Silviculture of Broadleaved Species in Western Germany

Hans-Jürgen Otto

Ministry for Resources, Land Use and Forestry,
Hanover, Germany.

1. *Natural Area of Oak and Beech*

About two thousand years ago, beech (Fagus silvatica) and oak forests (Quercus petraea and Quercus robur) formed the greater part of all forested land in Middle Europe, which was about 95% of the total land area.

Tacitus has told us that the Roman legions had to traverse large and broadleaved wildernesses with nearly no understory. This must have been the typical old beech stands which would tolerate no undergrowth under their shadowy canopy.

Indeed, the natural area of both European and sessile oak and of beech, covers all of central Europe.

The oak species can be found — in the northern Harz Mountains up to an elevation of about 500 to 600m. In Switzerland sometimes it reaches over 1000m and in the Caucasus and Pyrenees Mountains to 1500m. Typical sessile oak regions are considered to be located between sea level and 400 to 600m, going higher when there is a variation of local climates towards warmer and drier conditions. European oak will not go as high. Sessile oak will not follow European oak into the inner continent, where winters are long and hard. Its natural border to the east can be established as an average January temperature of –5° Celsius.

In climatical adaptation, beech seems to be very similar to sessile oak, but it does not extend its area west of Scotland and is lacking in Ireland. In its northern area it is present at sea level. In the Alps and the Carpathians an altitudinal border begins to form, which goes higher when advancing southwards. On the southern slope of the Alps this border is at about 950m, on Corsica 800m, in the Appennino Mountains at 1200m. This shows that a moderately humid, cool and not too dry and hot climate suits beech.

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The natural phytosocial associations of the broadleaved species show a vast variety of combinations. In central Europe we distinguish in a larger scale.

— limestone beech forests, associated with maple (*Acer pseudoplantanus*), ash (*Fraxinus excelsior*), limetree (*Tilia cordata* and *T. platyphyllos*), elm (*Ulmus glabra* and *U. laevis*), wild service tree (*Sorbus torminalis*) and European cherry (Prunus avium).
— brown forest soil beech forests, associated with maple, oak, spruce and a more grassy soil vegetation.
— European oak — hornbeam forests of low elevation sites on strong loams and clays, associated with limetree, maple and ash.
— Acid-brown to podsolic forest soils of sessile and European oak forests; on wetter sites dominance of European oak, on drier and warmer sites dominance of sessile oak, both associated with birch and aspen and on warmer sites with beech and hornbeam.

The classical altitudinal forest vegetation in northern Germany is (example of the Harz Mountains).

— a Querco — Carpinetum to an elevation of 300m;
— a Dentario — Fagetum on rich sites (*Dentario bulbifera*) between 300 and 600/800m elevation.
— a Luzulo — Fagetum on poorer sites (*Luzula albida*) between 300 and 600/800m elevation;
— a Fago — Picetum between 500 to 700/900m elevation, alternating with a Picea — Fagetum;
— a pure Picetum — hercynicum higher than 800/900m elevation.

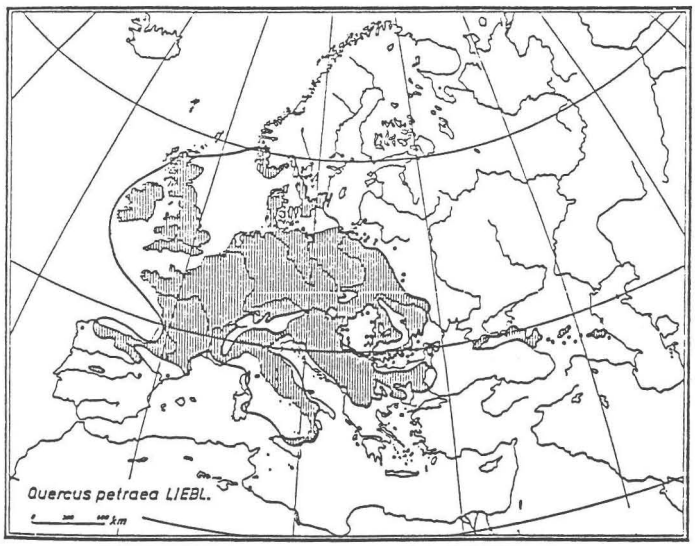


Fig. 1: Natural Area of Sessile Oak (MEUSEL 1965).

