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Note from the Secretariat

MONOSPECIES PLANTATIONS

1. Introduction

Forest plantations traditionally consist of one or a few species, frequently planted in pure blocks. The reasons for this are that such blocks are more simple to plant and to manage, that they are easier and cheaper to establish and that they produce a more uniform product than an intimate mixture of woody species. Most programmes, however, include more than one species over its total area of plantation, in order to take advantage of variations in site.

Most, if not all, forest plantations prior to the 1970s were established for industrial purposes plus, at times, for the rehabilitation or management of watersheds. The great majority of these plantations were in developed countries, as evidenced by the fact that the total area of forest plantations in the developing countries by the year 1980 was only some 11 million hectares and practically all of these plantations had been established over the past 10-15 years. The majority of all plantations, worldwide, were established using fast-growing local or introduced pioneer species, naturally adapted to grow in simple (single-species) formations, on open or disturbed sites; and to produce maximum amounts of wood per unit area.

With the realization that rural development must precede industrialization and that trees and shrubs play a fundamentally important role in such development, increasing areas of plantation in developing countries have, over the past decade, been established for non-industrial purposes (provision of fuelwood, fodder, land stabilization, shade and shelter etc.). Not always has the choice of species been well-conceived in these "non-traditional" plantations, and not always has the choice of plantation site been technically and socially sound, leading to frequent technical and social failure and increasing criticism.

Over the past years, there has been at times heated discussion and public opposition to single species plantations (somewhat erroneously termed by the popular press, "monocultures"). In developed countries, much of the criticism has been based on the monotonous visual appearance of large, regularly spaced and even-aged blocks of single species. In developing countries where forests and forest lands have traditionally been used by local populations to supplement needs for building poles, fuelwood, food, fodder, medicines and other wood and non-wood products, there have been explicit or implicit allegations that short-term economic gains are overriding pressing social needs at the local level. At times, as in the case

of species of the genus *Eucalyptus* in the Mediterranean region and Asia, antipathy is thought to have arisen because of the identification of given species with unpopular social policies. A strong and organized reaction by a relatively well-informed public against actual or alleged neglect by the authorities concerned to invest also in the conservation and management of the natural flora and fauna, has resulted in verbal and physical attacks on plantations of *Pinus radiata* in Australia and New Zealand.

On the technical and scientific levels there has been a suggestion from forestry outturn records in some countries that use of a single species without additions of soil nutrients through fertilizers or other means, may lead to reductions in yield in the second and subsequent rotations. In addition there is the danger that a "blanket" prescription to plant a single species may not only lead to failure to exploit the full potential of the site but also may, through a mismatch of species or provenance with site or subsequent changes in the environment, lead to increased susceptibility to pests, diseases, drought or other harmful influences. From an economic point of view the argument has been that the use of a single species which proves to be susceptible to a pest or disease, may lead to loss or considerable reduction of the investment, whereas use of several species may balance such potential losses. Debate related to "multipurpose management" has also tended to favour strategies based on species mixtures mimicking complex natural ecosystems, rather than favouring pioneer species established with one single management objective in mind.

FAO's Forestry Department is in the process of publishing a document which looks at the relative advantages and disadvantages of single species and mixed forest plantations, from the social, economic, technical and environmental points of view¹. As was the case in the study on the environmental effects of the genus *Eucalyptus* carried out a few years ago, the study is complicated by a lack of scientific evidence, by a vast array of possible scenarios, and by the mixture of technical, social and purely emotional arguments used in the ongoing debate.

The present paper, in line with the expected interests of the audience, will concentrate mainly on technical and scientific arguments, with special reference to forest plantations established with the explicit purpose of industrial roundwood production.

2. Objectives

Although any forest cover, including well-planned and silviculturally sound forest plantations, will by definition provide considerable environmental benefits, a man-made plantation is generally a simple system which is intensively managed for the production of one or a few products (such as wood, fodder) or environmental services (such as sand dune fixation, watershed rehabilitation). Therefore, plantations should not automatically be expected to provide the much wider range of goods and services that natural, largely unmanaged forests provide at less intensive levels. This is especially true where the main objective of a plantation is the production of wood for industrial use; it is better to specify explicitly one or a few main objectives, modified by the constraints of good forestry practice, than to attempt to meet many objectives which may be incompatible even if the problem of allocating priorities can be solved. Such a decision must, however, be made with the understanding that benefits

¹ Mixed and Pure Forest Plantations in the Tropics and Sub-Tropics.
FAO Forestry Paper. FAO, Rome 1992 (*in press*).

not derived from the plantations will be prioritized in other, complementary areas of the national territory (conservation of native flora and fauna, production of non-wood products such as fodder, medicinal plants etc).

