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THE WAY AHEAD IN RESEARCH AND PRACTICE.

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SUMMARY

Never doubting that timber production is, and will remain, the prime purpose of plantation forests, it was accepted that yields assessed in terms of quality and quantity must be related to, and be compatible with, the effective use and maintenance of soil and water resources, the effective capture and exploitation of solar energy, the conservation of wildlife, the prevention of environmental impairment and the provision of employment. Because of their diversity and complexity, the concurrent consideration of these different criteria necessitates a systems approach.

In seeking improvement, the meeting was concerned with design, as related to the architecture of individual trees before canopy closure, the canopy structure of tree stands subject to between-plant competition and the mosaics of large blocks of trees of different ages, the latter being important not only for harvesting but also for wildlife, notably the control of deer. With these considerations in mind, attempts were made to define ideotypes, including trees with large harvest indices, i.e. harvestable yield as a proportion of total biomass. When doing this, it was agreed that the conservation of genetic resources was of prime importance to ensure the continuing availability of material for the production of improved trees, whether propagated vegetatively or grown from seeds from controlled crosses.

The continuing appropriateness of existing methods of land classification was questioned.

Those based on past performance are likely to underestimate future yields, whereas others based on site characteristics are better indicators of the need for site preparation than of potential yields. Other methods are needed, recognizing that (i) wind is a major determinant of growth and (ii) crop improvement is an iterative process with the introduction of new variants increasingly warranting a reconsideration of silvicultural practices.

Tree nutrition is of fundamental importance. In the future, nutrient turnover should be budgeted, interrelating the application of artificial fertilizers with nutrients released during litter decomposition. The appreciable benefits of mycorrhiza were stressed in relation to events during establishment rather than in the longer term. It was foreseen that increasing amounts of nutrients might be applied in the future. But, because the production of artificial fertilizers uses appreciable amounts of energy, the need to quantify the role of nitrogen-fixing microbes and others involved in mineralization was stressed.

Plantations of different ages provide different habitats for pests, both vertebrate and invertebrate, pathogens, and also for desirable wildlife, both plants and animals. In studying the population dynamics of these plants and animals, it was stressed that their incidence should be judged against indices of damage, with the recognition of acceptable thresholds.

RÉSUMÉ

On sait que la production du bois est, et restera, la raison principale des plantations forestières; il est admis que la production définie en termes quantitatifs et qualitatifs, doit être reliée, et doit être compatible, avec une utilisation efficace des ressources du sol et des eaux, la capture et l'exploitation de l'énergie solaire, la protection de la faune sauvage et de l'environnement physique et doit constituer une source d'emplois. De par leur complexité et leur diversité ces différents critères demandent une approche systématique du sujet.

Le concept d'amélioration a été un des thèmes-clés de ce congrès, surtout en ce qui

concerne l'architecture; celle des arbres avant la fermeture du couvert, celle de la structure du couvert des peuplements sujets à une compétition entre individus, celles des mosaïques formées par de larges groupements d'arbres d'âge divers (celle-ci étant importante non seulement pour la récolte, mais aussi pour la faune sauvage et notamment le contrôle du cerf). En tenant compte de ces considérations, nous avons été tentés de définir des idéotypes, comprenant des arbres à indices de récolte importants, c'est à dire un rendement récoltable proportionnel à la biomasse totale. De cette façon il apparaît évident que la conservation des ressources génétiques est d'une importance primordiale pour assurer la disponibilité continue de matériaux producteur d'arbres meilleurs, qu'ils soient générés végétativement ou qu'on ait utilisé des semis provenant de croisements contrôlés.

