

ORIENTAL BEECH IN GEORGIA – PRESENT STATE AND CONSERVATION PRIORITIES

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ABSTRACT

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

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

ORIENTAL BEECH DISTRIBUTION IN THE REPUBLIC OF GEORGIA

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

The total area of Georgia is 6.95 million ha and of this, the total area of forests is 2,988,000 ha while the territory covered with high forest is 2,767,300 ha. The high percentage of forests at 39.1% is highlighted in comparison with other countries in the Caucasus at 27%. The total supply of wood amounts to 453 million m³, with an annual national increment of 4.6 – 4.8 million m³. Average wood supply from one hectare is 157.8 m³ and annual additional supply of the wood on one hectare forms 1.8 m³ (Materials of the forests arrangement of the Republic of Georgia 1990 – 1995, GIGAURI 1980).

According to GIGAURI (2000) the forests of Georgia are divided into mountain and lowland forests according to geographic conditions. Mountain forests occupy 98% of the area while only 2% is occupied by lowland forests. Forests are located on steep and gentle slopes. Forests area is decreasing along the lower part of mountain slopes and in the west of Georgia up to 500 – 600 m a.s.l., in the east

of Georgia up to 700 – 800 m a.s.l. and also in the sub Alpine region up to 1,800 – 2,500 m a.s.l. At high mountain levels and on steep slopes there are areas still covered with high forests in a natural state and not damaged by farming activity. 7.3% of the forests are situated at 500 m a.s.l. while 19.5% are at 501 – 1,000 m a.s.l. A further 35.5% are between 1,001 – 1,500 m a.s.l. while 37.7% are over 1,501 m a.s.l. Thus almost $\frac{3}{4}$ (73.2%) of forests are located at 1,001 m a.s.l. and higher.

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

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

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

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

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

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

Among them:

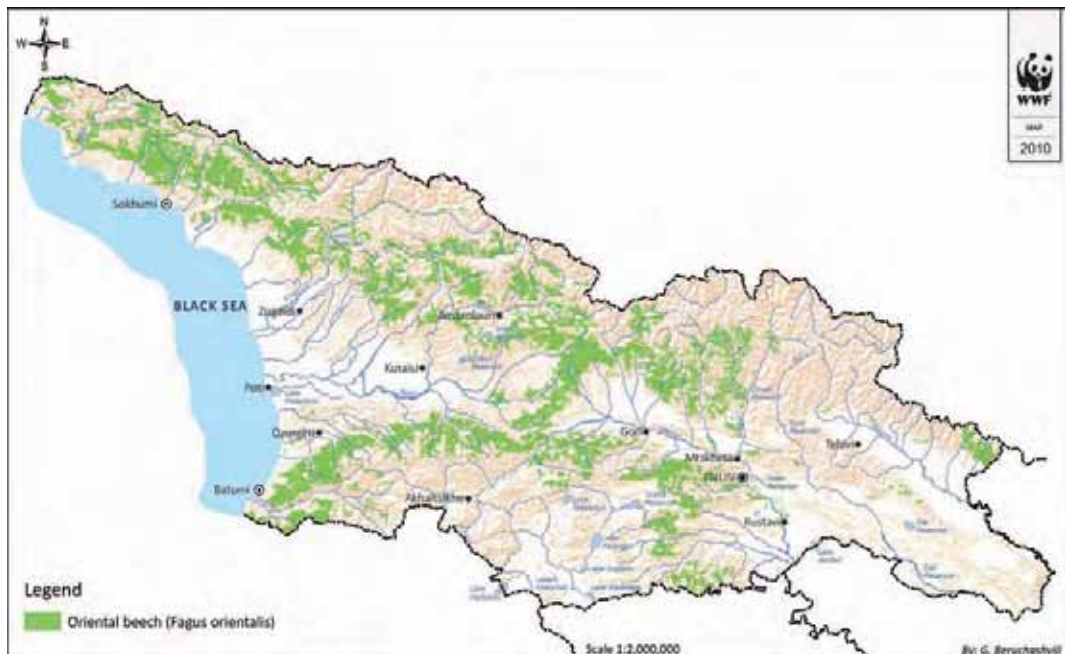
- forests of green zone – 265,700 ha;
- forests of resort zone – 890,600 ha;
- soil-protective water regulation forests – 1,335,800 ha;
- total: 2,988,000 ha (100%)

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

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

The Georgian forests are very diverse from the point of view of biological, genetical and economical importance and are presented as stands of valuable woody species. Based on the data of GIGAURI (2000), the broadleaved forests in Georgia occupy 83.6% of all forests and their supply of wood accounts for 251.3 million m³. The stands of hardwood species occupy 70.5% of broadleaved forests and their supply of wood accounts for 290.3 million m³. This includes the following:

The largest territories of Georgia's forests are occupied by oriental beech at 42.5% and with a volume of wood of 224.7 mil. m³ (see map).



- Oak (*Quercus iberica* STEV, *Q. macranthera* F. et M., *Q. imeretina* STEV, *Q. longipes* STEV and etc.) at 10.5%, and with a volume of wood of 23.6 mil. m³;
- Hornbeam (*Carpinus caucasica* GROSSH) stands at 9.9% with a volume of wood of 24.7 mil. m³;
- Chestnut (*Castanea sativa* MILL.) stands at 3.8% and with a volume of wood of 12.7 mil. m³.

The softwood species group form 10.8% and the total volume of wood at 20 million m³ and include: *Alnus barbata* C.A.M., *A. incana* (L.) MOENCH at 7.2% with a volume of wood of 13.8 mil. m³; *Betula verrucosa*, *B. litwinowi* A. DOLUCH at 2.7%, with a volume of wood which is 3.5 mil. m³; *Populus alba* L., *P. tremula* L., *P. nigra* L. at 0.6%, with a volume of wood 1.4 mil. m³.

Coniferous forests occupy 16.4% of all forests and the volume of wood of this forest category is 121.9 mil. m³ and include:

- Pine (*Pinus Sosnowskyi* NAKAI) group at 4.4% of the area covered with forests and providing a volume of wood of 14.6 mil. m³;
- spruce (*Picea orientalis* LINK) group at 5.0% and providing a volume of wood of 32.4 mil. m³;
- *Abies nordmanniana* (STEV) SPACH group at 6.9% and providing a volume of wood of 74.7 mil. m³ (Fig. 1).

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

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

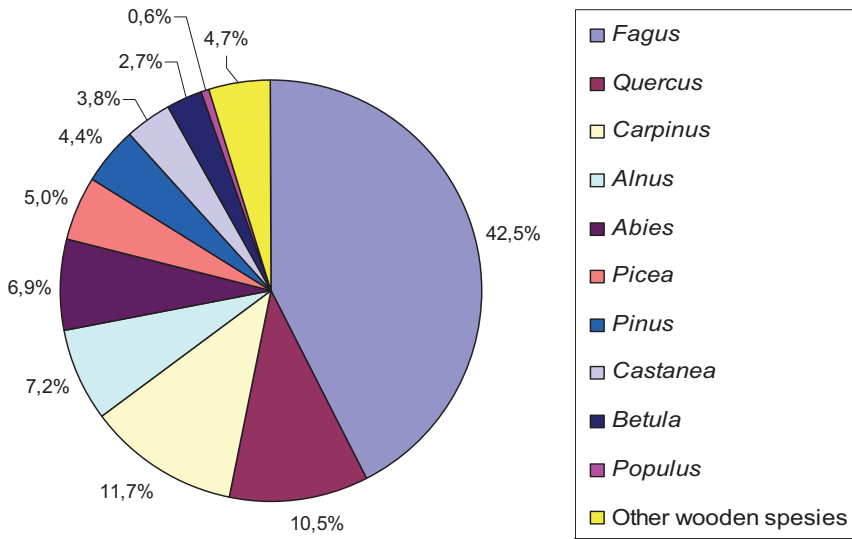


Fig. 1: Distribution of areas covered with forest according to main wood species (%)

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

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

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

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

CHARACTERISTICS AND FOREST MANAGEMENT

The principles of protection, sustainable development and management of the forests of Georgia are based on the Constitution of Georgia (web-site: www.parlamet.ge), the Declaration “On Principles of Sustainable Development of Forests” of the UN International Conference on Environment and Development in Rio de Janeiro, 1992 and on the principles, established by Article 5 of the law of Georgia (web-site: <http://aarhus.ge/uploaded/files/ee5a802ed8f21815f48f182cce57edfe.pdf>) “On Protection of Environment”; the principle of preservation of biological diversity is one of the most important of these.

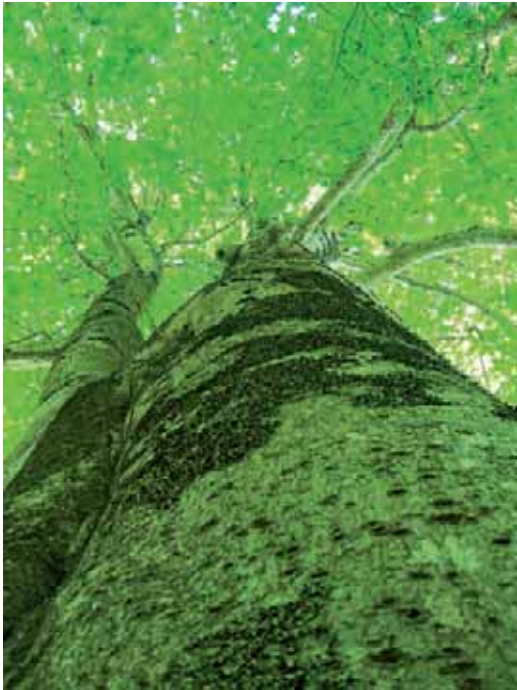


Photo 1, 2: *Fagus orientalis* LIPSKY (Z. Manvelidze)

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

According to typological point of view *Fagetum* of Georgia can be said to be studied widely. Studies have been undertaken by the following: GULISASHVILI (1964), DOLUKHANOV (1968), TUMAJANOV (1938), MAKHATADZE (1965), SVANIDZE, ABULADZE, PARJANADZE (1978), SVANIDZE (2001), KVACHAKIDZE (1992, 2001), BAKHSOLIANI (2002), MANVELIDZE, MEMIADZE, GORGILADZE (2004), DOLIDZE (2006) and others.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Stands of medium density (0.5 – 0.7) mainly dominate in Georgian beech forests. It is noteworthy that low-density stands occupy sufficiently large areas and the area of high-density stands have

significantly decreased. This is caused mainly by economic interference by man in the natural processes. Incorrect use of exploitation regulations of beech forests in separate regions has resulted in felling of high-density productive stands, or have resulted in significant decrease of density of these stands. As a result, these stands have suffered significant reduction of productivity and indices of marketable value of the stands (Fig. 2).

