Oak Silviculture, Management, and Defoliation Effects in France and Germany

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Abstract: A study tour of four areas of France and Germany (two in each country) was conducted to examine oak silvicultural and managerial practices and the influence of insect defoliators on the ecology and management of oak forests. The French and German situations may provide useful information for managing oak forests and gypsy moth in the United States, especially the central hardwood region.

Both France and Germany manage their oak stands for sawtimber and veneer production, the latter as the final and most valuable product. Frequent intermediate treatments and thinnings provide lower quality products and sawtimber throughout the rotation. Even-age systems are used almost exclusively with rotation ages varying by area (120 to 300+ years). Most regeneration is by natural regeneration using shelterwood cutting. In many areas, seed collection and direct seeding of oaks are done under the shelterwood system. Planting is used in areas of poor seed production due to frosts. Competition control, a major expense during the regeneration phase, is accomplished by a combination of chemical and mechanical (manual) methods. Many areas in France and some in Germany are in the process of converting oak stands from coppice with standards to high forests. The major species present are sessile oak, *Quercus petraea* Liebl., pedunculate (or English) oak, *Q. robur* Erh., and, in the drier areas of France, pubescent oak, *Q. pubescens* W. In both France and Germany, northern red oak, *Q. rubra* L., has been widely planted in some areas.

Outbreaks of insect defoliators occur in both France and Germany, but are closely linked to site and climatic conditions. Major defoliators are gypsy moth, *Lymantria dispar* L.; oak leafroller, *Tortrix viridana* L.; and winter moth, *Operopthera brumata* L.; some areas also have defoliation from large winter inchworm, *Hibernia defoliaria*, and common wanderer moth, *Thaumetopoa processionea*. The major effects of defoliation in oak stands are, in order of importance, loss of seed (mast) crops, growth loss, and tree mortality. Loss of seed crops is critical in many areas and mortality increases in importance on drier sites. Poor silviculture also contributes to increased mortality in stands due to lowered tree vigor and poorer crowns.

INTRODUCTION

During September and October of 1988, I conducted a study tour of four oak-forest areas in France and Germany: 1) the oak forests in the foothills (Lorraine Plateau) west of the Vosges Mountains in northeastern France; 2) the oak forests in the low plateaus around the Loire River Valley in central France; 3) the Spessart oak-forest area and areas adjacent to Main River Valley east of Würzburg in the northern portion (Upper Franken) of the State of Bavaria; and 4) the upper Rhine Valley oak forests and oak forests in the foothills of the Black Forest near Freiburg in the State of Baden-Württemberg. The purpose of the trip was to study oak silviculture and management and the impacts of oak defoliators on ecology and management of these forests. The situations and experience of the French and Germans in these areas may prove helpful for oak management and gypsy moth in the United States.

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The areas visited are in the productive oak forests of central and northern Europe and are not part of the Mediterranean or sub-Mediterranean zones. The two major species of oak that are native to and managed for in this region are English oak, *Quercus robur* Erh., also known as pedunculate oak (*Q. pedunculata*), and sessile oak, *Q. petraea* (Matt.) Liebl., also known as Durmast oak. Both species are in the white oak group. There are no native red oaks outside in Europe. Pedunculate (the name used in continental Europe) and sessile oak are similar and at one time were considered varieties of the same species. Recent work has shown that there are genetic, morphological, and ecological differences. At the INRA-CNRF Station de Sylviculture et de Production in Nancy, France, a multivariate analysis technique for separating the two species based on leaf morphology shows that less than 5 percent of the trees are hybrids. Current work is looking at isozyme analysis and an Italian lab is doing DNA electrophoresis. There are several major ecological differences between the two species: pedunculate oak is not as drought tolerant and grows on wetter sites, requires a better mineral nutrition, begins growing later in the spring and is less susceptible to late frosts, is more susceptible to the powdery mildew fungus, *Microsphaera alphitoides* (Grif. and Maubl.), and usually grows in valleys where conditions are humid and sites less well drained. Pedunculate oak also is the major species associated with oak decline, which usually occurs where this species was introduced (planted offsite). Pedunculate oak also has a higher mortality rate due to drought and defoliation than sessile oak, especially on drier sites. The two species often grow in mixed stands or forest areas, but sessile oak usually is predominant on all but the moistest sites.

FRANCE

France has 13.7 million hectares (ha) of forests which occupy 25 percent of the total land area and represent 40 percent of the European Economic Community's (EEC) forests (Anonymous 1984). The forest ownership is 12 percent state, 17 percent community, and 71 percent private. The state and community forests are managed by the National Forest Service. The private forests have more than 3 million owners; 25 percent hold fewer than 4 ha, 35 percent hold 4 to 25 ha, and 40 percent hold more than 25 ha. A third of all private forests are part of a farm. Of the country's forests, 30 percent are classified as unproductive or protection forests for water and soil (much of this is in the Mediterranean area), another 30 percent is coppice or coppice with standards forest that provides primarily firewood and pulpwood with some higher quality products, and 40 percent is in high (or seed origin) forests that provide pulpwood, sawtimber, and veneer. France's wood needs require 20 percent to be imported at a deficit cost of 14.1 billion francs ($2.27 billion) per year.

Conifers comprise 34 percent of the forested area and hardwoods 66 percent. Of the hardwood forest, oak types comprise 40 percent, common or European beech (*Fagus sylvatica* L.) 12 percent, hornbeam (*Carpinus betulus* L.) 4 percent and other hardwoods 10 percent. Oak (eight native species) occurs in five major forest types: pedunculate/sessile oak type; oak and beech mixed type, which includes the two major oak species mixed with beech; beech and oak mixed type, which is beech forest with the two major oaks mixed in; sub-Mediterranean oak type, which is pubescent oak (*Q. pubescens* W.), sweet chestnut (*Castanea sativa* L.), and beech mixed; and the Mediterranean oak type, which is holly-oak or holm-oak (*Q. ilex*, an evergreen oak), pubescent oak, European black or Austrian pine (*Pinus nigra* var. *nigra*), maritime black pine (*P. nigra* var. *maritima*), and Alep pine (*P. halepensis*).

Other oaks that occur in dry areas of southern and western France are cork oak (*Q. suber*) and tauzin oak (*Q. pyrenaica*). Sessile oak is by far the most common oak in the first three types, in which most of the quality oak veneer is grown. My visit was limited to the pedunculate/sessile oak and beech and oak mixed types and to state-managed forests. The two areas visited in France were the Lorraine Region in the northeast part of the country and the Loire Region in the center of the country.

Lorraine Region

Lorraine is one of the more heavily forested areas of France (40 percent of 2.2 million ha). These 865,800 ha of forest are predominately publicly owned (26 percent state and 41 percent community). It is first in France in the production of hardwood and second in the production of conifers. The area produces 12 percent of France's round logs and 12 percent of its lumber. Oak forests comprise 32 percent of the region, beech forests 29 percent, other hardwoods 11 percent, and conifers 28 percent. Coppice with standards occurs on 26 percent of the state forests and 57 percent of the community forests. The regional harvest from 1973 to 1982 averaged 6.4 m^3/ha/yr worth 1,310 fr/ha/yr on state forests and 4.2 m^3/ha/yr worth 790 fr/ha/yr on community forests. The area is composed primarily of the Lorraine Plateau with some portions of the Vosges Mountains. The Lorraine Plateau has a steadily increasing elevation that leads up to the Vosges Mountains. Composed of limestone, it is 200 to 400 m in elevation, with fertile, calcareous soils and oak and beech forests. It gives way to the pre-Vosgian hills, composed primarily of sandstone, at an elevation of about 300 to 400 m, with frequent silts and extensive beech and oak forests. Climate is continental with some oceanic influences; average annual temperature is 9.4°C and average annual precipitation is 700 mm over 170 days. This area is subject to late frosts in May.

Two forests were visited in the region. Champenoux State Forest is a 459-ha predominately oak forest just north of Nancy. Sessile oak is the principal species and is found on the plateau and slopes. Pedunculate oak is found in the moist bottoms. Other species include beech, hornbeam, littleleaf linden (*Tilia cordata* M.), European ash (*Fraxinus excelsior* L.), and various minor fruit species (wild or bird cherry, *Prunus avium* L.; serviceberry, *Amelanchier* spp.; European mountainash, *Sorbus aucuparia* L.). The forest was once a hunting preserve and managed in coppice with standards. Conversion to high forest began in 1826. Average production is 4.3 to 5.0 m^3/ha/yr. The forest is divided into 62 stands of 6 to 8 ha each. Haye State Forest, northwest of Nancy, is predominantly beech with some sessile and pedunculate oak. Some pubescent oak occurs with poor beech on the xeric soils on the southern slopes that fall off the plateau. Moist bottoms contain pedunculate oak, European ash, linden, sycamore maple (*Acer pseudoplatanus* L.), buckeye (*Aesculus* spp.), and fruit species. As the soils become deeper, productivity increases. At soil depths greater than 1 m, pedunculate oak is mixed with beech; at shallower soils, sessile oak is mixed with beech. Natural regeneration of beech is easily obtained.