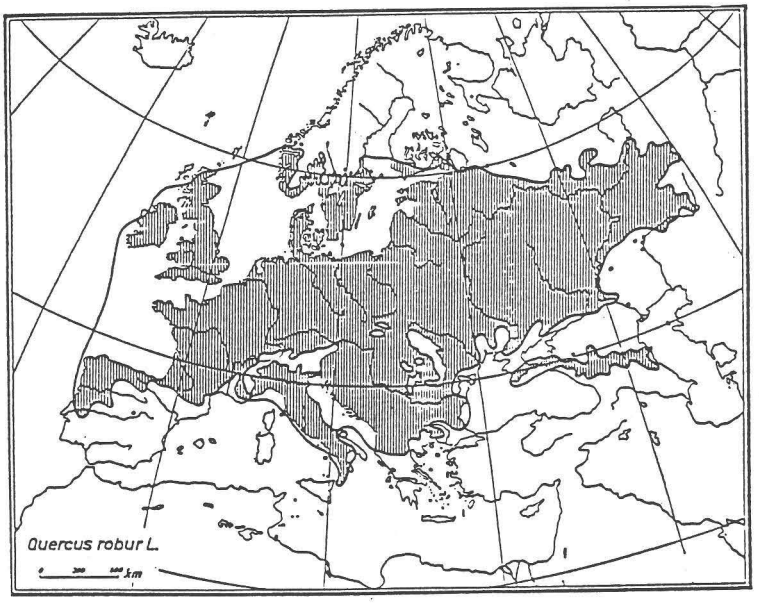


Fig. 2: Natural Area of European Oak (MEUSEL 1965).

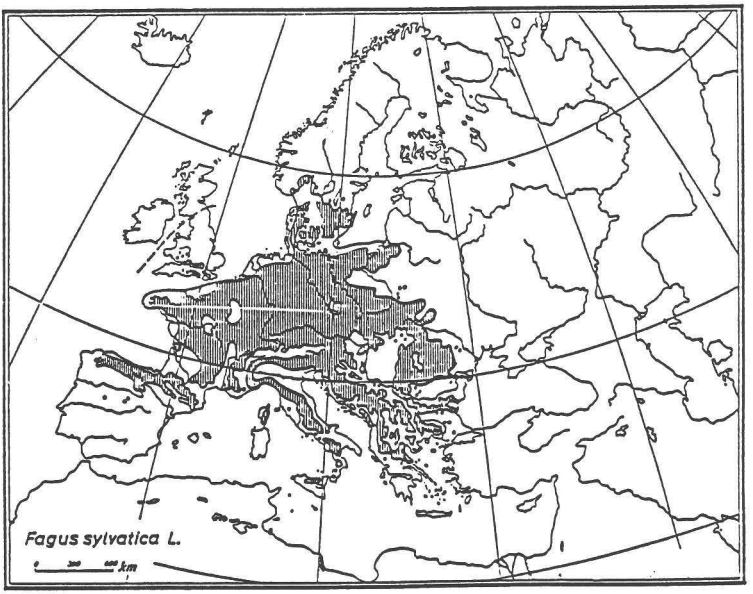


Fig. 3: Natural Area of Beech (MEUSEL 1965).

2. *Silvicultural and Economic Interest of German Forestry in Broadleaved Species*

To obtain an impression of the silvicultural and forest economic trends in West Germany an example from Lower Saxony will be considered (Fig 4).

— The vertical line shows the area of clearcut between 1975 and 1995, separating the main economic forest species; the horizontal line indicates the species used in reforestation.
— It can be seen that 1400 ha of oak is to be clearcut between 1975 and 1995. However, over the same time period it is planned to replace other species at clearfelling with oak, to reach a total of 10,450 ha of oak. Beech will be replaced by oak on 300 ha, but the total area of beech will remain about the same, being preferred to spruce and pine where appropriate.
— The area under spruce and pine will be decreased substantially. Douglas fir is the only coniferous species which will have its area increased, rising from 850 ha to 8.900 ha.

