# SILVICULTURE AND STAND DYNAMICS OF SCOTS PINE IN GERMANY

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## SUMMARY

The current structure of forests in Germany and their related biological diversity is a result of the natural, cultural and economic development of the last 10,000 years. The species composition, their distribution and the forest-field land proportion probably began to change about 3,000 years ago. Modern forestry evolved between 1750 and 1850 in Germany. The over-exploited and degenerated forests of that time were changed into highly productive pure conifer plantations. Solely by this measure, the increased demands of the timber using industries were satisfied. The proportion of natural pine forest in the potential natural vegetation is less than 3 % whereas the proportion of Scots pine in the current forest area is 28 %. The centre of distribution of these forests is the northern lowland regions of Germany where predominantly pure pine plantations occur on sites of natural hardwood forests. The age class structure is dominated by young stands up to 60 years old. This age class distribution complicates a cost-effective pine forestry. Within the last decades, alternative silvicultural regimes have been developed to solve these problems and to increase the degree of naturalness in existing pine plantations. In general these models aim to decrease costs, produce large and high quality timber, increase the structural diversity, increase the proportion of broadleaved species and of continuous cover forest systems. Diversity does not apply as an ecological quality criterion. For the assessment of the actual biodiversity a comparison with the potential natural vegetation is necessary.

**KEY WORDS:** Scots pine
Stand dynamics
Silviculture
Biodiversity

## INTRODUCTION

The German forests in which Scots pine stands are an important feature are managed for specific objectives. Therefore the current levels of genetic, species and ecosystem diversity cannot be considered as natural characteristics of our forests. They are the result of natural, cultural and economic development in central Europe during the last 10,000 years. To understand this process, it is necessary to take into account the post glacial evolution of the forests, the cultural and industrial development of society, and the influence of past forest management on the forest structure.

## POST-GLACIAL FOREST DYNAMICS TO THE BEGINNINGS OF REGULATED FORESTRY

Scots pine, together with birch and hazel, was amongst the first tree species which spread back into central Europe after the last ice-age. This pioneer forest type which is still widespread in the northern conifer zone in Siberia, was displaced slowly in central Europe by different, more nutrient demanding or more shade tolerant tree species (sycamore, lime, ash, alder, spruce) due to improving climatic conditions. Later, tree species characterised by a slower rate of spread (oak) colonised in the post glacial Atlantic period. Beech colonised first during the cooler and more humid subatlantic period 3000 years ago, when man had already started to affect the landscape through his activities as farmer and cattle breeder. The influence of man on vegetation since that time is clearly shown by pollen analysis (Liedtke and Marcinek, 1995).

The largest changes in the natural forests of Germany due to human influence occured in the early medieval period (1,100-1,300AD) when settlements were developed and forests were cleared to provide new arable land. Further extensive forest devastation took place in the highlands driven by the timber demand for mining, ore smelting, charcoal production, potash, and salt production.

Until the end of the Middle Ages the main forest utilisation was for firewood production and as forest pastures for rural communities. The main management system of the forests was based on coppicing. The utilisation of these forests on approximately 20 years rotations favoured those species with good coppicing capability (hornbeam, oak, birch) and led to a major decrease in the amount of beech forests.

These historic forest management practices caused important changes in the composition and the diversity of the vegetation. Coppicing and farming promoted the propagation of light demanding species and displaced shade tolerant ones or those sensitive to mechanical injury. The creation of artificial grasslands in Central Europe allowed the spread of annual and perennial species indigenous to the Orient, South East Europe and Southern Siberia.

In the eighteenth century the condition of forests in Germany reached a critical state. An increasing population, the demands of commercial businesses such as mining and salt production, and growing industrialisation, all led to a rapidly increased demand for timber and charcoal. The existing forests were over-exploited and also degraded by forest pasture and browsing. It was in this situation (devastated forests and increasing timber demand) that regulated forestry started as an independent commercial sector in Germany, between 1750 and 1850 (Gregorius and Schoppa, 1999; Liedtke and Marcinek, 1995).

## CHANGES IN FOREST COMPOSITION DUE TO FORESTRY SINCE THE 18th CENTURY

To meet economic demands the coppice forests have been transformed into high forests since the eighteenth century. The establishment methods used were firstly sowing and later planting. The different successional stages of the natural forest were mimicked as even-aged age class forests. The species selection considered mainly of Norway spruce in the foothills and mountains, and Scots pine in the north German lowlands. The aim of forestry at that time was to develop highly productive forests which could be managed to produce a sustained yield of timber over time. The formation of these forests and their species composition was supported by the following developments:

- Decline of forest grazing due to improvements in agriculture (stables) and the ending of litter raking.
- Decline in browsing damage by reduction of deer population.
- Changes in timber utilisation, timber demand, and timber-price-relations.
- Decline in firewood utilisation and increase in the production of industrial timber.
- Decrease in utilisation of energy-rich broadleaved firewood and increase in utilisation of lighter softwood as construction and mining material.
- High prices for softwood construction timber, low ones for firewood.

