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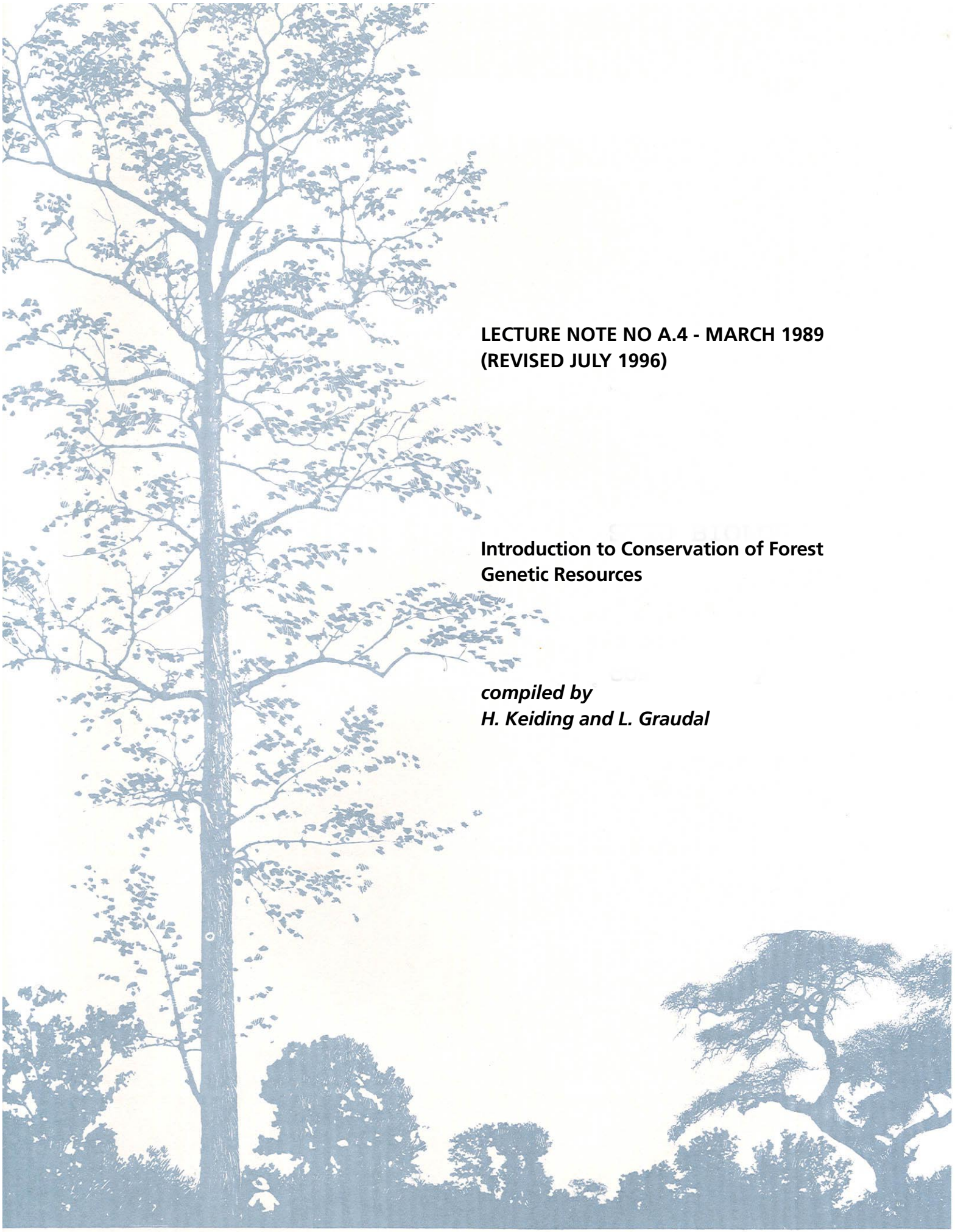

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Introduction to Conservation of Forest Genetic Resources

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1. INTRODUCTION

Planting of trees on an increasing scale for various purposes has become a common feature of countries in the tropical regions, and is a means to reduce the shortage of wood and the environmental degradation caused by the combined effect of growing populations and the pressure on natural forests.

