AIR POLLUTION AND CLIMATE CHANGE: CONSEQUENCES FOR GENETIC RESOURCES [1]

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ABSTRACT

The increase of human population is the main reason for the loss of plant genetic resources, and more specific, for forest genetic resources. Clearing of forest land for agriculture, urbanization, and traffic has already resulted in a reduction of gene pools and extinction of species in the past. Plantation forestry with few species on large areas supported this trend.

The increase of life standard and industrialization resulted in a continuous increase of air pollution and will probably result in climate change in future at a speed which exceeds conditions tree species experienced in the past. At the same time air pollution influences the gene pools of species more and more on regional and global scale. Loss of genetic information means also a loss of adaptability. Adaptability will however be even more important in future for survival of tree species under rapid environmental change.

Consequences for the conservation and utilization of forest genetic resources are discussed. These have to take into account the developmental stage of a country, the ecological conditions and the forest history. The problems of deforestation and uncontrolled loss of species are more serious in tropical countries today. In industrialized countries gene pools were already influenced by the historical management systems of forests. Reduced size and fragmentation of gene pools of tree species and losses due to air pollution are more serious problems there.

Methods of in situ and ex situ conservation are discussed on this background and present activities on national, regional and global scales are described. In situ and ex situ conservation have to be supplementary as well as conservation and utilization. However different strategies are required due to the different socio-economical environments, species and forestry developments. Conservation and utilization of forest genetic resources have to reflect the faster change of environmental conditions in future which can only be counterbalanced by a sufficiently broad genetic base for response in tree species. Maintaining and increasing adaptability is becoming urgent under the auspices of air pollution and climate change.

Keywords: genetic resources, conservation, utilization, air pollution, climate change

INTRODUCTION

FRANKEL (1970) states: *"evolutionary responsibility predicates that what we regard as our genetic heritage must be preserved for future generations."* This responsibility is not restricted to species of actual economic value but to all species.

Causes for loss of species and of genetic diversity within species are before all the growth of human population (Fig. 1), increasing life standard, and the associated threats to environment, including air pollution and climate change. The increase of human population is accompanied by simultaneous losses of forest area. These are most dramatic in those regions of the world, where population growth is most expressed (Table 1). Therefore, control of human population growth is the key issue for all environmental problems including species conservation. All efforts for conservation find their limitations in this central problem.

By the end of the 20th. century 15 % of plant species were lost, and 66 % at the end of the 21rst. century when deforestation gains speed (SIMBERLOFF 1986) (Fig. 2). Tree species diversity is richest in tropical countries and decreases towards boreal and alpine forests. 400 tree species are on the list of endangered plants, not including species where local populations are threatened or extinct (BOARD ON AGRICULTURE, NRC 1991).

In the tropical countries deforestation presently occurs at an annual rate of more than 15 mill ha (FAO

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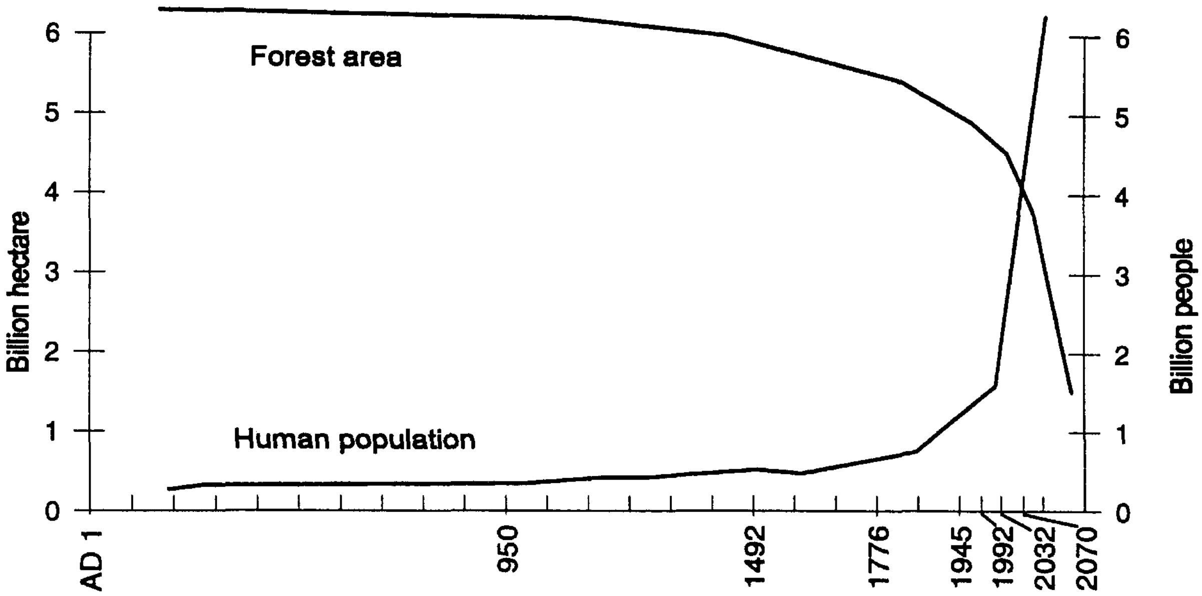