Loire Region

The Loire Region is only about 10 percent forested. It is a low plateau that is bisected by the Loire River and its many tributaries. Agriculture, especially vineyards, is important in the region. Climate is moderate but varies within the region. In Blois State Forest along the Loire River, the elevation is 89 to 144 m with many small valleys assuring good drainage. Average annual temperature is 10.9°C with monthly averages of 2.8 to 19.4°C. Average annual precipitation is 655 mm over 169 days and is distributed evenly throughout the year. Soils are primarily clay and flint based, with some limestone in the north and a layer of silt in the east. Sessile oak is 97.5 percent of the forest. Average production from 1949 to 1978 was 4.8 m^3/ha/yr worth 169 fr/ha/yr. From 1979 to 1987, the average harvest was 5.7 m^3/ha/yr worth 2,100 fr/ha/yr. The Bourges District Office (Soudrain and Thoux Forests) is in the Cher River Valley (tributary of Loire). Its geology is limestone giving calcareous soils that are shallow but good for forests when deep enough. Soil depths of 50 cm are adequate and depths of 1 m or more are perfect. Climate is more sub-Mediterranean, warmer and drier. Average annual precipitation is still 600 to 700 mm, but April and July have only 14 mm each and are very dry.

Blois State Forest, the first area visited in the region, is 2,753 ha of predominately sessile oak. In the northern portion of the forest, 10 percent is pedunculate oak, beech and hornbeam also are found. The climate is favorable for the production of acorns, with good crops occurring every 2 to

5 years, but poor for the production of beech with little or no seed production. In fact, beech is now planted in the area. The forest is a relic of a vast forest that was cleared during the Middle Ages. It was owned by the Count of Blois and was passed to Louis d'Orlèans in 1391 and to the King of France, Louis XII in 1498. Since 1791, the forest has been a National Forest. The area formerly was mixed beech and oak forest, but past management practices eliminated the beech. The last cutting of coppice was in 1686, the area has been managed as high forest since that time. Boulogne State Forest, near Blois, has a similar history of long ownership by royalty and the state.

In the Bourges District Office, two forests were visited. The 600 ha Soudrain State Forest was owned by a religious group. During the French Revolution (1789), all of the trees in the forest were cut. As a result, most of the stands are now 180 to 200 years old. Soils are 50 to 60 cm deep and affected by drought. There also has been with defoliation in the area. Thoux State Forest, 900 to 1,000 ha, was privately owned until 1960. It was managed as coppice with standards. The government bought it in 1973 after a gypsy moth outbreak had killed many trees. The soil is poorer here and very shallow. Pubescent oak occurs on shallower soils and pedunculate oak and sessile oak on deeper soils. Coppice is hornbeam and hedge maple (*Acer campestre* L.).

Oak Silviculture and Management

A key component of silviculture and management in France, is an extensive ecological site classification program based primarily on soils and natural vegetation. Since France has mostly natural forests and plantations of exotic species are rare, classification is possible using natural vegetation. France has divided into 100 natural regions on the basis of geology, topography, and climate. A typology is produced within each region. The product is a catalog of sites. The typology is developed by sampling forest types using transects with plots at 100-m intervals if site changes. At each point, vegetation is listed and complete soil and stand descriptions are prepared. Following the field work, a factorial analysis on understory vegetation is done. This is followed by analyzing soils with vegetation for homogeneity and then creating homogeneous units based on those two characteristics. After the typology is established, the productivity of each type is studied.

The ecological site classification system is used to determine what species should be managed, the rotation length, the thinning interval, and the expected productivity of the site. For example, on Haye State Forest, understory vegetation and soil depths changed with increasing productivity. On the steep slopes at the break of the plateau, soils are very shallow, calcareous, and nonproductive, and understory vegetation is *Cornus, Corylus, Lonicera, Crataegus, Ribes,* and *Hedera helix.* As you move to the top of the plateau and add 10 to 15 cm of clay loam on top of the calcareous soil, productivity is now 5 m^3/ha/yr, there are no longer any woody shrubs, and understory vegetation is grass, *Asperillum, Macullerlis,* legumes, *Hedera helix, Vinca,* and *Rosea.* Moving along the plateau to clay loam soils that are 25 to 40 cm deep, the understory is now grass and fern with grass being characteristic. Finally, as you reach the most productive sites (7.6 m^3/ha/yr) with a soil depth greater than 1 m, the understory vegetation is *Rubus, Oxalis,* and *Euphorbia.*

The management goal of state and community oak forests is a sustained yield of maximum value. This goal is met by producing high-quality timber using long rotations. Toward that goal, the Office National des Forêts (ONF, French Forest Service) began to convert coppice and coppice with standards stands to high forests in 1827. Not all of these stands will be converted as some areas will continue to be managed for fuelwood and/or for game habitat (Figure 1). The long rotations, 120 to 160 years for pedunculate oak and 150 to 210 years for sessile oak (some areas would like to extend the rotation to 240 years), also provide a great diversity of products and amenities. The goal is to produce high-quality oaks for veneer due to the high premium that veneer brings in Europe. Average prices in France for sales in October 1979 were: dbh 50 cm and more, 850 fr/m^3 ($775/M bf); dbh 30 to 45 cm, 279 fr/m^3 ($254/M bf); and dbh 25 cm and less, 18.5 fr/m^3 ($7.59/cord) (Oswald 1982).

Figure 1.—Typical coppice with standards stand located on the Champenoux State Forest. At the time of the last inventory in 1975, the oak standards were 190 to 200 years old, had 127 trees/ha, 19.85 m^2/ha basal area, average d.b.h. of 140 cm, and average height of 23.2 m. The coppice was 75 percent hornbeam and 25 percent linden with several other species. It was 58 years old, had 1,375 trees/ha, 8.58 m^2/ha basal area, average d.b.h. of 26 to 42 cm depending on species, and average height of 17 m. Total density of the stand was 1,505 trees/ha and 29 m^2/ha basal area.

More than 90 percent of the oak forests are obtained from natural regeneration. The usual technique is a multicut shelterwood sequence: a preparation cut, seed cut, 1 or more release cuts, and final removal cut (Figure 2). The preparation cut removes all of the tolerant understory that was shading the oak stems to prevent epicormic branches. The seed cut removes 50 percent of the overstory stems and about 35 to 40 percent of the volume. The preparation and seed cuts often are done in the same year. The first release cutting, usually about 3 years after the seed cut depending on seed crops (it usually is done 2 years after a seed crop), removes another 25 percent of the stems. The final cut, 3 to 4 years after the release cutting so long as there are sufficient seedlings, removes the remaining 25 percent. Epicormic branches that form during the shelterwood sequence are not a concern as they affect only the outer 1 cm of wood and do not degrade quality or price. When seed crops do not occur or more seedlings are needed, additional time occurs between cuts and additional release cuts can be made. In some instances, 20 years can pass between the seed cut and final removal cut. Within a stand, the seed cut and subsequent cuts are spread out over 10 years so that about 1.5 to 2 ha per year is cut. This procedure evens out the flow of wood and allows more precise tracking of regeneration. The resulting stand will have an initial potential variation of 10 years in age, though variation is usually less because the bulk of the regeneration is from the same seed crops.

Planting or seeding, is done where coppice stands are being converted to high forests, where cleared land is being forested, and where poor seed crops due to late frosts or insect defoliation fail to produce natural regeneration. In many areas, seed production stands are designated. These are high-quality genetic stands used for seed collection. Tarps are spread under the trees to catch

Figure 2.—Typical shelterwood sequence in a sessile oak stand. Figures 2A, B, and C are a 210-year-old stand in Blois State Forest, Figure 2D is a 180- to 200-year-old stand in Soudrain State Forest. A. Stand after the preparation cut has removed the tolerant understory, 245 trees/ha and 537 m^3/ha (upper left). B. Stand after the seed cut, 158 trees/ha and 306 m^3/ha (upper right). C. Stand after the first removal cut (lower left). D. Young stand of regeneration immediately after the final removal cut (in foreground), after first removal cut is in background (lower right).

acorns. Seed is used for plantations in a 100- to 150-km circular area around the stand. In France, northern red oak (*Q. rubra* L.) also is planted on some drier sites where native white oaks do not grow as well.