3. The Single Species in Nature

As mentioned above, many of the species used for plantations (such as species of the genera *Acacia*, *Eucalyptus*, *Pinus*), are pioneer species that grow naturally in pure associations. There are also climax associations that consist of pure species - for example, *Agathis* species in south Kalimantan (before recent logging), *Cynometra alexandri* in Uganda, or mangrove associations. Thus, a "natural stand" is not, by definition, mixed. There are, on the other hand, many natural forests which are mixed (either intimately mixed, "layered"= mixed in successional stages, or mixed in a mosaic of single-species groups), however, it is difficult at our present state of silvicultural knowledge to find two or more proven tree species which will grow compatibly together in forest plantations without one tending to dominate and finally to oust the other; it is even more difficult to demonstrate economic benefits from such mixtures.

4. Environmental and Social Effects of Plantations

Natural ecosystems are not stable but are in a constant state of change and development in response to their intrinsic characteristics as well as external pressures. The changes brought about by the establishment of forest plantations, whether of several or a single species, will cause more radical and faster changes than natural processes, and will often aim to "freeze" a given successional stage, considered economically beneficial.

Unless care is taken, the above man-made changes may lead to the extinction of varieties or provenances of native species present at the plantation site that may have values yet to be recognized. They will also frequently lead to the unavailability from the plantation area of plant or wildlife products which have traditionally been used by local people, in addition to secondary negative causes such as prevention of access to land traditionally used for grazing or other all-mans benefits. Intensive management and harvesting regimes may also negatively effect e.g. the soil conservation capability of watersheds.

The causes for disruption are more often the creation of a plantation, rather than the creation of a single-species plantation. This is especially true if management regimes and spacing do not adequately cater for soil and litter management and for the development (where appropriate) of a herbaceous or shrub layer.

5. The Evidence for Yield Decline

In the mid-nineteenth century a decline in second rotation yields that was detected in crops of pure spruce (*Picea abies*) that had been planted in Saxony. Investigations in the nineteen twenties found that growth was satisfactory on high elevation podsols, but second rotation decline occurred on lowland clay soils, many of which had formerly been cultivated by agricultural crops. The causes appeared to be a combination of shallow rooting in the second rotation, attack by the root rot *Fomes annosus*, the initial poor quality of the soils and the dense stands which caused an accumulation of humus; planting the spruce outside its natural range

(without adequate provenance testing) accentuated these constraints to healthy growth.

Failure to match species to site was also the cause of second rotation yield decline in pure stands of *Pinus radiata* grown in South Australia on poor, sandy soils. Intensive research showed that the management practice of burning slash after felling was contributing to a reduction in soil organic matter which led to a decline in available nutrients and soil moisture. The problem has been solved through the maintenance of soil organic matter (for example, by eliminating the burning of slash), the use of fertilisers and logging practices that avoid soil compaction.

The decline in yields was detected in South Australia because of a network of permanent sample plots, the first of which were established in 1935. In Swaziland, at the Usutu plantations, permanent sample plots have also been used to monitor yields in the second and later rotations in *Pinus patula*, *P. elliottii* and *Pinus taeda*. At the high elevations of Usutu (between 1 000 and 1 450 m altitude), nutrients are immobilised in the litter, which accumulates due to the low temperatures and resultant slow decomposition. Analysis of the results has been complicated by the confounding factors of poor rainfall in some of the years of the second rotation (which might be expected to reduce yields), offset by the benefits of planting into weed-free sites in the second rotation. The conclusion is that where the species is suited to the site there has been no reduction in yield, but on some small areas, where litter is accumulating, it has been necessary to fertilize to maintain yields.

In summary, the decline in yields in second and subsequent rotations appears to be a problem of infertile sites, lack of matching of species to site, or unsuitable establishment techniques, rather than by single-species plantations *per se*. On fertile sites it has not yet been possible to obtain statistically significant evidence of yield decline, but the loss of nutrients through logging, particularly where bark, small branches and foliage are removed from the site, leaves no room for complacency. Silvicultural and harvesting practices should emphasise soil conservation in any kind of plantation, especially by avoiding exposure of the soil and soil compaction, which may tend to deplete the topsoil of nutrients, moisture or organic matter. A network of permanent sample plots is part of sound forestry practice, and will give warning of decline in yields; there also needs to be sufficient research capacity to develop solutions, should such a decline occur.

6. Susceptibility to Attack by Pests and Diseases

Single species plantations are in theory particularly susceptible to attack by pests and diseases, mainly because of the concentration of host material. In the cases where exotic species are planted, these may lack resistance to indigenous insects or pathogens. On the other hand, indigenous tree species may themselves be susceptible to exotic pests or diseases, a point that has assumed much greater importance with the growth in air travel and air freight, which uses woody products for carcasing and packaging, and the intense exchange of germplasm over national borders.

While there have been many instances of widespread attacks by pests and diseases to single species plantations, there is no evidence that the use of mixtures would necessarily have prevented or even slowed that attack.

Where plantation species have been attacked by pests or diseases the cause has very often been that the species has been derived from a very narrow genetic base (and thus has lacked the genetic variation necessary to respond to the attack of a pathogen); or has been under stress because it has not been correctly matched to the site, or because of incorrect or inadequate management.

