Ann Sci For (1993) 50, 563-570

Original article

New perspectives in German oak silviculture

GK Kenk

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Wonnhaldestr 4, W-7800 Freiburg, Germany

(Received 6 January 1993; accepted 2 June 1993)

Summary — After decades of negligence, oak (*Q petraea* and *Q pedunculata*) is now being replanted throughout Germany on an increasingly wider scale. For the first time, the amount of oak now established in Baden-Württemberg is the same as it was 100–200 yr ago. This is a result of both ecological and economical factors. The concepts involved in establishing and tending an oak stand vary considerably – as do the costs. New perspectives in silviculture and in the proliferation of oak management have evolved from 3 areas: recent research findings in the field of wood technology which indicate a change towards lower planting densities; new developments in forestry equipment or equipment previously not used in forestry which now make it possible to plant an assortment of larger oaks without even having to clear the area; and the awareness that naturally regenerated pioneer trees and other tree species can replace intra-species competition in oak. Stands of 100-yr-old oak planted in rows of up to 5 x 2 or in some cases 5 x 5 m exist and are highly considered for their quality and diversity. All 3 areas–wood technological findings, new techniques used to grow stands and the utilization of natural seedings, combined with controlled, goal-orientated intervention – result in a decrease in the percentage of oaks planted per ha and lead to a drastic reduction in planting and maintenance costs without, in the author's opinion, jeopardizing the quality of the wood. Thus, an oak stand can be established at the same cost as a spruce of Douglas-fir stand and is, therefore, an alternative worth considering by the private forest owner.

silviculture / economy / wood quality / *Q petraea* / *Q robur*

Résumé — Nouvelles perspectives pour la sylviculture du chêne en Allemagne. *Après des décades d'oubli, les chênes (*Quercus petraea *et* Quercus pedunculata*) sont maintenant réintroduits en Allemagne à une échelle croissante. Pour la première fois, le nombre de chênes plantés dans le Baden-Württemberg a atteint le niveau d'il y a 100-200 ans. C'est le résultat combiné de facteurs liés à l'écologie et à l'économie. L'implantation et la gestion des peuplements de chênes impliquent des concepts qui varient considérablement, de même que leurs coûts. De nouvelles perspectives en sylviculture et méthodes d'aménagement du chêne se sont développées, à partir de nouveaux résultats de recherches dans le domaine de la technologie du bois, permettant l'utilisation de densités plus faibles à la plantation, de nouveaux développements dans les équipements forestiers ou dans l'utilisation d'équipements non encore employés en foresterie permettant maintenant d'utiliser une gamme de plants de chêne de taille plus élevée sans avoir à effectuer de dégagement ; et du fait que les arbres pionniers régénérés naturellement ou les autres espèces d'arbres peuvent remplacer les espèces de bourrage. Des peuplements de chênes âgés de 100 ans, plantés en lignes avec un*

espacement atteignant 5 x 2 m, et même dans certains cas 5 x 5 m, existent et sont particulièrement intéressants pour leur qualité et leur diversité. L'ensemble de ces 3 domaines — résultats en technologie du bois, nouvelles techniques utilisées pour faire croître les peuplements et l'utilisation de semis naturels combinée avec des interventions contrôlées — a promu l'usage d'un nombre réduit de plants par hectare et conduit à une diminution très importance des coûts de plantation et d'entretien sans jamais, à notre avis, compromettre la qualité du bois. Ainsi, un peuplement de chêne peut maintenant être établi à un coût identique à celui d'une plantation d'épicéa et de Douglas. C'est donc une alternative qui mérite d'être prise en considération par les propriétaires forestiers privés.

sylviculture / économie / qualité du bois / Q petraea / Q robur

INTRODUCTION

At present, ≈ 8% (880 000 ha) of Germany's forest area is covered with oak (*Quercus petraea* Libl and *Quercus pedunculata* Erh)*. According to Hesmer (1938) oak accounted for 20% of the original virgin forests. The number of oaks planted decreased particularly in the decades following World War I. Today most stands are made up of 80–140-yr-old trees; younger or older stands are rare.

