Trends in Forestry Research and Its Implication on Silviculture[1]

C. P. VAN GOOR[2]

Introduction

THE starting point of any meaningful forestry research should always be the whole compass of forestry practice. Forestry practice is today faced by three weighty problems:

1. A rapidly increasing need for wood and wood products in the whole world. Estimates based on the area of forests and not the area of forest land indicate that demand is probably greater than production. Therefore competition for wood in industrial countries will become stronger and stronger.
2. Labour costs are increasing to the detriment of profitability of forestry, the more so because of relative lag in prices for timber.
3. An increasing voice and interference from environmentalists, ecologists, biologists and the public at large.

These are the problem areas, that modern forestry research must also face. One objective of research is to raise timber production, which can be done by extending the forest area, by improving the internal growth factors of the trees such as the genetic properties or by improving the external growth factors of the site. Forest fertilization, soil improvement etc.

Another objective is to develop methods for rationalization and mechanization of forest work to decrease costs. However we have to be aware that the productivity of the forest as ecosystem must not be endangered by methods resulting in irreversible negative processes. An important aspect of forest research is to develop methods for engineering the ecosystem. Forestry is a way of land use in which ecological and biological principles play a leading role.

Engineering ecosystem in forestry is considered as a basic principle since the main objective of forestry is the everlasting maintenance of forest for posterity as a natural resource for sustained production of material and immaterial goods. Foresters — managers and research workers — should never evaluate any measure on short term rewards. The criteria for evaluating our activities must always be gathered from the complete production cycle and not, for instance, from the quality of a plantation. It is fundamentally incorrect to evaluate methods, techniques or measures only by immediate effects, though it happens every day and everywhere, in particular for establishment

1. Invited paper presented to the Thirty-Fifth Annual General Meeting of the Society of Irish Foresters, March 26th, 1977.
2. "De Dorschkamp," Research Institute for Forestry and Landscape Planning, Wageningen, The Netherlands.

methods and harvesting techinques. The full production cycle, on which the forester has only limited influence, depends largely on self maintained equilibrium in the ecosystem of the forest. The forester exercises his influence somewhere in the cycle. This influence should accord with natural processes in the forest community.

This is emphasized, because there is a clear tendency for increasing costs of labour to dominate decisions. Methods for the establishment of stands, for tending, thinning and harvesting, by which manpower is replaced by machines, are often evaluated by costs alone, and short term effect. But do we know, what the long term effect is? The influence on the full production cycle? On the ecosystem?

Forestry, all over the world is facing this dilemma. Foresters have to work as economically as possible in a society in which even 5 years is a long term. The concern of environmentalists is partly due to doubt about the correctness of modern forestry methods. And not without reason, taking into consideration the exploitation of many tropical rain forests or the large scale clearcut methods in the forests of the Northern hemisphere. It is of paramount importance to know what the carrying capacity is of forests as ecosystems for modern methods directed to increase timber production and to decrease costs.

An *ecosystem* is a biological community, which forms an interacting system with its physical environment. Ecosystems are arbitrary in size and are not static. Changes in plant communities – succession – are very evident in forest ecosystems for instance. These successions lead to complex and stable communities of trees, plants and fauna, which are defined as climaces. In the most stable ecosystems, as are found in the tropical rain forests, the balance between the inflow of energy and the production of biomass is in full equilibrium. Natural regeneration takes place without appreciable changes in the plant community. Exploitation of these systems should be carried out on a small scale, comparable with the so-called plenter-system of Switzerland. Exploitation of these systems with large scale clearcutting or even with large clearings may cause a complete collapse of the ecosystem. In the cooler regions of the world – like Europe – the physical environment does not permit the development of such complex communities, as in the tropics. The less complex the communities, the larger the changes in the plant communities during the natural regeneration. Regeneration probably takes place after disasters. A famous example is the significance of the spruce budworm in the forests of *Picea mariana* and *Abies balsamea,* in eastern Canada. In mature forests of pure *Abies balsamea,* this species is killed by spruce budworm and *Abies* forests regenerate by succession of *Picea mariana* and birch, which are not susceptible to the insect.