Nous avons discuté les méthodes existantes et prévalantes de classifications des stations: celles qui se basent sur le rendement futur, celles basées sur la production antérieure sous-estimeront probablement les productions futures, tandis que d'autres basées sur des caractéristiques de la station conviennent d'avantage à indiquer les améliorations de la station que sa production potentielle. Il est nécessaire d'utiliser d'autres méthodes en tenant compte du fait (i) que le vent a une influence capitale sur la croissance et (ii) que l'amélioration de la plantation est un procédé itératif: plus on introduit de variantes nouvelles, plus on a besoin de remettre en question les techniques sylvicoles. La nutrition de l'arbre est d'une importance primordiale. A l'avenir, il faudra calculer exactement l'apport total d'éléments nutritifs, en essayant de relier l'introduction d'engrais artificiels avec les éléments nutritifs libérés pendant la décomposition de la litière. Les avantages appréciables des mycorrhizes ont été signalés et soulignés pendant la période de création plutôt qu'à long terme. Nous prévoyons l'utilisation de plus en plus étendue d'engrais à l'avenir. Malgré cela, à cause de l'énergie considérable utilisée par leur production, il faut essayer de quantifier le rôle des microbes

fixateurs d'azote et d'autres, présents au cours de la minéralisation.

Les plantations d'âge mûr sont la demeure d'une série de parasites, vertébrés ou invertébrés, de pathogènes et aussi d'une faune et d'une flore sauvages désirables. Nous soulignons que toute étude de la dynamique de ces populations animales et végétales devra être mesurée et pesée contre les dégâts possibles, dans des limites acceptables.

ZUSAMMENFASSUNG

Da man nie in Frage stellte, dass die Holzproduktion der Hauptzweck von Forstpflanzungen ist und bleibt, wurde akzeptiert, dass der qualitative und quantitative Ertrag von folgenden Parametern abhängt, bzw. sich mit ihnen vereinbaren lassen muss: Ausnutzung und Erhaltung der Bodenkraft und des Wasserpotentials, Ausnutzungsgrad der Sonnenenergie, Erhalt der Fauna, Verhütung von Umweltschäden und Schaffung von Arbeitsplätzen. Wegen der Unterschiedlichkeit und Komplexität der genannten Kriterien ist es nötig, sie systematisch zu untersuchen.

Auf der Suche nach Ansätzen zur Produktion besserer Genotypen beschäftigte sich die Tagung mit äusseren Baumerkmale einzelner Bäume vor Kronenschluss, mit dem Aufbau des Kronenbereiches in Abhängigkeit von der Wettbewerbssituation und mit der heterogenen Struktur grosser Komplexe verschiedenalter Bäume. Letztere sind nicht nur für die Ernte wichtig, sondern auch für das Tierleben, insbesondere für Rehwild. Aufgrund dieser Überlegungen versuchte man, ideale Bestandestypen unter Einbeziehung ertragreicher Baumarten zu definieren, wobei die verwertbaren Erträge proportional zur Gesamtbiomasse sein sollten. Dabei kam man zu der übereinstimmenden Auffassung, dass die Erhaltung genetischer Ressourcen von vorrangiger Bedeutung für die Sicherstellung der Produktion von genetisch 'besseren' Bäumen sei, die entweder vegetativ oder aus definiertem Saatgut hervorgehen können.

Es wurde gefragt, ob die bestehenden Methoden der Standortsklassifikation weiterhin angemessen seien. Diejenigen, die auf ertragsgeschichtlichen Daten basieren,

unterschätzen leicht künftige Erträge, während andere, die sich auf physische Standortseigenschaften stützen, zwar gute Indikatoren für notwendige Standortsvorbereitungen liefern, aber nur beschränkt Ertragsprognosen erlauben. Man braucht andere Methoden, da man erkannt hat, dass (i) Wind ein wichtiger Wachstumsfaktor ist, (ii) die Verbesserung der Samen ein fortlaufender Prozess ist und die Einführung neuer Varianten ein Überdenken forstwirtschaftlicher Praktiken zunehmend erforderlich macht.

Die Nährstoffversorgung der Bäume ist von grundlegender Bedeutung. In Zukunft sollte der Nährelementumsatz wirtschaftlich dahingehend überdacht werden, dass man die Anwendung von Mineraldüngern und die natürliche Nährelementfreisetzung durch Streuzersetzung sinnvoll kombiniert. Der beachtliche Nutzen von Mykorrhizen wurde mehr in bezug auf das Geschehen während der Pflanzung, und nicht so sehr unter langfristigem Aspekt betont. Man konnte davon ausgehen, dass in Zukunft zunehmende Mengen an Dünger verwendet wurden. Da jedoch deren Produktion beträchtliche Energiemengen verbraucht, gewinnt die mengenmäßige Erfassung stickstoffbindender und anderer mineralisierender Mikroben immer mehr an Bedeutung.