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

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

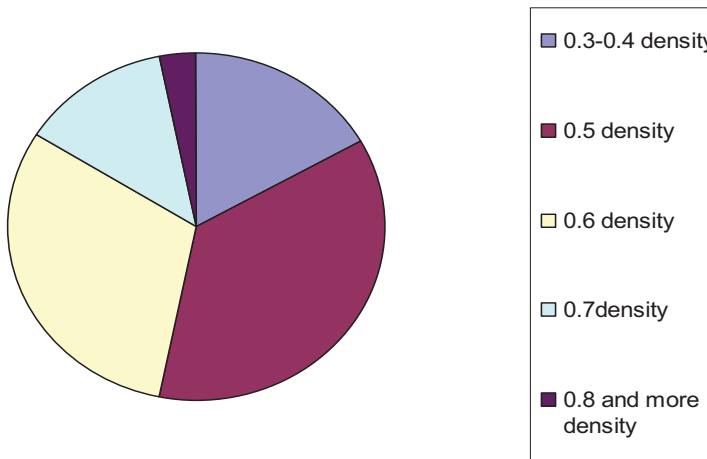


Fig. 2. Distribution of areas covered with beeches according to frequency

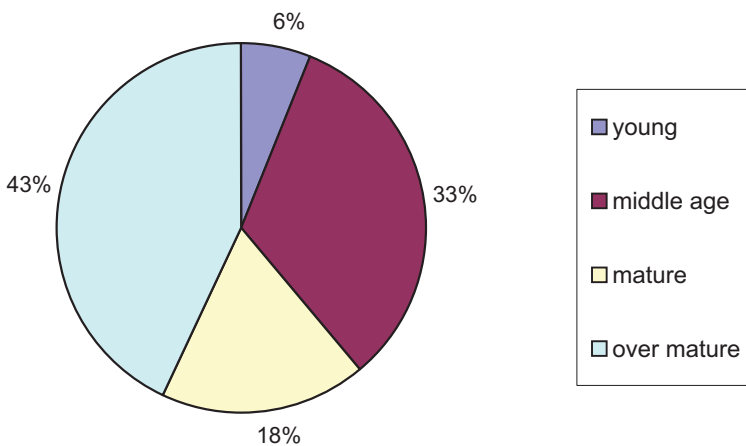


Fig. 3. Distribution of areas of beech forest according to groups of different ages

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

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

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

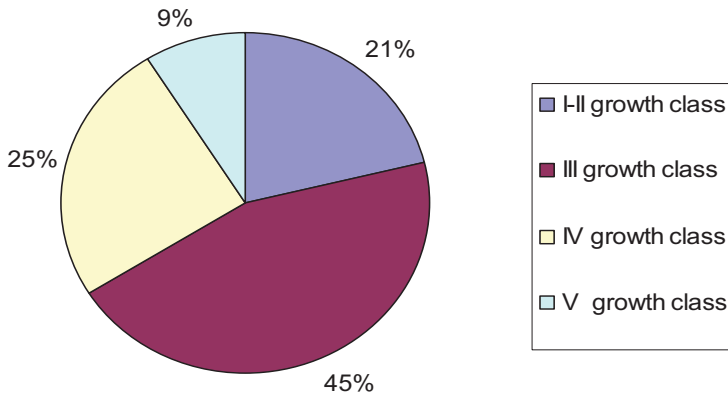


Fig. 4: Distribution of areas covered with beech forest according to quality classes

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

Based on data by GIGAURI, DZEBISASHVILI (1990), of the main species forming the forests of Georgia, oriental beech occupies one of the leading places after eastern spruce and fir, according to the index of accumulation of biomass by a tree of one and the same diameter, and at 100 cm diameter, its total volume on average contributes 16.71 m³ (Tab. 2).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Thanks to the environmental conditions (soil, climate) which are optimal for growth and development of forests, the virgin forests of Georgia, especially in the western part, are represented mainly by high productivity stands. In this connection the pure and mixed beech stands of Abkhazeti and Zemo Svaneti are especially distinguished where supply of wood per ha is frequently 1,000 – 1,200 m³, and in separate virgin forest areas can reach 1,600 – 1,800 m³ with annual increment of 20 – 25 m³. These forests are indeed monuments of nature not made by hands. The virgin fir and beech forests are unmatched by productivity index in the other countries of Europe and possibly Asia.

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

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

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

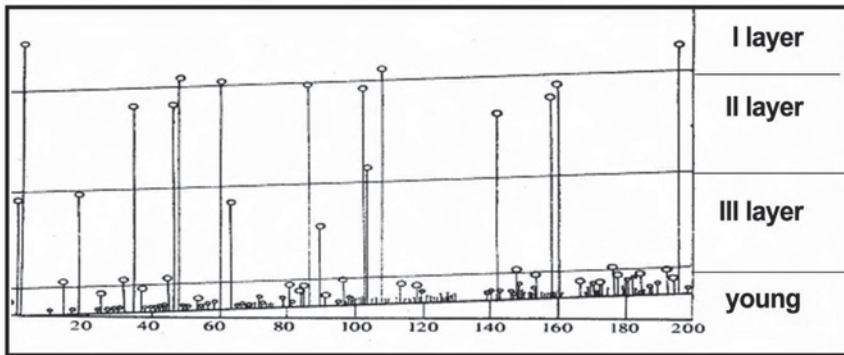


Fig. 5. Scheme of structure at height of beech group (according to GIGAURI 1980)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Each tree was numbered and characterized.

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

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

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

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

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

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

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

(“Launching the Conservation of Georgia’s Natural Monuments”) (<http://www.nacres.org>), in which the objects of high conservation value in the ecosystems of beech forests are included.

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

FOREST RESEARCH

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

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

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

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

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

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

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

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ABSTRACT

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

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

DISTRIBUTION OF EUROPEAN BEECH IN GERMANY

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

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

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

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

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

ECOLOGY AND BIODIVERSITY

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

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

A great advantage of beech ecosystems is their ability to catch ground water because of their low evaporation rate, smooth bark favouring an effective stem flow, leafless time for more than half a year. All these factors result in high percolation rates in beech forests, which are higher than in any

other forest species or grassland. The annual seepage will supply up to 40% of the precipitation to the ground water in optimal cases. Thus, beech forests are increasingly favoured in water catchment areas.

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

PESTS, DISEASES AND ABIOTIC IMPACTS

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

Air pollution was still heavily affecting beech, much more than the conifers as shown by the crown defoliation, although the main pollutants (SO₂, NO_x) have decreased substantially during the past years, except for NH₃ and O₃, the last one of which continued to be the most critical for the forest. Especially beech suffered from crown defoliation with a drastic increase of damaged trees from 30% (2003) to 55% (2004). This could be explained by the drought in 2003 and a heavy seed crop in 2004 because a positive correlation between crown defoliation and the intensity of seed production was found (BMVEL 2003, 2004).

SILVICULTURE AND MANAGEMENT

After the periods of heavy overuse of the forests during the past centuries, which continued up to the middle of the last century and also devastated large areas of beech forests, it was necessary to find a better way to protect and use the forests. The old credo of sustainable management first put into practice by Hannß Carl von Carlowitz in the 18th century was revived and extended to include

also aspects of ecology, nature protection and genetics beside the original economical aspect. Hence, clearcuts of the stands even with low acreage are avoided, uneven aged stands are well accepted, and natural regeneration is preferred wherever it is advantageous. This is the case when the quality and the origin of the stand to be regenerated are sufficiently adapted to the prevailing site conditions. If the prerequisites for the natural regeneration are not given or the regeneration fails, for instance in case of lack of seed crop, low number of beech trees per stand or insufficient preparation of soil, then seed or plants raised thereof or wildlings (young wild grown seedlings) taken from adjacent stands can be used to interplant and fill gaps in the stand to be regenerated. It is accepted practice to intervene during the development of the stand by early promotion of selected trees. Thinning measures are supporting this strategy, which is aiming at a high proportion of best quality stems in the stand for harvest. Felling is done at intervals in congruence with the development of the stand by optimizing increment and quality of timber. Dead wood is left in the stand in order to enhancing biodiversity.

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

Forest policy was encouraged to manage all forests with the aim to structure and to mix the stands with broadleaved tree species, to let the trees grow for a longer time, thus increasing the age, the standing volume and the increment. This management was extremely successful: The total standing volume for all forests increased up to 3,380 million m³, which is the highest in Europe followed by Sweden and France. For beech, the total standing volume grew by 25.8% within 15 years up to 583 million m³ (about 17.3% of the total) or 323 m³/ha. Most of the standing volume exists in stands older than 120 years (37%) followed by stands between 80 and 120 years (35%). The mean annual increment during a 15 year period (1987 – 2002) of all beech forest was 11.74 m³/ha, higher than in the past. Additionally, stand structure and management system have the advantage that the stands gain a higher stability and value in terms of ecology and biodiversity, support the wood industry with high quality timber continuously and cost efficiently, and increase the carbon sequestration (Federal Ministry 2002).

For future planning, the BMVEL (2005) investigated how much wood would be available for the period 2003 – 2042, by group of species, wood classification system, and region. The increment estimate, including all species on the total national forest area reaches 60 million m³/year of usable wood (stem wood and industrial wood) in the first years and will increase to 70 million m³/year by 2042. For beech wood the corresponding figures are 10.8 million m³/year for 2003, then the increment will rise up to more than 12.7 million in the years between 2008 – 2012 and drop slowly again down to 10.8 million. However, generally the supply of beech wood will be sustainable in the years to come.