In about 1970 oak began to be planted again on an increasingly wide scale. In Baden Württemberg's public forests, for example, the percentage of oak in the most recent age classes is 3 times greater than among the older age classes. Today's regenerated areas have the same percentage of oak as forests had 100–120 yr ago (Karius, 1992).

The oak revival has evolved from a greater emphasis currently placed on species planning in accordance with the specific site conditions and with the original associations found in natural forests. The problems connected with tropical hardwoods and economic factors have also played a decisive role. After all, in comparison with every other tree species, over the last decades the net proceeds from oak have increased most favorably. Today only oak can boast a 50% increase since 1950 in its actual monetary value: the value of all other species has decreased (Barthelheimer, 1990).

"High quality" wood is the undisputed production target of oak cultivation. This wood is produced by oaks with diameters of 60–80 cm at breast height (DBH) and is optimally suitable for use as veneer, or provides high-quality sawn timber.

Opinions vary widely on how oak stands should be established and tended (Kenk, 1984). In very rare cases stands are planted with only ≈ 2 500 trees per ha (*eg* Rosenstock, 1992); usually, however, the number ranges between 6 000 and 10 000, and up to 15 000 in former East Germany (Koch, 1992). In many cases sowing is considered the most expedient method of establishing a stand; thus there are often as many as 50 000 to 80 000 trees per stand ha, and many of these stands show the typical characteristics of overcrowding: crown shrinkage, low diameter growth, decline of secondary crop and/or curved and slanted stems.

At best, the cost of planting a new oak stand is ≈ DM 4 000 (Rosenstock, 1992) to DM 7 000 (Hein, 1991); normally, however, the cost lies somewhere between DM 20 000 to > DM 40 000!

The amount of intervention required in tending young oak stands ranges for the "predominately self-sufficient" (Fleder, 1981) to the early positive selection and promotion of potential crop trees (Kenk, 1980, 1984;

* Source : old German provinces: National Forest Inventory 1987; evaluation 5/1992

MLR, 1988). This may under certain circumstances also include pruning (Hochbrichler *et al,* 1990; FVA BaWü, 1991).

In tending young stands it is recommended that between ≈ 300–500 (MLR Baden-Württemberg, 1988) or 600 (Rebel, 1922) or even 1 000 (Leibundgut, 1976) or more trees be selected for preferential treatment.

Although the number and manner (preliminary or final) in which the trees are chosen varies considerably, selection and tending of potential crop trees during the thinning stage has for the most part become standard practice. In France the common practice is to select 70–100 trees for preferential treatment, based on the growing space required in a stand by trees with the customarily desired DBH of 60–80 cm. This practice is uncommon in Germany, and when found, is only followed on a regional basis (*eg* MLR Baden-Württemberg, 1988). Thinning takes place at the earliest when the stem's branchless sections reach lengths of 8 to 10 m, *ie* the dominant trees obtain a mean height of ≈ 16–17 m (Kenk 1984).

Stands of 80–110-yr-old oaks planted with wider spacing, as for example in rows of 5 x 2 m (Spiecker, 1986) or 5 x 5 m (Hein, 1990), show promise and have received much positive comment but, to my knowledge, these examples have yet to be adopted in practice.

New perspectives in silviculture and oak management techniques have evolved from 3 specific areas: 1) wood technology: new research findings indicate the beneficial effect of planting the stands more sparsely than in the past; 2) techniques used in establishing new stands: the use of recently developed machines, or machines previously not used in forestry, makes it possible to plant an assortment of large oak saplings without even having to clear the area; 3) seeding and competition from associated species: pioneer trees naturally sown in a stand and other tree species can replace intra-species competition otherwise present among oaks.

Wood technology

Modern concepts on stand maintenance focus on dominating vital trees. During the stand's early stages, these trees receive special tending and become increasingly dominant due to the thinning of neighboring oaks (1–2 per tree). In most cases, the thinned oaks were still vital but either cramped the selected tree or were of lesser quality; their removal allows the selected trees to grow in height without interference, achieve the desired crown level of ≈ 50% (Mosandl *et al,* 1991) and avoid the stem curvature often found in dense stands (Leibundgut, 1976; Röhle, 1982; Mosandl *et al,* 1991).