Large quantities of tree seed of technically improved quality and of well-adapted species, provenances and improved material are required to execute the planting programmes. This necessitates a national seed procurement programme which provides the technical facilities for collection, handling and distribution of seed as well as an adequate number of different types of seed stands representing the genetic resources of species and provenances. The genetic resources will be available in different stages of development varying from protected, demarcated stands in natural forests of indigenous species to clonal seed orchards with selected clones of either introduced or local species.

As one of the main purposes of developing a national tree seed programme is to provide seed and subsequently plants which are adapted to a variety of environmental conditions and which shall serve many different purposes, it is of fundamental importance to secure a broad and diverse genetic base.

However, the sources from which the genetic material should be collected are in many instances in danger of disappearing or of being depleted as a result of the increasing pressure on natural forests.

Therefore actions to protect and conserve sources of genetic variability are urgently required in order to meet, among other purposes, future needs of seed for tree plantings.

2. CONCEPTS OF GENE RESOURCE CONSERVATION

Conservation of a resource is best defined as the actions and policies that ensure its continued availability and existence. The term is used in the sense defined in the World Conservation Strategy (IUCN/UNEP/WWF, 1980): 'The management of human use of biological resources so that they may yield the greatest sustainable benefit to present generations, while maintaining their potential to meet the needs and aspirations of future generations'.

2.1 Genetic resources, genetic variation and tree improvement

Genetic resources are 'units of heritable variability of actual or potential value'. The variability must be **heritable** and be available in a form which may, sooner

or later, give rise to further generations (Roche & Dourojeanni, 1984). **Variability** denotes the variation in genetic composition between individuals or between groups of individuals (populations). In a broader sense, when all species, populations within species, and individuals are considered, we talk about **genetic diversity**.

Resource is defined as 'a stock or reserve upon which one may draw when necessary', indicating that both **actual** and **potential** resources are considered. The former are those which are immediately available, for instance different forms of seed that may be collected while the latter are either sources which have to be made available or about which we do not know their genetic value at present. Many multipurpose trees may still belong to the last category (Roche &Dourojeanni, 1984).

Genetic resources occur in different forms and at different stages of genetic development, covering reserves of trees in their natural habitats (natural forests), man-made forests, plantations, selected material from breeding, seed and pollen.

The 'amount' of variability will vary depending on the type of genetic resource we are dealing with, e.g. whether it is present in its 'wild' state in a natural forest or whether it is a highly selected material from a breeding programme. There is, generally speaking, a relationship between the gain in 'yield' in the broad sense (production, desirable characteristics) and the amount of variability. In the sequence of selections by which only a portion of the most advantageous, inheritable traits are favoured, the genetic variation will change and may be narrowed down, if the selection intensity is high. The process is illustrated schematically in figures 1 and 2.