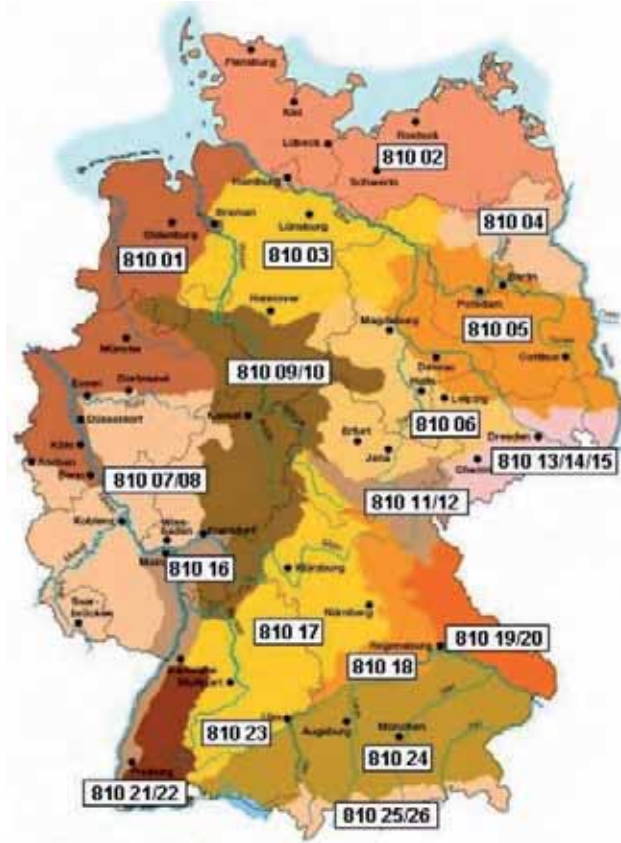


Fig. 1: The 26 regions of provenance of European beech in Germany

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

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

REGENERATION AND SEED PROCUREMENT

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

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

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

ECONOMICS

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

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

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

The prices for harvested stem wood reached about 90 to 120 €/m³ and for industrial wood between 23 and 30 €/m³ in the years 1995 to 2006. On average the forwarding cost to the forest roadside amounted to 26 €/m³, the corresponding prices came up to 48 €/m³ for unsorted beech wood. Thus

the earnings for the forest owner from the sale of the wood was 22 €/m³. The total income of beech forest owner has been calculated to about 260,000 €/1,000 ha and year, this includes also the earnings from other uses, primarily hunting leases, while the expenditures summed up to about 240,000 €/1,000 ha and year. Four jobs can be created in the forestry sector (two employees and two as service providers) permanently and additional four jobs in the wood industry and saw mills to process the wood from 1,000 ha. Besides these positive economics other valuable contributions of the beech forest to the total balance like the ecological and social functions should not be forgotten (JANSSEN 2002).

CONSERVATION

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

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

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

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

RESEARCH

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

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

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

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ABSTRACT

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

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

POPULATION HISTORY AND NATURAL DISTRIBUTION

European beech (*Fagus sylvatica* L.) is normally regarded as a native tree species in southern parts of Great Britain, including much of south-eastern and south-central England and some parts of south-eastern Wales. This natural range lies between 50.5 and 52.5 degrees north latitude. Naturally-arising British beechwoods are of the lowland or colline types, occurring between sea level and 300 m a. s. l. The major proportion occurs between 150 m and 300 m a. s. l. on the convex upper slopes of hill ranges geologically formed of Cretaceous chalk (e. g. the Chilterns, North and South Downs) or Jurassic oolitic limestone (e. g. the Cotswolds). A minor proportion occurs on acid sand and gravel sites, found over lowland Tertiary basin deposits (e. g. New Forest, Burnham Beeches). From palynological evidence, beech is seen to have colonized Great Britain from mainland Europe, not later than 4,000 years B. P., at first spreading fairly slowly (BIRKS 1989, RACKHAM 2003). It may

have had human assistance in this colonization – accidental or deliberate. It is certainly believed that beech spread into a landscape that had previously undergone significant anthropogenic clearance of natural mixed deciduous woodlands (dominated by oak, lime, ash, hazel and elm), which may have facilitated later, more rapid, colonization by beech. There is limited evidence that beech may have spread naturally beyond its current natural distribution, colonizing Carboniferous limestone hills to 300 m a. s. l. in areas of northern England and eastern Wales (to 54 degrees north). The extent of naturally-arising beech woodland has since been markedly reduced by clearance of woodland for agriculture and urban development and by replanting with alternative species. Nonetheless, semi-natural beech woodland remains the dominant land-cover type in a number of localities in the hills of southern England where it appears climatically suited and silviculturally valuable.

BEECH PLANTATION AFFORESTATION SINCE 1600

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



Fig. 1: Upland beech plantation – eastern Scotland

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



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



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

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

ECOLOGICAL TYPES OF BRITISH BEECHWOODS

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

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

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

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

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

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

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

Notes: ¹ Almost all of the area described as birch woodland will be spontaneous or sub-spontaneous woodland that is not under active management for birch timber production.

² There may be a significant but undefined quantity of mature beech, some potentially suitable for timber, submerged within the other/mixed broadleaved woodland category.

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

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

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

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

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



Fig. 4: Premier beech stand – Chiltern beechwoods

SILVICULTURE OF BEECH IN BRITAIN

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

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

with the intention that stands would later be rotationally felled. Yields would typically be 4 – 8 m³/annum over a final-felling rotation of 80 – 120 years. However in recent decades the area of regular beech woodland being felled and replanted has declined markedly, with most stands now being converted to lower-intensity forms of management (shelterwood, non-intervention etc.) aimed at amenity and conservation. Diversification by enrichment planting with other native species (oak, ash, cherry) has become a frequent response to perceived challenges to beech from increasing drought.

- **Fuelwood/coppicing** – a traditional form of management of beech woodland in certain regions, particularly the Cotswolds during Roman times and the Chilterns during the medieval and early-modern periods. Until the widespread adoption of coal as a domestic and industrial fuel, small-diameter beech was a major source of fuel for the city of London, for example – especially for industries such as bread-making. Beech does not coppice very reliably under British climatic conditions at the present time, but some areas of beech woodland in these regions appear to have been managed as coppice in the past. Beech remains a favoured fuelwood for log stoves and there is now renewed interest in the management of the species under short-rotation forestry systems to produce fuel chip.
- **Wood-pasture/pollarding** – a traditional form of management of beech woodland, particularly associated with lowland acid beech woodlands within the natural range. There are several prominent localities – Savernake Forest, New Forest, Burnham Beeches, Windsor Great Park and Epping Forest – where these systems have been applied intermittently over at least several centuries, leading to valued cultural landscapes of veteran beech and oak trees set within open grass parklands. Beech was traditionally pollarded to produce fresh growth beyond the reach of browsing livestock. In recent years there has been a considerable upsurge in interest in the restoration of such wood-pasture landscapes by re-introduction of cattle grazing and active beech pollarding (READ et al. 2010). Many beech wood-pastures are under public or charitable conservation ownerships, and almost all major examples have been designated as nature reserves or conservation sites. The preservation of the over-mature beech resource, including its standing deadwood, has been prioritized in support of the saproxylic invertebrates exclusively associated with this.
- **Low-intervention high forest** – areas where mature beech woodland (natural or planted) is allowed to remain with very limited management interventions, usually only amounting to the removal of dangerous unstable trees. In some cases this is due to inaccessibly steep terrain or to the abandonment of former selection forestry systems on economic grounds. In some cases there is an explicit nature conservation or landscape amenity basis for the adoption of low-intervention management, both on public and private forest estates. Some privately-owned mature beech woodlands are now used for sport – e. g. pheasant shooting. A considerable amount of the mature standing beech resource under low-intervention management regimes is in mixture with other species, including introduced conifers. The proportion of British beech woodland under low intervention management is increasing, particularly in districts where damage by introduced grey squirrel reduces productivity.

CONSERVATION MANAGEMENT OF BEECH WOODLANDS IN BRITAIN

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

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



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

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

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

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

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



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

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

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

MANAGEMENT OF BEECH REPRODUCTIVE MATERIAL WITHIN BRITAIN

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

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

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

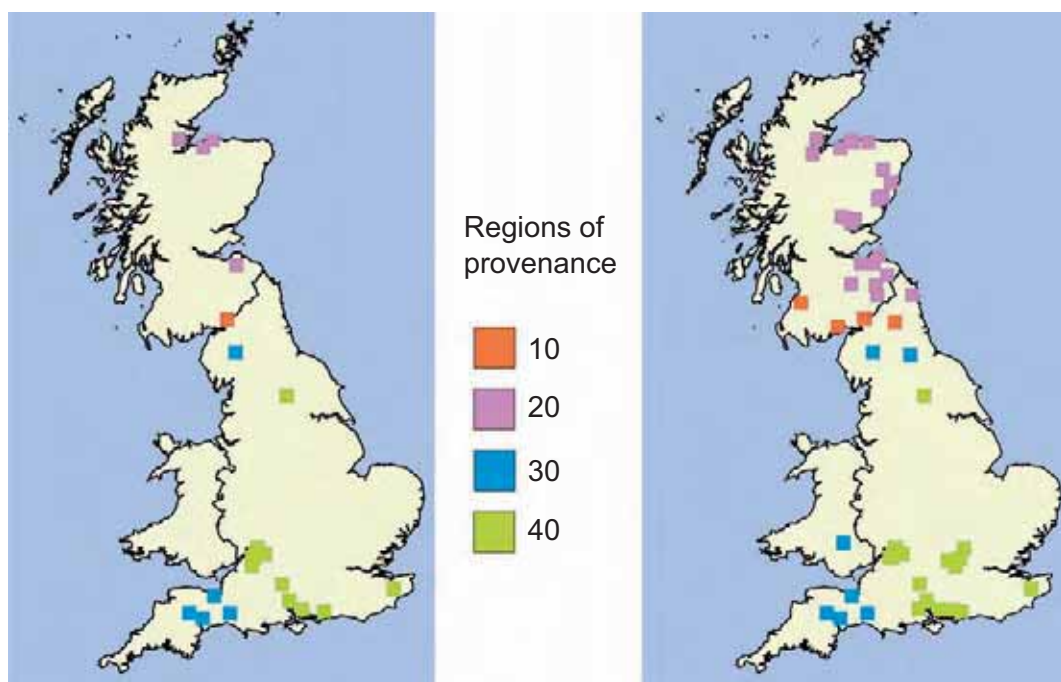


Fig. 6: Beech selected seed stand – North Scotland

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

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

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



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

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

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



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

RESEARCH PRIORITIES FOR BEECH IN BRITAIN

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

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

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



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



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

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

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

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

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

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

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

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CURRENT STATUS OF GENETIC RESOURCES OF BEECH IN GREECE

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ABSTRACT

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

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

NATURAL DISTRIBUTION OF BEECH

The mountains of Greece are well known for their rich flora and high biodiversity including many endemic species (DAFIS 1973, STRID 1989, STRID, KIT 1991, DIMOPOULOS, BERGMEIER 1998, DIMOPOULOS et al. 1995, FADY-WELTERLEN 2005). In Greece, beech ecosystems are very dispersed on the high mountains (Fig. 1), growing on a variety of sites which harbor a rich biodiversity. Beech forests represent about 10.02% (336,600 ha) of the total high forests of Greece and most of these, around 80%, are state forests. Beech grows in the mountains of N, NW, and E Greece, on the Pindos Mountain range up to Mountain Oxia in the central part of the country (MOULOPOULOS 1961, 1965, SPANOS 2010). Altitudinally, it grows from 180 m a. s. l (Kentavros Mountain – Xanthi) up to 1,600 – 2,000 m a. s. l. (mountains of Pindos, Olympos and Oxia). Beech forests have been evaluated systematically by MOULOPOULOS (1961, 1965) and DAFIS (1973, 1990). According to MOULOPOULOS (1961, 1965), beech forests are composed of *Fagus sylvatica*, *Fagus moesiaca* and *Fagus orientalis*. Horizontally, *Fagus sylvatica* is mainly distributed in the central and western mountainous parts of the country, *Fagus orientalis* in the forests of the eastern parts and *Fagus moesiaca* in almost all beech forests. Vertically, *Fagus orientalis* is found on lower altitudes (180 – 1,000 m a. s. l.), *Fagus sylvatica* in the higher and colder parts (up to 1,100 – 2,000 m a. s. l.) whereas *Fagus moesiaca* in all altitudinal ranges of beech (DAFIS 1973, 1990). Past studies (MOULOPOULOS 1961, 1965) have shown that *Fagus orientalis* is better adapted to relatively drier conditions whereas *Fagus sylvatica* prefers colder environments. It has been suggested that *Fagus moesiaca* is a hybrid (*Fagus* × *moesiaca*) of *Fagus*

sylvatica and *Fagus orientalis* or represents populations of *Fagus sylvatica* adapted to intermediate site conditions (MOULOPOULOS 1965). Other studies (e. g. GÖMÖRY et al. 1999) have suggested that populations of the putative taxon of *Fagus moesiaca* from the Balkan Peninsula seem to form an independent group. In recent studies, based on morphological and molecular variation, and Flora books (e. g. STRID 1989, STRID, KIT 1991) the two species are considered as subspecies of the cluster species *Fagus sylvatica* (e. g. *Fagus sylvatica* subsp. *sylvatica* and *Fagus sylvatica* subsp. *orientalis*).