The establishment of forests on former farmland, moorland and wasteland or the restoration of devastated forests involved overcoming unfavourable ecological conditions which required pioneer tree species such as Scots pine in the lowlands or Norway spruce in the uplands. The establishment of large areas of broadleaved forests proved less successful. Even under more favourable ecological conditions, increasing timber demand and timber prices for Norway spruce and Scots pine, plus their superiority in volume increment and timber out-turn favoured the conifers over the broadleaves (Gregorius and Schoppa, 1999). The converse of these economic advantages of conifer forestry was the serious increase in the risks of recurring damage due to insects, fires and wind blow. Historical investigations by Schwartz (1991) revealed that 69 % of the Scots pine area existing in Germany in the year 1913 (3,8 million ha) had been created since 1853. These findings illustrate the rapid structural and tree species conversion of German forest area in this correspondingly short time interval. The statement of Le Maitre (1998, page 416) that Germany silviculture «reverted to ´natural´ forestry from about 1875» is completely incorrect. The idea of «back to nature» management which arose at this time and also the «Dauerwald»-system (continuous forest) never achieved economical and practical significance. The majority of Scots pine forests were managed as even-aged pure stands with periodic thinnings and clearcutting at the end of the rotation period. Also the well known «Dauerwald» experiment in the forest district of Bärenthoren eventually failed because natural regeneration of artificial Scots pine stands on sites with higher nutrient status is an exception, not the rule (Hofmann, 1960; Anders *et al.,* 1999).

## THE PROPORTION OF PINE ECOSYSTEMS IN THE CURRENT FOREST AREA AND A COMPARISON WITH THE POTENTIAL NATURAL VEGETATION

In Germany approximately 10.4 M ha are covered with forests which is about 30 % of the total land area. The most important tree species are summarised in Table 1.

Scots pine covers an area of approximately 2.885 M ha, almost all as pure even-aged stands. The main area of pine forestry is the north-eastern German lowlands; however, substantial areas of pine also exist in other German regions (Table 2).

**TABLE 1**

**PERCENTAGE FOREST AREA OCCUPIED BY DIFFERENT TREE SPECIES [AFTER POLLEY (1994) AND BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN (1994 a, b)]**

*Porcentaje de superficie forestal ocupada por diferentes especies arbóreas [Polley (1994) y Bundesministerium für Ernährung, Landwirtschaft und Forsten (1994 a, b)]*

| Tree species | Percentage |
|---|---|
| Norway spruce | 33 % |
| Scots pine | 28 % |
| Beech | 14 % |
| Oak | 9 % |
| Other tree species | 16 % |

**TABLE 2**

**AREA OCCUPIED BY SCOTS PINE IN DIFFERENT GERMAN REGIONS**

*Área ocupada por el Pino silvestre en diferentes regiones alemanas*

| Region (State) | Area of pine stands (ha) | Percentage of pine ( %) of total forest areas |
|---|---|---|
| Brandenburg | 773,868 | 80.9 |
| Bayern | 578,454 | 22.9 |
| Niedersachsen | 380,208 | 35.6 |
| Mecklenburg-Vorpommern | 231,065 | 47.9 |
| Sachsen-Anhalt | 206,271 | 51.9 |
| Sachsen | 159,188 | 34.4 |

The age class structure of the pine stands shows the preponderance of young and pole-stage stands. More than half of all pine stands are younger than 60 years (Fig. 1). Analysis of volume structure by age-classes shows a similar pattern (Fig. 2). Half of the standing volume of pine is provided by stands up to 70 years old (deficiency of older age-classes with correspondingly high stem volumes). Correspondingly the mean diameter is small and economic return from these stands is low. The high percentage of pine stands related to the whole German forest area and the age class and standing volume structure shown above demonstrate the low degree of naturalness in large areas of forest landscape dominated by pine. The proportion of pine stands in the potential natural vegetation (after Tüxen, 1956) in Germany is very low. This is the conclusion of Hofmann (1991) summarising a series of investigations of the natural vegetation of Germany, carried out by many scientists [1] (Table 3).

[1] [Ackermann (1954); Bohn (1985); Buchwald (1951); Dengler (1904, 1910); Ellenberg (1982); Fukarek (1961); Gauckler (1938); Griese (1986); Grosser (1954, 1956, 1964); Hartmann (1934); Hofmann (1957, 1960, 1961, 1962, 1964 a, 1964 b, 1965 a, 1965 b, 1968, 1985); Hueck (1931); Kopp (1956); Krausch (1962); Krieger 1937); Matuszkiewicz (1962); Meisel-Jahn (1955); Oberdorfer (1957); Passarge (1960, 1962, 1963); Passarge and Hoffman (1964, 1968); Scamoni et al. (1975); Scamoni (1960 a, 1960 b, 1982); Schubert (1963); Seibert (1958); Tüxen (1950)].