Alternde Pflanzungen bieten hintereinander verschiedene Habitats für Schädlinge und Krankheitserreger, aber auch für erwünschte Pflanzen und Tiere. Die Untersuchung von deren Populationsdynamik soll im Zusammenhang mit Schadensverzeichnissen erfolgen, wobei für die Praxis bestimmte Schwellenwerte erarbeitet werden müssen.

EPILOGUE

This meeting took place at a time when many pressures are forcing foresters to take stock of the circumstances in which they work. The world demand for timber and timber products is continually increasing yet the unremitting loss of natural forest is becoming recognized as unacceptable by an ever-increasing number of people. Without doubt the demand, if it is to be met, will only be satisfied by the large scale establishment of plantation forests, but this is not to minimize the contribution from natural forests managed for sustained yields.

Although the main purpose of even-aged plantations is to produce timber, their managers work and take decisions in complex circumstances. They are responsible for managing large tracts of land, the tree crops on those lands and the plants and animals dependent on the habitats so provided. They must protect water supplies, meet economic and social goals by producing timber in suitable quantities and qualities, and directly or indirectly provide employment often in remote rural areas. The concept of multiple use of forests is not new. What is new, is the increased interest in this concept taken by people living in towns and cities, and the increasing pressures that they apply, forcing foresters to re-assess their management objectives. As pressures to control the use of fossil fuels become stronger, so will the demand, already strong in some parts of the world, for plantations as renewable resources of fuel. Forest managers will also need to become accustomed to assessing costs, not only in monetary terms but also in terms of energy inputs and outputs, relating yields to energy used during silvicultural and harvesting operations.

The problems can be stated readily, but their solutions are more difficult necessitating a greater understanding of forest ecology. At some sessions, participants were concerned with applied aspects of silviculture, in others with fundamental ecology. Even-aged plantations are becoming increasingly productive with improved cultivation procedures, including soil drainage, the greater use of exotic species, the increasing availability of better cultivars with larger harvest indices; the chemical control of weeds after planting, the application of inorganic fertilizer, the improved control of damaging insects and fungi and less wasteful and more complete methods of harvesting. Moreover, the potential for further improvement appears great. However, if large yields of timber are to be sustained from even-aged plantations, silviculturists and ecologists must be able to identify and control processes that could damage their plantations and soils, and deleteriously affect non-damaging populations of wildlife, both plants and animals. Four aspects, of outstanding importance, were stressed:

- (a) the long-term effects on the ecological stability of even-aged plantations of selecting restricted numbers of productive species, provenances and cultivars, with the consequent narrowing of their genetic base;
- (b) the effects on tree growth of soil amelioration by drainage, cultivation and the application of fertilizers, the effects of even-aged plantations on the organic layers of soils and their combined influences on the prediction of tree growth by site indices;
- (c) the effects of afforestation on catchment water yields and
- (d) the need for more information about the ecology of

insects, birds and other animals, of microbes, including mycorrhizal associates, and plants, so that their effects, beneficial or damaging, can be more accurately predicted.

GENETIC BASIS OF EVEN-AGED PLANTATIONS

Throughout the world extensive even-aged plantations are formed with exotic species. The search for increased yields of timber and other forest products has progressed inexorably to the selection of those species that are easy to propagate, are suited to 'pure', even-aged plantations, can adapt to a wide range of climates and sites, are relatively free from damaging pests and pathogens, and produce above average yields of useful timber. As tree improvement programmes develop, some provenances are identified which give important improvements in quality and quantity of timber, with some selections being confined to one of a few individuals instead of populations. Species of Pinus, Picea, Larix, Betula, Eucalyptus, Cryptomeria, Tectona and many others are being subjected to selection that progressively narrows the genetic base of the stocks ultimately used for even-aged plantations. The process is well recognized, the benefits are great but experience in agriculture has amply demonstrated possible long-term hazards.

