EUROPEAN FOREST GENETIC RESOURCES PROGRAMME (EUFORGEN)

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*Report of the first meeting*
*24-27 March 1996*
*Escherode, Germany*

**J. Turok, G. Eriksson, J. Kleinschmit and S. Canger,** *compilers*

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The European Forest Genetic Resources Programme (EUFORGEN) is a collaborative programme among European countries aimed at ensuring the effective conservation and the sustainable utilization of forest genetic resources in Europe. It was established to implement Resolution 2 of the Strasbourg Ministerial Conference on the Protection of Forests in Europe. EUFORGEN is financed by participating countries and is coordinated by IPGRI, in collaboration with the Forestry Department of FAO. It facilitates the dissemination of information and various collaborative initiatives. The Programme operates through networks in which forest geneticists and other forestry specialists work together to analyze needs, exchange experiences and develop conservation objectives and methods for selected species. The networks also contribute to the development of appropriate conservation strategies for the ecosystems to which these species belong. Network members and other scientists and forest managers from participating countries carry out an agreed workplan with their own resources as inputs in kind to the Programme. EUFORGEN is overseen by a Steering Committee composed of National Coordinators nominated by the participating countries.



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# Contents

# Introduction

The first EUFORGEN Noble Hardwoods Network meeting was held in Escherode, Germany, from 24 to 27 March 1996. Participants from 17 countries attended the meeting, and representatives of a further six countries were unable to attend (see List of Participants).

Dr Jochen Kleinschmit, Director of the Department for Forest Tree Breeding, NFV, welcomed the participants to Escherode. He mentioned that the increasing pressure on the environment, due to global human population growth, would inevitably increase the pressure on forests. Efficient conservation and sustainable management of the genetic resources of Noble Hardwoods, which are often considered an 'overlooked' group of species in Europe, has become imperative in view of the global changes. Several research project proposals on the genetic diversity of Noble Hardwoods have been prepared by various European institutions over the past few years, and J. Kleinschmit expressed his satisfaction on hosting a joint meeting of the EUFORGEN Network and scientists from institutions participating in the EU research project proposals (see List of Participants). He wished all participants a successful meeting.

The ongoing activities of EUFORGEN in general, as well as in the gene conservation networks, were presented by Jozef Turok, EUFORGEN coordinator from IPGRI. He stressed that the increasing activities of EUFORGEN confirmed the strong commitment of European countries to international collaboration in the field of forest genetic resources which were initiated at the Ministerial Conferences on the Protection of Forests in Europe and implemented through the multilateral collaborative networking activities. Jozef Turok then briefly summarized replies to a survey on Noble Hardwoods genetic conservation that had been provided by the participating countries prior to the meeting. He thanked the host of the meeting for its organization in Escherode and for the overall support.

Following these introductory statements, the agenda of the meeting was presented and approved (see Agenda). A concept for the general development of gene conservation strategies for forest trees was then presented by Professor Gösta Eriksson from Sweden (see page 159).

## Country presentations

Both the attending and the corresponding members of the Network prepared reports on the status of the conservation of genetic resources in Noble Hardwoods in their countries, and the attending members presented brief summaries at the meeting. All country reports are published in this volume. They gave an overview of the status of genetic resources and current conservation activities in European countries.

The reports are ordered from south to north, according to three major ecogeographic zones: the Mediterranean, the Temperate and the Boreal Zones. This order was found most suitable with respect to Noble Hardwood species' occurrence, their biological and known genetic characteristics and common concerns on the conservation and use of genetic resources. It does not imply any order of importance or priorities.

It was shown that Noble Hardwoods were becoming increasingly important in Europe. Reports were made of the numerous activities on conservation of genetic resources, breeding and genetic research. The presentations also confirmed that European countries were aware of the need to conserve and better use the genetic resources of their Noble Hardwoods. A possible impetus to the development of national conservation programmes has resulted from the increasing demand for suitable genetic material for new afforestation programmes and for high-quality timber production.

It was made clear from country presentations and discussions that Noble Hardwoods represent a heterogeneous group of species. The common understanding of this group includes several features: similar, scattered distribution patterns in European mixed forests, high ecological demands and timber of high quality. The importance of individual species, however, varies considerably from country to country. It was agreed that oaks and beech, considered by some countries as Noble Hardwoods, are subjects for the 'social broadleaves' Network, which is currently under establishment. Although not discussed any further at the meeting, a few country reports include references to these species.

The most important threats to the genetic resources of Noble Hardwoods were listed in the country presentations. Past intensive forest management, including the negative effects of clearcutting, industrial pollution, decreasing population sizes due to different factors and resulting in genetic drift, inadequate silvicultural practices and geneflow from unknown sources were most frequently mentioned. Reproduction of genetic diversity from local origins of Noble Hardwood species was stressed. The most endangered species at country level were mentioned. The role of an integrated approach to the conservation of genetic resources and their sustainable management was emphasized, both in wild populations *in situ* and within tree improvement activities *ex situ*.

Two main constraints were identified in regard to effective conservation of genetic resources. It was agreed that, besides insufficient funding, the lack of national strategies with clearly defined conservation objectives is a major constraint. The need was expressed to raise public awareness on the role of genetic diversity of Noble Hardwoods. Relatively little is still known on the distribution of many species belonging to the Noble Hardwoods and the importance of facilitating an information exchange in this area was discussed. The issue of practical implementation of conservation strategies with insufficient knowledge on genetic structures and processes was brought up. Increased genetic research is needed to serve as the basis of sound conservation strategies.

## Species of Noble Hardwoods

Based on the lists of priority species given by each attending country and following the subsequent discussion, it was decided that the species listed in Table 1 should be considered by the Network for collaboration. There was a lengthy discussion on advantages and disadvantages of choosing some species as 'core'. The suggestion of identifying any 'core' species was dismissed.

## Seed legislation

The national legal regulations of most countries and also both international regulations (OECD Scheme for the Control of Forest Reproductive Material Moving in International Trade from 1974, and the EEC Directive on the Marketing of Forest Reproductive Material from 1966 with amendments from 1975) provide a basis for the use of genetic resources of forest tree species including Noble Hardwoods. However, most of the Noble Hardwood species are either not covered by the regulations, or, as in the case of the voluntary OECD Scheme, the rules are currently not extended to the production and movement of reproductive material of Noble Hardwood species.

**Table 1.** Noble Hardwood species which are considered as very important (xx) or important (x) by individual countries.

| Species | A | B | CR | CZ | DK | F | FI | D | IT | LV | LT | M | NL | P | SK | E | S |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Alnus cordata* | | | | | | | | | xx | | | | | | | | |
| *Alnus glutinosa* | xx | xx | xx | xx | xx | x | | xx | | xx | xx | | xx | | xx | | |
| *Acer campestre* | x | | | | x | | | xx | | | | | xx | | xx | xx | xx |
| *Acer lobelii* | | | | | | | | | xx | | | | | | | | |
| *Acer platanoides* | x | | xx | xx | x | | xx | xx | xx | xx | xx | | | | xx | xx | xx |
| *Acer pseudoplatanus* | xx | xx | xx | xx | xx | xx | | xx | xx | | | | xx | | xx | xx | |
| *Betula pendula* | | | | | | | | | xx | | | | | | | | |
| *Carpinus betulus* | | | | | x | | | xx | | | | | xx | | | | xx |
| *Castanea sativa* | | | xx | | | | | xx | xx | | | | | xx | | xx | |
| *Fraxinus angustifolia* | | | xx | | | | | | xx | | | xx | | xx | | | |
| *Fraxinus excelsior* | xx | xx | xx | xx | xx | xx | xx | xx | xx | xx | xx | | xx | xx | xx | xx | xx |
| *Juglans regia* | | | xx | | | | | xx | xx | | | | | xx | | xx | |
| *Malus sylvestris* | x | | | xx | x | x | | xx | | | xx | | | | xx | | xx |
| *Prunus avium* | xx | xx | xx | xx | xx | xx | | xx | xx | xx | xx | | xx | xx | xx | xx | xx |
| *Pyrus amygdaliformis* | | | | | | | | | | | | xx | | | | | |
| *Pyrus pyraster* | x | | | xx | x | x | | xx | | | xx | | | | xx | | |
| *Sorbus aria* | x | | | | x | | | xx | xx | | | | | | xx | | |
| *Sorbus aucuparia* | x | | | xx | x | | xx | xx | xx | xx | | | xx | | | | |
| *Sorbus domestica* | x | | | | | xx | | xx | xx | | | | | | xx | | |
| *Sorbus torminalis* | x | | | xx | x | xx | | xx | xx | | | | | | xx | | |
| *Tilia cordata* | xx | | xx | xx | xx | x | xx | xx | xx | xx | xx | | xx | | xx | | xx |
| *Tilia platyphyllos* | xx | | xx | xx | | | | xx | | xx | | | xx | | xx | | xx |
| *Ulmus canescens* | | | | | | | | | | | | xx | | | | | |
| *Ulmus glabra* | x | xx | xx | xx | xx | xx | xx | xx | xx | xx | xx | | xx | xx | xx | xx | xx |
| *Ulmus laevis* | | xx | xx | xx | x | xx | xx | xx | xx | xx | xx | | xx | | xx | | xx |
| *Ulmus minor* | | xx | xx | xx | | xx | | xx | | | xx | | xx | xx | xx | xx | xx |
| *Ulmus procera* | | | | | | | | | | | | | | xx | | | |

A = Austria, B = Belgium, CR = Croatia, CZ = Czech Republic, DK = Denmark, F = France, FI = Finland, D = Germany , IT = Italy, LV = Latvia, LT = Lithuania, M = Malta, NL = Netherlands, P = Portugal, SK = Slovakia, E = Spain , S = Sweden.

This insufficient coverage of many Noble Hardwoods, including numerous rare and minor tree species, by the regulations was mentioned as one of the constraints to effective conservation and sustainable use of their genetic resources in European countries.

Since the reproductive material of tree species belonging to the Noble Hardwoods has the potential of increased use in forestry in future years, and since in many cases it is not in harmony with the requirements of present legislation for quality standards in major economic species, it was felt that the importance should be placed on the use of material of known origin and with recognized properties.