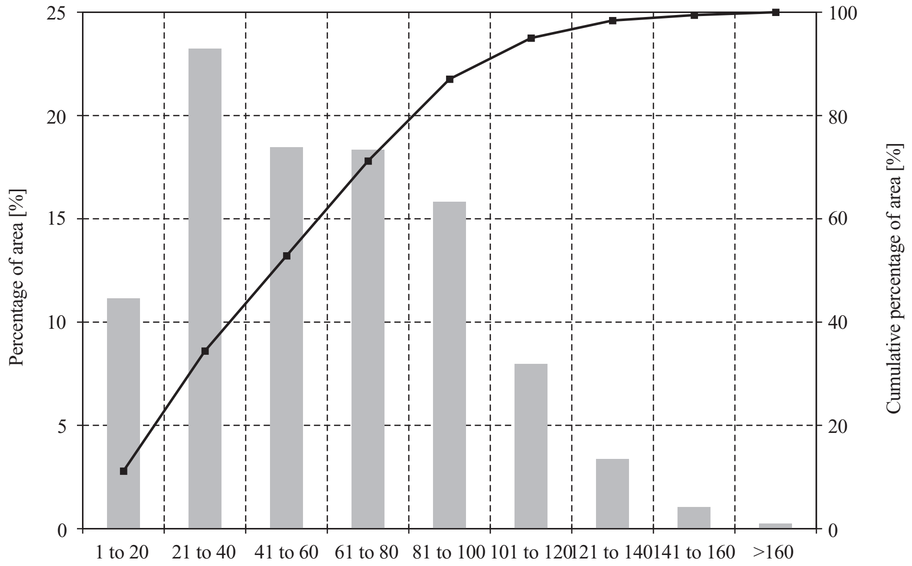


**Fig. 1.–Age class structure of pine stands in Germany [after Polley (1994) and Bundesministerium für Ernährung, Landwirtschaft und Forsten (1994 a, b)]**

*Estructura de las clases de edad de los pinares en Alemania*

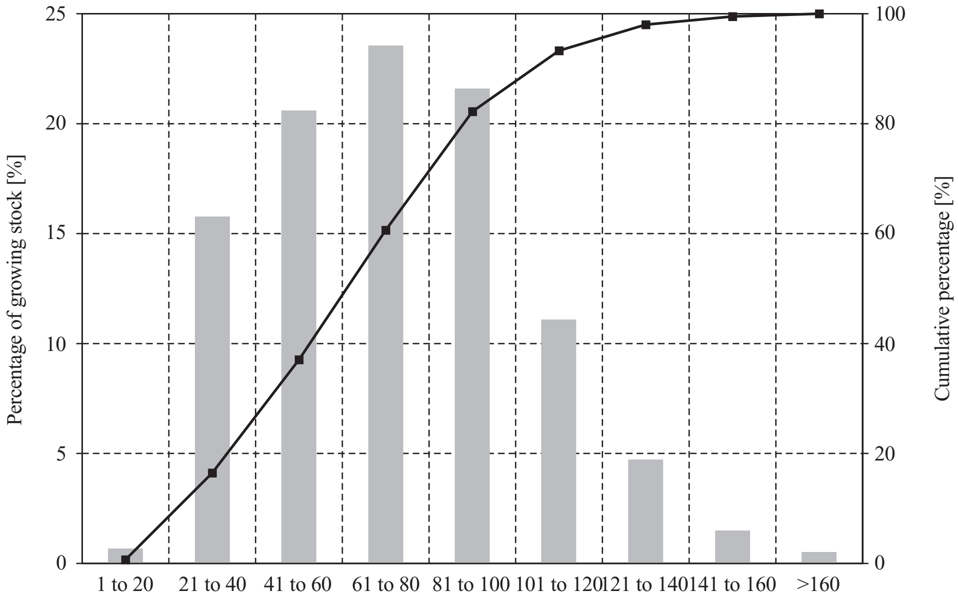


**Fig. 2.–Age class dependent volume distribution of pine forests in Germany [after Polley (1994) and Bundesministerium für Ernährung, Landwirtschaft und Forsten (1994 a, b)]**

*Distribución del volumen por clases de edad de los pinares en Alemania*

## TABLE 3

### PROPORTION OF PINE-DOMINATED FOREST TYPES IN THE POTENTIAL NATURAL VEGETATION OF GERMANY (AFTER HOFMANN, 1999)

*Proporción de tipos forestales dominados por pinos en la vegetación natural potencial de Alemania (Hofmann, 1999)*

| Pine forest type | Percentage of area |
|---|---|
| Pine-oak forests | 1.38 % |
| Dry oak forests with pine | 0.02 % |
| Pine forests in the borderland of the Alps | 0.15 % |
| Lowland pine forests | 1.31 % |
| | 2.86 % |

Natural Scots pine forests can only persist without human influence on poor and dry sites where natural regeneration of pine is not subject to competition from lush ground vegetation, shrubs and seedlings of other tree species (Table 4).

## TABLE 4

### PROPORTION OF DOMINATING GROUND VEGETATION PLANTS OF PINE FOREST TYPES RELATED TO THE CURRENT AREA OF PINE STANDS (AFTER HOFMANN, 1999)

*Proporción de tipos de pinares según su vegetación en relación con la superficie de los pinares (Hoffmann, 1999)*

| Pine forest type | Percentage of area |
|---|---|
| Pine forests with *Deschampsia flexuosa* and *Vaccinium myrtillus* | 60 % |
| Pine forests with *Rubus idaeus* and *Rubus fruticosus* agg. | 25 % |
| Pine forests with *Calamagrostis epigeios* | 5 % |
| Pine forests with *Molinia coerulea* and *Pteridium aquilinum* | 5 % |
| Pine forests with *Sesleria varia* and *Brachypodium pinnatum* | 2 % |
| Natural pine forests with *Vaccinium myrtillus, Calluna vulgaris, Erica tetralix* and *Cladonia* sp. | 3 % |

Therefore the pine forests mainly comprise artificial plantations which are located on sites of former broadleaved forests. Consequently the variability of these sites is large and led to the formation of specific plant associations dominated by specific species in the ground vegetation.