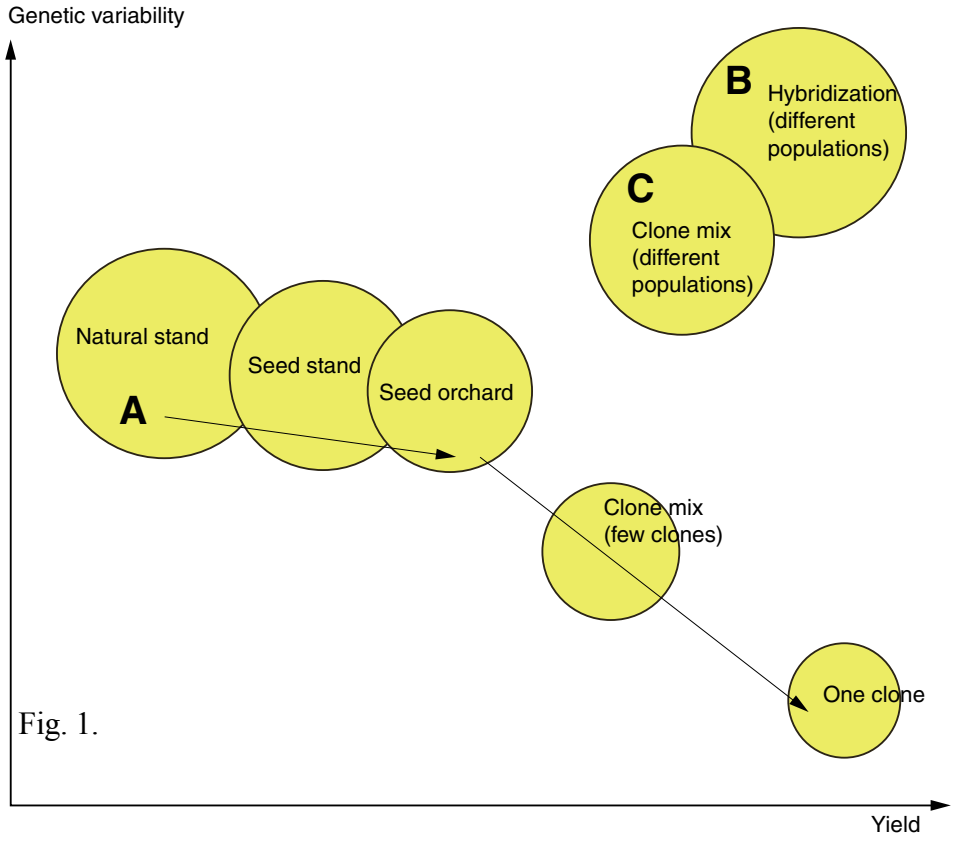


Fig. 1.

Fig 1.

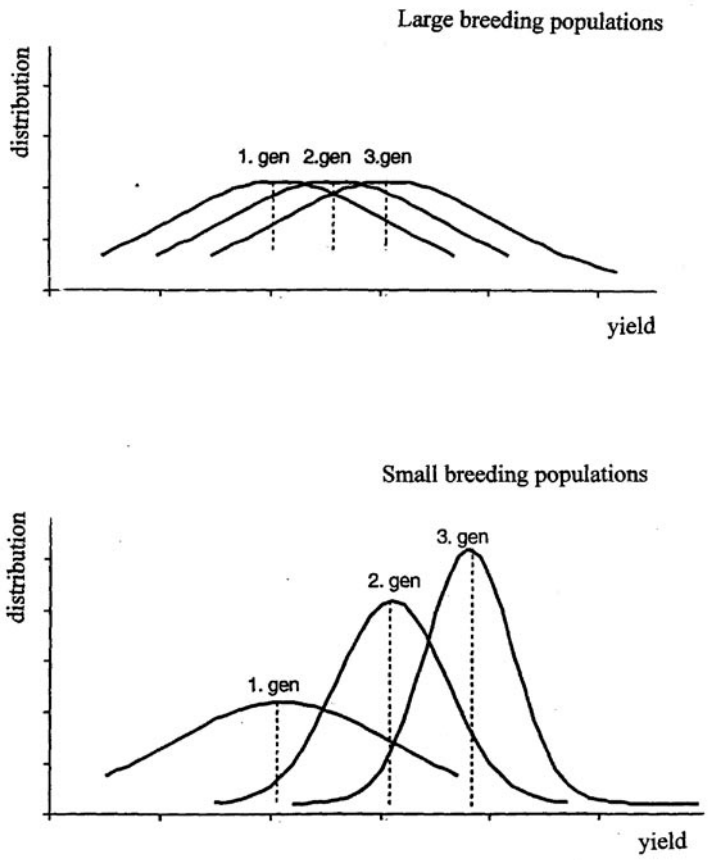
The connection in principle between variability, yield and different units of genetic resources corresponding to different levels of improvement intensity. The more well-defined a genetic resource the smaller the circle. The process starting at arrow A illustrates domestication from a single provenance. The level of variability is decreasing (natural stand -> seed stand -> seed orchard), because each step involves selection of the best individuals resulting in higher yields. How much the variation decreases depends on the population size and the selection intensity (see figure 2). The circles B and C illustrate domestication through hybridization and mixing of clones from different populations. Here the level of variability may increase compared to natural stands because new gene complexes arise.

