material for forestry use has traditionally been imported from Europe. Recently there has been renewed interest in establishing qualified sources of reproductive material for beech (elite trees, seed orchards). The paper concludes with a review of current research priorities for beech in Great Britain, focussing on disease, pest and climatic impacts.

Key words: European beech (*Fagus sylvatica* L.), natural distribution, woodland ecology, silviculture, reproductive material, genetic conservation, Great Britain, forest research

POPULATION HISTORY AND NATURAL DISTRIBUTION

European beech (*Fagus sylvatica* L.) is normally regarded as a native tree species in southern parts of Great Britain, including much of south-eastern and south-central England and some parts of south-eastern Wales. This natural range lies between 50.5 and 52.5 degrees north latitude. Naturally-arising British beechwoods are of the lowland or colline types, occurring between sea level and 300 m a. s. l. The major proportion occurs between 150 m and 300 m a. s. l. on the convex upper slopes of hill ranges geologically formed of Cretaceous chalk (e. g. the Chilterns, North and South Downs) or Jurassic oolitic limestone (e. g. the Cotswolds). A minor proportion occurs on acid sand and gravel sites, found over lowland Tertiary basin deposits (e. g. New Forest, Burnham Beeches). From palynological evidence, beech is seen to have colonized Great Britain from mainland Europe, not later than 4,000 years B. P., at first spreading fairly slowly (Birks 1989, Rackham 2003). It may have had human assistance in this colonization – accidental or deliberate. It is certainly believed that beech spread into a landscape that had previously undergone significant anthropogenic clearance of natural mixed deciduous woodlands (dominated by oak, lime, ash, hazel and elm), which may have facilitated later, more rapid, colonization by beech. There is limited evidence that beech may have spread naturally beyond its current natural distribution, colonizing Carboniferous limestone hills to 300 m a. s. l. in areas of northern England and eastern Wales (to 54 degrees north). The extent of naturally-arising beech woodland has since been markedly reduced by clearance of woodland for agriculture and urban development and by replanting with alternative species. Nonetheless, semi-natural beech woodland remains the dominant land-cover type in a number of localities in the hills of southern England where it appears climatically suited and silviculturally valuable.

BEECH PLANTATION AFFORESTATION SINCE 1600

Since around 1600 AD plantation afforestation has been pursued in many parts of Britain for both timber production and landscape amenity, using a wide variety of tree species. Beech was used extensively in this afforestation, particularly between 1680 and 1920, when it was favoured for planting on private estates, often using reproductive material sourced from famous superior stands of mainland Europe, such as Versailles (France) and Forêt de Soignes (Belgium). Planting during

Fig. 1: Upland beech plantation – eastern Scotland

this period took place both within and beyond the natural range of beech in Great Britain. Many plantations were established in more northern and montane areas such as Wales, Scotland and the north of England (Wilson 2006). This has extended the effective range of the species within Great Britain – northwards to 58.5 degrees latitude in Scotland and upwards to ~450 m a. s. l. in various parts of the British uplands. Beech has proven its ability to regenerate naturally throughout the mainland of Great Britain on suitable, freely-drained woodland sites and is not significantly climate-limited

Fig. 2: 18th century beech avenue – south Scotland

Fig. 3: 19th century beech shelterbelt – eastern Scotland

below 300 m a. s. l. The species has also become a characteristic landscape element in many open agricultural districts of Great Britain as a long-standing and common shelterbelt species. A more recent phase of beech plantation expansion took place between 1920 and 1960, mainly as part of publicly-owned afforestation schemes within the native range of beech in southern England. Many such plantations were on land formerly occupied by calcareous grasslands. This history of plantation afforestation with beech has significantly expanded its land cover – it is now the third most abundant productively-managed hardwood tree species in British forestry, following oak and ash.

ECOLOGICAL TYPES OF BRITISH BEECHWOODS

British beech woodlands are recognized to be of three main ecological types, dependent upon the underlying soil conditions (Avery 1958, Peterken 1993, Rodwell 1991, Watt 1934). These types closely resemble the classical beech woodland phyto-sociological communities of mainland/central Europe. The main beechwood types are:

- **Calcareous beechwoods** – classified as W12 in the UK National Vegetation Classification (NVC) (Rodwell 1991). These are developed on shallow soils over calcareous strata such as Cretaceous chalk and Jurassic limestone in southern England. Soils are mainly of the rendzina and calcimorphic brown-earth types, with pH > 7 in the subsoil. Many beech woodlands of this type are on very steep scarp slopes (> 45 degrees) and are known as "beech hangers". Common tree species associates are ash (*Fraxinus excelsior*), yew (*Taxus baccata*), whitebeam (*Sorbus aria*) and field maple (*Acer campestre*), with very localized occurrence of box (*Buxus sempervirens*) which may be a Roman introduction. Two introduced maple species (*Acer pseudoplatanus* and *Acer platanoides*) are also frequent. The predominant ground vegetation is of calcicole species such as *Mercurialis perennis*, *Allium ursinum*, *Sanicula europaea* and *Arum maculatum*. An extreme form of this community, where yew dominates over beech, has been recognized as NVC W13. Some ecologists have divided the British calcareous beechwoods into two sub-types, one with abundant *Mercurialis perennis* the other with *Sanicula europaea* prevalent (Watt 1934). The latter is thought to be associated with particularly shallow drought-prone rendzina soils.
- **Mesotrophic beechwoods** – classified as W14 in the UK National Vegetation Classification (NVC). These are developed on brown earth soils of moderate fertility, over a wide range of parent materials within and beyond the natural range of beech. Within the natural range, most mesotrophic beechwoods are found on argillic clay soils over calcareous strata such as Cretaceous chalk and Jurassic limestone. These occur extensively on the more gradual/concave "dip" slopes behind escarpments. Common tree species associates are pedunculate oak (*Quercus robur*), ash (*Fraxinus excelsior*), hazel (*Corylus avellana*) and the introduced sycamore (*Acer pseudoplatanus*). Elm species (*Ulmus procera* and *Ulmus glabra*) would also have been found in the past, prior to devastation by the Dutch elm disease pathogen between 1930 and the present. The predominant ground vegetation is of *Rubus fruticosus*, with mixed grasses/herbs. There is little apparent edaphic or floristic distinction of these mesotrophic beechwoods from the mesotrophic oakwoods (NVC W10), but beech does not grow well on the more poorly-drained clay soils and plantation of beech onto such sites has often led to stand decline.
- **Acid beechwoods** – classified as W15 in the UK National Vegetation Classification (NVC). These are developed on mild podzols and podzolic brown earth soils of very low fertility (pH < 4), over a range of parent materials within and beyond the natural range of beech. Within the native

range, most acid beechwoods are developed on low elevation sites (< 150 m a. s. l.) over gravel and sand deposits of Tertiary ages (Bracklesham beds etc.). A proportion of acid beechwoods within the natural range has an open wood-pasture/parkland structure, consisting of over-mature beech, known in Britain as "veteran trees". In upland areas of northern and western Britain, acid beechwoods have been created by planting (very locally to > 400 m a. s. l.) over hard rock geologies (granites, sandstones, schists etc). Common tree species associates are sessile oak (*Quercus petraea*), birch (*Betula pendula*), rowan (*Sorbus aucuparia*), holly (*Ilex aquifolium*), the introduced *Rhododendron ponticum* and a variety of conifer tree species not native to these sites. Many acid beechwoods have very sparse ground vegetation due to canopy shade, but the fine grass *Deschampsia flexuosa* often dominates, together with *Vaccinium myrtillus*. In artificial beech stands, a variety of other species can become dominant including the grasses *Agrostis capillaris*, *Holcus lanatus* and *H. mollis* and locally, *Luzula sylvatica*. The native climax vegetation on sites of this kind outside the natural range of beech would have consisted of open oak-birch woodland with strongly calcifuge ground flora.

THE CURRENT BRITISH BEECH RESOURCE – EXTENT AND AGE-CLASS DISTRIBUTION

The most comprehensive information concerning the current land-cover of beech in Great Britain comes from the National Inventory of Woodlands and Trees (NIWT), a nation-wide sample-based survey of the nation's forest resources conducted on a roughly ten-year cycle. The most recent available data arise from the last survey, reported in 2001 – 2002 (see Tables 1 and 2). Work is currently under-way on the next round of survey, known as the National Forest Inventory, which will produce up-dated information for publication over the next five years. There is unlikely to have been major change in the position of beech over the past decade as little new beech woodland has been planted and there has been limited felling of older beech.

Tab. 1: Extent and relative significance of the beech resource within Great Britain
Data obtained from the latest FC National Inventory of Woodlands and Trees (2001 - 2002)

Tree species	England (ha)	Wales (ha)	Scotland (ha)	Britain (ha)	Britain (%)
Oak	158,665	42,918	21,114	222,697	9.4
Ash	104,920	19,321	4,904	129,145	5.4
Beech	64,022	8,998	9,961	82,981	3.5
Sycamore	48,805	6,907	10,882	66,594	2.8
Birch[1]	69,633	12,579	77,780	159,992	6.7
Other/Mixed[2]	201,523	26,780	81,722	310,025	13.0
Broadleaves	647,568	117,503	206,363	971,434	40.8
Conifers	340,201	148,913	916,490	1,405,604	59.2
Forested area	987,768	266,416	1,122,583	2,376,767	100

Notes: [1] Almost all of the area described as birch woodland will be spontaneous or sub-spontaneous woodland that is not under active management for birch timber production.
[2] There may be a significant but undefined quantity of mature beech, some potentially suitable for timber, submerged within the other/mixed broadleaved woodland category.

Tab. 2: Age class distribution of the beech resource within Great Britain
Data obtained from the latest FC National Inventory of Woodlands and Trees (2001 – 2002)

Class	1991-1995	1981-1990	1971-1980	1961-1970	1951-1960	1941-1950	1931-1940	1921-1930	1911-1920	1901-1910	1861-1900	Pre-1861	Total timber	Non-timber	Small woods	Total
Country	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
England	785	1,014	1,968	5,685	7,689	5,613	3,925	5,707	5,252	2,136	9,961	4,889	54,624	5,948	3,450	64,022
Wales	100	20	13	250	872	421	688	319	408	81	1,090	274	4,536	2,833	1,629	8,998
Scotland	182	94	85	179	381	109	369	213	369	92	1,221	1,034	4,330	4,280	1,351	9,961
Total	1,067	1,128	2,066	6,114	8,942	6,143	4,982	6,239	6,029	2,309	12,272	6,197	63,490	13,061	6,430	82,981
% Total	1.3	1.4	2.5	7.4	10.8	7.4	6.0	7.5	7.3	2.8	14.8	7.5	76.5	15.7	7.8	100

Notes: 1. Age class data is only available within the NIWT survey for that portion of the beech resource which is classed as "High Forest Category 1" (i. e. potentially capable of producing sawlog quality timber at final harvest) and standing in woodlands in excess of 2 ha. Aggregated totals are provided for (a) the poorer material in woods > 2 ha in extent and (b) for material of any quality in smaller woodlands/linear features. This allows for reconciliation of the total resource with the data presented in Table 1 supra.

It will be seen from the data presented that a major proportion of the standing British beech resource is in the semi-mature and mature age classes, potentially suitable for timber harvest, having been established prior to the Second World War. This includes a significant amount of over-mature beech, established during the eighteenth and nineteenth centuries on private estates, which is retained mainly for landscape amenity and conservation purposes and is unlikely to become available for harvest under current market conditions. A number of the finer mature stands of beech timber, valuable as potential sources of selected reproductive material, were destroyed or seriously damaged during the major storms of late 1987 and 1990 that affected parts of southern England. This included the very famous stands at Slindon Park and West Dean in Sussex, which are currently in the thicket regeneration phase. Some valuable timber stands also suffered drought damage following the dry summers of 1975 – 1976. Nonetheless there remain a number of very fine stands of mature beech in Britain, most within the natural range in the Chilterns and Cotswolds, but with a scatter of examples elsewhere. Fine beech sawlog timber harvested in Britain finds markets for furniture-making and decorative joinery, but a major proportion of the total harvested volume is used for firewood.

The remainder of the standing beech resource in Britain is found in younger plantations on both public and private forest lands, established during the mid-twentieth century, often with a view to rotational timber harvest. These stands have, on the whole, been subject to a fairly low intensity of thinning/management due to low market prices for beech timber at present, coupled with grey squirrel damage. Improved fuelwood markets over the past two years have encouraged early thinnings in young beech stands, which should enhance final crops. Very little new beech woodland has been created for forestry purposes over the last 40 years, but the species has continued to find favour as an element within landscape and amenity planting.

Fig. 4: Premier beech stand – Chiltern beechwoods

SILVICULTURE OF BEECH IN BRITAIN

A variety of silvicultural approaches has been applied to beech woodlands in Britain over the past 300 – 400 years for which reliable records are available (Rackham 2003). These can be summarized as:

- **Selection forestry** – based on classic Continental European systems of beech woodland management for timber production. Many of the better quality stands of pure beech within the natural range in Britain have been managed under variants of the group selection and single-tree selection systems for production of quality timber for the furniture-making industry. This was the prominent system applied in the Chiltern beechwoods, during the period 1750 – 1950, where a traditional furniture-making industry developed, concentrated in the towns of High Wycombe and Princes Risborough. More recently, the best examples of this type of silvicultural management have been in the Cotswold beechwoods, principally in those owned by the Workman family. Only a small area of British beech woodland currently remains under traditional selection silviculture. Since the mid-1970s, timber values obtainable for mature beech crops have been depressed in Britain, with the exception of high quality stems suitable for veneer, and this has made it difficult to cover the costs of selection silviculture from timber income alone.
- **Regular forestry** – remains the predominant silvicultural approach in British woodlands managed for timber production on a rotational basis, both on public and private lands. During the two world wars significant areas of beech woodland were clear-felled under emergency timber supply programmes and later re-planted with new beech crops. Other areas of open ground were planted with beech during the twentieth century, particularly on the public forest,

with the intention that stands would later be rotationally felled. Yields would typically be 4 – 8 m^3/annum over a final-felling rotation of 80 – 120 years. However in recent decades the area of regular beech woodland being felled and replanted has declined markedly, with most stands now being converted to lower-intensity forms of management (shelterwood, non-intervention etc.) aimed at amenity and conservation. Diversification by enrichment planting with other native species (oak, ash, cherry) has become a frequent response to perceived challenges to beech from increasing drought.

- **Fuelwood/coppicing** – a traditional form of management of beech woodland in certain regions, particularly the Cotswolds during Roman times and the Chilterns during the medieval and early-modern periods. Until the widespread adoption of coal as a domestic and industrial fuel, small-diameter beech was a major source of fuel for the city of London, for example – especially for industries such as bread-making. Beech does not coppice very reliably under British climatic conditions at the present time, but some areas of beech woodland in these regions appear to have been managed as coppice in the past. Beech remains a favoured fuelwood for log stoves and there is now renewed interest in the management of the species under short-rotation forestry systems to produce fuel chip.

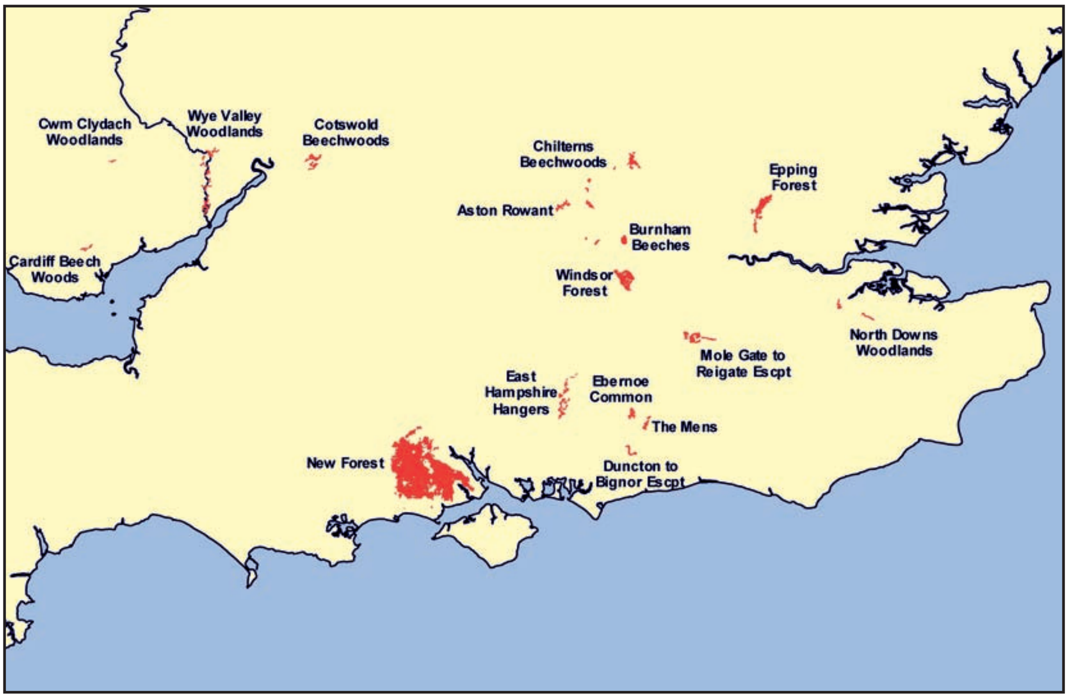
- **Wood-pasture/pollarding** – a traditional form of management of beech woodland, particularly associated with lowland acid beech woodlands within the natural range. There are several prominent localities – Savernake Forest, New Forest, Burnham Beeches, Windsor Great Park and Epping Forest – where these systems have been applied intermittently over at least several centuries, leading to valued cultural landscapes of veteran beech and oak trees set within open grass parklands. Beech was traditionally pollarded to produce fresh growth beyond the reach of browsing livestock. In recent years there has been a considerable upsurge in interest in the restoration of such wood-pasture landscapes by re-introduction of cattle grazing and active beech pollarding (Read et al. 2010). Many beech wood-pastures are under public or charitable conservation ownerships, and almost all major examples have been designated as nature reserves or conservation sites. The preservation of the over-mature beech resource, including its standing deadwood, has been prioritized in support of the saproxylic invertebrates exclusively associated with this.

- **Low-intervention high forest** – areas where mature beech woodland (natural or planted) is allowed to remain with very limited management interventions, usually only amounting to the removal of dangerous unstable trees. In some cases this is due to inaccessibly steep terrain or to the abandonment of former selection forestry systems on economic grounds. In some cases there is an explicit nature conservation or landscape amenity basis for the adoption of low-intervention management, both on public and private forest estates. Some privately-owned mature beech woodlands are now used for sport – e. g. pheasant shooting. A considerable amount of the mature standing beech resource under low-intervention management regimes is in mixture with other species, including introduced conifers. The proportion of British beech woodland under low intervention management is increasing, particularly in districts where damage by introduced grey squirrel reduces productivity.

CONSERVATION MANAGEMENT OF BEECH WOODLANDS IN BRITAIN

All woodlands in Great Britain are subject to generic protection through a system of felling regulation by the state Forestry Commission. Forestry operations are also influenced by the UK Forestry Standard and, on some ownerships, through adherence to the UK Woodland Assurance Scheme (FSC compliant certification). All notified fellings of trees beyond the arboricultural scale require felling licence approval from the Forestry Commission prior to work being carried out, with a system of legal enforcement and sanctions. Felling licences are normally conditional on effective restocking, either by natural regeneration or re-planting. Felling licences can be granted for individual silvicultural interventions or as a component of approval for the implementation of a Forest Design Plan (public forests) or Forest Plan (private forests). It has become very rare in recent years for hardwood stands to be felled and restocked with conifer species. However, in the case of planted beech woodlands, permission may be granted to change composition to an alternative hardwood species such as oak, or to mixed hardwood forestry. Mixed hardwood-conifer stands can be restocked to retain the mix.

Additional protection is given to what are known as "ancient semi-natural woodlands" in Great Britain. These represent the minor proportion of the overall British forest resource that has escaped clearance or extensive replanting with non-site-native tree species since at least 1600 AD (England and Wales) or 1750 AD (Scotland). In the case of beech, this would apply to most mature beech woodlands within the natural range that have not been cleared since 1600, although it is accepted that in some cases planting of beech may have occurred in the past, including with non-local reproductive material



Map 1: Geographical distribution of beech woodland Special Areas of Conservation (SAC's) within the British natural range

Tab. 3: European-level beech woodland conservation areas (SAC sites) in Great Britain
Data obtained from published records of the Joint Nature Conservation Committee

SAC site name	Annex I beechwood type	Beechwood habitat extent (ha)[2]
Aston Rowant	9130 *Asperulo-Fagetum*[1]	30
Burnham Beeches	9120 *Atlantic acidophilous*	345
Cardiff Beech Woods	9130 *Asperulo-Fagetum*	53
Chilterns Beechwoods	9130 *Asperulo-Fagetum*	565
Cotswold Beechwoods	9130 *Asperulo-Fagetum*	469
Cwm Clydach Woodlands	9120 *Atlantic acidophilous*[1] 9130 *Asperulo-Fagetum*	4 + 21
Duncton to Bignor Escarpment	9130 *Asperulo-Fagetum*	171
East Hampshire Hangers	9130 *Asperulo-Fagetu*m	266
Ebernoe Common	9120 *Atlantic acidophilous*	165
Epping Forest	9120 *Atlantic acidophilous*	642
Mole Gap to Reigate Escarpment	9130 *Asperulo-Fagetum*[1]	178
North Downs Woodlands	9130 *Asperulo-Fagetum*	53
The Mens	9120 *Atlantic acidophilous*	142
The New Forest	9120 *Atlantic acidophilous* 9130 *Asperulo-Fagetum*	1,990 + 410
Windsor Forest and Great Park	9120 *Atlantic acidophilous*[1]	273
Wye Valley Woodlands	9130 *Asperulo-Fagetum*	190

Notes: 1. Denotes sites where the beechwood is a qualifying feature but not the primary reason for original selection of the site as a candidate Special Area of Conservation (cSAC).
2. Great Britain is estimated to hold a total of 12,250 ha of natural beechwood habitat conforming to the 9130 *Asperulo-Fagetum* Annex I habitat and 7,250 ha conforming to the 9120 *Atlantic acidophilous* beechwood with u/s Ilex and *Taxus* Annex I habitat. A further 15,000 - 20,000 ha are thought to conform to the broader UK Habitat Action Plan definition for "Lowland Beech and Yew Woodlands". The remainder of British beech woodlands (around 50%) are in plantations, including on the more upland sites.

(for example from France and Belgium). In these ancient semi-natural woodlands, felling licences will rarely be issued for extensive group or clear-fellings, although thinnings to promote natural regeneration are permissible. The best examples of ancient semi-natural woodland are designated as "Sites of Special Scientific Interest" (SSSI's), which are protected from a wider range of "Potentially Damaging Operations" extending beyond tree felling. Some of these SSSI's sites have recently been incorporated within European-mandated "Special Areas of Conservation" (SAC's), for some of which, beech woodlands are Annex I qualifying habitats. Table 3/Map 1 detail SAC sites, within the British natural range, where beech woodland is a qualifying feature, although it may not occupy the entire site. SSSI/SAC sites can be under public, private or charitable ownership, and are effectively managed on a low-intervention basis equivalent to forest reserves in other countries. Some are small, discrete woodland sites, occupying a few hectares, whereas others cover woodland complexes over several hundred. Prominent SSSI's where public access is available are designated "National Nature Reserves" (NNR's), of which a small number feature natural beech woodland ecosystems. Protection of SSSI, SAC and NNR sites is administered by devolved public nature-conservation agencies –

Fig. 5: 18th century pollard or bundle-planted beech – south Scotland

Natural England, Countryside Council for Wales and Scottish Natural Heritage, who have powers of regular inspection and monitoring, enforcement and also grant-in-aid allocations.

Outside the natural range of beech, beech woodland sites would not be eligible for SSSI/SAC status, as they are regarded as "long-established plantations" rather than "ancient semi-natural woodlands". In some acid upland oak-birch woodlands, planted beech is regarded as an invasive introduced species, potentially threatening to the primary conservation interest. In this it is often considered together with *Acer pseudoplatanus* and *Rhododendron ponticum*, neither of which is native to the British Isles. This applies to several prominent woodland complexes in Wales, northern England and Scotland. Here, efforts are made to manually remove young regenerating beech seedlings and saplings, but mature and veteran beech trees are often permitted to remain for their inherent landscape and deadwood invertebrate values.

MANAGEMENT OF BEECH REPRODUCTIVE MATERIAL WITHIN BRITAIN

Great Britain has not previously operated a formal system of genetic reserves or genetic conservation units within existing woodland, as it was considered that the system of Sites of Special Scientific Interest (SSSI's), described earlier, provide for effective conservation of genetic diversity along with other components of biodiversity (landscape, structure, species). In recent years the concept of formal genetic conservation reserves has been re-evaluated but no decision to proceed with a novel system of designations has been implemented to date.

Sourcing of forest reproductive material in Great Britain is controlled by the domestic Forest Reproductive Material (FRM) Regulations, which implement relevant European directives. For beech, all domestic basic material sold for forestry must come from a source appearing on the Register of Basic Material, maintained by the Forestry Commission. Traditionally, much of the beech planting stock used in Great Britain has been grown from seed collections from a small number of premier stands in mainland Europe (Versailles, Forêt de Soignes etc.) which would equate to the present-day "selected seed stand" category of basic material. However, from time-to-time beech reproductive material has also been sourced from domestic seed stands. Great Britain is divided into four Regions of Provenance (10, 20, 30 and 40), with RoP 40 containing most of the natural range of beech within Great Britain (Lines 1999, Hubert, Cundall 2006).

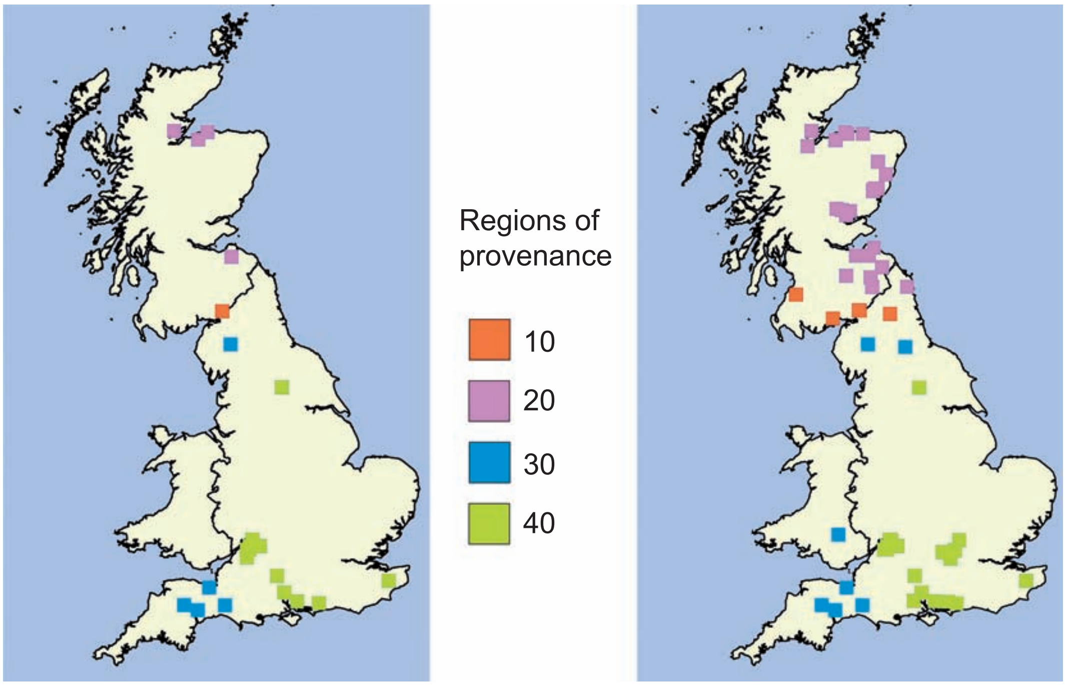
Great Britain has registered a domestic network of 25 selected seed stands of beech from which basic material can potentially be collected for forestry plantings. These are mostly very small stands of mature planted beech of notably superior stem form, covering a total area of 117 ha (see Table 4/Map 2). Although 15 of these stands are geographically located within the natural range of beech in Great Britain, none are registered as being of indigenous origin. Of the 25 stands, one is registered as of Versailles origin (planted 1680!) while the remainder are of unknown origin. Most are mature plantations that will embody both British and Continental European selected provenances from the period 1680 – 1920. Due to the low-level of planting of beech for forestry purposes, little seed is now taken from these. Nursery production of beech plants is overwhelmingly for landscape amenity and horticultural uses.

Fig. 6: Beech selected seed stand – North Scotland

Tab. 4: Distribution of selected seed stands and 110 elite trees for beech in Britain
Data relating to selected seed stands obtained from FC Register of Basic Material

Region of provenance	Number of selected seed stands	Area of selected seed stands (ha)	Number of recorded elite trees (in 2007)
10 (NW)	1	1.5	9
20 (NE)	4	7.2	43
30 (SW)	5	5.8	15
40 (SE)	15	102.5	43
TOTAL	**25**	**117.0**	**112**

Notes:
1. It is regarded as quite possible, and desirable, to identify additional elite trees from within Region of Provenance 30 (western England and Wales) prior to establishment of any future qualified seed orchard for that RoP.
2. It is unlikely to be possible to identify more than a small number of additional elite trees from Region of provenance 10 (western Scotland) and any future qualified seed orchard established for Scotland would be likely to have to combine RoP's 10 and 20.
3. One site within Region of provenance 40 (Kingscote Wood, Cotswolds) could potentially supply up to 20 elite trees, but this has been limited to 5 above for representativeness.



Map 2: Geographical distribution of beech selected seed stands and elite trees within Great Britain

Recently the four British Regions of Provenance have been sub-divided into smaller voluntary "local seed zones" which can be adhered to for plantings of native trees in or near existing ancient semi-natural woodlands in order to conserve genetic diversity (Ennos et al. 2000, Herbert, Samuel, Patterson 1999, Hubert, Cottrell 2007). For beech, this consideration would only apply within the natural beech range – covered by local seed zones 303, 402, 403, 404, 405. However, due to the long history of beech planting, no source-identified basic material for beech has been registered as being indigenous to date. Indeed there are currently no source-identified locations within Britain for beech.

Great Britain currently has no qualified or tested sources of beech basic material. A programme of elite tree selection, progeny testing and seed orchard establishment for beech was pursued by the Forestry Commission in the period 1945 – 1985, but the small seed orchards created at that time have been abandoned for many years. Over very recent years there has been revived interest in the improvement of hardwood species, with the formation of the collaborative British and Irish Hardwood Improvement Programme (BIHIP) (Savill, Fennessy, Samuel 2005). Due to low timber prices, climatic challenges and grey squirrel impacts, beech was not selected as an early priority for this programme. However in 2007 a new pre-selection of some 110 elite beech trees was made throughout Great Britain, suitable for the future formation of one or more qualified seed orchards, probably by clonal propagation methods (Wilson 2008a, b). A similar strategy has been successfully adopted for *Betula pendula* within the BIHIP priority species programmes.

Fig. 7: Seed collection from beech selected seed stand – North Scotland

RESEARCH PRIORITIES FOR BEECH IN BRITAIN

Over the past century a number of lines of active applied research have been pursued with regard to beech in Great Britain, both by the research branch of the Forestry Commission (now known as Forest Research) and by academic researchers in university forestry departments and government research institutes. The main areas of work have been:

- **Plant ecology and site affiliations** – early work between the two world wars adopted the Continental European phyto-sociological and edaphic approaches, leading essentially to the three-fold floristic/edaphic classification of the British beechwoods. Leading researchers in this period were Tansley, Watt and Bourne, based at the university forestry departments in Oxford and Cambridge (Tansley 1911, 1939, Watt 1923/25, 1931, 1934, Watt, Tansley 1930). The Chiltern and Cotswold beechwoods received particular attention. Later woodland ecologists such as Peterken and Rodwell have refined the basic classification of the British beech woodland communities, providing finer detail (Peterken 1993, Rodwell 1991).
- **Establishment and productivity** – post Second World War research, based at the Forestry Commission's Alice Holt Research Station, focussed on improving techniques for the establishment of new beech crops, particularly on rendzina soils/calcareous grasslands within the British natural range. There was also a programme of tree breeding, with early provenance trials, elite tree selection, progeny trials and seed orchard establishment (Savill, Fennessy, Samuel 2005). Leading Forestry Commission researchers on beech were J. M. B. Brown and D. Fourt (Brown 1953). Current advice would be to establish beech crops at 2,500 stems/ha or ideally more. Crops established at 1,100 stems/ha require intensive pruning to achieve satisfactory timber crops and this is rarely applied due to high costs for the required labour inputs.
- **Diseases and pests** – the long-standing disease of beech in Great Britain was beech bark disease, caused by an initial infestation by the felted beech coccus insect (*Cryptococcus fagisuga*) followed by lesion infection with the fungus *Nectria coccinea*. Together these cause significant canker and die-back of beech from the pole-stage onwards and were the subject of research at Alice Holt in the 1970s and 1980s (Lonsdale, Wainhouse 1987). More recently attention has turned to the highly aggressive *Phytophthora* fungus-like pathogens that have become established in western parts of Great Britain (*Phytophthora ramorum* and *Phytophthora kernoviae*). Although the main hosts for these species in Great Britain are ornamental shrub species such as *Rhododendron, Azalea, Syringa* and *Pieris*, these pathogens have demonstrated an ability to infect beech trees growing in close proximity, particularly in the warm-moist climates of south-western Britain. More recently *Larix kaempferi* has been affected in this region. A programme of research is currently being pursued, led by Forest Research at Alice Holt, to develop avoidance and mitigation measures for these new diseases across a range of tree species. Grey squirrels remain the main mammalian pest of beech within its British native range, causing significant bark stripping damage, especially at the pole-timber stage. This species was introduced to Britain in the 1800s and has since spread widely, displacing the native, and less damaging, red squirrel. A variety of research and development approaches has been pursued to enable effective control of grey squirrels in the forestry context by trapping and to examine the potential applicability of immuno-contraception.
- **Drought damage and die-back** – since the severe summer droughts of 1975 – 1976, increasing evidence has been found of mature beech within the British natural range suffering apparent drought damage (Peterken, Mountford 1996). This leads to crown recession and partial

defoliation, and in severe cases, stem lesions and mortality (Innes 1988, Power, Ashmore, Ling 1995, Stribley 2005). The Forestry Commission forest condition monitoring programmes detected such damage through the 1980s and 1990s when there were several episodes of atypically severe summer drought. The risks to beech are highest on shallow or sandy soils with

Fig. 8: European-scale beech provenance trial – Northmoor Trust

Fig. 9: Beech provenance trial – planted early 1950's – south Scotland

a low available water capacity and on poorly-drained clay soils where a high winter water-table can truncate beech root runs. Low-level ozone pollution from vehicle exhausts may exacerbate the impacts on beech by restricting stomatal closure during drought episodes, and there may be interactions with the periodic beech mast (Matthews 1955). Recently, increment coring techniques have been used to investigate these effects by studying ring-width patterns in mature beech over the past four decades (Wilson et al. 2008).

- **Climate-change impacts** – there has been increasing concern over recent years as to the potential impacts of predicted climate change on beech populations in Britain, particularly within the natural range in southern England (Broadmeadow, Ray, Samuel 2005). Climates within this region are already prone to summer soil moisture deficits due to low annual rainfall (locally 500 – 600 mm) and extended periods of drought. Summer droughts are predicted to become more frequent and severe over the next rotation under future climate scenarios considered by the UK Climate Impacts Programme (UKCIP). Analyses using information about the climatic tolerances of beech (for example the Ellenberg beech quotient) have indicated that beech may suffer decreases in vigour and yield performance in parts of its British natural range within this time period, with local mortality on vulnerable soil types, following episodes of severe summer drought (Wilson 2006, Wilson et al. 2008). Air pollution may also be a contributory factor. This has implications both for its suitability for timber production and for the conservation of Annex I lowland beech woodland habitat types (Wesche 2003). Consideration is being given to the refugial potential of beechwoods in the British uplands, beyond the current natural range, which may be less vulnerable to climatic change (Wilson 2006). This may promote changes to nature conservation policy and practice in upland beech and other woodlands.
- **Provenance trials** – to address climatic challenges to beech, Great Britain is currently participating in European-level beech provenance trial series, with two active fully replicated trial sites located within the British natural range of beech in south eastern England. These trials are under 15 years of age. There are also some smaller, more weakly replicated, trials of European beech provenances, stemming from the early 1950s, which are amenable to rapid mid-rotation re-assessment at the present time.