The present position can be summarised as follows:

The unfavourable age structure of German pine stands causes a difficult marketing situation. The traditional pine forestry characterised by pure even-aged plantations and the conventional production target of «construction timber plus a proportion of valuable sizes (veneer)» led to large amounts of low value assortments from thinnings during the first 7 decades of the rotation period. Today, over a full rotation period, only a negative or a low return is possible (Stoyan, 1998). This situation requires the development of new silvicultural systems and production aims characterised by a positive financial outcome.

The large stands of even-aged pine cause a low degree of structural diversity, a monotonous species distribution and uniform vegetation communities, especially in the younger age classes. On the other hand, species diversity within the ground vegetation is evidently higher in older pine stands on medium and high productive sites than in corresponding broadleaved forests. Therefore, an aim of the new silvicultural systems is to relieve the structural and species monotony of existing pine stands and to create a more diverse forest structure by introducing other natural tree species combinations suitable for the particular site.

The existing pure pine forests in Germany are mainly artificial stands which have replaced former natural broadleaved forests. They lack the capability of self-organising and natural regeneration. Typically, the artificial Scots pine ecosystems show a tendency towards natural forest succession, i.e. the regeneration of the natural hardwood seedlings such as *Betula spp., Sorbus aucuparia, Quercus spp., Carpinus betulus, Fagus sylvatica,* and a high risk of fungal and insect attack (eg *Armillaria mellea, Phaenops cyanea*). Natural regeneration of pine covering large areas is only possible on burnt sites. Wherever closed ground vegetation or a thicker humus layer exists, successful establishment of pine seedlings is impossible. In order to meet the production aims for pine forestry it is therefore necessary to support continuously the stand development by silvicultural management and work against the internal instability of the system.

In the past, forestry focussed mainly on the production of bulk products (mining timber, pulp and paper wood) and on the production of sawlogs rather than the production of high quality timber. To achieve large quantities of uniform sizes, the plantations were established with a relatively high planting density and a high stocking density was maintained throughout the rotation to allow the highest volume increment per unit area. Besides any negative effects on structural diversity, the economic return from such pine stands has hardly been attractive. Several silvicultural models have been developed in Germany with the aim of increasing the production of high quality timber, while taking into account the correspondingly increase in timber prices and the decline of the management costs. Only a few of these concepts have been applied to any appreciable extent. Before presenting these new concepts, the traditional approach to pine management will be described below.

## Establishment

Until the middle of this century, stand establishment with a planting density of 10,000 to 25,000 plants per hectare was common practice in order to achieve stems with small branches and narrow ring widths. Ring width and branchiness are closely related to the initial stocking (Erteld, 1986). In order to minimize the cost of establishment and tending, a reduced planting density of between 6,000 to 12,000 plants per hectare (Kramer, 1988) was recommended more recently in West Germany: this compares to 14,000 to 25,000 trees per hectare in East Germany (Erteld, 1986).

## Tending of regeneration

Tending in pure pine stands includes removal of super-dominant trees with large crowns and thick branches (´wolves´) and removal of competing broadleaves (cleaning).

## Tending in young stands

First thinnings with the aim of a severe reduction in stand density are carried out at stand mean height of 7 to 12 m at which stage the middle and the upper crown are formed. A systematic removal of whole lines may be possible in this early stage of stand development. Dittmar *et al.* (1976) recommend the removal of every fifth row in combination with a selective thinning of the remaining rows. The tending of the young stand aims to promote 200 to 250 final crop trees per hectare. From a mean height of 12 to 17 m onwards the management changes to low thinning.

## Stand tending in pole stands and old growth stands

The later thinnings are necessary to control optimum stocking density to maximise the volume increment per area. In order to avoid insect pests dead trees are removed. On fertile sites and in regions with sufficient precipitation (> 600 mm per year), pure pine stands were often underplanted with beech for additional timber production. Until the 1980s the harvesting of pine was carried out by clearfelling. If a quality beech understorey with high stocking density was present, it might be accepted as the next forest type.

A range of different silvicultural models were developed as alternatives to conventional pine forestry from the beginning of this century:

## Fast growth concept (Gehrhardt, 1924, 1925, 1929)

This method was developed for Norway spruce and aims to intervene strongly into the stand development at an early stage and to reduce stand basal area by 50 %. All suppressed and sub-dominant trees will be removed while dominant trees with large crowns are promoted.

Advantages: Target diameter reached earlier. Large timber gets higher proceeds (profits).

Disadvantages:Wide ring width and thicker branches do not meet the requirements of quality timber. Volume and return per area do not exceed that of other management models.

