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Cover: Dinaric fir-beech forest at the edge area of Rajhenav virgin forest remnant in the Kočev region – southern Slovenia (Photo: L. Kutnar)

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Genetic resources of beech in Europe – current state

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„Evaluation of beech genetic resources
for sustainable forestry“

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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

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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):

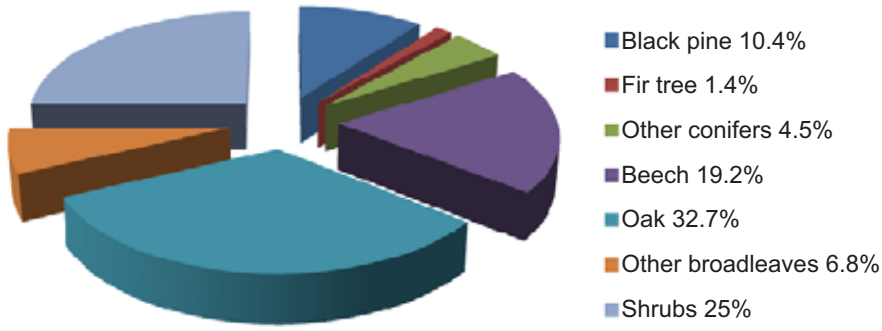

Fig. 1: Proportion (%) of European beech and other main forest trees in Albania (prepared by H. Haska)

- 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.

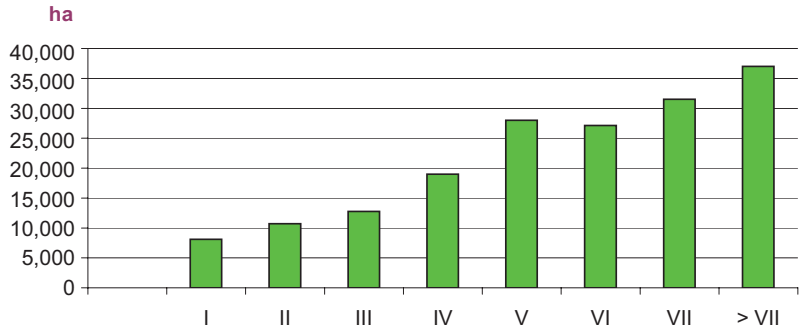

Fig. 4: Distribution of European beech area (high forests) according to age classes (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

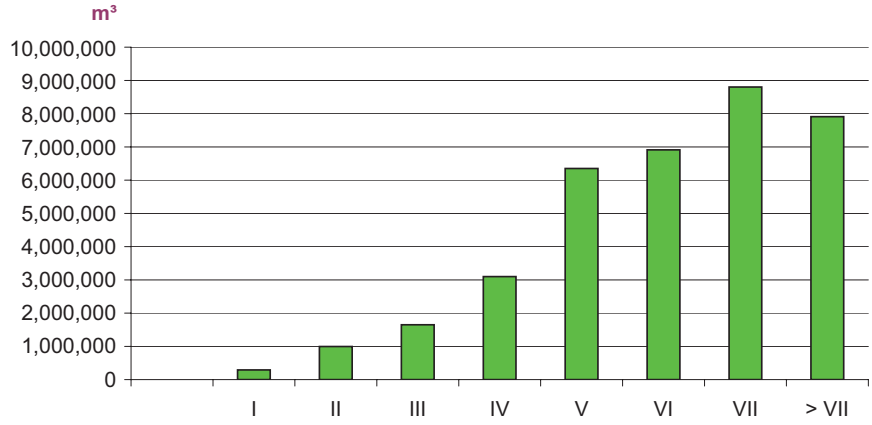

Fig. 5: Distribution of European beech volume (high forest) according to age classes (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

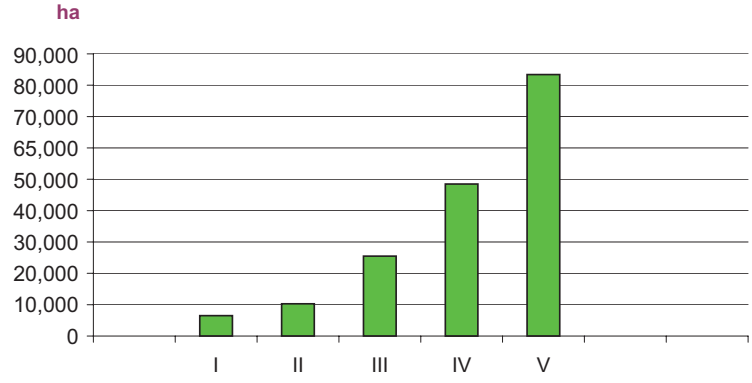

Fig. 6: Distribution of European beech surface (high forest) according to production classis (Source: Ecological Survey: Virgin forests in Albania, adapted by H. Haska)