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For information with respect to the designation and conservation of beech woodland Special Areas of Conservation, refer to www.jncc.gov.uk.

For information with respect to the GB National Inventory of Woodlands and Trees (NIWT) and the GB National Forest Inventory (NFI), refer to www.forestry.gov.uk/inventory

For information with respect to the control of beech reproductive material in Great Britain, including details of selected Registered Seed Stands, refer to www.forestry.gov.uk/frm

For information with respect to research into genetic conservation and tree improvement for British beech, refer to www.forestry.gov.uk/research and www.bihip.org

Reviewed

Contacts:

Dr. Scott McG. Wilson MICFor
Consultant Forester and Forest Ecologist
3 Thorngrove Crescent, Aberdeen AB15 7FH, Scotland, UK.
e- mail: scottmcgwilson@hotmail.com

CURRENT STATUS OF GENETIC RESOURCES OF BEECH IN GREECE

Konstantinos Spanos – Dionysios Gaitanis

N. AG. RE. F. - Forest Research Institute, Gr-57006 Vassilika, Thessaloniki, Greece

ABSTRACT

The presented work provides an overview of beech forests in Greece. Information on natural distribution of beech and country data are given. Information on the ecology of beech genetics and management of its genetic resources is also provided as well as the importance of beech at present and in the former times. Information on silviculture, propagation and forest management are also highlighted. Type and quality of wood products, volume of standing timber and of wood harvested are summarized. General information on health status, general conditions and threats to beech and its genetic resources and indications of recent climatic impacts on beech forests are provided. Further particularities including scientific studies on beech, the most important problems of beech ecosystems and sustainable silviculture are provided.

Key words: European beech, Oxia (in Hellenic), overview, beech forests, taxonomy, genetics, ecology, sustainable silviculture, wood production, forest management

NATURAL DISTRIBUTION OF BEECH

The mountains of Greece are well known for their rich flora and high biodiversity including many endemic species (Dafis 1973, Strid 1989, Strid, Kit 1991, Dimopoulos, Bergmeier 1998, Dimopoulos et al. 1995, Fady-Welterlen 2005). In Greece, beech ecosystems are very dispersed on the high mountains (Fig. 1), growing on a variety of sites which harbor a rich biodiversity. Beech forests represent about 10.02% (336,600 ha) of the total high forests of Greece and most of these, around 80%, are state forests. Beech grows in the mountains of N, NW, and E Greece, on the Pindos Mountain range up to Mountain Oxia in the central part of the country (Moulopoulos 1961, 1965, Spanos 2010). Altitudinally, it grows from 180 m a. s. l (Kentavros Mountain – Xanthi) up to 1,600 – 2,000 m a. s. l. (mountains of Pindos, Olympos and Oxia). Beech forests have been evaluated systematically by Moulopoulos (1961, 1965) and Dafis (1973, 1990). According to Moulopoulos (1961, 1965), beech forests are composed of *Fagus sylvatica*, *Fagus moesiaca* and *Fagus orientalis*. Horizontally, *Fagus sylvatica* is mainly distributed in the central and western mountainous parts of the country, *Fagus orientalis* in the forests of the eastern parts and *Fagus moesiaca* in almost all beech forests. Vertically, *Fagus orientalis* is found on lower altitudes (180 – 1,000 m a. s. l.), *Fagus sylvatica* in the higher and colder parts (up to 1,100 – 2,000 m a. s. l.) whereas *Fagus moesiaca* in all altitudinal ranges of beech (Dafis 1973, 1990). Past studies (Moulopoulos 1961, 1965) have shown that *Fagus orientalis* is better adapted to relatively drier conditions whereas *Fagus sylvatica* prefers colder environments. It has been suggested that *Fagus moesiaca* is a hybrid (*Fagus* ×*moesiaca*) of *Fagus* *sylvatica* and *Fagus orientalis* or represents populations of *Fagus sylvatica* adapted to intermediate site conditions (Moulopoulos 1965). Other studies (e. g. Gömöry et al. 1999) have suggested that populations of the putative taxon of *Fagus moesiaca* from the Balkan Peninsula seem to form an independent group. In recent studies, based on morphological and molecular variation, and Flora books (e. g. Strid 1989, Strid, Kit 1991) the two species are considered as subspecies of the cluster species *Fagus sylvatica* (e. g. *Fagus sylvatica* subsp. *sylvatica* and *Fagus sylvatica* subsp. *orientalis*).

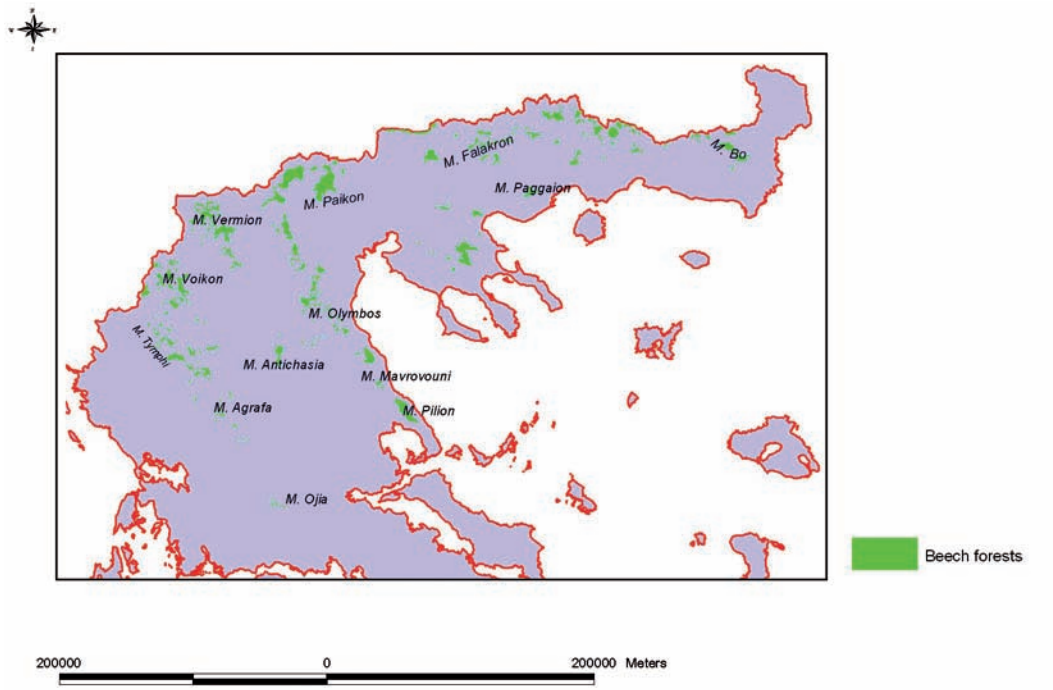

Fig. 1: Map showing distribution of beech in Greece

In Greece, beech is considered as a cold resistant species, it requires rich (in humus and nutrients) and humid soils, high air humidity and average mild climate close to Atlantic conditions. The climate where beech grows belongs to the mountainous supra-Mediterranean climate, characterized by high annual precipitation, high relative humidity and short dry periods (Dafis 1969, Athanasiadis 1985, 1986, Anon. 1991, 1996, Spanos et al. 1998, Larsson 2001). Beech forests belong to the sub-zone *Fagion moesiacae* (beech forests) of the *Fagetalia* (mixed beech-fir and mountainous supra-Mediterranean conifers) forest vegetation zone (Fig. 2).

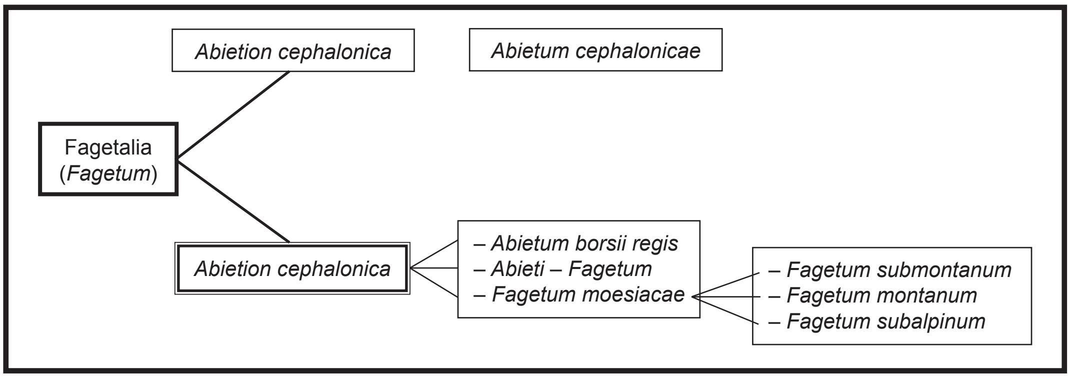

Fig. 2: Diagram showing the beech-fir forest vegetation zone (Fagetalia) (Dafis 1973, Athanasiadis 1985)

ECOLOGY OF BEECH (CLIMATE, SITE/SEA LEVEL, SOILS), MIXTURE WITH OTHER SPECIES

Phytosociological studies for the beech forests of Chalkidiki, Pieria Mt., Ossa Mt., Pilion Mt. and central Pindos mountain range have distinguished beech forests into six phyto-sociological units corresponding to six site quality types which have been classified into three groups as following (Dafis 1969):

- Site types I and II: here beech shows the maximum productive capacity. However, regeneration in this site type is suppressed due to the intense ground vegetation. To enhance and help natural regeneration, a series of shelterwood cuttings on large areas (for even-aged stand structure) or in small groups expanded (for uneven-aged stands) should be carried out.
- Site types III and IV: in these types, beech shows sufficient productivity. Natural regeneration develops relatively well because of the reduced competition from the ground vegetation.
- Site types V and VI: these types are mainly occurring on the hills and drier slopes. Beech stands here show low productivity and poor timber quality. In such sites the introduction of less demanding conifers (e. g. *Pinus sylvestris*, *P. nigra*) as a proportion of 60 – 80% is recommended.

The chorological significance of beech forests in Greece is reflected by many species of boreal, central European and temperate distribution, some of which are just reaching the southernmost limits in Greece (e. g. *Luzula luzuloides*, *Paris quadrifolia*, *Millium effusum*, *Corallorhiza trifida*) (Dimopoulos, Bergmeier 1998, Dimopoulos et al. 2005). According to the geographical pattern of beech forests the following groups/types can be distinguished: (a) western types (N, C and S Pindos), (b) eastern types (EC and NC Greece), (c) northern types (Varnous to Rodopi), and (d) northeastern types of *F. sylvatica* ssp. *orientalis* (E. Rodopi). Occurrence of taxa at their southernmost distribution limits is often vulnerable status and may require effective conservation (*in situ*) within beech forests (Medail, Quezel 1997, Dimopoulos, Bergmeier 1998, Spanos, Feest 2007). In Greece, beech forest soil contained the highest N content in comparison to conifers and many other broadleaved species (Kavvadias et al. 2001, Michopoulos, Baloutsos, Economou 2007) thus recognizing beech an important species for soil improvement.

GENETICS: TAXONOMY, GENETIC RESOURCES, LEGISLATION, MANAGEMENT AWARENESS OF THE GENETIC RESOURCES OF BEECH, AREA OF *IN SITU*, *EX SITU* RESERVES, COMMON GARDEN TESTS

Taxonomy of beech in Greece: *F. sylvatica* L., *Sp*. Pl.: 998 (1753) ssp. *sylvatica* (recorded from Europe). 2n = 22 and 24. Syn.: *F. moesiaca* (K. Maly) Czecz. in Roczn. Polsk. Towarsz. Dendrol. 5: 96 (1993), p.p. It is closely related to *F. sylvatica* ssp. *orientalis* (Lipsky) Greuter and Burdet in Willdenowia 11: 279 (1981), described from NW Iran. Typical ssp. *orientalis* from N. Iran and NC Turkey can be distinguished from ssp. *sylvatica* on the following characters (Moulopoulos 1965, Strid 1989): leaf size/shape and number of veins, cupula size and shape of scales. Beech stands show high differentiation in Greece. Various forms called *F. moesiaca* (K. Maly) Czecz. with intermediate leaves (between the two species) can be found throughout the range of ssp. *sylvatica* but are more frequent in the Balkan Peninsula and in NW Anatolia (Turkey) where the two subspecies meet. The shape and the size of the male perianth (diagnostic character) vary within the subspecies and even in the same tree and the same inflorescence (Moulopoulos 1965, Strid 1989, 1991). Another diagnostic character of ssp. *orientalis* is the spathulate cupula scales (Moulopoulos 1965, Athanasiadis 1986). In Europe, beech trees with such scales are found in SE Bulgaria, Romania and European part of Turkey. In Greece, and particularly in the north-eastern part of the country, some trees resemble ssp. *orientalis* in vegetative characters, but never have clear dilated cupula scales (Strid 1989). Such phenotypes usually grow at relatively low altitude (200 – 1,000 m), whereas typical ssp. *sylvatica* is mainly found in the western and central parts and rarely below 1,000 m (Moulopoulos 1965, Strid, Kit 1991). The two subspecies are considered typical geographical races, and have a broad range of intermediate forms in the zone of contact (Moulopoulos 1965, Strid, Kit 1991). Recent studies based on leaf morphological characters (e. g. Boutsios et al. 2004) and molecular markers (e. g. Vidali et al. 2005) have shown an increased genetic diversity in beech populations from NE and E Greece (Thraki region) in comparison to other parts of the country, and suggested a possible meeting of the two subspecies (*F. sylvatica* ssp. *sylvatica* and *F. sylvatica* ssp. *orientalis*) at this location.

The seed stands of beech have been selected according to EEC and OECD/international rules and terminology (E.E.C. 1966, O.E.C.D. 1967, Barner, Koster 1976, Matziris 1989). Beech selected seed stands are shown in Table 1 along with the parameters: latitude, longitude, altitude, mean annual temperatures, mean annual rainfall, summer rainfall and bedrock (E.E.C. 1966, Mavrommatis 1980, Matziris 1989). In the description of each stand other details are also given (e. g. prefecture, village, site name, local forest service).

Tab. 1: *Fagus sylvatica* selected seed stands in Greece

Species and provenance	Stand no.	Latitude	Longitude	Altitude (m)	Mean annual temperature (°C)	Mean annual rainfall (mm)	Summer rainfall	Bedrock
Fagus sylvatica								
Aridaia	59	41° 07‘	22° 05‘	1,400	-	746	133	granite
Konitsa	60	40° 05‘	20° 41‘	1,750	10.8	1,000	150	flysch
Drama	61	41° 22‘	24° 34‘	1,450	8.8	1,020	205	granite

Regions of provenances:

The whole country has been divided into five provenance regions based on the number of biologically dry (lack of growth) days (Mavrommatis 1980, Matziris 1989):

- Region GR-1/100–150: means the region characterized by 100 – 150 biologically dry days
- Region GR-2/75–100: means the region characterized by 75 – 100 biologically dry days
- Region GR-3/40–75: means the region characterized by 40 – 75 biologically dry days
- Region GR-4/1–40: means the region characterized by 1 – 40 biologically dry days
- Region GR-5/0: means the region characterized by zero (0) biologically dry days

The location of beech seed stands in Greece is also shown in Figure 3.

Fig. 3: Map showing the beech seed stands (register) in Greece (Matziris 1989)

The above mentioned three seed stands of *Fagus sylvatica* are considered sufficient to represent pure *Fagus sylvatica* material of best provenances for reforestation/afforestation demands in Greece. However, in case of future demands (reforestation/afforestation works) for drier climates and lower altitudes or to compete with the climate change, well adapted (dry conditions) provenances of the ssp. *orientalis* (e. g. from lower altitudes in Central-East and Eastern Greece) can be selected.

In general, in Greece, regeneration of beech is achieved by natural regeneration and there are no artificial plantations of beech, since beech seedlings' growth is limited without protection from the mother stand. Occasionally, beech is planted in State forests – seed collected from registered or local seed stands, in gaps (under shelterwood) where natural regeneration has failed. There are no provenance trials due to the above mentioned reasons, but it is recommended to consider a well-planned program of provenance trials for local adaptation (e. g. see FRAXIGEN 2005) and adaptation to climate change. Finally, sufficient research has been done on taxonomy and genetics of beech, and this can support political decisions to ensure sustainable management and future survival of beech ecosystems.

IMPORTANCE OF BEECH IN FORESTRY CURRENTLY AND IN FORMER TIMES

Beech forests produce valuable technical, industrial and fuel wood. Before the 1970s, beech forests have been used by local people for fuel wood and technical wood, grazing of domestic animals, mushroom and nut collection and hunting. Due to the past over-exploitation many beech stands have been degraded or converted into coppice forests. At the present time, most of the beech forests are under sustainable forest management and most of them have been converted into high forests (Fig. 4), and are considered of high value while serving the multiple-purpose functions of wood production, non wood products, water quality, ecosystem roles and rare/vulnerable taxa conservation. Additionally, some beech forests are part of national parks (e. g. Olympos Mt., Pindos Mt.) while most of them share part of most NATURA areas, and therefore they are of high conservation value. Beech forests are considered highly important, the stands in good sites are sufficiently productive and their wood is more valuable than that of conifers. Furthermore, beech stands are the most valuable resource for water quality protection and provide high social services (e. g. recreation, aesthetics, hunting).

Fig. 4: A degraded beech stand converted into high forest (Chalkidiki, Greece)

SILVICULTURE, REGENERATION, FOREST MANAGEMENT

Cultivation (thinning and tending)

Beech stands require continuous intensive silvicultural treatment by removing poorly-formed and less vigorous individuals while focusing on the best trees (Dafis 1969, 1990, Bassiotis 1972).

Cultivation treatments required:

– Tending of new growth
– Thinning of dense growth
– Cultivation of young stands (young stems)

Treatment of degraded stands

Uneven-aged beech stands with many gaps, often heavily degraded, must be rehabilitated quickly, and converted into mixed (seed originated), usually in age classes of even-aged stands. In such cases grazing is prohibited, gaps are planted with appropriate tree species (depending upon site conditions – beech, oak, pine, spruce, maple), the mature groups of beech are regenerated and existing new growth/dense growth and young stands are thinned, favouring various noble hardwoods.

Natural regeneration

Beech is highly tolerant of shading, the most tolerant of all broadleaved species in Greece. Natural regeneration of beech should be directed to result in: (a) uneven-aged stands mixed with conifers, oaks or noble hardwoods, and (b) pure even-aged stands or stands of mixed ageclasses.

Regeneration methods

- Regeneration using shelterwood cuttings in strips parallel to stand edge lines
- Regeneration in small groups of uneven-aged stands
- Regeneration without strict rules of spatial planning (degraded stands)

TYPE AND QUALITY OF WOOD AND OTHER PRODUCTS

Beech can produce significant amount of round wood, which is higher in comparison to other broadleaves and conifers. Beech can also produce significant quantities of fuel wood (Spanos 2010). The wood of beech is of average quality, uniform without showing distinctive heartwood, slightly elastic, easily split, relatively heavy and hard but easily workable. Beech forests produce technical, industrial and fuel wood. Stem treatment of beech wood can improve wood quality and mechanical properties. It is used in furniture, the panel industry, barrel making, railway lines‘ support and hand-tools. The industrial wood is used for panel and paper pulp production. It is also used for charcoal production.

COVER AREA, AMOUNT OF STANDING TIMBER, AMOUNT OF WOOD HARVESTED

In Greece the ownership status of forests is: 65.5% – State forests, 12.0% – communal, 8.0% – private, and 14.5% has some other status (e. g. owned by monasteries, mixed status: state/private, state/communal). The coniferous forests cover 42.57% of the total forests whereas the broadleaves 57.43%. Beech forests count 17.5% (336,600 ha) of the total broadleaves or 10.02% of the total high forests.

The total stock volume of beech forests is 30,437,000 m^3 (overbark volume) or 90.41 m^3/ha average for all beech forests (but it can produce more than 10 m^3/ha on good sites- rotation age 100 – 120 years) and the annual net growth (increment) is 2.8 m^3/ha on average. The total stock volume of beech forest is about 50% of that of the total broadleaves or 21.1% of the total high forests. The wood production of beech stands (high forests) is lower than that of fir (*Abies* spp.) and Norway spruce (*Picea abies*). The above ground wood volume of 100-year-old beech stands (first site quality class) can reach 660 $m^3.ha^{-1}$, whereas that of fir is 1,200 $m^3.ha^{-1}$ and of spruce averaged at 1,160 $m^3.ha^{-1}$. The wood volume of coppice beech stands at age of 35 years (first site quality class) is calculated to 220 $m^3.ha^{-1}$. The net mean annual increment of beech stands (high forests) is estimated to 3.4% (Ministry of Agriculture 1992, 2000).

HEALTH STATUS AND IMPORTANT DISEASES AND INSECTS, GENERAL CONDITION OF BEECH FORESTS, THREATS TO BEECH AND ITS GENETIC RESOURCES, INDICATIONS OF RECENT CLIMATIC IMPACTS ON THE BEECH FORESTS

In general, beech stands are considered resistant to biotic attacks (fungi, insects, animals). The fungus *Phytophthora omnivora* attacks young seedlings after germination, the fungus *Nectria ditissima* causes cancers in the stems, whereas the fungi *Polyporus igniarius* and *Fomes fomentarius* can attack the wood. Insect attacks are in general not harmful. Insects that may attack beech are *Melolontha vulgaris*, *Agrillus viridis*, *Orchestes fagi*. Early regeneration can suffer damages from mice, small and large mammals. Beech stands can be damaged if directly exposed to sun radiation (bark-burning), and may also suffer wind and snow damages. During the last 20 – 30 years, due to the reduction of grazing pressure (mainly sheep and goats), beech forests are expanding and competing with other species (e. g. oaks, chestnut, fir) particularly in cold and humid areas (usually in northern exposures) in the high mountains.

The recent drought conditions (last 20 – 30 years) can cause die-back (after long dry summers) and death of beech trees (medium age and old trees). However, the threat is still not serious since beech is a very competitive species in cool and humid environments with deep soils. Furthermore, beech is the most shade tolerant species in Greece and can grow in the understorey of other species (e. g. fir, spruce) and is able to create mixed stands with conifers or pure beech stands depending upon site conditions. Land use change is not a threat for beech, since it usually grows on high mountains where human pressure is not so heavy. In contrast, most of the mountain villages and agricultural land (farms, pastures) have been abandoned and taken over by forestry through natural afforestation.

FURTHER PARTICULARITIES

In general, the beech forests in Greece produce low amount of technical wood (sawn timber) and most of it is used for fuel wood, charcoal production or wood for industrial use (e. g. particle-board, MDF, paper pulp) (Spanos 2010). To increase technical wood production there is a need to convert all coppice and degraded stands into even-aged or uneven-aged seedling stands (high forests) aiming at production of good quality and trunks free from branches. Conversion of all coppice stands into high/seedling forests, well-planned cultivation (all stage thinnings), enrichment with conifers (e. g. *Abies* spp., *Picea abies*, *Pinus sylvestris*, *Pinus nigra*, *Pinus leucodermis*, *Pseudotsuga menziesii*, *Larix* *decidua*), oaks (*Quercus* spp.) or noble hardwoods (e. g. *Acer* spp., *Prunus avium*, *Fraxinus* spp., *Castanea sativa*, *Sorbus* spp., *Juglans regia*, *Tilia* spp.) are of highest priority. Although most of the beech forests form part of the National Parks and the NATURA areas and gene conservation stands, apart from the three seed stands mentioned above, others have not yet been selected. A well-planned program for establishment of gene conservation stands is considered worthwhile as safeguard against forest fires and climate change. This is an easy but very important task, since the Forest Service in Greece has all necessary data on beech forests.

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Reviewed

Contacts:

Dr. Konstantinos Spanos
N. AG. RE. F. - Forest Research Institute
Gr-57006 Vassilika, Thessaloniki, Greece
tel.: +30 2310 461171 (2, 3), fax: +30 2310 461341
e-mail: kspanos@fri.gr; kspa@fri.gr

CURRENT STATUS OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENETIC RESOURCES IN HUNGARY

Ernő Führer[1] – Csaba Mátyás[2] – György Csóka[3] – Ferenc Lakatos[2] – Sándor Bordács[4] – László Nagy[5] – Ervin Rasztovits[2]

[1] Forest Research Institute, HU-1023 Budapest, Frankel L. u. 42-44., Hungary

[2] University of West Hungary, HU-9400 Sopron, Bajcsy Zs. u. 4., Hungary

[3] Forest Research Institute, HU-3232 Mátrafüred, Hegyalja u. 18., Hungary

[4] Central Agricultural Office, Dept. of Forest and Biomass Reproductive Material, HU-1024 Budapest, Hungary

[5] Forest Research Institute, HU-9601 Sárvár Várkerület 30/30, Hungary

ABSTRACT

Most occurrences of beech in Hungary are submontane beech forests occupying the Hungarian Middle Mountains and the hills of the southwest. Provenance tests indicate the comparatively vigorous growth of Hungarian provenances. They are among the early flushing sources. The use of Hungarian provenances may increase with the growing interest in drought-tolerant reproductive material. A network of registered gene reserves has been selected, totalling about 750 hectares. The species reaches the limit of its warm-temperate distribution throughout Hungary and this exposure will increase with expected climatic changes. The gradually growing moisture deficit has already led to severe health decline and emergence of serious pests and diseases in Hungarian beech forests since the 1990s. Regarding the stability and future of beech ecosystems, long-term strategy of both forest management and nature conservation has to take into account the quantitative forecasts of genetic tests.

Key words: European beech**,** közönséges bükk (in Hungarian), provenance test, phenology, xeric limits, pests and diseases, gene reserve

DISTRIBUTION OF EUROPEAN BEECH IN HUNGARY

Out of the 20.3% of land covered by forests, beech currently occupies 107,940 ha, which amounts to 5.9% of the forest area (CAO 2008). The occurrence of beech is characteristically restricted to areas, where the humidity is high enough and the heat regime is well balanced (Fig. 1). It may be suspected that in earlier centuries its distribution was wider, especially in the Western half of Transdanubia. While beech forests gave way to agricultural land use at low elevations, in less accessible areas beech forests remained in close to natural state. Forest inventory data show that during the last century the area of beech remained stable and even increased slightly in certain regions (Mátyás 2002).

While the altitudinal occurrence is stretching from the lowlands up to 1,000 metres above sea level, the vast majority of the beech stands in Hungary can be found between 200 and 500 m. The lowest elevation where beech occurs is extrazonal, in the upper valley of the Drava river, due to favourable microclimatic conditions (South-West Hungary, altitude ca. 120 m a. s. l.). It is very obvious that in Hungary beech is reaching the limit of its continental, warm-temperate distribution at most locations and this exposure will increase with expected climatic changes.

BEECH IN CHARACTERISTIC FOREST ASSOCIATIONS

Typical mountain beech forests (*Aconito-Fagetum*) are found only at higher elevations of the North-Hungarian Middle Mountains (Tab. 1). Their presence is restricted to the Bükk and Zemplén Mountains, and to smaller occurrences in the Mátra and Börzsöny Mountains. These are highly productive forests mainly growing on lessivated brown forest soils. Beside beech, common ash (*Fraxinus excelsior*), sycamore (*Acer pseudoplatanus*), European rowan (*Sorbus aucuparia*) and mountain elm (*Ulmus glabra*) are admixed species. Only isolated, small fragments represent the mixed fir-beech forests (*Abieti-Fagetum*) in the Sopron and Kőszeg Mountains.

The largest occurrences are submontane beech forests (*Melitti-Fagetum*) occupying the lower elevations of the Hungarian Middle Mountains crossing the country from NE to SW (first of all in the Zemplén, Bükk Börzsöny, Bakony and Kőszeg Mts.). Westward, in Southwest Transdanubia beech occupies more frequently collinal sites under 400 m a. s. l. The latter region receives more precipitation and is under moderate sub-Mediterranean influence, therefore floristically distinguished as Illirian beech forests (*Vicia oroboidis-Fagetum*). Submontane beech forests are mixed with

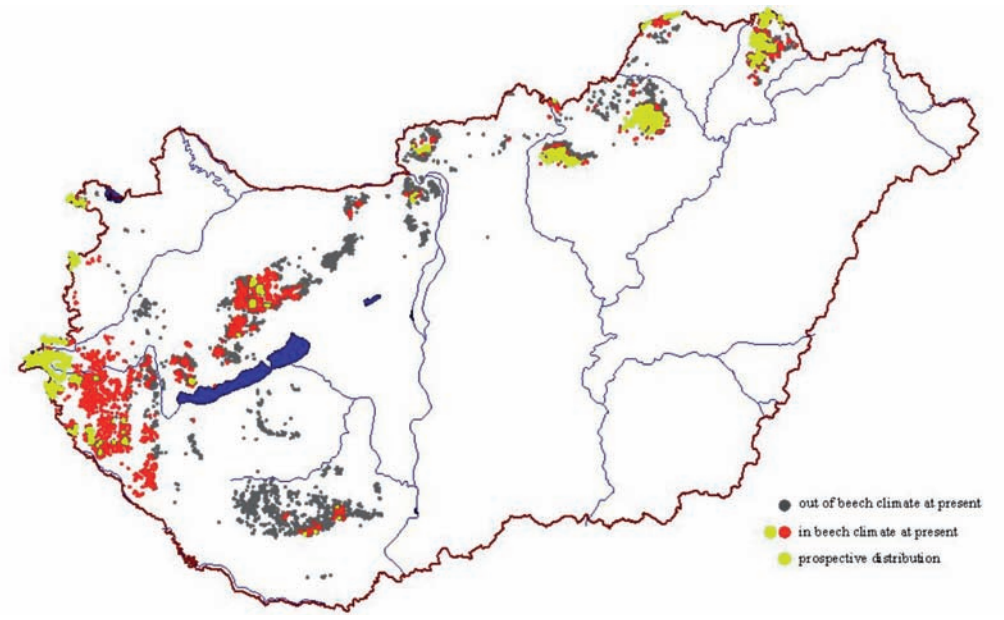

Fig. 1: Distribution of beech in Hungary based on forest inventory data. The map also shows the present and future ecological status of the species: the regions which will presumably remain in the beech climate on the long run (green), the occurrences presently in beech climate (red) and the ones already at present outside of beech climate (dark grey) (design/data: Führer 2008)

hornbeam (*Carpinus betulus*) and sessile oak (*Quercus petraea*) indicating higher temperatures and less favourable humidity conditions (Tab. 1).

Regarding specific site conditions, beech is a dominant tree species on humid-acidophilous sites (*Deschampsio flexuosae-Fagetum*). It is also present as admixed species beside common ash (*Fraxinus excelsior*) and large-leaved linden (*Tilia platyphyllos*) on the comparatively dry sites of calcareous ravine slopes of the Transdanubian Middle Mts. (*Mercuriali-Tilietum*). A relict-type occurrence with yew (*Taxus baccata*) in the Bakony Mts. has been described as *Taxo-Fagetum* (Majer 1980).

ECOLOGICAL CHARACTERISTICS

Due to its climate sensitivity, beech is used in forestry practice as an indicator species for the beech forest belt, providing the most favourable growing conditions in the country. The climatic envelope of beech can be well characterized using summer mean temperature and precipitation of the growing season (Rasztovits, Berki, Móricz 2009). According to Mátyás et Czimber (2000), typical associations are also differentiated by climatic conditions (Tab. 1).

Tab. 1: Climatic parameters of zonal beech associations* (Mátyás, Czimber 2000)

Forest association type (after Majer /1968/)	Percentage of total beech distribution (%)	Mean annual precipitation (mm)	Mean July temperature (°C)	Mean altitude (m a. s. l.)
Aconito-Fagetum	7.4	706	17.4	598
Melitti-Fagetum	61.9	745	18.7	436
Vicio orob.-Fagetum	30.7	773	20.2	209

* based on the reconstructed vegetation map of Zólyomi (1967)

A considerable part of beech stands are situated close to the xeric limits, i. e. at the drought-related (trailing, or retreating) end of their distribution range (Mátyás, Nagi, Ujvári-Jármay 2008). The probability of climatic-zonal presence of beech can be described reliably by climatic indices such as Ellenberg's quotient (Czúcz, Gálhidy, Mátyás 2009). Due to its ecological vulnerability, further indices have been developed in Hungary, using more detailed weighing of precipitation and thermal data, such as the "forest aridity index" FAI (Führer, Járó 2000, Führer 2010), and the "beech index" (Rasztovits, Berki, Móricz 2009).

GENETIC CHARACTERIZATION OF HUNGARIAN BEECH FORESTS

Presence of beech in the Carpathian Basin is documented for over 6,000 years and some researchers propose the existence of much older local refugia (Magri 2008). The Balkan origin of local beech is therefore still questionable and has not been decided by cpDNA studies either. Isozyme studies show a clear differentiation of beech populations of low elevations in Hungary and in Eastern Austria from more Western, less diverse populations. At some loci a significant East-West allelic frequency gradient was observed, proposing a westward migration route (Comps et al. 1998). Recent studies of

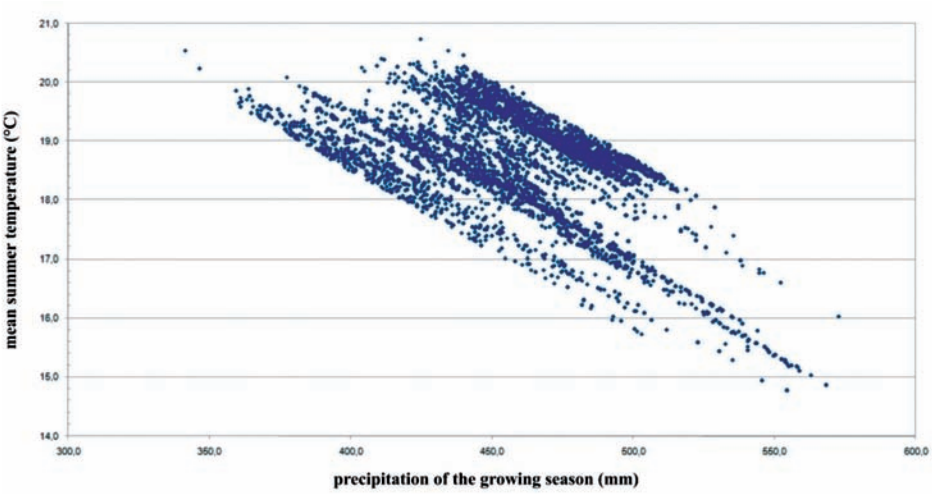

Fig. 2: Climatic envelope of beech in Hungary using climate data of the period 1975 – 2004 (design: RASZTOVITS 2009)

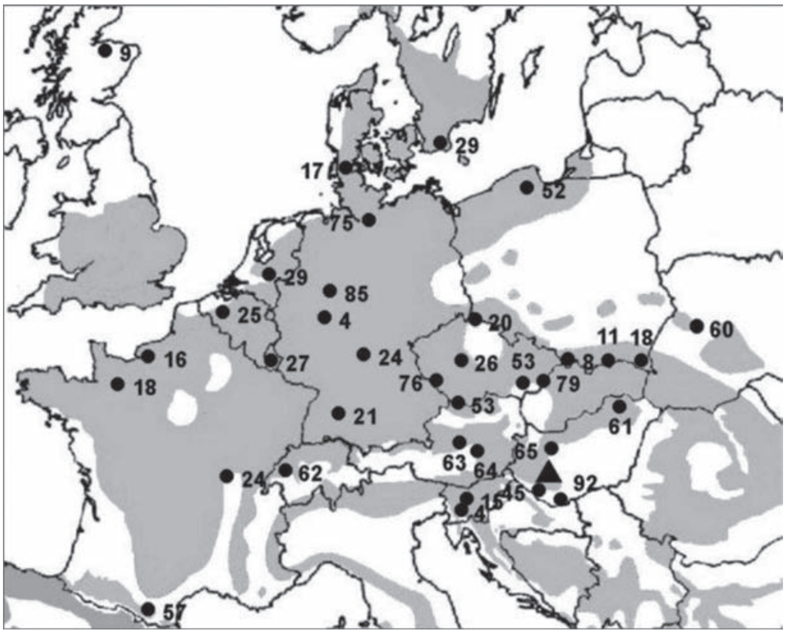

Fig. 3: Percentage of flushed plants per population in the Bucsuta beech provenance test on the 95th calendar (Julian) day in the second year after outplanting. Atlantic coast sources are late, Alpine and SE-European continental sources are early (Test location marked by triangle. Shaded: natural distribution area) (MÁTYÁS 2002)

genetic diversity patterns in Hungary strongly support the sweeping effect of extreme selection, close to the xeric limits of distribution for beech. At numerous isozyme loci, decline of heterozygosity and allelic diversity has been found (Borovics, Mátyás, unpubl.).