## F- tree management

The development of this concept is mainly connected with the authors Abetz and Huss (see Kramer, 1988). Already at the small pole stage approximately 200 crop trees $ha^{-1}$ of good form with larger diameter (so called *F*uture-trees) are selected and marked. All tending operations are carried out to promote these crop trees. Competing neighbours are removed while intermediates of lesser quality are neglected. The F- trees are pruned up to a height of 6 m.; this normally occurs only once during the pole stage. Harvesting takes place when the desired target-diameter is reached. Burschel et al. (1994) judge this management concept as a starting point to permanent cover forest initiating from an even-aged stand. Nowadays the F- tree management is widely applied in Lower Saxony.

Advantages: Minimising management cost by concentrating on 200 dominant trees; achievement of large timber sizes.

Disadvantages: Permanent superiority of volume and value efficiency up to older stand age not proven for this model.

### Target-diameter management

This concept was first used for the management of beech forests with single-tree harvesting at a desired target-diameter (Burschel and Huss, 1987). Now this concept has been extended to Scots pine plantations. Here, the operations do not intend to favour a particular stand structure but basically represent an extensive management system similar to selective exploitation.

Advantages: Extreme minimization of management costs.

Disadvantages: The continuous removal of the most vigorous and largest trees and their subsequent exclusion from further stand regeneration causes a decline in genetic diversity of the stand (Konnert and Spiecker, 1996). This selection concept counteracts the natural developments and it does not represent a silvicultural imitation of natural succession.

The *Eberswalde selective thinning* was mainly developed by Lockow and coworkers (see references below). This silvicultural model proceeds from the observation of the occurence of different growth types of pine within one stand. The so called A-type represents straight trees with thin branches and a relatively small crown projection area, but large vertical crown distribution and a large crown surface. This type comprises high quality trees characterised by a long lasting growth of the individual tree. The B-type trees are characterised by wide crowns, thick branches and are super-dominant. The A/B-type is a transition between A-types and B-types (Lockow, 1992, 1998, 1999; Lockow and Pofahl, 1994). The management concept refers to the work of Olberg (1950) and Erteld and Kräuter (1957) and consists of the following operations:

- early selective thinning;
- selective promotion of dominant A-type high quality trees with narrow, long crowns and thin branches (and removal of the B-type);
- pruning to 6 m in height;
- avoidance of crown damage of the promoted A-types-trees caused by competitors;
- broadleaved underplanting in the pole stage aiming at reintroducing beech (>600 mm precipitation), oak (<600 mm), at their corresponding sites, climatic regions and natural distribution areas. After harvesting the old pines, a high quality broadleaved understorey can form the new stand. So underplanting is a measure of stand transformation to increase the degree of naturalness. A prerequisite for a successful application of underplanting is knowledge of the forest site conditions, the local climate conditions and the distribution of the potential natural vegetation.

Advantages: With stand age older than 60 years the stem wood volume increment exceeds that obtained in fast-growth management. Taken overall, the most favourable compromise between volume and value efficiency is found with this system.

Disadvantages: Until now no disadvantages have been found in the experiments. The «Eberswalde selective thinning» method is widely applied in Brandenburg.

Beside the application of alternative management concepts in existing Scots pine stands, additional changes in pure pine management have occured within the last 10 years in order to meet the aim of greater naturalness or to increase the biological diversity:

– a general abandonment of establishing pure pine plantations in favour of planting of natural broadleaved tree species suitable for the particular site
– toleration and promotion of broadleaved tree species (birch, oak, beech, etc.) inside pine stands
– a break with the concept of volume and increment maximization, in favour of an emphasis on high quality timber production
– widespread renunciation of large scale clear felling; use of harvesting methods based on single tree or group selection
– toleration of remaining standing and fallen deadwood to promote survival of organisms dependant upon this habitat
– underplanting of pine stand on intermediate and rich sites with broadleaves (> 600 mm precipitation year$^{-1}$ with beech; in drier regions underplanting with oak, lime and hornbeam)

The sum of all these actions aims to develop a future forest type which is close to nature in tree species composition and is structurally built up as a multi-storey mixed stand.

## THE EFFECT OF LARGE AREAS OF PINE FORESTRY ON THE BIOLOGICAL DIVERSITY

The planting of artificial pine forests on former broadleaved sites led to ecological changes such as:

- In pine stands the light penetration increases in the polestage compared to broadleaved forests. The open structures allow more light to enter the canopy and increases heat exchange. In combination with a high crown interception, the latter leads to drier ground conditions as a whole.
- The litter of the pine stands decomposes poorly due to an unfavourable C/N ratio and generally results in raw humus or to a raw humus/mull intermediate with distinct acidic properties of the upper horizon.

Such ecological conditions result in the following change in species composition in pine ecosystems (Anders and Hofmann, 1997):

- The loss of the more nutrient and moisture demanding species
- Mosses characteristic of conifer sites develop high coverage.
- Colonisation and development of acidophilic, light and temperature demanding species with low nutrient demands is promoted.
- An increase of acidophilic species on intermediate and fertile sites following induced N-deposition.

In general a lower number of species is found in natural pine forests on nutrient poor soils. On richer sites in artificial pine forests the number of species increases strongly and may exceed the number of species occurring in corresponding broadleaved associations on the same site types.