It was suggested that seeds and other reproductive material be collected, stored, handled and moved under control of the authorities responsible for the implementation of national rules. Therefore, besides the major forest tree species that are subject to the present legislation in most European countries, there is a need to include Noble Hardwood species used in forestry. Certification of reproductive material of the category of 'source identified' and, more importantly, its wide use based on ecological and genetic characteristics of provenances, would contribute to improving overall forest quality standards. Delimitation of adequate regions of provenance for the Noble Hardwood species would be required. The production of reproductive material of the categories 'selected' and 'tested' may be further developed, and the rules applied if appropriate material is available.

Several countries mentioned existing incentives for the use of reproductive material of relevant Noble Hardwood species for afforestation purposes.

Besides the current insufficient coverage by the regulations, concern was expressed by some participants over the low level of public awareness shown regarding the importance of maintaining and using adapted genetic material from local sources.

## Research activities

At present, a number of research activities on Noble Hardwood species, related to the conservation and use of their genetic resources, are already being undertaken in European countries. Important research topics were discussed among participants from institutions involved in projects funded by the European Commission, and other Network members (see box, next page).

All countries participating in the meeting gave an overview of their research activities as part of the national reports. A large number of countries and institutions expressed their interest in participating in joint applications for EU-funded schemes, under various research programmes.

Different countries showed interest in particular species or genera. It was agreed that future coordinated research should concentrate on three principal species groups. The following species groups were identified for joint research activities in the near future, in their order of priority: *Ulmus; Acer* and *Fraxinus;* Rosaceae.

## History of the network and development of network objectives

During a follow-up meeting to Strasbourg Resolution 2 in early 1993, the international Follow-up Committee discussed further setting of priorities for collaboration on the conservation of forest genetic resources in Europe. Noble Hardwoods were identified as a priority group of species, taking into consideration the results of the international survey conducted by the Committee. It was foreseen that an advisory group should elaborate on this issue. However, no activity could take place until EUFORGEN had initiated the first network meeting.

Following a broad discussion at this first meeting on the different aspects of the conservation of forest genetic resources in general, and of Noble Hardwoods in particular, the main goal of the network was agreed upon:

- **Identification of minimum gene conservation activities in the long term from a European perspective.**

**Research topics suggested by institutions participating in EU-funded projects and relevant to the conservation and use of Noble Hardwood genetic resources.**

**Present range of distribution**
- Improvement of knowledge of present distribution range of the different species
- Study of pollination, outcrossing, selfing
- Influence of limited population sizes

**Hybridization**
- Introgression with other species and with cultivars
- Development of botanical keys for identification
- *In situ/ex situ* conservation methods in relation to conservation efficiency
- Consequences for forestry

**Natural variability (by traits)**
- Within- and between-population variation for morphological, phenological, biochemical/ genetic, phytopathological traits
- Collection of provenances and progenies for the study of adaptive traits
- Field tests
- Grafting techniques

**Development of conservation and utilization strategies**
- Size of breeding populations
- Improvement versus variability
- Study of the impact of management rules on conservation efficiency
- Economic potential of Noble Hardwoods
- Methods of cryopreservation

## Agreement on network tasks and development of a workplan

### Conservation strategy for Noble Hardwoods from a European perspective

*(Coordinators: G. Eriksson, E. Collin, B. Demesure, J. Kleinschmit, R. Stephan, M. Rusanen, V. Hynek and K. Vancura)*

To define a minimum long-term strategy for gene conservation of Noble Hardwood species included in the Network, Network members were asked to prepare substrategy papers on the different species, in accordance with the following plan.

| Species | Name | Country |
|---|---|---|
| *Ulmus* spp. | E. Collin | France |
| *Sorbus* spp. | B. Demesure | France |
| *Prunus avium, Malus sylvestris,* | J. Kleinschmit, | |
| *Pyrus pyraster* | R. Stephan | Germany |
| *Acer platanoides, Acer pseudoplatanus* | M. Rusanen | Finland |
| *Fraxinus excelsior, Fraxinus angustifolia* | V. Hynek, K. Vancura | Czech Republic |

The all-European perspective of the strategy was emphasized. The responsible Network members will deliver their contributions to the newly elected chairman of the Network, G. Eriksson, and to the EUFORGEN coordinator, J. Turok, **before 1 December 1996**. Clearly defined objectives and foreseen activities relevant to the individual species should be included in the strategy. It was suggested that a strategy for other species, not included in this first list, can be developed and delivered at a later stage. A review of the overall strategy will be compiled and presented **at the next network meeting** by G. Eriksson. J. Turok will follow up on this task and circulate a letter to the concerned network members, informing them about the progress being made **in July 1996**.

### Inventory requirements for existing genetic resources at the level of populations

*(Coordinator: J. Kleinschmit)*

Following a discussion on the basic requirements for *in situ* conservation stands (such as population size, minimum area, legal conservation status, indigenous origin, protection measures and others), it was agreed that development of inventory requirements for existing genetic resources is a basic task of the Network which should be carried out in a collaborative and coordinated manner. It was stressed that, as a basic requirement for *in situ* conservation stands, the effective population size for Noble Hardwoods should not be lower than 20 individuals. The issue of genetic inventory requirements will be further discussed **at the next Network meeting**.

### Preparation of a standard list of descriptors for European databases

*(Coordinator: S. Canger)*

As a result of the country presentations and the survey carried out prior to the meeting, it was found essential that better information flow between countries and a common database could contribute to the conservation efforts in individual countries and to the development of national programmes. The establishment of a simple, decentralized database should be well coordinated, and the existing databases on individual Noble Hardwood species should be taken into consideration. An example of database structure used at the Department in Escherode was demonstrated. J. Kleinschmit offered to prepare and circulate basic information on databases used in Germany in the area of conservation and use of forest genetic resources, to all members of the Network **by 1 July 1996**. Interested Network members, and particularly the task coordinator, are welcome to participate in a meeting aimed at harmonizing database structures among several institutions involved in EU research projects, which will be held in Escherode, 24-25 June 1996. J. Kleinschmit will exchange information on the meeting with J. Turok **before 1 May 1996**.

It was a common view that the required information for entries into the database should be limited, in order to ensure that all countries would be able to provide the necessary information and apply a minimum set of descriptors. It will be necessary to develop a descriptor list for Noble Hardwood species as a first step to build up a common information and database system. The following descriptors were mentioned:

- geographical data
- elevation
- approximate size of population
- size of conservation area
- conservation status (ownership, or other descriptors relevant to each of the member countries)
- health status (e.g. problems caused by pollution)
- origin (if information is available)
- climatic data.

It was agreed that S. Canger would prepare a proposal for passport data of a standardized minimum descriptor list and send it to J. Turok **by 1 October 1996.** S. Canger will receive copies of the standardized IPGRI descriptor lists for agricultural species, as well as the descriptor lists developed by two other EUFORGEN Networks (*Populus nigra* and *Picea abies*) from J. Turok **by 15 April 1996.** Network members will send descriptor lists and other relevant information from their countries to S. Canger **by 1 May 1996.** In regard to the development of passport data, the German model should be taken as a basis. J. Turok will circulate the proposal of S. Canger to all network members and to the database specialist at IPGRI **by 15 October 1996,** and will receive comments from the Network members **by 1 March 1997.**

### Synthesis of current *in situ* and *ex situ* conservation measures and ongoing activities for Noble Hardwood species

*(Coordinator: J. Turok)*

The participants asked the EUFORGEN coordinator to prepare a synthesis of conservation measures currently applied in European countries. Country reports as well as the survey of national gene conservation activities on Noble Hardwoods will serve as a basic source of information. J. Turok will identify and ask several participants from various European regions to contribute to the development of the synthesis. A first draft will be prepared **by 1 July 1996** and circulated among the contributors. The final reviewed version should be distributed in the Network **by 1 September 1996.**

### Literature review

*(Coordinators: S. de Vries, K. Vancura, F. Ducci, B. Demesure, R. Alia Miranda, E. Collin)*

It was suggested that in each of the European countries publications that are not published in international journals, but could be of general interest to scientists and forest managers involved in activities on genetic resources of Noble Hardwoods, be compiled and published. It was agreed that Network members from each country should compile lists of references particularly relevant to the conservation of genetic resources by species and send them to the responsible Network members as indicated below, **not later than 30 June 1996.** J. Turok will contact the corresponding members of the Network (and those unable to attend the first Network meeting) to ask them for inputs **before 15 April 1996.**

Titles of publications should be given in English and, if translated, the original language put in square brackets before mailing on diskette or via E-mail to the above-mentioned responsible Network members. For each reference the following information should be provided and the entries separated by tabs: **author, year of publication, title, source, original language and/or summary.**

Responsible coordinators will send their contributions by species to the EUFORGEN secretariat **by 1 December 1996.** The literature review will be published, preferably as a separate Network publication, by IPGRI **in early 1997.**

| Network member | Species |
|---|---|
| S. de Vries (Netherlands) | *Acer campestre, A. platanoides, A. pseudoplatanus, Tilia cordata, T. platophyllos, Alnus glutinosa* |
| K. Vancura (Czech Republic) | *Carpinus betulus, Fraxinus excelsior, Malus sylvestris, Pyrus pyraster* |
| F. Ducci (Italy) | *Alnus cordata, Acer lobelii, Betula pendula, Pyrus amygdalifolius* |
| B. Demesure (France) | *Prunus avium, Sorbus aria, S. aucuparia, S. domestica, S. torminalis* |
| R. Alia Miranda (Spain) | *Castanea sativa, Juglans regia, Fraxinus angustifolia* |
| E. Collin (France) | *Ulmus glabra, U. laevis, U. minor, U. canescens, U. procera* |

### Guidelines for *in situ* and *ex situ* conservation measures on rare and minor Noble Hardwood species

*(Coordinator: J. Kleinschmit)*

It was agreed that a group composed of J. Kleinschmit, R. Stephan, F. Ducci and possibly other volunteers would prepare a set of guidelines for *in situ* and *ex situ* conservation measures. The guidelines should focus on rare and minor Noble Hardwood species and consider the overall goal of the Network of identifying minimum gene conservation activities from a European perspective in the long term. A first draft of the guidelines will be prepared **for the next Network meeting**. The guidelines should assist local forestry management in European countries to make decisions on the implementation of practical genetic conservation, and to raise public awareness on the genetic diversity of forests.