Phenology and growth of local populations can be assessed in provenance tests. In Hungary, one test of the international series of 1998 has been outplanted in Bucsuta, Zala hills, Southwest Hungary. The test shows the generally vigorous growth of Hungarian provenances, which may be linked to better utilization of the vegetation season (Fig. 4). Beside relatively fast juvenile growth, a higher number of buds and shoots, and larger leaf area seem to be characteristic at early age. Judging on mature stands, stem quality in Hungary is strongly varying and shows no clear trend (Mátyás 2002).

Hungarian beech populations are among the early flushing sources. The provenance Magyaregregy from the southernmost occurrence (Mecsek Mts.) was the earliest among all provenances at Bucsuta in the year shown in Figure 3. The repeated phenology assessments indicate that although rank changes between years occur, trends are maintained, but with changing level of discrimination. Differentiation among sources depends on spring weather conditions: slow, gradual increase of heat sum yields the best discrimination.

The Central Agricultural Office established with 8 local sources a similar test with larger, 0.1 ha plots in the same year (1998) in Bucsuta and two other sites in NE Hungary. There are no results available yet.

Fig. 4: Average phenotype of a continental (Nr. 52 Magyaregregy, Hungary, mean H: 3.52 m, left) and of an Atlantic provenance (Nr. 13 Soignes, Belgium, mean H: 2.62 m, right) at age of 8 years from planting in the Bucsuta experiment. The Hungarian population shows denser crown structure and more vigorous growth (Photo archive Mátyás)

REGISTERED SOURCES OF REPRODUCTIVE MATERIAL

Although most of the beech forests are regenerated naturally (total area was 1,112 ha in 2007), there is a significant use and trade of reproductive material which may further increase with the growing interest in drought-tolerant reproductive material. Seed sources and reproductive material production are under control of the CAO[1], detailed data are presented in Tables 2 and 3. Seed production is rhapsodic, and is strongly influenced by the weather conditions of the preceding vegetation period (Mátyás 1969). Therefore often wildlings are lifted from natural regenerations (Tab. 3).

Delineation of seed zones by Cs. Mátyás followed available information on adaptive genetic variation of the species, and climatic selection type (zone 5 being the most continental, while zone 3 the driest and most endangered for beech). The five seed zones (provenance regions) for beech are shown in Figure 5 (there is no beech in zone 6).

Note: Only 4 zones numbered in map

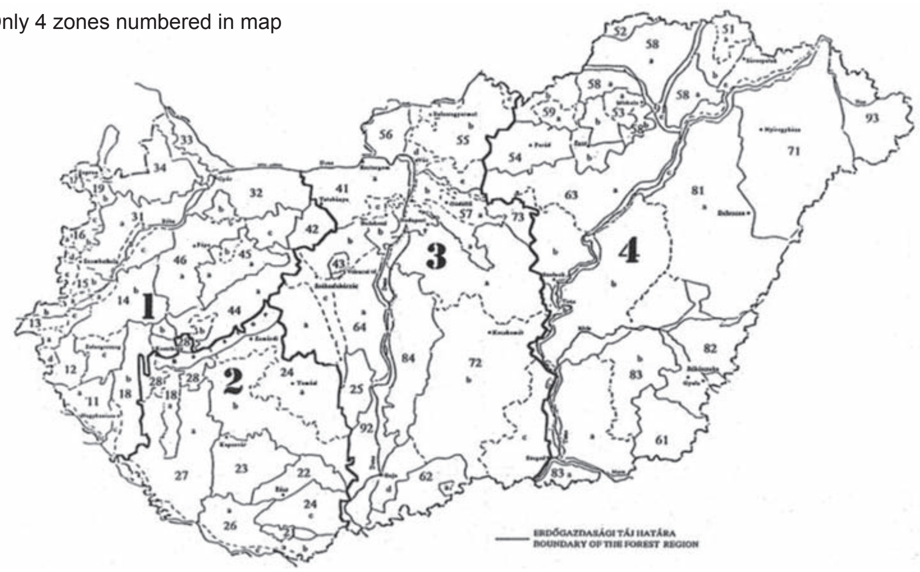

Fig. 5: The map of seed zones (provenance regions) valid for beech in Hungary (Mátyás 2002)

Tab. 2: Approved sources of reproductive material of European beech registered in Hungary, by genetic category* (2008 data by CAO, S. Bordács)

	'Selected' (S)	'Source identified' (SI)
Total number of approved stands	60	87
Total area (ha) of approved stands	930	59,327

* there are no registered sources of beech in categories 'Qualified' and 'Tested'.

1 Central Agricultural Office, Budapest (former OMMI)

CONSERVATION OF GENETIC RESOURCES

In 2004, the Forestry Committee of the Plant Gene Bank Council selected and registered 33 gene reserves, totalling about 750 hectares (Fig. 6), for a future network of beech gene conservation units. These populations sufficiently cover the range of beech in Hungary, as well as climatic, site and, presumably, genetic variation (Mátyás, Bach 1998). Due to inconsistent legal background and conflicts of interest with nature protection, the legal recognition of *in situ* forest gene reserves remains to be completed.

Apart from formal gene reserves, different categories of protected areas serve gene conservation of beech in a wider sense.

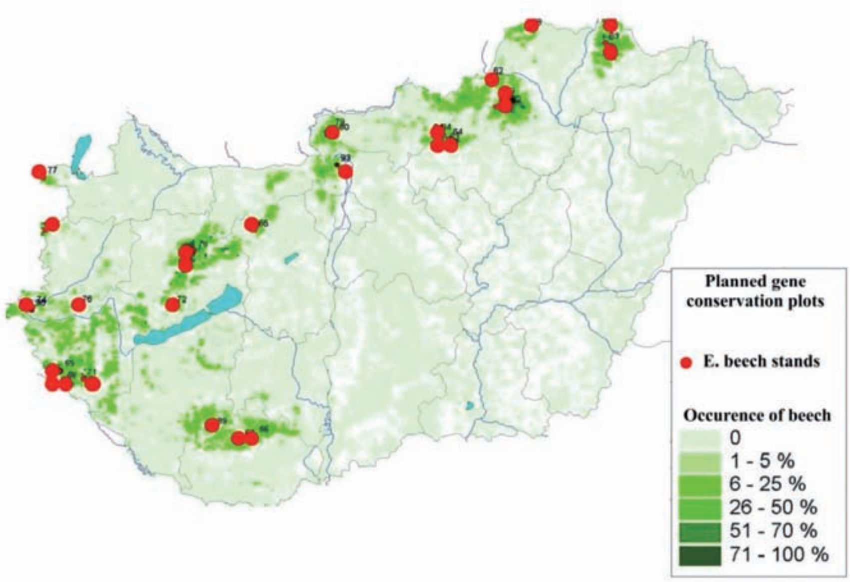

Fig. 6: Network of gene reserves of European beech in Hungary (design: Nagy 2009)

Tab. 3: Beech reproductive material produced and certified in 2004 – 2008 (data by CAO, S. Bordács)

	2004	2005	2006	2007	2008
Seed (S) (kg)	–	–	600	300	887
Seed (SI) (kg)	1,532	455	2,456	4,279	8,844
Wildlings lifted (tsd.)	53	181	1,025	490	348
Seedlings (tsd.)*	2,242	3,621	1,117	8,294	72,431

• Including exports

MAIN BEECH DISEASES AND PESTS

European beech harbours a high number of arthropod and fungal pests. Regularly none of them causes significant damage, except for large, country-wide gradations. The most recent outbreak (2004, 2005) of gypsy moth (*Lymantria dispar*) severely affected the mountain beech stands in Bakony and in Northern Hungary, causing large-scale defoliation (up to 80%) in some regions. Beech compensates the foliage loss much slower than oaks, but the refoliation can be almost perfect after 1 – 3 years of higher precipitation (Csóka, Hirka, Koltay 2006).

The woolly beech aphid (*Phyllaphis fagi*) occurred on 1,725 hectares in the average of the last 5 years. Damage of beech flea weevil (*Rhynchaenus fagi*) was recorded twice recently (1,500 hectares in 2000 and 500 hectares in 2005). The typical drop shaped galls of beech-leaf gall midge (*Mikiola fagi*) are common and widespread in every beech stand, particularly on younger trees (Hirka 2008).

HEALTH AND VITALITY LOSS DUE TO CLIMATIC EXTREMES

Beech is sensitive to water balance and therefore to relatively small changes in climate. The gradually growing moisture deficit in Hungary has led to severe health decline in Hungarian beech forests since the 1990s. The decrease of vitality is mainly connected to the climatic anomalies, particularly to the decrease of precipitation of the growing season (Lakatos, Molnár 2006). The trees weakened by drought become more sensitive to secondary pests and pathogens and show symptoms of health

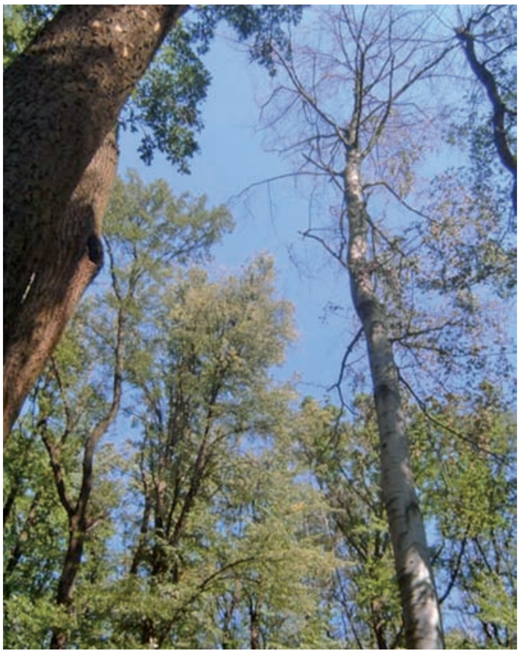

Fig. 7: Mortality caused by drought in late summer 2003 in a beech stand in Balatonszárszó (photo: Rasztovits)

deterioration (early leaf abscission, sparser crowns, etc.). This may lead to mass mortality if extreme dry summers appear in 3 – 4 years consecutively (Rasztovits, Berki, Móricz 2009).

In Zala County, a decline syndrome was triggered by the severe droughts of the period 2001 – 2003, in mature beech stands under regeneration, where the canopy closure was opened up recently (Fig. 7). This led to the outbreak of beech buprestid (*Agrilus viridis*). As a consequence, more than 100,000 m^3 sanitary felling had to be undertaken in 2005 (Góber 2005). Damage of *Biscogniauxia nummularia* disease and of the beech bark beetle (*Taphrorychus bicolor)* often occurred together with the buprestid damage. On average over the last 5 years (2004 – 2008) damage by these two insect species was recorded on about 300 hectares annually (Hirka 2008).

SILVICULTURE, FOREST MANAGEMENT

In Hungary, beech attains the culmination of its height growth increment at the age of 15 – 20 years, the diameter increment culminates – depending on crown closure – at the age of 50 – 60 years. On favourable sites it reaches 400 $m^3.ha^{-1}$ standing volume at the age of 50, and exceeds 600 – 700 $m^3.ha^{-1}$ at the felling age of 100 years. Compared to the total volume of Hungarian forests, the standing volume of beech represents, with 39.3 million m^3, a much larger ratio (11%) than its area.

In pure beech stands shelterwood cutting, in mixed stands group-, strip-, or strip-and-groupwise cutting is used for regeneration. At a young age beech thickets are kept very dense. Frequent interventions are necessary only in mixed stands. Juvenile stands differentiate well up to age 20 – 25; thinning is restricted to the upper storey. In adult forests, thinning is vigorous. For the support of silvicultural tending procedures, standard tending models have been developed by the Forest Research Institute, which are followed by the industry especially in stands producing high-valued timber (Bondor 1986).

Annually, 500,000 m^3 of beech are harvested in Hungary, so beech has an important role in Hungarian wood processing. 6 – 7% of the harvested assortment is veneer log; 35 – 40% is saw log. Low quality beech wood is used as pulp and fiber wood for HDF boards (20%) and as firewood (35 – 40%). On better sites the quality of the timber deteriorates after 100 years of age because of the development of false heartwood and other timber defects which reduce drastically the value of the timber (Molnár, Bariska 2006).

FOREST RESEARCH

Priority themes of beech research are in the field of ecology, forest yield and silviculture, as well as in forest genetics. Exploration of the ecophysiological processes, such as water and organic substance uptake and discharge of beech forests is carried out in permanent ecological research areas in order to forecast the effects of changing climatic conditions. The investigation of the total organic material sink volume of beech ecosystems represents an important element in the clarification of the role of forests in the carbon cycle.

Forest yield research has been maintained for more than 50 years in approximately 100 permanent yield experiments in beech. Research results, such as structural investigation of stands, are indispensable to define growth functions and to deduct optimal measures of yield regulation. Silvicultural research work is carried out in tending test series to define the effect of various silvicultural interventions and to develop optimized methods for practical forest management.

In the field of forest genetic research, research is aimed at investigating the impact of various silvicultural interventions on genetic diversity and at defining the conditions to maintain genetic sustainability. In provenance experiments adaptability, plasticity and phenology of populations are analyzed, above all to model the impacts of expected climate change.

THE FUTURE OF BEECH IN HUNGARY

Summing it up, the most important outcome of ecological and genetic evaluations is that beech reaches the limit of its warm-temperate distribution at most locations in Hungary. This exposure will increase with expected climatic changes. Model calculations with different tree species reveal that increasing drought stress close to the xeric limit of distribution leads to the exhausting of the genetic potential of adaptability. The loss of tolerance and health decline is therefore a genetic problem (Mátyás, Nagy, Ujvári-Jármay 2008).

The gradually growing moisture deficit in Hungary has already led to severe health decline and emergence of serious pests and diseases in Hungarian beech forests since the 1990s. The climatic scenarios for the 21st century predict besides loss of productivity and carbon sequestration also the decline of stability of many forest ecosystems (Führer, Mátyás 2006).

Regarding the stability and future of beech ecosystems, both forest management and nature conservation have to take into account in strategic planning the quantitative forecasts of forest genetic tests, and take steps to develop flexible gene conservation programs (Mátyás 2005).

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Reviewed

Contacts:

Dipl. Ing. Ervin Rasztovits
University of West Hungary
HU-9400 Sopron, Bajcsy Zs. u. 4., Hungary
tel.: +36 99-518-391
e-mail: raszto@titanic.nyme.hu

BEECH (*FAGUS SYLVATICA*) IN IRISH FORESTRY

David Thompson[1] – John Fennessy[2]

[1] Coillte Teoranta – The Irish Forestry Board, Kilmacurra Park, Kilbride, Co. Wicklow

[2] Forest Service, Department of Agriculture, Fisheries and Food, Kildare Street, Dublin 2

ABSTRACT

Beech (*Fagus sylvatica*) is not a native species to Ireland, but has been widely planted since the 17th century and it accounts for 1.4% of the forest tree species and 5.7% of the broadleaved forest in the Republic of Ireland. It is well adapted to the maritime climate and with a 100 to 120-year rotation it typically produces 4 to 8 m^3/ha/yr on average. Beech has been, and will continue to be, an important component of broadleaved forestry in Ireland. The main concern in Ireland is to identify and source the best reproductive material for seed importation to supplement home collected sources.

Key words: beech, *Fagus sylvatica*, fea (in Irish), reproductive material, ecology, silviculture, management, insects and diseases

BACKGROUND

Ireland, located between 51° and 56° North latitude, experiences a much milder climate than would be expected at these latitudes as a result of the warm waters of the Gulf Stream and its distance from the main European continent. Average winter temperatures are about 6.5 °C with average summer temperatures of 12.5 °C. The climate is maritime with cool, wet winters and cool wet summers. Rainfall varies from a high of over 3,000 mm in parts of the northwest to 750 mm in the southeast and is distributed equally during the year (rainfall ranges from 190 days/year in the east to 250 days/year in the west).

During the last Ice Age most of the island was covered by glaciers which eliminated almost all earlier vegetation. All the "native" tree species migrated to the island, possibly across land bridges from the United Kingdom and the Continent before these were flooded by rising sea levels as the ice melted. Unfortunately, beech was only able to cross the English Channel and establish itself in southern England and was not among the species to naturally reach Ireland. In the sub-montane region of central Europe which has a similar climate to Ireland, beech dominates large areas suggesting that this would be the natural forest type had the species migrated here after the last Ice Age.

The date of introduction of beech (*Fagus sylvatica* or Fea in Irish) into Ireland is not known but according to Nelson et Walsh (1993), like sweet chestnut (*Castanea sativa*), beech may have been an early import, coming with the Normans to whom this was a familiar tree. More definitive evidence suggests that beech was introduced to Ireland from England sometime during the 17th century because reports of groves of beech being defoliated in 1697 have been found in letters of the time (Fitzpatrick 1966). Nevertheless, it has become a widely planted species, especially in old estates and has become naturalized in Ireland.

A recent inventory of all forest land in the Republic of Ireland (Anonymous 2007) reported that there were a total of 625,750 hectares of forest land in Ireland or about 9% of the total land area. Ownership of this land is divided between public (52%) and private (48%). The national forest estate currently consists of 74% conifer species, 24% broadleaves and 2% unstocked. Of the total forest land about 8,710 hectares or about 1.4% of the total are planted with beech. Of the 151,950 hectares designated as broadleaved forest, beech accounts for 5.7% of all broadleaves.

In Irish beech stands age distribution is heavily weighted towards the older age classes with almost 60% of the area in the 51+ year age category. This consists largely of the 1930s phase of beech planting in the public sector and the old woodland remnants of the private sector.

Beech has been planted in most areas of the country, but the majority is planted along the east coast and south of a line running from Dublin on the east coast to Galway on the west coast. It was one of the main species planted in the old estates and many of the mature beech trees that can be seen in the Irish countryside were planted in late 1700s under a grant system administered by the Royal Dublin Society. The species was also extensively planted around the edges of conifer plantations in the 20th century to enhance their appearance and provide autumn colour. Today its greatest use is for hedging in suburban gardens.

Despite its undoubted potential beech has not featured prominently in grant aided planting of recent decades, possibly because of establishment difficulties caused by heavy grass competition on agricultural sites.

SILVICULTURE AND MANAGEMENT OF BEECH IN IRELAND

Current beech stands have been categorized in the national forest inventory as, 47% being afforestation sites, 37% semi-natural sites and 16% reforestation or replanted sites (Anonymous 2007). About 72% of the beech plantations are below 100 m in elevation with most of the rest below 200 m in elevation.

Beech has generally been managed under the clearcut silvicultural system but this is likely to change as shelterwood systems will be used for most broadleaves in the future, to maintain forest cover.

Mean tree age in both public and private plantings is 44 years (Anonymous 2007). In Irish beech stands 58% of the trees are in the top layer of the canopy, with 22% in the middle and 20% in the bottom layer of the canopy. Current estimates are that there is approximately 1.7 million m^3 of beech growing stock in Ireland with most of this being in public ownership.

Current recommendations are to plant between 6 to 7,000 plants per hectare (Joyce et al. 1998). It is rarely planted pure because early thinnings have little value. For this reason it is commonly planted in mixture with a conifer that will provide income from the thinnings. In the past, beech has been used in mixtures with western red cedar (*Thuja plicata*), Scots (*Pinus sylvestris*) or Corsican pine (*Pinus nigra* var. *maritima*), or European larch (*Larix decidua*). Mixtures with wild cherry (*Prunus avium*), oak (*Quercus petraea*, *Q. robur*) and Spanish chestnut (*Castanea sativa*) are also mentioned, but may not be practical. Mixtures are planted as a 50 : 50 (alternate line or bands) mixture or a 75 : 25 conifer : beech mixture.

Currently about 35% of the beech stands are unthinned. Essentially all Irish beech stands are left unpruned and most are considered "medium branched". Over 40% of the Irish beech stands are classed as "high forest" with 26% classified as "overmature" and 13% developing "high forest".

Stem form of beech in Ireland is very poor in relation to stands on the continent. This may be due to provenance but equally, environmental factors such as silvicultural management or exposure may play a significant role. Most of the older beech stands in Ireland have undergone some degree of "high grading" where the best individuals have been removed.

Almost 80% of the beech stands are classed as producing saw logs (20 cm+), but because of downgrade, most of this material would actually only be useable as pulp (Anonymous 2007). The average growing stock for publicly owner land is 170 m^3/ha while for private ownership it is 213 m^3/ha for an overall average of 172 m^3/ha. On average, beech stands in Ireland grow at a yield class of between 4 to 8 with perhaps a maximum of 10 m^3/ha/year on a rotation length of 100 to 120 years.

Currently beech accounts for approximately 2% of the sowing programme in state nurseries (600,000 plants in 2009).

DISEASES AND PESTS IN IRELAND

In Ireland beech tends to break bud in mid-April and as such it can be damaged by late spring frost. Young plants can be killed by frost due to an inability to produce new leaves. Frost can also cause shoot dieback which results in poor stem form.

Beech leaves may be attacked by fungi causing powdery mildew (*Microsphaera alphitoides*) or a leaf spot (*Gloesporium fagi*) and by the beech leaf miner (*Rhynchaenus fagi*). The fungus *Ganoderma applanatum* can cause a decay of the wood and young stems can be damaged by cankers caused by fungi of the genus *Nectria* (*Nectria ditissima* and *N. coccinea*). The beech woolly aphid (*Phyllaphis fagi*) can kill young beech plants. Beech bark disease which involves both woolly aphids and *Nectria coccinea* has not definitively been identified in Ireland. Mature trees may suffer from foot rots caused by the fungus *Armillaria mellia*.

Major stem damage is caused by non-native grey squirrels (*Sciurus carolinensis*) that strip the bark from trees in the late spring. Deer can also damage the lower stem of trees.

ECOLOGY

Beech is a species well adapted to Ireland's maritime climate, although this may affect stem form. It grows on a wide range of soil types but reaches its best development on free draining soils of neutral to moderately alkaline pH. The tallest beech tree in Ireland recorded in the Specimen Tree Register of Ireland is 39 m with a circumference of 5.1 m (Anonymous 2005). It is not a good pioneer species because it requires shelter for successful establishment especially in afforestation situations in Ireland. Beech will not tolerate exposure once it has been established. As a shade tolerant species it will undoubtedly play an increasing role as an understory species in continuous cover forestry.

Beech begins to flower at age 50 to 60 years. Late spring frosts can prevent good seed crops but generally mast years occur every 4 to 5 years. Natural regeneration can be prolific and beech is often regarded as an invasive alien species in native woodland, particularly on limestone soils.

Photo 1: Stand of beech in Kilbora Property, Camolin Forest, Co Wexford (J. Fennessy)

REPRODUCTIVE MATERIAL

Because beech is not a native species in Ireland, the question of "what is the best seed source for Irish conditions" has been asked and continues to be asked. Records of the seed sources sown in state nurseries during the period 1930 to the present show that a wide range of material has been planted during the last 78 years. In many cases it was the price of the seed that determined its purchase. During the 1930s seed sources from Germany, the Netherlands, Austria and "Central Europe" were planted. During the period 1939 to 1953 beech seed was exclusively from "home collected" sources, mainly mature stands in old estates around the country. A number of the best stands has been registered as seed stands and the total area registered to-date amounts to 81 ha in total. In the 1960s two beech seed orchards were established using grafts of selected Irish sources to ensure a supply

Photo 2: Stand of beech in Kilbora Property, Camolin Forest, Co Wexford (J. Fennessy).

of seed. Unfortunately no details regarding the origin of the clones remain and these orchards have never been used for seed collection.

In the period 1954 to 1960 most seed continued to come from home collected sources, but imports from Germany and Italy were also planted. During the period 1960 to 1980 the majority of seed was imported from Romania, Bulgaria, Germany, Czechoslovakia and Denmark with very little home collected seed used. From 1980 to the present Hungarian, Romanian, Slovenian and Czech material continued to be planted until 1996 when Irish Forest Service recommendations were established. These recommendations are to plant only Irish, British, Dutch, Belgian, northern French, Danish and northern German sources in an attempt to use reproductive material from sources with similar climatic conditions.

An analysis of commercial stands established between 1930 and 1980 with these imported seed sources showed that both German and UK material were superior to other imported sources in terms of survival, growth rate and stem form (J. Neilan, unpublished). In fact stands of Romanian, Bulgarian and Czechoslovakian sources could not be found, suggesting that this material had proven to be unsuitable for use in Ireland. One UK “research” seed source has consistently produced good quality plantations that are currently used as seed stands, however the exact origin of this material is unclear. Indeed several other home collected sources in old estates were also found to produce good stands although their original seed source is unknown.

In 1995 and again in 1998 Ireland participated in a EU funded international beech provenance trial. Unfortunately the 1995 trial failed due to an exceptionally dry summer when established, but the 1998 trial has established reasonably well and is one of a network of 21 similar trials throughout Europe. It consists of 34 provenances from across the natural species range. While only preliminary results (after 9 growing seasons) are available at present, they show that while initial survival rates averaged 77% (range of 17 to 98%) some provenances (from France, the Czech Republic, Austria and Sweden) continue to show losses (Thompson 2007). Material from eastern and south-eastern Europe is the most vigorous, mainly because they break bud early in the spring which could make them very susceptible to late spring frost damage. However, in the years since this trial has been established there has been no serious incidence of frost damage. The results suggest that the use of home collected seed (individuals that have grown for one generation under Irish conditions) or material from British sources would be best suited to current Irish climatic conditions. Other low elevation sources from northern France and Germany, as well as material from Britain, Belgium, the Netherlands and Denmark should also be suitable for use in Ireland.

A study comparing flushing date of 3 home collected sources of beech with several continental sources suggested that perhaps some selection for late flushing had taken place in the home collected material. However, Worrell (1992) concluded that no significant adaptation of continental sources of beech had taken place in Britain.

CONCLUSIONS

Although not a native species, beech has proven to be a species that is well adapted to conditions where it has become naturalized. There are no limiting insect or disease problems, although the grey squirrel may cause problems for beech as well as many other broadleaved species. If necessary, seed sources from other oceanic areas of northern Europe appear to do well under Irish conditions. Beech has been, and will continue to be, one of the important broadleaved species, especially if continuous cover forestry becomes a widespread practice in Irish forestry.

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Contacts:

John Fennessy, M.Sc.
Forest Service, Department of Agriculture, Fisheries and Food
Kildare Street, Dublin 2, Ireland
e-mail: john.fennessy@coford.ie
Dr. David Thompson
Coillte Teoranta – The Irish Forestry Board
Kilmacurra Park, Kilbride, Co. Wicklow, Ireland
e-mail: david.thompson@coillte.ie

GENETIC RESOURCES OF BEECH IN ITALY

Raffaello Giannini[1] – Paolo Capretti[2] – Giovanni Emiliani[1] – Marco Fioravanti[1] – Susamma Nocentini[1] – Cristina Vettori[3]

[1] Department of Agricultural and Forest Economics, Engineering, Science and Technologies, University of Florence, Italy

[2] Department of Agricultural Biotechnology, University of Florence, Italy

[3] Plant Genetics Institute, National Research Council, Italy

ABSTRACT

This paper reports on the main characteristics of European beech forests in Italy. The natural distribution and the country data (surface and main typology) indicate that the beech stands cover more than 1 million hectares located from the Alps in the north, to the mountains of the island of Sicily, which is the southeast border of the natural range of the species. The silviculture and forest management practices, as well as the health status are described. Some additional data concerning the lumber production and timber supply are also provided. Particular emphasis is placed on the genetics resources. The data on genetic variability, the phylogeographic relationship as well as phenological and growth parameters and molecular genetics features of Italian populations of beech are also presented.

Key words: distribution, silviculture, management, genetics, disease, wood production, European beech, faggio (in Italian)

NATURAL DISTRIBUTION AND COUNTRY DATA

According to the Italian National Forest Inventory (IFNC 2005), the total area covered by beech forests in Italy is 1,042,129 hectares, which corresponds to 9.4% of the country's total forest area. Beech is present in all administrative regions with the exception of Sardinia (Fig. 1). In the Alps, beech forms pure/mixed stands above 1,000 m a. s. l. in areas with relatively lower rainfall, while it is present at around 600 – 700 m in more humid areas. On the Apennine mountain range, beech usually grows above 900 – 1,000 m a. s. l. In southern areas with high air moisture conditions, beech can descend to an altitude of 400 – 500 m, where it is found in association with evergreen oak (*Quercus ilex* L.). The southern populations located in the island of Sicily (Etna Mt., volcanic soils; Nebrodi Mt., sandy soils; Madonie Mt., calcareous soils) are important because they increase the value of biodiversity for the whole country.

Over 53% of the total area covered by beech has a long history of coppicing. High forests cover 34% of the total beech area and 13% has complex structures which have not been classified in "regular" types (INFC 2005). Coppice is so widespread because it provides mountain populations with firewood and charcoal. Beech coppice is more diffused in northern and central Italy. During the last decades, the practice of coppicing has been progressively abandoned in many areas because of the high labour costs and due to mountain depopulation.

Beech high forests are most common in southern Italy where they play an important and attractive role in many protected areas, such as in the Abruzzi and Gran Sasso-Maiella National Parks. Many beech stands, including those near 'old-growth' forest types, are listed under NATURA 2000 conservation sites.

SILVICULTURE AND FOREST MANAGEMENT

The present structure of beech forests in Italy is as a result of many interacting factors. One of the greatest impactas has been the type of cultivation and management which has characterized the history of each stand (Nocentini 2009). Beech coppice is generally clear felled leaving 60 – 80 standards per hectare. Rotation age is usually 24 – 30 years. A particular type of beech coppice is 'selection coppice' (or uneven aged coppice), where shoots of different ages (usually three age classes) grow on each stump (Giannini, Piussi 1976).

Over the last few decades, forest policies have been increasingly directed to favouring beech coppice conversion to high forests, considered more productive and ecologically more desirable.

In general, conversion to high forest has been carried out, progressively reducing density by frequent thinning of the shoots. The aim is to favour growth of the best stems and at the same time reduce re-sprouting (Bagnaresi, Giannini 1999). Conversion to high forest is completed with seedling establishment following regeneration felling. Conversion to high forest requires a long period of time, varying in relation to site quality, but generally it takes several decades, often up to 60 – 80 (100) years after the first thinning (Nocentini 2009).

In high forest management, the uniform shelterwood system is usually prescribed because of the supposed natural tendency of beech towards even-aged structures. Plans usually prescribe rotation ages varying between 100 and 140 years. Most of beech high forests, especially in the southern regions, have a complex structure which is the result of the particular type of selection felling carried out by the owners. These are repeated in each compartment at short intervals (8 – 10 years), creating small gaps – 40 to 100 square meters – where beech regeneration quickly sets in. This type of forest management, not part of regular management plans, but described according to unwritten rules passed on by owners and woodsmen from generation to generation, can be considered as a part of local traditional knowledge.

Silviculture and management aspects, which are currently under investigation, present the possibility of managing beech stands with the objective of increasing structural diversity. Particularly interesting are the results of investigations, currently undertaken , on the structure, regeneration and productivity of beech high forests following small group selection felling (Ciancio et al. 2008).

Of importance also are the investigations on natural beech regeneration in even-aged, monospecific stands of silver fir (*Abies alba* Mill.) in the northern Apennines and in Austrian pine (*Pinus nigra* Arn.) plantations, where the management objective is to favour re-naturalization, i. e. the gradual transformation towards self-regenerating, mixed stands with complex structures (Nocentini 2009).

GENETICS

The genetic variability and the phylogeographic relationships as well as phenological and growth parameters or molecular genetic features of Italian beech populations were extensively analyzed in the past years using a variety of traditional and molecular approaches.

Provenance studies revealed differences in chilling needs (Bagni et al. 1980), bud break and flushing (Borghetti, Giannini 1982), phenology, xylem embolism (Borghetti et al. 1993) and drought resistance (Tognetti, Johnson, Michelozzi 1995).

Molecular fingerprinting with isozyme markers in 21 Italian populations (Leonardi, Menozzi 1995) revealed levels of genetic diversity comparable to those reported for European stands. Similar values were also reported by Belletti et Lanteri (1996) for 11 stands from Piemonte (north-western Italy). I-SSRs and RAPDs (DNA based markers) were able to detect a higher level of variability for a population from the Northern Apennine region (Troggio et al. 1996) and to obtain a preliminary estimation of pollen migration.

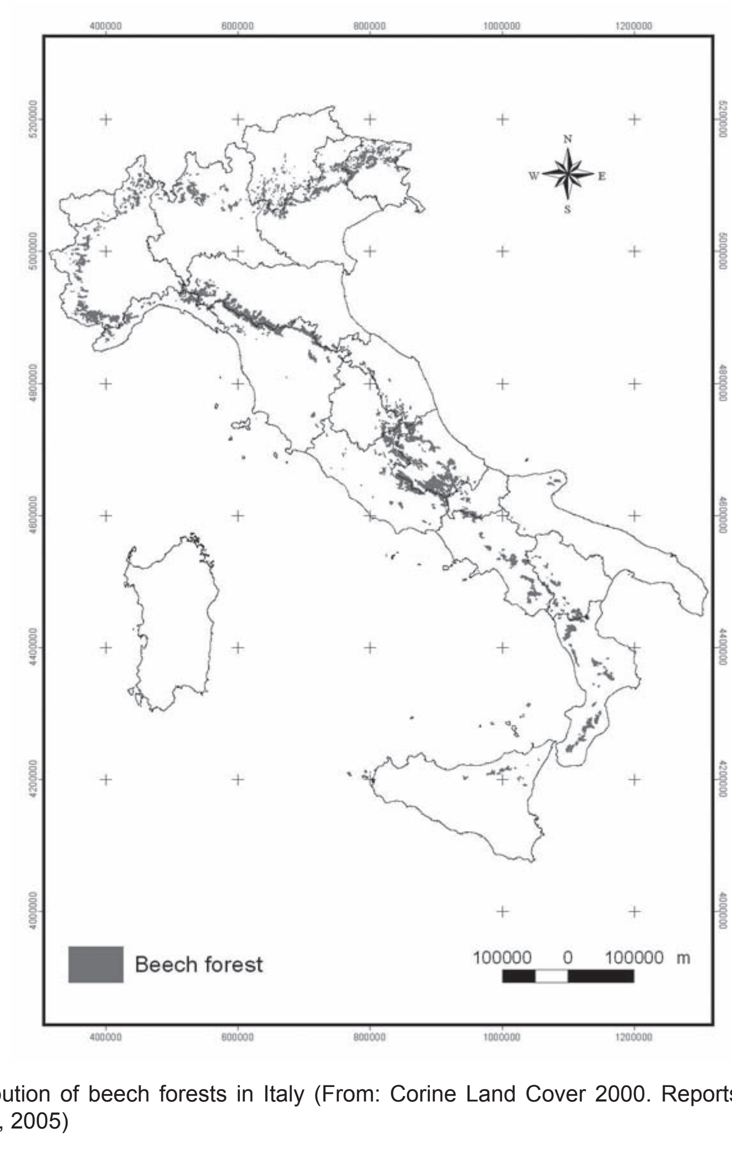

Fig. 1: Distribution of beech forests in Italy (From: Corine Land Cover 2000. Reports 36/2005. APAT, Rome, 2005)

In general, all genetic variability studies revealed a low estimate among stands diversity as well as a low geographic structure (Leonardi, Menozzi 1996) with a consequential strong diversity component within population. These findings are consistent with the European stand data and wind-pollinated, low self-compatibility reproductive biology, characterized by a low level (2 – 4%) of inbreeding (Rossi, Vendramin, Giannini 1996).

Emiliani et al. (2004) using RAPD and cpDNA PCR-RFLP markers analyzed 30 populations located in southern Italy. The analysis showed that the south of Italy represents a diversity hotspot with more than one glacial (micro) refuge nuclei, and that the genetic variability among populations is substantially higher than that reported in literature.