Weeding is an integral part of the regeneration process. It is used under the shelterwood sequence to reduce competition from grasses, weeds, shrubs, and undesirable tree species. Weeding also ensures the establishment and early growth of seedlings. Weeding is common on all forests, but what is removed and how this is accomplished varies from forest to forest. For example, in Blois State Forest, glyphosate is applied before the first cut and then manual methods are used to cut all grass that is taller than the oak seedlings. Between 5 and 7 years, the *Rubus* and all woody stems other than oak are cut. In Soudrain State Forest, fluazifop-p-butyl is applied in June to kill grass (it does not harm oak seedlings) and glyphosate is used to kill *Rubus*. Some manual weeding is done as well. Weeding costs are high by our standards. Standard regeneration costs for the Loire Region for 1983 were:

Natural regeneration

Item	*FF/ha*	*Dollars/acre*
Site preparation (ditching, herbicide, understory removal)	3,558	240
Supplementary planting (200/acre)	2,165	146
Competition control/release (manual)	16,000	1,146
Total	22,713	1,532

Artificial regeneration

Item	*FF/ha*	*Dollars/acre*
Site preparation (ditching, herbicide, mowing, pulverization)	6,078	410
Seedlings (1000/acre)	6,746	455
Planting (400/person/day)	2,595	175
Replanting (10 percent)	1,186	80
Competition control and pruning (chemical, manual, mechanical)	7,784	525
Total	24,389	1,645

Weeding is facilitated by the establishment of a system of tending trails in the stand. Major access routes, 3 to 4 m wide, are put in at intervals of 100 by 50 m and serve to mark off 0.5-ha blocks. Tending trails, 1 to 2 m wide, are then put in at right angles to the major trails; intervals are 10 to 12 m and depend on the estimated number of crop trees in the final stand. The trails usually are established by brush mowers. Weeding and subsequent cleaning operations are done intensively on both sides of the trail to a depth of 2 to 3 m and less intensively beyond that distance. Trails are recut every 4 to 5 years until they remain open.

After the stands are established and the final removal cut made, cleanings are done when the trees reach a total height of 3 to 4 m (about age 15). Cleanings remove non-oak competitors, wolf trees, and forked and crooked dominant and codominant trees. They should favor the growth and crown development of well-formed dominant trees. Species that eventually will form the understory (hornbeam, beech, linden) are not eliminated but are cut back to a smaller size than the oaks. Cleanings are continued at 6-year intervals until about age 30 (total height of 10 to 15 m). Some of the material cut in cleanings may be used for firewood. The regeneration goal is to have many thousands of oaks per hectare so that the competition will select the best trees and the dense stocking will maintain good form. During the weeding, cleaning, and thinning stages, the number of oaks is reduced tremendously.

Thinnings are begun around age 30. Before thinning, crop trees to leave are chosen — about 70 to 100/ha or one tree every 10 to 12 m. Crop trees are marked and thinnings are made to release them. A yield table (density rules) for each age is used to give the number of trees per hectare to leave in the thinning (Oswald 1981). Wood from thinnings is used for wood parquet flooring starting at age 30 and also for firewood and pulpwood. Understory species and beech are retained to provide shade on the oak stems and prevent epicormic branches. Thinnings are done every 5 to 15 years depending on site and age. Younger stands and better sites have more frequent thinnings. As stands age, sawtimber can be sold from the thinnings. Because the goal is to produce high-quality veneer, the trees must not have epicormic branches, irregular growth patterns (alternating groups of wide and narrow rings), or growth rings exceeding 2 to 2.5 mm. Therefore, light thinnings are conducted frequently to maintain uniform, narrow growth rings. Once crop trees are selected, a crown thinning is done in the first third of the rotation, followed by intermediate thinning in the middle third, and low thinning in the last third. In some areas, true crop trees are not selected until they have a clear stem of 10 to 14 m (total height of 20 m and 65 years of age). Selections before that are potential crop trees. Crop trees are selected almost exclusively from dominant trees, due to the difficulty in promoting smaller trees.

The final harvest goal is to have 70 to 100 veneer trees/ha for sessile oak (28 to 40 trees/acre) and 50 to 80 trees/ha for pedunculate oak. The trees usually will average 70 cm dbh and 2 to 2.5 mm/yr ring width and clear stems 10 to 14 m long (Figure 3). At this point, the stand is then regenerated. Trees are sold on the stump by auctions; they are marked at dbh and on the stump to provide control over the harvest. Buyers examine the trees at one time. Borings are made into the tree on all four sides below the stump line to check the color of the wood. Color determines the price that the tree will bring, with bright yellow having the most value. Branches are cut off before

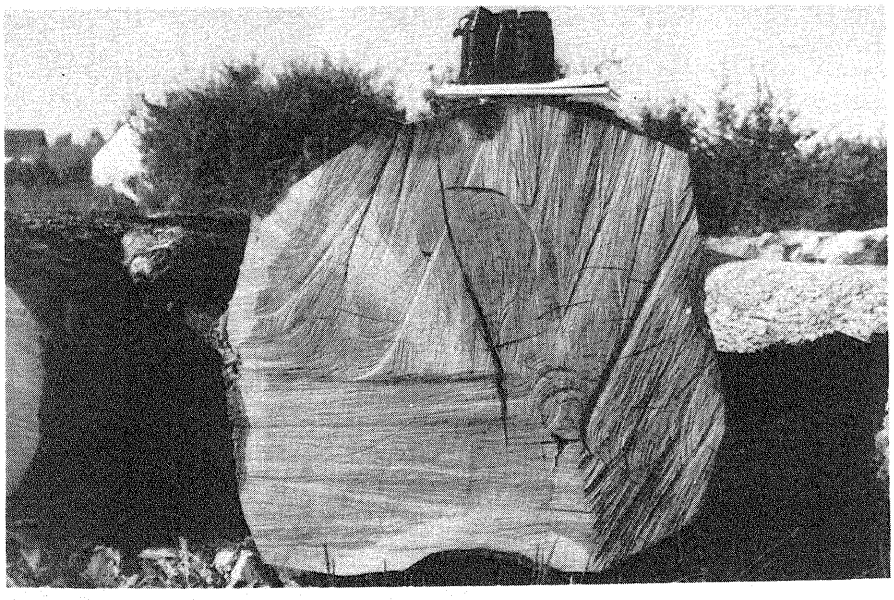

Figure 3.—Veneer log from 180 to 200-year-old tree removed in shelterwood sequence on the Soudrain State Forest in France. Diameter is about 75 cm (30 inches).

felling to prevent the veneer log from splitting. A stand in Soudrain State Forest that is being harvested in a shelterwood sequence is bringing 1 million fr/ha or $65,200/acre. The price received for the wood is 10,000-12,000 fr/m^3 ($9,120-$10,944/M bf) for the first 6 m if the color is good.

GERMANY

The Federal Republic of Germany has 7.11 million ha of forest (about half of France's area) that covers 29 percent of the total land area. This forest area accounts for slightly more than 20 percent of the EEC's forests (Anonymous 1982). The federal government owns little forest land. Most public forests are owned by state governments or communities and several other public owners. Private owners also hold significant areas of forest. In Germany, states run the forests and have State Forest Services. State foresters manage all publicly owned forests as well as all privately owned forests that are too small to employ foresters. Large private owners can employ foresters and manage their own lands but all forest land must be managed by a forester by law. If the private owner does not employ a forester, the state will manage the land and charge the landowner.

The two German states that I visited were Bavaria and Baden-Württemberg. Bavaria has 2.45 million ha of forest which is 35 percent of its land area. The forest land ownership is 53.3 percent private, 32.2 percent state, 13.1 percent community, and 1.4 percent federal. Baden-Württemberg's 1.353 million ha of forest represents 38 percent of its land area. Of this land, 41 percent is in community and other public forests, 24 percent is in state forests, and 35 percent is in private forests. Both of these states extend from low-elevation river valleys through foothills and plateaus to the Alps and Black Forest mountains. There are a variety of forests: mixed hardwoods, oak, beech, pines, Norway spruce, silver fir and larch.

Upper Franken Region of Bavaria

Würzburg is the Unterfranken (Upper Franken) Regional Office of the Bavarian State Forest Service. Unterfranken, one of seven regional offices in Bavaria, has 340,000 ha of forest divided into five forest districts and 30 forest offices (forstamt). The land ownership is 31 percent state, 40 percent community, 27 percent private, and 2 percent federal. The forest composition is 51 percent hardwoods and 49 percent conifers. Of the hardwoods, 23 percent is beech, 20 percent is oak (primarily *Q. petraea*), and 8 percent is other hardwoods (hornbeam, birch, hawthorn, mountainash, etc.). The forest in some of the area has been under management for centuries. The area lies along the Main River with plateaus and foothills of the Alps. Two main areas, Spessart and the Frankish Plateau, were included in the trip with two forstamts in each.

The Spessart or "red sandstone" region, known as the best oak growing area of Germany, is bounded by the Main River which loops around and makes the area almost square (with river on three sides). It can be divided into the Spessart foothills, North Spessart, and High Spessart Range. I visited the High Spessart Range; forests in the other two areas are predominantly coniferous. The High Spessart Range is predominantly beech forest with European oak (*Q. petraea*), hornbeam, and birch (*Betula pendula*) with a ground cover of grass, predominantly wood rush (*Luzula albida*).