Figure 1. Development of human population and forest area (GORE 1992; FAO, GTZ 1992; BURSCHEL 1995; modified by KLEINSCHMIT 1994)

Present world forest inventory and related changes (DIXON *et al.* 1994)

Areas of Forests in Million of Hectares

Forest Type	Region	Total	Protected	Plantation	Annual changes in area
Boreal					
	Russia	884	178	43	–0.2
	Canada	436	9	3	–0.5
	Alaska	52	2	1	–
	Total	1372	189	47	–0.7
Temperate					
	USA	241	14	2	–0.1
	Europe	283	40	1	+0.3
	China	118	–	31	+0.6
	Australia	396	18	1	–0.1
	Total	1038	72	35	+0.7
Tropical					
	Asia	310	49	22	–3.9
	Africa	527	113	2	–4.1
	America	918	105	6	–7.4
	Total	1755	267	30	–15.4
Overall total		4165	528	112	–15.4

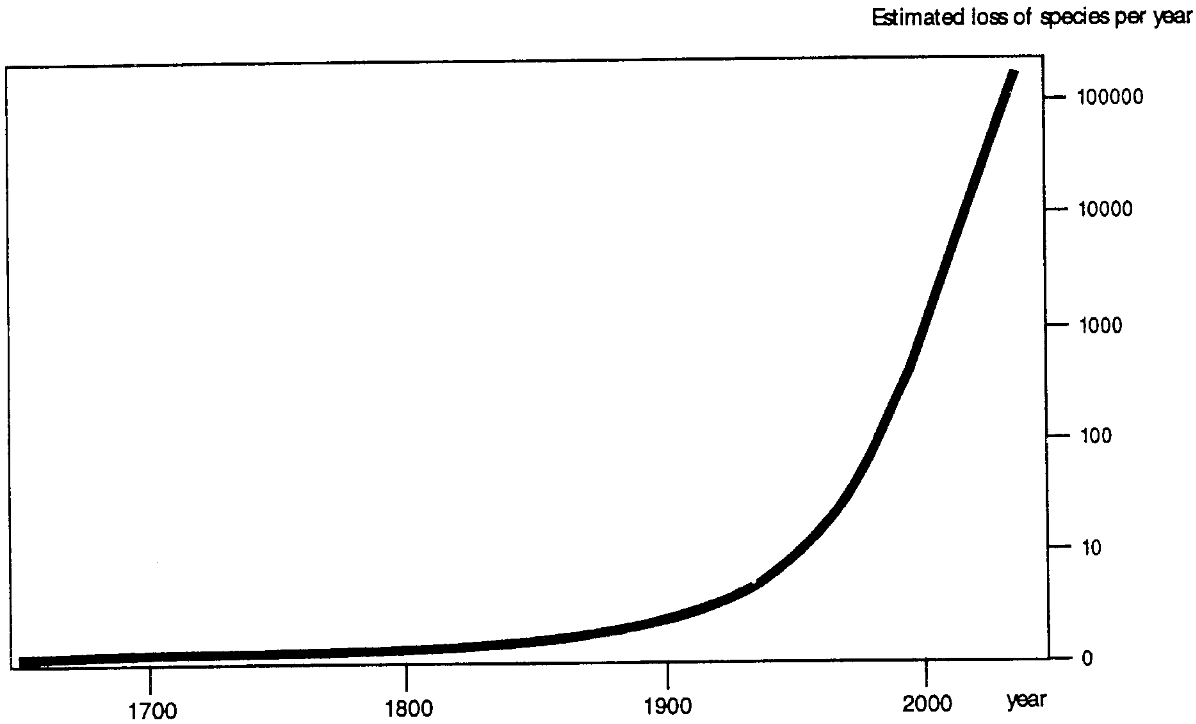

Figure 2. Estimated annual loss of species above normal natural loss (GORE 1992).

1993; SINGH 1993; KOROTKOV & PECK 1993), and it is the main cause for endangerment of species. The main causes of deforestation in industrialized regions with higher latitudes are air pollution and soil degradation (ROBERTS 1987). But deforestation, intensive forest management, and other human interferences contributed to endangerment of species and genetic erosion in these regions of the world in the past, too (KLEINSCHMIT 1994).

Forests are a sink for CO_2 (BURSCHEL 1995), but on the other hand utilization of fossil energy and over utilization of forests increases CO_2 content of the atmosphere (WEBER 1995), which influences global warming (Fig. 3), but it is extremely difficult to predict regional distribution of physical climate changes with sufficient confidence (GRAVENHORST 1991).

Expected gradual warming is 1.5–4.5 °C within the next few decades (ERIKSSON *et al.* 1993). The speed of environmental change by air pollution and global warming exceeds conditions tree species have ever experienced during evolution, and it may exceed adaptability and migration rate (PETERS 1990). If selective forces require a quicker evolutionary response than certain species or individuals have available, the competitive situation between and within species can change, increase of spatial distance of trees can increase inbreeding, and the equilibrium of an ecosystem can be endangered (SCHOLZ 1991). High genetic diversity is a precondition for high adaptability to heterogeneous natural conditions (LEDIG 1986; GREGORIUS 1989). Heterozygous genotypes are more frequent in tolerant than in sensitive groups of trees (SCHOLZ 1991; MÜLLER-STARCK 1985).

