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 *Hylocoetus dermestoides*). In the late phase fungi like *Fomes fomentarius* and other fungi causing white rottenness are damaging the trees until they die off. This complex disease has already been described in the west of Germany (Eifel, Hunsrück and Saarland) years ago and is still expanding. Besides this, the small beech bark beetle (*Taphrorychus bicolor*) has damaged the cambium after heavy storms in south-west Germany. Browsing by deer is critical; during the time of regeneration and protective fencing is necessary.

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

SILVICULTURE AND MANAGEMENT

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

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

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

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

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

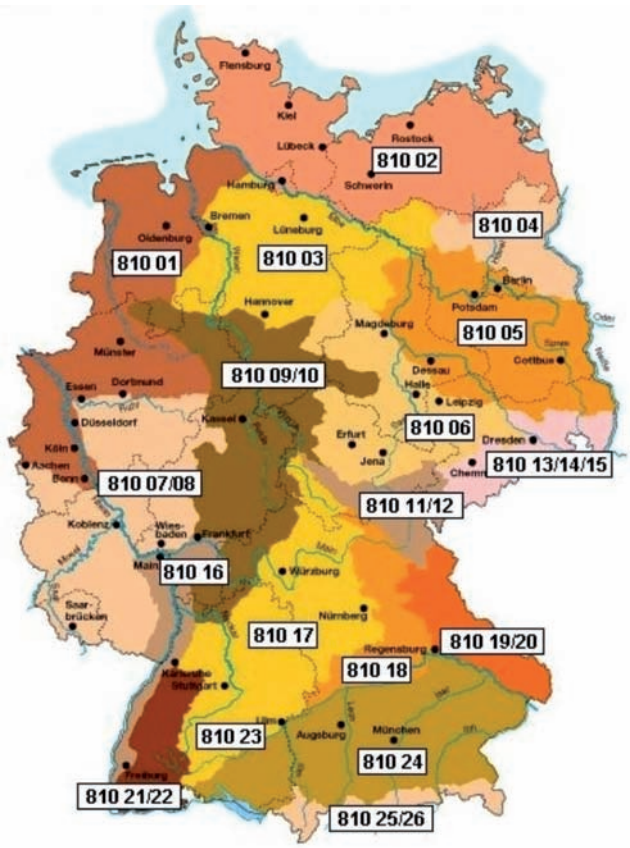

Fig. 1: The 26 regions of provenance of European beech in Germany

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

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

REGENERATION AND SEED PROCUREMENT

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

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

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

ECONOMICS

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

As shown above, the standing volume of beech wood is high, especially in stands of high age class. Thus, a total of 10 million m^3/year was harvested, of which about 7.4 million m^3/year was used for industry (pulp, paper, chipboard) or domestic fuel and 2.6 million m^3/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 m^3 and for sawn timber 384 thousand m^3. The figures for import are 37 thousand m^3 raw wood and 56 thousand m^3 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 €/m^3 and for industrial wood between 23 and 30 €/m^3 in the years 1995 to 2006. On average the forwarding cost to the forest roadside amounted to 26 €/m^3, the corresponding prices came up to 48 €/m^3 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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