The area has kept its original pure hardwood forest character because it was used as a feudal hunting preserve by the Archbishop of Mainz and the King of Bavaria. The elevation is 300 to 450 m with a maritime-influenced climate. Upper areas are cool, rainy, and foggy. The mean annual temperature is 7 to 8°C and the mean annual precipitation is 1000 to 1100 mm. There is danger of late spring frosts until the middle of May or even June and a spring drought that can damage

young growth is possible due to low precipitation. The geology is Lower Red Sandstone and in the west coarse-grained Middle Red Sandstone. Clay lenses are scattered. Gentle, sloped ridges are typical while down the valley, slopes are steeper with flat areas located between them. The sandy soils that result are poor nutritionally. Clay lenses, alluvial sediments, and loamy soil can provide a better nutrient supply when mixed in. Relief and exposure is important. Site is submesic with deep sands and east to southwest exposure. There is no site mapping for this area, but there are site-class ratings (site class I = 7.5 m^3/ha/yr; site class IV = 3.5 m^3/ha/yr).

The 6,100 ha Rothenbuch forstamt was established in 1485 by the Archbishop of Mainz as a hunting preserve for mast production for wild boar and deer. From 1700 to 1850, most of Middle Europe's forests were damaged (cut, burned, and used for glassmaking) and later planted to spruce, pine, and larch. Many of these areas are now being converted to beech, oak, and maple. The first inventory was in the 18th century when every stem was counted. Seedlings (regeneration) were planted for the first time in 1790. The Rothenbuch forstamt became part of Bavaria in 1814 and part of the Bavarian State Forest Service in 1885.

The office employs six foresters, each of whom manages 1,000 ha (2,420 acres). Rothenbuch (red beech) has 36 percent conifers with a planning goal of 30 percent, and 64 percent hardwoods with a planning goal of 70 percent. The breakdown is 38 percent beech with a goal of 37 percent and 26 percent oak with a goal of 33 percent. The annual cut is 5.3 m^3/ha/yr. The volume cut is divided into 62 percent from thinnings and 38 percent from final cuts. Of the latter figure, only 7 percent is in oak veneer.

The 5,544-ha Rohrbrunn forstamt just south of Rothenbuch has many of the same characteristics. Entirely state owned, the area is 93 percent forested. The forstamt is 74 percent hardwoods (28 percent oak and 46 percent beech) and 26 percent conifers. It is divided into six areas with a forester for each. Half of all the oak veneer in Upper Franken comes from this forstamt.

The Fränkische Platte (Frankish Plateau) within the Würzburg Regional Office has a different geology. It is composed of primarily loam, chalk, and alluvium bases. The flattened area is in the rain shadow of Spessart and Rhön and has a warm, dry subcontinental climate with a long growing season. It is in a protected position and includes many wine-growing areas. The elevation ranges from 160 to 420 m in southern portion of the plateau. The average annual temperature is 6.5 to 9.0°C (14.0 to 17.0°C in May to September). The average annual precipitation is 560 to 730 mm (280 to 390 mm in May to September). The average drought index is 25 to 35. The vegetation in the southern portion is primarily oak mixed forest with some beech. A climate quotient was developed that uses the mean temperature in the warmest months divided by the yearly precipitation times 1,000. The quotient is then related to the forest vegetation type. Spessart has an index of 15 to 20 which is defined as beech-oak area. An index of 21 to 30 indicates the oak-beech-hornbeam area. Areas with values of 21 to 25 have more vigorous beech while an index of 26 to 30 indicates less beech. Areas with values above 30 are the oak-hornbeam-linden type. This climate creates many problems related to insect defoliation. Two forstamts were visited in this area.

The Würzburg forstamt has 16,621 ha of forest, of which 28 percent is state owned, 49 percent is community owned, and 23 percent is privately held. Of the area, 15 percent is forested. It has nine employees in the bureau office and nine district foresters. The average district is 1,000 ha but some are as large as 2,500 ha. There are 31 woodcutters and four apprentices. The area is characterized by an elevation of 225 to 372 m, average annual temperature of 8°C, annual precipitation of 640 mm, and late frosts. On state forests, composition is 81 percent hardwoods (48 percent beech, 21 percent oak, 12 percent mixed hardwoods) and 19 percent conifers. On private land, composition is 78 percent hardwoods (40 percent oak and 38 percent beech and mixed

hardwoods) and 22 percent conifers. Harvest on state forests is 10,750 m^3 in thinnings and 12,500 m^3 in final cuts (23,250 m^3 or 5.3 m^3/ha/yr). The forstamt had profits in 1986 of 232 DM/ha or 1 million DM ($51.55/acre or $549,000). Costs for the forstamt (in percent) are:

35 for supervising of community forest, 1.46 million DM/yr
30 for final cutting and thinning
11 for regeneration
15 for cleanings and precommercial thinnings
5 for protection, 193,000 DM/yr (81,000 DM for insects and 112,000 DM for deer and boar fences).

These costs are subtracted from the income for the year to determine profits. There is no interest or carrying of costs over the rotation.

The Wiesentheid forstamt just east of Würzburg forstamt has 14,700 ha of forest or 21.3 percent of the land area. The elevation is 200 to 240 m with an average temperature of 8.5°C and a maximum annual precipitation of 500 mm (246 to 267 mm in some areas). The vegetation composition is 26 percent hardwoods (21 percent oak and 5 percent others) and 74 percent conifers primarily Scotch pine. The area is very warm and dry. Harvest is 2,000 m^3 from thinnings and 1,500 m^3 from final cuts (3,500 m^3 or 4.1 m^3/ha/yr).

Rhine Valley/Black Forest Foothills of Baden-Württemberg

Baden-Württemberg's forests are 65 percent conifers, mainly Norway spruce, Scotch pine, and silver fir, and 35 percent hardwoods. The hardwoods are made up of 20 percent beech, 7 percent oak, and 8 percent others. *Q. robur* grows in the valleys where it is humid and sites are less well drained, and *Q. petraea* grows in the foothills. Recreation is an important use of the forest; 62 percent of the state's 6 million people visit the forest at least once a week to participate in leisure walking, hiking, horseback riding, biking, or skiing. The annual hunting harvest is 130,000 roe deer, 2,100 red deer, 2,800 wild boar, 88,000 hares, and 28,000 foxes. Deer populations are excessive and damage the forest. In 1980, state forests provided 230 million DM from timber sales and 220 million DM in nontimber benefits. There are four regional offices in the state; my visit included only the Freiburg Regional Office area and two forstamts within it.

The Offenburg forstamt is north of Freiburg in the Rhine Valley. This area has special sites for German oak—very wet in spring and very dry in summer. Soils are fragile and require lots of roads to harvest. *Q. rubra* is planted on sites that do not receive enough water. In 1984, this area was affected by the gypsy moth for the first time, though there are records of periodic damage by the oak leafroller and winter moth. In areas close to the Rhine River that have high water tables, there are stands of pedunculate oak mixed with ash, sycamore maple, elm (*Ulmus glabra*), alder (*Alnus glutinosa*), cherry, and pear (*Pyrus communis*). Areas with lower water tables have some sessile oak mixed with pedunculate oak.

Markgräflerland is the region of the Rhine Valley and face of the Black Forest that extends from Freiburg in the north to Basel, Switzerland, in the south. It encompasses vineyards and oak forests in the Valley, mixed oak and beech forest in the foothills and lower elevations, and spruce-fir forests in the higher elevations of the Black Forest. It is a popular recreation area with activities such as hiking and skiing. The Müllheim forstamt is in the middle of this area, halfway between Freiburg and Basel. The oak forest area has elevations of 270 to 470 m. The average annual temperature is 9.5°C and annual precipitation is 900 mm. Soils are calcareous with a layer of loess—very fertile soils used for wine growing and hardwood forests. The natural vegetation in the foothills is beech, a strong competitor of oak. In 1873, the hardwood forest was 90 percent oak and 10 percent beech. In 1985, it was 52 percent oak, 33 percent beech, 8 percent other hardwoods, and 7 percent conifers.

There are 868 ha of oak forests with 470 ha in Müllheim. Müllheim forstamt is 6,300 ha, 1,000 ha of which is hardwood foothills. Ownership is 1,000 ha state, 5,000 ha community, and 300 ha private. The forest office has a director, one assistant, and one administrator, three secretaries, and seven forest districts. The elevation ranges from 1,220 m in the Black Forest portion of the forstamt to 400 m in the foothills and 210 m in the Rhine Valley. Precipitation ranges from 1,900 mm in the Black Forest to 1,000 mm in the foothills and 730 mm in the Rhine Valley. Precipitation during the growing season is 600, 430, and 330 mm, respectively. The average annual temperature is 4.5, 9.2, and 10°C, respectively, while the growing season temperature is 12, 16.3, and 17°C.

The Black Forest has soils from granite and kneiss bedrock. Native vegetation is silver fir (*Abies alba*) and beech while Norway spruce and Douglas-fir have been introduced (about 25 percent each). The composition of the forstamt is 57 percent conifers and 43 percent hardwoods (18 percent beech, 10 percent oak, 2 percent hornbeam, and 13 percent other). The annual harvest is 6.6 m^3/ha/yr.