Air pollution can cause immediate losses, as for example recently experienced in the Erzgebirge region of Germany, where 3000 ha forests died and 20.000 ha are actually endangered (SÄCHSISCHES STAATSMINISTERIUM 1996) and it can induce continuous degradation of the forests accompanied by genetic erosion (SCHOLZ 1984; SCHOLZ & VENNE 1989; KARNOSKY *et al.* 1989; SCHOLZ 1991; KRIEBITZSCH & SCHOLZ 1996). Air pollution was initially a local problem but it became a regional and global problem with industrialization, traffic increase, and deforestation (DEGEN & SCHOLZ 1994; ERIKSSON 1995 A; KIM & HATTEMER 1994).

The more air pollution becomes a large scale problem, the more ecosystems and species are involved. Consequences can be the loss of species, the loss of locally adapted provenances, the loss of sensitive individuals (BERRANG *et al.* 1986, 1991, KARNOSKY 1981) and the loss of specific genes (MÜLLER-STARCK &HATTEMER 1989; BRADSHAW 1984). Environmental changes can result in an increase of climatic extremes, an increase of UV-B radiation, and new biotic situations.

Time is a crucial point in evolution. Tree species

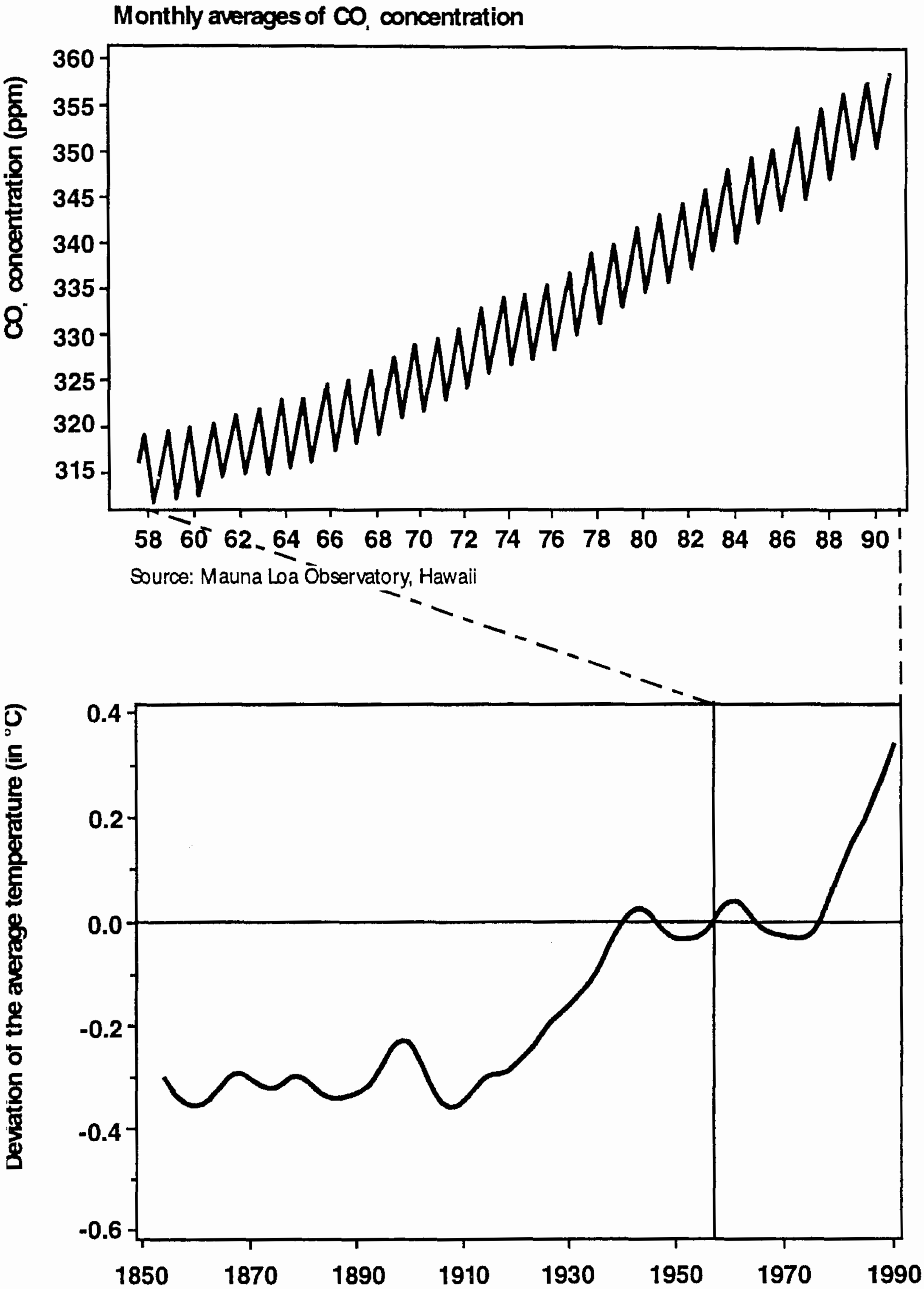

Figure 3. Temperature of the atmosphere 1850–1990 and CO_2 concentration 1958–1990.