### Development of joint research proposals

*(Coordinators: different coordinators of the respective project proposals)*

Summary of the discussion on joint research proposals for submission to the Commission of the European Communities is given in **Research Activities** (above).

### Evaluation of genetic resources by species (morphology, phenology, resistance characteristics, biochemical/genetic traits)

*(Coordinator: B. de Cuyper)*

The Network members asked B. de Cuyper to prepare an overview table for each species indicating the current practice of evaluation of genetic resources by means of morphology, phenology, resistance characteristics and biochemical/genetic traits.

Basic information to be used as input to the tables must be sent from each country to B. de Cuyper, who will then circulate draft tables **not later than 1 July 1996**. B. de Cuyper will receive comments from the participants **by 1 September 1996** and will then compile the information and prepare it **for the next Network meeting**.

## Conclusions

G. Eriksson was unanimously elected to act as Chair of the Network and J. Kleinschmit as Vice-chair.

The report of the meeting was endorsed by the participants with few comments.

The participants agreed to hold the second meeting of the Network in Spain in March 1997, and 22-26 March 1997 were suggested as possible dates of the meeting. The final dates will be decided and announced. G. Eriksson thanked all participants for creating a nice working atmosphere and for contributing to the discussions, and acknowledged the local organizers for their excellent preparation of the meeting and for their hospitality.

# Country Reports: the Mediterranean

## Conservation of genetic resources of Noble Hardwoods in France: Overview

*Brigitte Demesure*
Centre de Recherches Forestières ONF, INRA Orléans, 45160 Ardon, France

Interest in the conservation of forest genetic resources has increased over the last 10 years. The Ministerial Conference on the Protection of Forests in Europe held in Strasbourg in 1990 pointed out the importance of genetic diversity and its conservation. Noble Hardwoods are very important for this objective. Indeed, they contribute to increasing the interspecific diversity of forests.

Noble Hardwoods represent 5.4% of the total forest area in France, around 100 million $m^3$, and represent a heterogeneous group, defined as:

- scattered species
- forest trees with great economic importance
- species with high value of wood.

Although these tree species are generally considered as wild populations, only marginally affected by artificial selection or breeding, scattered species such as Noble Hardwoods are threatened by intensive forest management, inadequate silviculture practice, decreasing population sizes, industrial pollution and genetic pollution.

Until now, the main problem facing an integrated approach to the conservation of genetic resources was the lack of knowledge of genetic diversity. Nevertheless, during the past years an important effort has been made to initiate research on the conservation of genetic resources, breeding and genetics.

### Programmes on the conservation of genetic resources

Noble Hardwoods are formed into three groups in French programmes:

#### 1. *Ulmus* sp.

The genus *Ulmus* was well represented all over France before 1970 but has declined dramatically since then because of the Dutch elm disease (see Collin and Bilger, this report). The Ministry of Agriculture initiated a programme for the conservation of genetic resources in 1987. In the framework of the Programme led by CEMAGREF (French Institute of Agricultural and Environmental Engineering Research), which aims at maintaining the genetic diversity of elms in France, a thorough survey was carried out in five regions to list every mature and healthy elm tree (diameter of the trunk >15 cm and height >1.3 m). Most trees were cloned by cuttings which were planted in a plantation at Nogent-sur-Vernisson comprising about 400 trees.

In the second step, genetic and pathology research was carried out to acquire a better knowledge of the variability. N. Machon (University of Paris XI) showed high levels of diversity without clear geographic patterns among the French elms.

The first artificial inoculation in the clonal plantation showed an important diversity, but further experiments with different inoculation dates are necessary before a conclusion can be made on clonal tolerance to Dutch elm disease. Other research conducted on material propagated by CEMAGREF involves the cryoconservation of buds in liquid nitrogen (AFOCEL) and *in vitro* propagation (ENSH).

**2. *Fraxinus* sp. and *Acer* sp.**

The interest of tree planters in these species is increasing considerably in France. The area covered represents 308 228 ha with 21.9% increase in 10 years. Current seed provenances are not precisely known and transfers have occurred from the northeastern part to the rest of France. The number of stands is generally very low and the genetic basis narrow.

Moreover, little is known about this complex. The main problem is the purity of each species. Indeed hybridization between *Fraxinus excelsior* and *Fraxinus angustifolia* and genetic pollution from industrial clones are problems. The ENGREF (N. Frascaria and B. Jung Muller) are studying the genetic variability for a better understanding of the phenomenon. In 1998 the CEMAGREF will edit the rules for seed transfer in accordance with the variability shown by the complex and for the conservation of genetic resources regionally.

In addition, there are three provenance trials (50 provenances) established from European material and four provenance trials are part of French commercial provenances. There are also four progeny tests with 25 open-pollinated progenies from four French stands.

In *Acer* sp. little is known and done, which seems to be a paradox, because tree planters in France are interested in this species. Presently, France has 87 clones of *Acer pseudoplatanus* planted and studies have been made of most of them, originating from the region of Franche-Comté.

**3. Rosaceae**

*Prunus avium* is one of the pilot species chosen for the implementation of the forest genetic conservation programme (see Héois *et al.* in this report). Indeed the genetic resources of wild cherry are seriously endangered, mainly because of uncontrolled seed transfer and clonal plantation. For 15 years this species was planted on a very large scale from a small number of mother trees. Therefore, a narrow genetic base for plantation is of concern. CEMAGREF and INRA, working in close cooperation, are trying to understand the diversity of this species. The strategy comprises the following:

- better knowledge of genetic resources using genetic markers
- *in situ* dynamic conservation
  - natural stands in the northeast
  - artificial plantations in the rest of France
- *ex situ* conservation including seed orchards.

*Sorbus* sp. is of great interest to forestry. At present, its wood has the highest value in France. *Sorbus domestica* and *Sorbus torminalis* are rare and endangered species in France. As recent inventories show, natural regeneration is absent in most cases. The main objectives of the *Sorbus* programme are:

- to analyze the geographic structure of genetic variation
- to identify the importance of pathogenic fungi
- to develop seed storage and germination techniques
- to conserve resources *in situ*.

*Sorbus domestica* is distributed all over France, except in high-altitude zones. Until 1980 it was a minor species regenerating at a low rate. Intensive exploitation reduced the genetic reservoir of this species because of increasing interest, so it seems very important to have a better idea of the genetic variability of this Noble Hardwood. The first step was seed collecting in the Mediterranean region and planting of the different provenances. The inventory also including the production of cuttings from remarkable trees. The second step consists of isoenzymatic studies to be carried out with different provenances.

*Sorbus torminalis*: in order to study the diversity of this species a project was begun last year with the intensive collection of 31 populations. Studies of genetic structure and phylogeny will be carried out using isoenzymes (15 loci), but also cpDNA. One of the aims of this programme is to create rules for seed transfer and better conservation of populations, because *Sorbus torminalis* is increasingly planted with a restricted number of trees. Our strategy is to improve the conservation of genetic resources in close relation with genetic researchers.

## Conclusion

Maintenance of a sufficient genepool of Noble Hardwoods is fundamental to the conservation of several endangered species. From the economic point of view, keeping the diversity of the species is also a guarantee of obtaining better results in the selection and genetic improvement programmes.

# Conservation and study of native elm genetic resources in France

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## Context

Since 1972, the genetic diversity within French elm species has been eroded by a second epidemic of Dutch elm disease (DED). In France, there are three species of elm, and these show differential susceptibility to the disease:

- field elm (*Ulmus minor* Mill., *sensu lato*), which has almost disappeared from the landscape, except for a few old trees and many young sucker shoots (the latter generally succumb to the disease after a few years)
- Wych elm (*U. glabra* Huds.), which was first considered as relatively resistant to the disease, but is at present suffering heavy losses in many of the montane forests
- European white elm (*U. laevis* Pall.), which is indigenous to the northeast and central France, is often undamaged, probably owing to its unattractiveness to the vector *Scolytus*.

In 1987, the Ministry of Agriculture put CEMAGREF in charge of building a national *ex situ* programme for the conservation of indigenous genetic resources in elms (Fig. 1). Collecting clones from different regions and environments was judged an urgent preliminary course of action. Further genetic and pathologic research was considered necessary in a second step, in order to assess the genetic variability of elm and its possible geographic partitioning in France, as well as to determine gaps in the national clonal bank.

## The national clonal bank

Surveys of old surviving elms were conducted by CEMAGREF in different regions of France with the collaboration of forestry administrations, conservationist associations and the local agricultural press. In each region, a representative sample of the inventoried resource was chosen among the different elm species and environments in the surveyed area. The material was propagated by softwood cuttings taken at the end of May, several ramets of each clone were planted in two field collections (one in Nogent-sur-Vernisson, in the Région Centre, and one in Guémené-Penfao, in Bretagne). These clonal banks are hedged for protection from contamination by *Scolytus* which feed on small twigs.

The collecting effort was initially focused on the field elm and concentrated on the northern half of France, which was first swept by the spreading of DED. Because of its rarity in France, special attention was then given to the European white elm, and collections carried out in the valleys of Rhine, Saône and Loire. CEMAGREF will soon collect material from southern France, as well as make collections of Wych elm.

At present, 414 clones are held in CEMAGREF's field genebanks, out of which 36 are introduced or unidentified material and 378 are indigenous clones with passport data: about 232 clones of *U. minor;* about 37 intermediate forms between *U. minor* and *U. glabra;* 28 clones of *U. glabra;* 81 clones of *U. laevis*.