Dominant trees have somewhat wider tree rings. Trees in sessile oak (*Quercus petraea* Liebl) stands of various densities exhibiting distinctly greater dimensions and more rapid and uniform growth do not show any negative effects connected with the strength and homogeneity of their wood properties (Hapla and Backer, 1990). In fact, in the lower and mid-sections of the stems, these trees actually produce wood of somewhat better quality. "... The quality and volume of useful wood from the sawn timber produced from these logs both clearly surpass the wood produced from the more densely established naturally regenerated stands. This is due mainly to quick callusing prompted by the faster and more uniform growth..." (Becker *et al,* 1990).

Irregularly shaped lop-sided crowns and/or curved or slanted stems lead to high levels of tension and wood of poor stability; or can cause dimensional instability in solid wood, or undulations in veneer wood (Nepveu, 1990).

These findings combined with important economic factors indicate the beneficial effect of wider spacing and increased maintenance of oak stands.

Techniques used to establish new stands

The "dredger technology" according to Rosenstock (1992) or the plant plough designed by Hein (1991) has made it possible to plant large saplings without clearing, or when absolutely necessary with minimal clearing. This forestry technique provides a higher quality of work than previously achieved and is still extremely cost-efficient. With this procedure provisions are made for wide spacing between the plants and "biological automation". Decomposing slash covers up to a third of the ground area, thus dispersing the competing ground vegetation and reducing the number of competing pioneer trees (Spurr, 1959). Branch wood or crowns left lying on the ground provide diverse habitats for forest animals. The animals transport the seeds across wide areas where they are dispersed and propagate, thereby creating a greater diversity of species. Site-indigenous woods can develop in a less disturbed manner *via* browsing game (Griese 1987). In many cases it is therefore no longer necessary to fence a forest off from roe deer. Oak stands can thus be established in a cost-efficient manner.

Seeding and competition from associated species

When saplings are used to regenerate a stand, accompanying species which naturally settle in the area, in particular pioneer trees, almost always play a positive role in respect to site ecology, species diversity and management goals.

Here the following questions are to be considered:

– To what extent during the important stand-tending phase and up to the point when the branchless sections of the stems reach lengths of 8–10 m do the accompanying species replace intra-species competition otherwise present in oak, thereby reducing maintenance costs and strengthening the argument in favor of silvicultural rationalization?

– What type of growth dynamics can be expected from the oak and associated species?

– What effects on the quality (stem) and vitality (crown) of the oak can be expected?

These questions are currently being examined in our "natural reforestation" research project. At the moment the answers available are incomplete; the research is projected to last 3 yr.

Examples of naturally reforested areas

The following focusses on the growth and the composition of species on 2 naturally reforested areas. In both cases the previous stands were cleared for planned but aborted purposes (*ie* military maneuvers, test site for automobile factory). On both sites representative samples were taken in circles, stripes or squares in order to determine the number, distribution and heights of the trees. For growth analysis predominant trees (in the case of oak more " slightly" codominant to dominant) were analysed (age and annual shoot length) and interpreted (data base, Harvard Graphics).

Example area 1:"Herrenberg Kerhau" succession area

Location: Herrenberg forest district (region Neckarland, "Oberes Gäu and Heckengäu");

Geological substratum: upper shell limestone;

Elevation above sea level: 560 m;

Site homogeneity: lime covered with varying levels of fine loam;

Average annual temperature: 8.2°C;

Annual precipitation: 780 mm;

Neighboring stands: predominately spruce and fir with beech, ash and oak;

Start of natural reforestation: spring 1987 after the area was clearcut and completely mulched. Note: although the stand is fenced, influence of browsing roe deer can nevertheless be determined.

Stand size: ≈ 16 ha.

Figure 1 shows the seeding frequency according to species, as well as the height distribution, in height growth and annual height increments of oak and the pioneer trees birch, goat willow and aspen.