Forest fire may have the same significance in forest ecosystem of the temperate zones. In the mountains of Anatolia it appears, that forests of *Abies bornmulleriana* are destroyed by fire. After the fire the area becomes covered with *Pinus sylvestris*. Under the canopy of this species *Abies bornmulleriana* will regenerate. In general, natural regeneration is a fluctuation around an equilibrium. Fluctuation is stronger the more extreme the physical conditions, in other words the less complex the forest ecosystems.

What does this mean for foresters? Broadly it means two things: things:

1. With the due maintenance of forests as a natural resource, exploitation of forests in the temperate and cool regions of the world by clearcut is generally in accordance with natural processes. This is not so in complex systems as for instance the tropical rain forests.
2. By changing complex systems into simple systems, like the conversion of such tropical forests into pine or eucalypt stands, a major part of the energy is stored in the trees and production of timber can be increased enormously. Pure stands will generally show the highest timber production. But these stands are not always ecologically stable and need permanent human interference to maintain a certain equilibrium.

In Europe, man has used and abused forests for centuries. In particular grazing, litter removal and burning have impoverished forest ecosystems. In many cases the forest has been destroyed and changed gradually into bare land. By afforestation restoration of the forest ecosystem is taking place.

Topical matters in commercial forestry are mechanization, use of fast-growing species, soil improvement by fertilizers, drainage and tillage. These practices have effects on the forest ecosystem. They can be positive or negative and it is interesting to review them in more detail.

Choice of tree species

In those parts of Europe, where the natural forest is composed of hardwoods, foresters have introduced softwoods on a large scale to increase and speed up timber production. But serious die-back of such artificial stands of Norway spruce in Saxony at the end of the last century and the beginning of this one, caused a reaction to this practice. In particular in Central Europe, but also in our country and in Belgium use of softwoods on sites of natural hardwood forests was considered erroneous. It was assumed that plantations of such species would degrade the soil, form raw humus, fix nutrients and accelerate podsolization. It was considered necessary to mix softwoods with hardwoods or to underplant them with soil improving shrubs like

Prunus serotina – now a pest – to improve humification of organic matter.

After the Second World War this problem was studied more intensively after advances in soil science and it became evident, that, compared with hardwoods, coniferous species had little or no untoward effect on productivity of the site.

It was observed that:

1. soil development was independent of the difference in species of tree. For maintenance of productivity of the site use of exotic tree species appeared to be of no risk.
2. decrease of growth and die-back in subsequent generations of softwood stands was not caused by changes in the soil. The observed die-back proved to be related to incorrect choice of tree species, wrong provenance, or adverse soil conditions.
3. if properties of the site met with the needs of the species no difficulties of this sort arose.

A special case is choice of tree species in afforestation of heath. Heath is the result of centuries of misuse of land by man. The natural oak-beech forest was destroyed or degraded and biological, nutritional and physical status of soil has declined. Afforestation of such land is the start of a long succession to a more stable ecosystem. On these acid soils poor in nitrogen, phosphorus and other nutrients only a few species are adapted to the site. Specifically the species, with low demand for nitrogen, like larch and pine can be used successfully and sometimes spruces, when besides phosphate fertilization, some help is given with nitrogen supply. But mostly, spruces grow less than pine and larch.

After one generation of pines or larch, enrichment of the site can be observed. The nitrogen level in the soil has increased considerably and this has its consequences for choice of species. The site has become suitable for species demanding more nitrogen. Even the suitability for larch, which is more susceptible to excess of nitrogen than other species decreases.

It is interesting that the improvement is stronger with better moisture relations and a higher phosphate level. A normal Douglas-fir *(Pseudotsuga menziesii)* plantation of more than 50 years of age has been analyzed on height growth. Comparing this height growth with the height growth of Douglas-fir in the yield table, it appears that the site-index improved in time (Fig. 1). Comparing growth of second generation, with that of first generation Douglas-fir shows an increase in volume increment (Table 1).