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			

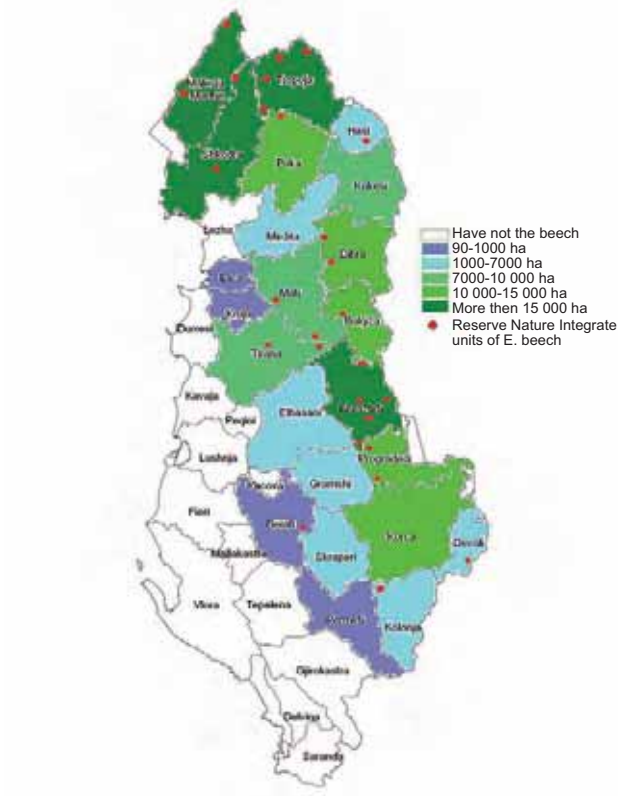

Fig. 7: Distribution of European beech and Nature Reserve Integrate units (NRI) in Albania according to districts (prepared by H. Haska)

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

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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, ղաժի (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).