In a wider geographic context, the distribution of chloroplast DNA (cpDNA) variation was studied using PCR-RFLP and microsatellite markers in 67 Italian beech populations (Vettori et al. 2004). The authors confirm the role of southern and central Italy as the hotspots of haplotype diversity (highest level of total haplotype diversity $h_t = 0.822$, high level of genetic differentiation $G_{st} = 0.855$) and the highest number of haplotypes. Nevertheless, all haplotypes found along the Apennines remained trapped in the Italian peninsula.

The phylogeography of beech was extensively analyzed with molecular genetics and paleobotanical approaches by Magri et al. (2006) suggesting, in accordance with Emiliani et al. (2004) and Vettori et al. (2004), that beech populations might have survived during the last glacial period at different locations in the Italian peninsula, with the consequence that no clear large-scale migration trends can be recognized in southern and central Italy. Furthermore the authors suggest that the presence of populations displaying high divergence in central-southern Italy may be associated to the fact that beech populations persisted in these regions since the middle Pleistocene.

Recently, microsatellite loci were used to examine the impact of forest management on genetic diversity (Buiteveld et al. 2007). The comparison between two Italian stands – one near to the 'old-growth' forest and one with high management-intensity (shelterwood system) – revealed no significant differences in genetic diversity parameters.

Using an innovative approach on fossil pollen DNA, Paffetti et al. (2007) demonstrated, in contrast to current knowledge based on palynological and macrofossil data, that the *F. orientalis* complex was already present during the Tyrrhenian period in what is now Venice lagoon (Italy). This finding represents a new and important insight, considering that nowadays Western Europe is not the natural area of the *Fagus orientalis* complex, and that the presence of the complex during the last interglacial period in Italy has never been hypothesized before.

The individuation of retrotransposable elements in beech (Emiliani, Paffetti, Giannini 2009) offers an interesting insight into *F. sylvatica* genome and the possibility for the development of new markers for genetic diversity screening and for evolution studies.

A genetic linkage map of European beech was constructed according to a "two-way pseudo-testcross" mapping strategy, using a total of 312 RAPD, AFLP and SSR markers scored in 143 individuals from a F_1 full-sib family (Scalfi et al. 2004). In the same pedigree, the association with genetic markers of several quantitative traits: leaf area, leaf number and shape in two different years, specific leaf area, leaf carbon-isotope discrimination and tree height were also investigated obtaining QTLs associated with leaf traits explaining a variation between 15% and 35%.

GENETIC RESOURCES AND REPRODUCTIVE MATERIAL

The competences for legislation and transfer regulation of forest reproductive material of beech have been transferred from the Ministry to the local regions. Each region is actually discussing the situation in the "Economic Development Programme" and to date no tree seed zone or seed stands were identified by the Regional Administration as programmed in the D. L. 386/2003.

In Table 1 there are listed the seed stands that are to be included in the register as foreseen by the aforesaid Law (italic), the seed stands (underlined) included in the National legislation on reproductive material (D. L. 269/1973, no more in force), and seed stands from Sicily suggested by Vettori et al. (2007) on the basis of population genetic fingerprinting (bold).

LUMBER AND TIMBER

The Italian National Forest Inventory (IFNC 2005) estimates a standing volume of about 1,270*10^6 m^3 of wood (including logs and big branches) in the area of forests in the country. Beech forests give a lumber and timber supply of 240 million per m^3, which represents 19% of the total national timber production. In term of timber quality there is a remarkable difference between wood obtained from coppice stands and wood obtained from high forest stands. The main product from coppice stands is firewood, while that from the better high forest stands, it is possible to obtain lumber suitable for industrial transformation such as rotary cutting for plywood production and sawn timber for furniture. Italian beech wood production is not sufficient, both in terms of quantity and quality, for sustaining domestic demand, especially demand coming from the plywood industry. For this reason every year, large amounts of beech timber are imported from France, former Yugoslavia and central European countries (Hungary, Romania).

HEALTH STATE

Beech forests are generally considered non-problematic with regard to their susceptibility to pathogens and insects. However, during the past decades a certain number of diseases and mortality situations have been reported (Luchi et al. 2007). Most beech problems are concentrated in the few beech plantations present in Italy rather than in natural forests. They are generally influenced by climatic and unfavourable environmental situations. Main symptoms consist of the progressive drying of the upper parts of the crown, necrosis of leaves and branches, as well as the main stem, associated with the presence of fungus *Biscogniauxia nummularia* (Bull.) Kuntze, an endophyte/parasite typical of stressed plants, naturally diffused in the environment. It causes cankers along the stem but also "white rot". In general, fungi of the family Xylariaceae cause charcoal canker in the Fagaceae family (Capretti et al. 2003). There is good evidence that these species occur in healthy living trees as endophytes and then become invasive under water stress conditions.

Biotic and abiotic stresses may also favour other pathogens present on the soil or on the root system as Ascomycetes fungi responsible for white root rot: *Ustulina deusta* (Hoffm.) Lind and *Xylaria polymorpha* (Pers.) Grev. Both have been found occasionally in connection with occurrence of damages by *Heterobasidion annosum* Fries. Bref. causing beech tree decay and uprooting of trees in mixed stands with conifers (*Abies* and *Pinus* spp.) (Capretti et al. 2003).

Root diseases were also locally registered, showing symptoms typical for *Phytophthora*: increased crown transparency, abnormally small and often yellowish foliage, dieback of the crown, necroses of

Tab. 1: Beech seed stands in Italy

Name of stands (region)	Lat.	Long.	Alt. (m)
Molveno (Trentino-Alto Adige)	46° 10’	10° 57’	1,350
Millifret, Cansiglio (Veneto)	46° 03’	12° 22’	1,130 – 1,500
Airole, Tencione (Liguria)	44° 14’	8° 07’	1,100 – 1,200
Pian degli Ontani, Abetone (Toscana)	44° 05’	10° 40’	1,200 – 1,400
Marsigliana, Monte Amiata (Toscana)	42° 53’	11° 36’	1,000 – 1,400
Cappadocia, Campo Ceraso - Coste Calde (Abruzzo)	42° 05’	13° 17’	1,300 – 1,400
Cinquemiglia, Piano d‘Albero, Serra Nicolino (Calabria)	39° 23’	16° 06’	950 – 1,200
Val Loana, Finero, Malesco (Lombardia)	46° 06’	8° 32’	1,350
Vanezzo della Soda, Val di Sella (Trento)	46° 02’	11° 24’	900 – 1,000
Vallesessera, Mosso S. Maria (Piemonte)	45° 39’	8° 8’	900
Belfè, Ala di Stura (Piemonte)	45° 18’	7° 18’	1,300
Consolata, Ceres, Mezzenile (Piemonte)	45° 18’	7° 23’	975
Richiaglio e Viù (Piemonte)	45° 12’	7° 23’	1,100
Cugn, Pradleves (Piemonte)	44° 25’	7° 16’	1,100
Colle Missignana, Villa Collemandina (Toscana)	44° 21’	10° 42’	1,200
Colle Melogno – Calizzano (Liguria)	44° 14’	8° 12’	1,100 – 1,200
Madonna d‘Ardua, Chiusa di Pesio (Piemonte)	44° 13’	7° 39’	1,200
Terme di Valdieri, Valdieri (Piemonte)	44° 12’	7° 16’	1,750
Palanfré, Vernante (Piemonte)	44° 11’	7° 30’	1,400
La Verna, Chiusi della Verna (Toscana)	43° 71’	11° 93’	1,190
Val Fondillo (Abruzzo)	41° 50’	13° 52’	1,200 –1,400
Piano Battaglia, Petralia Sottana (Sicilia)	37° 52’	14° 01’	1,600 – 1,700
Mt. Soro, Lago Biviere (Sicilia)	37° 56’	14° 41’	1,600 – 1,700
Linguaglossa (Sicilia)	37° 47’	15° 02’	1,900 – 2,000

the inner bark and cambium with tarry spots on the bark surface and bleeding cankers (Jung et al. 2005).

Other fungi, generally associated with humid and shaded environments, may also cause problems on branches and leaves of beech trees in the juvenile stage (ex. *Nectria ditissima* Tul. & C. Tul., and *Apiognomonia errabunda* /Roberge ex Desm./Höhn.) (Luchi et al. 2007).

MYTHOLOGY

In Italy many single trees or stands are recognized as folk symbols. For example in the Vallombrosa Forest there is an old beech tree which is known locally as the Holy beech of Saint John Gualbert (Patron of Foresters), founder of the Vallombrosan monastic order in the XIth century. According to the legend, the Saint, John Gualbert escaped from Florence one winter night and when he arrived in Vallombrosa he fell asleep under the beech tree. To protect the sleeping saint, the beech tree sprouted leaves and bent its branches. The Holy beech which is today growing in the Vallombrosa Forest probably dates from the XVIIIth century, and is thought to be a sprout of the original beech tree.

A very peculiarly feature of this beech tree is that every year it opens up its leaves (flushes) a few days before the other beech trees in the forest.

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Contacts:

Prof. Raffaello Giannini
Department of Agricultural and Forest Economics, Engineering, Science and Technologies
University of Florence, Italy
e-mail: raffaello.giannini@unifi.it

Dr. Cristina Vettori
Plant Genetics Institute, National Research Council, Italy
e-mail: cristina.vettori@cnr.it

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN THE NETHERLANDS

Sven M. G. de Vries

Alterra Green World Research PO BOX 47, 6700 AA Wageningen,
The Netherlands

ABSTRACT

Beech is an important broadleaved species in The Netherlands as regards to forestry and landscape. The species currently covers 3.8% (12,000 ha) of the forest area in The Netherlands. The species is mainly growing on sandy soils in the middle and eastern parts of the country. In relation to predicted changing climate beech is expected to suffer health problems in the (near) future in relation to drought as well as changing ground water tables. This combined with the fact that most beech forests are planted evokes need for (international) provenance research. Three areas with a total of 440 ha have been categorized for gene conservation and for use of forest reproductive material in the category "Source Identified Basic Material" in the National Catalogue.

Key words: European beech (*Fagus sylvatica* L.), beuk (in Dutch), genetic resources, distribution, provenance research

EUROPEAN BEECH DISTRIBUTION IN THE NETHERLANDS

European beech is considered to be an important broadleaved tree species in Dutch forestry. The majority of the beech forests are concentrated on the sandy soils in the middle and eastern parts of The Netherlands. The Dutch government intends to promote further expansion of the area planted with beech. Besides its use in forestry, beech is also used on a large scale in roadside plantings and in landscaping (amenity plantations). Beech is autochthonous in The Netherlands (Fig. 1), but through numerous imports in the past original material is very rare.

FOREST MANAGEMENT AND CHARACTERISTICS

The total forest area in The Netherlands covers 360,000 ha of which beech constitutes 3.8% with 12,000 ha (Vijfde Nederlandse Bosstatistiek 2007). The ownership of Dutch forests is 31% private; the State Forest Service manages 27% for the Ministry of Agriculture, Nature and Food Quality; 17% is owned by nature conservation agencies and the rest is owned by municipalities and other governmental organizations.

Most of the beech plantations are planted; of this an unknown amount with imported plant material. Almost all planting material came from unknown sources from abroad as well as from unknown Dutch sources. Less than 1% is considered as naturally regenerated. However, the latest opinions

Photo 1: Ede-01. Roadside plantation of beech in the category “selected basic material”

regarding reforestation favour natural regeneration generally and especially in the case of beech forests. Nowadays natural regeneration is becoming more and more popular among forest managers, and this is specifically the case with beech forests.

Dutch forests are relatively young: 52% are between 25 and 65 years of age. The standing volume of beech is 3,186,000 m^3, it is about 5% of the total standing wood volume in the country. The distribution of standing wood into diameter classes for beech ranges from 10 cm to 120 cm with more than 70% of the standing wood volume in the classes from 20 to 70 (Vijfde Nederlandse Bosstatistiek 2007).

European beech in The Netherlands is mostly growing in even-aged monocultures (41.8%), but it also appears in mixtures with either conifers (17.3%) or other broadleaves (38.2%).

Natural distribution of *Fagus sylvatica* in The Netherlands

Extracted from:

Beech Forests, Rob Peters, 1997
Kluwer Academic Publishers, The Netherlands.

Houtteelt der gematigde luchtstreek Deel 1: De Houtsoorten
Dr. G. Houtzagers, 1954
N.V. Uitg.-Mij W.E.J. Tjeenk Willink, Zwolle.

Fig. 1: Natural distribution of *Fagus sylvatica* in The Netherlands

The majority of the beech forests are concentrated on the sandy soils in the middle and eastern parts of the country; 58.2% of the beech forests grow on poor sandy soils and 31.8% on rich sandy and on more loamy soils.

In relation to predicted changing climate, beech is expected to suffer health problems in the (near) future in relation to drought as well as changing ground water tables (De Vries 2007). Climate scenarios made by the Intergovernmental Panel on Climate Change (IPPC) predict for The Netherlands higher temperatures and more precipitation, but most of this precipitation is expected to fall outside the growing season and therefore will not directly benefit the trees. On the other hand it could mean rising ground water tables, and it is well known that beech can suffer much from both changing ground water tables and from higher temperatures. The question is to what extent beech forests can adapt to these changing situations or to what extent they are plastic enough to cope with the changes. Another possibility could be to introduce beech reproductive material from sources with comparable climates as predicted for The Netherlands in the future. Well-adapted basic material is of high importance both now and in the future. Present provenance research is carried out using Dutch provenances (Kranenborg, Jager, de Vries 2010) as well as provenances from foreign countries from several locations covering the entire distribution range of beech (Kranenborg, de Vries 2001). A special reference can be made for the International beech trial established in Wageningen in 1998 that is part of a network of European international field trials network (Wühlisch et al. 2008).

GENETIC RESOURCES, CONSERVATION AND THE USE OF FOREST REPRODUCTIVE MATERIAL

Most of the beech plantations in The Netherlands are planted, an unknown amount with imported plant material and from unknown sources. However, inventories showed that there is still some beech forest from putative autochthonous origin. This autochthonous material is scarce, often located on private estates or nature reserves and therefore less easily accessible and the price of seeds and plants is therefore relatively high. As a result of an often negative selection in the forests owned by community (the best performing trees were harvested first) in the past it appears that the quality of trees from these rare sources did not meet the requirements in terms of forestry standards mentioned in the former EU Directive on Forest Reproductive Material (no. 66/404/EEC) (de Vries 1998a, b). However, the new Directive on Forest Reproductive Material (no. 1999/105/EEC) is now implemented in Dutch National Law, in the Seed and Plant Act 2005. This new Directive enables EU countries to introduce a new category "Source Identified Basic Material" (SI) in their National Catalogues of basic material. This opened new ways and possibilities for autochthonous seed sources of beech to be included in the system of certification of Forest Reproductive Material and to be used in restoration projects of original ecosystems and forests. In this category of SI to date three areas of beech forest with a total of 440 ha have been selected with the aim of gene conservation and use of this valuable original genetic material.

The Dutch List of Recommended Varieties and Provenances of Trees is issued every other five years; the latest was issued in June 2007 covering the period from 2007 to 2012. Intermediate updates are provided in the case basic material is renewed, removed or changed (Kranenborg, Jager, de Vries 2010). In the category "Selected basic material" a total of 21 stands of beech have been selected by the Board for Plant Varieties (Raad voor plantenrassen) (Anonymous 2007). The majority of these are roadside plantations. The Dutch List of Recommended Varieties and Provenances of Trees also contains a number of provenances from Germany and Belgium recommended for use in The Netherlands.

A National Policy Document of the Government of the Netherlands was introduced during the COP meeting on Biodiversity in The Hague in April 2002: "Sources of Existence: Conservation and the sustainable use of genetic diversity" (Anonymous 2002). It covers genetic resources of all kinds including agricultural and horticultural crops, animal genetic resources and forest genetic resources. The content of this document enables relevant parties to implement the conservation of forest genetic resources in different ways. To date for beech only the designation of nature reserves has taken place and no other initiatives in relation to, for instance, gene banks have been undertaken.

In relation to the EU funded project "European Information System on Forest Genetic Resources (EUFGIS)" so far one Gene Conservation Unit (GCU) has been designated for The Netherlands.

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Reviewed

Contacts:

Ir. Sven M. G. de Vries
Alterra Green World Research
PO BOX 47, 6700 AA Wageningen, The Netherlands
tel. +31 317 485 437, fax. +31 317 419 000
e-mail: sven.devries@wur.nl

CONSERVATION OF GENETIC RESOURCES OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN POLAND

Małgorzata Sułkowska

Forest Research Institute, Department of Genetics and Physiology of Woody Plants, Sękocin Stary, 3, Braci Leśnej St., 05-090 Raszyn, Poland

ABSTRACT

European beech stands cover 5.2% of the forest area in Poland. The most typical forest tree associations are formed at the lower forest range in the Carpathians and Sudeten Mountains in the South of Poland and at morainic landscape of Pomeranian Lake District of North Poland. In Poland beech reaches the north-eastern limit of its natural range. The growth of beech stands outside the natural beech range indicates that the species possesses a potentially much wider range. Methods are presented which are used in conservation of Polish beech genetic resources and state of research related to genetic variation as well as silvicultural problems.

Key words: European beech (*Fagus sylvatica* L.), buk zwyczajny (in Polish), distribution, genetic variation, Poland, forestry research

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN POLAND

European beech stands cover 5.2% (447,500 ha) of forest area in Poland (Forests in Poland 2009). European beech belongs to the dynamic species in Pomerania and frequently supplants other forest species, mainly oak and sometimes also Scots pine. *Fagus sylvatica* forms enter woods of the lower mountain forest range in southern Poland (usually altitude 450 m a. s. l.). Its role was considerably restricted in the Sudeten Mts. due to Norway spruce promotion in the past. The most elevated locations of the species were reported from about 1,000 – 1,200 m in this mountain range. The occurrence of European beech has not been limited so strongly in the forests on the Carpathians. European beech dominating forests are especially extensive in the eastern part of this range growing there up to altitude about 1,200 m. It forms the upper forest limit in the Bieszczady Mts. European beech stands of the highest quality are located mainly in the north-western part of Poland, central part and the southern part of Poland (Boratyńska, Boratyński 1990). The present genetic structure of European beech populations in Poland was formed by many different factors, not only by environmental and genetic, but also by anthropogenic factors. Very important factors that affected the gene pool were glacial epoch, the location of beech refugia, and the postglacial migration paths of the species (Szafer 1935, Huntley, Birks 1983, Ralska-Jasiewiczowa 1983, Hazler et al. 1997). Different environmental condition resulted in a great number of ecotypes and populations that characterized various ecological requirements (Dzwonko 1990, Giertych 1990). In Poland, European beech reaches the north-eastern limit of its natural range (Szafer, Pawłowski 1972,

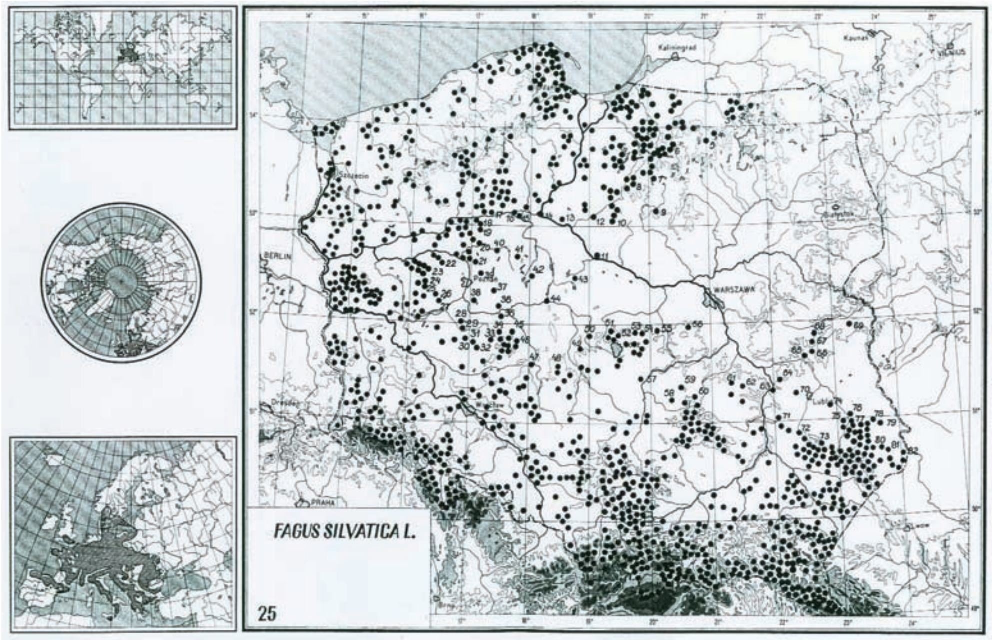

Fig. 1: Natural distribution of European beech in Poland – Gostyńska-Jakuszewska, Zieliński (1976)

Boratyńska, Boratyński 1990). The geographic range of European beech is limited by: continental climate, soil conditions, winter temperatures and air humidity (Sławiński 1947, Jedliński 1953, Boratyńska, Boratyński 1990). The growth of European- beech stands outside its natural limit indicates that this species possesses a potentially wider range (Brzeziecki 1995, Tarasiuk 1999).

Polish European beech dominant communities were formed 2,000 years ago (Środon 1990). Their typical habitats are moderate wet and good aerated soils, e. g. leached brown soils or brown soils, formed from light, medium, or heavy clays, loess soils and limestone soils (Tomanek 1970, Dzwonko 1990).

In Poland European beech attains 40 – 47 m in height and 1.5 – 2 m in diameter. It starts to produce seeds when it is 80-year-old in stands, or when it is 50-year-old as an open-grown tree. Seeds are produced in irregular intervals – usually every 5 – 8 years (Tomanek 1970, Boratyńska, Boratyński 1990).

There are the following well characterized dominant European beech forest associations in Poland (alliance *Fagion*) – Matuszkiewicz (2005):

- *Fagetum carpaticum–Luzulo-Fagenion, Luzlo-luzuloides-Fagetum* – acid beech stand, *Dentario glandulosae-Fagetum* – fertile Carpathian beech stand and *Dentario enneaphyllidis-Fagetum* – fertile Sudeten European beech stand;
- *Melico-Fagetum – Luzulo pilosae-Fagetum* – acid lowland European beech stands, *Galio-odorati-Fagetum* – fertile lowland European beech stands.

Generally, European beech forests in Poland are in good health condition. However, some problems are connected with silvicultural practice during reforestation, for example with early and late frost, and with damage by game.

The economic importance of European beech wood is high and in some regions this wood is the main product. In Poland generally coniferous species are considered as economically the most important, however European beech wood has been used both in the furniture industry and in the construction of buildings.

METHODS OF CONSERVATION OF EUROPEAN BEECH GENETIC RESOURCES

The conservation of forest genetic resources should ensure: continuity of the basic ecological processes, preservation of the forest and sustainable utilisation of ecological systems; restitution of forest in destroyed habitats; conservation of biological and genetic diversity for future generations and enhancement of natural resistance of stands. *In situ* conservation consists in passive and active measures. The former ones are related to conservation in national parks and nature reserves, the latter concern reproduction of seed stands in managed forests, which is regulated by internal state forest service law. The program for the preservation of genetic resources of forest trees (among others European beech) in Poland for 1991 – 2010 (Matras et al. 1993) has just ended. In the first step, 33 gene reserves with a total area of 797 ha were included in the program of forest genetic variability conservation (State Forest and National Parks area). 553 European beech plus trees were also selected in State Forest Regional Directorate (Matras 2005). The next steps of active European beech stand conservation is progeny testing (field experiments) of selected populations, followed by plus tree selection, and establishment of seed orchards in order to determine their genetic value and breeding utilisation as potential forest reproductive material – this will also involve using molecular genetics methods.

As an integral part of the program of forest gene resources conservation, there has been Forest Regionalization for seeds and seedlings (Government Decree 2004) undertaken. The principles of Forest Reproductive Material (FRM) movement into controlled directions are intended to reach the following goals: to promote the valuable forest tree populations and enlarge the genetic diversity of the species in those areas, where the local resources of reproductive material are insufficient; to increase the forest sustainability and silvicultural targets (obtaining high quality and quantity production) through the use of the tree populations that suit best the local site natural conditions, to preserve the genetic diversity of mountain populations and their adaptation to particular elevations zone – six zones were distinguished. Among the total of 91 seed regions, 68 European beech regions of provenance were distinguished in Poland where beech occurred. In some of these seed regions the species occurs as admixture by single individuals or only as shrub layer.

The next program of forest genetic resources conservation and forest tree improvement (2011 – 2035) will focus on the problem of global climate changes for example warming effect and water stress (Fonder 2005).

Methods of seed storage (Suszka 1990) elaborated in Poland facilitate the sowing of seeds of European beech up to five years after harvesting. There are three seed storage houses in Poland: in Dukla in the Carpathians, in Białogard in the Pomeranian Lake District and in the Gene Bank built in the Sudeten Mountains at Kostrzyca. Storage period of seeds in traditional way does not allow a long enough period for regeneration of the best ecotypes and populations. New technology enables storage of seeds, germs and parts of plants for up to 30 years in liquid nitrogen. This method will help to protect seeds, especially in regions characterized by low European beech phenotype plasticity and seed productivity. Long-time storage of seeds is a complementary method for establishing *ex situ* gene conservation stands.

RESEARCH ACTIVITIES RELATED TO GENETIC RESOURCES OF EUROPEAN BEECH

The first European beech experiment representing 11 Polish provenances was established in 1967 (Rzeznik 1976, 1990). Six parallel provenance field trials were established. In this experiment two ecotypes of European beech were distinguished: mountain and lowland. Afterwards the provenance experiment with 45 populations of European beech was established with six trials in the 1992/1995 series (Barzdajn 2002, Matras et al. 2005). Adaptive characteristics (survival and growth) and phenology (flushing and growth cessation) were analyzed. Among European beech populations in Poland, populations of high plasticity were selected, well adapted to different sites like Kwidzyn, Wipsowo and Lezajsk provenances. Provenances which originate from places where European beech was not widely found were characterized by relatively low survival and slow growth rate of forest cultures (Karnieszewice, Lipusz). Flushing revealed great differentiation and two phenological forms were distinguished – late form (Pomeranian region) and early form (southern part of Poland). Cessation characteristics did not show any clear trends. In this experiment genetic variability of mother stands and progeny were also compared using progeny studied at the experimental plot in Bystrzyca Klodzka. Statistical analyses showed high genotype × environment interactions for most of the studied silvicultural features, as well as varying plasticity of populations. Biochemical studies (isoenzyme and RAPD markers) revealed that genetic variation of parent populations confirms the results of phenotypically based assessments to a significant degree. Provenance Kwidzyn (Forest Directory Kwidzyn, forestry Polno) was proposed to be certified as the national standard population according to its high plasticity value and silvicultural characteristics. Regional European beech standards were chosen there e. g. in Forest Districts Gryfino, Milicz, Zdroje, Łosie (Sabor et al. 2004).

Isoenzyme analysis showed (Sułkowska 2002, Gömöry et al. 2003): high genetic diversity of beech in Poland, similar to other neighbouring European populations, slight decrease of average number of alleles per locus and level of differentiation towards the north of the natural range limit, which generally confirms the migration paths after glaciations but it is not the basis to distinguish geographic regions.

Recently, population differentiation of nine European beech provenances from selected stands and their progeny for selected genetic parameters and on the basis of soil characteristics of their habitats were studied (Sułkowska, Kowalczyk, Przybylski 2008). According to phytosociological characteristics following plant associations were classified: fertile Pomeranian beech – *Galio-odorati-Fagetum* (Gryfino i Kartuzy), fertile Carpathian beech – *Dentario glandulosae-Fagetum* (Lutowiska i Łosie), acid beech – *Luzulo-luzuloides-Fagetum* (Miechów, Suchedniów, Tomaszów, Zwierzyniec), fertile Sudeten beech – *Dentario enneaphyllidis-Fagetum* (Zdroje). The analyzed selected stands are practically homogenous related to site conditions which reflect ecological index values (Zarzycki et al. 2002): light – semi-shade, thermic – temperate cool climate conditions, edaphic – clay-sandy or sandy-clay soils and regarding to humus mineral-humus soils. There were only differences determining moisture and acid factors of the soils. The stem and shape of the crown of most of the stands were of good quality. The genetic analyses were performed using isoenzyme electrophoresis and DNA-RAPD methods. The importance of very high intra-population diversity was shown, as well as high variation of investigated populations. Genetic diversity and differentiation of European beech populations and their progeny are correlated with the level of mineral ions important for growth and functions of plants. European beech provenances originating from fertile habitats with higher soil pH were characterized also by higher differentiation value of genetic parameters, as e. g. Miechów provenance pH of the soil 5.51 (0 – 20 cm layer) up to 7.05 (20 – 40 cm layer) – measured in H_2O. For the mother stand of provenance Miechów (South Poland) average number of 2.3 alleles per locus (isoenzyme markers) was estimated, while percentage of polymorphic loci was 77.8% and for progeny 2.6 and 88.9%, respectively. The lowest average number of alleles per locus (1.9) was found for Zwierzyniec mother stand (south-east Poland natural range border), characterized by percentage of polymorphic 66.7% and for the progeny stand 2.3 and 66.7%, respectively. The mother stand of Kartuzy population (north Poland) was also characterized by low value of analyzed genetic parameters: average number of alleles per locus 1.9, with percentage of polymorphism 66.7%, but for progeny stands the values were higher at 2.4 and 88.9%, respectively. The Kartuzy population was characterized by the lowest pH of the soil value – 4.35 (0 – 20 cm layer) up to 4.52 (20 – 40 cm layer) – measured in H_2O. On the basis of DNA-RAPD markers a slight decrease of average number of alleles per locus and level of differentiation towards the north of Poland was observed, but this trend was not so clear. The results pointed at the ecotype character of genetic variation of European beech related probably with site differentiation. So, use of local European beech ecotypes, taking into account its plasticity seems to be the best advice to obtain success in forest management.

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Contacts:

Dr. Małgorzata Sułkowska
Forest Research Institute, Department of Genetics and Physiology of Woody Plants, Sękocin Stary, 3, Braci Leśnej St., 05-090 Raszyn, Poland
e-mail: sulkowsM@ibles.waw.pl

GENETIC RESOURCES OF BEECH (*FAGUS SYLVATICA*) IN THE REPUBLIC OF MOLDOVA

Gheorghe Postolache – Dragos Postolache

Botanical Garden (Institute), Academy of Sciences, Department of Geobotany and Forestry, Padurii 18, MD-2002 Chisinau, Republic of Moldova

ABSTRACT

This paper presents data about the natural distribution, establishment of natural distribution maps, diversity analysis, forest regeneration applications, inventory of genetic resources, *in situ* conservation and rational use of forest genetic resources of beech (*Fagus sylvatica*) in the Republic of Moldova.

Key words: European beech (*Fagus sylvatica*), fag (in Moldavian), beech diversity, plant associations, natural species composition, natural distribution, maps of natural distribution, inventories of genetic resources, *in situ* conservation

GENERAL CHARACTERISTICS

Forests are the most inestimable, renewable natural resources and all forests belong to the first functional group, which means that the function of these forests is a protective one, according to Art. 14 of the Forest Code.

The National Forest Fund of the Republic of Moldova covers 400,900 ha (11.0% of the country territory) including 362,700 ha covered by forests (10.7%) (Galupa et al. 2006). State forests are subject to forest management plans that provide the description of the state of forest biodiversity parameters: typological diversity of forests, species composition of forest sub-compartments, state of grassy cover, regeneration, etc. Deciduous species cover 97.8% and conifers 2.2%.

The natural forests in Moldova consist of broadleaved formations of the Central European type. The main species components of the forest are pedunculate oak (*Quercus robur*), sessile oak (*Q. petraea*), pubescent oak (*Q. pubescens*) and beech (*Fagus sylvatica*). Their distribution depends on the altitudinal levels, on the exposure level and the degree of slope inclination, on the soil and other conditions. These and other factors determined the formation of different types of forests and associations (Postolache 1995).

NATURAL DISTRIBUTION

Beech is found in the northwestern part of the Codrii Reserve from the central part of Moldova and considered at the eastern border of the natural range in Europe (Borza 1937, Soceava, Lipatova 1952, Gheideman 1969, Tishkevici 1984, Postolache 1995). From the climatic, pedologic and geomorphologic point of view this part of Moldova is different from the rest of the country. Many researchers (ANDREEV 1957, GHEIDEMAN et al. 1964, POSTOLACHE 1995) consider this part of Moldova as a particular subregion. Hydrothermic coefficient is 1.0 – 1.1.

Beech forests cover 2,062.8 ha. Most of beech forests, 1,441.9 ha, are present in protected areas (Plaiul Fagului/The Beech Region, Codrii, Căbăieşti – Pârjolteni, Cazimir – Milesti, Cabac, Bogus, Harjauca – Sipoteni, Sadova (Fig. 1, 2). The rest of the beech forests, 620.9 ha, are situated in the forest districts Harjauca, Calarasi, Ciorăşti and Păruceni.

Fig. 1: Beech forests from the "Plaiul Fagului"/The Beech Region reserve

Fig. 2: The protected area of “Cabac”

ESTABLISHMENT OF MAPS OF NATURAL DISTRIBUTION OF BEECH (*FAGUS SYLVATICA*)

The distribution maps of the natural range of beech forests have been developed based on floristic and phytocenological investigations and forest planning information (Andreev 1957). The herbarium illustrated the distribution of pedunculate oak, sessile oak and beech in Moldova. Gheideman (1969, 1986) presents general data about the distribution of these species in geobotanic districts. Data about the distribution of beech are included in the works of Soceava et Lipatova (1952), Postolache (1976, 1995) etc.

In 1975, 1995, 1992 – 1996, the forest fund planning in Moldova was completed. These materials contain data about the forest stand composition. In 1966 – 1972 the forest types and forest associations with beech from the forest farms in the centre of Moldova were mapped and classified. Turok et al. (2000) published a distribution map of the beech forests in southeastern Europe, comprising also the beech in the Republic of Moldova. Postolache (2002) published the vegetation map of Republic of Moldova, where the distribution of beech forests was presented.

From these maps it can be observed that the largest surface area of beech (*Fagus sylvatica*) was recorded in the central part of Moldova (scientific reserves "Codri", "Plaiul Fagului"/The Beech Region, the forest farms Calarasi, Nisporeni. All the beech areas in Moldova can be attributed to the category of the marginal ones, as they are located at the easternmost border of the beech distribution range in Europe.

PLANT COMMUNITIES DIVERSITY

Beech communities are distributed at an altitude of 200 – 400 m, more often on the upper part of slopes with an inclination of 10 – 40, with north and north-east exposures. These communities are represented by small areas, often in the form of narrow strips near the breaks caused by landslides, or along valleys and small rivers where in many places they go down below 200 m of altitude. Beech communities are growing on brown forest soils.