Analyzing needles, which is done to get an impression of the nutrient status of the site, demonstrates, that with the low nitrogen demanding Japanese larch the nitrogen content of the needles is high

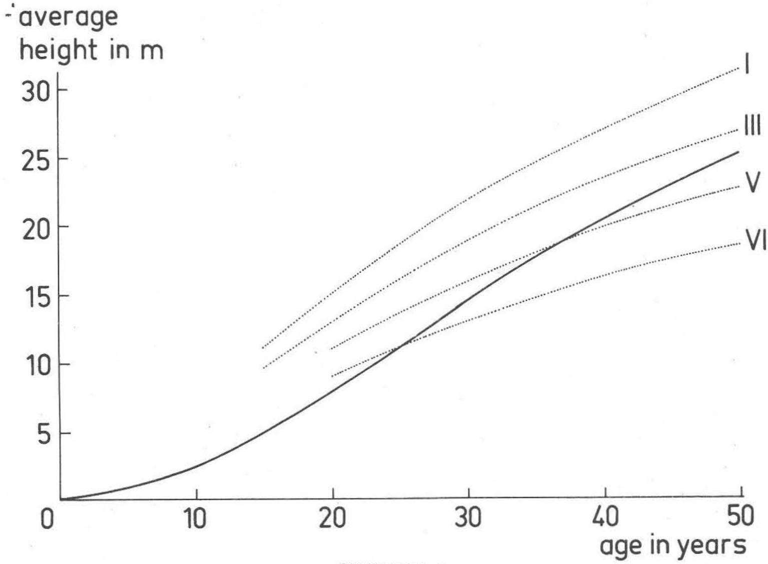

FIGURE 1
Height growth of a 50 year old Douglas-fir plantation as a first generation heathland afforestation (full line). Comparing this growth with the height growth according to the yield table (dotted lines) indicates a permanent improvement of growth with age.

TABLE 1
Average volume increment in m³ per year per ha (based on yield table, 50 years rotation) of first and second generations of Douglas-fir plantations in heathland afforestations on identical soil types.

generation	age	mean height increment, last 5 years in m	mean annual volume increment in m^3/ha
1	25	3.6	17
1	24	3.1	13
1	23	3.0	13
2	22	4.0	20
2	18	4.7	22
2	19	4.7	22
2	18	4.6	22
2	24	5.0	25

and for first and second generation equal. For the more exigent Norway spruce however, first generation stands show nitrogen deficiency, while the stands of second generation are adequately supplied with this element. (Fig. 2).

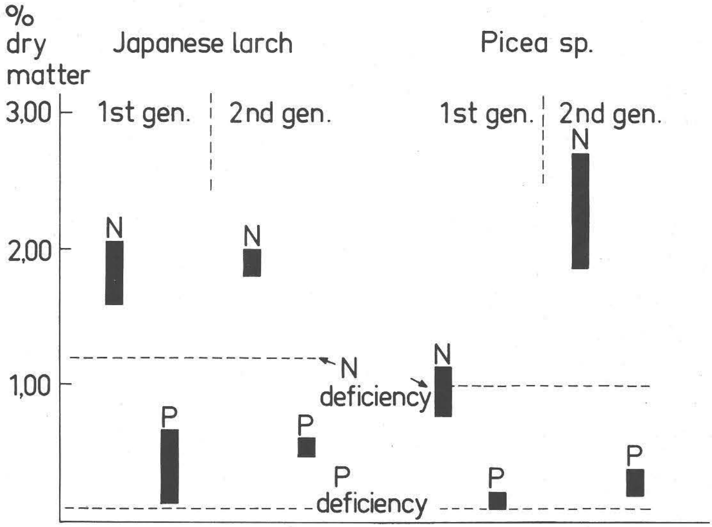

FIGURE 2

Nitrogen and phosphate content of the needles of a first and second generation of Japanese larch and Norway spruce in heathland afforestations. A distinct increase of the nitrogen content of the needles of the second generation of Norway spruce can be observed, which is not the case for the low nitrogen demanding Japanese larch. Nitrogen content of the needles of the first generation of Norway spruce indicate nitrogen deficiency. The nitrogen content in the needles of Japanese larch and the second generation of Norway spruce demonstrate adequate supply of this nutrient.

So without any nitrogen fertilization the soil has been enriched with this nutrient by means of the forest itself. Estimates indicate a 50-70 kg N/year/ha in a first generation.