Oak Silviculture and Management

In contrast to France, Germany has not prepared an ecological site classification for the country. The amount of site work varies widely from state to state and region to region within a state. Most areas have maps of their forests that incorporate some type of productivity measure and perhaps information on soils. Other areas have more detailed maps that provide information on soils, moisture status, climate, vegetation, and the probability of storms, drought, and insect attack. A higher proportion of the German information is based on long-term experience with the sites.

The management goal for Germany's oak forests is similar to that for oak forests in France—the production of high-value products, particularly veneer, on long rotations. Long rotations also satisfy many of the social amenities connected with forests and results in the production of firewood, pulpwood, and sawtimber as intermediate yields. One social need not satisfied is that for natural forest areas. Beginning early in this century, Bavaria began to set aside certain forest areas as natural areas that will not be managed. In addition, the federal government has set aside a few parks that will not be managed. While all of the states and regions in Germany have the same management goal, the approach can vary. For instance, the philosophy of oak culture in the Würzburg area is to produce wood with narrow annual growth rings and a tall clear bole. This goal encompasses three stages: in the first stage, about 100 to 150 years, a clear stem is grown to a height of 20 to 25 m, the second stage, about 200 to 300 years, is marked by frequent thinning to allow continual growth at a uniform rate; in the third stage, from 300 to 600 years, all mature trees are harvested slowly over time and then the stand is regenerated (Fleder 1981).

In Freiburg, the goal is to grow shorter, fatter trees in less time, (faster growth and wider rings). The first 40 years are spent in stem reduction as good-quality, spaced trees are encouraged; the second stage, from 40 to 140 years, is spent selecting crop trees and thinning to produce knot-free wood on the crop trees; the last period, from 140 years to rotation age, is spent caring for crop trees and harvesting declining trees, and then harvesting at rotation (Kenk 1984).

Regeneration in Germany is a combination of natural and artificial processes. All of the higher productivity oak sites have beech as the climax forest type, so they have to work against succession. Most regeneration is done through a shelterwood sequence, but clearcutting is sometimes used. A two- or three-cut sequence consists of a preparation/seed cut and final removal cut or a preparation/seed cut, first removal cut, and final removal cut. All regeneration work is timed to acorn crops. In Spessart, seed crops are obtained every 7 to 10 years, so sufficient area must regenerated in one year for the next 7 to 10 years of forest regulation. In Würzburg and Wiesentheid, seed crops occur every 6 years. In Müllheim, seed crops are infrequent due to late frosts and insect defoliators.

In Spessart, all regeneration is geared toward mast crops. In spring, the flower crop is inspected for damage by insects or late frosts. In summer, the crop is checked again and in mid-September the acorns are ripe. In October, a shelterwood cut removes 50 percent of the stand (Fig. 4). Branches are then removed and given to citizens for firewood. Licenses are issued for the collection of acorns. By law, acorns can be collected only from recommended stands. Sellers receive 100 DM for 50 kg of acorns ($0.50/lb). In 1982, the last mast year, 6000 kg of acorns were collected.

After the shelterwood cut has been completed, a fence is installed to keep out wild boar and roe deer. The site is prepared with a machine that makes rows for seeding (the wheel frees mineral soil), 800 kg/ha of acorns are sown by a crew of 10 to 20 people (usually women), and the acorns are covered with soil (5 cm or deeper is better to avoid late spring frosts) (Nüßlein 1978). The shelterwood is used to provide natural regeneration of beech along with the oak, protect seedlings from frost and heat, and reduce grass growth. This process, which imitates natural regeneration of oak, produces 100,000 natural oak seedlings to 10,000 beech seedlings/ha. Beech usually is left in the overwood as all of the oak veneer has been removed by the time the stand is regenerated. The area is seeded from October until late December. In 1983, nearly 80 ha were regenerated from the 1982 seed crop. Oak seedlings are transplanted from dense areas to areas that need seedlings. Light grass is not a problem, but heavy grass is packed down by snow and mice girdle the seedlings under the grass. Beech is used to give high shade to oak trunks and keep them free of branches. Beech seedlings and oak seedlings with low branches are cut at 5 to 6 years. Oak seedlings with clear stems are left to grow with the new stand. When seedlings are 1 to 1.5 m tall, removal of the overwood is begun. The fence is left for 10 to 15 years. Manual weeding is done to remove heavy grass, birch, and conifers and to prune the beech below the oaks. *Rubus* is not a serious problem. In 1982, the cost of regenerating the stand (Figure 5) was:

Item	**DM/ha**	**Dollars/acre**
Removing brushwood/slash	1,500	333
Preparing seedbed	500	111
Acorns	800	178
Hand sowing	2,000	444
Fencing (8-foot woven wire)	1,200	267
Total	6,000	1,333

The cost range is 6,000 to 9,000 DM/ha or $1,333 to 2,000/acre. Costs for weed control are 1,500 DM/ha ($333/acre) per year for 3 years and 200 DM/ha ($44/acre) per year for mouse control.

In the Freiburg region, seed production is irregular due to late frosts and insect defoliation. Oak is managed partially with natural regeneration and partially by planting. Fifteen years ago, 10,000 to 12,000 seedlings/ha were planted; this amount has since been reduced to 3,000 to 3,500/ha, including 1,500 hornbeam seedlings/ha. Beech sometimes is planted as well, 1,000 to 2,000 oaks/ha are planted and natural seedlings of beech, birch, hornbeam, etc. are used to fill in. Early tending measures are used to keep the oaks dominant. Site/species selection criteria are again being used to prevent offsite problems that have developed on past plantings. In the future, oak will account for 10 to 15 percent of the forest (70 to 80 percent of it managed by planting and 20 to 30 percent by natural regeneration). In some areas, coppice with standards may be used to reduce the costs of establishing oak stands. In the flat Rhine Valley forests of Baden-Württemberg, 20 to 25 percent of the area is planted to *Q. rubra* because of its better growth on the drier sites (average yield of 8 to 10 m^3/ha/yr). The cost of establishing 1 ha by planting to end of the cultivation phase including fencing, weeding, cleaning, etc. ranges from 10,000 to 12,000 DM to 25,000 DM ($2,222/acre to $5,555/acre). The cost of natural regeneration ranges from 8,000 DM to 12,000 to 14,000 DM/ha ($1,778/acre to $3,111/acre).