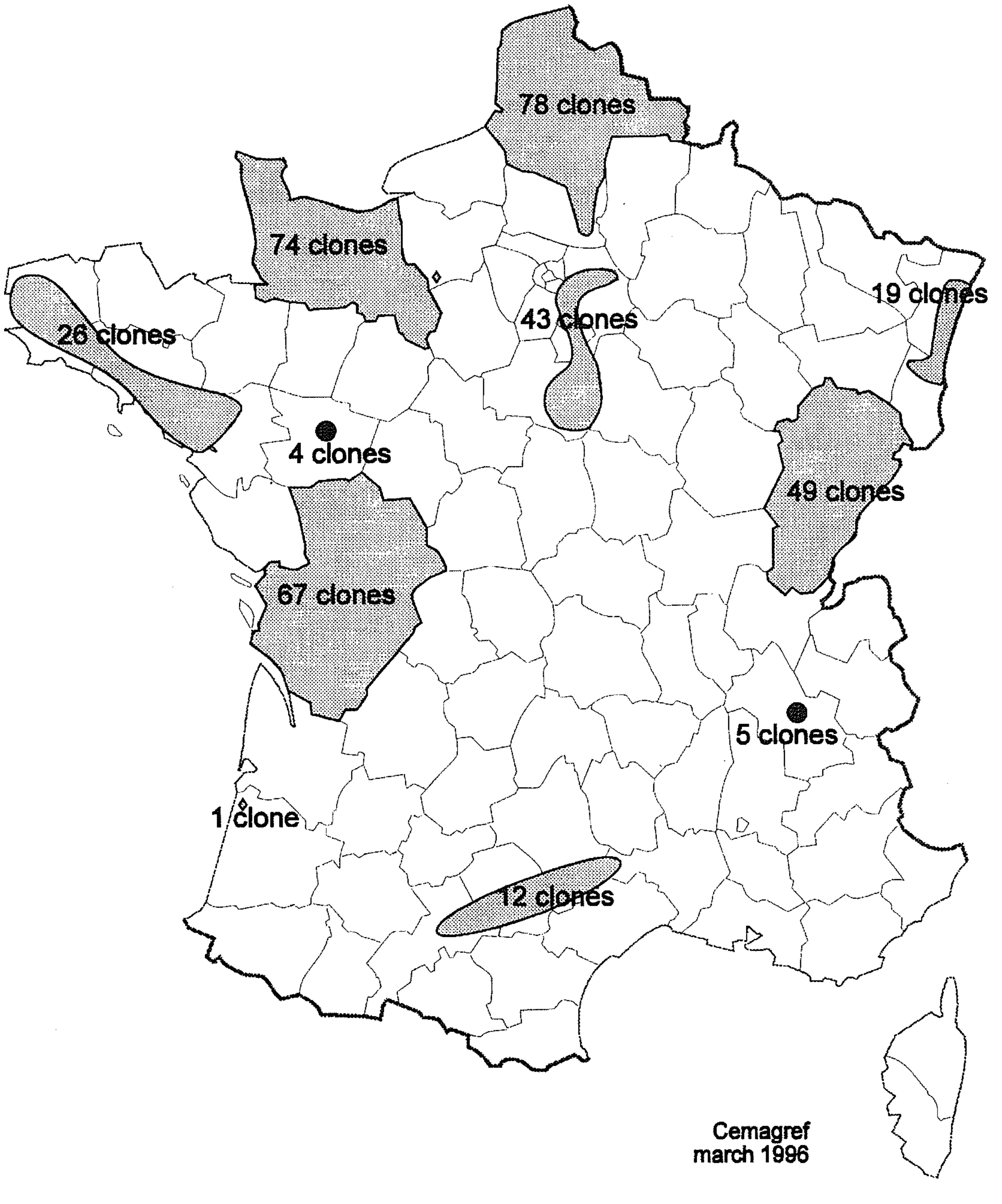


**Fig. 1.** *Ex situ* elm conservation: origin of the clones conserved in CEMAGREF's collections.

## Scientific data

Genetic research on the material collected by CEMAGREF was carried out with isozymes by N. Machon at the University of Paris XI.

The four main results (Machon *et al.* 1995, 1996) obtained on 351 accessions analyzed for seven polymorphic enzyme systems, controlled by nine gene loci, are:

- the three species are segmental tetraploids, i.e. they behave as tetraploids for part of the genome and as diploids for the rest of it
- the genetic diversity of French elms is large, but with no clear geographic pattern
- a marker was found for *U. laevis*
- the genetic distance between *U. minor* and *U. glabra* is very short despite some differences in allelic frequencies.

Other genetic studies on the French collection are being undertaken by J. Armstrong at the University of Glasgow using AFLPs and microsatellites.

Research for possible tolerance to DED is currently conducted by INRA (J. Pinon) and CEMAGREF through artificial inoculation in young clonal plantations. This involved the planting of 135 clones (over 850 plants) for pathology tests. The first artificial inoculations, carried on a set of 33 clones in spring 1995, show large variation in clonal response (i.e. percentage of infected twigs above and below the inoculation point). Further experiments with different inoculation dates are necessary before making conclusions on clonal tolerance to DED.

Other research being conducted on material propagated by CEMAGREF involves the cryoconservation of buds in liquid nitrogen (AFOCEL) and *in vitro* micropropagation (ENSH).

## European network

### Present state

CEMAGREF was involved in two elm-related projects proposed for EU programmes in 1995, and is particularly interested in promoting European cooperation for the genetic conservation of elms. Obviously, genetic characterization and conservation of forest trees cannot be undertaken efficiently and economically within the boundaries of one or two nations, but should be considered in the context of the entire European range of the concerned species. This is why we coordinated the proposal on Conservation of Elm Genetic Resources for the EU Programme for Conservation, Characterization, Collection and Utilization of Genetic Resources in Agriculture.

The objective of this proposal was to create a European collection of elms composed of native resources originating from eight partner states and representative of the full range of the species variation in Europe. This collection would have included material already stored or precisely identified in France, Spain, Italy, Germany and Great Britain; complementary material would have been acquired in Greece, Belgium and Sweden. All this material would have been described with passport data, molecular and morphological characteristics, and recorded in a database. It also would have been evaluated for its susceptibility to DED to increase the diversity of material available for afforestation and for the reconstruction of hedges.

Unfortunately, the project was not funded. The most important concern was the fact that we did not include material from the Netherlands (where a breeding programme has been carried out) and that no collecting effort was proposed in other species or non-EU varieties considered as potentially resistant. This criticism can easily be dealt with since several partners in the project (J. Pinon,

L. Mittempergher, L. Gil and others) have long experience with species or varieties considered as potentially resistant, particularly with the clones obtained by H. Heybroek in the Netherlands. Apparently, the reviewers would also have appreciated cooperation with groups working on *in vitro* propagation and cryopreservation. Although CEMAGREF already collaborates with AFOCEL for cryopreservation of elm buds and with ENSH for *in vitro* micropropagation of elm, we did not have the space to mention this in the original proposal.

CEMAGREF was also a partner in the proposal for FAIR coordinated by J. Kleinschmit (Study of Valuable Rare Forest Tree Species). CEMAGREF's main projects in the frame of this proposal were devoted to the inventory and conservation of populations of *U. laevis*, and to research on differential susceptibility of elm species to newly emerged populations of *Scolytus*; this would have complemented a previous study (Sacchetti *et al.* 1990) and provided a better understanding of the reasons why *U. laevis* seems for the moment less susceptible.

Collaboration with non-EU member European countries, where highly diverse or relict elm resources exist, should certainly be developed. CEMAGREF has already started informal collaboration and material exchanges with a Romanian forest researcher (G.F. Borlea) preparing a thesis on the Romanian elms and their susceptibility to DED. Financial support from the EU would permit transformation of such informal exchanges into organized cooperation.

## Perspectives

CEMAGREF is ready to resume its coordination effort and is preparing an improved proposal for the second round of the EU Programme for Conservation, Characterization, Collection and Utilization of Genetic Resources in Agriculture. In this context, we would very much appreciate any comments and suggestions from the European Network for the study and conservation of Noble Hardwoods.

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# Conservation of *Prunus avium* genetic resources in France

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## Introduction

*Prunus avium* is one of the first four pilot species[1] chosen by France for the implementation of the National Forest Genetic Conservation Programme. *Prunus avium* could be a model for the conservation of genetic resources of scattered and insect-pollinated species. In fact, its genetic resources are seriously endangered, mainly by the extension of forestry plantations (uncontrolled seed transfers and clonal plantations).

The domestication of *P. avium* and *Prunus cerasus* has modified the genetic exchanges inside this species complex over a long period; more recently the evolution of silvicultural practices has altered diversity and genetic variability of its resources in France. The trend toward increasingly homogeneous stands has made *P. avium* much rarer, as is the case for numerous other scattered species. This Noble Hardwood has been planted on a very large scale for about 15 years (Cazet *et al.* 1993): 1 300 000 planted in 1993. Far from being an advantage, it is also a danger to its genetic diversity, mainly because of the unknown origin and rather narrow genetic basis of the planted Forest Reproductive Material (FRM).

These are some of the reasons why CEMAGREF has been carrying out a genetic conservation programme since 1993. This was done in close cooperation with INRA, which mainly manages the breeding population. This connection between conservation and breeding purposes was stressed in the recommendations of the Steering Committee of EUFORGEN, "recognizing the basic link between conservation, tree improvement and managed use of forests..." (Turok *et al.* 1995).

Our strategy for wild cherry genetic resource conservation could be seen as:

1. Regionalized dynamic conservation *in situ* (CEMAGREF and Office National des Forêts), which concerns:
   - large and diverse natural stands for the northeastern part of France (in total about 10 sites)
   - artificial plantations in three homogeneous regions, each with material from the corresponding region, for the other parts of France where wild cherry is scarce (west, southwest and southeast).
2. *Ex situ* national tree breeding and seed orchard establishment (INRA and CEMAGREF). Methodology has been simultaneously developed in order to define rules for the management of *in situ* conservation stands.

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[1] The other species are *Fagus sylvatica*, *Abies alba* and *Ulmus* sp.

## *Prunus avium:* a valuable, bred and managed hardwood species with high priority for the conservation of genetic resources

Wild cherry is a very common species widely distributed in France, except in the Mediterranean plains and high-altitude zones, but there are threats to its genetic resources. The species is scarce above 1000 m altitude, in the southwest, in Bretagne and in the Loire valley (Fig. 1).