By research on growth site relationship much information has been gained about the requirements of various trees and many countries now use site suitability maps for forestry planning.

Internal growth factors

Use of exotics — conifers on sites of hardwoods — requires choice of the correct provenance or race. Genetical properties have an important influence on growth and health of stands. The influence of the genetic properties on growth rate is assessed in experiments with various provenances, races, progenies and hybrids.

The contributions of tree breeding to increase wood production are in some cases sensational, like with the hybridization of Aigeiros poplar. Volume production of new clones is sometimes doubled, comparing the traditional clones.

The effect of tree breeding on health of trees and stands is particularly with coniferous species, much more difficult to investigate.

Die-back without any pathogenic cause can be observed regularly in conifer plantations. Apparently these phenomena are related to physiological processes in the tree.

In the Netherlands the best growing provenances of Douglas-fir show die-back or top dying in the early stage of the plantations at a height of about 1 to 3 meters. In cold and sunny winters, young Douglas fir exposed to sunlight, becomes yellow and brown during February and March and sometimes die; at least the top is dying. This is not caused by drought, but probably by uncompensated respiration. If the trees are protected against the direct sunlight, they stay green and healthy. Growth in the season after the winter is better with than without protection. The phenomena are not observed when the winter is mild and damp. The best provenances of green Douglas fir from regions with a maritime climate are not adapted to continental winters. Therefore Douglas fir in our country is planted in strips which are protected by old forests.

The same kind of die-back is observed in Norway spruce and Scots pine, but mostly much later, when the stands are 25 years or older. In some stands of Scots pine, with discoloration during wintertime – symptoms similar to these of deficiency of potash – die-back occurs. This die-back begins with decrease of growth in height, die-back of the rootsystem and is followed by top dying. Sometimes, but not always, this phenomenon is accompanied by pests, which are probably secondary.

Even attack of pines by *Aradus cinnamomeus,* which is often noticed is probably not the primary cause. Also here it is supposed, that yellowing provenances of Scots pine – Northern, continental origins – are not adapted to certain climatic conditions in Western Europe during dormancy. There is as yet no evidence about decisive climatic factors. But provenances from England, Scotland and Western Norway do not show die-back.

Norway spruce, which has its natural range in continental climates with cold winters, shows severe die-back at 30 years of age and older after a series of mild winters. Perhaps here too the physiological activity during the mild dormancy season exhausts reserves of carbohydrates, retards regeneration of the root system and induces die-back. In the Netherlands die-back was serious before the gales of 1972 and 1973 and destroyed many Norway spruce plantations. It seems, that the practical significance of the physiology of trees has often been neglected. The physiology of a tree is largely determined by genetic properties and changes with the age of a tree. If the physiological condition of a tree is weakened the tree will become more susceptible to diseases. A striking example is a trial with various provenances of Scots pine on a field intensively infested with *Armillarea mellea*. This fungus is generally considered as a primary parasite of conifers. But in this trial yellowing provenances were much more attacked by this fungus than others. Obviously some of

FIGURE 3
Lay-out of the test plot with different provenances of Scots pine. Die-back by *Armillarea mellea* is given in percentages within the parcels. German provenances show the highest percentages of die-back.

Block I

sel. nr.	% dead trees	$\bar{h}$
1452D	34.5	3.12
1714	9.8	3.44
1448	13.0	3.88
1717	9.9	3.68
1715	22.7	2.97
1713	15.9	3.27
1453D	35.6	2.86
1454	34.0	2.99
1718	12.8	3.50
1449	10.8	3.95
1443	14.2	3.60
1450	11.2	4.04
1446	16.0	3.87
1716	9.6	3.48
1720	14.5	3.14
1451	16.0	3.49
1719	12.4	3.01
1455D	14.2	3.33

Block II

sel. nr.	% dead trees	$\bar{h}$
1720	33.5	2.96
1718	24.2	2.98
1451	24.0	3.10
1448	14.5	3.44
1719	17.0	2.83
1717	12.0	3.05
1455D	36.9	2.47
1452D	33.3	2.50
1454D	55.6	2.43
1449		3.48
1715	26.8	2.46
1716	27.5	3.10
1714	33.2	2.97
1453D	60.3	2.50
1450	28.5	3.35
1446	19.2	3.27
1713	35.9	2.90
1443	36.3	3.28