Why are we doing this? The reasons for doing so are as follows:

(1) The distribution of spruce and pine are the result of three historical conditions.

— Scots pine (P. sylvestris) was used 150 years ago as a pioneer species on devastated heathland in northern Germany. These soils were strongly acid. It was hoped that such planting would result in site improvement through the hundred year accumulation of humus. This would allow a wider selection of more valuable and productive species to be planted on these improved soils.
— The existing vast area of Norway spruce is the result of this species economic association with mining industries in the Harz Mountains.
— Theoretical forest net interest calculations based on the expectation of an optimal soil rent and normal forest age class distribution led to a consequent expansion of fast growing coniferous species.

However, over 200 years of experience in middle European forestry shows that this expectation has proved to be fundamentally wrong.

From this long experience it is now clear that the abiotic risks of stormthrow, snowbreak, wildlife, and the biotic risks of beetles and other insect or fungal attacks must be seriously considered, along with mistakes in forest management and incorrect choice of species.

Figure 4: Clearcut and reforestation in ha between 1975 and 1995 — Lower Saxonian State Forests.

cut \ replanted		oak	beech	other hardwoods	softwoods	spruce	Douglas fir	pine	larch
oak	1400	1400	—	—	—	—	—	—	—
beech	1300	300	800	—	—	100	100	—	—
other hardwoods	50	—	—	50	—	—	—	—	—
softwoods	1100	300	—	100	300	—	—	400	—
spruce	6500	2600	200	—	—	1700	1000	1000	—
Douglas fir	850	150	—	—	—	100	600	—	—
pine	29500	5600	400	—	200	1200	7100	14500	500
larch	300	100	—	—	—	—	100	—	100
	41000	10450	1400	150	500	3100	8900	15900	600

Table 1: *Species area changes in Lower Saxonian state forests from 1960 to 1986.*

	Oak	from 27,000 ha (1960) to 32,000 ha (1986)
	Beech	from 72,000 ha (1960) to 65,000 ha (1986)
	Other Hardwoods	from 4,000 ha (1960) to 7,000 ha (1986)
	Softwoods	from 8,000 ha (1960) to 11,000 ha (1986)
	All broadleaved	from 111,000 ha (1960) to 115,000 ha (1986)
	Spruce+Douglas fir	from 107,000 ha (1969) to 111,000 ha (1986) (86:9000 ha Douglas fir)
	Pine and larch	from 87,000 ha (1960) to 90,000 ha (1986) (86:15000 ha larch
	All coniferous	from 194,000 ha (1986) to 201,000 ha (1986)

Table 2: *The standing volume in 1986 in these forests in* /m^3

	Oak	Beech	Other Hard	Soft-Wood	Broad-Leaf/ All	Spruce/ Douglas Fir	Pine/ Larch	Conif./	All Species
MI0 m^3	6.3	17.1	0.9	1.0	23.9	23.9	12.0	35.9	61.2
M^3ha	197	263	129	91	220	215	133	179	194

Permanent periodical losses of valuable timber may be accentuated by these risks and when species are planted on wrong sites or when thinnings are not executed at the right period or when too dense monocultures are maintained over a too long period. These dangers, even under the best forest management, still remain a non-calculable possibility.

The dramatically different natural evolution of broadleaved species and coniferous species is seen in Figure 5. As a matter of fact throughout Germany, logging of valuable coniferous species, accumulated over only a 100-150 year rotation period, will not be able to pay the necessary investment in new plantations and expensive thinnings. Therefore, we have to conclude that avoiding risks is the soul of silviculture and of forest economics.

This therefore, leads us to consider the broadleaf option. As oak and beech constitute the main species in natural forests in Central Europe they are well adapted to these site conditions. The correct choice of site is the first thing that is required to avoid risk. Good site mapping will show the possibilities of all the different species choices. In other words the right tree for the right soil. This makes sense ecologically and economically.