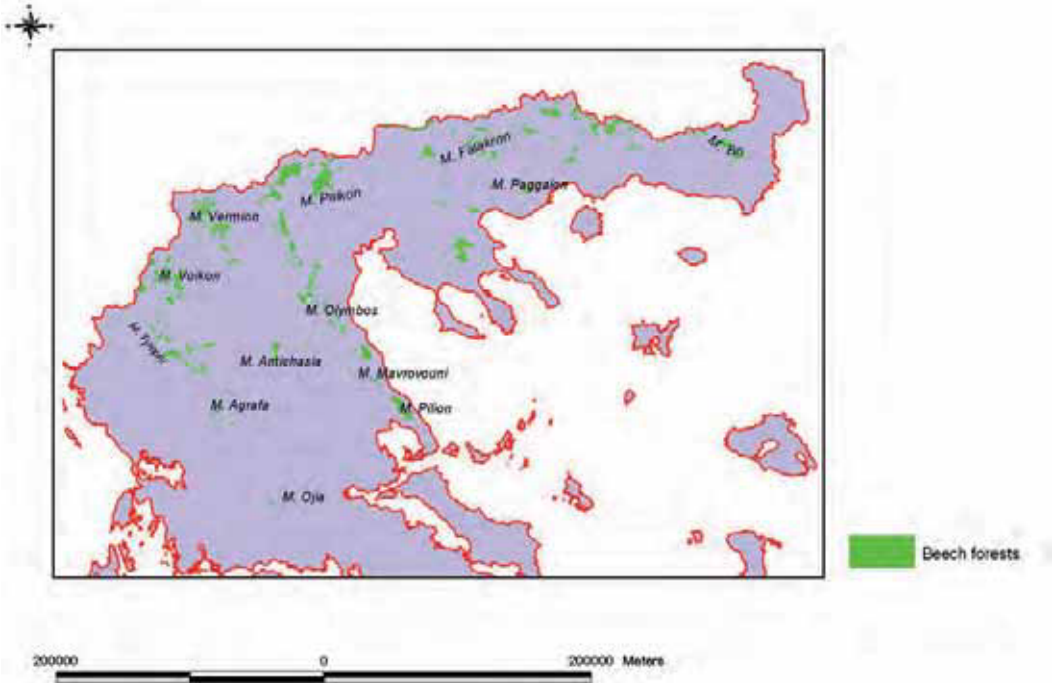


Fig. 1: Map showing distribution of beech in Greece

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

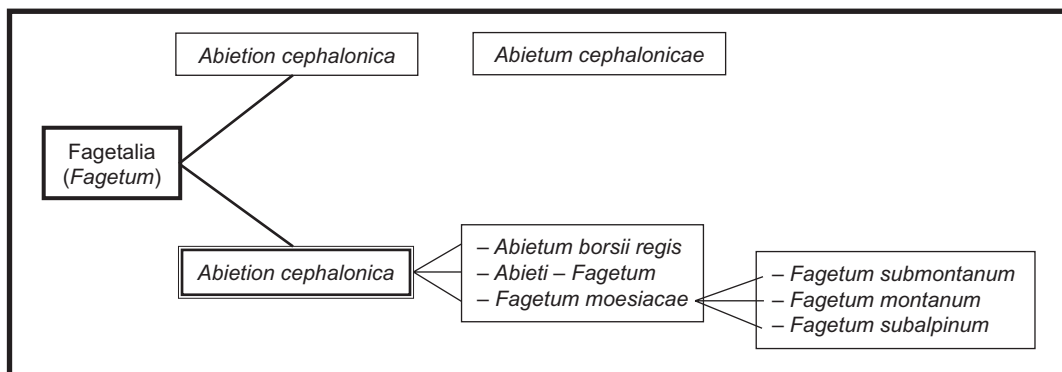


Fig. 2: Diagram showing the beech-fir forest vegetation zone (Fagetalia) (DAFIS 1973, ATHANASIASIS 1985)

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

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

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

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

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

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

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

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

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

Regions of provenances:

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

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

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



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

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

In general, in Greece, regeneration of beech is achieved by natural regeneration and there are no artificial plantations of beech, since beech seedlings' growth is limited without protection from the mother stand. Occasionally, beech is planted in State forests – seed collected from registered or local seed stands, in gaps (under shelterwood) where natural regeneration has failed. There are

no provenance trials due to the above mentioned reasons, but it is recommended to consider a well-planned program of provenance trials for local adaptation (e. g. see FRAXIGEN 2005) and adaptation to climate change. Finally, sufficient research has been done on taxonomy and genetics of beech, and this can support political decisions to ensure sustainable management and future survival of beech ecosystems.

IMPORTANCE OF BEECH IN FORESTRY CURRENTLY AND IN FORMER TIMES

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



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

SILVICULTURE, REGENERATION, FOREST MANAGEMENT

Cultivation (thinning and tending)

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

Cultivation treatments required:

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

Treatment of degraded stands

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

Natural regeneration

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

Regeneration methods

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

TYPE AND QUALITY OF WOOD AND OTHER PRODUCTS

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

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

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

The total stock volume of beech forests is 30,437,000 m³ (overbark volume) or 90.41 m³/ha average for all beech forests (but it can produce more than 10 m³/ha on good sites- rotation age 100 – 120 years) and the annual net growth (increment) is 2.8 m³/ha on average. The total stock volume of beech forest is about 50% of that of the total broadleaves or 21.1% of the total high forests. The wood production of beech stands (high forests) is lower than that of fir (*Abies* spp.) and Norway spruce (*Picea abies*). The above ground wood volume of 100-year-old beech stands (first site quality class) can reach 660 m³.ha⁻¹, whereas that of fir is 1,200 m³.ha⁻¹ and of spruce averaged at 1,160 m³.ha⁻¹. The wood volume of coppice beech stands at age of 35 years (first site quality class) is calculated to 220 m³.ha⁻¹. The net mean annual increment of beech stands (high forests) is estimated to 3.4% (Ministry of Agriculture 1992, 2000).

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

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

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

FURTHER PARTICULARITIES

In general, the beech forests in Greece produce low amount of technical wood (sawn timber) and most of it is used for fuel wood, charcoal production or wood for industrial use (e. g. particle-board, MDF, paper pulp) (SPANOS 2010). To increase technical wood production there is a need to convert all coppice and degraded stands into even-aged or uneven-aged seedling stands (high forests) aiming at production of good quality and trunks free from branches. Conversion of all coppice stands into high/seedling forests, well-planned cultivation (all stage thinnings), enrichment with conifers (e. g. *Abies* spp., *Picea abies*, *Pinus sylvestris*, *Pinus nigra*, *Pinus leucodermis*, *Pseudotsuga menziesii*, *Larix*

decidua), oaks (*Quercus* spp.) or noble hardwoods (e. g. *Acer* spp., *Prunus avium*, *Fraxinus* spp., *Castanea sativa*, *Sorbus* spp., *Juglans regia*, *Tilia* spp.) are of highest priority. Although most of the beech forests form part of the National Parks and the NATURA areas and gene conservation stands, apart from the three seed stands mentioned above, others have not yet been selected. A well-planned program for establishment of gene conservation stands is considered worthwhile as safeguard against forest fires and climate change. This is an easy but very important task, since the Forest Service in Greece has all necessary data on beech forests.

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

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ABSTRACT

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

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

DISTRIBUTION OF EUROPEAN BEECH IN HUNGARY

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

While the altitudinal occurrence is stretching from the lowlands up to 1,000 metres above sea level, the vast majority of the beech stands in Hungary can be found between 200 and 500 m. The lowest

elevation where beech occurs is extrazonal, in the upper valley of the Drava river, due to favourable microclimatic conditions (South-West Hungary, altitude ca. 120 m a. s. l.). It is very obvious that in Hungary beech is reaching the limit of its continental, warm-temperate distribution at most locations and this exposure will increase with expected climatic changes.