Example area 2: "Bad Mergentheim Boxberg" succession area

Location: Bad Mergentheim forest district (region Neckarland, "Vorderes Bauland");

Geological substratum: middle shell limestone;

Site homogeneity: moderate fresh clay based;

Elevation above sea level: 360 m;

Average annual temperature: 8.1°C;

Average annual precipitation: 660 mm;

Previous stand and neighboring stands:

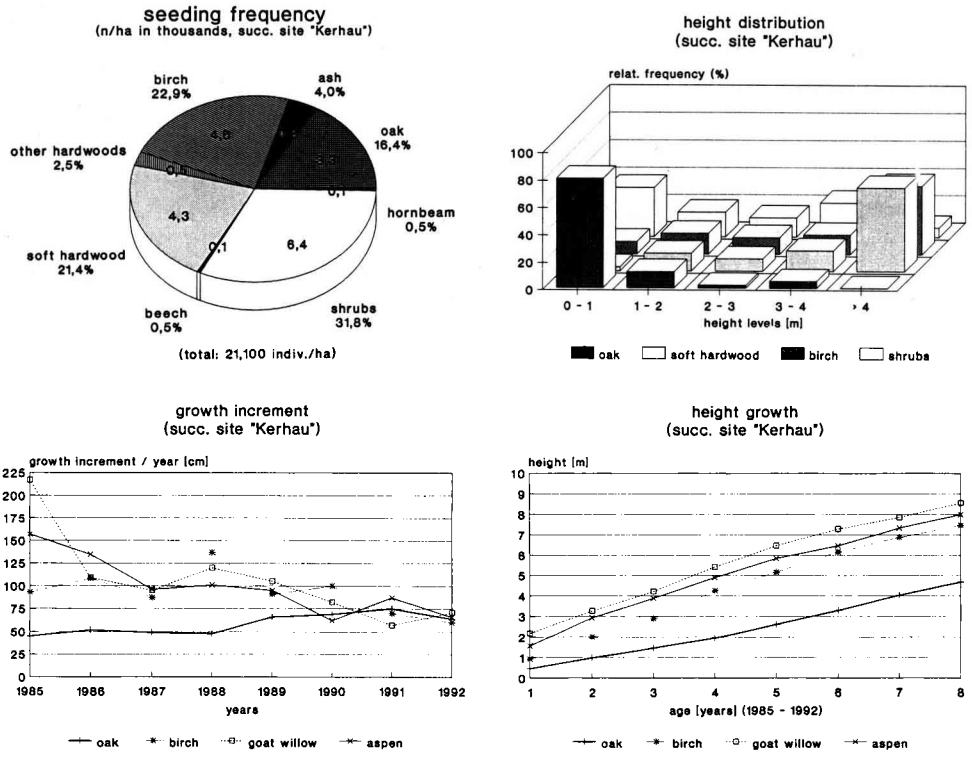

Fig 1. "Herrenberg Kerhau" succession area.

oak, beech, hornbeam, ash, linden among others.

Figure 2 again shows the seeding frequency according to species, together with height distribution, growth in height and annual height increment of oak, hornbeam, birch and soft hardwood trees.

In both cases the number of trees per ha ranges between 11 000 and 21 000. On the average there are several hundred economically valuable species of oak, beech, hornbeam, ash, maple, linden, cherry per ha. There are > 1 000 per ha of the inferior species — almost exclusively goat willow and aspen — including numerous shrubs, mainly hazel, white and blackthorn. Wood-plant communities with an abundance of species and individuals have developed, making intervention necessary if forest management goals are to be met.

As expected, the pioneer species initially grow in height at a superior rate: growing in the first yr in "Herrenberg-Kerhau" has 5-fold higher than in oak (fig 1). After 8 yr this relationship changed to the benefit of oak. In the 8th yr the pioneer trees were twice the height of oak, but their annual growth increment diminished during the first yr and did not equal that of oak until the 6th or 7th yr (fig 1). Oak cannot keep pace with the rapid height development of the pioneer trees. A canopy which developed for the last 2 to 4 yr over the tallest oaks does not appear to have an effect on their height growth. In contrast, the growth in height in Bad Mergentheim Boxberg indicates an increasing height differentiation (fig 2).