Fig 2.

Theoretical distributions of yield over three generations of improvement. The connection between selection intensity (population size), yield and diversity.

Top: large breeding populations - the average yield is gradually improved and the diversity is maintained.

Bottom: small breeding populations - the average yield is gradually improved and the diversity is narrowed down.



Improvement in yield may thus be obtained at the cost of genetic variability depending on the improvement strategy. This is important to bear in mind in the context of gene resource conservation.

2.2 Genetic erosion

This term was first applied to highly bred agricultural crops like wheat, maize, rice etc. in which very high yields and other advantages were achieved through systematic breeding and special combinations of a limited part of the genetic potential (Ref. section 2.1: Genetic resources). The high-yielding strains quickly spread replacing less productive but more variable cultivars. As a result higher yields were obtained with much more genetically uniform crops but at the same time also more vulnerable to large-scale attacks by pests or diseases. Adaptability or 'resistance' was not taken sufficiently into account in the endeavour to improve production.

Agriculturists and crop breeders therefore realised the importance of maintaining genetic resources containing a wide range of the original genetic potential and from where, for instance, disease-resistant genes may be drawn and incorporated in the breeding, thus providing a reduction of the 'erosion effect'.

How does genetic erosion concern forest trees when breeding generally is at a primitive or introductory phase compared to agriculture?

In a longer perspective a narrowing of the genetic possibilities may take place in connection with

1) choice of species and provenances (seed sources)
2) increasing use of vegetative propagation.

The demand for planting trees is immediate. The choice of tree species and seed sources is therefore affected by their availability and ease of establishment. As a consequence relatively few species, largely represented by the genera *Pinus* and *Eucalyptus,* have dominated the early plantings. This dominance of a few species deriving from a limited number of sources resembles in principle the widespread use of high yielding, but genetically specialized food crops with some of the same consequences. It is important therefore to secure a diversity of genetic resources within the most commonly planted species as well as among different, alternative species. The latter is further emphasized by multiple uses of trees demanding a broader spectrum of species.

Vegetative propagation of forest trees has been practised for e.g. eucalypts in clonal plantings, but otherwise only on a limited scale in connection with research. However, with the development of vegetative propagation, it may become a more widespread practice especially for species difficult to raise in greater quantities from seed. Although very spectacular results have been obtained with clonal plantings of eucalypts (Brazil, Congo) the risk of genetic erosion will increase. The securement of a genetic resource base becomes even more important.

2.3 Methods for the maintenance of genetic variability (Extract from FAO, 1989)

The principles of genetic conservation are the same for all living organisms. However, the strategies and methodology of conservation will vary according to the precise objectives of conservation and the distribution and biological nature of the material to be conserved.

The conservation of an **ecosystem** will maintain the variation between species and the dynamics of their interdependence in correlation with the environment and is *per se* conservation *in situ* (on site).

For conservation of genetic resources of species and diversity within species (populations, individuals, genes), there are two methods:

In situ (on site), i.e. protection and maintenance of species and populations in the ecosystem in which they occur

and

Ex situ (off site), i.e. protection and maintenance of genetic resources outside their original environment, e.g. production stands, breeding material, conservation/seed stands, seed, pollen and tissue.

The difference between the two methods is basically that *in situ* conservation of plant genetic resources allows evolution to continue within the area of their natural occurrence.

Although most frequently applied to populations regenerated naturally, *in situ* conservation may include artificial regeneration when planting or sowing is done without conscious selection and in the same area where the seed was collected (FAO, 1985).