Block III

sel. nr.	% dead trees	$\bar{h}$
1448	31.7	3.45
1453D	62.7	2.70
1717	33.1	2.86
1455D	67.4	2.41
1454D	54.7	2.64
1715	48.9	2.20
1449	14.7	3.26
1451	41.6	2.84
1443	25.3	2.98
1713	15.0	3.21
1716	13.7	3.28
1714	12.6	3.38
1450	5.5	3.59
1446	10.9	3.56
1719	7.7	3.07
1720	25.7	2.53
1452D	55.2	2.43
1718	25.7	2.73

$\bar{h}$ = average height (m)
D = German provenance

the most maritime provenances were not attacked at all. The lay-out of the experiment and the percentage of dead trees, killed by *Armillarea mellea,* are indicated in Figure 3. The plots with high percentages are planted with German, more continental provenances.

Therefore it is not only of importance to use fast growing provenances, but also provenances of which the physiology is adapted to the site.

Soil preparation

For the afforestation of bare land — heathland, land reclaimed from the sea, peatland — some kind of soil preparation is always necessary to improve conditions for growth of trees. Often the soil is compact and should be loosened.

There is however also a current trend to cultivate the soil for reafforestation, with the aim of mechanised planting. But here soil conditions are different from those of non forest land. The soil is a distinct part of the ecosystem, it can even be considered as an ecosystem itself, with the edaphon in dynamic equilibrium with the physical environment. Tillage markedly increases biological soil activity, turn-over of the organic components and mineralisation. This will generally be beneficial in colder and wetter regions where there is a tendency for organic matter to accumulate. But in temperate and warmer regions it can be dangerous, because organic matter, which is the heart of the fertility in many forest soils may be affected. On the lighter soils on the Continent of Europe we clearly observe the adverse effect of soil tillage in the long run. Even in heath afforestations the enrichment of the soil achieved in the first generation is lost after soil tillage.

In several experiments soil tillage was tested in its effects on growth during subsequent years. One experiment was carried out with two types of planting material of Scots pine (transplanted and undercut) on tilled soil and soil with only a planting place prepared by the so-called kulla cultivator. After the first years the annual height growth of the pines on the cultivated soil is dominating, but in the last two years it is lagging behind the growth of the pines on the uncultivated soil (Figure 4). At the moment, the total height is still greater on the cultivated soils, but the conversion is already beginning. The effect of soil cultivation is persistent, because a tilled soil can never be converted into an untilled soil; an irreversible process therefore, which is harmful for the forest ecosystem.

Intensive use of heavy machinery for harvesting causing considerable damage to the soil, may have the same negative effect as soil tillage.