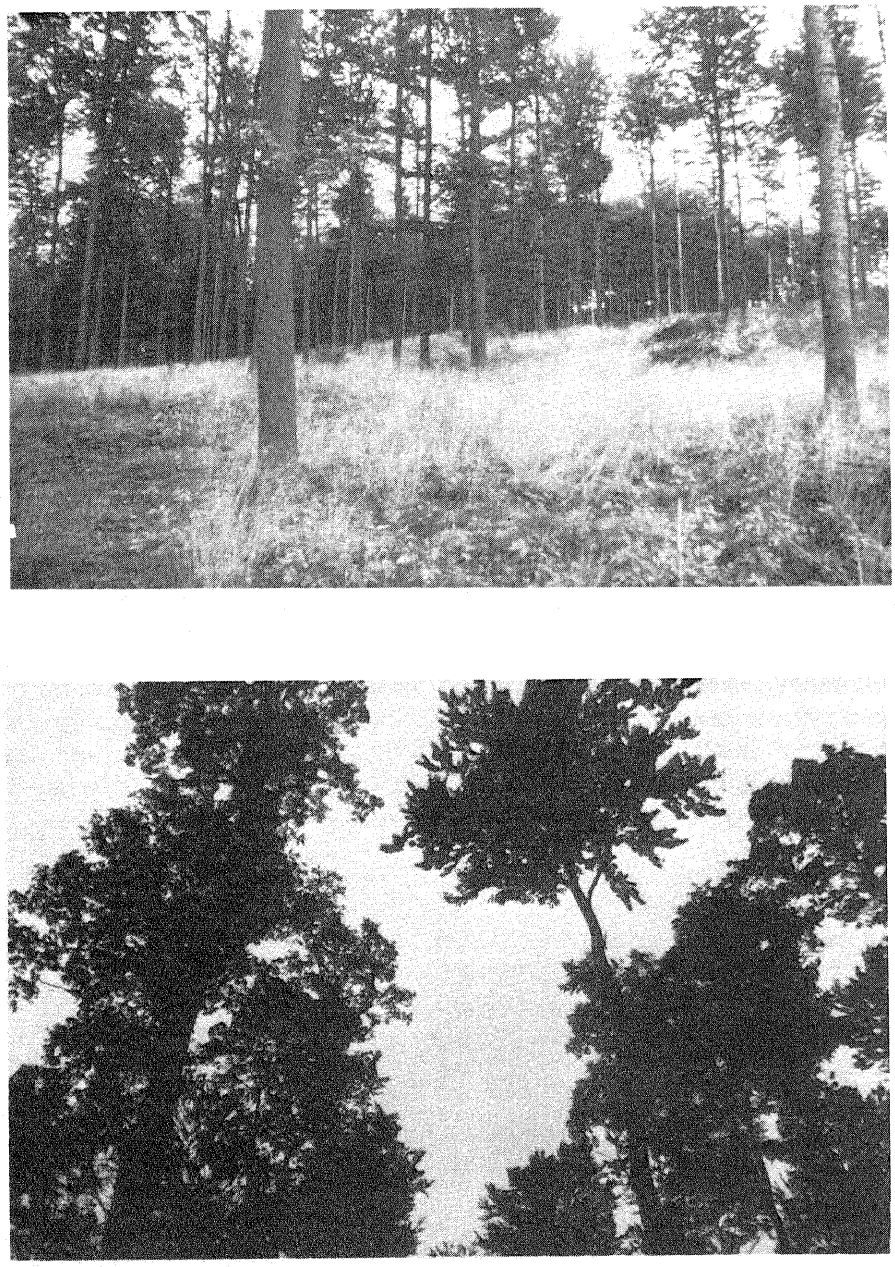

Figure 4.—A shelterwood cut in Spessart area of Germany, Rothenbuch forstamt, completed in 1982, provided shelter for direct seeded seedlings. A. Overstory has been reduced by 50 percent and grass cover results (upper). B. Crown coverage from 50-percent reduction (lower).

In planting, the soil is not prepared due to compaction problems. Planting stock usually is 60 to 70 cm tall. Fencing is used to protect seedlings from roe deer and wild boar. Due to severe weed competition from *Rubus*, the stands are weeded twice in the first year and then once a year until the 5th or 6th year. The seedlings are fertilized 1 year after planting with a handful per tree. Because of early fall or late spring snows can bend the seedlings, a wide spacing is used to give each stem more stability. Major disadvantages of planting are high costs and difficulty in obtaining sufficient quality seed.

Figure 5.—Direct seeded 6-year-old seedlings from 1982 seed crop in Spessart Region. The seedlings are under the shelterwood in Figure 4 and have been weeded manually.

Natural regeneration of oak from seed can occur when there are good seed crops as in 1984 in the Freiburg region. A preparation cut removed one-third of the growing stock following natural regeneration from the seed crop. A first removal cut removed another one-third after 2 years, and a final removal cut the remaining one-third after 5 years (another 3 years). The area has 70,000 to 300,000 seedlings/ha. Atrazine and indolebutyric acid for 1 year controlled grass, but had limited success against *Rubus*. *Rubus* was manually cut to give oak enough light to keep them above the weeds. In 1988, rows were marked in the natural seedlings. Oak seedlings in between rows were removed by mowing or cutting. Some of these seedlings were transplanted into areas of rows without seedlings. Manual weeding was done twice. The high density of seedlings should be lowered as fast as possible. This will be accomplished by transplanting seedlings to other clearcuts and doing precommercial thinnings and cleanings. Natural regeneration can be obtained in 1 year if a clearcut is made immediately after the seedlings appear.

As in France, early cleanings in Germany are used to set up paths in the stand. In natural regeneration, a common arrangement is a 1-m-wide path at spacings of about 30 m. The purpose of the cleanings is to remove conifers, birch, and oak wolf trees. Beech are cut off below the oaks but not eliminated. Where beech is weak, some oaks may be cut to improve it. Oaks are kept dense to prevent forking and are thinned by natural competition (Figure 6). In planted stands, cleanings remove non-oaks within and between rows. A stand is cleaned from about age 4 to 20. The switch to thinnings occurs at about 20 years of age, earlier than in France.

In Germany, the first 2 to 3 thinnings (ages 20 to 50, up to 80) are precommercial, with most of the wood used for firewood. In Müllheim, farmers come do the cutting in exchange for the wood at no cost or for a small fee. In Spessart, this wood may be used by the forstamt or sold. In all areas, the small trees cut in these early thinnings are cut into 1-m-long pieces and carried from the woods to prevent damage to residual trees. These thinnings are done by selecting crop trees and carefully promoting them through crown thinnings to increase crown size; wolf trees not removed in cleanings also are removed. Beech is retained in the understory to shade the oak stems and prevent epicormic branches. Thinnings at intervals of 10 to 15 years maintain a uniform growth

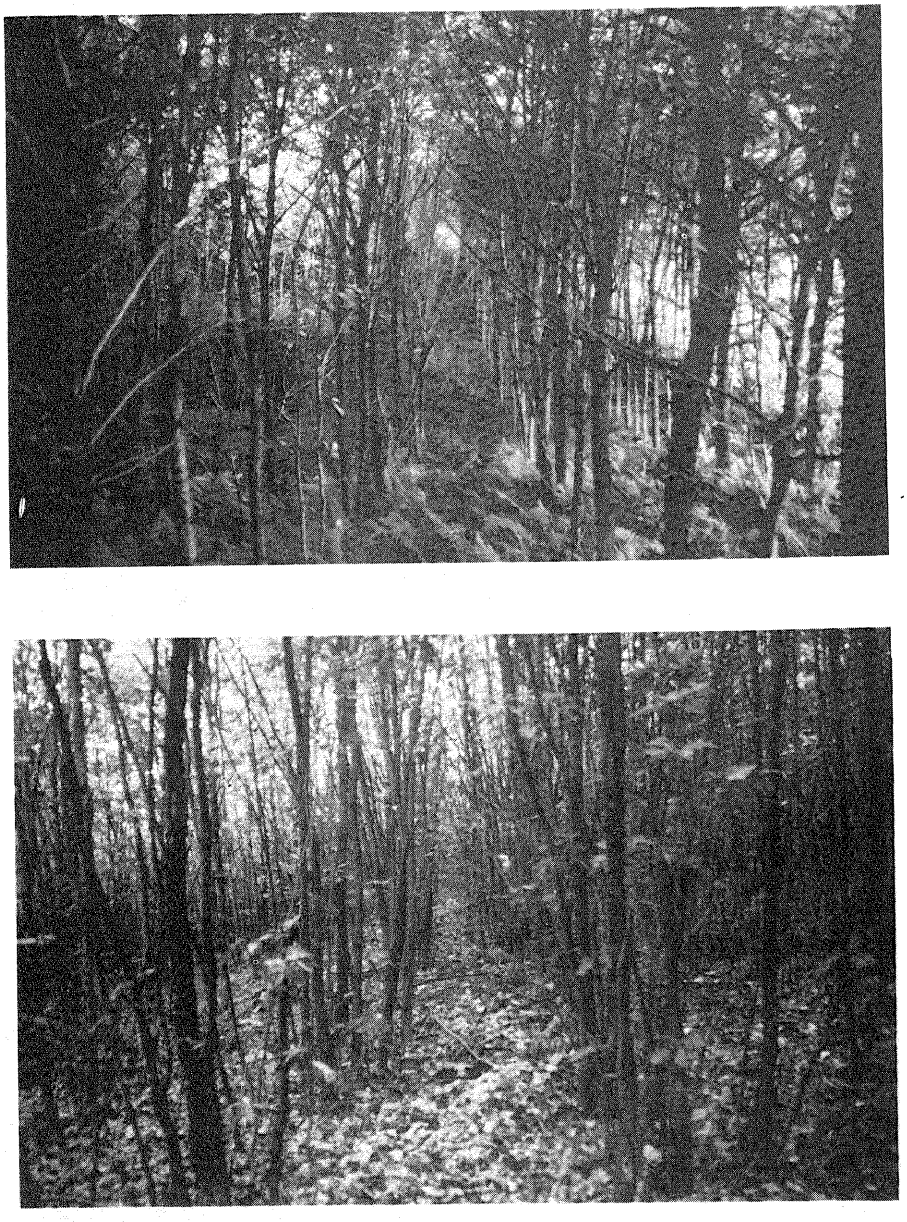

Figure 6.—Young managed stands in Germany. A. Stand in Müllheim forstamt is 10 to 15 years old after planting in 1-m spacing by 2.1-m rows. Cleanings have removed other competitors. Precommercial thinning has not began because the stand is still naturally pruning (upper). B. 18-year-old stand in Rothenbuch forstamt that was direct seeded in 1970. It was cleaned in 1974 and again in 1986-87. Access paths were cut in 1981 (lower).

rate. Most areas select 80 to 100 crop trees/ha by age 30 to 40 (Figure 7). In some areas, precommercial thinnings do not begin until natural pruning is completed.