In situ conservation of land races or advanced cultivars is thus also possible and implies conserving the population on the site where it or its immediate ancestors have grown naturally.

2.4 Evolutionary and static conservation of genetic resources

There are basically two different ways of conserving genetic resources: evolutionary conservation and static conservation (Guldager 1975).

The concepts of evolutionary and static conservation introduced by Guldager (1975) correspond to the more commonly quoted differentiation of conservation and preservation made by Frankel and Soulé (1981). More recently, evolutionary conservation has been denoted dynamic conservation (Eriksson *et al.* 1993).

Evolutionary conservation is carried out in 'living' populations, *in* or *ex situ,* or in ecosystems where the genetic composition of target species is allowed to adapt to the prevailing environmental conditions and their change with time.

Static conservation maintains specific genetic compositions, *e.g.* in the form of seedlots or gametes in long term storage or vegetatively propagated clones (cultivars) in clone collections, and will usually be *ex situ*.

'Conservation in use', *i.e.* the conservation of genetic variation through, for example, existing agricultural practices, can be either static or evolutionary.

3. CHOICE OF CONSERVATION STRATEGIES

(Extract from FAO, 1989)

Both *in situ* and *ex situ* strategies are important; they should always be considered complementary and be carried out in parallel, as an integral part of programmes aiming at improved use of genetic material available in nature.

There are three main dimensions to conservation: **quantity**, **quality** and **time**. Quantity refers to the number of ecosystems, species, populations, individuals and/or genes considered and to the related amount of germplasm that is available for utilization. Quality reflects both allelic composition and distribution, and their fluctuations within a species and its populations. The time-scale of concern is the period over which conservation activities are projected and ranges from short-term practical utilization to long-term evolutionary responsibility (Frankel and Soulé, 1981).

In choosing conservation strategies all three dimensions must be considered.

Ex situ conservation is usually applied in well defined situations:

- To safeguard populations which are in danger of physical destruction, thus for example if intense pressure exists on an important species or the area where it grows, and protection *in situ* is not possible.

- To safeguard populations which are in danger of genetic deterioration. The genetic integrity of a natural gene pool may be contaminated if populations of exotic but hybridizing populations are planted in the vicinity. If in this case it is desired to conserve the natural gene pool, it must be done *ex situ*, either by collecting seed at a time or in an area where the adulteration by foreign pollen can be avoided, or by vegetative propagation.

Ex situ collections may also be established to respond to other necessities:

- To ensure a readily available, continuous supply of reproductive material, either through storage or by creating a production source (conservation/ seed production stands) in the area where the material is meant to be used. This will often be done where there is a need for immediate utilization, generally on a large scale. The classic example is the value of a species being more appreciated by introducing countries than by the countries in which it is indigenous.

° To allow commercial improvement of a species through breeding activities. The commercial objective of breeding is to produce a genotype or set of genotypes that will return an economic yield sufficiently higher or safer than the current level of yield. Through conscious selection the genetic variation will be narrowed down to meet this end.

Ex situ activities are normally applied to species of principal, economic importance, and are, as stressed above, a useful complement to *in situ* conservation initiatives, especially when the aim is to conserve specific genotypes; however, it can never replace *in situ* conservation fully.

In situ conservation of plant genetic resources presents a number of advantages as compared to *ex situ* conservation:

° It usually allows wider sampling, increasing the probability of conserving a larger range of potentially interesting genes.

° It is especially adapted to species which cannot be established or regenerated outside their natural habitats. These species may be divided into three groups:

- species which are members of complex climax ecosystems, e.g. the moist tropical forest, where the interdependence between species makes it impossible to plant them, individually, in monocultures;

- species with seeds having short lived germination capacity or with seeds possessing dormancy which cannot be broken by known artificial methods; and

- species which have highly specialized breeding systems, depending for example on a single species of insect, bird or bat for pollination which, in turn, is dependent on other components of the ecosystem.