are long living, immobile, highly heterozygous, generally outbreeding organisms. They grow in a heterogeneous environment in space and time and usually do not show very fine grained patterns of adaptation, which is an advantage under environmental changes (KLEINSCHMIT 1987; KLEINSCHMIT *et al.* 1996 b). They can react to environmental changes by phenotypic plasticity, survival of the best adapted, or by migration (which can be supported by men). Phenotypic plasticity can be quite extreme and is an efficient buffer against environmental changes.

It is obvious that the situation of forests need actions for the conservation of genetic resources world wide. Genetic diversity is the precondition for species to be able to adapt to changing environments and to survive. The Convention on Biological Diversity (1992) is the international legal framework for conservation and sustainable utilization of genetic resources. In the following years, a series of national and regional meetings took place (e.g. ROGERS & LEDIG 1996; TUROK 1995; MÜLLER- STARCK 1995; BML 1996) to prepare the national and regional contributions for the report on "The State of the Worlds Plant Genetic Resources for Food and Agriculture" (FAO 1996). These include forest genetic resources too.

OBJECTIVES AND PRECONDITIONS

Under the above situation the objective must be to maintain all tree species, including their associate species, in a state which allows evolution and adaptation under rapidly changing environmental conditions. For some specific cases, like in breeding programs, one may have additional objectives like optimization of additive variance in gene conservation populations, or capturing of all genes of frequencies above 0.01 (ERIKSSON 1995b; HATTEMER 1995).

The precondition for an efficient conservation strategy is the knowledge of threatened species:

- their present range
- their genetic structure between and within populations
- the mating system and gene flow
- the risk of loss of genetic information and of extinction
- the effect of management practices on genetic structure
- the associate species depending on the target species,

just to mention the most important ones.

The knowledge is becoming available more and more for economically important species now, but it is still missing for most other ones (BARADAT *et al.* 1995; ROGERS & LEDIG 1996; FAO 1996; MÜLLER-STARCK & ZIEHE 1991). The conservation and, if possible, increase of genetic diversity can therefore be only based on guesses deduced from well studied species.

PROBLEMS

Worldwide about 50000 tree species have been described (BOARD ON AGRICULTURE 1991). Only about 1000 of those are of potential economic interest in near future, 140 are under actual management, and for only 60 of them intensive breeding programs exist. This means that our knowledge about the genetic structure is derived from roughly 0.1 % of the existing species. It also shows that it will be absolutely impossible to get sound information for all species in due time. Therefore in most cases "educated" guesses will be the only solution.

Present range

Inventories of forests, in spite of modern remote sensing techniques, often do not determine species composition, stocking and structure. Even in temperate zones with comparatively few species, inventories are mostly concentrated on the economically most important species. So there is an obvious lack of knowledge for most species. A global assessment and monitoring of forest resources would be necessary (LANLEY 1993). The exploration and inventory of species distribution is a first step.

Genetic structure between and within populations

Discussions arise already about the methods how to measure the genetic structure. Some scientists prefer adaptive traits, others biochemical and genetic markers. Obviously the different methods give different information (ERIKSSON 1995 b; LIBBY & CRITCHFIELD 1987; BOARD ON AGRICULTURE 1991; LEDIG 1986). It will be necessary to use in parallel as many methods as possible but never to exclude adaptive traits.

Some general principles can be applied to all species: A decrease of population size under a critical level is associated with a decrease of genetic variation, an increase of inbreeding and genetic drift, and with an increase of vulnerability. But where is this critical level (20 ?, 50 ?, 500 ?, 5000 ?, ... individuals) ? And how to control it in natural stands?

Genetic differentiation and genetic variation within and between populations can be differentially distributed and this can be different for the different traits. Wind pollinated widely spread species have more clinal patterns, while species with isolated populations have more ecotypic structures. Marginal populations show less variation. Life history and environmental factors lead to differences of variation even between populations within species. Seedling populations may be highly structured (TIGERSTEDT 1984; O'MALLEY & BAWA 1987). Pioneer species have necessarily a different structure compared to climax species (REH-

FELDT & LESTER 1969). But even in climax species often naturally occurring local populations are neither optimally reproductively fit nor ideal for selection even within their area of origin due to random events in evolution, as we know from various own provenance experiments and the studies in other countries (NAMKOONG 1969; GOULD & LEWONTIN 1984; MAYR 1988; ERIKSSON *et al.* 1972). Regularly the variation on provenance level is by far exceeded by individual variation within provenances (KLEINSCHMIT *et al.* 1996 b).

For most species there is an obvious lack of knowledge of genetic diversity and its organization within populations. A more systematic approach is necessary to study the genetic structure of species not under management or in breeding programs.