Although benefits are likely to accrue from the selection of progenies able to tolerate stresses attributable to severe cold, soil moisture deficits etc., larger yields are likely in most instances to be obtained sooner by selecting trees whose harvestable yields form increasing proportions of total biomass. Tree breeders and silviculturists must continually modify the characters of the ideal tree, or ideotype, to take account of the improved understanding of ways in which trees in plantations interrelate one to another at different stages of development; those that show promise before canopy closure may not continue to succeed afterwards. For the future, it is also desirable to know how genetically less heterogeneous stands of improved trees respond to severe competition for limited resources of water and nutrients as compared to their unimproved progenitors, remembering that sites, with improved preparation, will inevitably be less variable.

SITE CLASSIFICATION, SITE AMELIORATION AND NUTRIENT CYCLING.

Participants at the meeting recognized that site classification is an essential basis for silvicultural decisions when establishing even-aged plantations. Because of their importance, the different types of site indices, designed to predict future production of timber, were critically reviewed. Some are based on yields of previous tree crops, others focus on soil types which incidentally integrate influences of climate on soil processes. Site indices based on past yields tend to underestimate what can be achieved in the future with improved silvicultural practices, whereas those

based on soil types tell more about what needs to be done to prepare sites for planting than they do about potential yields. From our limited knowledge of forest climates - which needs to be greatly strengthened particularly for remote upland and mountain sites - assessments of exposure to wind can be made simply and effectively using standardized tatter flags. But how can the observations obtained be related to mechanisms and processes controlling stomatal behaviour and water loss? How can this information be used in early selection procedures?

Many speakers emphasized the importance of soil organic matter for the continuing success of even-aged plantations. Some suggested that large yields of timber may have been gained from the first generation of plantations at its expense, while others mentioned the development of fissures following the irreversible drying and contraction of peats in some areas after having been planted with lodgepole pine. The importance of organic matter decomposition was discussed in relation to amounts of nutrients released and relative to (i) applications of artificial fertilizers and (ii) the requirements of forest trees at different stages of their development.

A consideration of basic aspects of nutrient cycling in even-aged plantations lead to another closely related subject considered important by participants. Frequent reference was made to the knowledge and experience gained from agricultural research and practice. Farmers ameliorate their soils by drainage and ploughing; foresters have also achieved improvements in this way. Farmers amend their soils by adding organic and inorganic fertilizers and the amounts of these often are finely adjusted to the needs of individual species and cultivars; an iterative procedure with amounts of fertilizer and the nature of other agricultural practices being reconsidered and adjusted as, and when, new cultivars are introduced. For instance, the dramatically increased applications of fertilizers following the replacement in the early 60's of long- by short-strawed cultivars of wheat. This approach can also take account of local variations in climate and soil and could therefore be regarded as an example upon which to base regional silvicultural prescriptions. Silviculturists working in protection forests and with long rotations accept that their silvicultural systems must be well-buffered against hazards, but in even-aged plantations this attitude may not be so appropriate as soil scientists and engineers continue to find ways of reducing edaphic site variations by drainage, cultivation and the application of fertilizers.

In addition to discussing the use of fertilizers and the release of nutrients from decomposing litter, two other aspects of tree nutrition were debated. For some conditions it

would appear profitable to study the use of mixtures, including trees such as Alnus species, with root colonizing, nitrogen-fixing microbes and additionally there could be merit in identifying within-species variants that more efficiently exploit available nutrients. These ideas lead to a renewed interest in mycorrhizas which, at this meeting, centred on their beneficial effects on the rapid establishment of trees after planting.

EFFECTS OF AFFORESTATION ON CATCHMENT WATER YIELDS.

On many occasions during the meeting there were references, direct and indirect, linking trees and water: the need for drainage to facilitate establishment, the inter-relation between water availability and stomatal behaviour, the ability of trees to withstand stress whether attributable to drought or waterlogging and very importantly the water yields from afforested catchments. The latter are of particular significance with afforestation and the conservation of water being regarded, in some areas, as incompatible land uses. Although some catchment studies have been made there is a need for more so as to be in a position to predict the effects of trees, compared with those of other types of vegetation, in a diverse array of environments. These studies should include estimates of water quality in addition to quantity.