In a worldwide market competition we are convinced that no pulpwood, and comparable quick growing product, will be able to successfully compete with the production of such material from other regions where the growth conditions — climate — are much more favourable.

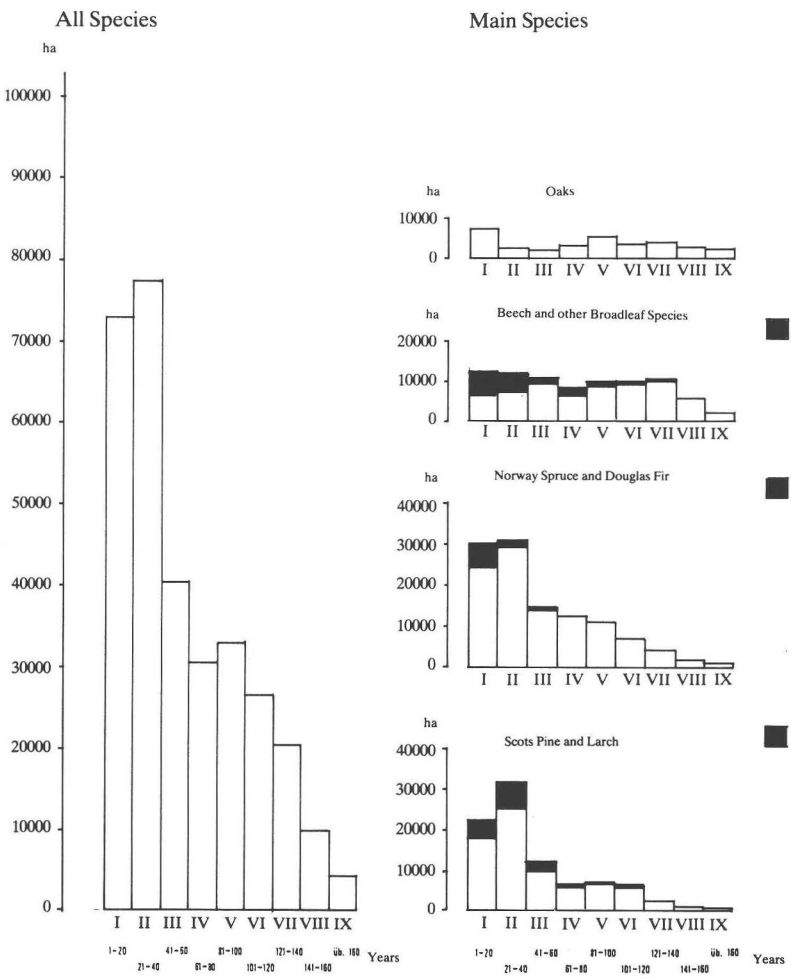
Our best sliced veneer oak, produced on a rotation of about 240 years will cost 10,000-15,000 DM/m^3. Such timber, which is not thrown too early by periodic storms, does exist in our forests; it is not simply a paper calculation. Beech timber, although not as valuable, is also present in old stands.

The consequences of these facts and the results of site mapping is that, using the same example of Lower Saxony, the following modification can be outlined (Table 1) while the standing volume in 1986 in these forests is shown in Table 2.

In the Federal Republic of Germany, species distribution on a total forest area of 7,400,000 ha (corresponding to 29.7% of the national territory) is as follows:

Oak	592,000 ha.	= 8% of the forest area
Beech and other broadleaf	1,7000,000 ha.	= 23% of the forest area
Norway spruce and other	3,108,000 ha.	= 42% of the forest area
Scotch pine and larch	2,000,000 ha.	= 27% of the forest area

Figure 5: *Age Classes in Lower Saxonian State Forests 1984.*



The most valuable sessile oak forests are to be found in the centre of the Republic in the Spessart Mountains in a rather warm mountain climate influenced by the warm air of the Rhine valley, and in the Pfälzerwald in southwestern Germany. Good oak forests of both species can also be seen in the Steigerwald in Bavaria and in Lower Saxony.