BEECH IN CHARACTERISTIC FOREST ASSOCIATIONS

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

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

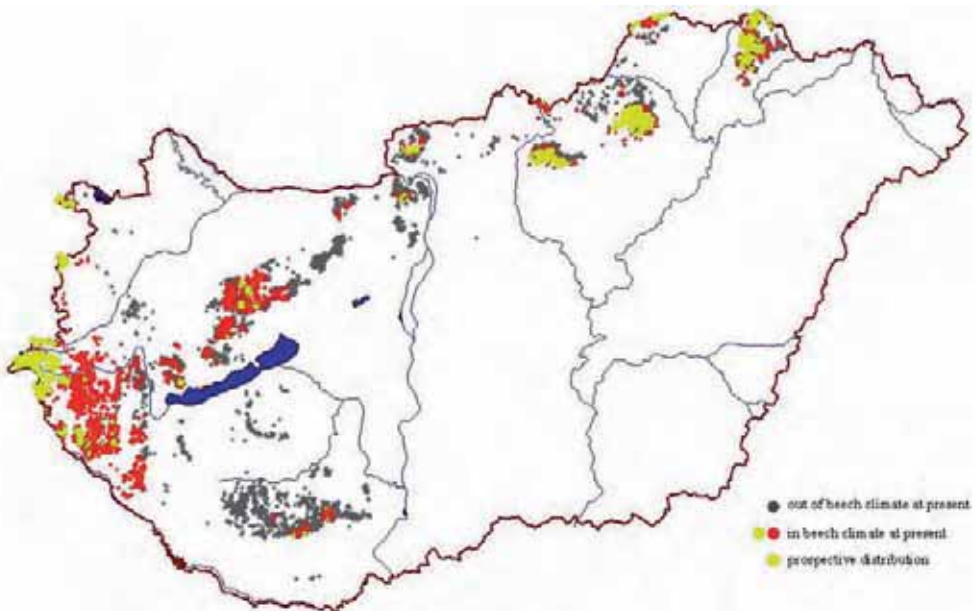


Fig. 1: Distribution of beech in Hungary based on forest inventory data. The map also shows the present and future ecological status of the species: the regions which will presumably remain in the beech climate on the long run (green), the occurrences presently in beech climate (red) and the ones already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

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

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

ECOLOGICAL CHARACTERISTICS

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

Tab. 1: Climatic parameters of zonal beech associations* (MÁTYÁS, CZIMBER 2000)

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

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

A considerable part of beech stands are situated close to the xeric limits, i. e. at the drought-related (trailing, or retreating) end of their distribution range (MÁTYÁS, NAGI, UJVÁRI-JÁRMAY 2008). The probability of climatic-zonal presence of beech can be described reliably by climatic indices such as Ellenberg's quotient (CZÚCZ, GÁLHIDY, MÁTYÁS 2009). Due to its ecological vulnerability, further indices have been developed in Hungary, using more detailed weighing of precipitation and thermal data, such as the "forest aridity index" FAI (FÜHRER, JÁRÓ 2000, FÜHRER 2010), and the "beech index" (RASZTOVITS, BERKI, MÓRICZ 2009).

GENETIC CHARACTERIZATION OF HUNGARIAN BEECH FORESTS

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

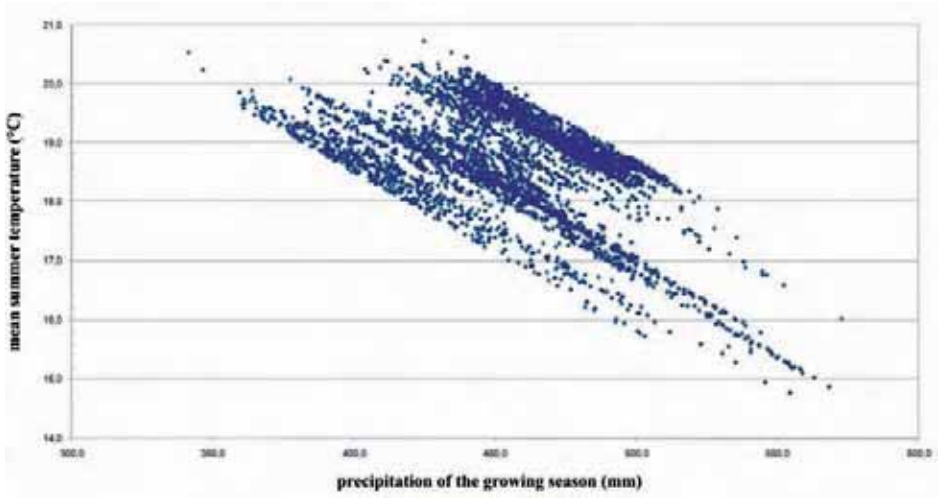


Fig. 2: Climatic envelope of beech in Hungary using climate data of the period 1975 – 2004 (design: RASZTOVITS 2009)

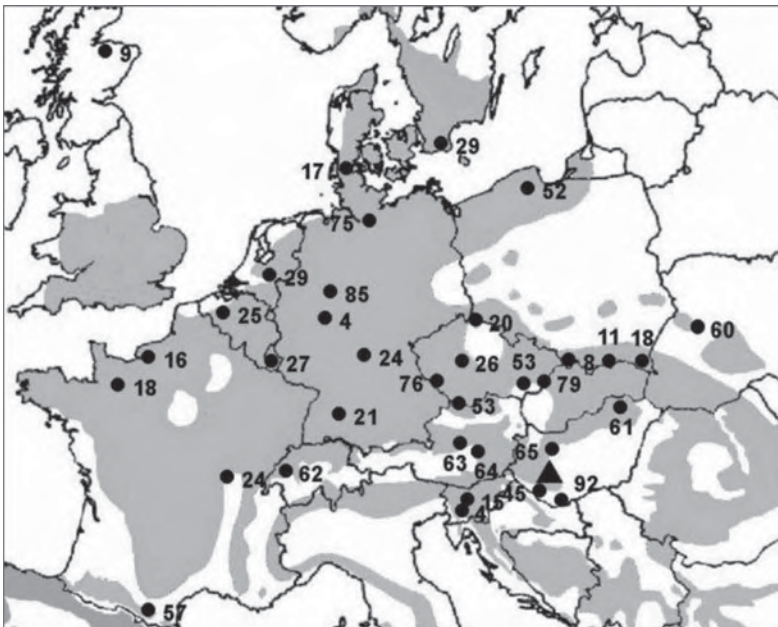


Fig. 3: Percentage of flushed plants per population in the Bucsuta beech provenance test on the 95th calendar (Julian) day in the second year after outplanting. Atlantic coast sources are late, Alpine and SE-European continental sources are early (Test location marked by triangle. Shaded: natural distribution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

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

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

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

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



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

REGISTERED SOURCES OF REPRODUCTIVE MATERIAL

Although most of the beech forests are regenerated naturally (total area was 1,112 ha in 2007), there is a significant use and trade of reproductive material which may further increase with the growing interest in drought-tolerant reproductive material. Seed sources and reproductive material production are under control of the CAO¹, detailed data are presented in Tables 2 and 3. Seed production is rhapsodic, and is strongly influenced by the weather conditions of the preceding vegetation period (MÁTYÁS 1969). Therefore often wildlings are lifted from natural regenerations (Tab. 3).

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

Note: Only 4 zones numbered in map

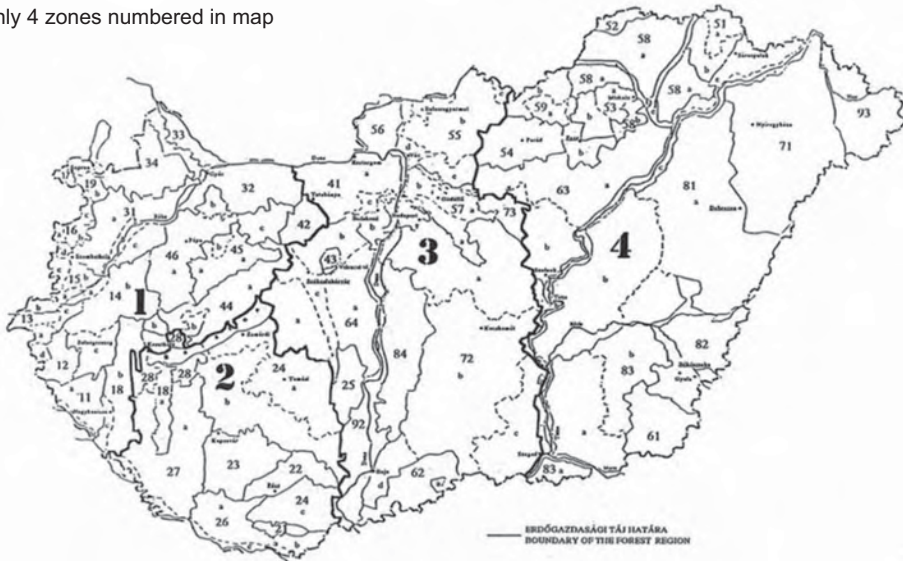


Fig. 5: The map of seed zones (provenance regions) valid for beech in Hungary (MÁTYÁS 2002)

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

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

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

¹ Central Agricultural Office, Budapest (former OMMI)

CONSERVATION OF GENETIC RESOURCES

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

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

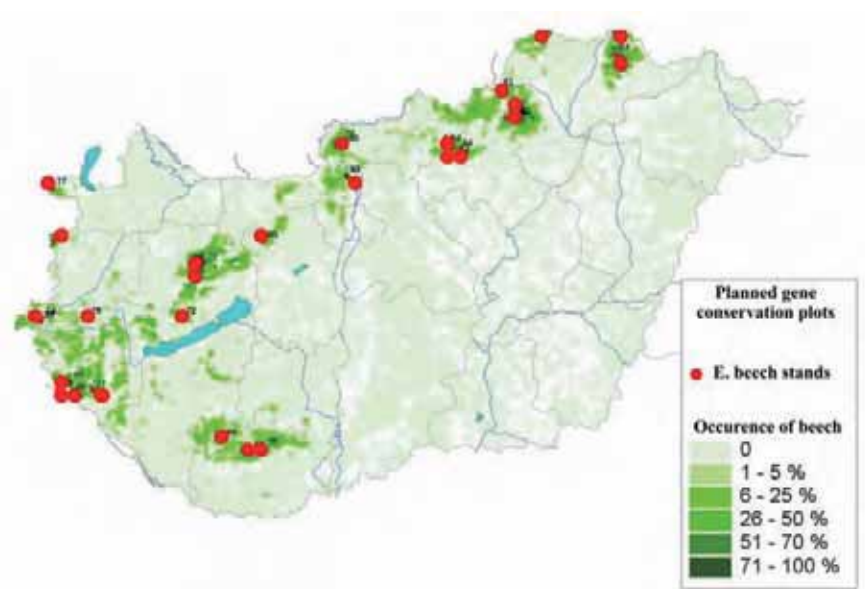


Fig. 6: Network of gene reserves of European beech in Hungary (design: NAGY 2009)

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

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

- Including exports

MAIN BEECH DISEASES AND PESTS

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

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

HEALTH AND VITALITY LOSS DUE TO CLIMATIC EXTREMES

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



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

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

In Zala County, a decline syndrome was triggered by the severe droughts of the period 2001 – 2003, in mature beech stands under regeneration, where the canopy closure was opened up recently (Fig. 7). This led to the outbreak of beech buprestid (*Agrilus viridis*). As a consequence, more than 100,000 m³ sanitary felling had to be undertaken in 2005 (GÓBER 2005). Damage of *Biscogniauxia nummularia* disease and of the beech bark beetle (*Taphrorychus bicolor*) often occurred together with the buprestid damage. On average over the last 5 years (2004 – 2008) damage by these two insect species was recorded on about 300 hectares annually (HIRKA 2008).

SILVICULTURE, FOREST MANAGEMENT

In Hungary, beech attains the culmination of its height growth increment at the age of 15 – 20 years, the diameter increment culminates – depending on crown closure – at the age of 50 – 60 years. On favourable sites it reaches 400 m³.ha⁻¹ standing volume at the age of 50, and exceeds 600 – 700 m³.ha⁻¹ at the felling age of 100 years. Compared to the total volume of Hungarian forests, the standing volume of beech represents, with 39.3 million m³, a much larger ratio (11%) than its area.