## NUMBER OF SPECIES, BIODIVERSITY AND NATURALNESS

The number of species found in pine ecosystems can vary strongly due to the combination of different ecological factors. Solely from the number of species, it is not possible to assess the ecological quality, stability or naturalness. The ecological conditions within an ecosystem give rise to the number of species. The number of species by itself cannot be related to an ecological assessment. It is necessary to compare the number of species with potential natural conditions and to assess the vegetation qualitatively and quantitatively considering the site conditions (Anders and Hofmann, 1997).


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## RESUMEN

### Selvicultura y dinámica de las masas de Pino silvestre en Alemania

La estructura actual de los bosques en Alemania y su diversidad biológica relacionada es un resultado del desarrollo natural, cultural y económico de los últimos 10.000 años. La composición de especies, su distribución, y la proporción de bosques-tierras agrarias empezó a cambiar probablemente hace unos 3.000 años. La selvicultura moderna se desarrolló en Alemania entre 1750 y 1850. Los bosques sobre-explotados y degenerados de ese tiempo se cambiaron a plantaciones puras de coníferas altamente productivas. Gracias a esta medida se satisfizo el incremento de la demanda de madera de las industrias. La proporción de bosques naturales de pinos en la vegetación potencial forestal es menos del 3 % mientas que la proporción de Pino silvestre en la superficie forestal actual es del 28 %. El centro de distribución de esos bosques son las regiones bajas del norte de Alemania, donde existen predominantemente plantaciones puras de pinos en sitios de bosques naturales de frondosas. La estructura de las clases de edad está dominada por rodales jóvenes de hasta 60 años de edad. Esta estructura de edades complica la existencia de una selvicultura rentable. Durante las últimas décadas se han desarrollado tratamientos selvícolas alternativos para solucionar estos problemas y para incrementar el grado de naturalidad de las plantaciones de pino existentes. En general, estos modelos buscan disminuir los costes, producir madera mayor y de más calidad, incrementar la diversidad estructural, incrementar la proporción de frondosas y conseguir una cubierta continua de los sistemas forestales. La diversidad no se constituye como un criterio ecológico de calidad. Para la evaluación de la biodiversidad real se necesita una comparación con la vegetación potencial natural.



**PALABRAS CLAVE:** Pino silvestre
Dinámica del rodal
Selvicultura
Biodiversidad

## REFERENCES


ACKERMANN H., 1954. Die Vegetationsverhältnisse im Flugsandgebiet der nördlichen Bergstraße. Schr. Natursch. St. 2. Darmstadt.

ANDERS S., HOFMANN G., 1997. Vielfalt in der Vegetation von Wäldern und Forsten. Schriftenreihe des BML «Angewandte Wissenschaft», Heft 465 «Biologische Vielfalt in Ökosystemen», 97-108.

ANDERS S., BECK W., BOLTE A., KRAKAU U.-K., MÜLLER J., HOFMANN G., JENSSEN M. 1999. Waldökosystemforschung Eberswalde – Einfluß von Niederschlagsarmut und erhöhtem Stickstoffeintrag auf Kiefern-, Eichen- und Buchen-Wald- und Forstökosysteme des nordostdeutschen Tieflandes. Final report of the research project promoted by the Fedaral Ministry of Education and Research. Federal Research Centre for Forestry and Forest Products, Institute for Forest Ecology and Forest Assessment, Eberswalde, Germany.

BOHN U., 1985. Vegetationskarte der Bundesrepublik Deutschland, M 1:2,4 Mio., n.p..

BUCHWALD K. 1951. Wald- und Forstgesellschaften der Revierförsterei Diensthoop, Forstamt Syke bei Bremen. Angew. Pflanzensoziol., Stolzenau/Weser, 1.

BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN, 1994 a: Bundeswaldinventur - eine Wertung..

BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND FORSTEN, 1994 b: Der Wald in den neuen Bundesländern..

BURSCHEL P., HUSS J., 1987. Grundriß des Waldbaus. Ein Leitfaden für Studium und Praxis. Verlag Paul Parey. Hamburg und Berlin, 352 p..

BURSCHEL P., BOEDICKER C., AMMER C., 1994. Kiefernbewirtschaftung. Moderne Kiefernwirtschaft, dargestellt am Beispiel eines Bestandes in der bayerischen Oberpfalz. I: Der Wald Berlin 44, 3, 82-85; II: Der Wald Berlin 44, 4, 116-119.

DENGLER A., 1904. Untersuchungen über die natürlichen und künstlichen Verbreitungsgebiete einiger forstlich und pflanzengeographisch wichtiger Holzarten in Nord- und Mitteldeutschland. I. Die Horizontalverbreitung der Kiefer. Mitt. a. d. Forstl. Versuchsw. Preußens, Neumann, Neudamm, 131 S..

DENGLER A., 1910. Neues zur Frage des natürlichen Verbreitungsgebietes der Kiefer. Zeitschrift für Forst- und Jagdwesen, 42.

DITTMAR O., KNAPP E., KOHLSTOCK N. 1976. Jungwuchs- und Jungbestandspflege in Fichte und Kiefer unter der Sicht rationeller Pflegeeingriffe. Beiträge für die Forstwirtschaft Berlin 10, 124-128.

ERTELD W., 1986. Grundrisse der Kiefernwirtschaft. Lehrstuhl für Waldwachstumskunde der Universität München.