Wild cherry was a minor species until the 1960s when it was regenerated at a rather low scale. The interest in this species has been on the increase for more than 15 years and the high price of its wood has led to an intensive exploitation of the more valuable trees. This serious erosion of the genetic resources has increased because of its near-exclusion from homogeneous stands. Furthermore, tree planters became more interested in wild cherry afforestation: a dramatic modification of the extension of the species has occurred with the increase of artificial plantations. At the beginning of this trend, there was very little good quality FRM. Sometimes plantations were made with distillery or imported origins (Lemoine 1986). Since 1989, wild cherry FRM has been regulated. Although these stands could produce good-quality material, rather unsatisfactory seed tranfers are being made because of the scarcity of good harvests in France. The supply has been improved at a national level, but difficulties remain.

### Sustainable forest management

Foresters are increasingly aware of the problems induced by too-homogeneous stands. Therefore, they have modified silvicultural pratices for maintaining a sufficient interspecific diversity in the forests. Results are achievable in the long term.

### Selection of seed stands

Since 1989, 102 seed stands (410 ha) have been phenotypically selected by CEMAGREF. Figure 2 shows the repartition of these selected stands: they are concentrated within a wide northeastern region. In the rest of the area (2/3 of France), there are only 10 selected stands (27 ha). This is partly because the selection effort has not had the same intensity all over France, and partly because of the repartition of the natural resources.

### Breeding

For about 20 years, INRA has selected 400 plus trees (Santi *et al.* 1994). They have been tested in multisite clonal trials. Two years ago, eight clones were registered, but owing to the demand for a more diverse forest, these clonal varieties will probably represent a smaller part of further afforestation.

### Varietal outputs

A seed orchard is being set up from the same breeding population in order to provide foresters with a more sustainable and diverse resource; the genetic basis will also be larger than in most selected stands. Twenty clones were chosen and grafted in 1995 on dwarfing rootstock. This rootstock will also promote early flowering; a first seed production is expected in 5 years.

However, the present supply of wild cherry FRM is unsatisfactory. Anarchic long-distance seed transfers are going on and may have a bad effect on local genetic resources. On the one hand, the quantity and the quality of imported FRM are not precisely known, and on the other hand, seed transfers have been made between northeast selected stands and the rest of France. Moreover, only a small number of these stands (21-35 out of 102) are harvested: 66% of the seeds actually come from five to six stands.

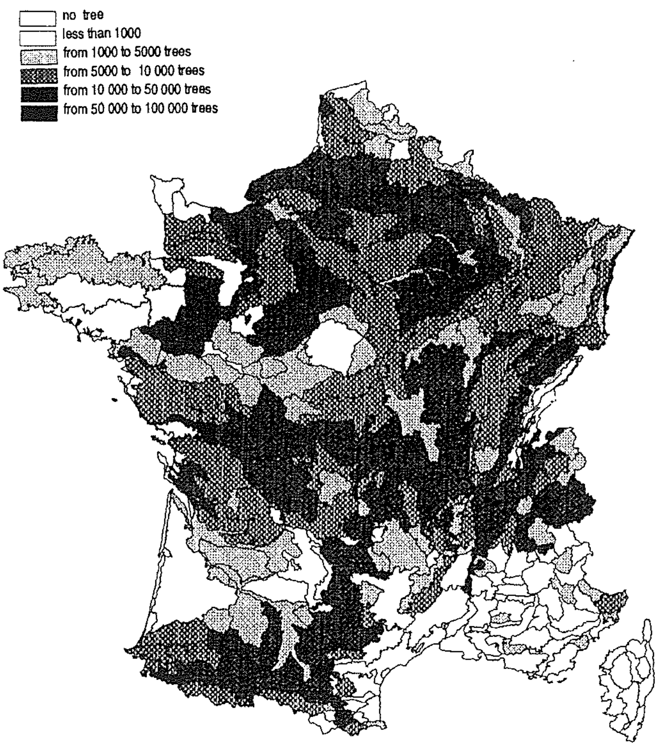


**Fig. 1.** Estimated number of wild cherry trees per 1000 ha of forest.

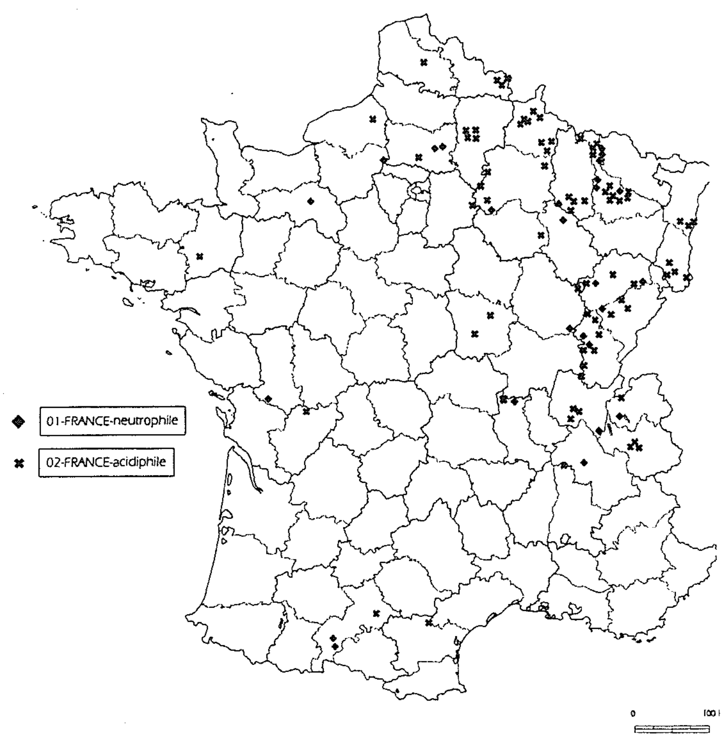


**Fig. 2.** Selected seed stands of wild cherry.

Finally, the surface of these selected stands is generally very low (Fernandez *et al.* 1994) and their genetic basis may be very narrow (Frascaria *et al.* 1993). The suckering process may lead to a very small number of genotypes within a single stand because the area of clonal spots may extend from 20 to 5000 $m^2$. It was recommended that seeds be mixed into seedlots in order to guarantee a sufficient genetic basis (Fernandez *et al.* 1994). This is rarely done.

These FRMs are being planted in most French regions and we are not able to measure the actual impact of genetic pollution on local populations. This is the reason for implementation of a concrete conservation programme by CEMAGREF.

## *Prunus avium* conservation strategy: need for European cooperation

A concrete regionalized conservation programme has been initiated in France. From the viewpoint of a breeder, the mixture of different genetic origins of high quality could be an advantage for selection purposes. However, it is certainly wise to preserve a small number of local populations from introgression because of seed transfers, possibly of bad quality. Although it seems that there is little differentiation among populations in France, it was decided to create a genetic resource conservation network on a regional basis. Indeed, very low inter-population diversity was found with a sample of eight populations and seven enzyme gene loci.

The French wild cherry conservation network consists of two kinds of stands:

- a few large and diverse natural stands, specifically managed for conservation purposes
- artificial plantations with vegetative materials originating from a single homogeneous region.

Both could be qualified as dynamic conservation *in situ*; some of them could become high-quality seed stands with a high level of phenotypic performance and large genetic basis.

The first *in situ* conservation of natural stands seems obviously to be the simpler and more efficient method. Unfortunately, for scattered species, it is difficult to have large stands with a wide genetic basis; each stand must have at least 50 different genotypes. As a result, less than 10 single or groups of selected stands could fit these requirements. Over the long term, selected stands are not the only ones to be conserved; marginal populations must be taken into account. Enzymatic studies will be used to assist in selecting and managing these stands, and field collecting could begin in 1996. This method could be operational mainly in the northeastern part of France.

For the other areas of France, the only way to conserve genetic resources is to survey genotypes within a region and to let them inter-breed in a plantation. Three regions have been defined (Fig. 3): Bretagne, Midi - Pyrénées at more than 600 m elevation, and Southern Alps.

### Present state of the French programme

Survey and harvest of open-pollinated seedlots began in 1994 in the two first regions (Bretagne and Midi-Pyrénées). Between 30 to 40 seedlots were collected in each region and sown in nurseries. Plantations will be started in the original region next autumn. Each plantation will have a total surface of about 5 ha. We intend to split it into several separated replications in order to take into account its scattered distribution patterns. About 500 adult trees are expected at the end of the rotation period.

Information (passport data) is available in a database; for each family of the collection, we have: geographic origin, type of environment and date of collection.

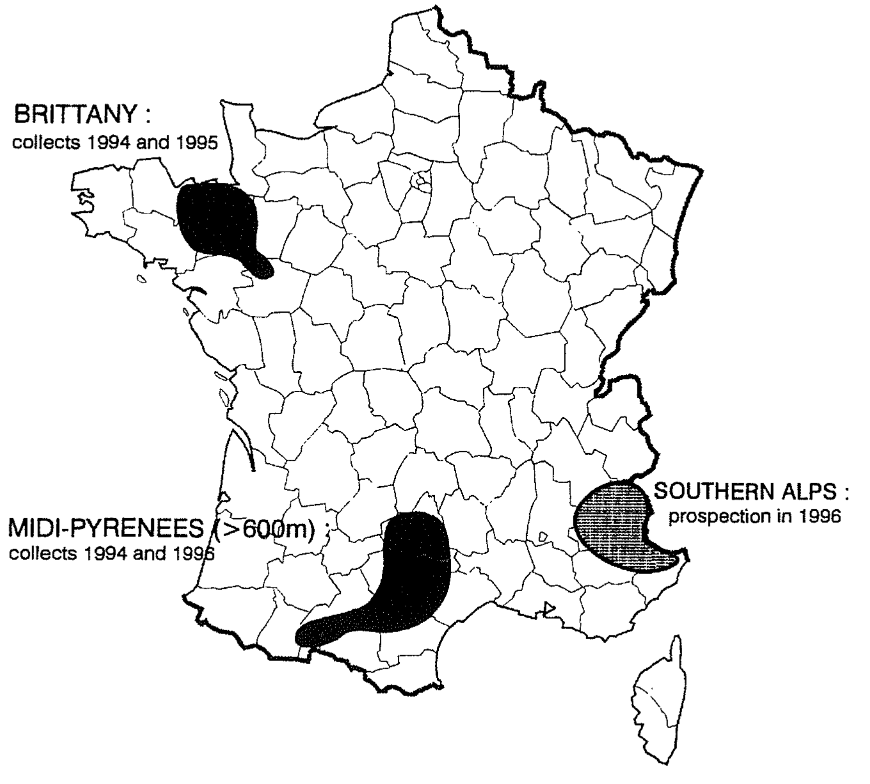


Fig. 3. Plans for regionalized *in situ* wild cherry plantations.