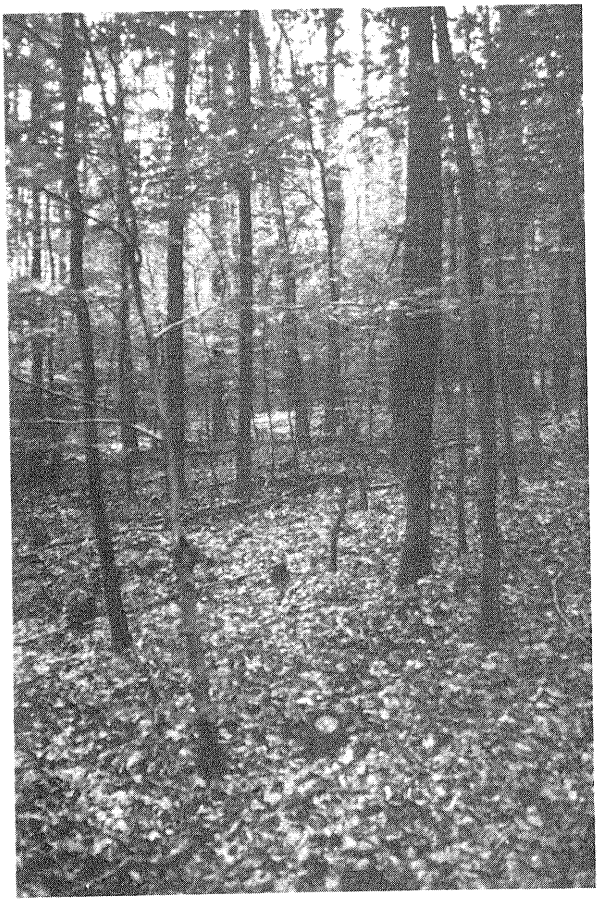

Figure 7.—50-year-old crop tree that has just been released in Müllheim forstamt (note stumps). Beech understory trees were not cut.

Commercial thinning begins at 50 to 80 years depending on the region. Small-diameter trees are sold for parquet flooring and large trees for sawtimber. All trees that are competing with the crop trees are removed. In Spessart, all marking is done by crowns; a tree must have a good crown to be left. Thinning goals are to continue increasing crown size on crop trees and maintaining uniform growth (Spiecker 1983). In the State of Baden-Württemberg, thinning for crown size ends at age 120 to 140. This is followed by thinning based on caring for the growing stock, a low thinning approach by which declining and rotten trees of oak and beech are removed while beech is maintained in the understory. Beech trees are removed as soon as they begin to grow into the oak crowns. They are quickly replaced by smaller beech trees, and shade on the oak stems is maintained. Natural regeneration of the beech under these conditions is easily obtained. Using beech rather than understory trees like hornbeam or linden results in harvests of high-quality beech sawtimber (and veneer) rather than firewood.

The Spessart region uses a similar commercial thinning system, but thinning is continued until around age 200 before the switch to low thinnings. The goal at age 200 is 71 trees/ha, a height of 33.2 m, basal area of 27.4 m^2/ha, and volume of 500 m^3/ha. This goal is similar to the final harvest goal in France. In the Spessart region, the beech understory also is used to keep the oaks branch free and to produce sawtimber. Before 1840, pure oak stands with no beech were created

and the problem with oak branches and short clear stems was discovered. In 1840, beech was planted in the understory of oak stands and in all new stands since then (as planted or natural regeneration) to improve stem quality. It is possible to obtain two or three rotations of beech sawtimber (140 to 150 years) from one rotation of oak.

In Baden-Württemberg, the rotation is 220 to 230 years for *Q. petraea* and 160 to 180 years for *Q. robur*. In Spessart, the rotation for sessile oak is 240 years, though many trees are carried longer. In drier areas of Upper Franken, the rotation is 150 to 160 years. The goal is to have trees that average 70 cm at rotation, similar to France's goal. Goals for clear bole differ with regions: Spessart wants 18 to 20 m while other areas are satisfied with 4 to 12 m. Spessart often holds the oak veneer trees from age 200 to 600, slowly cutting out veneer trees and allowing beech to replace them. The stands move from oak stands with beech understory to mixed oak-beech stands to beech stands (Figure 8). After all of the oak has been cut out, the beech is left for 10 to 50 years. A shelterwood cut then is done with seeding of oak beneath the beech. Minimum product diameters are 20 cm for parquet flooring, 25 cm for sawlogs, and 35 cm for veneer. It is possible to sell veneer from thinnings in some stands. In Germany, all trees are harvested by state crews. The material is then sold as decked wood. Information on the wood to be sold is published and mailed to buyers, who have three weeks to inspect it before the auction. Separate auctions are held for sawtimber and veneer, the latter is harvested only in the winter. Auctions generally are held in December and March. The average price for oak veneer is 1700 to 1800 DM/m^3 or \$5,289-5,600/M bf. In 1983, the Rohrbrunn forstamt sold one veneer tree with three logs that set a record for price and income. The tree brought 72,000 DM (\$39,528) broken down as:

Log	Length	Middiameter	Volume	DM/m^3	Dollars/M bf
1	9.1 m	77 cm	4.24 m^3	14,150	44,021
2	5.7 m	67 cm	2.01 m^3	4,910	15,275
3	3.6 m	61 cm	1.05 m^3	2,110	6,564

The third log, starting at a height of 49 feet extending to 61 feet, brought about the same price as oak veneer in the United States, while the lower logs brought up to eight times the price of our veneer. At a 1987 auction a two log tree brought 62,347.6 DM (\$34,229). As in France, color is important in determining the value of the log; bright yellow has the highest value while gray or red colors bring lower prices.

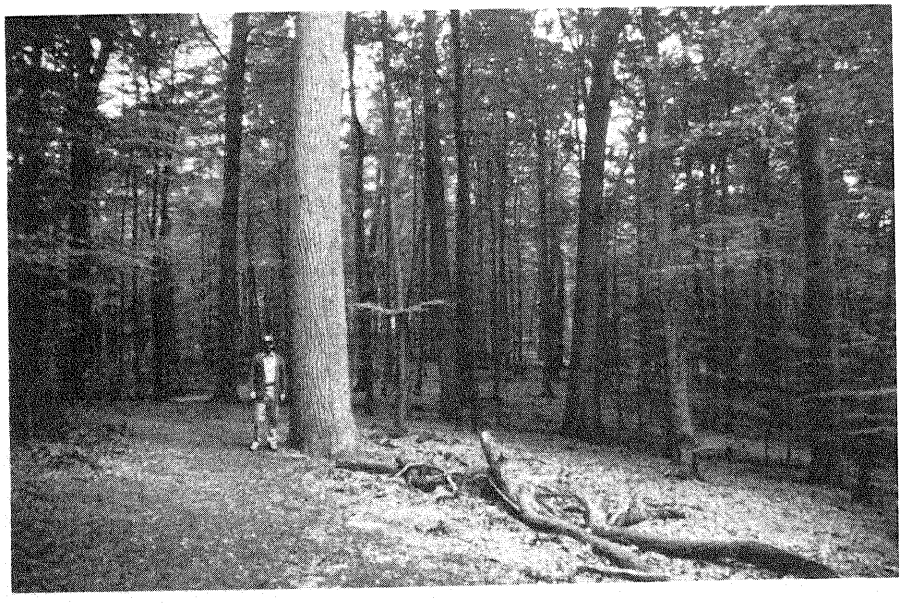

Figure 8.—360-year-old stand in Rohrbrunn Forstamt that is mature and slowly being harvested. It is now a mixed oak-beech stand with well-developed beech sawtimber. Eventually it will be regenerated after all of the oak has been harvested.

DEFOLIATION IMPACTS

In both France and Germany, two defoliating insects, the oak leafroller (*Tortrix viridana* L.) and the winter moth, (*Operopthera brumata* L.) occurred, often together, in outbreaks in all oak stands. Apparently, there were some differences in outbreak frequency in different areas and climates, but there was insufficient information to discover a pattern. Both species defoliate very early in the growing season. Major defoliation effects are loss of seed crops and growth loss; mortality is rare. The oaks recover quickly from this early defoliation without incurring severe damage. However, the effect on seed crops is severe in most areas. In the Müllheim forstamt, almost yearly outbreaks of oak leafroller and winter moth since 1958 have resulted in little or no natural reproduction in the area most years. In some areas, defoliation also is caused by less widespread insects. In the Spessart region, defoliation was caused by the large winter inchworm (*Hibernia defoliaria*); the common wanderer moth (*Thaumetopoa processionea*) caused defoliation in the Bourges region of France; and several species of Noctuids have defoliated trees in the Frankish Plateau of Germany.

Outbreaks of the gypsy moth (*Lymantria dispar* L.), the other major oak defoliator in Europe, are smaller and appear confined to specific climatic and site conditions. Apparently, gypsy moth outbreaks are restricted to warm, dry climates and sites that are warm and dry, especially during the larval period. In Germany, gypsy moth is considered a major pest only in areas with fruit (apple) orchards and vineyards. The Spessart region, which is cool and moist, has never had a gypsy moth outbreak, while the Frankish Plateau, only 10 to 30 km to the east with a warm, dry climate, has the most frequent and numerous gypsy moth outbreaks in Germany. The stands in both areas are predominantly sessile oak.