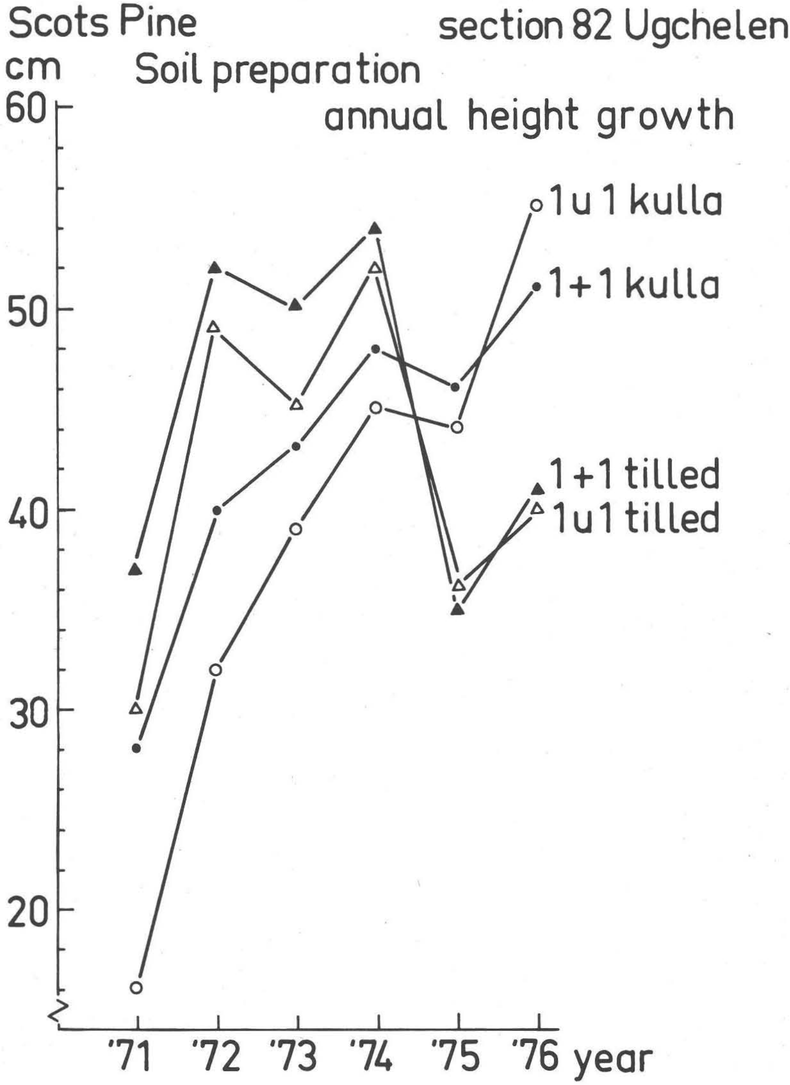

FIGURE 4
Annual height growth of Scots pine on tilled and untilled soil (kulla). The transplanted plants show a better initial growth, than the seedlings which have not been transplanted, but undercut in the nursery. Growth on the tilled soil is better in the first four years and after that lagging behind the growth of the trees in the uncultivated soil.

Herbicides and planting material

If the soil is not tilled before planting, weed growth generally is severe. Research with herbicides is well advanced and many techniques have been developed for forestry to apply herbicides, selectively and with undue harm to the environment. Herbicides like dalapon 2, 4, 5-Tester and glyphosate are optimal for controlling grass and dicotyledons. However, public opinion in many countries is against use of chemicals in forests. In some places chemical weed control is prohibited — so methods should be developed to carry out reafforestation without it. Planting stock must be adapted to the conditions of the site. Quality of the planting material is becoming a decisive factor for the success of plantations. The current trend in production of planting stock is efficiency in operations. In general this means rather small plants, not so well adapted to competition with weeds. They can only be successfully planted on sites with little weed growth. An improvement are the tubed seedlings, but, depending on the species, even these rather small plants suffer from large-sized weeds. Another development in research of planting material is the following. As pre-commercial thinnings are minimized or cut out, because they are becoming more and more expensive, spacing of plantations tends to grow wider.

Hence part of the selection of the precommercial thinnings takes place in the nursery. Grading in the nursery should therefore be directed to genetical properties of the planting stock. According to the effect of seed properties and germination on growth of seedlings, this grading should also take place in the year after germination. Planting material should therefore be older than 1 year. Moreover, larger planting material is better suited for competition with weeds, at least when its quality is optimum.

Within the Common Market criteria for this quality have been developed, these however are not related to the quality requirements of practical forestry but meant to liberate trade in planting material. Quality criteria are a minimum size with a certain age and a maximum ratio height and diameter root collar. But besides the physiological condition of the planting material should be such, that every plant after planting keeps on growing. Quality particularly has a great influence with Douglas fir planting.

The effect of quality on growth of Douglas fir after planting continues for many years. Even 5 years after planting, the height growth of planting stock with a height/diameter ratio of more than 5 is lagging (Figure 5).