A common European strategy is needed in order to coordinate our national efforts. The European scale is the right one for the management of *P. avium* genetic resources because of the natural extension of this species. A possible new programme could include:

- definition of a common database for the genetic resources and their characterization
- characterization, evaluation and comparison of our collections with common traits
- use of common methods and management rules; comparison between countries
- collecting of new material and particularly survey and harvest of open-pollinated seedlots in the southeastern region, maybe in collaboration with Italy and other countries around the Alps
- analysis of virus contamination of *P. avium* collections.

**Development of the methodology needed to manage the regional conservation programme**

Conservation of wild cherry genetic resources on a regional basis is a wise but expensive way for the management of genetic resources. We therefore want to know if these regional resources have specific features, compared with the breeding population which is being managed for national purposes. We also need precise management rules for dynamic *in situ* conservation. For this objective, we wish to explore the genetic diversity of the collected material more completely. Sampling should be guided by all types of traits, morphological, metric and biochemical markers (Eriksson 1995).

***Present state***

The two regional collections are being assessed for:

- isozyme diversity (Santi and Lemoine 1990a, 1990b; Frascaria *et al.* 1993, Beaver *et al.* 1995), in collaboration with the Laboratoire d'Evolution et Systématique végétale de l'Université Paris XI Orsay
- variability of traits such as phenology, growth rhythms, genetic architecture and sensitivity to rust diseases in short-term trials.

These will be compared with the breeding population and the selected seed stands. Natural regeneration is also being modelled on a test site in Bretagne.

***Aspects to be developed within the framework of the EU programmes***

Extension of the analysis to other collections and to a more complete view of the genetic variability includes:

1. Analysis with other molecular markers (RAPDs, microsatellites); collaboration between European institutes would allow the development of these new molecular markers
2. GxE interaction in early and field tests (Héois 1994) in contrasted ecological conditions with the aim to study consequences for adaptability, quality and growth traits
3. Simulation studies in order to:
   - define pratical methods of dynamic *in situ* conservation
   - measure the impact of silviculture (plantation extension and density, thinning intensity, natural and/or artificial regeneration) on the evolution of the variability
   - measure the respective parts of vegetative and sexual regeneration, for both natural stands and plantations
4. Hybridization studies in order to have a better knowledge, particularly of the relationships between wild and sweet cherry.

## Conclusion

*Prunus avium* is one of the most important Noble Hardwoods in Europe. With its high-value wood, this species is of great economic interest. As with the other scattered species, wild cherry is clearly involved in the interspecific diversity of European forests, but its genetic resources are threathened by anarchic seed transfers and by hybridization with sweet cherry. Breeding work and forest management of this species need to be organized at a European scale and in a more integrated manner.

A genetic resource conservation network could become an integrated framework toward the development of wild cherry. Further research is needed to increase the knowledge of conservation methods. The European scale is also needed, because of the natural extension of the species, and for the management of a common heritage. The common public interest in the conservation of these valuable genetic resources is probably the best means to develop a European cooperation on wild cherry, from genes to raw material of high quality.

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# Noble Hardwoods in Spain: conservation of genetic resources

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## Introduction

Noble Hardwoods grow over large areas in Spain, in small stands or as isolated trees mixed with other species. In order to plan a programme of gene resources conservation for these species the following details must be made clear: their importance and main characteristics, the work already carried out and the steps to be followed in the development of such a programme.

## Importance and main characteristics of Noble Hardwoods in Spain

The following species have been classified as Noble Hardwoods: *Juglans regia*, *Castanea sativa*, *Acer* sp. (*pseudoplatanus*, *campestre* and *platanoides*), *Prunus avium*, *Ulmus minor*, *Alnus glutinosa* and *Fraxinus* sp. (*angustifolia*, *excelsior*). The importance of these species in Spain is difficult to estimate. Noble Hardwoods cover about 4% of the total surface area. However, these species are usually mixed with other, dominant species, and their proportion is thus underestimated.

Table 1 presents economic variables that characterize the importance of the species. Wood from these species is usually of a very high quality and has a special use for furniture. Afforestation represented 12.5% of the total surface in 1980-91.

**Table 1.** The main characteristics of Noble Hardwoods in Spain.

| | | Economic importance of the species | | |
|---|---|---|---|---|
| Species | Distribution* | Annual cuts ($m^3$ with bark) | Value of wood (x 1000 Pts) | Price of wood (Pts/$m^3$) |
| *Juglans regia* | I-S, AS | 3 275 | 157 370 | 48 052 |
| *Castanea sativa* | S, AS | 109 583 | 1 124 834 | 10 265 |
| *Ulmus* sp. | S, AS | 11 469 | 51 357 | 4 478 |
| *Prunus avium* | I,NS | | | |
| *Fraxinus* sp. | I, AS | 2 431 | 16 058 | 6 606 |
| *Alnus glutinosa* | I, AS | 18 000 | 103 283 | 5 738 |
| *Acer* sp. | I, AS | | | |

* I = isolated trees, S = stands, AS = all of Spain, NS = northern Spain.

In the following a summary is made of the main characteristics of each of the species, the gene conservation and breeding activities being carried out and the centres involved in these activities.

### *Juglans regia* L.

*Centres: IRTA and CIF-Lourizán*

This species is found in Spain throughout the countryside, usually as isolated trees for nut production. The wood is of high quality but it is usually not planted for wood production. A breeding programme with this species (Aleta 1996) primarily concentrates on walnut as a fruit tree. Another programme is under preparation for breeding the species for wood production.

***Castanea sativa* Mill.**

*Centre: CIF- Lourizán*

Chestnut is spread all over Spain, covering 140 000 ha. The main distribution is in Gallice and the Cantabrian Mountains. This species is found in pure stands, mainly coppice, and only 9% of the surface is covered by high forests. There is intensive production of wood in 50% of the chestnut forest stands. The main threats to the species are the use of cultivars for nut production and the effect of different diseases (*Phytophthora* and *Endothya*) which have affected the distribution of chestnut in Spain.

A breeding programme is being carried out in Gallice (Fernández and Pereira 1993; Pereira and Fernández 1995) based on the production and characterization of cultivars for nut production and resistance to *Phytophthora cambivora*. At present more than 143 cultivars have been collected and characterized. Data from phenology, location and isozyme characterization are available. The programme will extend the activities to other areas in Spain, considering chestnut for wood production.

***Ulmus minor* L.**

*Centres: ETSIM and Dir. Gral. de la Conservación de la Naturaleza*

Dutch elm disease has dramatically reduced the number of trees in Spain, and it must be considered an endangered species. Other species of the genus can be found in Spain, but they are of minor importance.

The breeding programme in Spain (Gil 1992) is focused on collecting material to preserve the native germplasm and to obtain resistant varieties to the Dutch elm disease. Objectives of the programme include characterization of the material and evaluation in tests (growth, architecture and susceptibility to Dutch elm disease). Therefore, characterization of the material includes five different types of data:

- geographic information
- morphological traits of seeds and leaves
- phenology
- pests and diseases
- susceptibility to Dutch elm disease.

Presently, more than 200 individuals have been collected and the characterization of this material is ongoing. The selected individuals have been propagated by seed and planted in an experimental test located in Mallorca where Dutch elm disease is not present. Half of them have been propagated by grafting or cuttings and two genebanks have been established in Madrid and Valsain.

***Prunus avium* L.**

*Centres: Dir. Gral. de Montes de Navarra, CIF-Lourizán*

Wild cherry is found in the north of Spain (Gallice, Cantabrian Mountains), where it is presently used in afforestation programmes mixed with other species in small stands. The main danger for this species is excessive felling of trees for commercial purposes.

A breeding programme has been started in Navarra (Puertas and Traver 1996) and Gallice. There are 75 selected trees in Navarra and 18 in Gallice, most of which have been propagated by grafting (45+6) and establishment in a clonal bank. The selection criterion is the quality for wood production (growth, straightness). Available data include location of the trees and phenological characterization of growth, branch habit and stem form.

**Other species (*Acer* sp., *Alnus glutinosa* and *Fraxinus* sp.)**

*Centres: Dir. Gral. de la Conservación de la Naturaleza, CIF-Lourizán and CIFOR*

Human activity has affected the distribution of the species. At present several activities are carried out, mainly in the scope of seed production, with the objective of characterizing trees or stands (Table 2). These species are included in breeding programmes of Gallice and Dir. Gral. de la Conservación de la Naturaleza, in order to identify base material for commercial use.

**Table 2.** Current situation[1] per species and issues.

| Species | Survey, collection | Germplasm banks | Evaluation, characterization | Genetic markers |
|---|---|---|---|---|
| *Juglans regia*[2] | + | + | – | – |
| *Castanea sativa*[2] | ++ | ++ | ++ | ++ |
| *Ulmus* sp. | +++ | +++ | ++ | – |
| *Prunus avium* | ++ | + | + | + |
| *Fraxinus* sp. | + | – | – | – |
| *Alnus glutinosa* | + | – | – | – |
| *Acer* sp. | + | – | – | – |

[1] Importance of the work already carried out: – none; + low; ++ moderate; +++ high.

[2] As a fruit tree.

## Needs for programme development

The following needs to be in place prior to the formation of a national programme for genetic resoources conservation for the concerned species:

- descriptors for each of the species
- strategy of genetic resources conservation
- increased genetic information of the species.

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# Noble Hardwoods and their genetic resources in Portugal

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## Historical background

### Main composition and changes

The primitive forest of Portugal had a totally different dimension and composition than what it has today, as the whole country was covered mainly by the *Quercus* species.

In the northern regions *Quercus robur* was dominant in the more humid zones, whereas *Quercus pyrenaica* occurred in higher and drier sites. In more temperate conditions the dominant species was *Quercus faginea*.