ECOLOGY OF THE FAUNA AND FLORA OF EVEN-AGED PLANTATIONS.

The importance to the continued success of even-aged plantations of knowledge about damaging populations of pests and pathogens is self-evident. Less obvious but equally essential in the long term, is the need to learn more about organisms that at present appear insignificant but may be potentially valuable or dangerous. If the meeting had been held in 1975 this statement would have been applicable to the pine beauty moth (Panolis flammea), whose normally quiescent populations in Scots pine growing in the U.K. have, in the interim, increased in a few plantations of lodgepole pine to damaging proportions. The large yields of even-aged plantations may justify some risks and the acceptance of limited losses, but we must seek to minimize the occurrence of large infestations and epidemics which may be uncontrollable or require the use of extensive and expensive control measures with possible side effects on wildlife and other forest assets. It is necessary to recognize that the study of associated plants and animals, including pests and pathogens, is an integral part of forest ecology. If their behaviour and population dynamics were better understood, control could be exercised with increased discretion.

RESOLUTIONS

After the main purpose of the meeting had been successfully achieved, namely the provision of a forum for discussing the ecology of even-aged plantations, participants agreed the following resolutions:

- I. Projections of world wood production and supply and of world wood demand, indicate that sooner or later, and probably by the turn of the century, there will be a world shortage of wood which will become increasingly severe.
- II. To meet this shortage it is inevitable that the use of intensive plantation forests will be extended.
- III. Economic production through plantations will only be sustained so long as foresters are fully aware of the direct and indirect effects that plantations have on the environment.
- IV. To ensure that production will be sustained at economic levels, it is essential to augment the amount and range of fundamental research upon which applied research and management can draw.
- V. In particular, the following are recognized as key research fields:
 - (a) Plantation forestry often leads to a reduction in numbers of species grown, dependence on a limited genetic base and probably, in an increasing number of instances, to the use of clones. To safeguard the future, international action is required to conserve tree species in their natural habitats, an important part of the work already being done by F.A.O. through its Panel of Experts on Forest Gene Resources; significant and fully representative areas of natural forest must be conserved with equal emphasis on trees, soil and associated fauna and flora.
 - (b) By analogy with agriculture, the use of exotic species, the narrowing of the genetic base and the intensification of management increase the risks from pests, invertebrate and vertebrate, and pathogens. Research on species, which may affect forests of the future, is needed.
 - (c) Fertilizer requirements need to be linked to nutrient budgets. In particular, the possibility of exhausting the store of soil organic matter, and hence of nitrogen, needs attention.
 - (d) Too little is known of the effects on (i) soils and (ii) yields of water catchments; the latter deficiency reflecting an imperfect appreciation of the water relations of trees in different situations, particularly when comparing evapotranspiration from forests and grasslands.
 - (e) Experience in many parts of the world has shown that damaging populations of herbivorous animals, e.g. small

rodents and deer, often develop in plantation forests. Their behaviour, reproductive ability and patterns of dispersal need to be investigated so as to define what constitutes a potentially damaging population.

CONCLUDING REMARKS.

Productive even-aged plantations are now distributed throughout the world. They include plantations of Pinus taeda in southeastern United States, Pinus radiata in New Zealand and Australia, the clonal plantations of Cryptomeria japonica in Japan, the second and third generation plantations of Tectona grandis at Nilambur in southern India, the Pinus oocarpa plantations on the Jos plateau of Nigeria and the Picea sitchensis stands of Galloway and Eskdalemuir in southern Scotland. In his opening paper, Mr G.D.Holmes emphasized the contribution that even-aged plantations must make to world supplies of timber and in his closing remarks, Professor D.Mlinsek, Coordinator of Division 1 of I.U.F.R.O. emphasized three main qualities of the forest resource, namely timber production, site protection and social benefits. Furthermore, Professor Mlinšek stressed that managers of plantation forests still had much to learn from those tending naturally regenerating forests, as in Central Europe, where there is concern for site protection, in its broadest sense, in addition to timber production.