° It allows natural evolution to continue and this is a valuable option for conservation of disease and pest resistant species, which can co-evolve with their parasites, providing breeders with a dynamic source of resistance. This stands in contrast to *ex situ* conservation of reproductive material where 'specialisation', i.e. a certain narrowing of the genetic variability takes place. Refer figure 1.

° It can serve several sectors at the same time, since gene pools of value to different sectors (e.g. crop breeding, forestry, forage production, wildlife) may often overlap, and thus may be maintained in the same protected area.

- It facilitates research on species in their natural habitats. Morphological and ecological characteristics and environmental conditions can be related to the genetic variation, and thus allow a better evaluation and utilization. Several valuable characteristics of wild plant species have been found through observations made in their natural environments, e.g. salt tolerance, drought resistance, etc.

- It ensures protection of associated species. When species of present economic importance are conserved *in situ* within a natural ecosystem, conservation of many subsidiary species, of no present economic value but part of nature's heritage, can be obtained as a bonus. The contribution of these species to the functioning and long-term productivity of ecosystems should not be overlooked.

For the majority of situations it is safe to say that *in situ* conservation is the ideal method of conserving wild plant genetic resources. *Ex situ* conservation is a valuable complementary method for many species and is the only hope for rescuing genetic resources threatened with inevitable loss in their natural habitat (FAO, 1985).

For their success both *in situ* and *ex situ* strategies depend upon frequent monitoring and continued up-dating and improvement of management techniques and technology applied.

Whereas the *ex situ* conservation strategy is technically well known, widely used and fairly well developed, very little action has yet been taken for *in situ* conservation, especially of within species diversity.

The main reasons for this lack of action have been (i) limited cross-sectoral cooperation (notably between user sectors, such as the crop breeding and forestry sector on one hand, and the nature- conservation/protected-areas sector on the other); (ii) concentration on *ex situ* methods by the user sectors; and (iii) focus on solely the levels of ecosystems and on species, especially endangered species, by the nature-conservation/protected-areas sector.

4. IDENTIFICATION OF GENETIC RESOURCES AS OBJECTS FOR CONSERVATION

There may be a number of reasons for initiating conservation measures of ecosystems, species and populations of trees varying from protection of rare and endangered species and environ-mental protection to conservation of genetic resources. Usually the objectives are interrelated (see later), but the incitement to action will often be more specific like for instance the request for seed.

The prerequisite for starting or running a national seed procurement programme is an estimate of planting targets and the corresponding seed requirements. Next, a survey of existing seed sources and their possibilities for satisfying the seed demand, both in quantity and genetic quality, has to be made. Such surveys will indicate the need for identifying, protecting and establishing seed sources additional to those already in use. Ref. Lecture Note nos. B-2 and B-3.

Different situations may be recognised:

4.1 Indigenous species

Species occurring in natural forests and known for their valuable wood or other characteristics (fuel, fodder, medicine, etc.)

A common feature of many of these species is their vulnerable position in different types of tropical forest. Measures for conservation and utilisation depend on the biology and distribution of the different species.

With the increasing pressure on natural forests and consequently the risk of losing valuable genetic resources, their protection and conservation have become urgent tasks in connection with most national tree seed programmes.

This is further emphasized by the recognition of the protective role of the natural forests in respect of soil conservation and water resource management.

When protection and conservation measures are required for one or several reasons combined, decision has to be made on which methodology should be applied. Criteria for making such decisions are outlined in section 3: Choice of conservation strategies, in which principles and requirements for employing *in situ* and/or *ex situ* conservation are briefly described.

Having decided on the principal method of conserving a gene resource, i.e. whether *in situ* or *ex situ* or whether a combination of both should be applied, the important question of management of the conservation arises. As this depends very much on the specific situation and the different conservation purposes involved, it will be treated in a separate lecture (ref: Lecture Note D-9).

4.2 Introduced or exotic species

It is expected that these species will continue to play an important role in the planting programmes.