The best beech stands are located in the Lower Saxonian Mountains and the Hesse Mountains in an atlantic climatic pattern.

3. *Silvicultural Properties of Oaks and Beech*

Sessile oak, and European oak, are light-demanding species with a moderate tendency of sessile oak to tolerate some more shade in its early youth. The consequence of this is low competition tolerance in the successional pattern. The canopy of both oaks can easily be influenced by side competition of other crowns, and a too dense canopy will cause a formation of water-sprouts on the stems of cramped crowns, which devalues timber quality for veneer.

Both oaks are easily drawn up in the nursery phase with few problems. Both species have a high survival rate when planted out because even young plants tolerate a lot of drought. There are only a few risks in plantations: moderate insect and fungus diseases, and perhaps bud damage by hares and roedeer, so that plantations need to be fenced. The most irritating damage is caused by late frosts which can heavily attack young plantations up to ten years of age. But these late frost injuries never kill a young oak, because a general property of all oaks are the sleeping buds and regular prolepsis sprouting. So black frozen leaves will be immediately replaced by the sprouting of sleeping buds during the same vegetation period.

Both oaks are characterised by a long life duration. Thick timber can be harvested at an age of 160 to 180 years, but over 300 years the wood will get no rot and can go on growing in dimension and to a total height of some 35m in the Spessart, and about 30m in northern Germany. This long life duration means a high flexibility in rotation times and a timber harvest corresponding to the best market conditions.

In contrast, beech is one of the most shade-tolerant and superstrong species in competition. It is a latecomer in the successional pattern, and a climax species which will win every competition with other species. Only its vitality will diminish under cooler high mountain conditions, where it can be suppressed by Norway spruce.

The greatest risks to young beech are late frosts, mice, hare and roedeer attacks. Young seedlings can tolerate a long shadow

condition. The sprouting may be moderate in an early age. Best growth will begin at an age of only 60 years and continue until an age of about 150 years. The crowns of beech can respond readily to any opening; so dense stands can grow again in diameter even after very late thinnings.

The rotation time cannot be modified in the same way as described with oaks, because the natural life duration of beech is restricted to about 200 years. Beyond 160 years white rot quickly devalues the timber, so that a rotation time betime 140 and 160 years seems to be the best.

Beech is a good mixture species. It is a stabilising factor in spruce and pine stands and is necessary in oak stands to avoid sprouting from sleeping buds. With beech stands can be mixed ash, maple, silver fir, spruce, Douglas fir, European and Japanese larch and many others, but all mixtures need help by thinnings against the competitive strength of beech. The total height of beech stands may reach 40m.

4. *Silvicultural Techniques*

4.1. *Sessile and European Oak*

4.1.1. *Site Choice:* A good sessile oak site is a sandy loam with a regular moderate water supply, but with no stagnant water. Nutrition can be at a low level, soil reaction between pH 3.5 and 5.0 (KC1 analysis). European oak tolerates heavier loams and clays and is a species of groundwater soils of the vast river plains, but also tolerates a low nutrition and pH grades.

4.1.2. *Regeneration:* Because of low temperatures natural regeneration of oaks is an exception in Germany — in contrast to French conditions. To obtain a natural regeneration it is necessary to clearcut the old stand the same winter because the seedlings need full light and warmth in the following spring.

The normal procedure is as follows: Clearcut. Take off all brush. Plough the soil totally in the whole area, or in plots or in furrow planting strips. Use plant material of 2/0, 1/2 or 2/1. Planting rate should be at 7,000 to 10,000 plants per hectare with an additional 2,000 plants per hectare of beech, hornbeam or limetree in mixture.

In southern Germany, with richer seed crops, sowing methods are more usual, sometimes a soil preparation has to be executed, but not always. Most frequently, strips are opened at a spacement of 1.2 to 1.5m with 15 to 20 acorns sown per metre run. The acorn must fall into the mineral soil. In plantation work the same spacing is adopted to facilitate cleaning later.

4.1.3. *Cleaning Operations in Young Stands:* Bad stem form as well as competition from birch, pine and softwood vegetation have to be controlled. Sometimes the grassy ground vegetation must be controlled.