Mating system and gene flow

Most tropical forest trees have hermaphroditic flowers (flowers with male and female organs), most temperate tree species are monoecious, and a few are dioecious. Dioecy is more frequent in tropics. Mixed systems occur, too.

Most temperate tree species are wind pollinated, but trees that are insect and bird pollinated also exist. In tropical forests, insect and other animal pollination predominate, sometimes with high specificity (BAWA *et al.* 1985; O'MALLEY & BAWA 1987). The potential pollination distance can be quite different depending on the pollinator species.

Gene flow occurs by pollen and seed. Wind pollination, light pollen and seed, and continuous range favour gene flow. Fragmentation of range, heavy pollen and seed and low distance transport vectors favour differentiation between populations. Migration by pollen and seed can be quite different in the same species. In tropical species genetic variability and outcrossing rate can be quite high in spite of low frequency and fragmentation. They show levels of genetic differentiation of populations similar to those in temperate species (O'MALLEY & BAWA 1987; SOONHUAE *et al.* 1995). Inbreeding can occur by selfing or by pollination between related groups of trees.

Reproduction can be episodic, creating genetic and demographic mosaics (BOARD ON AGRICULTURE 1991). The effective population size is usually much smaller than the total number of adult trees. Introduction of exotics or non adapted provenances can influence local populations by pollen, and may alter adaptability of local provenances.

Knowledge of flower biology, mating system and gene flow for most tree species is scarce.

Risk of loss

The risk of loss is high for most species not under management, especially in those regions of the world where deforestation proceeds rapidly or where air pollution load is high. Control of these species and of the factors influencing population viability is not existing.

Genetic drift and loss of genetic information increase drastically if the effective population size drops below 20 (ERIKSSON 1996). The sizes, which are necessary, depend very much on the preconditions of the model and the biological situation, and can range from 50 to 2000 (FRANKEL & SOULÉ 1981; NAMKOONG 1984; GILPIN & SOULÉ 1986). These sizes are not reached in most cases by rare species even in the temperate zone. Reconstitution of interbreeding populations is a necessary consequence.

In some countries changes of health are observed over time for major species, but mostly this information is not available.

Effect of management practices

It is possible to conserve an ecosystem and nevertheless to lose some species. Furthermore it is possible to conserve a species and still lose genetically distinct populations (PALMBERG-LERCHE 1996). Also in the future forestry will depend on managed areas. Separation of land for merely conservation purposes will be possible only in some areas, because of population pressure, the need for forest products, and reduced forest area. The majority of forests has to be managed. Here conservation and utilization of forest genetic resources must be closely integrated. Proper management systems, which take into account genetic diversity, wood production and other utilities of forest land have to be developed. In tropical countries the protection of forest areas seems to be the only way to conserve the majority of species. Pressure can be taken from natural forests by high yielding plantations in temperate and tropical countries (BASTIEN 2001, GLADSTONE & LEDIG 1990).

"On farm" conservation (= managed forests) allows evolutionary processes to continue which generate diversity. Landraces do not remain static, but continue to evolve even without tree breeding. However, the effects of normal management practices on the genetic diversity, especially in uneven aged mixed forests, are very little known. Management of genetic resources needs the understanding of reproductive biology. Only for species included into breeding programs a certain control of genetic diversity is possible. The conservation and/or increase of diversity can be one major objective of the breeding program. A good example is given by the Multiple Population Breeding System as proposed by NAMKOONG *et al.* (1980), NAMKOONG (1989), ERIKSSON *et al.* (1993). Usually breeding tends to diminish genetic variation. Therefore, more attention should be devoted to plant breeding approaches which will maintain and increase genetic diversity, and thereby reduce genetic vulnerability (FAO 1996). Breeding should aim more at adaptive traits. Conservation is a base for breeding too. There exists a mutual dependency.

Associated species

Forest ecosystems are complex. Different species within the system depend directly or indirectly on one another: Insects, birds, bats serve for pollination; mycorrhiza for nutrient uptake; animals to feed on fruits, leaves, and wood, and disseminate their seeds etc. Comparatively little is known about these mutual relationships in complex tropical rainforests. This is another argument for protection of ecosystems as a whole in these regions until appropriate management practices are developed. On the other hand conservation programs for other than tree species can enforce conservation of forest ecosystems, as the example of the spotted owl in the US Pacific North-West demonstrates. Influences of air pollution and climate change on associated species may be even higher, because they did not evolve mechanisms of flexibility like tree species. But tree species are depending mutually on some of these species (pollination, nutrient cycle e.g.).

Other problems

Socio-political structures have an influence on conservation programs as has land ownership. This may lead to vulnerability of some species. On private land, coordinated programs are more difficult to carry out than on public land. But even on public land difficulties may be immense if the local population is depending on the resources. In South and Southeast Asia, 200–300 million of resource-poor people are dependent on forest resources for their livelihood and security.