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

Annually, 500,000 m³ of beech are harvested in Hungary, so beech has an important role in Hungarian wood processing. 6 – 7% of the harvested assortment is veneer log; 35 – 40% is saw log. Low quality beech wood is used as pulp and fiber wood for HDF boards (20%) and as firewood (35 – 40%). On better sites the quality of the timber deteriorates after 100 years of age because of the development of false heartwood and other timber defects which reduce drastically the value of the timber (MOLNÁR, BARISKA 2006).

FOREST RESEARCH

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

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

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

THE FUTURE OF BEECH IN HUNGARY

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

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

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

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BEECH (*FAGUS SYLVATICA*) IN IRISH FORESTRY

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ABSTRACT

Beech (*Fagus sylvatica*) is not a native species to Ireland, but has been widely planted since the 17th century and it accounts for 1.4% of the forest tree species and 5.7% of the broadleaved forest in the Republic of Ireland. It is well adapted to the maritime climate and with a 100 to 120-year rotation it typically produces 4 to 8 m³/ha/yr on average. Beech has been, and will continue to be, an important component of broadleaved forestry in Ireland. The main concern in Ireland is to identify and source the best reproductive material for seed importation to supplement home collected sources.

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

BACKGROUND

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

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

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

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

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

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

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

SILVICULTURE AND MANAGEMENT OF BEECH IN IRELAND

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

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

Mean tree age in both public and private plantings is 44 years (Anonymous 2007). In Irish beech stands 58% of the trees are in the top layer of the canopy, with 22% in the middle and 20% in the bottom layer of the canopy. Current estimates are that there is approximately 1.7 million m³ of beech growing stock in Ireland with most of this being in public ownership.

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

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

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

Almost 80% of the beech stands are classed as producing saw logs (20 cm+), but because of down-grade, most of this material would actually only be useable as pulp (Anonymous 2007). The average growing stock for publicly owned land is 170 m³/ha while for private ownership it is 213 m³/ha for an overall average of 172 m³/ha. On average, beech stands in Ireland grow at a yield class of between 4 to 8 with perhaps a maximum of 10 m³/ha/year on a rotation length of 100 to 120 years.

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

DISEASES AND PESTS IN IRELAND

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

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

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

ECOLOGY

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

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



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

REPRODUCTIVE MATERIAL

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



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

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

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

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

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

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

CONCLUSIONS

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

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GENETIC RESOURCES OF BEECH IN ITALY

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ABSTRACT

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

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

NATURAL DISTRIBUTION AND COUNTRY DATA

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

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

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

SILVICULTURE AND FOREST MANAGEMENT

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

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

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

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

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

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

GENETICS

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

Provenance studies revealed differences in chilling needs (BAGNI et al. 1980), bud break and flushing (BORGHETTI, GIANNINI 1982), phenology, xylem embolism (BORGHETTI et al. 1993) and drought resistance (TOGNETTI, JOHNSON, MICHELOZZI 1995).

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



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

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

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

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

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

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

Using an innovative approach on fossil pollen DNA, PAFFETTI et al. (2007) demonstrated, in contrast to current knowledge based on palynological and macrofossil data, that the *F. orientalis* complex was already present during the Tyrrhenian period in what is now Venice lagoon (Italy). This finding represents a new and important insight, considering that nowadays Western Europe is not the natural area of the *Fagus orientalis* complex, and that the presence of the complex during the last interglacial period in Italy has never been hypothesized before.

The individuation of retrotransposable elements in beech (EMILIANI, PAFFETTI, GIANNINI 2009) offers an interesting insight into *F. sylvatica* genome and the possibility for the development of new markers for genetic diversity screening and for evolution studies.

A genetic linkage map of European beech was constructed according to a “two-way pseudo-testcross” mapping strategy, using a total of 312 RAPD, AFLP and SSR markers scored in 143 individuals from a F_1 full-sib family (SCALFI et al. 2004). In the same pedigree, the association with genetic markers of several quantitative traits: leaf area, leaf number and shape in two different years, specific leaf area, leaf carbon-isotope discrimination and tree height were also investigated obtaining QTLs associated with leaf traits explaining a variation between 15% and 35%.

GENETIC RESOURCES AND REPRODUCTIVE MATERIAL

The competences for legislation and transfer regulation of forest reproductive material of beech have been transferred from the Ministry to the local regions. Each region is actually discussing the situation in the “Economic Development Programme” and to date no tree seed zone or seed stands were identified by the Regional Administration as programmed in the D. L. 386/2003.

In Table 1 there are listed the seed stands that are to be included in the register as foreseen by the aforesaid Law (*italic*), the seed stands (underlined) included in the National legislation on reproductive material (D. L. 269/1973, no more in force), and seed stands from Sicily suggested by VETTORI et al. (2007) on the basis of population genetic fingerprinting (**bold**).

LUMBER AND TIMBER

The Italian National Forest Inventory (IFNC 2005) estimates a standing volume of about $1,270 \times 10^6 \text{ m}^3$ of wood (including logs and big branches) in the area of forests in the country. Beech forests give a lumber and timber supply of 240 million per m^3 , which represents 19% of the total national timber production. In term of timber quality there is a remarkable difference between wood obtained from coppice stands and wood obtained from high forest stands. The main product from coppice stands is firewood, while that from the better high forest stands, it is possible to obtain lumber suitable for industrial transformation such as rotary cutting for plywood production and sawn timber for furniture. Italian beech wood production is not sufficient, both in terms of quantity and quality, for sustaining domestic demand, especially demand coming from the plywood industry. For this reason every year, large amounts of beech timber are imported from France, former Yugoslavia and central European countries (Hungary, Romania).

HEALTH STATE

Beech forests are generally considered non-problematic with regard to their susceptibility to pathogens and insects. However, during the past decades a certain number of diseases and mortality situations have been reported (LUCHI et al. 2007). Most beech problems are concentrated in the few beech plantations present in Italy rather than in natural forests. They are generally influenced by climatic and unfavourable environmental situations. Main symptoms consist of the progressive drying of the upper parts of the crown, necrosis of leaves and branches, as well as the main stem, associated with the presence of fungus *Biscogniauxia nummularia* (BULL.) KUNTZE, an endophyte/parasite typical of stressed plants, naturally diffused in the environment. It causes cankers along the stem but also “white rot”. In general, fungi of the family Xylariaceae cause charcoal canker in the Fagaceae family (CAPRETTI et al. 2003). There is good evidence that these species occur in healthy living trees as endophytes and then become invasive under water stress conditions.

Biotic and abiotic stresses may also favour other pathogens present on the soil or on the root system as Ascomycetes fungi responsible for white root rot: *Ustulina deusta* (HOFFM.) LIND and *Xylaria polymorpha* (PERS.) GREV. Both have been found occasionally in connection with occurrence of damages by *Heterobasidion annosum* FRIES. BREF. causing beech tree decay and uprooting of trees in mixed stands with conifers (*Abies* and *Pinus* spp.) (CAPRETTI et al. 2003).

Root diseases were also locally registered, showing symptoms typical for *Phytophthora*: increased crown transparency, abnormally small and often yellowish foliage, dieback of the crown, necroses of

Tab. 1: Beech seed stands in Italy

Name of stands (region)	Lat.	Long.	Alt. (m)
<u>Molveno (Trentino-Alto Adige)</u>	46° 10'	10° 57'	1,350
<u>Millifret, Cansiglio (Veneto)</u>	46° 03'	12° 22'	1,130 – 1,500
<u>Airole, Tencione (Liguria)</u>	44° 14'	8° 07'	1,100 – 1,200
<u>Pian degli Ontani, Abetone (Toscana)</u>	44° 05'	10° 40'	1,200 – 1,400
<u>Marsigliana, Monte Amiata (Toscana)</u>	42° 53'	11° 36'	1,000 – 1,400
<u>Cappadocia, Campo Ceraso - Coste Calde (Abruzzo)</u>	42° 05'	13° 17'	1,300 – 1,400
<u>Cinquemiglia, Piano d'Albero, Serra Nicolino (Calabria)</u>	39° 23'	16° 06'	950 – 1,200
<i>Val Loana, Finero, Malesco (Lombardia)</i>	46° 06'	8° 32'	1,350
<i>Vanezzo della Soda, Val di Sella (Trento)</i>	46° 02'	11° 24'	900 – 1,000
<i>Vallesessera, Mosso S. Maria (Piemonte)</i>	45° 39'	8° 8'	900
<i>Belfè, Ala di Stura (Piemonte)</i>	45° 18'	7° 18'	1,300
<i>Consolata, Ceres, Mezzenile (Piemonte)</i>	45° 18'	7° 23'	975
<i>Richiaglio e Viù (Piemonte)</i>	45° 12'	7° 23'	1,100
<i>Cugn, Pradleves (Piemonte)</i>	44° 25'	7° 16'	1,100
<i>Colle Missignana, Villa Collemantina (Toscana)</i>	44° 21'	10° 42'	1,200
<i>Colle Melogno – Calizzano (Liguria)</i>	44° 14'	8° 12'	1,100 – 1,200
<i>Madonna d'Ardua, Chiusa di Pesio (Piemonte)</i>	44° 13'	7° 39'	1,200
<i>Terme di Valdieri, Valdieri (Piemonte)</i>	44° 12'	7° 16'	1,750
<i>Palanfré, Vernante (Piemonte)</i>	44° 11'	7° 30'	1,400
<i>La Verna, Chiusi della Verna (Toscana)</i>	43° 71'	11° 93'	1,190
<i>Val Fondillo (Abruzzo)</i>	41° 50'	13° 52'	1,200 – 1,400
Piano Battaglia, Petralia Sottana (Sicilia)	37° 52'	14° 01'	1,600 – 1,700
Mt. Soro, Lago Biviere (Sicilia)	37° 56'	14° 41'	1,600 – 1,700
Linguaglossa (Sicilia)	37° 47'	15° 02'	1,900 – 2,000

the inner bark and cambium with tarry spots on the bark surface and bleeding cankers (JUNG et al. 2005).

Other fungi, generally associated with humid and shaded environments, may also cause problems on branches and leaves of beech trees in the juvenile stage (ex. *Nectria ditissima* TUL. & C. TUL., and *Apiognomonina errabunda* /ROBERGE ex DESM./HÖHN.) (LUCHI et al. 2007).