4.1.4. *First Thinnings:* The first thinnings begin at an age of about 25 to 40 years with dominant heights of about 8m. These first thinnings must be very moderate, because the natural differentiation still has to express itself. In a negative selection bad stem forms are eliminated. The mixture is held at an understory position.

4.1.5. *Following Thinnings:* The young stand thinnings end at an age of 50 years. Until now, a well thinned stand has to be equalised to a good spacement of future trees.

4.1.6. *Main Thinnings:* They begin at an age of about 50 years (dominant height 14 to 18m) with moderate but repeated interventions during

50 and 80 years, two times per ten years;
80 and 100 years, one time per ten years;
100 and 150 years, one to 0 times per ten years.

In the first operation, 140 to 300 future trees will be selected at a spacement of 9 to 6m in the dominant canopy. The thinning method has to be principally a thinning from above to guarantee a good permanent development of the crowns. With the same operation, the beech or hornbeam or limetree understory usually develops, but should not be allowed to compete with the crown of the future trees.

In Bavaria (Spessart) no future trees are selected, but an individual estimation of the best trees takes place at every thinning.

4.1.7. *Old Stand Thinnings:* In old stands the crowns of the future trees can no longer be influenced by thinnings. So the thinnings are confined to the elimination of ill trees, competing understory beech and some good oak stems as an early harvest.

4.2. *Beech*

4.2.1. *Site Choice:* A good beech site is on limestone with the exception of too-dry rendzina — soils, good mild loams with a pH over 4.0; and near the German coast, also loamy sands. Beech roots will not tolerate bad aeration and stagnant or ground water.

4.2.2. *Regeneration:* Beech is the classical species of natural regeneration in Germany. Occurrence of good seed crops is every

Figure 6: *Net Profit Calculation for Sessile and European Oak* (Lower Saxonian State Forest, RIPKEN 1987).

		Sessile Oak			European Oak		
Rotation Time/Years		200			180		
Yield/^{3} per Hectare and Year		4	5	6	4	5	6
A. **Financial Returns (without harvesting costs)**							
1. Value at 200/180 years	**DM/ha**	**82.360**	**97.550**	**111.380**	**51.400**	**64.900**	**76.650**
	DM/year/ha	412	488	557	286	361	426
2. Returns of Thinnings	**% of 1**	**40**	**50**	**60**	**30**	**40**	**50**
	DM/year/ha	165	244	334	86	144	213
Total of Financial Returns in DM per Hectare and Year		577	732	891	372	505	639
B. **Financial Expenses**							
1. Regeneration	**DM/ha**	**17.000**	**17.000**	**17.000**	**17.000**	**17.000**	**17.000**
	DM/year/ha	85	85	85	94	94	94
2. Cleanings (2 x rotat. time)	**DM/ha**	**1.400**	**1.400**	**1.400**	**1.500**	**1.500**	**1.500**
	DM/year/ha	7	7	7	8	8	8

3. Fertilising (1 x rotat. time)	**DM/ha** DM/year/ha	**400** 2	**400** 2	**400** 2	**400** 2	**400** 2	**400** 2
4. Insect Control	**DM/ha** DM/year/ha	— 5	— 5	— 5	— 5	— 5	— 5
5. Protection against Game Species (without fences)	**DM/ha** DM/year/ha	— 8	— 8	— 8	— 8	— 8	— 8
6. Other Control Measures	**DM/ha** DM/year/ha	— 1	— 1	— 1	— 1	— 1	— 1
7. Road Construction	**DM/ha** DM/year/ha	— 30	— 30	— 30	— 30	— 30	— 30
8. Other Expenses	**DM/ha** DM/year/ha	— 22	— 22	— 22	— 22	— 22	— 22
9. Administrative Expenses	DM/year/ha	265	265	265	265	265	265
Total of Financial Expenses in DM per Hectare and Year		425	425	425	435	435	435
Net Profit in DM per Hectare and Year		152	307	466	–63	70	204

7 to 15 years. At an age of 120/130 years a seed harvesting cut is executed when a good crop appears. Normally the soil will be moderately cultivated to ensure adequate covering of seed. After germination and first development of the young seedlings, so-called lighting-cuts will follow every 3 to 7 years to open the old stands. This is very necessary because old crowns of beech quickly close again after thinnings. Twenty to twenty five years after the sowing-cut a final-cut will end the operation. This method — a very traditional one — has a major disadvantage. It gives no chance for the development of mixture species (mainly ash and maple), which nevertheless are very welcome, because they can increase considerably the economic value of the stands.