Governmental organizations with long-term funding are necessary for conservation in forestry. These can only be effective if the concomitant conditions are favourable. Exclusion from utilization often cannot work due to urgent necessities of forest products. National economics often depend on the harvest of timber. Links between conservation and utilization are poor in most countries of the world. The knowledge of the public and of foresters about these problems is very limited, though public relation activities and information are prerequisite for conservation activities!

The exaggerated demands for utilization of forest products on the one hand and for nature protection on the other hand often prevent long term meaningful solutions. Therefore the poor countries need support from the wealthier countries for solving these problems. Pragmatic approaches, accompanied by case studies, are the only possibilities to handle conservation and utilization of forest tree genetic diversity. Successful conservation must be considered as an integral part of development and not as a constraint to it (SOUVANNAVONG *et al.* 1994).

CONSERVATION STRATEGIES

From the earlier discussion it is obvious, that the method of conservation has to reflect the level of organization, the aim of conservation and the knowledge about the tree species (Table 2).

This means that at the moment the majority of tree species can only be conserved "in situ" by protection of ecosystems or biotopes and only about 2 % of the existing species can enter into a combined "in situ" and "ex situ" conservation. It would be desirable to store seed of many more species, if the seed is orthodox and a sufficiently broad genetic base can be collected. In situ and ex situ conservation should be complementary as far as possible.

Organisation and Conservation of Biodiversity

Level of organisation	Conservation	Application
Between ecosystems Within ecosystems Between species	Protection of ecosystems, biotopes e.g.	Most tree species (ca. 49000)
Within species Between populations Between individuals Within individuals	Species conservation programs Gene pool conservation Conservation of genetic diversity Breeding programs (*e.g.* MPBS)	Few tree species under management (ca. 1000 max)

In situ conservation

By the definition of the Convention on Biological Diversity (1992) "*in situ conservation means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties*".

Characteristics of *in situ* conservation are:

- all growth phases of the species are maintained
- land use is limited to interventions which have no detrimental effects on the conservation objectives
- regeneration occurs without or with minimal human intervention.

In situ conservation is the traditional method for forest ecosystems and wildlife. It allows to conserve a wide range of potentially interesting alleles under the influences of evolution in a changing environment. This allows the development of genetic diversity and adaptability. But it does not exclude the risk of total loss. In situ conservation allows to serve multiple purposes at once like production, conservation and habitat protection. "On farm" conservation (= forestry under intensi ve management) allows landraces to evolve. Natural selection and selection imposed by men work together (*in situ* management, FAO 1996). The silvicultural system should include conservation aspects. Protection of associated species is ensured, which, even without known economic value, may contribute to the functioning and productivity of the ecosystem. These habitats and ecosystems facilitate the research on species.

"In situ" conservation is the only method for species which cannot be established or regenerated outside their natural habitat. It is a logical way for species with non-orthodox seed like *Quercus, Fagus, Aesculus, Podocarpus, Araucaria, Dipterocarps*.

The definition of regional reserves, their size and the control of local pressure are difficult. The gathering of data is important for conservation (type and distribution of the species, pattern of intraspecific diversity, relationship between species and ecological conditions, effective population size). The gap between necessities and reality is demonstrated by the fact that there does not exist any species list, even for two thirds of the "Men and Biosphere Reserves".

Forest environments are heterogeneous and difficult to manipulate. It is difficult to conserve simultaneously many different species with different frequencies and biology in the same reserve. Therefore, and for the representation of species, several reserves under different ecological conditions are necessary.

Under temperate conditions the problems in industrialized countries with intensively managed forests are comparatively minor. But in these countries only few undisturbed forests for *in situ* conservation are left.

Ex situ conservation

In agriculture, *ex situ* conservation is the predominant approach with about 6 million samples worldwide (FAO 1996). In forestry, it is a necessary addition for all species, especially for those under more intensive management or included into breeding programs (Table 3). For rare and endangered species it is probably the only possibility to re-establish genetically diverse interbreeding populations. *Ex situ* conservation can diminish the risk of genetic losses or of extinction.

Ex situ measures	
Plantations	in the field
Seed orchards	technically simple
Clonal archives	not sophsticated
Storage of	
seed	under controlled conditions
pollen	technically susceptible
tissue	increasingly sophisticated
DNA sequences	

One form of unintentional *ex situ* conservation is the planting of exotics, which may be quite efficient. Outside of its natural range in North America about four million hectares plantation forests of *Pinus radiata* exist (ROGERS & LEDIG 1996). It is estimated that at least 25 North American tree species are planted on more than 15 million hectares as exotic species in other countries. Douglas fir provenances which are lost due to settlement in North America, exist in European plantations. However there can be genetic changes due to different selection pressure under the new environment. These resources are generally not evaluated.

Tree breeders have done most of the ex situ collections in seed orchards, clone archives, breeding populations, provenance- and progeny tests, and in pollen, seed or tissue in storage. This material has been most intensively studied and forms the base for many decisions in conservation of forest genetic resources (KLEINSCHMIT 1995). Sampling of diversity is a difficult topic for ex situ conservation unless adequate information of the material is available (MARSHALL & BROWN 1975).