Pure forest stands and mixed beech forests stands were distinguished according to their composition and structure. The coverage of tree canopy is around 0.8 – 0.9. Beech (*Fagus sylvatica*) dominates the upper part of the tree layer. Beech as the main species of these forests attains the height of 30 – 35 m, diameter of the trunk 50 – 70 cm. It is characterized by a forest stand with a diverse composition and structure. Forest stands are composed of a range of 15 different tree species. Besides *Fagus sylvatica* and *Quercus petraea* also *Tilia tomentosa*, *T. cordata*, *Fraxinus excelsior* have been recorded. Hornbeam (*Carpinus betulus*) dominates at the lower tree layer. Also scattered broadleaves species like *Cerasus avium*, *Acer platanoides*, *A. pseudoplatanus*, *A. campestre*, *Sorbus torminalis*, *Ulmus glabra*, *Populus tremula*, *Malus sylvestris*, *Pyrus pyraster* are present. The shrub layer is poorly developed and is represented by solitary species like *Sambucus nigra*, *Swida sanguinea*, *Crataegus monogyna*, *C. curvisepala*, *Corylus avellana*, *Staphylea pinnata*, *Viburnum lantana*, *Cornus mas*, *Euonymus europaea*, *E. verrucosa*. The herb layer is sometimes as poorly developed as the shrub layer. Therefore the coverage of herb layer varies from 4% to 50%. However, in the spring when ephemeral plants flourish (*Scilla bifolia*, *Corydalis solida*, *C. marschaliana*, *Dentaria bulbifera*, *D. glandulosa*, *Allium ursinum*, *Anemone ranunculoides*, *Ficaria verna*, *Gagea lutea*, *G. pusilla*, *Isopyrum thalictroides*), herb layer may reach a coverage of 60 – 90% in some places. During the summer period the herbs are represented by species such as: *Galium odoratum*, *Carex pilosa*, *C. brevicollis*, *C. digitata*, *C. sylvatica*, *Asarum europaeum*, *Hedera helix*, *Aegopodium podagraria*, *Galeobdolon luteum*, *Sanicula europaea*, *Polygonatum latifolium*, *P. multiflorum*, *Pulmonaria obscura*, *Alliaria petiolata*, *Circea lutetiana*, *Mercurialis perennis*, *Geranium robertianum*, *G. phaeum*, *Viola reichenbachiana*, *V. mirabilis*, *Dryopteris filix-mas*, *Epipactis heleborine*, *Stachys sylvatica*, *Actaea spicata*, *Convallaria majalis*, *Poa nemoralis*, *Mycelis muralis*, *Neottia nidus-avis*, *Salvia glutinosa*, *Scrophularia nodosa*, *Arum orientale*, *Athyrium filix-femina*, *Cephalanthera damasonium*, *Cephalanthera longifolia*, *Dactylis glomerata, Stellaria holostea*, *Urtica dioica*, *Euphorbia amygdaloides*, *Geum urbanum*, *Lamium maculatum*, *Lunaria rediviva*, *Melica uniflora*, *Milium effusum*, *Platanthera bifolia*, *Astragalus glycyphyllos*, *Cardamine impatiens*, *Equisetum telmateia*, *Glechoma hirsuta*, *Lamium purpureum*, *Lathyrus niger*, *Parietaria erecta*, *Ranunculus auricomus*, *Scutellaria altissima*, *Tussilago farfara*, *Vicia dumetorum*, *Monotropa hypopitis*. Most of these species are characterized by a very low abundance, and some of them can be found only in a few exemplars. In beech forests 25 species of rare plants have been recorded, most of them are listed in the Red Book of Moldova: *Daphne mezereum*, *Dryopteris dilatata*, *D. carthusiana*, *D. caucasica*, *D. filix-mas*, *Polystichum aculeatum*, *Thelypteris palustris*, *Athyrium filix-femina*, *Cystopteris fragilis*, *Gymnocarpium dryopteris*, *Cephalanthera damasonium*, *C. longifolia*, *C. rubra*, *Cypripedium calceolus*, *Lunaria rediviva*, *Telekia speciosa*, *Dentaria quinquefolia*, *D. glandulosa*, *Ortilia secunda*, *Pyrola rotundifolia*, *Majanthemum bifolium*, *Platanthera bifolia*, *P. chlorantha* (Gheideman 1969, Postolache 1995, Postolache, Chirtoaca 2005).

According to the phytocenologist Gheideman (1969), there are seven associations of beech forests in the country. According to the authors Postolache and Chirtoaca (2005) from the central European school, the beech forests comprised in the scientific reserve "Plaiul Fagului"/The Beech Region were classified as association *Carpino-Fagetum silvaticae* Pauca 1941.

In these communities, the dominant plant species are mesophilic – 47.7%, followed by mesohygrophilic – 32.6% and xeromesophilic – 17.5%. The mesoxerophilic and hygrophilic species are presented in 1% each. The life forms spectra are dominated by hemicryptophyte species (33%) and geophyte species (30%) followed by phanerophyte species (25%). The floristic elements analysis reveals the dominance of Eurasian element (Euras. – 35.2%), European element (Eur. – 20.5%) and Central-European element (Eur. centr. – 11.4%). Relatively well represented are circumpolar elements (Circ. – 10.2%).

BEECH DIVERSITY

Many researchers have studied beech populations, but up to the present there has not been a consensus regarding the systematics of Moldovian beech. Savulescu et Rayss (1926) indicated two forms of beech in the beech forests in Basarabia: (a) f. *cuneifolia* Beck and (b) f. *rotundifolia* Beck. Borza (1937) considered that there are two varieties of beech in Basarabia: (a) *Fagus sylvatica* var. *podolica* spread in the North of Basarabia and (b) *Fagus sylvatica* var. *moesiaca* Czecz. spread in the Centre of Basarabia. Soceava et Lipatova (1952) attributed the beech from Moldova to the var. *moesiaca* Czecz.

Istrati (1975, 1980), after studying the vegetative and generative organs of beech populations, concluded that according to the leaf form the beech belongs to the *Fagus sylvatica* species and differs from *F. orientalis* Lipsky and *F. taurica* Popl. A special peculiarity of the beech population is the asymmetry of the leaf blade.

On the basis of the investigations on the vegetative and reproductive organs of beech populations Tishkevici (1984) made similar conclusion, that the Moldovian beech has some specific peculiarities but is the closest to *Fagus sylvatica.*

Thus the problem of the beech population structure is not resolved. It is possible that one of the principles is the phylogenetic problem of the beech. Mattfeld (1936) quoted by Borza (1937) presumed that long ago during the preglacial period the differentiation of beech (*Fagus sylvatica*) took place from a tertiary species into two species. After the glacial period the environment became more favourable for beech (*Fagus sylvatica*). According to Wulff (1931) *Fagus sylvatica* developed after the glacial epoch from *Fagus orientalis*.

Following this short characteristic of the beech populations it may be concluded that the beech population has a complex structure and it is necessary to protect all these areas as they are both of scientific and practical interest.

As the beech in Moldova is situated at the eastern border of its distribution area, it has been attributed to the category of marginal forest genetic resources.

FOREST REGENERATION APPLICATION

Between 1975 and 1984 some experiments on the establishment of beech plantations were performed (Tishkevici 1984). During the years 1997 – 2005 other experiments regarding beech regeneration, by the method of successive cuttings, were carried out in the scientific reserve "Plaiul Fagului"/The Beech Region on an area of 294.9 ha. The purpose of this work was to optimize the forests structure where hornbeam is abundant.

Nowadays the developed successive cuttings are applied in several forest districts in order to optimize the composition and structure of beech forests.

INVENTORY OF *FAGUS SYLVATICA* GENETIC RESOURCES

Resulting from analysis of forest plans, 236 sub-compartments with beech with a total area of 2,062.8 ha were delineated in the state forest fund. According to the abundance of beech in forests stands 65 sub-compartments (274.3 ha) have been distinguished in natural forest stands, where the beech represents more than 50%. The rest of beech sub-compartments 152 (1,737.0 ha) are located in derivative forest stands with a beech proportion of 10 – 49% and the other 19 sub-compartments are planted forests with an area of 51.5 ha. The areas protected by the state (Plaiul Fagului/The Beech Region, Codrii, Căbăiești – Pârjolteni, Cazimir – Milesti, Codrii, Cabac, Bogus, Harjauca – Sipoteni, Sadova) contain 1,441.9 ha of beech forests or forests with beech (Fig. 1, 2). Outside the protected areas there are 620.9 ha of beech forests managed by the forestry institutions from Harjauca, Calarasi, Ciorăşti, Păruceni.

Taking into consideration that the beech in Moldova is situated at the eastern border of the distribution area in Europe it should be stressed that it is necessary to extend the state protected areas within the beech forests. The forest genetic resources in these areas have been sampled based on the quality of the forest stands.

Three categories of forest genetic resources have been established:

- Optimal forest genetic resources of beech (*Fagus sylvatica*) include the most valuable genetic resources. The volume of the wood is 340 – 460 $m^3 \cdot ha^{-1}$. The height of the tree range is 26 – 38 m and the diameter of the stems is 32 – 56 cm. Ten forest genetic resources of beech have been attributed to this category.
- Forest genetic resources seed stands include forest stands which are less productive than the optimal ones (230 – 308 $m^3 \cdot ha^{-1}$). Three forest genetic resources seed stands have been established.
- The forest genetic resources from the reserves are a separate category. In the reserves 11 forest genetic resources have been established with a total area of 1,441.9 ha (Tab. 1).

CONSERVATION AND RATIONAL UTILIZATION OF THE FOREST GENETIC RESOURCES

There are nine state protected areas of beech of which two of them: "Plaiul Fagului"/The Beech Region, and "Codrii", are scientific reserves. One beech forest "Hîrjauca – Sipoteni" was attributed to the category of protected areas being considered a monument of nature. Four protected areas such as "Cabac", "Sadova", "Bogus" and "Leordoaia" were attributed to the category of nature reserves, while two protected areas "Cazimir – Mileşti" and "Căbăieşti – Pârjolteni" were assigned to the category of landscape reserves.

Nowadays within these nine protected areas only 1,441.9 ha of beech forests and forests with beech are under the protection of the state, representing a total of 70% of the existing beech forests. These 204.1 ha include natural-fundamental forests in which the beech represents more than 50%. Also registered is an area of 1,193.6 ha of derivative beech forests where the participation of the beech tree varies between 10 to 40%. In the scientific reserve Plaiul Fagului/The Beech Region and in nature reserve Căbăieşti – Pârjolteni, 14 areas were planted with beech trees, an area of 44.2 ha (Tab. 1).

Tab. 1: Area (ha) occupied by different categories of beech forests within the protected areas

Protected areas	Natural-fundamental forest stands	Derivative forest stands	Planted forest stands	Total
Plaiul Fagului	130.9	691.0	26.7	848.6
Căbăieşti – Pârjolteni	5.0	256.0	17.5	278.5
Cazimir – Milesti	18.5	166.8	–	185.3
Codrii	38.0	28.2	–	66.2
Cabac	7.3	39.7	–	47.0
Bogus	1.8	7.8	–	9.6
Harjauca – Sipoteni	1.3	4.1	–	5.4
Sadova	0.8	–	–	0.8
Leordoaia – Palanca	0.5	–	–	0.5
Total	204.1	1,193.6	44.2	1,441.9

CURRENT LEGISLATION

Based on the research undertaken by Borza (1937), eight compartments were identified within the forest vegetation classification, among which there were two with beech forests (Pârjolteni – 10 ha and Hârjauca – Palanca – 7 ha). In conformation with a decision of the Romanian Council of Ministers taken in July 19, 1937, these areas along with others were declared Monuments of Nature in Basarabia. Based on the decision of Moldova S. S. R. taken on January 8, 1975, No. 2 "Regarding the settlement of natural areas and complexes from the territory of Moldova S. S. R. under the protection of the state" several areas with beech forests of nine protected areas (Plaiul Fagului/The Beech Region, Căbăieşti – Pârjolteni, Cazimir – Milesti, Codrii, Cabac, Bogus, Harjauca – Sipoteni, Sadova, Leordoaia – Palanca) were put under the protection of the state.

In agreement with the Law on Natural State Protected Areas Fund adopted by the Parliament of the Republic of Moldova No. 1538 – XIII in February 25, 1998, these protected areas were reconfirmed and attributed to several categories of protected area status. Thus were established: two scientific reserves (Plaiul Fagului/The Beech Region, Codrii), one monument of nature (Harjauca – Sipoteni), two landscape reserves (Căbăieşti – Pârjolteni, Cazimir – Milesti) and four nature reserves (Cabac, Bogus, Sadova, Leordoaia - Palanca).

FOREST RESEARCH

The beech forests were studied by several groups of researchers. During 1949 – 1951 one group of researchers from Sankt-Petersburg guided by B. Soceava investigated the spread of beech forests in Moldova. The results of this research were published in a number of articles by Soceava et Lipatova (1952).

The researchers from the Agriculture University of Chisinau under the guidance of G. Tishkevici investigated the biological, ecological and physiological properties, systematic position, natural regeneration and productivity of beech during the period 1970 – 1980. These results were published in the monograph "Okhrana i vosstanovleniye bukovikh lesov" [Conservation and reconstruction of beech forests] (Tishkevici 1984) and in a number of articles.

Other research activities regarding different aspects of the beech tree and beech forests were performed within the Botanical Garden (Institute) from the Academy of Sciences of Moldova.

During 1966 – 1969, T. Gheideman investigated the plant associations, microclimatic conditions, hydric regime of beech trees and other components of beech forests. The results of these investigations were published in the monograph "Bukovaya dubrava Moldavskoi S. S. R. [Beech forests of Moldova S. S. R.] (Gheideman 1969).

Later, during 1997 – 2000, a group of researchers under the guidance of Professor Gh. Postolache, performed important research studies on the identification of beech genetic resources (*Fagus sylvatica*) within the collaborative project with Bulgaria, Moldova and Romania "Genetic resources of broadleaved forest tree species in southeastern Europe" initiated by IPGRI (International Plant Genetic Resources Institute). The selection of beech forest genetic resources was performed by means of a methodical selection of forest areas which included exploration, sampling and classification. Based on this research the monograph of "Genetic resources of *Fagus* spp. in southeastern Europe" was prepared and published by Turok et al. (2000).

Postolache (2004) in his work "State of Forest and Tree Genetic Resources in the Republic of Moldova" presented information regarding the forest genetic resources of beech. Postolache and Chirtoaca (2005) investigated beech forests in the scientific reserve "Plaiul Fagului"/The Beech Region that was attributed to the association *Carpino-Fagetum sylvaticae* Pauca 1941. They show the floristic and phytocenological composition of beech forest communities.

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Contacts:

Dr. habil. Gheorghe Postolache
Botanical Garden (Institute), Academy of Sciences, Department of Geobotany and Forestry
Padurii 18, MD-2002 Chisinau, Republic of Moldova
e-mail: ghpost@asm.md, ghpost@mail.ru

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

Lucia Ioniță – Gheorghe Pârnuță

Forest Research and Management Institute Department of Genetics and Tree Breeding
Bd-ul Eroilor nr. 128, Code 077190 Voluntari- Ilfov, Romania

ABSTRACT

The paper outlines the state of European beech (*Fagus sylvatica* L.) in Romania. The information included deals with the distribution, ecology, taxonomy, phenotypic and genetic variability of European beech. Information about characteristics and forest management, as well as methods for preservation of European beech genetic resources, are also included.

Key words: European beech (*Fagus sylvatica* L.), fag (in Romanian), Romania, distribution, phenotypic and genetic variability, genetic resource, forest research

DISTRIBUTION AND ECOLOGY OF EUROPEAN BEECH IN ROMANIA

In Romania, European beech is the dominant species, covering 32.3% of the forest land (about 2,041,000 hectares, INS 2008) and amounting for 37% of standing wood volume. Romania has 11.7% of Euro-Asian beech stands, thus ranking third in the world. The map of natural distribution range of *Fagus sylvatica* was elaborated by Blada et al. (2002) and is presented in Figure 1.

European beech is a hill and mountain tree growing in both pure and mixed stands with silver fir, Norway spruce and sessile oak. The sub-zone of European beech covers a great deal of Banat, Transylvania, Maramureș, the two slopes of the Carpathians and the central plain of Moldavia. As for the beech extension in altitude, it is very variable depending on the geographical location: 150 m in Banat (seldom 60 m along the Danube Valley and 100 m in Cerna Valley), 800 m in the Transylvanian Alps. The upper limit of closed beech stands lies between 1,200 and 1,400 m but can reach even 1,500 m in the Transylvanian Alps and 1,700 m in the Western Carpathians on the northern slopes.

The optimum range is characterized by a range of precipitation of 650 – 1,250 mm depending on the geographical region and a mean annual temperature of 5.2 – 8.7 °C. European beech stands of high productivity can be found only on deep and rich soils, with a high availability of water and nutrients. Such kind of stands exists in the Western Carpathians (Banat and Crișana regions).

Ecological researches regarding Romanian beech forests were performed by Pauca-Comănescu (1989).

Fig. 1: Map of natural distribution range of *Fagus sylvatica* (Blada et al. 2002)

PHENOTYPIC AND GENETIC VARIABILITY OF EUROPEAN BEECH IN ROMANIA

Phenotypic variability of European beech population in Romania area was described by Milescu et al. (1967) who classified the systematic subunits of *Fagus sylvatica* as follows: *F. sylvatica* ssp. *europaea* (ssp. *sylvatica*), *F.* var. *moesiaca sylvatica* ssp. *orientalis*, var. *grandifolia* and *F. sylvatica* ssp. *taurica*, var. *grandifolia*.

The ecological units of European beech were defined based on the natural types of beech forests. After Ienciu (2005) other subunits of European beech had been described, by many authors, based on the form and structure of the crown, characteristics of leaves, bark and wood and also other traits as follows:

- *F. s.* var. *pendula* Lodd. Catal. (Florescu, Dumitriu-Tătăranu 1960), in Banat Mountains at 800 m, Aleşd, Black Forest (Bihor) (Beldie 1952) and Jerălău Valley (Banat);
- *F. s.* f. *dentata* Dalla Torre et Sarnth, in Transylvania at Braşov, in Muntenia at Schitu Goleşti-Grădiştea Forest (Muscel), (Beldie 1952);
- *F. s.* var. *vulgaris* (Dom.) Beldie Syn., the most common in Romania, the most interesting population from genetic, ecological and productivity points of view being the ones from Beliu,

Dumitreşti, Dobra, Voineşti, Bârzava, Sudrigiu, Radna, Mihăieşti, Fântânele, Soveja and Făget (Chiriţă et al. 1981);

- *F. s.* var. *typica* C. K. Schneider f. *crenata* Kárp., at Băile Herculane (Banat) (Karpati 1937);
- *F. s.* f. *beckii* Dom., in Parâng (Beldie 1952);
- *F. s.* var. *moesiaca* (Maly) Hayek Emend. Dom., in Transylvania, Banat, Oltenia, Moldovia and Dobrogea (Beldie 1952), the most valuable populations being Berzasca, Orşova, Bozovici, Anina, Mehadia and Tismana (Dumitriu-Tătăranu, Ocskay 1953);
- *F. s.* var. (Maly) Dom. *moesiaca* f. *czeczottae* Paşcovschi, in Neva Valley, at Sviniţa (540 m) and in Little Mountain at Sebeş (1,200 m) (Paşcovschi 1945);
- *F. s.* f. *roseo-marginata* Henry. Syn. in Timiş Park (Braşov) (Beldie 1952) and in Arinilor Park at Sibiu (Ţopa 1956);
- *F. s.* f. *leucodermis* Georgescu et Dumitriu-Tătăranu in Cheia, Bistriţa, Argeş Region, Bistricioarei and Zănoaga (Dumitriu-Tătăranu 1959), in Brădiştea (Milescu et al. 1967), in Mehedinţi and Vulcan Mountains, at Săcărâmb, and in Apuseni, at Suharău (Enescu 1975);
- *F. s.* f. *quercoides* Pers., Ciucaş Mountain (1,060 m) and Red Mountain (1,240 m) (Băile Herculane) (Dumitriu-Tătăranu, Ocskay 1953);
- *F. s.* var. *borzae* Dom., in Banat (Domogled Mountain), in Moldova at Grăjdeni, Feredeu-Deleni, Repedea (Iaşi) (Beldie 1952);
- *F. s.* f. (var.) *microcarpa* Aschers-Graebn., in Cheile Bicazului (1,000 – 1,120 m) (Ţopa 1956), in Neteda Plai Mountain (1,500 m) (Georgescu 1958) and in Hurcu Mountain (Banat) (1,200 m) (Florescu, Dumitriu-Tătăranu 1960).

Fagus orientalis Lipsky was found in Banat at Moldova Nouă and Orşova (900 – 1,100 m), Cerna Mountain (1,160 m), in Moldavia at Buhuşi, Huşi, Piatra Neamţ Regions, Măgura Odobeşti, Berneşti and Iaşi, and in Snagov Forest, Dobrogea and Lucoviţa. Three forms – f. *major* Dom. (Fata lui Matis, Herculane), f. *minor* Dom. and f. *fallax* Dom. (Duhova, V. Gratca, Orşova at 70 m, Snagov Forest) – were identified.

One hybrid – *Fagus orientalis* × *Fagus sylvatica* – was also identified in the plains of the south-west and east of the country.

CHARACTERISTICS AND FOREST MANAGEMENT

In the past European beech wood was not used very much for industrial purposes. Nowadays it is widely used for lumber, parquetry fillet, veneer, plywood, lumber-core plywood, particle boards, rural buildings, fuel wood, etc. Recently, it has been used even for pulp and paper production.

European beech stands in Romania are almost all (95%) naturally regenerated, the national policy in this field being to increase the share up to 100%.

Wood production is the main destination of European beech forests in Romania. The total wood production at 100 years old in pure European beech stands varies between 453 $m^3.ha^{-1}$ in the lowest (Vth) site class and 1,155.5 $m^3.ha^{-1}$ in the highest (Ist) site class. At 80 years of age, the mean growth of pure European beech stands in the Ist site class is 11.9 $m^3.ha^{-1}.yr^{-1}$ and decreases down to 4.3 in the (lowest) Vth class. At 100 years of age, in the Ist site class, the proportion of industrial wood is 72%, of which 65% is sawnwood (Enescu 1993).

The amount of European beech wood harvested in the forests (state and private) of Romania in the past 10 years is shown in table 1.

Tab. 1: Amount of beech wood harvested in Romania in the past 10 years (Romanian Statistic Yearbook 2008)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Harvested volume (million m^3)	3.963	4.505	4.956	4.480	4.439	4.748	5.412	4.794	4.997	5.182

FOREST RESEARCH

In Romania, because of only natural regeneration (by seed), European beech has not been the topic of a breeding programme. For that reason its phenotypic and genetic variability was barely searched in-depth.

A biosystematic research in 60 natural populations has investigated traits of pulp production interest (Ciocnitu et al. 1975). Populations with high pulp value were found in the north of the Eastern Carpathians, Suceava Plateau, south Eastern Carpathians, Mehedinți Plateau and in Western Carpathians (Apuseni Mountains).

Another study (Urecheatu 1992) using 77 natural populations took into consideration 42 morphological and anatomical parameters and showed a very large inter- and intrapopulation variability. The research carried out by Stănescu and Şofletea in 1990 – 1992 in European beech populations from a relevant proportion of its natural range in Romania showed a large variation of some leaves' morphology and bark colour.

The first study regarding phenotypic and genotypic variation of European beech in Romania was initiated by Enescu et Muhs (1988). The first step was the study of phenotypic variation of some evolutionary traits in natural populations of European beech from Romania. The biosystematic research of 21 natural populations selected after 5 altitudinal profiles containing the main parts of European beech natural range had included the measurement and observation of 29 traits of forest interest. The first results showed the existence of a large variation of those traits. The second step was the establishment of international provenance trials in Romania in 1995 and 1998 (Wuehlisch von 2007). These trials were the object of other research projects performed by Ioniță in 2005 – 2008 (Mihai et al. 2008).

Researches on differentiation in European beech at allozyme loci were performed by Gömöry et al. (2003). The Romanian Carpathians are unambiguously the centre of the allelic richness, both at the regional and population level. On the other hand, allelic richness exhibits very distinct trends. Despite local variations, centres of high as well as low allelic multiplicity can easily be identified. Extremely low values occur at the northeastern limit of the distribution range – Baltic coast and centre of Poland. The highest values were found in the Romanian Carpathians, mainly in the Apuseni Mts. and at the southeastern edge of the Carpathians (regions Ploieşti and Braşov).

European beech continues to be the most resilient species among the most important Romanian forest species. Its defoliation proportion was 15.6% in 2004, 11% in 2005 and 11.5% in 2006 (Badea et al. 2005 – 2007). In some particular areas (NE and Central Romania) beech decline has been recorded, due to a complex mixture of abiotic factors (water fluctuation, frost, etc.), favouring (agedness, compact soil, low drainage, etc.) and aggravating (bark and wood insects, diseases – *Phytophthora* spp., *Nectria* spp., etc.) (Chira et al. 2005, Chira, Chira 2007). As a new phenomenon, *Lymantria dispar* defoliations have been recorded in beech stands in the last years (Tăut, Neţoiu 2007). Also beech canker is widely spread in hilly and low mountain areas (Chira, Chira 1998).

CONSERVATION OF EUROPEAN BEECH GENETIC RESOURCES

In Romania, the beech genetic resources are conserved only *in situ*, with the exception of 4 populations that are included in the international field trials of European beech established in our country.

A first method of conservation is the seed stand, which amounts for 7,665 ha spread all over the phytogeographic subzones of our country (Seed Stands Catalogue 2001). Other virgin stands, with garden-like patterns, are preserved under total non-intervention regime in old forests legally dedicated as nature monuments. Eight virgin forests – Văliug Forest District, compartment 37, Mehadaia Forest District, compartments 214 and 94, Bozovici Forest District, sub-compartment 110 C and compartment 47, Nera Forest District, compartments 38 A and 64, and Făget Forest District, sub-compartment 110 A – were identified. Among these forests, Nera and Făget are protected areas.

A second method of conservation is the selection of genetic resources of European beech which are included in the National Catalogue of Forest Genetic Resources (Pârnuţă et al. 2008). The genetic resources of European beech consist in 123 conservation units, with 11,803 ha total surface, of which 3,106.4 ha as core zone and 8,696.6 ha as buffer area.

The map of *Fagus sylvatica* genetic resources distribution on regions of provenances is presented in Figure 2.

Scattered stands of European beech located outside of the natural range such as Bucovăţ-Craiova, Bucoviciorul-Dolj, Luncaviţa-Măcin, Mănăstirea Câlnic-Tulcea, are also preserved. To the same group belong the scattered individuals or small groups of European beech trees located in the Transylvania Plateau (Sivaşul de Câmpie-Mureş) and in the Muntenia Plains (Ţigăneşti-Snagov, Curcubeul-Gherghiţa).

An important proportion of European beech forests are subject of NATURA 2000 programme in Romania (273 of SCI, which amounts for 2,023,601 ha, including beech forests also) (Stoiculescu 2007).

The Romanian legislation regarding the forest genetic resources consists of the Governmental Ordinance no. 11/2004 on the production, marketing and utilization of forest reproductive material, approved by Law no. 161/2004 and Law no 46/2008–Forest Code.

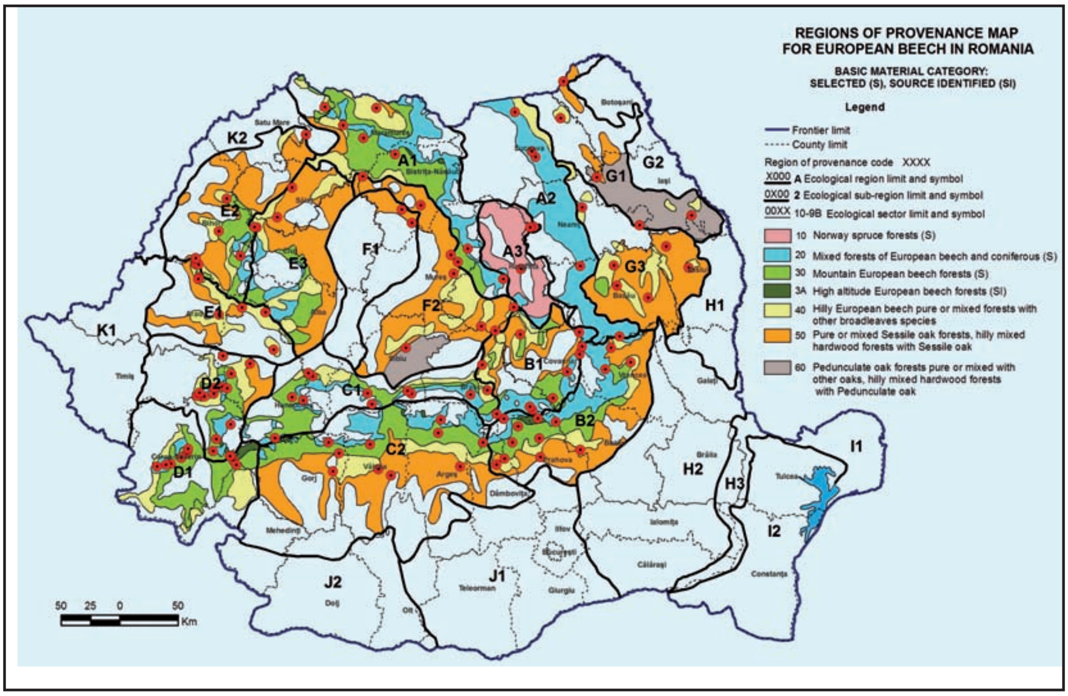

Fig. 2: *Fagus sylvatica* (L.) genetic resources distribution on regions of provenances

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Reviewed

Contacts

Dr. Lucia Ioniță, Prof. Dr. Gheorghe Pârnuță
Forest Research and Management Institute Department of Genetics and Tree Breeding
Bd-ul Eroilor nr. 128, Code 077190 Voluntari- Ilfov, Romania
tel.: +4021 350 3238; +4021 350 3245
e-mail: luciaionita1@yahoo.com, gh_parnuta@icas.ro

CURRENT STATE OF BALKAN BEECH (*FAGUS SYLVATICA* SSP. *SYLVATICA*) GENE POOL IN THE REPUBLIC OF SERBIA

Mirjana Šijačić-Nikolić[1] – Saša Orlović[2] – Andrej Pilipović[2]

[1] Faculty of Forestry, University of Belgrade, Kneza Višeslava 1, 11030 Belgrade, Republic of Serbia

[2] University of Novi Sad, Institute of Lowland Forestry and Environment, Antona Čehova 13, 21000 Novi Sad, Republic of Serbia

ABSTRACT

Total forest area of Serbia is 2,412,940 ha. The dominant species in the forest growing stock is beech (50.4% by volume) with a wide range of vertical distribution, occurring in a great number of forest types, in different structural forms, in pure or mixed stands, of different origin, at different sites. The main characteristic of the beech gene pool in Serbia is high individual and group variability in many morphological and genetic-physiological traits, which results in numerous intraspecific taxa described in this region.

Key words: Balkan beech, bukva (in Serbian), taxonomy, morphology, variability, range, forest community, environmental conditions, state, forest management system, fungi, insects, gene pool

TAXONOMY

In Serbia, in addition to European beech (*Fagus sylvatica* L.) and oriental beech (*Fagus orientalis* Lipsky), according to Jovanović (2000), there is also Balkan beech which is the most represented species. This author considers Balkan beech (*Fagus moesiaca* Domin, Maly/Czeczott.), as a separate species in the region of the Balkan Peninsula and Serbia.

Balkan beech was first described as a separate taxon by Josef Karel Malý in 1911. The description of this taxon was later completed by Czeczott (1933). Opinions regarding the taxonomical status of this taxon varied. Frequently, it is described as a separate unit (Czeczott 1933, Fukarek 1954). Mišić (1957) considers it a phylogenetical link between *F. sylvatica* and *F. orientalis*. Sometimes it is considered a hybrid between both species morphologically closer to *F. sylvatica* (Becker 1981), a mixture of *F. sylvatica* and *F. orientalis* with the occurrence of transition forms dominated by characters of one of the two species (Stoyanoff 1932), an ecotype (Staňescu 1979) or identical with the Crimean beech *Fagus taurica* Popl. (Didukh 1992).

The morphological description of "*F. moesiaca*" is rather vague. There is no agreement among different authors about the morphological traits discriminating between the Balkan and European and/or Eastern beech. For most characters, the mean values are different but the ranges of variation overlap considerably. In comparison with pure *F. sylvatica*, "*F. moesiaca*" has larger leaves with more lateral veins, larger beechnuts and longer cupule peduncle (Czeczott 1933, Mišić 1957, Staňescu 1979). In addition to the morphology, "*F. moesiaca*" differs from *F. sylvatica* by a high sprouting capacity and a considerably higher frequency of seed years, as well as ecological requirements (Mišić 1957).

Furthermore, the description of the distribution range of Balkan beech is not unequivocal. The main part of the range seems to be the former Yugoslavia (Bosnia, Serbia, Montenegro, Macedonia), Albania, Bulgaria and Greece (Fukarek 1954, Mišić 1957), but isolated occurrences have been reported from south-eastern Rumania, Hungary and even Poland and the former Czechoslovakia (Karpáti ex Fukarek 1954, Staňescu 1979). Croatian and Slovenian populations are generally considered *F. sylvatica*. European beech belongs to those forest tree species whose genetic variation has been very thoroughly documented within the majority of its range employing isozyme markers. However, the data for Balkan beech are scarce, especially for our main area of interest, i. e. the southern Balkans, and for Eastern beech they are practically missing. Comps et al. (1991) investigated beechwoods from the continental and Mediterranean parts of Croatia, and reported the presence of differences between these two regions. Data from Balkan countries were also included in a wide study of beechwoods in Central Europe (Comps et al. 1990), but the data from Serbia, Bulgaria and the Romanian Carpathians were pooled, so that no differentiation patterns within this large area could be identified. Recently, a study focusing on this region was published by Hazler et al. (1997). Although there is a gap in their material between Macedonia and Croatia, a north-west to south-east cline can be identified in their presentation of PCA results. In all these reports, beech in this region was denoted as *Fagus sylvatica* L.

The final question to be solved is the taxonomical status of Balkan beech. Unfortunately, the criteria for distinguishing species in the plant kingdom are very vague. The populations in this region can be distinguished from the remaining common beech by morphology, and they are genetically differentiated, so that they can be considered a separate taxon. Nevertheless, the rank of a separate species seems to be too high. There are other beechwoods, e. g. in Calabria, which are even more differentiated, but they are denoted as *F. sylvatica*. Therefore, the rank of a subspecies appears to be more appropriate for Balkan beech (Gömöry et al. 1999).

MORPHOLOGY

Balkan beech is a deciduous tree capable of reaching a height up to 30 (45) m, a diameter of 2 m, and a lifespan up to 300 years. It has a dense crown, which is spherical in isolation, and reduced in stand conditions. Its root system is variable, shallow to medium deep, with well-developed lateral roots. Its bark is whitish-grey and smooth.

It has thin twigs and long shoots with alternately arranged buds and leaves in two rows. The buds are long, spindle-shaped, prominently long, pointed. Bud scales are brown, naked and glossy. Balkan beech leaves grown in sunlight (resembling *F. sylvatica* leaves) differ from the leaves grown in the shade (which are similar to the leaves of *F. orientalis*). Sun leaves are smaller, thicker, ovate (elliptic), and shade leaves are larger, thinner, obovate with a wedge shaped base (elongated) with 5 – 12, most often 9 pairs of veins. The leaves are entire, sometimes crenate, sparsely toothed, with bristles.

Flowers are unisexual. Staminate flowers appear on the shoots hanging on peduncles in globular inflorescences. Perigon parts are shorter and broader than in *Fagus sylvatica* L. Female flowers, two per cupule, are on the upper end of strong shoots. Male and female flowers occur in two-flowered dichasia. The flowers appear simultaneous with the leaves in April or May. Beechnuts, 1.3 – 1.8 cm long, are borne in pairs in each cupule. Cupules are formed by fusing numerous scaly stipules (bracts), 13 – 35 mm long, split in the upper part, with four valves. Stipules are variable, leaflike-wide (as in *F. orientalis*) or thread-like narrow (as in *F. sylvatica*). Beech nuts are brown, triangular, containing usually one, rarely two seeds. They mature in the autumn from September through November, when they fall (Jovanović, Cvjetićanin 2005).

VARIABILITY

In Serbia, Balkan beech has three ecological races, four varieties and two forms. Near the lake Vlasinsko Jezero (altitude about 1,300 m) there is a beech tree with golden-yellow leaves, which is designated as a special variety *Fagus moesiaca* (Maly) Czecz. var. *aurea* Obrad. 1892 Em Jov. It was used for the cultivar 'Zlatia' which is cultivated in parks and botanical gardens in Europe.

In the study of beech variability and ecology of the former Yugoslavia, in the area of Serbia, Mišić (1957) describes Balkan beech as a separate species and distinguishes three ecological races:

1. *Fagus moesiaca* (Domin, Maly) *brevipedunculata*;
2. *Fagus moesiaca* (Domin, Maly) *macrocarpa*;
3. *Fagus moesiaca* (Domin, Maly) *longipedunculata*.

He further reports that "... three separate races occupy predominantly three altitudinal belts of our mountains, forming specific altitudinal regional associations. On some lower mountains, there is only one race – *macrocarpa*, because the boundaries of some vegetation belts are moved downwards, due to specific climate effects. At the particular sites there are individual trees or small groups of trees, which by some characteristics resemble one race, and by other characteristics – another race. They are transitory or hybrid forms. All three beech races have approximately equal alternation of seed years. The statistically determined differences are not equal in all the studied characteristics of the three races. The two oldest taxonomic forms of beech in Serbia are *macrocarpa* and *brevipedunculata*, and they exhibit the slightest differences. There is a series of transitory populations among the three altitudinal races regardless of the substantial differences in the majority of morphological characteristics among individual races. All the above shows that the races are not completely differentiated, formed and stabilised.