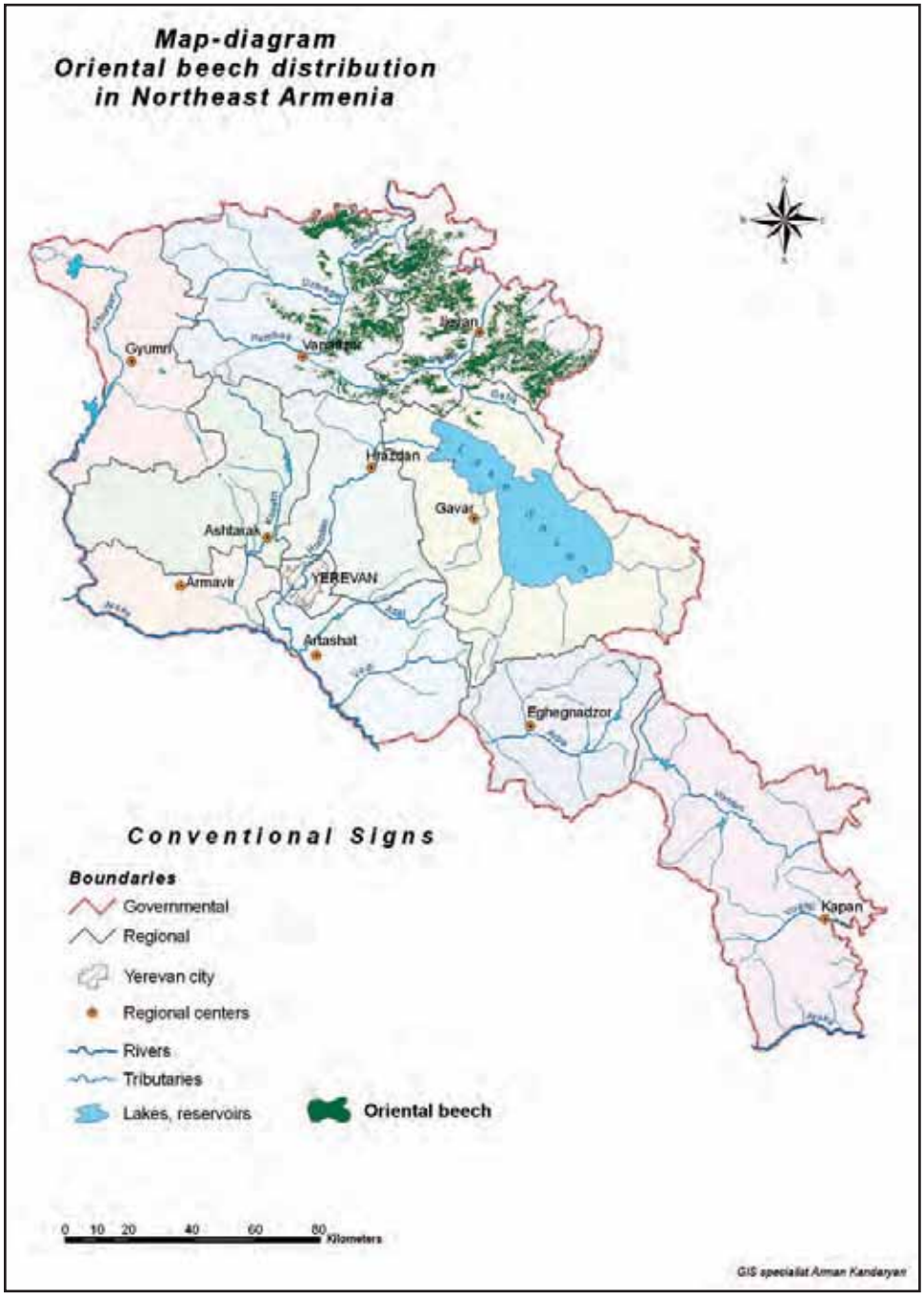

Fig. 5: Map of oriental beech distribution in northeastern Armenia

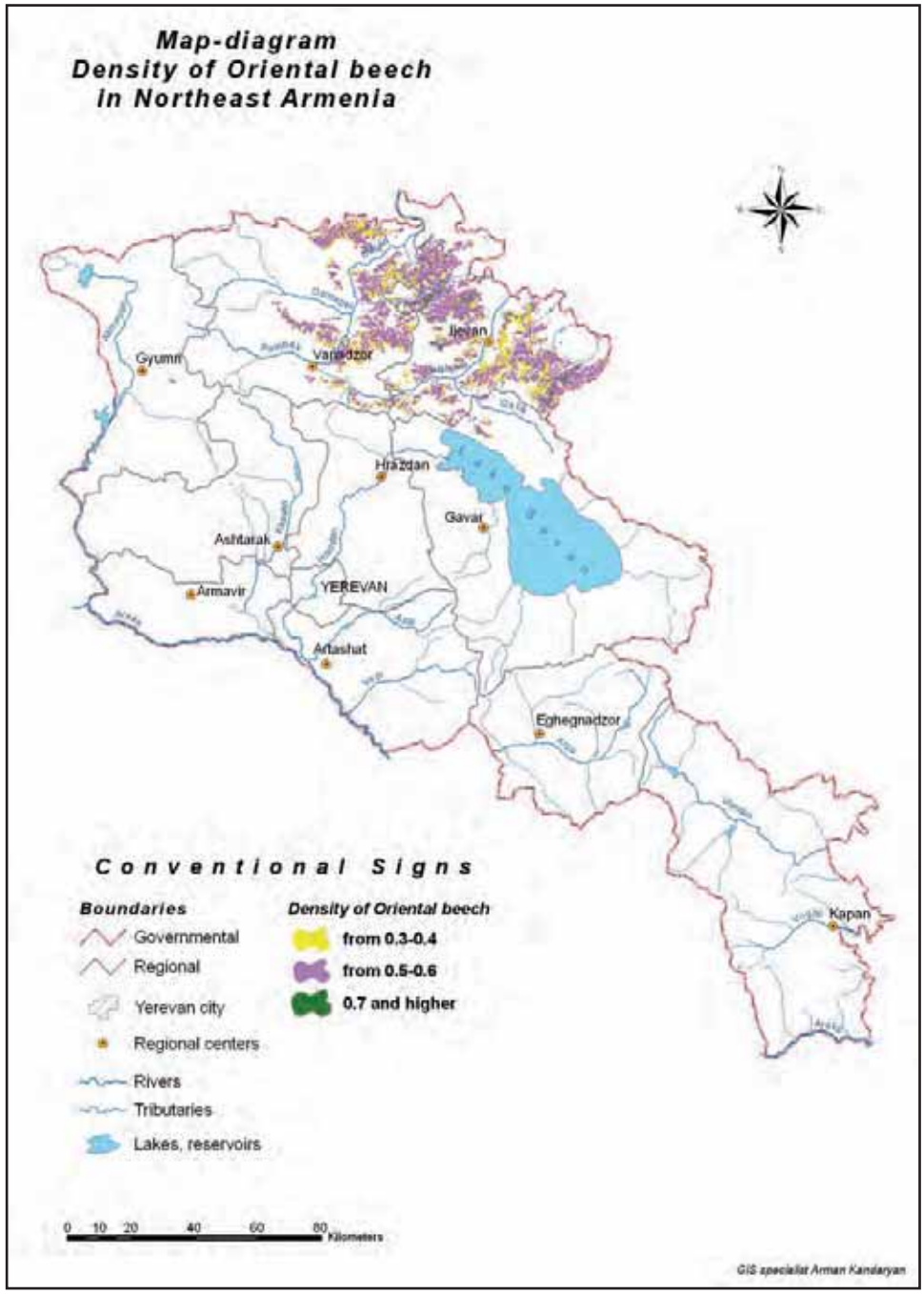

Fig. 6: Map of oriental beech density in northeastern Armenia

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

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

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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

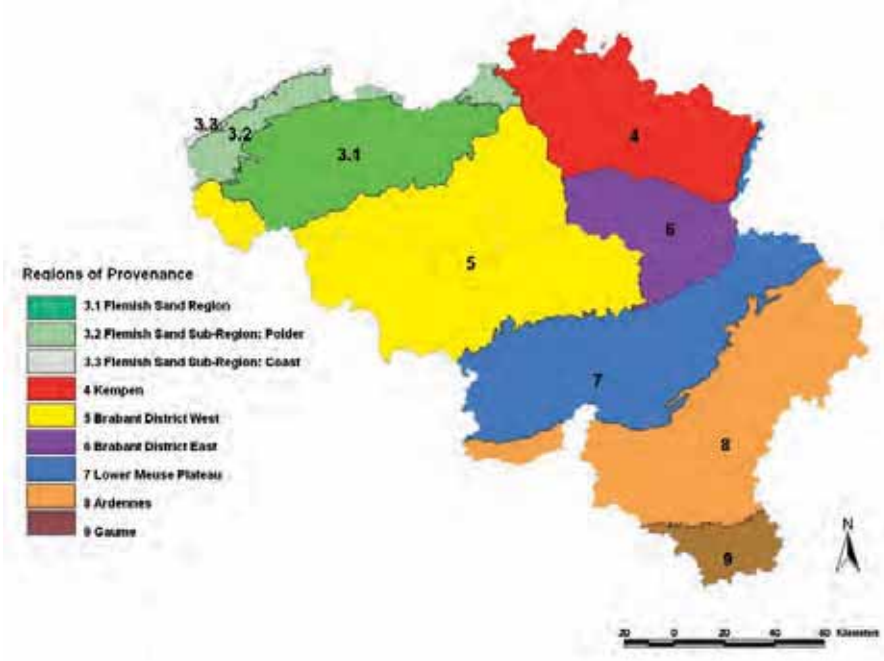

Fig. 1: Provenances regions in Belgium (Vander Mijnsbrugge et al. 2004[2], Orvert 2008[3])

20 $m^2.ha^{-1}$. 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 $m^3.ha^{-1}$ and 33 $m^2.ha^{-1}$ 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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AN OVERVIEW OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN BOSNIA AND HERZEGOVINA

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

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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.