Collections in arboreta and botanical gardens are less suited because of hybridization and narrow genetic base. Early tree breeding programs also started with a very narrow genetic base. Seed orchards with 10 to 20 clones were not exceptional. NAMKOONG was one of the first who stressed long-term aspects in forest tree breeding including a sufficiently broad genetic base

(NAMKOONG *et al.* 1980, NAMKOONG 1984, 1989). This was further developed to the Multiple Population Breeding System to combine breeding and conservation for improving diversity and adaptability (ERIKSSON *et al.* 1993).

Ex situ conservation is an important tool to maintain diversity under air pollution conditions.

The integration of *ex situ* conservation into management practice can support conservation and production at the same time. Breeding populations can produce highly adaptable material which may go back into ecologically oriented silviculture for example. A lack of knowledge about optimal combinations of in situ and ex situ conservation with forest management and forest tree breeding is obvious.

Research is needed on ex situ methods, on development and improvement of appropriate conservation technologies for species with recalcitrant seed, for characterization of material concerning genetic diversity, to control health aspects e.g.. documentation and international information exchange are urgent, too.

Organisational structures

Conservation has to be carried out at the local level but supported by strong national programs. Information and education of local groups is an important prerequisite for success. In Germany the formulation of a national concept for conservation of forest genetic resources in 1987 (BUND-LÄNDER-ARBEITSGRUPPE 1989) and political support for these activities really stimulated activities on a broad scale (KLEINSCHMIT 1995; BUND-LÄNDER-ARBEITSGRUPPE 1996). Different meetings with forest tree breeders, forest geneticists, people responsible for nature conservation, agricultural and horticultural conservation supported cooperation, improved methods, and created a broad interest of the public (INSTITUT FÜR PFLANZENBAU UND PFLANZENZÜCHTUNG 1985; FORUM 1988; SCHOLZ *et al.* 1989; BOMMER & BEESE 1990; HATTEMER 1990; FRANKE 1991; MÜLLER-STARCK & ZIEHE 1991; NORDDEUTSCHE NATURSCHUTZAKADEMIE 1991; GESELLSCHAFT FÜR PFLANZENZÜCHTUNG 1992; BEGEMANN & HAMMER 1993; KLEINSCHMIT & WEISGERBER 1993; MUHS 1993; BLÜMLEIN *et al.* 1995; INSTITUT FÜR WEITERBILDUNG UND BERATUNG IM UMWELTSCHUTZ 1995; KLEINSCHMIT *et al.* 1995; NATIONALES KOMITEE 1995). The German program war revised in 1999 (PAUL *et al.* 2000).

On regional level the European Forest Genetic Resources Programme (EUFORGEN) is a collaborative program among European countries aimed at ensuring the long term conservation and the sustainable utilization of forest genetic resources in Europe. EUFORGEN works with species related networks (TUROK & FRISON 1995; ARBEZ 1995; TUROK *et al.* 1995, TUROK & KOSKI 1997, KOSKI *et al.* 1997, TUROK *et al.* 1998, TUROK *et al* 1999). Since tree species do not respect political boundaries, a regional cooperation is necessary to be efficient. On global level activities in research are coordinated by IUFRO, in administration by FAO.

The Commission on Sustainable Development (CSD) of the United Nations established in 1995 for a two year period an "Intergovernmental Panel on Forests" (IPF), which gave over one hundred negotiated proposals of action on a number of issues related to sustainable forest management to CSD in 1997. Following the establishment of IPF in July 1995, an informal, high level Interagency Task Force on Forests (ITFF) was set up to coordinate the inputs of international organizations to the forestry policy process. The United Nations established in 1997 an "Intergovernmental Forum on Forests" (IFF), with the mandate

I. to promote and facilitate the implementation of the proposals of the IPF and reviewing, monitoring, and reporting on the process

II. to consider matters left pending and other issues from the IPF process

III. to promote international arrangements and mechanisms for the management, conservation, and sustainable development of all types of forests.

The IFF held four sessions until February 2000. The secretariat of IFF is located in the Division for Sustainable Development of the United Nations in New York (http://www.un.org/esa/sustdev/aboutiff.htm; 20. 8. 2002).

It was clear from the outset, that insufficient time would be available for in-depth discussions of several of the very complex and sensitive issues during the four regular sessions. The Forum therefore welcomed initiatives by countries to organize expert meetings where particular issues could be discussed and analysed before they were scheduled for discussion in the IFF. Strengthening of local awareness, of national and regional activities are important preconditions for an international agreement and for further actions. On national level the conservation has to be included into forestry programs and legal regulations.

SUMMARIZING DISCUSSION

The main threat for genetic resources is the rapid increase of human population (Fig. 5) with all the associated negative effects on the environment. With increasing speed this growth induces environmental changes which threatens biodiversity. These changes have negative implications for genetic diversity of tree species, which is necessary for the trees to be able to adapt to these rapid environmental changes.

More and more forests all over the world have to be utilized in a sustainable way to cover human needs.