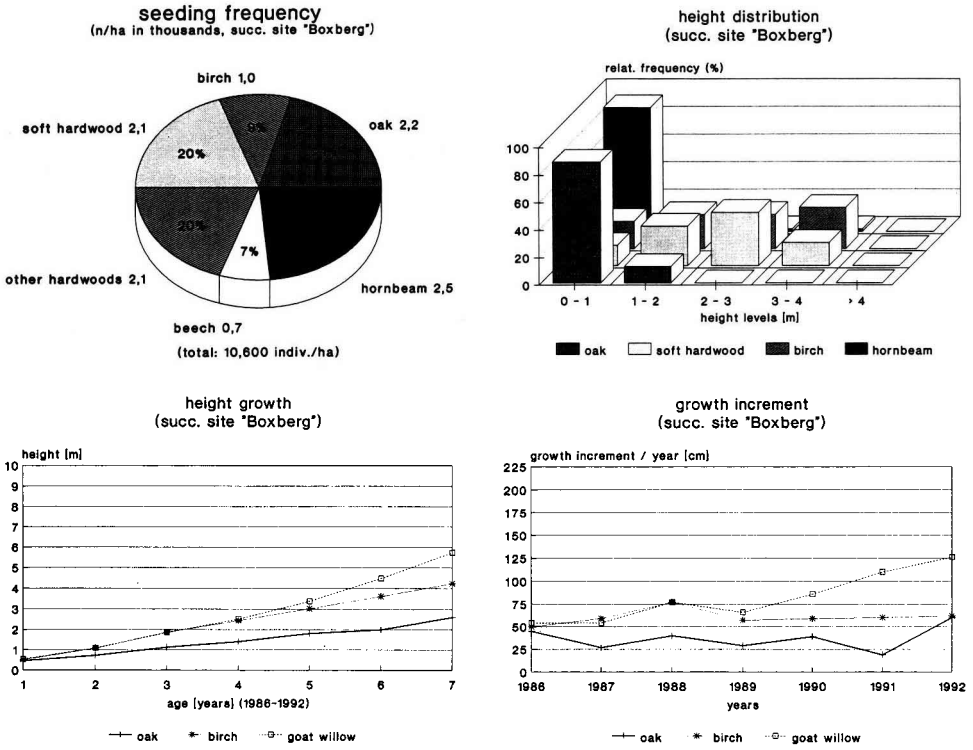

Fig 2. Start of natural reforestation: spring 1986 following clear cutting stand size: ≈ 13 ha.

The results of this research on a clear-cut area that was allowed to naturally reforest confirm Rosenstock's (1992) expectations regarding additional natural regeneration and species diversity in widely spaced plantations.

These findings are not unique: the potential for natural regeneration even on less optimal sites is normally underestimated. The time it takes for the successions sequence to progress from pioneer trees to managed trees is, on the other hand, overestimated. This can be illustrated by an area (Keuperbergland) around Stuttgart. In an isolated part of the forest not far from the town of Leonberg, a sandstone quarry was shut down between 1950 and 1960. The area was left untended; its development is outlined in table I.

Within 2 to 4 decades after the pioneer trees began to settle on the site a stand finally became established of the more suitable and economically valuable species. There are no particular data available on the qualitative composition of the species. It is obvious, considering the stand's present state and the relatively high number of trees, that enough crop trees or crop tree candidates exist. If the crop continues to be tended through controlled intervention, then they will most certainly become the dominant crop.

Table I. Stages in the development of a naturally reforested area derived from the forest's present state (simplified).

No	*Stages*	*Years*	*Intervention*
1	Virgin soil after sandstone exploitation		
2	Settlement of pioneer trees and shrubs: aspen, birch, pine, goat willow, mountain-ash, hazel, elder, blackthorn	1–5	
3	Beech, oak, maple, ash, spruce (fir) settlement from neighboring trees and from the greater surrounding area seed under the protective canopy of pioneer trees	up to 10	
4	Naturally regenerated trees and shrubs begin to grow. The pioneer species become lighter and begin to decline, *eg* goat willow	15	First controlled intervention: to regulate diversity and competition
5	Naturally regenerated "managed species" outgrow pioneer shrubs; increased decline in pioneer trees	20	
6	Naturally regenerated "managed species" reach the canopy of the pioneer trees; these continue to decline	30	
7	Naturally regenerated "managed species" form a stand ("climax"; solitary long-living pioneer trees, *eg* pine and birch still present)	40	Second controlled intervention: to select and promote crop trees
		Total length of time ≈ 40 yr	

Further research on largely self-sufficient stands appears to be a worthwhile investment for the development of rationalization techniques in silviculture, thereby achieving another desirable goal, *ie* that of creating more diversity within the stands.