MYTHOLOGY

In Italy many single trees or stands are recognized as folk symbols. For example in the Vallombrosa Forest there is an old beech tree which is known locally as the Holy beech of Saint John Gualbert (Patron of Foresters), founder of the Vallombrosan monastic order in the XIth century. According to the legend, the Saint, John Gualbert escaped from Florence one winter night and when he arrived in Vallombrosa he fell asleep under the beech tree. To protect the sleeping saint, the beech tree sprouted leaves and bent its branches. The Holy beech which is today growing in the Vallombrosa Forest probably dates from the XVIIIth century, and is thought to be a sprout of the original beech tree.

A very peculiarly feature of this beech tree is that every year it opens up its leaves (flushes) a few days before the other beech trees in the forest.

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

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ABSTRACT

Beech is an important broadleaved species in The Netherlands as regards to forestry and landscape. The species currently covers 3.8% (12,000 ha) of the forest area in The Netherlands. The species is mainly growing on sandy soils in the middle and eastern parts of the country. In relation to predicted changing climate beech is expected to suffer health problems in the (near) future in relation to drought as well as changing ground water tables. This combined with the fact that most beech forests are planted evokes need for (international) provenance research. Three areas with a total of 440 ha have been categorized for gene conservation and for use of forest reproductive material in the category "Source Identified Basic Material" in the National Catalogue.

Key words: European beech (*Fagus sylvatica* L.), beuk (in Dutch), genetic resources, distribution, provenance research

EUROPEAN BEECH DISTRIBUTION IN THE NETHERLANDS

European beech is considered to be an important broadleaved tree species in Dutch forestry. The majority of the beech forests are concentrated on the sandy soils in the middle and eastern parts of The Netherlands. The Dutch government intends to promote further expansion of the area planted with beech. Besides its use in forestry, beech is also used on a large scale in roadside plantings and in landscaping (amenity plantations). Beech is autochthonous in The Netherlands (Fig. 1), but through numerous imports in the past original material is very rare.

FOREST MANAGEMENT AND CHARACTERISTICS

The total forest area in The Netherlands covers 360,000 ha of which beech constitutes 3.8% with 12,000 ha (Vijfde Nederlandse Bosstatistiek 2007). The ownership of Dutch forests is 31% private; the State Forest Service manages 27% for the Ministry of Agriculture, Nature and Food Quality; 17% is owned by nature conservation agencies and the rest is owned by municipalities and other governmental organizations.

Most of the beech plantations are planted; of this an unknown amount with imported plant material. Almost all planting material came from unknown sources from abroad as well as from unknown Dutch sources. Less than 1% is considered as naturally regenerated. However, the latest opinions



Photo 1: Ede-01. Roadside plantation of beech in the category “selected basic material”

regarding reforestation favour natural regeneration generally and especially in the case of beech forests. Nowadays natural regeneration is becoming more and more popular among forest managers, and this is specifically the case with beech forests.

Dutch forests are relatively young: 52% are between 25 and 65 years of age. The standing volume of beech is 3,186,000 m³, it is about 5% of the total standing wood volume in the country. The distribution of standing wood into diameter classes for beech ranges from 10 cm to 120 cm with more than 70% of the standing wood volume in the classes from 20 to 70 (Vijfde Nederlandse Bosstatistiek 2007).

European beech in The Netherlands is mostly growing in even-aged monocultures (41.8%), but it also appears in mixtures with either conifers (17.3%) or other broadleaves (38.2%).

Natural distribution of *Fagus sylvatica* in The Netherlands

Extracted from:

Beech Forests, Rob Peters, 1997
Kluwer Academic Publishers, The Netherlands.

Houtteelt der gematigde luchtstreek Deel 1: De Houtsoorten
Dr. G. Houtzagers, 1954
N.V. Uitg.-Mij W.E.J. Tjeenk Willink, Zwolle.



Fig. 1: Natural distribution of *Fagus sylvatica* in The Netherlands

The majority of the beech forests are concentrated on the sandy soils in the middle and eastern parts of the country; 58.2% of the beech forests grow on poor sandy soils and 31.8% on rich sandy and on more loamy soils.

In relation to predicted changing climate, beech is expected to suffer health problems in the (near) future in relation to drought as well as changing ground water tables (DE VRIES 2007). Climate scenarios made by the Intergovernmental Panel on Climate Change (IPPC) predict for The Netherlands higher temperatures and more precipitation, but most of this precipitation is expected to fall outside the growing season and therefore will not directly benefit the trees. On the other hand it could mean rising ground water tables, and it is well known that beech can suffer much from both changing ground water tables and from higher temperatures. The question is to what extent beech forests can adapt to these changing situations or to what extent they are plastic enough to cope with the changes. Another possibility could be to introduce beech reproductive material from sources with comparable climates as predicted for The Netherlands in the future. Well-adapted basic material is of high importance both now and in the future. Present provenance research is carried out using Dutch provenances (KRANENBORG, JAGER, DE VRIES 2010) as well as provenances from foreign countries from several locations covering the entire distribution range of beech (KRANENBORG, DE VRIES 2001). A special reference can be made for the International beech trial established in Wageningen in 1998 that is part of a network of European international field trials network (WÜHLISCH et al. 2008).

GENETIC RESOURCES, CONSERVATION AND THE USE OF FOREST REPRODUCTIVE MATERIAL

Most of the beech plantations in The Netherlands are planted, an unknown amount with imported plant material and from unknown sources. However, inventories showed that there is still some beech forest from putative autochthonous origin. This autochthonous material is scarce, often located on private estates or nature reserves and therefore less easily accessible and the price of seeds and plants is therefore relatively high. As a result of an often negative selection in the forests owned by community (the best performing trees were harvested first) in the past it appears that the quality of trees from these rare sources did not meet the requirements in terms of forestry standards mentioned in the former EU Directive on Forest Reproductive Material (no. 66/404/EEC) (DE VRIES 1998a, b). However, the new Directive on Forest Reproductive Material (no. 1999/105/EEC) is now implemented in Dutch National Law, in the Seed and Plant Act 2005. This new Directive enables EU countries to introduce a new category "Source Identified Basic Material" (SI) in their National Catalogues of basic material. This opened new ways and possibilities for autochthonous seed sources of beech to be included in the system of certification of Forest Reproductive Material and to be used in restoration projects of original ecosystems and forests. In this category of SI to date three areas of beech forest with a total of 440 ha have been selected with the aim of gene conservation and use of this valuable original genetic material.

The Dutch List of Recommended Varieties and Provenances of Trees is issued every other five years; the latest was issued in June 2007 covering the period from 2007 to 2012. Intermediate updates are provided in the case basic material is renewed, removed or changed (KRANENBORG, JAGER, DE VRIES 2010). In the category "Selected basic material" a total of 21 stands of beech have been selected by the Board for Plant Varieties (Raad voor plantenrassen) (Anonymous 2007). The majority of these are roadside plantations. The Dutch List of Recommended Varieties and Provenances of Trees also contains a number of provenances from Germany and Belgium recommended for use in The Netherlands.

A National Policy Document of the Government of the Netherlands was introduced during the COP meeting on Biodiversity in The Hague in April 2002: "Sources of Existence: Conservation and the sustainable use of genetic diversity" (Anonymous 2002). It covers genetic resources of all kinds including agricultural and horticultural crops, animal genetic resources and forest genetic resources. The content of this document enables relevant parties to implement the conservation of forest genetic resources in different ways. To date for beech only the designation of nature reserves has taken place and no other initiatives in relation to, for instance, gene banks have been undertaken.

In relation to the EU funded project "European Information System on Forest Genetic Resources (EUFGIS)" so far one Gene Conservation Unit (GCU) has been designated for The Netherlands.

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CONSERVATION OF GENETIC RESOURCES OF EUROPEAN BEECH (*FAGUS SYLVATICA* L.) IN POLAND

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ABSTRACT

European beech stands cover 5.2% of the forest area in Poland. The most typical forest tree associations are formed at the lower forest range in the Carpathians and Sudeten Mountains in the South of Poland and at morainic landscape of Pomeranian Lake District of North Poland. In Poland beech reaches the north-eastern limit of its natural range. The growth of beech stands outside the natural beech range indicates that the species possesses a potentially much wider range. Methods are presented which are used in conservation of Polish beech genetic resources and state of research related to genetic variation as well as silvicultural problems.

Key words: European beech (*Fagus sylvatica* L.), buk zwyczajny (in Polish), distribution, genetic variation, Poland, forestry research

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

European beech stands cover 5.2% (447,500 ha) of forest area in Poland (Forests in Poland 2009). European beech belongs to the dynamic species in Pomerania and frequently supplants other forest species, mainly oak and sometimes also Scots pine. *Fagus sylvatica* forms enter woods of the lower mountain forest range in southern Poland (usually altitude 450 m a. s. l.). Its role was considerably restricted in the Sudeten Mts. due to Norway spruce promotion in the past. The most elevated locations of the species were reported from about 1,000 – 1,200 m in this mountain range. The occurrence of European beech has not been limited so strongly in the forests on the Carpathians. European beech dominating forests are especially extensive in the eastern part of this range growing there up to altitude about 1,200 m. It forms the upper forest limit in the Bieszczady Mts. European beech stands of the highest quality are located mainly in the north-western part of Poland, central part and the southern part of Poland (BORATYŃSKA, BORATYŃSKI 1990). The present genetic structure of European beech populations in Poland was formed by many different factors, not only by environmental and genetic, but also by anthropogenic factors. Very important factors that affected the gene pool were glacial epoch, the location of beech refugia, and the postglacial migration paths of the species (SZAFER 1935, HUNTLEY, BIRKS 1983, RALSKA-JASIEWICZOWA 1983, HAZLER et al. 1997). Different environmental condition resulted in a great number of ecotypes and populations that characterized various ecological requirements (DZWONKO 1990, GIERTYCH 1990). In Poland, European beech reaches the north-eastern limit of its natural range (SZAFER, PAWŁOWSKI 1972,