In the southern regions *Quercus suber* dominated in humid sites where there was maritime influence, while *Quercus rotundifolia* grew in the drier areas of the country's interior, together with *Quercus lusitanica* and *Quercus coccifera*.

Species like *Fraxinus, Ulmus, Alnus* and *Salix* grew along rivers and streams. Some of the species, gradually replaced by mountain pastures at higher altitudes in the highest northern and central mountains, were *Betula celtiberica, Taxus baccata* and *Pinus sylvestris*.

The forest cover, however, was not a continuous one. It was widely separated by open spaces caused by human population settlements and by the fires that are so frequent in the Mediterranean climate.

Main dominance trends of climax taxa in Portugal as a function of mesological factors are set forth in Figure 1.

Over the years this forest composition has altered quite drastically. Riparian species were the first to be damaged, occupying fertile valleys and bordering rivers with a mostly linear population design, because of agricultural needs. Species with a more favourable genetic population design, like *B. celtiberica* and *Prunus* sp. for instance, also suffered significant reductions of their areas, mainly due to intensive exploitation and replacement by fast-growth species.

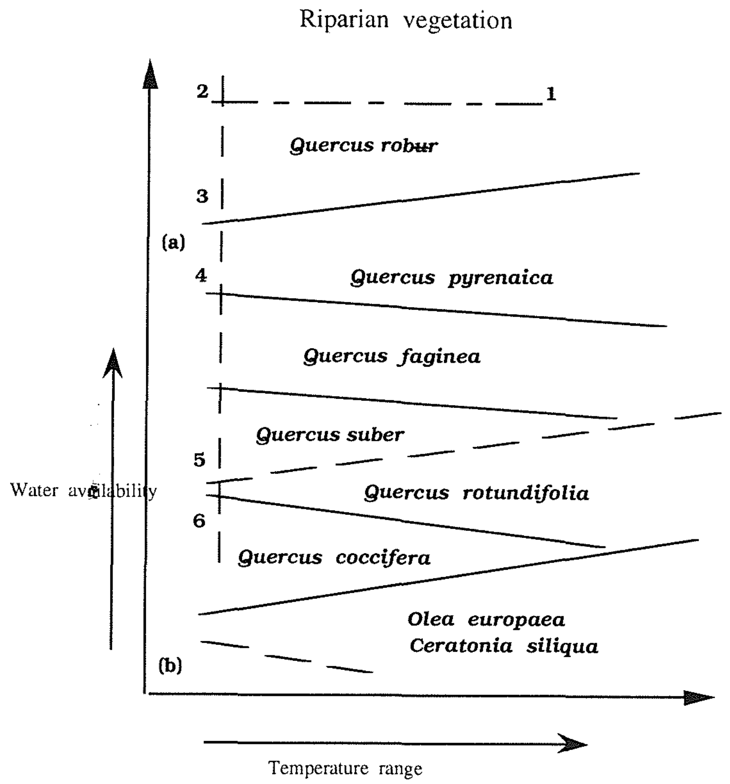
During the past 800 years the combined effects of agriculture, wood exploitation for naval construction, charcoal and settlements in Portugal have had a significant impact on the forest, causing a steady decrease until, at the beginning of the 18th century, it almost disappeared. In 1874, the total forest area was approximately 7% of the whole country.

Main transformational trends in forest composition at that time were:

- Deforestation of hardwoods north of Tagus with extension of softwoods
- Increased cork and holm oak proportions and its valorization in the south
- Quick increase of maritime pine.

After 1886, with the creation of the Forest Service and the development plans, forest area increased substantially, reaching approximately 1/3 of the territory (Fig. 2).

Presently about 90% of the whole forest area of Portugal is covered by pine (mainly *Pinus pinaster*), eucalyptus (mainly *Eucalyptus globulus*), *Q. suber* and *Q. rotundifolia* stands, the last two having heavy agricultural occupation of the land. The forest distribution area by species is shown in Fig. 3.




1 *Fraxinus angustifolia* subsp. *australis*
2 *Laurus nobilis*
3 *Prunus lusitanica* subsp. *lusitanica*
4 *Persea indica*
5 *Myrica faya*
6 *Phillyrea latifolia*
7 *Quercus canariensis*
degraded elements:
*Rhododendron ponticus* subsp. *baeticum*
*Euphorbia obtusifolia*

**Fig. 1.** Forest taxa trends as a function of mesological parameters.

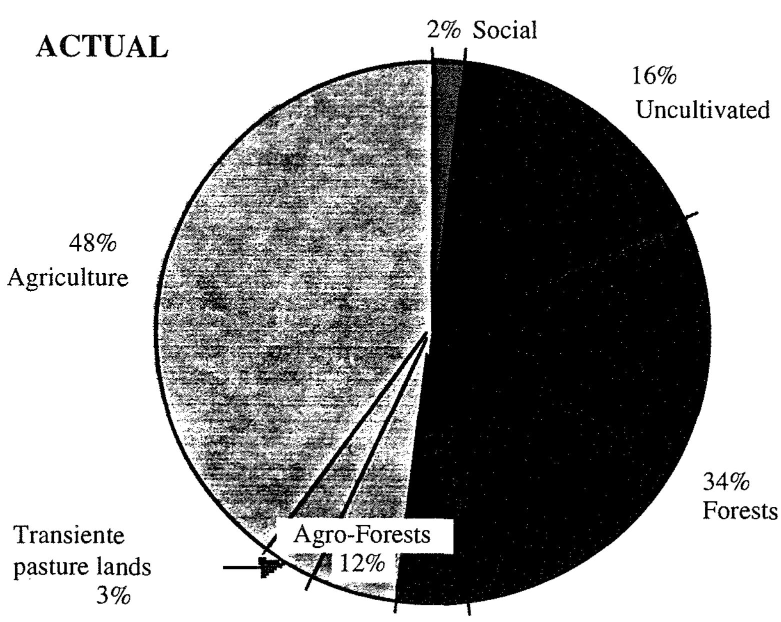
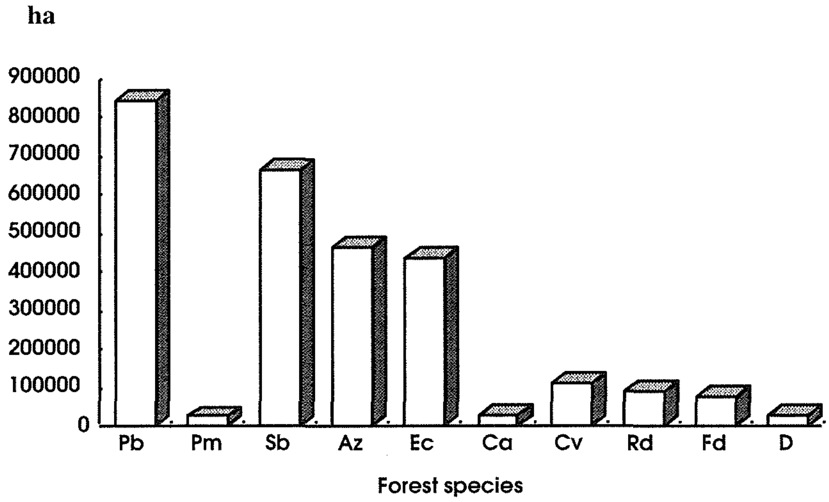



**Fig. 2.** Land-use categories in Portugal.




Pb – *Pinus pinaster**
Ca – *Castanea sativa*
Pm – *Pinus pinea*
Sb – *Quercus suber*
Rd – Other softwoods
Az – *Quercus rotundifolia*
Fd – Other hardwoods
Ec – *Eucalyptus globulus**
D – Other species
Cv – *Quercus* sp. (except Sb and Az)

* The 1990 aerial survey with field corrections of 1992 (including the burned areas and felling cuts for *Pinus pinaster*); other figures correspond to aerial photography of 1980-85.

**Fig. 3.** Distribution area of the main species in Portugal.

## Noble Hardwood species in Portugal

Since the focus of the Noble Hardwoods network excludes *Quercus* spp., the choice of species of common interest to Portugal, and included in this broad classification, is based on socioeconomic and ecological features. A foreseeable increase in demand for forest products has been taken into consideration, as well as their actual economic value and also the development of a desirable biodiversity policy. In this context Noble Hardwoods of interest to Portugal are: *Castanea sativa, Prunus avium, Juglans* sp., *Fraxinus angustifolia, Ulmus* sp. and *Alnus glutinosa.*

The size of the forest area in Portugal is currently about 3 million ha – 35% of the whole territory, with 44% conifers and 56% broadleaves. The main objective, for the management of around 60% of these forests, is wood production. Conifers are managed as high forest (especially *P. pinaster* and other pines) and broadleaves as coppice (particularly *E. globulus* and *Castanea sativa*). The remainder, 40% (mostly *Q. suber, Q. rotundifolia* and *Pinus pinea*), provides non-wood forest products such as cork and fruits. In this context Noble Hardwoods represent about 3% of the total forest area, principally because these species have been much exploited without the necessary technical support for reposition.

Land-use capability mapping shows that Portugal has a forest potential area of 5 million ha. In this sense the Noble Hardwoods can play an important role in new afforestations, mainly owing to the new concepts of conservation.

From the small area referred to above, chestnut accounts for about 20 000 ha. The other species are mostly dispersed and are seldom found in stands. Beyond this species there is a significant nucleus of *P. avium, Juglans regia* and small spots of *Ulmus procera* in Portugal, all in good health, in several parts of the country. They grow in protected areas (Natural Parks and Nature Reserves).

Therefore, from actual information available, the current rank, based on area proportion of Noble Hardwoods will be: *C. sativa, Juglans* sp., *F. angustifolia, P. avium, A. glutinosa* and *Ulmus* sp. The situation of *Ulmus procera* deserves high priority.

It is possible to have an up-to-date inventory of Noble Hardwoods based on the LIFE Programme. This Programme, "Cartografia da vegetação natural e semi natural no território de Portugal continental" [Cartography of natural and semi natural vegetation in Portugal], is a cooperative action including the Nature Conservation Institute (ICN), the National Centre of Geographic Information and several universities. It is due to be completed in 1997.