ERTELD W., KRÄUTER G., 1957. Untersuchungen über die Erkennbarkeit guter und schlechter Zuwachsträger bei der Kiefer. Archiv für Forstwesen Berlin 6, 5/6, 361-420.

ELLENBERG H., 1982. Vegetation Mitteleuropas mit den Alpen. 3. Aufl., Verlag Eugen Ulmer, Stuttgart.

GAUCKLER K., 1938. Steppenheide und Steppenheidewald in der Fränkischen Alb in pflanzensoziologischer, ökologischer und geographischer Betrachtung. Ber. Bayer. Bot. Ges. 23.

GEHRHARDT E., 1924. Über die Stammzahlhaltung im jungen Fichtenbestand. Allgemeine Forst- und Jagdzeitung 100, 343-352.

GEHRHARDT E., 1925. Fichtenschnellwuchsbetrieb. Allgemeine Forst- und Jagdzeitung 101, 276-283.

GEHRHARDT E., 1929. Über das Wesen und die zuwachsfördernde Wirkung angespanntester Durchforstungen. Silva 17, 213-218.

GREGORIUS H.-R., SCHOPPA F. N., 1999. BML-Forschungsauftrag «Biodiversität in Wäldern», Teilprojekt II: «Folgewirkungen waldgeschichtlicher Entwicklungen für die aktuelle genetische Zusammensetzung unserer Waldbaumpopulationen», vorläufiger Abschlußbericht (not published).

GRIESE F., 1986. Die Kiefer – ein prägendes Element in der Landschaftsgeschichte des niedersächsischen Flachlandes (unpublished manuscript).

GROSSER K.-H., 1954. Forstliche Vegetations- und Standortsuntersuchungen in der Oberlausitzer Heide und in den natürlichen Fichtenvorposten der südlichen Niederlausitz. Eberswalde, Diss..

GROSSER K.-H., 1956. Waldvegetation und forstlicher Standort in der Oberlausitzer Heide. In: Archiv für Forstwesen, 5.

GROSSER K.-H., 1964. Die Wälder am Jagdschloß bei Weißwasser (OL). In: Abh. U. Ber. Naturkunde Museum Görlitz. 39.

HARTMANN F.K., 1933. Zur soziologisch-ökologischen Charakteristik von Waldbeständen Norddeutschlands. In: Silva 21 u. 22 (1934).

HOFMANN G., 1957. Zur Soziologie einiger Kiefernforsten im Bereich der Kalktrockenlaubwälder Südthüringens. In: Archiv für Forstwesen, 6.