So modern tendencies are to lengthen the regeneration period over 40 years to open the canopies in an irregular manner with a group selection to remove bad stem forms. In the openings, so created, the fast but light-demanding mixture species can develop with an advance of 10 to 20 years before the beech regeneration will come. The management for valuable mixture trees is then much easier.

4.2.3. *Cleaning Operations in Young Stands:* Young beech may be heavily attacked by mice and game species. So grass control, even by herbicides, is necessary. Softwoods have to be taken out, a fence built and trespassing roedeer shot.

4.2.4. *First Thinnings:* In beech stands, strong competition has to work a long time. For up to 40 years (dominant height of about 15m) thinnings will hardly take place in order to favour the best stems and natural pruning. Only very bad stem forms are removed.

4.2.5. *Main Thinnings:* From 15 to 20m in height (corresponding to 40 to 60/70 years) the dense closure of the stand is abandoned. 200 to 400 future trees will be selected with at least 5m of branch-free height. Two times per ten years, up to an age of 120 years, thinnings will be carried out to help the main crowns of the best formed stems. From 120 to 150 years these thinnings pass to regeneration cuts as described. The most important difference in old beech thinnings compared with oak thinnings is the possibility of increasing diameter development even at an old age of beech. In every thinning, consideration to assist mixture species is absolutely necessary in old stands.

Figure 7: *Net Profit Calculation for Beech* (Lower Saxonian State Forest, RIPKEN 1984).

		Beech		
Rotation Time/Years		120	135	150
Yield/m^3 per Hectare and Year		8	8	8
A. **Financial Returns (without harvesting costs)**				
1. Timber Price/m^3 at Rotat. Time/DM		250	274	345
2. Average Price of Thinning Material/m^3/DM		145	184	163
Total of Financial Returns in DM per Hectare and Year		395	458	508
B. **Financial Expenses**				
1. Regeneration	DM/year/ha	42	37	33
2. Cleanings	DM/year/ha	20	18	16
3. Disease Control	DM/year/ha	13	13	13
4. Road Construction	DM/year/ha	40	40	40
5. Other Expenses	DM/year/ha	24	24	24
6. Administrative Expenses	DM/year/ha	200	200	200
Total of Financial Expenses in DM per Hectare and Year		339	332	326
Net Profit in DM per Hectare and Year		56	126	182

5. *Financial Returns*

The financial returns of oaks and beeches are shown in Figs 6 and 7. They are based on a net profit calculation, which can be explained as follows:

— For sessile oak have been calculated different models for a production of 4.5, and 6m³ of wood per hectare per year and expecting a rotation time of 200 years;
— For European oak the same conditions have been conceived, but a shorter rotation time adopted;
— For sessile oak a percentage of 10% of very valuable timber (veneer and others) has been estimated, 5% for European oak;
— For beech three current rotation times with a high yield class (8m³ per year per hectare) have been calculated, but based on prices and costs of 1984.

The results can be commented upon as follows:

— The longer the rotation time the better will be the net profit. This is the result of thicker timber with lower harvesting costs and the distribution of all investment costs over a longer period.
— The lower the yield class, the less one can expect a reasonable return on oak production.
— As a matter of fact, the returns are influenced largely by the fluctuations of market prices, and the increase of costs — mainly the administrative expenses — which can hardly be influenced.

Final Remarks

The outlined silvicultural techniques can only give a raw impression of the many varieties practiced with broadleaved species in Western Germany. Many silvicultural techniques have been considered for a long time in the different German regions. This overview can only give the main and principal rules, more or less in use everywhere.