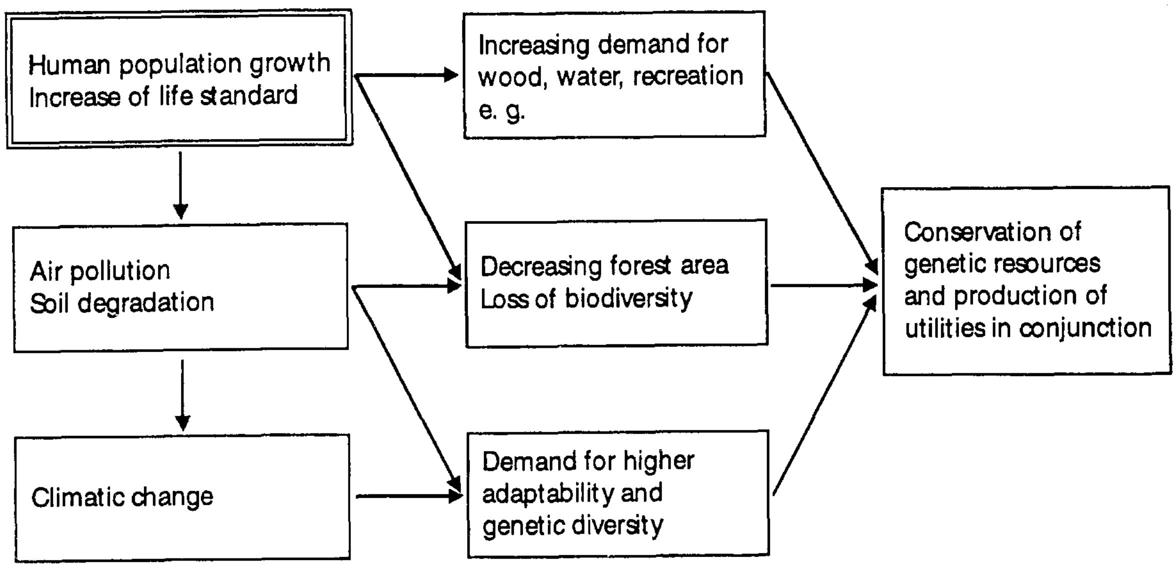

Figure 4. Influences on conservation and utilization of forest genetic resources (ERIKSSON 1995, modified).

Large unmanaged nature reserves will not be possible due to political and socio-economical reasons in future. Therefore, gene conservation has to be considered together with utilization of forest genetic resources. Integrated systems with differential main emphasis are necessary:

- protected reserves for all minor and non-commercial species without utilization
- ecologically oriented managed forests combining conservation and utilization in management strategies
- strongly production oriented intensive plantation forestry, where conservation of the tree species is integrated in the breeding programs

The scarce knowledge about most tree species and the high number of species predicates that many decisions have to be based on guesses. However future research should be directed to gain more knowledge of the different biological and ecological types of minor species as discussed by ERIKSSON (1995 b).

All conservation activities should include sufficient security. In addition to in situ conservation ex situ storage of seed should be done wherever this is biologically and technically possible. Strategies have to be different for managed, economically important species and for species not economically important at the moment, and different for tropical regions as compared to temperate or boreal forest regions with a limited number of tree species. In tropical countries protected areas are the only immediate possibility for conservation of minor species until better management systems, which include conservation aspects too, are developed. Long term reserves of a sufficient size will be impossible due to human population growth. Therefore, the development of such management systems should get high priority in technical aid for developing countries. These systems need the knowledge of seed handling, plant production, and enrichment planting.

In general, species with an actual economic value have adequate genetic resources in reserves, gene banks, and plantations. As far as breeding programs are carried out these should take into account adaptive traits and long term conservation of genetic diversity and - if possible – increase of diversity too.

In temperate forests a fast change can be observed in economic appreciation for minor and rare hardwood species and some rare conifers like *Taxus*. There is an increasing request for plant material due to rapidly increasing market prices. But sufficiently suitable material of high genetic diversity is usually not available. Here the reconstitution of genetically diverse, adaptable, and valuable interbreeding populations to counteract the negative effects of fragmentation and genetic erosion is an urgent necessity. Many activities in this field have been started in Europe during the last 20 years.

Complete inventories of the actual existing genetic resources are necessary to be able to plan efficiently conservation activities. Information systems and data bases about conservation activities have to be established. They are the precondition for coordinated efforts on local, national, regional and global level.

It is much easier to handle abundance than scarcity. But scarcity will be the rule in future and this needs integrated land use systems considering the different needs simultaneously. This however requires education of people, information exchange, and participation of all groups of the human society to prevent unbalanced solutions.

Advantages of forest tree species are their high physiological plasticity, their high heterozygosity, and their high diversity within populations. Their long life span facilitates in situ conservation. Plasticity, heterozygosity and diversity assure more adaptability than even professionals often believe. These are good preconditions to react to fast environmental changes. In future appropriate reaction will be only possible if we are able to maintain and support the further development of these favourable characteristics and at the same time control and reduce environmental pollution to a tolerable level for trees and other members of the ecosystem including the species *Homo sapiens*. The central question is however the growth of the human population, which can easily counteract all conservation efforts.

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