Within the race *brevipedunculata* Mišić (1957) distinguishes the variety *rotundicarpa* in the ravines, and the variety *microcarpa* on the prominent ridges. Beech with quercoid bark (*Fagus moesiaca* var. *quercoides*) was described in Serbia by Tucović et Jovanović (1964). On the mountain Golija, there is a beech stand on acid siliceous bedrock, in which bark colour is very similar to that of white-bark pine. The new form of beech was named *Fagus moesiaca* (D. M.) Cz. *leucodermis* by Korać (1974). The Balkan beech form with pendulous branches (*Fagus moesiaca* /Domin, Maly/ Czecz. f. *pendula* /Dum-Cour./ Lodd.) on Šar Planina was described by Ostojić et Dimović (1999).

DISTRIBUTION, FOREST COMMUNITIES AND ECOLOGICAL CONDITIONS

Total area under forests in Serbia is 2,412,940 ha. Beech is the dominant species (50.4% by volume) with a wide range of vertical distribution, occurring in a great number of forest types, in different structural forms, in pure or mixed stands, of different origin, on different sites.

Although the question of the ranges of European beech (*Fagus sylvatica* L.), Balkan beech (*Fagus moesiaca* Domin, Maly/Czeczott.) and Oriental beech (*Fagus orientalis* Lipsky) in Serbia has not been completely resolved, as they are often mixed and occur together in this area, all beech stands in Serbia are treated as Balkan beech forests and are studied and described as such.

Beech forests in Serbia occur in the form of special altitudinal belts, at the altitudes between 40 m in the Đerdap area and 2,100 m on Mt. Prokletije. The beech altitudinal zone is divided into four beech altitudinal belts: submontane beech forests (*Fagenion moesiacae submontanum*), montane beech forests (*Fagenion moesiacae montanum*), beech and fir forests (*Abieti-Fagetum*) and subalpine beech forests (*Fagenion moesiacae subalpinum*). Submontane beech forests grow in oak altitudinal belt, and above it beech forms a climate-regional vegetation belt. The characteristic of beech forest belt (altitudinal range) in Serbia is the migration to the higher altitudes going from the north to the south, both of the lower and the upper boundaries of distribution. The lower boundary in the north part is at the altitude of about (40) 250 m (Northeast Serbia), and in the south, about 600 – 800 m (Suva Planina, Kopaonik). The identical phenomenon also occurs on the upper boundary of this belt, which is in Northeast Serbia about 1,100 m, and on Kopaonik and Suva Planina about (1,300) 1,800 m (Krstić 2005).

Syntaxonomically, beech forests in Serbia belong to the class of Eurosiberian deciduous forests (*Querco-Fagetea* Br.-Bl. et Vlieg 1973), order – beech forest (*Fagetalia sylvaticae* Pawl. 1928), suborder – forest of Balkan beech (*Fagenalia moesiacae* B. Jov. 1986), and to the alliance of Balkan beech forests (*Fagion moesiacae* Blეč. et Lak. 1970). This alliance is divided into seven suballiances, four of which are designated by altitudes, and three are based on the edaphic differences (Jovanović, Cvjetićanin 2005).

The dominant soil types characterize not only the edaphically conditioned coenoses of beech forests, but also the orographically conditioned coenoses. Based on the criteria of Soil Classification (Škorić, Filipovski, Ćirić 1985), the 10 main soil types in beech forests are divided into four classes: undeveloped (diluvium), humus-accumulating (rendzina, black earth on limestone and ranker), cambic (acid brown soil, eutric brown soil and brown soil on limestone) and eluvial-illuvial soils (illimerized, brown podzolic, and podzol). The soils are formed on different parent rocks, such as all types of eruptive and metamorphic rocks and several types of sedimentary rocks (Knežević, Košanin 2005).

The range of beech forests in Serbia is characterized by two types of regional climate: the drier continental climate and the colder, more humid mountainous climate. The elements of regional climate are under a strong local impact. Regarding air temperature, beech belongs to the ecological group of mesothermal plants, which grow best on the sites with moderate temperatures, and the extreme temperatures can be harmful and can lead to tree damage or death. Regarding mean annual relative humidity, Balkan beech has a wider ecological range (65 – 80%) than European beech (75 – 85%) and Oriental beech (70 – 80%) (Krstić 2005).

THE STATE AND FOREST MANAGEMENT SYSTEM

Beech is the dominant species in the growing stock in Serbia (50.4% per volume). The percentage of beech forests in the total area of state forests in central Serbia is 47.11%, the percentage of mixed forests of beech and fir, and beech, fir and spruce is 4.03%. Regarding the origin, high forests occupy 69.3%, coppice forests 29.8%, brushland 0.7%, and degraded forests used for fodder 0.2%. The area of degraded and destroyed forests in beech forests is 28,279 ha (7.6%) (Medarević et al. 2005).

The average volume in beech forests is 217 $m^3.ha^{-1}$, average current volume increment is 4.55 $m^3.ha^{-1}$; the average volume in mixed forests of beech and fir is 308 $m^3.ha^{-1}$, volume increment is 6.95 $m^3.ha^{-1}$; the volume in mixed forests of beech, fir and spruce is 353 $m^3.ha^{-1}$, volume increment 8.24 $m^3.ha^{-1}$. The average volume in high forests is 255 $m^3.ha^{-1}$, volume increment 5.04 $m^3.ha^{-1}$; the average volume in coppice forests is 166 $m^3.ha^{-1}$, average volume increment 4.30 $m^3.ha^{-1}$. Regarding the average volume and volume increment in high forests, only about 85% of the total production potential are used, and in coppice forests, about 65% of the production potential are used (Medarević et al. 2005).

Beech forests are classified into 35 specific purpose entities, in which 18 special objectives of management have been defined. Production forests occupy 277,315 ha or 74.40% of the total area of beech growing stock. Protection forests cover 18.48% and national parks 7.12% (Medarević et al. 2005).

The main characteristics of forest management systems applied in beech forests, according to Milin (1988), can be defined as: shelterwood management system characterized by seed tree felling or shelterwood felling with three cuts (preparatory, regeneration and removal cut) which are performed during the regeneration period; selection management system characterized by selection cutting, in which the trees which reached the target diameter are cut, and of the smaller diameter trees only those that should be removed because of silvicultural reasons; and group selection management system characterized by silvicultural groups which are not defined by the size of the area, but by the homogeneity of stand conditions, the basic silvicultural requirement and the respective basic silvicultural operation.

THE MOST FREQUENT PHYTOPATHOLOGICAL AND INSECT DAMAGES

In the research of parasitic and saprophytic mycoflora in beech high and coppice forests in Serbia, 147 species of fungi have been identified on beech trees, of which 33 species occur on cupules, fruits and seedlings, 56 species on foliage and bark of branches and stems, and 58 species are wood rotting and sap stain fungi. The most harmful disease agents are *Nectria* species (*coccinea, ditissima, galligena*), and somewhat less harmful are the fungi *Phytophthora cactorum* (Leb. et Cohn) Schr., *Apiognomonia errabunda* (Rob. ex Desm.) Hohnel, *Cytospora* spp., *Diatrypella verruciformis* (Her. ex Fr.) Nits., *Melanconium stromaticum* Corda and *Stilbospora angustata* Pers. The fungus *Nectria coccinea*, together with the insect from fam. Eriococcidae *Cryptococcus fagisuga* Lind., causes the so-called beech bark disease. Of the 58 fungi species which infest wood, 48 species destroy beech wood (i. e. cause wood decay), four species cause sap stain, and six species are secondary pests and therefore they have not a practical significance. Among wood rotting fungi, the greatest economic damage is caused by fam. Polyporaceae *Fomes fomentarius* (L. ex Fr.) Fr. and *Hypoxylon deustum* (Hoffm. ex Fr.) Grev. and, somewhat less, by *Armillaria mellea* s. l. (Vahl. ex Fr.) Karst., *Bjerkandera adusta*

(Willd. ex Fr.) Karst., *Fomitopsis pinicola* (Sov. ex Fr.) Karst., *Ganoderma applanatum* (Pers. ex Wallr.) Pat., *Pholiota adipose* (Fr.) Kumm., *Pleurotus ostreatus* (Jacq. ex Fr.) Kumm., *Polyporus squamosus* (Huds.) Fr. and *Trametes hirsuta* (Wulf. ex Fr.) Pil. These fungi infest live trees, and continue the destruction of wood after tree felling (i. e. on the dead wood) (Karadžić, Milijašević 2005).

In beech stands in Serbia, a total of 142 phytophagous insect species have been identified to date. Of the total number of insect pest species, 93 species or 65.5% are primary pests, nine species or 6.4% are secondary pests, 17 or 11.9% are tertiary, and five species or 3.5% are quaternary pests. Six species or 4.2% are very significant pests of beech, of which three (*Phyllaphis fagi* L. from Aphidae, *Cryptococcus fagisuga* Lind. from Eriococcidae, and *Rhynchaenus fagi* L. from Curculionidae) are oligophagous and specific for beech, and the other three butterflies (*Lymantria dispar* L. from *Lymantridae, Operophtera brumata* Hbn. and *Erannis defoliaria* L. from Geometridae) are wide polyphages and during mass outbreaks they also cause damage to beech stands (Mihajlović 2005).

GENE POOL CONSERVATION

The main characteristic of beech gene pool in Serbia is the high individual and group variability of numerous morphological and genetic-physiological traits, which resulted in numerous intraspecific taxa recorded in this area. Taking into account the beech domination in the growing stock of Serbia, its wide range of horizontal and vertical distribution, its presence in a great number of types of forest communities, the conservation of its gene pool should be performed on the original sites (*in situ* conservation), aiming at the conservation of the adaptable potential of the species (dynamic gene conservation). This means the selection of the superior natural populations, the revision of the existing ones and the designation of the new seed forests, groups or individual trees. Also, conservation can be done in artificially established *ex situ* sites, such as provenance tests, archives, clonal or seedling seed orchards.

To enhance the production of good-quality reproductive material, and as a form of gene pool conservation, 19 seed stands have been designated to date in Serbia, total area 137.57 ha. The spatial distribution of the designated seed stands covers almost completely its coenological, ecological and population diversity.

The Law on Reproductive Material of Forest Trees adopted in 2005 defined clearly the production of reproductive material at the level of provenance regions, which resulted in the designation of five beech provenance regions in Serbia.

The degree of variability and the potential of different beech provenances in the juvenile stage of development were assessed in the framework of the project "Conservation and directed utilisation of beech gene pool in Serbia" which was financed by the Ministry of Agriculture, Forestry and Water Management in the period 2004 – 2006 (Šijačić-Nikolić et al. 2006, 2007, Šijačić-Nikolić, Milovanović, Knežević 2006).

During the 1980s in Serbia, 74 beech test trees (plus trees) were designated, and the clonal progeny has been obtained from 64 trees to date. A high degree of rooting of up to 90 to 100% was achieved by autovegetative propagation of beech by aerial rooted cuttings, using growth stimulators such as β-indole butyric acid in concentrations 0.5, 1.0 and 2.0%. Two live archives of beech (Belgrade and Beočin) were established by propagated vegetative copies, as the basis of the collection of secondary scions and further vegetative reproduction of plus trees. A beech clonal seed orchard was established by planting grafts of 30 clones in the Arboretum «Šuplja Stena» on Mt. Avala near Belgrade (Jovanović 1971).

Within the last series of European provenance tests in 2007, funded by the Ministry of Agriculture, Forestry and Water Management RS, two provenance tests were established in Serbia: one on Mt. Fruška Gora and the other in the Faculty of Forestry Teaching Centre at Debeli lug. The above tests were established from two- and three-year old seedlings of 24 European provenances. The experiment established on Fruška Gora is situated in FMU 3804 Popovica-Majdan-Zmajevac, compartment 29f, managed by NP "Fruška Gora". It is characterized by Northwest aspect, altitude 350 – 380 m, area 1 ha, with sample plot area 0.4 ha, on acid brown to lessivé acid brown soil, slope 11 – 15°. The Faculty of Forestry site "Pripor-Felješana" at Debeli lug is at the altitude of 742 m, east aspect, ridge of uniform slope, on humus-siliceous soil, with humid continental climate.

The monitoring of the development and phenology of the represented provenances started during 2008, within the project "Research of forest tree genetic potential within the network of European provenance tests" funded by the Ministry of Agriculture, Forestry and Water Management of Republic of Serbia.

Fig. 1: Location Debeli lug, Serbia, photo Mirjana Šijačić Nikolić, 2008

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Reviewed

Contacts:

Prof. dr. Mirjana Šijačić-Nikolić
Faculty of Forestry, University of Belgrade
Kneza Višeslava 1, 11030 Belgrade, Republic of Serbia
tel. + 381 11 3053873
e-mail: sijacic68@open.telekom.rs

Prof. dr. Saša Orlović
University of Novi Sad, Institute of Lowland Forestry and Environment
Antona Čehova 13, 21000 Novi Sad, Republic of Serbia
e-mail: sasa.orlovic@minpolj.sr.gov.yu

EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GENETIC RESOURCES IN SLOVAKIA

Dušan Gömöry[1] – Ladislav Paule[1] – Roman Longauer[2]

[1] Technical University in Zvolen, Faculty of Forestry, T. G. Masaryka 24, SK-96053 Zvolen, Slovakia

[2] National Forestry Centre, T. G. Masaryka 22, SK-96092 Zvolen, Slovakia

ABSTRACT

The study gives an overview of the current state of European beech (*Fagus sylvatica* L.) and its genetic resources in Slovakia. Basic information about the horizontal and vertical distribution, representation in forest stands, plant communities and management of beech stands is provided, along with an overview on the sources of forest reproductive material and gene conservation measures. Past and recent research activities on the field of beech genetics are also mentioned.

Key words: European beech (*Fagus sylvatica* L.), European beech, buk lesný (in Slovak), distribution range, gene-pool conservation, forest reproductive material, Slovakia

DISTRIBUTION OF EUROPEAN BEECH IN SLOVAKIA

Slovakia with the proportion of forested land of 41% belongs to the most forested countries of Europe. The total area of forests is 1,932,900 ha, the average standing stock is 232 $m^3.ha^{-1}$.

Beech is one of the most important forest tree species in Slovakia. It is the most widespread one, sharing 31.2% of the present tree species composition (Ministry of Agriculture 2008), whereby this share is quite stable over the last 60 years or more. The natural range covers almost the whole country from the Small Carpathians in the west to the Poloniny Mts. in the east, with the exception of lowlands (Zahorie, Danube and East-Slovakian lowlands), river valleys, dry karst plains of southeastern Slovakia, and subalpine and alpine environments. Beech is also absent at the southern slopes of the Tatra Mts. even at lower elevations. However, in several regions the share of beech in the tree species composition was severely reduced during the last centuries, when indigenous broadleaved and mixed forests were replaced by conifer (mainly spruce) monocultures (Upper-Hron valley in Central Slovakia, Orava and Kysuce regions in the northwest).

Generally, continuous distribution of beechwoods is limited by approx. 330 m and 1,200 m a. s. l. However, sporadic occurrence of beech has been reported at the elevations of 120 m in the Burda Mts. in the southwest and at 180 m in the Vihorlat Mts., in eastern Slovakia; on the upper limit, beech climbs up to 1,480 m a. s. l. in the Low Tatra Mts. (Blattný, Šťastný 1959). In several mountain ranges such as the Velka Fatra Mts. or Poloniny Mts., where summits were deforested during the Wallachian colonization in the 16th century to obtain pastures for sheep, beech forms an artificial upper forest limit. Although no true krummholz beech stands are found in Slovakia, in several mountains stand height is severely reduced at sites exposed to wind and low temperatures.

Because of its high share in the tree species composition, beech is represented in many primeval forest remnants (56 out of 74 forest national nature reserves, whereas in 36 it is a dominant species, cf. Korpeľ 1989). Four virgin forests (Stužica, Havešová, Rožok, Kyjov), together with the Ukrainian beech reserves, have been recorded since July 28, 2007, in the UNESCO World Natural Heritage list.

BEECH COMMUNITIES

In Slovakia, beech occurs naturally in six out of eight vertical forest vegetation zones, from the 2nd up to the 7th. The optimum for beech constitutes the 4th vegetation zone, where even natural pure beechwoods occur. However, beech is naturally represented in most forest plant communities of Slovakia, covering almost 90% of the forest area (Table 1). At low elevations, beech occurs in the mixture with sessile oak and hornbeam. In the optimum, beech forms dense pure stands with a very poor herb layer (communities *Fagetum pauper*) or communities with the occurrence of typical beechwood species such as *Galium odoratum*, *Dentaria bulbifera*, *Galeobdolon luteum* or *Asarum europaeum* (*Fagetum typicum*). With increasing altitude, silver fir and Norway spruce become admixed; this so-called "Carpathian mixture" represents the most productive forests of Central Europe (typical representatives can be found in nature reserves Dobroč or Hrončecký Grúň, where beech reaches heights up to 47 m (Holeksa et al. 2009). On sites with a rapid nitrogen turnover, beech is mixed with sycamore, common ash, mountain elm and linden, on rocky sites with Scots pine and European larch.

The most common soil types in Slovak beechwoods are cambisols. However, beech is able to survive and compete on a broad variety of soil types from podzols over andosols on volcanic bedrock up to rankers and rendzinas on carbonate rocks, on the other hand it avoids heavy soils on loess. The distribution of beech communities according to the CORINE classification including the

Tab. 1: Review of the phytosociological units (groups of forest types sensu Zlatník) containing beech (Randuška, Vorel, Plíva 1986)

Typological unit	Vegetation zone	Share (%)
Fagetum quercinum	2	2.70
Fageto-Quercetum	2	15.53
Querceto-Fagetum	3	8.40
Fagetum pauper	4	18.25
Fagetum typicum	4	3.80
Fagetum dealpinum	4	4.00
Abieto-Fagetum	5	11.50
Fageto-Abietum	6	9.20
Fageto-Aceretum	6	3.50
Fagetum abietino-piceosum	6	5.50
Remaining communities		6.85
Total		89.23

corresponding typological units can be found on the webside of the National Forestry Centre (http://www.forestportal.sk/ForestPortal/).

MANAGEMENT OF BEECH STANDS

Beech is an important commercial tree species, but primarily it is considered a stabilizing element of forest stands. It is reflected also in the health state: beech is generally considered resistant to native pests and pathogens, the mean defoliation degree on a 0 to 4 scale is 0.86 compared to 1.36 in the case of Norway spruce. Therefore, it is not an object of intensive breeding, but much more emphasis is given to the preservation of its adaptedness and ecological stability through the gene-pool conservation of the existing indigenous populations. Natural regeneration is generally considered the best tool for fulfilling these tasks. Therefore, silvicultural systems based on natural regeneration have traditionally been applied in beech forests. A tendency towards forest management close to nature is declared and reported in Green Reports of the Ministry of Agriculture. Officially, the share of clearcuts in the forests of Slovakia decreased from 85% in 1990 to 32% in 2007. However, the reality may deviate from official declarations, with an increasing use of heavy mechanization, there is a shift from shelterwood group cuttings towards logging schemes allowing higher logging concentration such as strip felling, and even small-scale clearcuts are sometimes applied also in beechwoods. This is also documented by the extent of natural regeneration: although it increased from 18% in 1990 to 34% in 2007, it does not correspond to the declared decrease of clearcuts.

Beech mostly grows in high forests, beech coppices are exceptional. Generally, the proportion of coppices is very low in Slovakia, being 1.82% in 2007, and the majority of these are oak and hornbeam stands.

As mentioned, the actual proportion of beech is over 31%, but the share on potential natural forest vegetation is much higher, 48%. A long-term target is increasing this proportion to approx. 36%. The average age of beech stands is 71 years, whereby a shift towards a higher representation of older age classes has been observed in recent years. The current annual increment amounts to 5.97 $m^3.ha^{-1}$.

FOREST REPRODUCTIVE MATERIAL AND GENE POOL CONSERVATION

The reconstruction of a more natural tree species composition is hardly possible without extensive reforestation. This is an up-to-date topic mainly in the Kysuce region where conifer plantations, declining today, had replaced natural stands, and a reconstruction of a more natural tree species composition is under way. As very few beech stands remained in this area, finding appropriate seed sources is a difficult task.

In Slovakia, the problems of the biological quality of forest reproductive material have been legally regulated since 1939. At present, there are two legislative norms in this field: the Act no. 217/2004 on Forest Reproductive Material, and the Decree no. 571/2004 on the Sources of Forest Reproductive Material, its Procurement, Production and Use, elaborating detailed rules of procuring and transfer of Forest Reproductive Material (FRM). Both legal norms implemented the rules set by the OECD Scheme and the EU Directive 105/1999/EC. A revision of the legislation is just under preparation, but the basic principles will not be probably changed. In general, reproductive material for forestry purposes is allowed to be procured only from the sources explicitly given by the law (even in the case when it is collected for own use) and the transfer is also strictly regulated.

Currently, 38 plus trees were selected for beech (out of 4,278 in total). The main source of beech seeds are approved seed stands of two categories: there are 2,342 ha of category A stands and 23,007 ha of category B stands, representing 41% of the approved stands area. Moreover, there are 184 ha of so-called seed stands, which are reproductive plantations established from the material originating from category A approved stands, i. e. serving for the preservation of gene pools of the most valuable stands *ex situ*. There are neither seed orchards nor tested basic material of beech in Slovakia. The use of reproductive material of the category "identified" must be approved by the Ministry of Agriculture and is allowed only when no suitable material of higher categories is available.

Concerning the transfer of FRM, the territory of the country is divided into five provenance regions, out of which three are located within the natural distribution range. Although it is not explicitly stated in the legislative norms, for provenance regions situated within the natural range, transfer is allowed only within a region. Moreover, the decree defines altitudinal zones of 200 m; transfer is allowed only within a zone or into the neighbouring zones. In practice, however, these rules are frequently not followed by foresters and nursery managers. The working capacities of the responsible authority, which is the Centre for the Control of FRM in Liptovský Hrádok, belonging to the National Forestry Centre, are limited, and the attention is primarily paid to conifer species, so that the collection of beech seeds or seedlings from the understorey is rarely supervised by the regional inspectors of the Centre.

Gene reserves as spatially continuous complexes of predominantly indigenous forest stands of more than 100 ha with a balanced age structure can also serve as sources of FRM and are specifically destined for gene conservation *in situ*. At present, there are 18 gene reserves declared only for beech with a total area of 5,017 ha. Moreover, beech is represented in further 24 gene reserves with a total area of 5,480 ha, where its average share is 67.6%.

The supply of beech seeds is variable. Most seeds of forest tree species are processed and stored centrally in a specialized branch of the state forest enterprise Lesy SR (OZ Semenoles, Liptovský Hrádok). The optimum supply of beechnuts, estimated at 56,000 kg, was exceeded only after a mast year in 2006, otherwise there is a permanent deficit in beech seeds. No beechnuts are stored in the gene bank, which is also managed by OZ Semenoles.

During the last ten years, the amount of beech plants in forest nurseries oscillated around 40 millions seedlings and plants of different ages, out of which approximately 15 millions are used for reforestation. Most frequently, bareroot 2-year-old seedlings are used for planting (~4 million of plants), followed by 3-year-old seedlings (~3.5 millions of plants), containerized seedlings are less frequently used with beech. The amount of plants transplanted after one or two years (mostly bareroot) is approx. 6 million of plants.

RESEARCH ACTIVITIES

Provenance research of beech in Slovakia started in the 1960s by establishing a small initial trial with only three provenances (Balkovič 1965). Later, in 1972, a larger provenance experiment with 20 Slovak beech provenances was established on a site at School Forest Enterprise of the University College of Forestry and Wood Technology in Zvolen, which was later evaluated by Paule (1982). The assessments of both trials focused on height and diameter growth and its seasonal dynamics, as well as spring phenology.

Large-scale exploration of the genetic variation of European beechwoods employing allozyme markers started in the late 1980s in cooperation between the Faculty of Forestry in Zvolen and the team of B. Comps at the University of Bordeaux, later it continued by own activities supported by several successive grants of the Slovak Grant Agency for Science. Within these projects, almost 300 populations covering the whole distribution range of *Fagus orientalis* and the whole eastern half of the range of *F. sylvatica* were analyzed, demonstrating rangewide as well as regional trends and patterns of genetic diversity and differentiation in western-Eurasian beech taxa (Gömöry, Paule, Vyšný 2007).

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Reviewed

Contacts

Doc. Ing. Dušan Gömöry, DrSc., Prof. Ing. Ladislav Paule, PhD.
Technical University in Zvolen, Faculty of Forestry
T. G. Masaryka 24, SK-96053 Zvolen, Slovakia
e-mail: gomory@vsld.tuzvo.sk, paule@vsld.tuzvo.sk

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

Gregor Božič – Lado Kutnar – Mihej Urbančnič – Dušan Jurc – Andrej Kobler – Tine Grebenc – Hojka Kraigher

Slovenian Forestry Institute, Večna pot 2, 1000 Ljubljana, Slovenia

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.

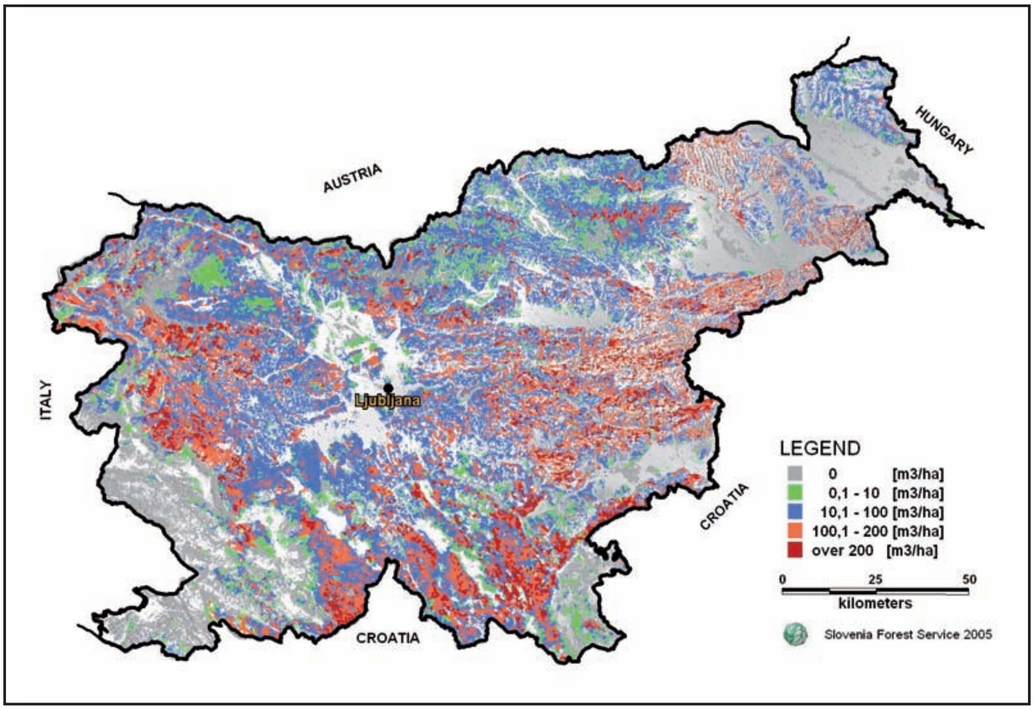

Fig. 1: Present distribution of beech (*Fagus sylvatica* L.) in Slovenia according to its share in growing stock (SFS, Pisek 2005)

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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Contacts

Dr. Gregor Božič
Slovenian Forestry Institute
Večna pot 2, 1000 Ljubljana, Slovenia
tel.: +386 1 200 78 21, fax: +386 1 257 35 89
e-mail: gregor.bozic@gozdis.si

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) FOREST AND GENETIC RESOURCES IN SPAIN

DIANA BARBA[1,3] – GUILLERMO MADRIGAL[1,3] – JOSE A. REQUE[2,3] – RICARDO ALÍA[1,3]

[1] Dpto de Sistemas y Recursos Forestales. INIA.Carr. Coruña km 7.5 28040 Madrid

[2] Dpto de Producción Vegetal. Universidad de Valladolid.

[3] Sustainable Forest Management Research Institute UVa-INIA [SFM-RI]

ABSTRACT

A summary of the current state of European beech (*Fagus sylvatica* L.) in Spain is provided, including information on the distribution, main typologies of beech forest, plant communities, site conditions, and forest management practices usually applied in Spain. Also include is information concerning genetic aspects of beech: regions of provenance, national register, and status for conservation of genetic resources.

Key words: European beech, *Fagus sylvatica*, haya (in Spanish), distribution, Spain, genetic resources

DISTRIBUTION OF EUROPEAN BEECH IN SPAIN

European beech covers 330,000 ha in Spain, where it reaches the south-western limit of the species distribution. European beech is located at medium and high altitudes in the mountains (above 1,000 meters), usually on north facing slopes. The distribution range covers the Cantabrian Mountain, Pyrenees and Iberian range, with scattered stands in the Coastal Catalonian Range, Beceite Mountains and Central Range (Fig. 1).

The altitudinal range of the species is variable depending on the geographical area where it is located (Tab. 1).

CHARACTERISTICS AND FOREST MANAGEMENT

Typology of beech forests

It is possible to distinguish four main types of beech forests in Spain depending on soil and climatic characteristics (SAINZ 1992):

1) The oligotrophous beech forests are distributed in continental and dry climate, with vegetation not very abundant and generally acidophilous. This type of forests reaches a lower density and height in comparison to the eutrophic beech forests.

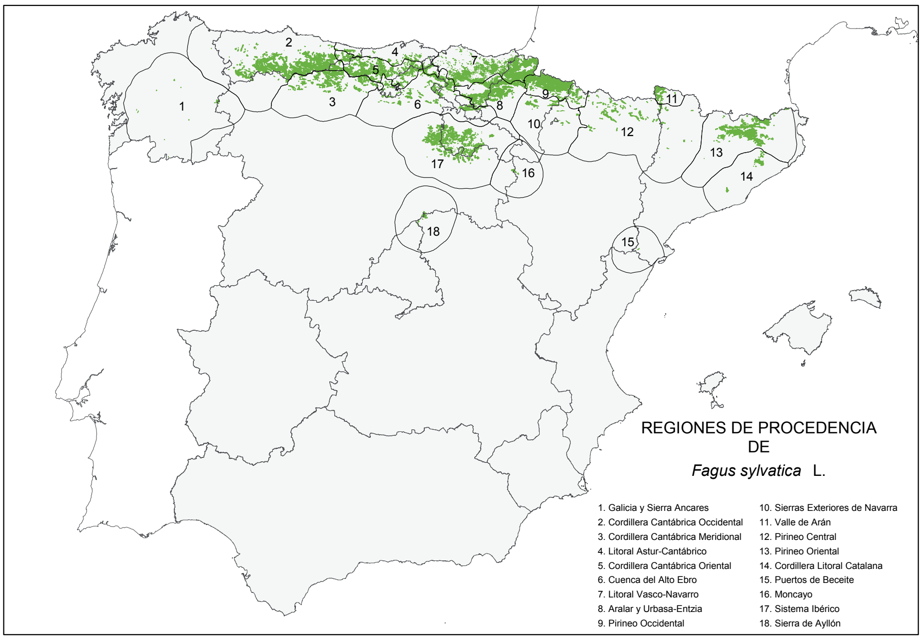

Fig. 1: Distribution of European beech in Spain (including the regions of provenance of the species)

Tab. 1: Altitudinal range and some ecological characteristics of European beech in Spain (Agundez et al. 1995)

Region of provenance	Altitude (m)	Annual rainfall (mm)	DI	Geological background
1. Caurel and Ancares	800 – 1,200	1,972	0	Siliceous
2. Western Cantabrian Range	800 – 1,600	1,713	0	Calcareous/Siliceous
3. Southern Cantabrian Range	1,200 – 1,600	1,367	0.5	Calcareous/Siliceous
4. Cantabrian/Asturias	600 – 1,000	1,824	0	Calcareous
5. Eastern Cantabrian Range	800 – 1,600	1,562	0	Calcareous/Siliceous
6. High Ebro River	800 – 1,200	771	1	Calcareous/Siliceous
7. Litoral Vasco-Navarro	600 – 1,000	1,860	0	Calcareous/Siliceous
8. Aralar and Urbasa-Enznia	800 – 1,200	1,380	0	Calcareous/Siliceous
9. Western Pyrenees	800 – 1,600	1,650	0	Calcareous/Siliceous
10. Navarra Mountains	800 – 1,200	898	0.2	Calcareous/Siliceous
11. Aran Valley	1,000 – 1,800	955	0	Siliceous
12. Central Pyrenees	1,200 – 1,600	1,134	0	Calcareous
13. Eastern Pyrenees	1,000 – 1,400	945	0	Calcareous
14. Montseny	1,000 – 1,400	906	0	Siliceous
15. Beceite Mountains	1,200	789	1.5	Calcareous
16. Moncayo Mountain	1,200 – 1,600	637	1.5	Siliceous
17. Iberian System	1,000 – 1,600	910	0	Siliceous
18. Ayllon Range	1,400 – 1 ,800	942	1.5	Siliceous

DI – Length of drought season (no. of months with Rainfall < 2*Temperature)

2) The eutrophic beech forests are found on deep soils which are rich in nutrients. They are located in flat areras or on low slopes, where this type of soil can develop under any type of substratum, being more frequent in lime soils. These beech forests are the most evolved ones being the habitats with a minor exploitation. In lower altitudes, they are mixed forests. When the climate has a major tendency towards a Mediterranean climate, the air and soil moisture is very low and the accompanying vegetation is very scarce. These zones represent the transition of the beech forests towards sub-Mediterranean type.

3) The sub-Mediterranean calcareous beech forests are located in drier zones, in environments of transition towards the Mediterranean climate, where the importance of the accompanying vegetation is very important, due to low moisture and high pH of the soil. The fraction of area covered by the canopy is lower than in the previous types, which allows the penetration of light and the enrichment of the accompanying vegetation (especially *Buxus sempervirens* and *Amelanchier ovalis*). In some of these sites, the beech forests have low density, and low height, under stony and steep areas.

4) And finally the beech-silver fir (*Abies alba*) forest, where the beech forms a continuous canopy that can reach 30 m in height, and the silver fir up to 35 m. It constitutes a very complex ecosystem, with high productivity and the maximum biological value of the forests of the temperate region. The structure of this type of forest is efficient in the use of water, light and soil resources. This type of formation is distributed principally between 1,000 and 1,700 meters of altitude, occupying valleys, on shady and humid hillsides.

Seed production and regeneration

In Spain seed production starts (commercially), when the trees are 60 – 80 years old, with a mean production of 3 – 10 kg/tree. Mast years occur every 4th – 6th year and are mainly dependent on weather; they can be detected for broad regions (Rodríguez-Guitián, Ferreiro 2005).

Natural regeneration in beech forests is affected by different ecological and management practices. Limitations to regeneration are related to late frost in the Mediterranean region, mortality during the summer due to drought, low levels of air humidity, high levels of radiation, browsing by cattle, and by the existence of ancient coppice forest structures with older and decaying trees with low seed production. These factors have a higher impact under Mediterranean conditions. On the contrary, in the Cantabrian Range production of 900 seed/m^2 have been reported. In this region densities of 100,000 – 200,000 seedlings/ha are observed, with a survival of 10% after 10 years, and the seedlings are usually found in the gaps in the canopy (Blanco et al. 1997).

Regulation and marketing of reproductive material

Commercialization of beech reproductive material is regulated by EU Directive 105/CE, and Spanish RD 289/2003. According to these norms, regions of provenance of the species were defined (Agundez et al. 1995, Alía et al. 2009), and at present basic material (seed sources and stands) from 16 out of the 18 regions of provenance has been included in the Spanish National Register, for production of identified (267 seed sources and stands) or selected (20 stands) forest reproductive material. Seed transfer recommendations have also been established (Martín, Diaz-Fernández, de Miguel 1998) to facilitate the use of forest reproductive material in Spain.