In the Netherlands forest practice is working in this way at the moment with spacing as wide as possible and quality adapted to the competition. In fact in most of our reafforestation areas we use large

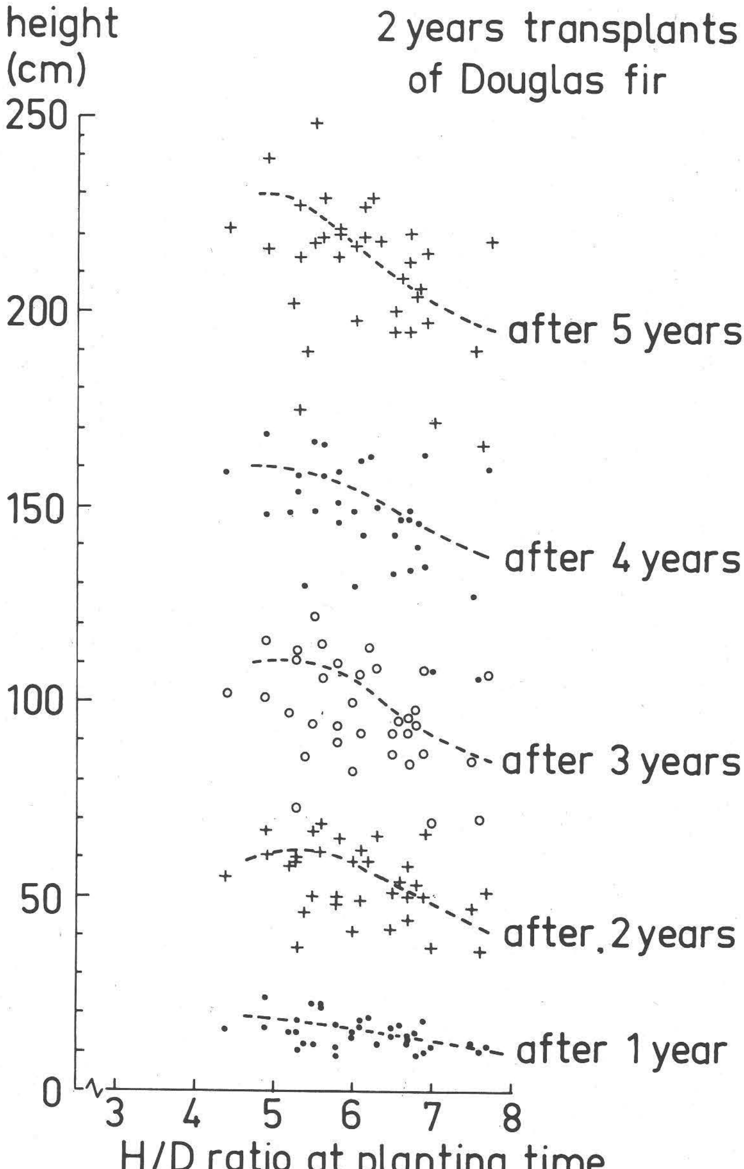

FIGURE 5
Height growth of Douglas fir plantations in relation to the height diameter ratio at planting.

planting material. Usually no soil preparation is needed and weed control can be kept to a minimum. Costs are relatively low, at least not higher than with small planting material, weed control and narrower spacing. Only on sites with little weed growth is smaller stock used, without weed control.

Fertilization

Research on forest fertilization started about 100 years ago and belongs to the most traditional subjects of research. But only after the Second World War has this research been enormously intensified. We have extended our knowledge of tree nutrition, soil fertility and techniques of applications, thanks to sophisticated methods of soil analysis, experimentation in controlled conditions, physiological research and soil classification. I will not enlarge, but I would like to discuss the significance of fertilizers in growth improvement and engineering of the ecosystem.

The main elements used in fertilization are nitrogen, phosphorus, potassium and now and then trace elements. The effect of these elements on the forest ecosystem is different. Almost always phosphate will remain in the ecosystem permanently. Phosphate is not very mobile in the soil and will be fixed by iron, aluminum or calcium and magnesium. As phosphate is a basic source for the edaphon, biological activity increases and the metabolism of the edaphon speeds up. In particular the nitrogen status is improved by nitrogen fixation of soil organisms. Therefore phosphate fertilization is extremely important to impoverished heathland soils in Western Europe. In fact it is very difficult, if not impossible, to start the enrichment of the forest ecosystem in such land without phosphate fertilizers.