HOFMANN G., 1960. Untersuchung und Karttierung der Kiefernforstgesellschaften des südwestlichen Flämingvorlandes am Beispiel Bärenthoren. IFE, Internal report.
HOFMANN G., 1961. Untersuchung der Kiefernforstgesellschaften in Neubrandenburg. IFE, Internal report.
HOFMANN G., 1962. Untersuchung der Kiefernforstgesellschaften in Mittelbrandenburg. IFE, Internal report.
HOFMANN G., 1964 a: Kiefernforstgesellschaften und natürliche Kiefernwälder im östlichen Brandenburg, I. Kiefernforstgesellschaften. In: Archiv für Forstwesen, 13.
HOFMANN G., 1964 b: Kiefernforstgesellschaften und natürliche Kiefernwälder im östlichen Brandenburg, II. Natürliche Kiefernwälder und Gehölze. In: Archiv für Forstwesen, 13.
HOFMANN G., 1965 a: Waldgesellschaften der östlichen Uckermark. In: Feddes Rep., Beiheft 142.
HOFMANN G., 1965 b: Die Kiefernforstgesellschaften des nordostdeutschen Flachlandes. In: Tagungsberichte der Akademie der Landwirtschaftswissenschaften zu Berlin, 65.
HOFMANN G., 1968. Über Beziehungen zwischen Vegetationseinheit, Humusform, C/N-Verhältnis und pH-Wert des Oberbodens in Kiefernbeständen des nordostdeutschen Tieflandes. In: Archiv für Forstwesen, 17.
HOFMANN G., 1969. Zur pflanzensoziologischen Gliederung der Kiefernforsten des nordostdeutschen Tieflandes. In: Feddes Rep., 80.
HOFMANN G., 1985. Die potentielle natürliche Nettoprimärproduktion an oberirdischer Pflanzentrockenmasse – ihre Quantifizierung und Kartierung für das Gebiet der DDR. In: Beiträge für die Forstwirtschaft, 19, Beil. 3.
HOFMANN G., 1999. Flächenanteile natürlicher Kiefernwälder an der potentiell natürlichen Vegetation Deutschlands; Flächenanteile von Kiefernforst-Typen mit deren deckenbildenden Vegetation an der heutigen Kiefernreinbestandsfläche. pers. Communications.
HUECK K., 1931. Erläuterung zur vegetationskundlichen Karte des Endmoränengebiets von Chorin (Uckermark). In: Beiträge zur Naturdenkmalpflege. Neudamm, H. 2.
KONNERT M., SPIECKER H., 1996. Beeinflussen Nutzungen einzelner Bäume die genetische Struktur von Beständen? AFZ/Der Wald 23, 1284-1291.
KOPP D., 1956. Standortskundliche und vegetationskundliche Grundlagen für die Umwandlung eines märkischen Kiefernreviers. Berlin.
KRAMER H., 1988. Waldwachstumslehre. Verlag Paul Parey, Hamburg and Berlin.
KRAUSCH H. D., 1962. Der Sandnelken-Kiefernwald an seiner Westgrenze in Brandenburg. In: Mitt. flor.-soziol. Arb. Gem. N. F. 9, Stolzenau/Weser.
KRIEGER H., 1937. Die flechtenreichen Pflanzengesellschaften in der Mark Brandenburg. In: Beiheft Bot. Cbl. 57.
LIEDTKE H., MARCINEK J., 1995. Physische Geographie Deutschlands. Justus Perthes Verlag Gotha.
LE MAITRE D. C. 1998. Pines in cultivation: a global view. In: RICHARDSON D. M.(ed.): Ecology and Biogeography of Pinus, Cambridge University Press, Chapter 20: 407-431.
LOCKOW K.-W., 1992. Zum Wachstumsablauf und zur Wuchsdynamik der Kiefer mit einigen Schlußfolgerungen für die Bestandesbehandlung. Der Wald, Berlin, 42, 5, 170-173.
LOCKOW K.-W., 1998. Langfristige Versuchsflächen Eberswalde. Der Kieferndurchforstungsversuch Chorin 97 - Ziel und Ergebnisse für die Praxis. Beiträge für Forstwirtschaft und Landschaftsökologie 32, 1, 15-23.
LOCKOW K.-W., 1999. Kieferndurchforstungsversuch Chorin 97. AFZ Der Wald 17, 915-916.
LOCKOW K.-W., POFAHL U., 1994. Neue Erkenntnisse über die Gesetzmäßigkeiten des Einzelbaumwachstums der Kiefer. Beiträge für Forstwirtschaft und Landschaftsökologie, Berlin 28, 2, 83-86.
MATUSZKIEWICZ W., 1962. Zur Systematik der natürlichen Kiefernwälder des mittel- und osteuropäischen Flachlandes. In: Mitt. flor.-soziol. Arb. Gem. N. F. 9.
MEISEL-JAHN S., 1955. Die Kieferngesellschaften des nordwestdeutschen Flachlandes. In: Angewandte Pflanzensoziologie, Stolzenau/Weser, 11.
OBERDORFER E., 1957. Süddeutsche Pflanzengesellschaften. In: Pflanzensoziologie, 10, Jena.
OLBERG A., 1950. Die Durchforstung der Kiefer. Hannover.
PASSARGE H., HOFMANN G., 1964. Soziologische Artengruppen mitteleuropäischer Wälder. Archiv für Forstwesen, 13.
PASSARGE H., HOFMANN G. 1968. Pflanzengesellschaften des nordostdeutschen Flachlandes II. Jena.
PASSARGE H. 1960. Untersuchung der Kiefernforstgesellschaften in der Altmark. Internal report, IFE.
PASSARGE H., 1962. Zur Gliederung und Systematik der Kiefernforstgesellschaft im Hagenower Land. Archiv für Forstwesen, 11.
PASSARGE H., 1963. Zur soziologischen Gliederung von Kiefernwäldern im nordöstlichen Mitteleuropa. In: Archiv für Forstwesen, 12.
POLLEY H., 1994. Der Wald in den Bundesländern. Allgemeine Forstzeitschrift 6, 318-322.

SCAMONI A., GROSSER K.-H., HOFMANN G., JESCHKE L., PASSARGE H., SCHLÜTER H., SCHRETZENMAYR M., SCHUBERT R., 1975. Karte der natürlichen Vegetation. Atlas der DDR, Karte 12.

SCAMONI A., 1960 a: Waldgesellschaften und Waldstandorte. Berlin.

SCAMONI A., 1960 b: Kiefernforstgesellschaften. In: Forst und Jagd, 10.

SCAMONI A., 1982. Unsere Wälder. Berlin, Deutscher Landwirtschaftsverlag.

SCHUBERT W., 1963. Die Sesleria-varia-reichen Pflanzengesellschaften in Mitteldeutschland. In: Feddes Repert., Beiheft 140.

SCHWARTZ E., 1991. Geschichtliches zur Kiefernwirtschaft. In: Die Kiefer (Pinus sylvestris), Berichte aus Forschung und Entwicklung, No. 24, 68-71, Institut für Forstwissenschaften Eberswalde, Germany.

SEIBERT P., 1958. Die Pflanzengesellschaften im Naturschutzgebiet «Pupplinger Au». In: Landschaftspflege und Vegetationskunde. München, 79.

STOYAN D., 1998. Unpublished data on management production and return costs of typical Scots stands in the north eastern German lowlands. personal communications; Eberswalde Forestry Research Institute of the Land of Brandenburg.

TÜXEN R., 1950. Neue Methoden der Wald- und Forstkartierung. (Vortragsreferat), Mitt. Flor.-soziol. Arbeitsgem. N.F.2.

TÜXEN R., 1956. Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung. Angewandte Pflanzensoziologie, la 13, Verlag Stolzenau/Weser.