SILVICULTURE AND FOREST MANAGEMENT

In general, the beech forest in Spain has a medium to low productivity in comparison to other European countries. In natural forests, beech is usually found in even-aged stands (Madrigal 1992). In southern and mountainous areas, it is common to find uneven aged stands. Only in open stands it is possible to find uneven aged stands as a result of species mixture or stands of different ages.

Clearcuttings are not used nor recommended in Spain, due to the special ecological characteristics of the stands. The silvicultural treatment most frequently used (to favour natural regeneration) is the shelterwood system (Madrigal 1992). Rotation age in even-aged stands varies from 100 to 150 years, with a regeneration period of 20 to 30 years. In the Spanish beech forests, stands with age class structures close to uneven forests can often be found (Cirac 1992, Sánchez de Medina et al. 2001). Generally these types of structure have their origin in poor silvicultural management or high grading. A major part of the beech forests has traditionally been managed as coppice forests for fuel wood which explains the broad representation of even-aged structures in mountain forests. In this case, low thinning of the pole-woods is the most common treatment.

GROWTH AND PRODUCTION

In general, the growth and the production of the Spanish beech forests are lower than those from Continental Europe (Germany, NE France) and of Atlantic Europe (Great Britain, Belgium, W France). The mean value is 1.9 – 6.0 m^3/ha/year. In Spain, the less productive sites correspond to the Mediterranean beech forest type. Among the different tools for forest management of the beech forests in Spain, can be mentioned the density functions (Ibáñez 1989):

$$N = 10{,}000 * \exp\left[(-0{,}25+0{,}006\ SI) * (H0-3)\right]$$

where, N: no. of trees/ha; SI: site index in m, H0: top height in m.

There are also different yield tables for the Spanish beech forests (Ibáñez 1989, Madrigal 1992). Table 2 includes the value of the mean annual growth, defined for a rotation age of 120 years, and comparing different yield tables for different zones of Europe and the two most representative types of Spain.

Tab. 2: Mean annual increment (m^3/ha/year). Comparison among different site indexes, and for a rotation period of 120 years (Madrigal et al. 2008)

Navarra, Spain (Madrigal 1992)	La Rioja, Spain (Ibáñez 1989)	Great Britain	Continental Europe
-	-	9.4	9.4
-	-	7.5	7.5
6.1	-	5.8	-
5.0	4.8	-	5.4
3.9	3.6	4.0	-
2.8	2.3	-	3.4
1.9	1.2	-	1.7

PEST AND DISEASES

The effects of pollution in Spanish forests are lower than in other areas in Europe, although higher concentrations of some elements (Ca, Mg and S) or damages by ozone have been reported in some areas. Economically, the most important disease is the red heart, which depreciates the wood, being caused by the mycelia of some fungi (e. g. *Ungulina marginata*, *Ganoderma applanatum*, *Fomes connatus*) penetrating by wound. In timber already cut, the first two fungi can result in red colorations and putrefactions. The insect *Euproctis chrysorrhoea* consumes leaves, sprouts and flowers, the insect *Orchestes fagi* consumes the leaves.

EUROPEAN BEECH GENE POOL CONSERVATION

European beech is included as one of the priority species within the National Strategy for Forest Genetic Resources Conservation. Studies on the genetic variation of the species in Spain have shown large differences among populations for several traits of interest evaluated mainly in provenance tests. The results (Puertas 1992, Vega et al. 1992, Puertas, Traver, Olave 1995) show that no clear pattern of variation related to the origin is found in nursery or after 10 years in the field. Using isozymes (Comps et al. 1993) it is possible to distinguish three main groups of populations: Cantabrian Mountains, Pyrenees and an Iberian group. Genetic resources of European beech are not endangered in Spain as a whole, although some populations need some conservation activities (Goikoetxea, Agundez 2000) mainly due to new conditions derived from climatic change. Special attention needs to be paid to the correct use of forest reproductive material in afforestation and restoration programmes.

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Contacts

Dr. Ricardo Alía
Dpto de Sistemas y Recursos Forestales
INIA.Carr. Coruña km 7.5 28040 Madrid, Spain
Sustainable Forest Management Research Institute UVa-INIA [SFM-RI]
e-mail: dbarba@inia.es, alia@inia.es

CURRENT STATE OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN SWEDEN

Rolf Övergaard[1] – Lars-Göran Stener[2]

[1] Southern Swedish Forest Research Centre,
Swedish University of Agricultural Sciences, P. O. Box 49, S-230 53 Alnarp, Sweden
[2] Skogforsk, Ekebo 2250, S-268 90 Svalöv, Sweden

ABSTRACT

More than half of Sweden is covered with forests. Beech migrated from more southern areas of Europe approximately 4,000 years ago and is today located in the very southernmost part of the country. Beech has been used for several industrial purposes over recent centuries. A large part of the original beech forests was converted into spruce woodland in the 20th century due to economical reasons. As a result the "Hardwood Tree Forestry Act" was approved with the aim to protect beech and other hardwood forests. Today beech forests are primarily regenerated naturally and managed using an intensive thinning program. The rotation period generally varies from 80 to 140 years. It is primarily recommended to use regeneration material from seed orchards or from approved seed stands close to the cultivation location. Research is mainly focused on cost-effective management, but also assesses issues relating to biodiversity, recreation and vitality (indicated by crown defoliation and reduction of soil pH). Tree breeding work with beech is very extensive. Future climate change is predicted to increase yield within the species present distribution and may also lead to an increase of the beech forest area in Sweden.

Key words: European beech, *Fagus sylvatica* L., bok (in Swedish), Sweden, current state

GENERAL FOREST DATA OF SWEDEN

The major part of Sweden belongs to the boreal vegetation zone: in the southernmost part there is the nemoral zone and between, there is a transition zone called the boreo-nemoral or hemi-boreal vegetation zone (Ahti, Hämet-Ahti, Jalas 1968). The total land area of Sweden is 41.3 million hectares of which 23 million hectares (55%) is forest land. The total volume of growing stock is 3 billion m^3 distributed as follows – 38% Scots pine, 42% Norway spruce, 11% birch, 2% hardwoods, 3% other broadleaves and 3% dead trees. The mean growing stock per hectare is 132 m^3. Since the 1920s the growing stock in all of Sweden has increased by 80%, while in the southern part of Sweden it has more than doubled. The mean annual increment per hectare is 5.3 m^3 giving a total annual increment of 110 million m^3. The annual cut is around 80 million m^3 (Swedish National Forest Inventory 2008).

GENERAL INFORMATION ABOUT BEECH IN SWEDEN

The only beech species in Sweden is European beech (*Fagus sylvatica* L.) which was a late migrant to Sweden. It arrived from the south about 4 000 years ago, at the same time as Norway spruce migrated from the north. When humans started to settle in southern Sweden, about 2 500 years ago, beech was mostly concentrated in the outlands, since it competed with different crop species. In the 17th century beech and oak were the dominant tree species in the forests of southern Sweden. The sparse forests were at that time mostly used as pasture land for animals and for fuel-wood. In the 18th and 19th centuries the beech forests were exploited for industrial purposes. Production of potash from beech, used for making soap, glass and gunpowder, was profitable. There was also a great need for beech barrels, used for storing herring. Since the need for arable land was high among farmers, large areas of beech forests were cut down.

Beech was mostly found in areas belonging to the nobility, who could afford to keep forests for hunting purposes. That is the explanation why beech and other hardwood species are called "noble trees" (Eickhoff et al. 1995). During the 20th century many beech forests were converted into Norway spruce stands due to economical reasons and the beech forest area decreased dramatically (Swedish Environmental Protection Agency 1982). In 1974 this resulted in the Beech Forestry Act, with the purpose to preserve the beech forests by appropriate management and forbidding conversion into other tree species (SOU 1971:71). It was replaced in 1984 by the Hardwood Tree Forestry Act with the same purpose, but also including other "noble" tree species such as ash (*Fraxius excelsior*), elm (*Ulmus glabra*), hornbeam (*Carpinus betulus*), lime tree (*Tilia cordata*), maple (*Acer platanoides*), oak (*Quercus petraea, Q. robur*) and wild cherry (*Prunus avium*), (SOU 1992:76). An implication of the Hardwood Tree Forest Act is the prohibition on the conversion of low-yielding beech stands into stands consisting of other tree species potentially better suited to local site conditions. As a result there are many beech forests on sites which are inappropriate for beech production.

Today the primary product of beech is mostly used for floors, furniture and carpentry. Beech is also used for production of high quality paper. There is a big price differential for different log qualities. Large trunks (> 50 cm) receive the highest financial returns. Beech forests often have a long continuity and are important for biodiversity. Many red-listed lichens and insects can be found in old trees. These forests are also very popular for recreation (Eickhoff et al. 1995).

In Sweden beech grows up to around N 58° and up to 200 meter above sea level where the climate is maritime (Dahl 1998) (Fig. 1). Beech is often found on slopes and grows well on silt, calcareous moraines with good water supply. Mixtures with other broadleaved species are common, especially oak, ash and hornbeam, and in the northern parts of the distribution area also pine and spruce can be found. Beech covers an area of about 58,000 hectares defined as areas where more than 65% of the basal area is beech. The total volume is about 21 million m^3. Trees with diameters of at least 25 cm at 1.3 m above ground accounts for roughly 85% of the total volume. The annual increment is approximately 450,000 m^3 and the annual cut approximately 400,000 m^3 (Svensson 1995, The Swedish Forest Agency 2008).

The Swedish name for beech is "bok". Sometimes it is called "rödbok" (red beech) synonymous to the German "Rotbuche". To separate it from "avenbok", the Swedish name for hornbeam, beech is also sometimes named "vanlig bok" (common beech) (The Virtual Flora 2008).

SILVICULTURE AND RESEARCH

The common way to regenerate beech is by natural regeneration. Mast years appear every second or third year, but large variation occurs, depending on the weather conditions (Övergaard, Gemmel, Karlsson 2007). Soil preparation with the intention of exposing large areas of mineral soil should be done before the seed-fall. Seeds should then be covered with soil to protect them from seed-eating animals. During winter a heavy thinning is conducted, leaving just a sparse shelter of trees. This shelter is removed within a 10 – 20-year period by felling trees at 2 – 4 occasions in order to gradually increase the amount of light. Most often some retention trees are left for biodiversity reasons. Since the seedlings are abundant there is mostly no need for fencing. The management is intense in the young stands with at least two cleanings and frequent thinning. When the stand is older, the thinning intervals increase. The normal rotation period varies from 80 – 140 years, shorter on the more fertile sites, but also it depends on the quality of the stand, target diameter and timber prices.

Establishment of beech plantations is often both a costly and risky business. Fencing is necessary and herbicides are needed, at least on former arable land. Using shelter trees, like larch, birch or alder, may be one way to protect the plants from extreme temperatures during the first years of establishment. Problems one always has to consider in new plantations are those caused by rodents and mice.

Photo 1: A Swedish beech forest in the springtime (J. Norman)

Cheaper and better ways to regenerate beech forests are important research issues. Sowing and planting are two methods with a big potential to improve as well as naturally regeneration on poor, acid soils. Examples of questions where the Swedish research tries to find answers are: 1) is it possible to minimize the costs for pre-commercial thinning and to shorten the rotation period with retained stem quality? 2) Could the thinning program be more rational, but less intensive without any major effect on growth and stem quality? Tree-living lichens in close-to-nature managed forests, biodiversity in beech production forests, innovations and use of the beech wood, and recreation and health-aspects of hardwood forests are other research fields also in progress (The broadleaf program 2008).

GENETIC RESOURCES AND LEGISLATION

Climatic adaptation is of great importance for practical forestry. If the reforestation material is not climatically adapted to the plantation site, there will be a considerable risk of damage, reducing growth and deteriorating timber quality, with resultant economic losses. Climatic adaptation is therefore one of the key traits for a successful establishment of high quality beech forests.

Today there is a lack of good Swedish indigenous forest reproductive material of many broadleaved species, among others beech, which is compensated for by importing material mainly from Poland and Germany. However, our knowledge about north transfer effects on survival, vitality and growth is very limited, and might be crucial since the northern limit of natural distribution of many "noble hardwood" species is found in southern Sweden. Thus, it is recommended primarily to use material from seed orchards and as a second choice from approved seed stands close to the cultivation location.

The tree breeding work with beech is very extensive. Earlier activities, in the 1940s and 1950s, had resulted in two seed orchards. Both orchards contain untested plus-trees from southern Sweden. The plus-trees are now being tested in two progeny tests established in year 1998. To increase the knowledge of the transferring effects of different beech material within Europe, two series of international beech provenance trials (1993/95 and 1996/98) were established throughout Europe. One trial in each of the series was established in Sweden.

Only reproductive material from seed sources approved by each of the member countries of EU can be used commercially. In Sweden the application is examined by the Swedish Forest Agency. All approved seed sources in Sweden are registered in a national list which can be found on the web, http://www.svo.se/episerver4/templates/SNormalPage.aspx?id=11530. A seed source is approved when it is expected to produce forest stands with good prerequisites for good development and acceptable yield.

In Sweden, the approved basic material is divided into seed orchards, seed collection stands and seed collection areas. The different seed sources are listed separately and maps over the seed collection areas are provided. The seed collection stands are selected based on factors stipulated by the OECD. The seed collection areas consist of several stands of genetically more or less homogenous, mainly autochthonous forests. Mixing of seeds is only allowed within a region of provenance (Fig. 2). Each seed orchard and seed collection area is considered to be a region of provenance.

HEALTH STATE AND IMPACT OF CLIMATE CHANGE

Special surveys of crown health condition of beech and oak forests in southern Sweden were carried out in 1988, 1993 and 1999, showing increased crown defoliation in the beech stands. The soil condition of the subsurface mineral layer at a depth of 20 – 30 cm was highly acid with a pH value less than 4.2 in 86% of the forest stands surveyed (Andersson, Sonesson 2000).

The beech distribution area (Fig. 1) may be expanded in the future as an effect of climate change, since spring frost, which is an important limiting climatic factor, may be less frequent during flowering. Furthermore, an increased temperature will enhance the breaking-down process of organic material, liberating more nutrients in the soil. This will, together with high nitrogen deposition and longer growing season, promote yield and shorten the rotation period in the present beech distribution area (Berg et al. 2007).

Fig. 1: Beech distribution area

Fig 2: Regions of provenances

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Reviewed

Contacts

Dr. Rolf Övergaard
Southern Swedish Forest Research Centre
Swedish University of Agricultural Sciences
P. O. Box 49, S-230 53 Alnarp, Sweden
e-mail: rolf.overgaard@ess.slu.se

RESOURCES OF BEECH IN SWITZERLAND

Pascale Weber[1] – Andrea R. Pluess[2] – Urs Mühlethaler[3]

[1] Swiss Federal Research Institute WSL, Birmensdorf, Switzerland
[2] Swiss Federal Institute of Technology ETH, Zürich, Switzerland
[3] Bern University of applied Sciences SHL, Forest Ecology, Zollikofen, Switzerland

ABSTRACT

Beech is the second most important tree species in Switzerland, covering a wide range of the forested area with varying site conditions. In many forest communities of the sub-montane and lower montane range, beech is the dominant tree species; whereas from the lower to middle montane zone, beech becomes less important in comparison to spruce and fir. Beech accounts for around 17% of the Swiss total growing stock, which explains its importance for timber production. The rotation time for good quality timber is around 100 – 140 years. Since beech has been regenerated naturally for a long time, beech provenances for artificial regeneration have played only a marginal role so far. Nevertheless, in studies from the beginning of the 20th century, Swiss lowland provenances were compared to provenances from higher altitudes. Furthermore, in the Danish provenance trial, the two tested Swiss provenances Adliswil and Sihlwald were found to be of superior economic returns. However, Switzerland is not carrying out provenance trials under COST E52, although some Swiss provenances have been tested in other European countries. Recently, several projects have been undertaken studying environmental impacts on beech in Switzerland. Further investigations will be needed to understand better the impact of climatic changes and raising CO_2 on the distribution and growth of beech in Switzerland. At least model simulations suggest an altitudinal upward shift in beech distribution due to increasing drought, if beech does not have the plasticity or the evolutionary potential combined with the required time to adapt to future environmental conditions.

Key words: *Fagus sylvatica* L., distribution range, provenance, Switzerland

COUNTRY DATA

Area: 41,285 km^2

Elevation: between 193 m a. s. l. (Lago Maggiore) and 4,634 m a. s. l. (Dufourspitze)

Climate data: annual precipitation: between 521 mm (Ackersand Stalden) and 2,701 mm (Säntis)
annual mean temperature: between -7.9 °C (Jungfraujoch) and 11.6 °C (Lugano)

Climate is regionally diverse.

These climate data are norm values for the period 1961 – 1990 and are taken from the website of the Federal Office of Meteorology and Climatology MeteoSwiss.

Forest area: 12,746 km^2, 31% of total area (FOEN/WSL 2007)

ECOLOGY AND DISTRIBUTION OF BEECH IN SWITZERLAND

Beech is the second most important tree species in Switzerland. After spruce (*Picea abies* (L.) Karst.) (43.1%), beech covers 17.9% of the forest area (Brassel, Brändli 1999). However, in the colline and sub-montane forest zones of the Jura and the Pre-Alps, beech is the most important tree species with 35.1% and 31.7% of stems, respectively (Brändli 1998). The current presence of beech, as monitored in the National Forest Inventory sample plots, conforms approximately to its suggested natural distribution area (cf. Fig. 1). Beech is very shade tolerant, and therefore, under natural regeneration, occupies a large ecological niche. As illustrated in figure 1, forest associations with beech have the potential to cover Swiss forests to a large part; beech is present from the colline to the subalpine forest zones. However, in particular in the Swiss Plateau (Mittelland), it is assumed that the portion of beech (23.8% of stems) has been replaced substantially by spruce (37.1% of stems) due to former forest management (Brassel, Brändli 1999). Today, the Jura, the Swiss Plateau and the Pre-Alps are the most important regions for beech, with high density growing stock in the forest (Tab. 1).

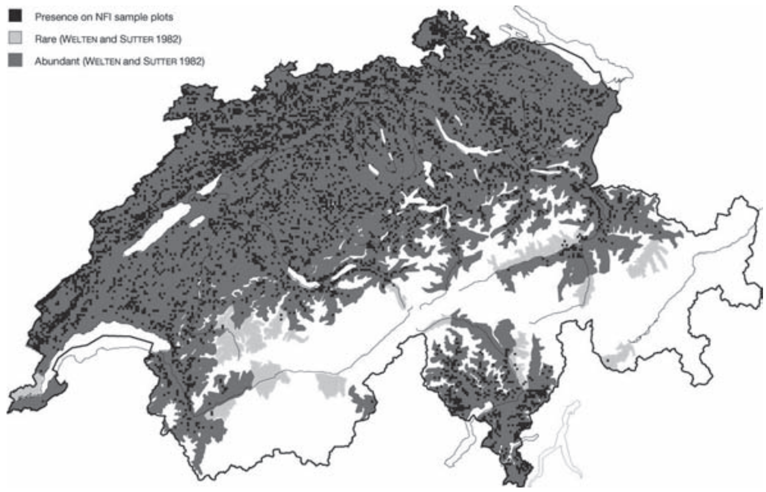

Fig. 1: Distribution map of beech according to Brändli (1998). Current distribution (presence on NFI sample plots) conforms more or less to natural distribution according to Welten, Sutter (1982).

Beech is present in more than half of the 71 forest associations that have been described for Switzerland (Ellenberg, Klötzli 1972, in the following abbreviated EK). In forest associations which are dominated by beech (EK units 1 – 17), the basal area of beech reaches an average of 30% of total forest basal area (Brassel, Brändli 1999). These forest associations belong to the sub-alliances *Luzulo-Fagion* (EK units 1 – 4 on acidic soils), *Eu-Fagion* (EK units 5 – 13 on nutrient-rich soils) and *Cephalanthero-Fagion* (EK units 14 – 17 on dry and nutrient-poor soils, often on steep slopes), and are mainly found in the sub-montane to lower montane forest zones (400 to 1,000 m a. s. l.). In forest associations of the silver fir-beech alliance (*Abieti-Fagion*) (EK units 18 – 21), beech makes up 18.3% of the basal area (Brassel, Brändli 1999). These forests are often found in the lower to middle montane zone (800 to 1,400 m a. s. l.). In the remaining broadleaved forest associations (EK units 22 – 45), beech accounts for 12.5% of total forest basal area (Brasse, Brändli 1999).

Tab. 1: Number of stems (DBH ≥ 12 cm), growing stock and timber use for beech according to the five production regions as estimated from the National Forest Inventory (NFI) (Brassel, Brändli 1999)

	Switzerland	Jura	Swiss Plateau	Pre-Alps	Alps	South of the Alps
Number of stems (1,000)	97,595 ± 2	29,148 ± 4	24,076 ± 4	19,425 ± 5	12,743 ± 8	12,202 ± 9
Portion per region (%)	100.0	29.9	24.7	19.9	13.0	12.5
Portion of all tree species	18.3	32.0	23.8	17.8	7.8	18.1
Growing stock (1,000 m^3)	70,770 ± 2	22,791 ± 4	22,068 ± 4	14,861 ± 6	6,674 ± 8	4,376 ± 10
Portion per region (%)	100.0	32.2	31.2	21.0	9.4	6.2
Portion of all tree species (%)	17.1	31.5	22.3	15.0	5.9	14.5
Timber use (1,000 m^3) Time span: NFI1-NFI2 = 10 yrs	11,521	3,240	5,149	1,922	825	385

GENETIC RESOURCES OF BEECH IN SWITZERLAND

At the beginning of the postglacial period, beech most likely expanded to Switzerland from the Slovenian refuge (Magri et al. 2006). The expansion along the North-Alpine forelands started before the beginning of large-scale Neolithic human activities and therefore, was mainly driven by climatic changes (Tinner, Lotter 2006).

Most of the Swiss forest (around 80%) is regenerated naturally (Brassel, Brändli 1999) and artificial regeneration has ceased continually since 1965. Regarding beech, the portion of natural regeneration is near 100%, due to optimal regenerating conditions for this tree species over a wide area and the difficulties to obtain high quality timber by regenerating beech artificially. This high amount of natural regeneration allows for the conservation of the genetic diversity of native tree species in Switzerland (Bonfils, Rotach 2003). In the case of plantations, national regulations exist for seed collection and utilization (Art. 21), as well as for import and export of seeds (Art. 22) (Verordnung über den Wald). All tree species under these regulations are listed (Anhang 1: Verordnung über forstliches Vermehrungsgut). Seeds are collected and forest genetic resources are handled according to the OECD regulations. For this purpose, Switzerland is divided into 14 provenance regions, which belong to the five main production regions corresponding to geographical regions (Fig. 2). In case of artificial regeneration, foresters are obliged to use the closest available provenance.

Although some Swiss provenances have been tested in different provenance trials in other European countries, no recent provenance trials have been undertaken within Switzerland. Some of the current provenance trials of COST E52 include the Swiss provenances Oberwil and Aarberg (Wühlisch et al. 2008). In an earlier Danish provenance trial, the provenances Sihlwald (cf. Fig. 3) and Adlisberg were tested among other European provenances. They were found to be superior in economic returns due to a higher frequency of trees with straight stems and long boles (Hansen, Jorgensen, Stoltze 2003, Wühlisch 2005). Burger (1948) reported about early provenance tests with different beech provenances in Switzerland, e. g. differences in height growth between provenances of lower and higher altitudes. In these studies, it was shown that fast growing provenances from the lowlands might experience problems at higher altitudes. In recent germination tests at the Swiss Federal Institute WSL the germination capacity of different Swiss beech provenances ranged usually between 50 – 80% (personal communication Anton Burkart).

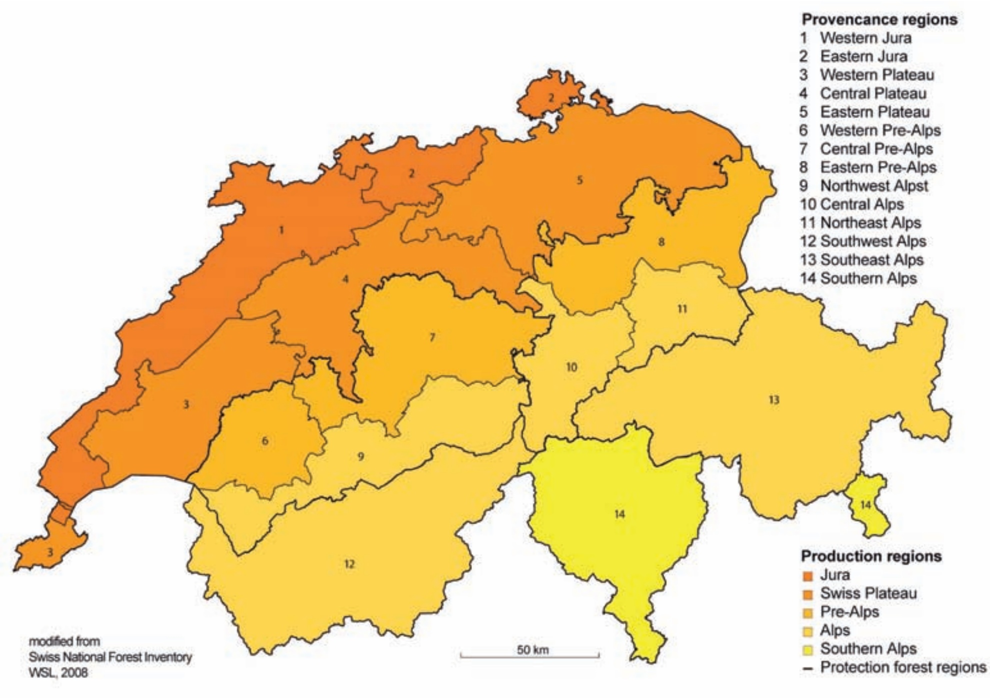

Fig. 2: Map of the Swiss provenance and production regions

FOREST MANAGEMENT AND TIMBER HARVESTING

Due to its high amount of growing stock (17.1% across Switzerland, cf. Tab. 1), beech plays an important role in timber production, in particular in the beech regions Jura (324,000 m^3/yr) and Swiss Plateau (514,900 m^3/yr) (Tab. 1).

Most of the beech trees grow in even-structured high forest (73%, cf. Brändli 1998). In accordance with earlier studies by Leibundgut, Auer, Wieland (1971), Zingg et Ramp (2004) found that thinning in such forests improved stem quality of beech, but also led to a slightly reduced total production. In another study, Zingg (1996) recorded that, after 1950, the basal area increment of pure beech stands moved clearly above the values that were expected from yield tables. This deviation may be partly induced by a changing climate, nitrogen deposition or CO_2-fertilization. However, the complex reasons are still under investigation. Noteworthy is the speciality "plenter forest" – a single-tree management form, leading to a mixture of trees of different sizes, ages and heights – which is common in the Jura and the Emmental. In Switzerland this silvicultural technique is particularly abundant in the silver fir-beech forest in the montane forest belt. Alltogether, around 3% of beech trees grow in plenter forests (Brändli 1998). Along with this practice, *Abies alba* and *Picea abies* trees are often fostered at costs of *Fagus sylvatica* trees (Schütz 2001).

The rotation time for growing high quality timber depends on the prevailing site conditions, but often is between 100 and 140 years. On the other hand, fuelwood, which is optimized for quantity, may be produced within a shorter time. Overall, one third of the Swiss beech forests exhibit a stand age of 80 – 120 years (Brändli 1998). Around 2% of the stands are estimated to be older than 160 years, i. e. the amount of ecologically important old growth forest is comparably low.

Within the European forestry community, it is well known that high quality timber of beech can be found in many places in Switzerland. It is not rare to identify tree heights of 40 m with straight stems up to 20 m (Fig. 3) (cf. Hansen, Jorgensen, Stoltze 2003). However, although the physical

Fig. 3: Beech stand in the forest reserve "Sihlwald" (Picture: P. Weber)

appearance is excellent, red heartwood is abundant. A few studies have been conducted on the occurrence and economic implications of red heartwood in beech in Switzerland (cf. Pöhler, Klingner, Künniger 2004). Red heartwood is developed facultatively and is difficult to diagnose in standing trees. In 2002, a survey of the cantonal forestry departments resulted in approximately 50% of beech timber being affected by red heartwood, leading to a decrease of sometimes up to 50% in value. However, Pöhler, Klingner, Künniger (2004) demonstrated that the mechanical and technological properties of beech wood are not reduced due to red heartwood.

BEECH UNDER CHANGING ENVIRONMENTAL FACTORS

The effect of the increasing atmospheric CO_2 concentration on beech growth was tested in Switzerland on saplings (e. g. Spinnler, Egli, Körner 2003) and adult trees (e. g. Asshoff, Zotz, Körner 2006). Spinnler, Egli, Körner (2003) demonstrated that growth of saplings under elevated atmospheric CO_2 depends on the soil type with increased growth on calcareous and decreased growth on acidic soils. Growth responses of the four tested provenances were highly variable (Spinnler, Egli, Körner 2003) but there was no indication that one of the provenances would be superior under elevated CO_2 conditions. If approximately 100-year old beech trees are exposed to elevated CO_2, stem basal area increased in two of four experimental years (Asshoff, Zotz, Körner 2006). However, Asshoff et al. (2006) stress the point that only three beech trees were exposed to the elevated CO_2 treatment which is not enough to make the case for the whole species. In the same experimental setup Leuzinger et al. (2005) found evidence for a CO_2 driven mitigation during the very hot and dry summer of 2003. Future CO_2 concentration might thus counteract damage by increased temperature and drought. Under ambient CO_2 conditions during the exceptional year 2003, several beech trees throughout Switzerland shed their leaves earlier (Zingg, Brang 2003). However, it is difficult to tell whether this was already an indication that beech locally comes to its physiological limit, or whether beech will be able to adapt within its genetic/phenotypic flexibility to more frequent drought periods.

According to forest model simulations for Switzerland under climate change (Zimmermann et al. 2006), beech is suggested to retreat to higher altitudes and to lose its dominance in the sub-montane and lower montane zone where more drought tolerant species are expected to come to dominance. Currently, it is under investigation, how Mediterranean beech provenances germinate and grow in Switzerland (COST-Action FP07032, Mühlethaler et al.) to potentially introduce such provenances to our natural beech stands.

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Reviewed

Contact

Dr. Pascale Weber
Swiss Federal Research Institute WSL
Birmensdorf, Switzerland
e-mail: pascale.weber@wsl.ch

CURRENT STATE OF ORIENTAL BEECH (*FAGUS ORIENTALIS* LIPSKY) GENETIC RESOURCES CONSERVATION IN TURKEY

GAYE EREN KANDEMIR

Turkish Ministry of Environment and Forestry, Forest Tree Seeds and Tree Breeding Research Directorate, Department of Biotechnology, Gazi Tesisleri, 06560 Ankara, Turkey

ABSTRACT

The purpose of the following paper is to describe the current state of oriental beech (*Fagus orientalis* LIPSKY) in Turkey. It provides information on the distribution of the species, together with details of breeding activities and related seed transfer zones. It also provides information on the conditions of forest stands with associated plant communities. Oriental beech natural distribution in Turkey is 1.7 million ha and it is the main broadleaved species. There are almost 7,000 ha of *in situ* conservation areas of oriental beech in the country.

Key words: oriental beech (*Fagus orientalis* LIPSKY), kayin (in Turkish), distribution, gene-pool current state, Turkey, forestry research

ORIENTAL BEECH DISTRIBUTION IN TURKEY

Forest land covers 21,188,747 ha in Turkey out of a total area of 77,846,000 ha. 10,621,221 ha of forests are productive while 10,567,526 ha are degraded. The composition of forest tree species is mainly represented by conifers (12,772,654 ha). Deciduous forests cover 8,416,093 ha area and conifers-deciduous mixed forests are also included in these figures and account for 2,204,267 ha with the remainder made up of coppice and high forest (http://www.ogm.gov.tr/bilgi/orman_01.htm).

Turkey has two species of beech, oriental beech (*Fagus orientalis* LIPSKY) and European beech (*Fagus sylvatica* L.). The main beech species is oriental beech while European beech has limited distribution. European beech is distributed in Kırklareli-Demirköy, Çanakkale-Bayramiç, Edremit-Kazdağları and Kütahya-Simav area in Turkey (DAVIS 1982) (Fig. 1).

Oaks (6.4 million ha), consisting of 18 different oak species, are predominant in species composition. Pines are the next most important group with Turkish red pine (*Pinus brutia*) covering an area of 5.4 million ha while European black pine (*Pinus nigra*) covers an area of 4.2 million ha. Beech covers an area of 1.7 million ha in Turkey (Anonymous 2006). In the past, most beech stands were felled and replaced generally by conifers and in some cases converted to agricultural lands, especially for the production of tea plantations and for hazelnut production.

Oriental beech is distributed in the northern part of Turkey mainly on the slopes of the mountains overlooking the Black Sea. The optimal spreading areas of oriental beech are the lower slopes of the mountains of Black Sea Region and in the Marmara Region. Dense oriental beech forests in these regions reach down to the Murat Mountain in the inner Aegian region. In addition to these dense oriental beech forests there are small marginal populations in central Anatolia and in the southern part of Turkey. The oriental beech forests in the southern part of Turkey, particularly in the Amanos Mountains and Adana-Maraş districts, are relic populations. In contrast, European beech which has its main distribution in the European subatlantic climatic regions has a very limited distribution in Turkey. There are also some scattered populations in the Kaz Mountains and in Kütahya-Simav.

Optimal growing conditions for oriental beech are found at the altitude ranging from 700 m to 1,200 m. As the thermal requirement for the species is higher than for fir and spruce, it cannot grow at high altitudes but there are some exceptions. The altitudinal minimum for oriental beech populations is in the locality of Sinop-Bektaşağa from sea level to 30 m along the Black Sea coast. The altitudinal maximum of oriental beech is recorded in the eastern Black Sea Region in the location of Artvin-Yusufeli at 2,100 m. From an economic viewpoint, oriental beech is the most important broadleaved species in Turkey.

Proximity to the sea and climate have positive effects on length of beech vegetation period. Therefore the relatively more temperate, moist and high precipitation areas, as found in parts of the Black Sea region such as in parts of the Marmara Region, are the most suitable lands for growing beech.

The wood of oriental beech has a reddish white colour and reddish brown heartwood formation occurs when the trees reach the age of 80 to 100 years. Beech wood is classified as of medium density (0.66 $g.cm^{-3}$). As a hardwood species, the wood is heavy, hard, strong and highly resistant to shock. It is also suitable for steam bending. Nevertheless, the main use of oriental beech wood is for fuel, but there are other uses such as particleboard, furniture, flooring veneer, mining poles (props), railway sleepers and the paper industry (Kandemir, Kaya 2009). According to research on the wood quality of beech from samples which were taken as cross sections from trees grown at different altitudes,

Photo 1: Oriental beech forest compete with *Rhododendron ponticum* (Kandemir 2008)

the widest annual rings and the highest number of trachea were found in samples from the optimal growth area (Kahvecí, Huss 2009).

Dense vegetation cover, mainly *Rhododendron ponticum* L. and *Rhododendron flaum* Don., in oriental beech growing sites, causes problems for natural regeneration. Other species which have negative effects on the natural regeneration of beech forests are *Ilex aquifolium* L., *Vaccinium arctostaphylos* L., *Prunus laurocerasus*, blackberry (Kahveci, Huss 2009). Other factors which prevent regeneration in oriental beech forests in Turkey are the predators of seed such as rodents and infrequent seed formation.

In the past, especially up to the 1980s, the wood quality of beech was considered to be poorer than that of conifers and therefore degraded and coppiced forests of beech were replaced by conifers (Kahveci, Huss 2009).

In the past, oriental beech forest in Turkey suffered from the effect of improper silvicultural treatments and other anthropogenic factors (Çalikoğlu, Kavgaci 2001). These affected the quality of oriental beech timber and the genetic base of beech stands. The regeneration with seedlings resulted in genetic recombination and the provision of a larger genetic base needed for adaptation to existing or changing environmental conditions. Thus, regeneration of oriental beech forests in such places should be gradually replaced through seedlings rather than coppicing (Kandemir, Kaya 2009).