Nitrogen itself is highly mobile if not combined with the organic components of the soil. So nitrogen fertilization has only a temporary effect. Only methods introducing nitrogen into the organic matter — urea, green manuring with lupines or alder — have a more permanent effect. Operations in the forest ecosystem with a temporary effect can disturb the equilibrium between the root system and the crowns. Therefore the wisdom of nitrogen dressing in later stages of a forest stand is debatable. In the colder regions of the Northern hemisphere the biological activity of the soil is so low that nitrogen is always at a minimum. Mobility of nitrogen is less than in the temperate and warmer regions. Probably the significance of nitrogen fertilization increases the colder the climate.

Potassium stands somewhere between phosphate and nitrogen. In certain soils it is rather mobile and is not built into the ecosystem. In others it depends on clay in the soil.

In Western Europe the most important trace element seems to be copper. Some minor elements are permanently built into the ecosystem like copper, others remain mobile, for instance boron. Generally it is of more importance to fertilize, if necessary, with elements that stay permanently in the ecosystem and let the ecosystem itself develop to the nitrogen level natural for other physical, chemical and biological conditions. Consequently, forest dressing should in my opinion be a one-time operation. An element added to the ecosystem, which remains in it, need not to be added again. All our heath plantations were fertilized with phosphate and after one rotation no effect in the second generation was observed with another phosphate fertilization. Other elements, which were not limiting in first plantations became limiting in the second rotation. This is so in particular with copper. Because of the higher nutritional and biological status of the soil in many stands copper deficiency can be observed, even when there was no reaction to copper fertilizer in the first rotation.

Harvesting

Mechanization of thinnings and clearfelling is a topical question. I think that if care is taken to preventing damage to soil and trees and if thinnings are not carried out systematically there is not much against it. Systematic thinning in stands with 2,500 trees per ha or less proved unsuitable.

The stands should be treated in such a way, that they become as stable as possible against gales, which are so common in Western Europe. That means full occupation of the area with regular distances between the trees. Moreover spacing should certainly be wide in the young phase to build up stability. In general stands with trees which have a height-diameter ratio of less than 70 from the start, are stable against strong winds. Heavy thinnings at the beginning of the development of a stand is essential. It will be difficult to combine systematic thinning with this requirement.

Some striking examples can be seen in storm-damaged Douglas fir plantations. In Table 2 you may observe that exposed stands with a H/D ratio over 80 have more damage than the stands with a lower ratio. A Douglas fir stand grown up from the beginning in a wide spacing was, though intensively exposed to the gales of 1972 and 1973, hardly damaged. A stand without narrow spacing in the beginning and light thinning intensities on the same kind of soil was severely damaged and lost more than 80% of its trees.

Mechanised clear felling is more profitable the larger the area cleared. But it is becoming more evident nowadays, that such large areas introduce certain ecological disadvantages. The conditions of

TABLE 2

Wind-throw in older Douglas fir plantations exposed to the gales of 1972 and 1973. Stands with a low ratio of height and diameter are less damaged than those with a higher ratio (*** = very heavy damage, ** = heavy damage, – = hardly any damage).

location	dom. height in m (H)	diam. in cm (D)	nr. of stems/ha	H/D	damage
Garderen-72	22	24	525	84	***
Garderen-73	23	51	–	43	–
Kon. Park	40	79	149	50	–
Kon. Park	39	68	147	57	–
Het Loo	34	54	205	63	**
Het Loo	37	54	183	68	**
Speulderbos-24	24	37	–	58	–
Uddel	33	42	287	76	**
Schoonlo	29	32	420	82	–
Kootwijk	31	37	295	81	**
Kootwijk-95	28	57	–	45	–
Vorden	19	22	960	84	**

micro climate change, wet soils can become waterlogged, weed growth is stimulated and regeneration is difficult. Therefore the current trend is, to limit the area of clearfelling in Western Europe.

I have given you a birds eye view of some problems in forestry and the way a research worker can look at them. I am aware, that my talk includes some personal philosophy. But when you start as an enthusiastic young fellow, you think that nature can be split up into separate aspects. And so you think of forestry. But as you grow older and gain more experience – often bitter experience – you discover more and more the interrelationship of all these separate aspects.

Forest is a living being, which is born, grown, dies and regenerates. We foresters have to know how this organism functions and to act accordingly.