REFERENCES

Bartelheimer P (1991) Ökonomische Aspekte der Eichenwirtschaft. *Forstw Cbl* 110, 185-195

Becker G, Hapla F, Teutenberg A (1990) Untersuchung der Holzqualität von Traubeneichen aus unterschiedlich dicht begründeten Beständen. *Holz Roh- Werkstoff* 48, 339-343

Fleder W (1981) Furniereichenwirtschaft heute. *Holz-Zentralblatt* 107, 1509-1511

Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg (1991) Wertästung. *Merkblatt* No 20 (2 Aufl), 11 S

Griese F (1987) Untersuchungen über die natürliche Wiederbewaldung von Heideflächen im niedersächsischen Flachland. *Diss Univ Göttingen*, 163 S

Hapla F, Becker G (1990) Physikalische und technologische Holzeigenschaften von Traubeneichen aus unterschiedlich dicht begründeten Beständen. *Holz Roh- Werkstoff* 48, 461-465

Hein F (1991) Maschinenpflanzung im Kottenforst. *Landwirtsch Zeitschr Rheinland* 18, 26-27

Hesmer H (1938) *Die heutige Bewaldung Deutschlands*. Paul Parey, Berlin

Hochbichler E, Krapfenbauer A, Mayrhofer F (1990) Ein Pflegemodell für Eichenjungbestände – Grünastung, eine wirtschaftliche Problemlösung der Wertholzerziehung. *Cbl Ges Forstwes* 107, Jg, H 1, 1-12

Karius K (1992) Waldaufbau nach Alter und Baumarten in Baden-Würtbemberg. *Forst Holz* 47 Jg, No 13, 371-379

Kenk G (1980) Pflegeprogram "Werteiche": Überlegungen zu einem Betriebszieltyp. In: Begründung und Pflege von Werteichenbeständen, herausgegeben vom EM, Ba-Wü, Stuttgart

Kenk G (1984) Werteichenproduktion und ihre Verbesserung in Baden-Württemberg. *AFZ* 17/18, 428-429

Koch H (1992) Pflanzenzahlen und Pflanzverbände am Beispiel von Kiefer, Eiche und Buche. *AFZ* 5, 245-247

Kurth H (1990) Die Entwicklung der Forstwirtschaft in der DDR. *AFZ* 35, 892-896

Leibundgut H (1976) Grundlagen zur Jungwaldpflege. *Mitt Eidgen Anst Forstl Versuchswesen* 52, 313-317

MLR (Ministerium für Ländlichen Raum, Ernährung, Landwirtschaft und Forsten Baden-Württemberg) (1988) Jungbestandspflege in den wichtigsten Betriebszieltypen. 12 S

Mosandl R, El Kateb H, Ecker J (1991) Untersuchungen zur Behandlung von jungen Eichenbeständen. *Forstw Cbl* 110, 358-370

Nepveu G (1990) Les facteurs influençant la qualité du bois de chêne (chêne rouvre et chêne pédonculé). *Ref For Fr* 2, 128-133

Rebel R (1922) *Waldbauliches aus Bayern*. Huber-Verlag, Munich

Röhle H (1982) Struktur und Wachstum von Stieleichen-Mischbeständen auf grundwasserbeeinflußten Standorten in den Auewaldgebieten Süd-Bayerns. *Forstl Forschungsberichte* H 51

Rosenstock A (1992) Baggertechnologie. *AFZ* 6, 293-295

Spiecker H (1986) 100jähriger Eichenbestand aus 5 x 2 m Pflanzverband. *AFZ* 37, 910

Spiecker H (1991) Zur Steuerung des Dickenwachstums und der Astreinigung von Trauben- und Stieleichen. Schriftenreihe der Landesforstverwaltung Ba-Wü. *Bd* 72, 155 S

Spurr SH (1956) Natural restocking of forests following the 1938 hurricane in central New England. *J Ecol* 37 (3), 443-451