Photo 2: An example of stem sprouting regeneration of oriental beech in Sinop (Black Sea Region of Turkey) (Kandemir 2008)

CHARACTERISTICS AND FOREST MANAGEMENT

Geographically, Turkey is mainly divided into three phytogeographical regions and the diversity of the species is depending on this division. These floristic regions are:

a) The Euro-Siberian Floristic Region: Black Sea and Marmara Geographical regions are Euro-Siberian phytogeographical regions with vegetation types of broadleaved deciduous forests, humid and sub-humid forests, dry forests and pseudomaquis and maquis. In the eastern Black Sea region, oriental beech is in mixture with *Picea orientalis*, *Alnus barbata*, *Castanea sativa* and *Abies nordmanniana*. In the mid section of Black Sea region, productive beech forests are found together with *Castanea sativa*, *Alnus barbata*, *Prunus* spp., *Carpinus betulus* and *Rhododendron flavum*. At the low elevations of the western Black Sea region, oriental beech is in mixture with *Tilia* spp., *Pinus brutia*, *Laurus*, *Castanea sativa* and *Carpinus betulus* while *Pinus sylvestris*, *Abies bornmulleriana*, *Rhododendron flavum*, *Taxus baccata*, *Quercus* spp., *Prunus* spp., *Acer* spp., *Cornus* spp. generate the species mixture with *F. orientalis* at higher elevations. In the Marmara region, oriental beech *Castanea sativa*, *Carpinus betulus* and *Quercus* spp. are a typical species of low elevations and *Abies* spp., *F. orientalis*, *Pinus nigra* are characteristic at high elevations.

b) Mediterranean (Aegean-Mediterranean) Floristic Region: This region occupies the northern coasts of the Marmara Sea, all of Mediterranean region and sub-region of the Aegean Geographical region. Mediterranean mountain forests are diverse. In the Mediterranean belts (800 – 1,200 m) oriental beech and hornbeam are present as a small group in the Amanos Mountains.

c) Irano-Turanian Floristic Region: This region covers all central, eastern and south eastern Anatolia. Dry oak and Scots pine forests are the main vegetation types of this floristic region. There are some small patchy oriental beech groups in this floristic region (Zencirci et al. 1998).

Oriental beech is the only broadleaved tree in Turkey which has been part of the National Breeding Program. The main purpose of oriental beech breeding is to enhance the height and volume growth, together with maintaining the quality of stem. The natural distribution area of oriental beech has been divided geographically into two main breeding zones based on the climatic and ecological conditions (Atalay 1992). The border between the Black Sea coastal and inland regions is along the first coastal mountains parallel to the Black Sea, where the climate changes slightly from maritime towards continental. The borderline follows township administration boundaries, except for Taşova which is divided by the Kelkit River.

Tab. 1: Oriental beech breeding zones in Turkey (Koski, Antola 1993), Fig. 2

Breeding zones (Sub zones)	Region	Altitude (m a. s. l.)
1 (1.2)	Black Sea Region Coast (mid zone)	500 – 900
1 (1.3)	Black Sea Region Coast (High elevation zone)	901 – 1,300
2 (2.3)	Black Sea Region Inland (High elevation zone)	1,100 – 1,500
3 (3.1)	Marmara Region * (low elevation zone)	0 – 500
3 (3.2)	Marmara Region * (mid zone)	501 – 1,000
3 (3.3)	Marmara Region * (high elevation zone)	1,001 – 1,500
4 (4.1)	Amanos Mountains Region (gene conservation area) (high elevation zone)	1,100 – 1,500

* Thracia is not in the breeding zones, it is only for seed production.

Under these two main breeding zones there are sub-breeding zones and one seed production zone (Tab. 1).

In addition to these breeding zones there are also seed transfer zones for oriental beech in Turkey (Tab. 2, Fig. 2). There are three seed transfer zones and one gene conservation area which are delaminated by geographic, geomorphologic and climatic conditions (Atalay 1992).

Tab. 2: Seed transfer zones and sub zones of oriental beech in Turkey

Seed transfer zones and subzones	Regions
1	***BLACK SEA REGION***
1.1	Camili Basin
1.2	Göktaş-Muratlı Çoruh Basin
1.3	Sarp-Ordu
1.4	Ordu-Sinop
1.5	Sinop-Ereğli
1.6	Ereğli-Akçakoca
1.7	Çatalca-Kocaeli
1.8	Samanlı Mountains
1.9	Istranca Mountains Eastern site
1.10	Istranca Mountains Mid and Western site
1.11	Istranca Mountains Southern site
2	***BACKWARD REGION OF BLACK SEA***
2.1	Ortaköy and Dökmeci Basin
2.2	Artvin Region
2.3	Yukarı Altıparmak (Barhal) Basin
2.4	Orta Harşit Basin
2.5	Koyulhisar-Taşova, Northern site of Kelkit River
2.6	Southern side of Kelkit River
2.7	Ladik-Boyabat Basin
2.8	Kastamonu Basin
2.9	Araç River Basin (Karabük-Araç)
2.10	Dokurcun Basin
3	***MARMARA REGION***
3.1	Samanlı Mountains western site
3.2	Katırlı-Avdan Mountains northern site
3.3	Southern Marmara (Kapıdağ-Karadağ)
3.4	Uludağ-Domaniç Mountains
3.5	Çatal-Ömeraltı Mountains
3.6	Biga-Gönen
3.7	Kazdağı
3.8	Akdağ (Dursunbey)
3.9	Demirci-Şaphane-Murat Mountains (North-East Aegean Site)
4	***GENE CONSERVATION REGION***

Wide distribution of oriental beech in Turkey results in the creation of seed transfer zones to facilitate seed production and afforestation. Beech forests have different growing regions according to site quality, productivity and floristic composition. Therefore all ecological properties which affect the growth of beech are considered when establishing these seed transfer zones. Oriental beech forests are divided into four main seed transfer zones and 30 subzones which have been established taking into consideration precipitation, temperature, aspect, altitude and the floristic compositions of the regions (Atalay 1992).

Oriental beech is important economically. Average prices of the third class beech round wood in Turkey was approximately 135 Turkish Liras (TL)/m^3 (83 €/m^3) in 2005, 138 TL/m^3 (70 €/m^3) (http://www.ogm.gov.tr/ip1/index) in 2008, 165 TL (84 €/m^3) in 2010.

GENETIC CONSERVATION *IN SITU* AND *EX SITU*

Gene pool conservation of oriental beech in Turkey is mainly through *in situ* conservation. These are seed stands, gene conservation areas and national parks. In Turkey there are 23 gene conservation forests of oriental beech. The area of these gene conservation forests is 3,042.9 ha. There are 28 seed stands which cover 3,439.6 ha.

The most important *ex situ* conservation activities are grafting and establishment of clonal archives and seed orchards. Although there are many seed orchards with conifers and some with broadleaves such as *Liquidambar orientalis* and *Sorbus torminalis* in Turkey, there is no seed orchard with oriental beech. There are other conservation programs in other locations such as National Parks and Nature Conservation areas where oriental beech stands can be used as seed sources if allowed. Seeds collected from these areas can be used for reforestation according to the seed transfer zones.

Fig. 1: Natural distribution of oriental beech in Turkey

Conservation of oriental beech genetic resources is done mainly by setting up seed stands and gene conservation forests through *in situ* programs. Seeds collected from these areas can be used for reforestation according to the seed transfer zones. In reforestation programs, although oriental beech is used, the minimum requirement is that the origin of the reproductive material is known and its adaptive characters appropriate for the ecological conditions at the regeneration site. For this purpose, the guidelines for oriental beech seed transfer zones (Atalay 1992) based on climate, soil and bedrock characteristics have been used until a more ecologically and genetically sound seed transfer set of guidelines is prepared.

The establishment of *ex situ* conservation plantations of oriental beech may be necessary in order to conserve the genetic variation of threatened populations that cannot be maintained at the original site such as relic populations. The objective will be to establish a new population that maintains as much as possible of the original genetic variability and allows for long-term adaptation to the local conditions at the new planting site.

FOREST RESEARCH

Research on oriental beech in Turkey is generally concentrated on regeneration and afforestation studies. There is only limited research on the genetics of oriental beech. Because of the requirement of genetic diversity of oriental beech forests a couple of projects has started, supported by the Turkish Ministry of Environment and Forestry and The Scientific and Technological Research Council of Turkey. One of these projects contains 33 populations with representatives from all seed transfer

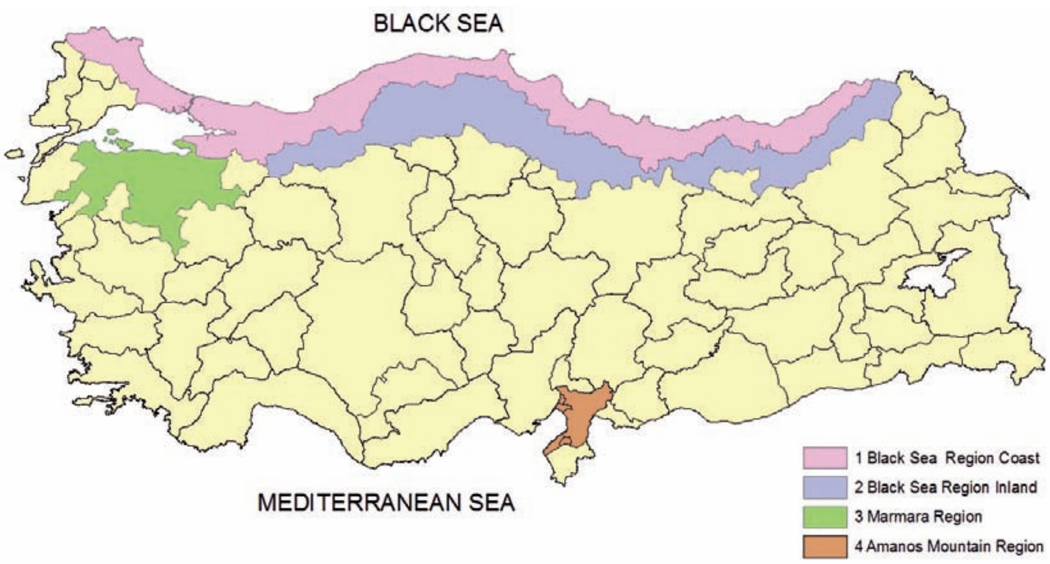

Fig. 2: Breeding zones of oriental beech in Turkey

zones and marginal populations and this will provide genetic reference data for effective gene conservation activities concerning oriental beech in the future.

There are also research projects on provenance, seedling quality and other characteristics. Other studies include adaptive traits and information on height growth characteristics of various subpopulations under various site conditions. These research plots are of a long-term character, and will continue to provide results with increasing age.

In addition, in the Forestry Faculties of Universities the main purpose of a number of ongoing projects is to study the genetic background, seeds germination-dormancy properties, adaptive properties of seedlings and is mainly directed to the protection and reproduction of oriental beech gene resources. These studies will contribute to creating conditions for preserving and increasing proportion of this species in the forest stands.

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Reviewed

Contact

Dr. Gaye Eren Kandemir
Turkish Ministry of Environment and Forestry
Forest Tree Seeds and Tree Breeding Research Directorate
Dept. of Biotechnology, Gazi Tesisleri, 3'nolu Bina, 06560 Ankara, Turkey
tel.: (+90312)2126519/128
e-mail: gayeeren@gmail.com

EUROPEAN BEECH (*FAGUS SYLVATICA* L.) FORESTS IN THE UKRAINE

HRYHORIY KRYNYTSKYY[1] – VASYL PARPAN[2] – ROMAN KUZIV[1]

[1] Ukrainian National Forestry University, Gen. Chuprynky Str. 103, 79057 Lviv, Ukraine
[2] Ukrainian Research Institute of Mountain Silviculture
Grushevskogo Str. 31, 79000 Ivano-Frankivsk, Ukraine

ABSTRACT

Information on the distribution of European beech as a forest resource in the Ukraine is presented. The significance of this tree species is discussed, and information on beech virgin forests is also presented. The principal felling methods for beech forests are characterized. Fruiting data and natural reproduction of European beech are outlined. In the Ukraine, European beech occurs naturally only in the Carpathians (up to 1,400 m above the sea level), Sub-Carpathians and at higher elevations in the Volyn-Podillya highlands. The area of beech forests is 503,000 ha, of which beech virgin forests are around 39,000 ha. In the Ukraine beech is characterized by high productivity and an uneven age structure. The beech stands are generally managed under the shelterwood silvicultural system (on 90 – 94% of the area) while much less selective fellings are used (less than 5%) and clearcuts (1.5 – 2%).

Key words: European beech (*Fagus sylvatica* L.), бук (in Ukrainian), Ukraine, distribution, forest resources, methods of principal felling systems, fruitage, natural reproduction

EUROPEAN BEECH DISTRIBUTION IN UKRAINE

In the Ukraine, European beech (*Fagus sylvatica* L.) occurs naturally only in the Carpathians, Sub-Carpathians and at higher elevations in the Volyn-Podillya highlands (Fig. 1). The modern border of the continuous distribution of European beech is almost identical with the border of the Carpathian sub-mountains. At the north-east of this border, beech has only isolated distribution. The border of this isolated distribution of European beech follows approximately the line Volodymyr-Volynskyy, Kremenets, Sataniv, Hermakivka, Kamyanets-Podilskyy (MOLOTKOV 1966). Beyond this borderline, only individual trees or small groups of European beech are reported close to the village Goryngrad, situated 40 km east of Rivne (MOLOTKOV 1966), in the Novomalyn forest of the State Enterprise "Ostrog forestry management" (south of Rivne) (IVCHENKO, VOYTYUK 1978), north-east of Kremenetsk mountains in the Volyn forest of the State Enterprise "Kremenets forestry management" (MELNYK, KORINKO 2005), close to the town Starokostyantynova in the Khmelnytsk area (MELNYK, KORINKO 2005, POSTRYGAN 1957, BILOUS 1962b), near Kuzminsk in the Vyshnivetske forest of the State Enterprise "Yarmolynets forestry management", near Verbovets in the Grytsiv forest (Khmelnytsk area), close to the village of Stanislavchyk in the Khmelnytsk region and the village of Shenderivka

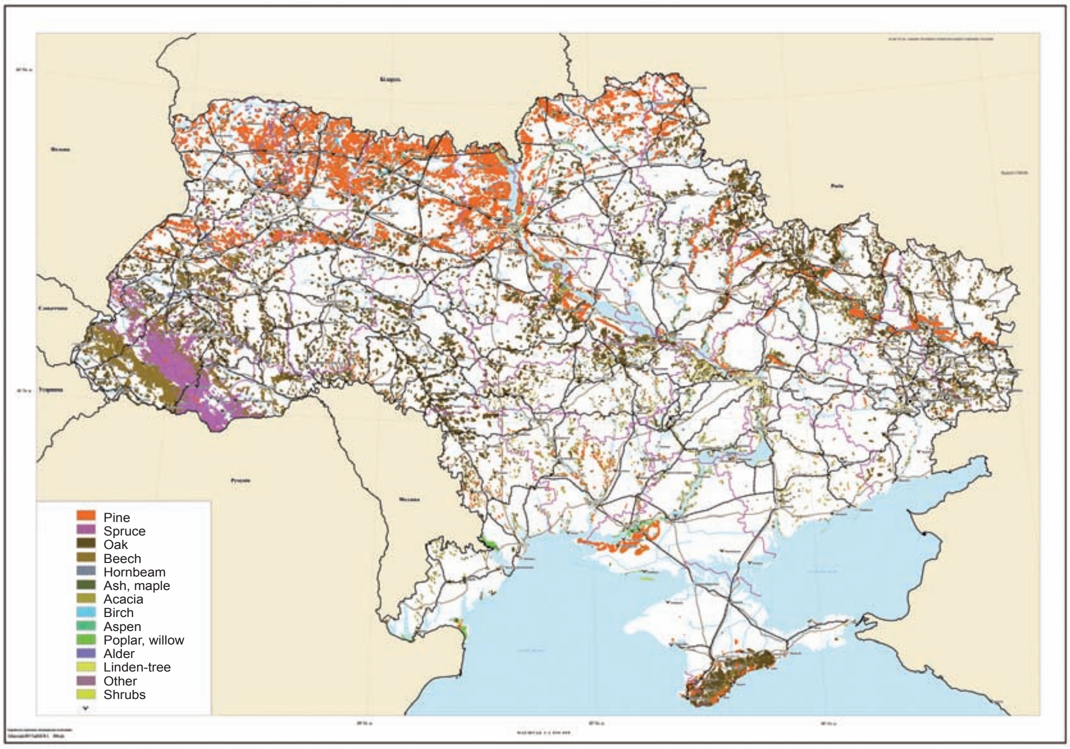

Fig. 1: Distribution map of European beech and other species in Ukraine

Source: developed by Ukrainian Research Institute of Forestry and Forest Melioration named after G. N. Vysotsky (URIFFM)

in the Mogyliv-Podilskyy region of the Vinnytsya area (Bilous 1962b, Zaveruha, Ivchenko 1986), close to the town of Murovani Kurylivtsi and the villages Berezove in the Murovane-Kyrylivetskyy region of the Vinnytsya area (Melnyk, Korinko 2005, Zaveruha, Ivchenko 1986).

Beyond the north-east border of the distribution range in the vicinity of Cherkassy, Zhytomyr, Vinnytsya or Kyiv, European beech is partly present in artificially established stands, and despite a dry continental climate, it grows rather well (Bilous 1962a, c, 1995).

In the Ukraine, the largest beech forest massifs are situated on the southwestern side of the Carpathian mountains, within an altitudinal span of 500 to 1,200 m, characterized by sufficient precipitations (700 to 1,200 mm per year), high air humidity, and mild temperature without major fluctuations in the winter (Shelyag-Sosonko, Andriyenko 1985). Pure beech forests occur in the altitudinal belt between 600 and 800 (900) m a. s. l. This is the ecologically optimal altitudinal range, where beech almost completely out-competes all other species (Molotkov 1966).

In the Carpathians European beech plays an essential role in forming tree stands up to 1,300 to 1,350 m, and solitary beech trees reach elevations up to 1,400 – 1,450 m, for example at the mountain Goverla (Molotkov 1966).

On the eastern limit, beech occurs over 280 m above sea level (Melnyk, Korinko 2005). Here the climate and ecological conditions for European beech are very specific. Temperature fluctuations, particularly the winter minimum temperature, and a lower air humidity negatively influence European beech and limit its range (Molotkov 1966, Pogrebnyak 1968).

FOREST RESOURCES OF EUROPEAN BEECH IN UKRAINE

Stands with the prevalence of European beech in the Ukraine represent almost 7.4% of the forest area (Parpan, Stoyko 1995). The area of beech stands managed by the State Forestry Committee of the Ukraine in six western regions with an almost continuous natural distribution of European beech is 502,889 ha, out of which 53.3% is situated in the Zakarpattya, 18.1% in the Lviv region, 17.5% in the Ivano-Frankivsk region, 8.3% in the Chernivtsi region, and only 2.6% and 0.2% in the Ternopil and Khmelnytsk regions, respectively.

In the mountains, 78.3% of beech forests grow and 21.7% in the highlands. In the Zakarpattya region, mountain conditions represent 99.7% of the area of beech forests, whereas in the Ivano-Frankivsk, Lviv and Chernivtsi regions these shares are 81.4%, 49.5% and 23.3%, respectively.

In the mountains, 9.7% of beech forests grow on very steep slopes (over 30° on south slopes and over 35° on north slopes), 47.9% slopes are steep (21 – 30° on south slopes and 21 – 35° on north slopes), and 35.0% are moderate (11 – 20°). Very steep and steep slopes are most frequent in the Zakarpattya region (11.8% and 52.7%, respectively), which shows the important soil protection, water protection and water regulating function of beech forests in this region.

Optimum, and nearly optimum sites (nutrient-rich fresh and moist soils) represent 64.6% of the beech stands area. Most fresh rich soils are present in the Ternopil and Khmelnytsk regions (90.9 and 92.9% respectively), but a significant part can be found in the Chernivtsi region (41.7%). In the Lviv and Zakarpattya regions, most beech sites are represented by wet rich soils (56.4 and 48.7%, respectively), whereas in the Ivano-Frankivsk region, most represented are wet, moderately rich soils (53.5%). In total, of the range of European beech forests 35.4% are found on sites with fresh and moderately nutrient-rich soils.

Growing mainly in favourable habitats, European beech forms highly productive forest stands: 32.2% of the beechwood area are classified as Ia quality class or higher, and in some places beech stands even of reach quality classes Ic and even Id. The largest percentage of highly productive stands is found in the area of Ternopil (43.5%), followed by Lviv (37.2%), Chernivtsi (35.9%), Khmelnytsk (35.0%), Zakarpattya (33.6%), and Ivano-Frankivsk (18.9%).

Because of poorly regulated control, and after the Second World War destruction of the forest, the current age structure of beech stands is extremely irregular. In particular, large areas are represented by forest stands of the third and fourth age class[1] (22.9% and 24.1%, respectively) and the proportion of the other age classes is quite small. For instance, the 8th, 9th and 10th age classes represent only between 2.8 and 3.9 of the beech stand area. Especially affected is the age structure of beech stands in the Ternopil area, where 43.7% of stands belong to the 4th age class, 21.1% to the 5th, and 13.9% to the 3rd age class. Predominance of beech stands of the 3rd to 5th age classes (especially compared to older stands) is characteristic also for the Lviv, Ivano-Frankivsk and Chernivtsi regions but is less pronounced in the Zakarpattya region.

[1] Age class span is 20 years. The oldest tree stands belong to the 16th age class.

Pure stands represent 57.4% of the beech area, while 42.6% of stands are mixed. The largest proportion of pure stands is found in the Zakarpattya area (64.9%), whereas they are considerably less represented in the other areas (Ivano-Frankivsk 52.3%, Lviv 48.9%, Ternopil 46.0%, Chernivtsi 43.0%), and the lowest proportion is found in the Khmelnytsk area (21.3%), which means that towards the north-eastern limit, the area of pure beech stands is decreasing.

BEECH VIRGIN FORESTS

Beech virgin forests of Ukraine represent a unique natural area. A decision was made by World Heritage UNESCO in June 2007, to include it together with beech virgin forests of eastern Slovakia in the World Natural Heritage category under the designation "Beech Virgin Forests of Carpathians".

The series of UNESCO-protected beech virgin forests consists of ten separate forest complexes situated in a 185 km long east-west gradient from the Chornohirskyy Hrebet in the Ukraine to the Bukovske Verhy and Vihorlat mountains in Slovakia.

Beech virgin forests in Ukraine occupy in total 38,680 ha. The largest massifs are located on the Polonyna ridge (13,500 ha) and in the Svydovets (11,240 ha). Beech virgin forests are also found in the Gorgany (6,094 ha), Chornohory (4,092 ha), Marmarosha regions (3,600 ha), and in the Volcanic Carpathians (154 ha).

Most beech virgin forests are situated below the elevation of 1,000 m a. s. l., and fewer occur within the altitudinal range between 1,000 and 1,400 m and very rarely they are found over 1,400 m. Most frequently they occur on slopes of 20 to 30° inclination.

A major part of beech virgin forests is formed of pure stands, but considerable areas are represented by mixtures with *Picea abies* (L.) KARST., *Abies alba* MILL., *Acer pseudoplatanus* L. and other tree species.

Beech virgin forests are inhabited by many endemic, rare and endangered elements of flora and fauna. They have a very important aesthetic and recreational function.

From the scientific point of view, beech virgin forests of Ukraine represent a valuable object for studies on the history of the development of vegetation cover during the postglacial period. Its structural organization with peculiarly high biotic diversity, developmental dynamics and decomposition processes can be used for building models of sustainable forest use, as well as for the transformation of the current forest use towards close-to-nature management models.

FOREST MANAGEMENT IN BEECH STANDS

At present, beech stands in the Ukraine are generally managed under the shelterwood system. Much less selective fellings are used, and very rarely clearcuts. For the period 1999 to 2008, shelterwood fellings were planned on 93.7% of the area while prescribed cutting, selective fellings and clearcutting were planned for 4.8% and 1.5%, respectively.

However, even though clear fellings are avoided, natural regeneration of beech stands is not always warranted. During the period 1999 to 2008, beech forest stands were naturally regenerated on 69.3%

of felling area only, whereas the remaining felling area (30.7%) necessitated being reforested. This means that on a considerable area, beech natural regeneration was insufficient, not only after clear fellings, which is quite typical, but also after shelterwood fellings. However, as a rule, beech stands of artificial origin with the highest tree quality are regenerated naturally.

There is not a regular periodicity educed in beech fruit set in the Carpathians (Maltsev 1980). Prolific beechnut crop occurs on average once in ten years, moderate crops are repeated more often, every four to six years (Molotkov 1966). In the western part of the Podillya highlands, good harvest of European beech nuts has been recorded once in 12 to 15 years, weak and moderate crops once on a two to four years cycle (Krynytskyy et al. 2004).

Tab. 1: European beech fruitage dynamics in Volyn-Podillya highlands (north-eastern part of beech area)

Year	Nuts harvest, kg/ha	Nuts quantity, 1,000/ha		The proportion of healthy nuts, %	Mass 1,000 seed crops, g	Crop capacity category
		total	good quality			
2003	269 ± 24	2,124 ± 177	447 ± 37	21.0	133.2	very poor
2004	17 ± 2	185 ± 29	0.6 ± 0.1	0.3	90.6	absence
2005	320 ± 23	1,887 ± 129	1,249 ± 85	66.2	169.7	poor
2006	351 ± 19	2,189 ± 181	1,265 ± 69	57.8	160.1	poor
2007	102 ± 12	700 ± 86	227 ± 28	32.4	146.0	absence
2008	323 ± 23	1,905 ± 123	1,095 ± 70	57.5	170.0	poor

Within our research conducted at the Sukhodil beech site (western part of the Podillya highlands) during the period 2003 – 2008, findings show one year of absence of fruiting of European beech, two very poor and three poor crops were registered (Table 1). The proportion of filled living seeds ranged from 0.3 to 66.2%. A considerable part of the nut crop was empty (14.8 – 71.5%) and disease-affected (11.9 – 42.7%). During the autumn and winter periods the healthiest nuts, and in some years even the entire seed crop (99.5%) were predated by murine rodents.

In general, beech regeneration in the Carpathians is good (Golubets, Malynovskyy 1968, Gorshenin 1974, 1976, Hensiruk 1995, Krynytsky, Savych 1973, Krynytsky et al. 2004, Parpan, Viter 1999, Saban 1995, Tretyak 1954 and others]. In mature and over-mature beech and oak-beech stands, up to 5,000 seedlings and undergrowth trees per hectare were recorded in 10% of beech stands, 5,000 to 10,000 seedlings per hectare on 24%, 10,000 to 20,000 seedlings per hectare on 38%, 20,000 to 50,000 seedlings per hectare on 17%, and 50,000 to 100,000 seedlings per hectare on 11% (Molotkov 1966). In optimum conditions, with the stocking of 0.6 – 0.7 and under a rich fruit set, almost 200,000 seedlings per hectare may appear (Krynytsky, Savych 1973, Tretyak 1954).

The relatively low success of natural regeneration in beech stands under current forestry practice is not caused by infrequent heavy-crop years, but rather by insufficient protection of the beech understory during the main felling operations.

Our experiments conducted at the Sukhodil beech site showed that the main methods of shelterwood and selection fellings ensure a satisfactory natural regeneration of European beech. In 2003 – 2008, the highest number of seedlings and understory trees of beech appeared in the compartment where regular two-stage shelterwood felling was performed, namely 23,600 individuals per hectare. Slightly less seedlings were found in the compartment with the selection ("plenter") fellings of moderate and high intensity (21,300 and 20,300 individuals per hectare). Considerably less seedlings and understory trees appeared in the compartments managed under the three-stage group-selection system, regular three-stage shelterwood cutting and three-stage group-shelterwood fellings (15,600, 13,000 and 10,000 seedlings per hectare, respectively). In the compartments managed using group selection felling and Wagner irregular shelterwood fellings, 8,500 and 7,000 seedling per hectare appeared, whereas on the control plot without any felling, understory density was 6,600 individuals per hectare. In the compartments with clear and strip fellings, the number of understory trees was even considerably smaller compared to the control plot, namely, 2,400 and 3,800 seedlings per hectare.

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Reviewed

Contacts

Prof. Hryhoriy Krynytskyy
Ukrainian National Forestry University
Gen. Chuprynky Str. 103, 79057 Lviv, Ukraine
e-mail: krynytsk@ukr.net

Reviewers Directory

Prof. Alexander H. Alexandrov, D.Sc.
Forest Research Institute
Kliment Ohridski Blvd. 132
BG-1756 Sofia
Bulgaria
E-mail: forestin@bas.bg

Ricardo Alía, Dr.
INIA
Avda A Coruña, km 7.5
ES-28040 Madrid
Spain
E-mail: alia@inia.es

Prof. Alvaro Aunós
Univesity of Lleida
Rovira Roure 191
ES-25.198 Lleida
Spain
E-mail: alvaro.aunos@ull.es

Gregor Božič, Dr.sc.
Slovenian Forestry Institute
Večna pot 2
SI-1000 Ljubljana
Slovenia
E-mail: gregor.bozic@gozdis.si

Peter Brang, Dr.
WSL Swiss Federal Institute of Forest,
Snow and Landscape Research
Zuercherstrasse 111
CH-8903 Birmensdorf
Switzerland
E-mail: brang@wsl.ch

Prof. Dr. Harald Bugmann
Forest Ecology, Inst. of Terrestrial Ecosystems
Dept. of Environmental Sciences
ETH Zurich, CHN G76.1
CH-8092 Zurich
Switzerland
E-mail: harald.bugmann@env.ethz.ch

Dr. ir. Joukje Buiteveld
Alterra, Wageningen UR
P. O. Box 47
NL-6700 AA Wageningen
The Netherlands
E-mail: joukje.buiteveld@wur.nl

RNDr. Václav Buriánek
Forestry and Game Management Research Institute
Strnady 136
CZ-156 04 Praha 5-Zbraslav
Czech Republic
E-mail: burianek@vulhm.cz

Ing. Rudolf Bruchánik, PhD.
Lesy SR, š. p.
Námestie SNP 8
SK-975 66 Banská Bystrica
Slovakia
E-mail: rudolf.bruchanik@lesy.sk

Dr. Alexander Delkov
Forest Research Institute
St. Kliment Ohridski Blvd.132
BG-1756 Sofia
Bulgaria
E-mail: forestin@bas.bg

Rumen Dobrev, D.Sc.
Forest Research Institute
Kliment Ohridski Blvd. 132
BG-1756 Sofia
Bulgaria
E-mail: r.d.dobrev@mail.bg

Dr. Bruno Fady, senior scientist
INRA-URFM
Domaine St Paul
FR-84914 Avignon
France
E-mail: fady@avignon.inra.fr

John Fennessy, M.Sc.
Research Manager Tree Improvement & Non-wood Forest
COFORD
Department of Agriculture (4W)
Kildare Street
Dublin 2
Ireland
E-mail: john.fennessy@coford.ie

PD Dr. Matthias Fladung
vTI, Institute of Forest Genetics
Sieker Landstr. 2
D-22927 Grosshansdorf
Germany
E-mail: matthias.fladung@vti.bund.de

Norbert Frank PhD.
associate professor
Institute of Silviculture and Forest Protection
Faculty of Forestry
University of West Hungary
Ady E. str. 5.
HU-9400 Sopron
Hungary
E-mail: frank@emk.nyme.hu

Ing. Josef Frýdl, CSc.
Forestry and Game Management Research Institute
Strnady 136
CZ-156 04 Praha 5-Zbraslav
Czech Republic
E-mail: frydl@vulhm.cz

Univ-Doz. Dr. Dr. Thomas Geburek
Federal Research Centre for Forests, Natural Hazards and Landscape
Department of Genetics
Hauptstraße 7,
A-1140 Wien,
Austria
E-mail: thomas.geburek@bfw.gv.at

Doc. Ing. Dušan Gömöry, DrSc.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: gomory@vsld.tuzvo.sk

Dr. Bernhard Götz
University of Applied Sciences
Botanical Gardens
Am Zainhammer 5
D-16225 Eberswalde
Germany
E-mail: bgoetz@fh-eberswalde.de

Dr. Joso Gračan
Hrvoja Macanovića 43
HR-10 000 Zagreb
Croatia
E-mail: josog@sumins.hr

Jon Kehlet Hansen, Dr.
Senior Scientist
Forest & Landscape Denmark
Hørsholm Kongevej 11
DK-2970 Hørsholm
Denmark
E-mail: JKH@life.ku.dk

Prof. Dr. Hajri Haska
Director of Forest Directory
Agency of Environment and Forestry
Ministry of Environment, Forest and Water Administration
Rruga : "Halil Bega", Nr: 23, Tirane
Albania
E-mail: haskahajri@yahoo.com

Alwin Janßen, Dr. forest. Dipl.-Forstwirt,
Northwest German Forest Research Institute
Department of Forest Genetic Resources
Prof.-Oelkers-Str. 6
D-34346 Hann. Muenden
Germany
E-mail: alwin.janssen@nw-fva.de

Ir. Jitze Kopinga
Alterra Wageningen UR
Postbus 47
NL-6700 AA Wageningen
The Netherlands
Email: jitze.kopinga@wur.nl

Dr. François Lefevre
INRA, URFM - Ecologie des Forets Mediterraneennes
Domaine Saint Paul, Site Agroparc,
FR-84914 Avignon Cedex 9
France
E-mail: lefevre@avignon.inra.fr

Ing. Roman Longauer, CSc.
National Forest Centre – Forest Research Institute
T. G. Masaryka 22
SK-960 92 Zvolen
Slovakia
E-mail: Roman.Longauer@fris.sk

Doc. Ing. Ivan Lukáčik, CSc.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: lukacik@vsld.tuzvo.sk

Prof.dr.M.Sc. Valeriu-Norocel Nicolescu
University "Transilvania" of Brasov
Faculty of Silviculture and Forest Engineering
Sirul Beethoven nr. 1
RO-500123 Brasov
Romania
E-mail: nvnicolescu@unitbv.ro

Dr. Eduardo Notivol
C.I.T.A. – Government of Aragon
Forest Resources Unit
Zaragoza
Spain
E-mail: enotivol@aragon.es

Prof. Ing. Ladislav Paule, PhD.
Technical University in Zvolen
TG Masaryka 24
SK-960 53 Zvolen
Slovakia
E-mail: paule@vsld.tuzvo.sk

Alistair Pfeifer, M.Sc.
Research Programme Manager
Research Division, Department of Agriculture
Kildare Street, Dublin 2
Ireland
E-mail: alistair.pfeifer@gmail.com

Dr. Flaviu Popescu
Forest Research and Management Institut - Simeria
Str. Biscaria. 1,
Simeria, HUNEDOARA
Romania
E-mail: flaviu.popescu@rdslink.ro

Dr. Peter Rotach
Forest Management Group, Department of Environmental Sciences, Swiss Federal Institute of Technology (ETH)
Zürich
Switzerland
E-mail: peter.rotach@env.ethz.ch

Prof. dr hab. Janusz Sabor
Al. 29 Listopada 46
PL-31-425 Kraków
Poland
E-mail: rlsabor@cyf-kr.edu.pl

Heinz Peter Schmitt, Dr.
Forstdirektor
Am Hang 1
D 59872 Meschede
Germany
E-mail: Schmitt-Remblinghausen@t-online.de

Prof. Dr. Álvaro Soto de Viana
Universidad Politécnica de Madrid
ETSI Montes. UD Anatomía, Fisiología y Genética
Ciudad Universitaria s/n
ES-28040 Madrid
Spain
E-mail: alvaro.soto.deviana@upm.es

Ing Alain Valadon
Conservatoire Génétique des Arbres Forestiers
USC ONF-INRA
Centre de Recherches d'Orléans
2163 Avenue de la pomme de pin
CS 40001 ARDON
F-45 075 OrleansS Cedex 2
France
E-mail: valadon@orleans.inra.fr

Prof. dr. Dragica Vilotić
Faculty of Forestry University in Belgrade
Kneza Viseslava 1
RS-11030 Belgrade
Serbia
E-mail: vilotic@ptt.rs

Ir. Sven M.G. de Vries
PO BOX 47
NL-6700 AA Wageningen
The Netherlands
E-mail: sven.devries@wur.nl

Dr. Georg von Wühlisch
Institute for Forest Genetics
Sieker Landstr. 2
D-22927 Großhansdorf
Germany
E-mail: georg.wuehlisch@vti.bund.de

Asc.Prof.Dr. Petar Zhelev
University of Forestry
BG-1756 Sofia
Bulgaria
E-mail: zhelev@ltu.bg

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