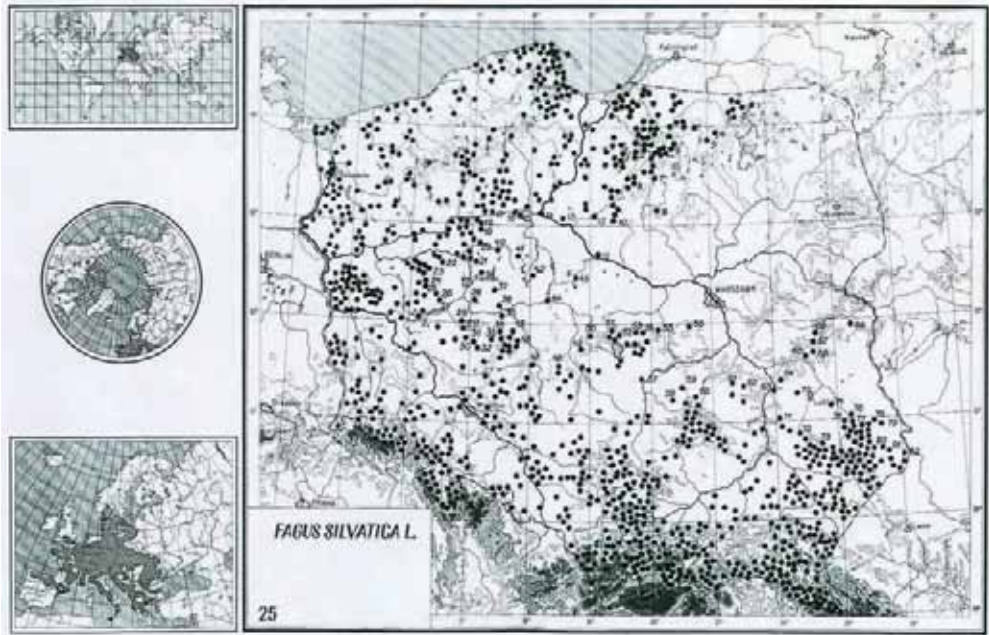


Fig. 1: Natural distribution of European beech in Poland – GOSTYŃSKA-JAKUSZEWSKA, ZIELIŃSKI (1976)

BORATYŃSKA, BORATYŃSKI 1990). The geographic range of European beech is limited by: continental climate, soil conditions, winter temperatures and air humidity (SŁAWIŃSKI 1947, JEDLIŃSKI 1953, BORATYŃSKA, BORATYŃSKI 1990). The growth of European- beech stands outside its natural limit indicates that this species possesses a potentially wider range (BRZEZIECKI 1995, TARASIUŁ 1999).

Polish European beech dominant communities were formed 2,000 years ago (ŚRODON 1990). Their typical habitats are moderate wet and good aerated soils, e. g. leached brown soils or brown soils, formed from light, medium, or heavy clays, loess soils and limestone soils (TOMANEK 1970, DZWONKO 1990).

In Poland European beech attains 40 – 47 m in height and 1.5 – 2 m in diameter. It starts to produce seeds when it is 80-year-old in stands, or when it is 50-year-old as an open-grown tree. Seeds are produced in irregular intervals – usually every 5 – 8 years (TOMANEK 1970, BORATYŃSKA, BORATYŃSKI 1990).

There are the following well characterized dominant European beech forest associations in Poland (alliance *Fagion*) – MATUSZKIEWICZ (2005):

- *Fagetum carpaticum-Luzulo-Fagenion, Luzulo-luzuloides-Fagetum* – acid beech stand, *Dentario glandulosae-Fagetum* – fertile Carpathian beech stand and *Dentario enneaphyllidis-Fagetum* – fertile Sudeten European beech stand;
- *Melico-Fagetum – Luzulo pilosae-Fagetum* – acid lowland European beech stands, *Galio-odorati-Fagetum* – fertile lowland European beech stands.

Generally, European beech forests in Poland are in good health condition. However, some problems are connected with silvicultural practice during reforestation, for example with early and late frost, and with damage by game.

The economic importance of European beech wood is high and in some regions this wood is the main product. In Poland generally coniferous species are considered as economically the most important, however European beech wood has been used both in the furniture industry and in the construction of buildings.

METHODS OF CONSERVATION OF EUROPEAN BEECH GENETIC RESOURCES

The conservation of forest genetic resources should ensure: continuity of the basic ecological processes, preservation of the forest and sustainable utilisation of ecological systems; restitution of forest in destroyed habitats; conservation of biological and genetic diversity for future generations and enhancement of natural resistance of stands. *In situ* conservation consists in passive and active measures. The former ones are related to conservation in national parks and nature reserves, the latter concern reproduction of seed stands in managed forests, which is regulated by internal state forest service law. The program for the preservation of genetic resources of forest trees (among others European beech) in Poland for 1991 – 2010 (MATRAS et al. 1993) has just ended. In the first step, 33 gene reserves with a total area of 797 ha were included in the program of forest genetic variability conservation (State Forest and National Parks area). 553 European beech plus trees were also selected in State Forest Regional Directorate (MATRAS 2005). The next steps of active European beech stand conservation is progeny testing (field experiments) of selected populations, followed by plus tree selection, and establishment of seed orchards in order to determine their genetic value and breeding utilisation as potential forest reproductive material – this will also involve using molecular genetics methods.

As an integral part of the program of forest gene resources conservation, there has been Forest Regionalization for seeds and seedlings (Government Decree 2004) undertaken. The principles of Forest Reproductive Material (FRM) movement into controlled directions are intended to reach the following goals: to promote the valuable forest tree populations and enlarge the genetic diversity of the species in those areas, where the local resources of reproductive material are insufficient; to increase the forest sustainability and silvicultural targets (obtaining high quality and quantity production) through the use of the tree populations that suit best the local site natural conditions, to preserve the genetic diversity of mountain populations and their adaptation to particular elevations zone – six zones were distinguished. Among the total of 91 seed regions, 68 European beech regions of provenance were distinguished in Poland where beech occurred. In some of these seed regions the species occurs as admixture by single individuals or only as shrub layer.

The next program of forest genetic resources conservation and forest tree improvement (2011 – 2035) will focus on the problem of global climate changes for example warming effect and water stress (FONDER 2005).

Methods of seed storage (SUSZKA 1990) elaborated in Poland facilitate the sowing of seeds of European beech up to five years after harvesting. There are three seed storage houses in Poland: in Dukla in the Carpathians, in Białogard in the Pomeranian Lake District and in the Gene Bank built in the Sudeten Mountains at Kostrzyca. Storage period of seeds in traditional way does not allow

a long enough period for regeneration of the best ecotypes and populations. New technology enables storage of seeds, germs and parts of plants for up to 30 years in liquid nitrogen. This method will help to protect seeds, especially in regions characterized by low European beech phenotype plasticity and seed productivity. Long-time storage of seeds is a complementary method for establishing *ex situ* gene conservation stands.

RESEARCH ACTIVITIES RELATED TO GENETIC RESOURCES OF EUROPEAN BEECH

The first European beech experiment representing 11 Polish provenances was established in 1967 (RZEZNIK 1976, 1990). Six parallel provenance field trials were established. In this experiment two ecotypes of European beech were distinguished: mountain and lowland. Afterwards the provenance experiment with 45 populations of European beech was established with six trials in the 1992/1995 series (BARZDAJN 2002, MATRAS et al. 2005). Adaptive characteristics (survival and growth) and phenology (flushing and growth cessation) were analyzed. Among European beech populations in Poland, populations of high plasticity were selected, well adapted to different sites like Kwidzyn, Wipowo and Lezajsk provenances. Provenances which originate from places where European beech was not widely found were characterized by relatively low survival and slow growth rate of forest cultures (Karnieszewice, Lipusz). Flushing revealed great differentiation and two phenological forms were distinguished – late form (Pomeranian region) and early form (southern part of Poland). Cessation characteristics did not show any clear trends. In this experiment genetic variability of mother stands and progeny were also compared using progeny studied at the experimental plot in Bystrzyca Klodzka. Statistical analyses showed high genotype \times environment interactions for most of the studied silvicultural features, as well as varying plasticity of populations. Biochemical studies (isozyme and RAPD markers) revealed that genetic variation of parent populations confirms the results of phenotypically based assessments to a significant degree. Provenance Kwidzyn (Forest Directory Kwidzyn, forestry Polno) was proposed to be certified as the national standard population according to its high plasticity value and silvicultural characteristics. Regional European beech standards were chosen there e. g. in Forest Districts Gryfino, Milicz, Zdroje, Łosie (SABOR et al. 2004).

Isoenzyme analysis showed (SUŁKOWSKA 2002, GÖMÖRY et al. 2003): high genetic diversity of beech in Poland, similar to other neighbouring European populations, slight decrease of average number of alleles per locus and level of differentiation towards the north of the natural range limit, which generally confirms the migration paths after glaciations but it is not the basis to distinguish geographic regions.

Recently, population differentiation of nine European beech provenances from selected stands and their progeny for selected genetic parameters and on the basis of soil characteristics of their habitats were studied (SUŁKOWSKA, KOWALCZYK, PRZYBYLSKI 2008). According to phytosociological characteristics following plant associations were classified: fertile Pomeranian beech – *Galio-odorati-Fagetum* (Gryfino i Kartuzy), fertile Carpathian beech – *Dentario glandulosae-Fagetum* (Lutowiska i Łosie), acid beech – *Luzulo-luzuloides-Fagetum* (Miechów, Suchedniów, Tomaszów, Zwierzyniec), fertile Sudeten beech – *Dentario enneaphyllidis-Fagetum* (Zdroje). The analyzed selected stands are practically homogenous related to site conditions which reflect ecological index values (ZARZYCKI et al. 2002): light – semi-shade, thermic – temperate cool climate conditions, edaphic – clay-sandy or sandy-clay soils and regarding to humus mineral-humus soils. There were only differences determining moisture and acid factors of the soils. The stem and shape of the crown of most of the

stands were of good quality. The genetic analyses were performed using isoenzyme electrophoresis and DNA-RAPD methods. The importance of very high intra-population diversity was shown, as well as high variation of investigated populations. Genetic diversity and differentiation of European beech populations and their progeny are correlated with the level of mineral ions important for growth and functions of plants. European beech provenances originating from fertile habitats with higher soil pH were characterized also by higher differentiation value of genetic parameters, as e. g. Miechów provenance pH of the soil 5.51 (0 – 20 cm layer) up to 7.05 (20 – 40 cm layer) – measured in H₂O. For the mother stand of provenance Miechów (South Poland) average number of 2.3 alleles per locus (isoenzyme markers) was estimated, while percentage of polymorphic loci was 77.8% and for progeny 2.6 and 88.9%, respectively. The lowest average number of alleles per locus (1.9) was found for Zwierzyniec mother stand (south-east Poland natural range border), characterized by percentage of polymorphic 66.7% and for the progeny stand 2.3 and 66.7%, respectively. The mother stand of Kartuzy population (north Poland) was also characterized by low value of analyzed genetic parameters: average number of alleles per locus 1.9, with percentage of polymorphism 66.7%, but for progeny stands the values were higher at 2.4 and 88.9%, respectively. The Kartuzy population was characterized by the lowest pH of the soil value – 4.35 (0 – 20 cm layer) up to 4.52 (20 – 40 cm layer) – measured in H₂O. On the basis of DNA-RAPD markers a slight decrease of average number of alleles per locus and level of differentiation towards the north of Poland was observed, but this trend was not so clear. The results pointed at the ecotype character of genetic variation of European beech related probably with site differentiation. So, use of local European beech ecotypes, taking into account its plasticity seems to be the best advice to obtain success in forest management.

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