7. Site Selection, Management Techniques

Plantations should not be used to replace natural forest but should be established where soil fertility has been lost through intensive agriculture, or where the original forest cover has been destroyed or degraded to the point where it can no longer provide the necessary range of goods and services.

The danger that nutrients will be immobilised in the litter has already been mentioned. The breakdown of litter can be achieved through timely thinning and pruning which will also promote the growth of an understorey of shrubs and herbs; these will in effect form a plantation of a "mixture of species", which will help to prevent soil loss and may provide some non-timber forest products.

Especially where the ecosystem has been changed radically through the establishment of a plantation using exotic species, then samples of the native ecosystem should be conserved, even if these are considered degraded.

This is best done, however, in separate areas managed for this specific purpose.

Conservation of representative samples of native ecosystems should be complemented by the conservation of genetic resources of their component species, capturing also intra-specific variation of these species in a network of conservation areas, in which conservation purposes can generally be harmonized with those of production.

It is, furthermore, necessary to pay maximum attention to the maintenance of a broad genetic base of those native or introduced species which are used in the plantation programme, as an insurance against changes in the environment or in end-use requirements, and as a basis for the continued improvement of the species used. The maintenance of base populations containing a broad genetic base is particularly important for breeding programmes in support of clonal plantations, where a single species may be planted over a large area in a mixture of clones in mosaic, while supported by continuing research and development of new clones, to be introduced regularly into the planting programme.

8. Mixtures and Different Plantation Types

The requirements for large scale industrial roundwood plantations are for a uniform product with the maximum growth on the valuable species. Single species blocks are therefore the preferred option; the insurance against failure in this case should be early warning of potential dangers supported by adequate research and control facilities so that any potential threat can quickly be suppressed, with effective plant quarantine measures as a first line of defence and alternative strategies should the control measures fail. Mixtures may occur within a block through spontaneous regeneration of locally-occurring tree species, and where this does not

interfere with the stated, main objectives of the plantation, it should be encouraged; the development of a shrub/herb understory should also be encouraged (see section (7) above).

The role of mixtures in industrial plantations would appear to be mainly as an insurance against total loss from pests and disease, especially in cases where the grower has limited access to monitoring services or research facilities. Mixtures are also an option in small-scale and less intensively managed plantations established for the supply of posts, poles and fuelwood; and may be preferred in fodder plantations, where feed should be available throughout the year. Mixtures may further be preferred where watersheds are being rehabilitated or degraded sites are being planted about which there is little knowledge for reliable species selection.

9. Conclusions

There is no evidence that single species plantations have environmental or economic drawbacks, so long as the species and provenances used have been correctly matched to site and silviculturally sound management techniques are practised; and provided that allowance is made for the conservation of local flora and fauna elsewhere. From the socio-economic point of view, it is important to identify traditional, local uses of the lands being planted, and compensate for any benefits foregone in an appropriate manner.

The role of mixtures of species in plantations is one kind of insurance against catastrophic losses occurring from attack by pests or diseases, or from abiotic factors not foreseen at the time of plantation establishment. This form of insurance is most appropriate where the owner has relatively little capital, the product does not have to be highly uniform and management is less intensive. It is also appropriate where there is inadequate information to match species and site reliably, where continuity of e.g. fodder or browse production throughout the year is sought, or where the aim is the production of a range of goods and services for local use, at modest production and management levels.

Industrial roundwood plantations require a uniform product which is raised under conditions of intensive management. Plantations consisting of blocks of a single species within a programme of a few species, or a mosaic of clones, are therefore in general economically more feasible. Enterprises involved in such plantations are usually well-capitalized and can afford the other form of insurance, which is effective monitoring and investment in continuing research. The monitoring should cover not only early warning of the incidence of pests and diseases, but also, through permanent sample plots, changes in site quality and yields. The research may be supplied by external institutions such as the government or a university. Government should also provide an effective plant quarantine service and to take part in regional dialogue to get early warning of potential threats (perhaps coordinated by FAO).

In addition, it is the role of the government, supported by the wood growing industry, to ensure that traditional rights of local populations foregone or environmental benefits reduced through intensive management for wood production on given sites, are compensated by introducing complementary management regimes in other areas, aimed at the provision of goods for local use, and the conservation of ecosystems and genetic resources of plants and

animals.

In summary, many drawbacks which are perceived to arise on the technical level from plantations of a single species are, in fact, due to failure to match species and provenance to site, or to neglect of sound silvicultural or harvesting practices. Adequate investment in research and development, will minimize related risks. Environmentally, it should be realized that not all objectives can be met from all areas simultaneously. Environmental safeguards introduced at the national rather than the local level should ensure that ecosystems and genetic resources of local plant and animal species are conserved for present-day and future benefit; the industry and other plantation owners have a moral commitment and should be obliged to contribute to such efforts. Major problems may arise from the loss of traditional rights for use and privileges of local people to industrial plantation sites; such problems are due to unequal distribution of land and to poverty. All efforts possible must be made between the Government and the plantation owners to find solutions to such problems, through the identification of alternative sources of income and goods for landless people.