Gypsy moth has occurred in the warmer Rhine Valley on the Offenburg Forstamt, but not in the cooler, moister foothills of the Black Forest in Müllheim forstamt, only tens of kilometers away. In the warm and dry Bourges region of France, the gypsy moth often is accompanied by other defoliators. In the Frankish Plateau in Germany, the gypsy moth, oak leafroller, winter moth, and Noctuids together caused defoliation at various locations from 1979 to 1988.

As with the oak leafroller and winter moth, the major effects of gypsy moth defoliation in oak stands are loss of seed or mast crops and growth loss. However, tree mortality can occur following defoliation by gypsy moth. Such defoliation occurs in late spring and early summer and damages the lammas (long shoot) growth of the oaks. When all three insects interact, the oaks are defoliated early, refoliate, and then are defoliated again by gypsy moth. In this situation, crown dieback and eventually mortality can occur (Figure 9). Mortality also results when refoliated leaves are infected with the European powdery mildew (*Microsphaera alphitoides* (Grif. and Maubl.)), a fungal disease. In the Frankish Plateau, many defoliated trees die following an attack by the cambial borer, *Agrilus biguttus*.

Mortality increases in importance on drier sites. In the Bourges region, there was an inverse relationship between soil depth and mortality, especially with pedunculate oak. Poor silviculture also contributes to increased mortality in stands. Many areas that are heavily and frequently defoliated by gypsy moth are managed or have been managed as coppice with standards (Figure 10). A lack of thinning that creates stands that are too dense or overstocked results in trees with smaller, thinner crowns and increased mortality due to lowered tree vigor and poorer crowns. Mortality also increases in trees of advanced age. In most areas of France and Germany, tree mortality is only 5 to 10 percent in most gypsy moth areas. Most of this mortality is salvaged promptly, so one rarely observes dead trees in the stands. In the Offenburg forstamt, however, mortality in pedunculate oak was 40 to 50 percent following 2 to 3 years of defoliation combined with powdery mildew infection in the last year. In Thoux Forest in the Bourges region of France, mortality of oak standards exceeded 80 percent on half of the area and ranged from 0 to 30 percent on the other half. Mortality was greater on shallower soils and where there was more pedunculate oak than sessile oak.

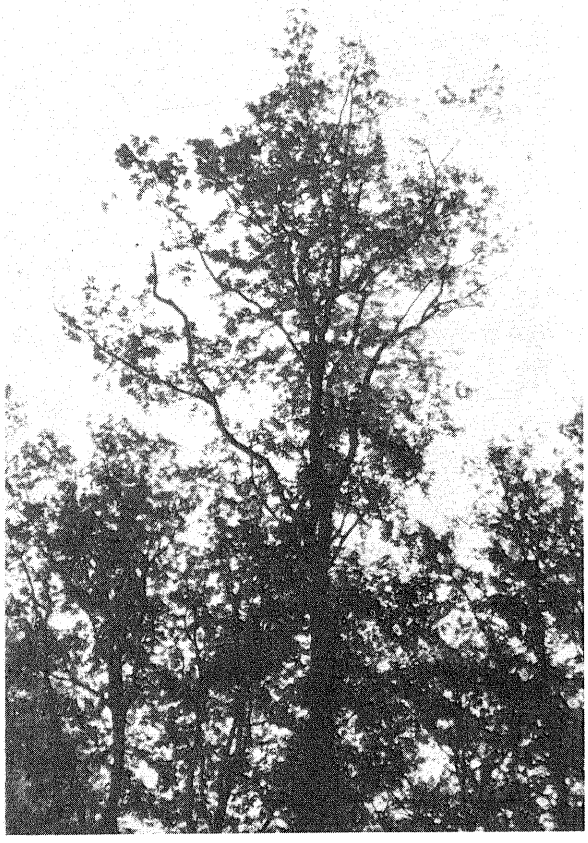

Figure 9.—Crown dieback in 200-year-old sessile oak on the Soudrain Forest in France. Gypsy moth defoliated the stand completely for two years, resulting in mortality of 6 to 8 percent.

Control of defoliating insects is done with aerial application of insecticides by helicopter. Small blocks of 60 to 70 ha are marked with hydrogen-filled balloons. The most common material used is Dimilin which is applied at 40 l/ha and 300 g/ha. The dose may soon be reduced to 159 g/ha. Ultra-low volume applications are not allowed due to the high drift that results. The bacteria, *Bacillus thuringiensis* or *Bt* is also commonly used, especially on insects other than gypsy moth. Pyrethrins are used in situations where large larvae must be sprayed. Viruses are used to a small extent when possible. Thresholds for treatment are: 1 to 2 egg masses per lower 2 m of stem for gypsy moth (equals 20 egg masses per tree); 1 female moth per cm of circumference on sticky bands around the tree for winter moth; and 500 eggs per 1000 buds (1 egg/2 buds) for oak leafroller when in combination with gypsy moth.

CONCLUSIONS

Defoliation impacts in French and German oak forests have serious implications for silviculture and management. The most severe is the loss of acorn crops. A lack of mast for wildlife, a major

Figure 10.—Oak stands managed as coppice with standards that are frequently defoliated by gypsy moth. A 110-year-old stand that was managed as coppice with standards until 1900. Located in Poppenhecke on the Frankish Plateau of Germany, it has old oak with little understory. The area was defoliated by the gypsy moth and oak leafroller in 1980 and by the winter moth in 1986-88.

use of oak forests, and lack of seed for regeneration are other concerns. The latter concern drives the entire silvicultural system for regeneration in many areas. Planting and direct seeding are used to circumvent problems associated with a lack of natural regeneration due to poor seed crops. The loss of diameter growth and wood volume is less serious. Since most areas are managed to produce high-quality veneer with uniformly narrow growth rings, defoliation does not affect quality as it would if trees were being managed for uniformly wide growth rings.

Growth loss is affected more by gypsy moth than by other defoliating insects. Gypsy moth causes more mortality, though usually less than 10 percent. This level of mortality is not a limitation to silviculture, the dead trees being salvaged as part of the normal thinning process. In rare situations where mortality is heavy, difficult silvicultural and managerial decisions are needed. For example, in the Offenburg forstamt, where mortality in young to middle-aged stands was heavy, do you manage understocked stands with severe epicormic branches that reduce the potential for quality wood or do you prematurely regenerate them?

With regard to the silviculture and management of oak forests in France and Germany, differences are most apparent when one looks at the regeneration process. The use of natural regeneration versus direct seeding/planting depended on the frequency of seed crops, climate, and insect defoliations. Unlike France, Germany fences to exclude roe deer and wild boar. However, there also are many similarities: intensive weeding is used to establish and promote the growth of young seedlings; tending trails are used to facilitate early entry for cleanings that remove wolf trees and non-oak competitors; crop trees are selected at young ages and thinned to promote crown development first and then a uniform growth rate; and understory trees and beech are used to shade oak stems to prevent epicormic branches while producing high-quality veneer. In addition, management is toward trees that are 200 to 240 years old and an average final diameter of 70 cm, though

there are differences in height of clear stem, with Spessart managing for 18 to 20 m as opposed to shorter heights. Spessart also harvests mature trees over long periods with eventual conversion to beech before initiating the regeneration process; while other areas regenerate at the end of the rotation.

Differences in the silviculture and management of oak forests in France and Germany versus the United States are nearly too numerous to mention. Our rotations generally are much shorter but final diameters are similar, so we grow trees much faster with wider growth rings. And our stands are usually managed for sawtimber, though some logs are used for veneer. Also, management in the United States generally is much less intensive: cleanings are rare and commercial thinnings are less frequent. Because our markets for small-diameter oak are much poorer, we thin initially at older ages and larger sizes. As a result, natural competition and overstocking play a larger role in the development and health of U.S. stands. These overstocked stands with small crowned trees are more vulnerable to mortality when defoliated by insects than are intensively managed stands in Europe.

During regeneration, we generally do not pay as close attention to seed crops and do not spend as much time and money on intensive weeding, fencing, and other cultural practices. One factor contributing to this difference is the accounting methods used for these expenditures. In Europe, the forests need show a profit only on an annual basis; all regeneration and other management expenses are paid for from that year's income, whether from timber sales, hunting, etc. In contrast to the United States, there is no tracking of investments at compound interest rates over the rotation.

Similarities between Europe and the United States include an attention to silvical and ecological site factors that affect productivity and management actions, and a desire to regenerate and manage oaks on high quality, productive sites. On these highly productive sites, management for oaks is fighting succession to other species. In Germany, for example, most of the productive sites would become beech stands except for the intensive management that keeps beech secondary to oak. In natural areas set aside to show what happens without intensive management, beech is growing through the oak crowns and killing the oaks. In the United States, we also are fighting a battle against succession on the best sites, but we have been unable to develop biologically and economically effective silvicultural treatments to allow oak to prevail. Perhaps we should take a lesson or two from Europe and look at more intensive management practices in some areas, especially regeneration, and at how we finance silviculture and management.

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