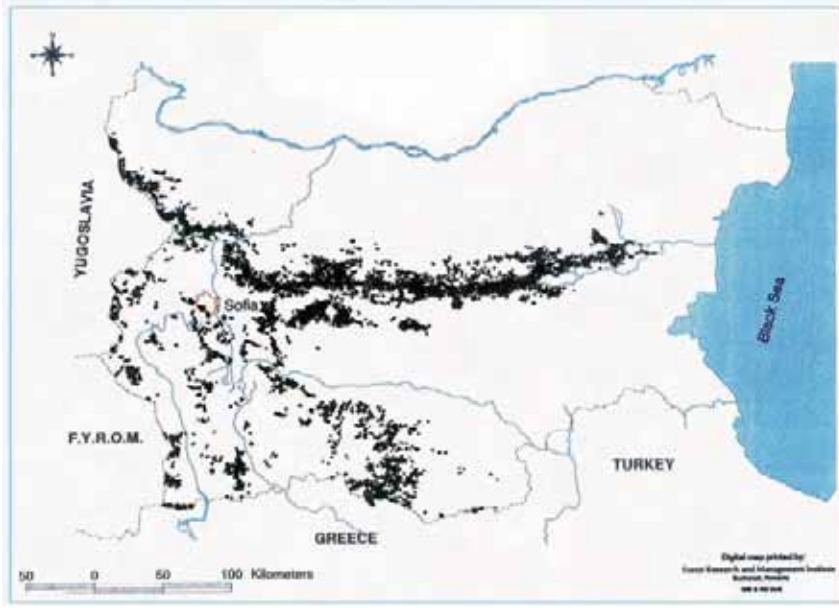

Fig. 1: Natural distribution of *Fagus sylvatica* in Bulgaria

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

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

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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.

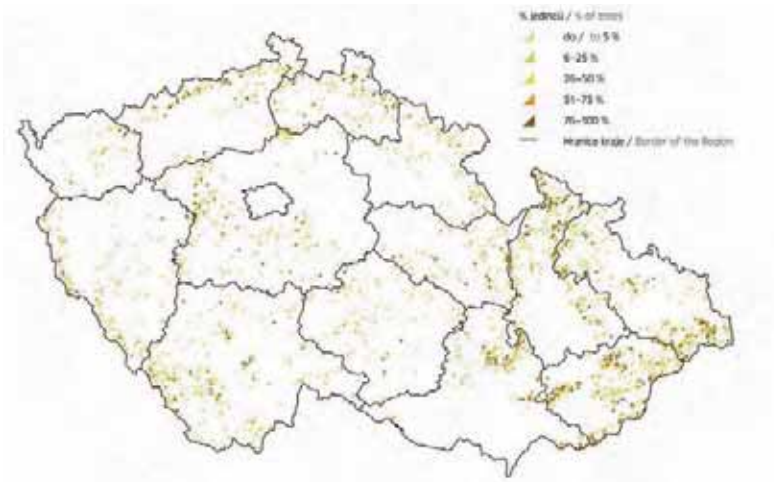

Fig. 1: Present distribution range of European beech in the Czech Republic (Source ÚHÚL: Národní inventarizace lesů v České republice 2001 – 2004)

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

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

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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 $260 \star 10^6$ m^3 (11%) and the annual production is $8.4 \star 10^6$ m^3 per year (8%). The individual number is $884 \star 10^6 + 50 \star 10^6$. 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

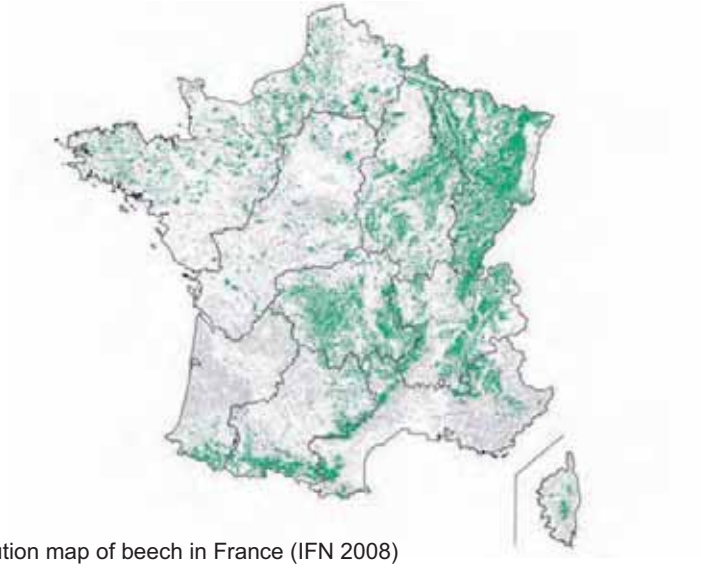

Fig. 1: Distribution map of beech in France (IFN 2008)

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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