To secure adaptability and improvement of exotics, studies of the genetic history is required for both the already introduced material and the planned introductions (ref. Lecture note A-1 and D-1).

When sources have been identified as promising for wider application through species and provenance trials or plantation inventories, the next step is to safeguard the genetic material and make it available for sustained utilization by seed production from selected seed stands, conservation stands, clonal and seedling seed orchards or by vegetative propagation from clone collections.

The implications of conserving an appropriate genetic base in an improvement programme are discussed in Lecture Note D-9.

4.3 Regional and international considerations

Many of the species most commonly planted have a wide geographic distribution which is not confined to national borders. This applies for instance to many of the Acacia species whether originating from Africa or elsewhere. Although as a rule of thumb it is advisable to use locally adapted provenances, considerable genetic gains may be obtained by introducing provenances from other parts of the distribution area. This has been shown by results from provenance trials of several species.

However, to identify and develop the best sources for local use, explorations, collections and testings at regional or international level are required and call for international cooperation both between national seed procurement and tree improvement programmes.

4.4 Exploration

In the initial phases of genetic resource identification it is necessary to explore the genetic potential of the selected species.

Certain basic information about the species is required such as:

a) Distribution and pattern of distribution
b) Climatic factors, average and range
c) Topography, soils
d) Reproductive biology in flowering and fruiting
e) Special characteristics of importance for survival

Part of this information may be extracted from botanical institutes, herbaria and

records of climate and vegetation via satellites, but it will have to be supplemented by field surveys and, most essentially, local knowledge of occurrence.
On the basis of the data collection and field surveys, plans for the actual seed collections may be prepared. This should aim at sampling as much as possible of the expected genetic variation for subsequent testing in provenance or provenance-cum-family trials depending on whether collec-tions are kept separate from individual trees or bulked from all trees within the population. Reference is made to Lecture Note D-9 with regard to methodology of collection, i.e. minimum number of trees required per population, choice of mother trees, equal amount of seed per tree etc.

In short, a substantial part of the efforts to identify genetic resources and their demands for protection will depend on exploration and collection for provenance testing. This applies especially to many of the indigenous species, which have so far only been investigated on a limited scale and which often exist in a vulnerable state.

5. CASE STUDY

5.1 *Pinus merkusii*

The species is found naturally throughout SE-Asia from the Philippines to Burma and Indonesia under distinct different climatic conditions and in more or less isolated occurrences. Due to the species' importance for industrial utilization its genetic potential was explored, i.e. provenance collections were carried out and trials established (1969-1973).

A particularly interesting and valuable ecotype was identified through the trials and the origin traced to NE-Thailand, where its status as gene resource in its natural environment (*in situ*) was seriously threatened. By combined Thai/Danish efforts some mixed forest areas, in which *P. merkusii* was found, were demarcated and protected in 1979.

Thus the instigation to conserve was caused by the economic/genetic interest in a particular ecotype.

Later the scope of conservation was extended to the whole ecosystem in which three different forest types were identified thereby requiring sectors other than forestry to participate in ecological/botanical surveys and to prepare a management plan for the conservation.

The conservation of this particular ecotype of *P. merkusii* thus became part of a broader object for conservation from which some valuable hardwoods associated with the pine trees also benefitted. Although the management plan had to take the extension of the object of conservation into consideration, the seed production and gene resource conservation aspect of *P. merkusii* was maintained.

In order to utilize the gene resource more widely in plantation establishment it was necessary to combine the *in situ* and *ex situ* conservation methods. The former because the evolution of genetic diversity is maintained (ref. section 3) and the latter because seed production and collection is easier and better regulated outside the *in situ* conservation area.

Thus seed is harvested from the original stands and used for *ex situ* conservation and seed production stands, properly protected from contamination of inferior sources. Supplementary planting within the conservation areas where natural regeneration is sparse is also carried out.

Besides being important sources for seed, the *ex situ* conservation stands also serve as a basis for further selection and breeding.

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