## National strategies for conservation systems

Until the present, only *Q. suber* was the subject of genetic conservation initiatives. However, there is an awareness of the need for a national long-term strategy for conservation systems. Relevant partners (EFN, ICN, Research Institutes, Universities) should put their efforts into creating adequate legislation and claim for the essential resources and funds.

As mentioned, forest structure in Portugal has suffered over the years through drastic changes. It can be said that nowadays not a single zone has been left undisturbed by humans.

Fortunately, some small areas still exist where the primitive ecosystem is not completely destroyed, or where it has somehow recovered from endured aggressions. The remnants of the original forest composition and biotopes were classified by the CORINE project Biotopes and some of them are now under protective laws and sheltered in National Parks and Reserves.

Since 1971, areas for National Parks and Reserves have been classified. They now cover about 500 000 ha, representing 16% of the total forest area. This is the result of a clear conservation policy (*in situ* conservation strategy). The government nature conservation agency (ICN) has the mandate to define not only the areas to be preserved, but also the maintenance and scientific studies deemed necessary to fulfil their purposes.

In terms of forest management and the implications of policy on biodiversity, it is necessary to say that although it has been expressed informally in the laws, or in forest management guidelines, some conservation measures have been part of management plans and expressed by the allocation of conservation series in the more sensibly managed forest areas under the management of the State Forest Service. However, this is done on an individual and *ad hoc* basis, and is not a main determinant in private forestry, which represents about 85% of the forest total area.

Economic and social pressures, along with a strong deregulation of private forest activities and the weakness of forest extension, make the elaboration of acceptable objective guidelines urgent for biodiversity conservation, where genetic conservation is certainly a key element. Some alterations are being undertaken in silvicultural operations, mainly in pine stands in northern regions of the country.

In fact some afforestation projects, especially those made after forest fires, are now taking conservation and biodiversity aspects into account (EU Regulation 2080). The cutting of continuous large areas has been reduced, and the use of hardwood species (mostly *Fraxinus* sp., *Juglans* sp., *C. sativa* and *P. avium*) bordering these stands has been implemented, thus building a mosaic appearance.

In this field of work there is, however, a clear flow of knowledge concerning the genetic structure of Noble Hardwoods. It is also important to create conditions conducive to the future evolution of these species. Therefore, considering the state of the art and the weakness of Portuguese research funding for studies in this subject, it is necessary to characterize Noble Hardwoods by geographic and ecological traits.

The first objective of gene conservation for Noble Hardwoods in Portugal should be an inventory of the situation of the various species. This information shall frame the respective conservation programmes.

Noble Hardwoods are clearly a threatened group of species in Portugal, the major threats being:

- **Anthropogenic** (urbanism, agriculture, replacement by fast-growing species): given the degree of heavy human impact in the rural Portuguese landscape, it is fair to say that almost all species were negatively influenced. Slow-growing species like Noble Hardwoods were most strongly affected.
- **Pest and diseases:** the most important are *Phytophthora cinnamoni* (*C. sativa* and *J. regia*); *Curculio elephas* (*C. sativa* fruits); *Scolytus* sp. and *Ophiostoma ulmi* (*U. procera*).
- **Environmental factors** (fires, pollution): affect all types of forests; riparian species are particularly sensitive to freshwater pollution.
- **Genetic factors** (exploitation, reduced genetic variability, uncontrolled introduction of species, altered population dynamics): this threat affects almost all tree species mentioned.

Chestnut is one of the species where some research activity has been carried out. Among others the following can be referred to: isoenzyme analysis to characterize clones resistant to *Phytophthora cinnamoni*; control measures, mainly genetic (use of selected clones) as well as biological (seedling mycorrhyzation). Integration of the results of the various ongoing research lines is expected to contribute to the improvement of the global strategy of nursery management for the production of vigorous and healthy plants.

The ongoing research on *J. regia* has the main objective of dealing with fruit quality production.

# Noble Hardwoods in Malta: status and perspectives of their genetic resources

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## Introduction and general background information

### Geography

The Maltese Islands lie in the central Mediterranean region, 93 km due south of Sicily, 352 km due north of Tripoli and 288 km east of Tunis. The archipelago runs northwest to southeast and is 45 km in length. The islands are situated between Latitude 36°N and Longitude 14°. The total population is 375 000 which, with a yearly influx of over one million tourists, makes the population density per square kilometre one of the highest in the world. It goes without saying that the stress on the natural environment is also very high.

The Maltese archipelago consists of three main islands (Malta, Gozo and Comino), with a total area of ca. 316 $km^2$. Malta is the largest island. It is 27 km long and 14 km at its widest point and has a total area of 246 $km^2$. The land mass tilts from west to east. The highest ground reaches up to 251 m above sea level. The geology of the Maltese islands consists mainly of sedimentary tertiary deposits, the oldest being 25 million years old; the land rose above the water surface around 10 million years ago. Five different rock layers make up the Maltese Islands: Lower Coralline limestone, the Globigerina limestone, the Blue Clays, Green sand layers and the Upper Coralline limestone layer. The layers are of variable thickness and tilted at various angles.

Of interest are the three main soil types found in the Maltese Islands, namely Terra Rossa soils (the oldest soils), Xerorendzinas and Carbonates Raw soils. All these soil types are alkaline and of relatively recent origin. Like other soils of the Mediterranean-type climate, these are immature with a high calcium carbonate content giving a pH value of around 8.

### Geomorphology

Malta has neither mountains nor rivers but the Maltese landscape is quite varied. This has resulted from various erosion factors on the main rock layers. Inland the country is characterized by gently undulating hills with slopes usually terraced for agricultural use whereas cliffs are the dominant coastal features, especially on the southwest. The following landscape features are worth mentioning.

#### *Erosion of rock strata*

- Lower Coralline limestone: coastal; sheer cliffs. Inland: Karst landscape with shallow soil pockets. These shallow pockets result from the gradual dissolution of the calcium carbonate by acid present in rainwater.
- Globigerina limestone: because of the higher erosion rate this gives rise to flat plains mostly covered by soil and used mainly for agriculture. An ever-increasing urban sprawl is continuously reducing the land area available for cultivation.
- Clay: gives characteristic slopes because of its plasticity when wet.
- Sandstone: degrades and erodes very rapidly under the action of rainwater.
- Upper Coralline limestone: again contributes to sheer cliffs and Karst plains, but because the Upper Coralline limestone rests on softer substrata, which erodes faster, this layer tends to break up into blocks under its own weight.

***Faults***

There are two main groups of fault lines; those running in a NW to SE direction and several others which run roughly from SW to NE. The latter give rise to a number of ridges and valleys with rich natural vegetation or deep soil for intensive cultivation.

***Watercourses***

There are, at present, very few perennial springs but a number of watercourses have water flowing through them for a good part of the year. These are mainly located on valley beds in the Buskett/Dingli area and further north such as at Bahrija. These valley beds are especially important, since the nature of our climate has confined the two hardwood species present on Malta to these limited habitats.

**Climate**

The Maltese climate is a Mediterranean type modified by maritime influence. It can be broadly described as biseasonal with relatively mild wet winters and hot, dry summers. Although averages are not usually a reliable indication of climate, one can refer to the following main general features:

- In most years June, July and the main parts of May and August are completely dry. In some years no rain falls until mid-October.
- There is usually an abrupt increase in rainfall between August and September followed by a gradual drying in April - May.
- There is an enormous variability in rainfall from year to year. This year is already one of the wettest with an average exceeding 850 mm, but figures lower than 300 mm have been registered at the other extreme. The average over a 133-year period is given as 529 mm (standard deviation of 153 mm).
- The majority of the rains in any month are heavy but of short duration. These heavy rains are particularly evident in October and November when thunderstorms are frequent.
- It is usual to have intervening dry periods which are frequently windy. This severely reduces the available water in the soil, making it impossible for certain tree species to survive on high ground.
- Overall, the climate is warm and healthy. There are no biting winds, fog, snow or frost. A few hail showers fall during winter. The temperature averages 14.1°C and hours of sunshine are 6.46 h/day between November and April (i.e. in the wet season). Temperature averages 32°C and hours of sunshine are 10.11 h/day between May and October (i.e. in the dry season).

**Vegetation**

As in other locations, the type of vegetation characteristic of Malta is climate-dependent. The Mediterranean type of climate gives rise to a Mediterranean biome where the species have a characteristic structure. The main factor is that evapotranspiration is greater than the total annual precipitation so that at some time of the year there is insufficient water for plant growth. Because of this the main vegetation on the Maltese Islands is the sclerophyllous scrub although one also finds a number of geöphytes. Sclerophyllous shrubs and trees have thick-skinned leaves and may also be covered with hairs, both being adaptations against water loss. Examples include the evergreen oak (*Quercus ilex)*, the olive (*Olea europea)*, the bay laurel (*Laurus nobilis)*, the carob (*Ceratonia siliqua*) and the Mediterranean buckthorn (*Rhamnus alaternus*).

The major types of vegetation habitats on the Maltese Islands can be classified under four main categories – Evergreen wood, Maquis, Garrigue and Steppe –

which are in effect a successional series. Although there are indications that the Maltese islands were originally covered with trees, very little of the original evergreen woods remains. The extant woods are of secondary origin.

The few pockets of remnant forest which are left deserve special attention in terms of the conservation of plant genetic resources. The estimates are for 57 large tree and shrub species which are either native (present before people set foot on the islands) or archaeophytic (introduced by humans in ancient times and now considered as native). Of these, 37 are rare (endangered), 6 are extinct in the wild and only 15 species are common.

#### *Evergreen wood*

The semi-natural wood present at Buskett and Verdala is a predominantly conifer wood where the Aleppo pine (*Pinus halepensis*) dominates. A narrow strip of deciduous woodland bordering the watercourse is found at the lowest reaches of this area. The history of this semi-natural wood, in its present partly managed form, goes back some 500 years but it is situated on an area of old natural forest vegetation. Planted trees and naturally regenerating forest are intermixed. It is therefore rather hard to assess which of the extant vegetation present is derived from the original forest.

#### *Maquis*

The evergreen maquis consists of scattered low trees, separated by low-growing, mainly evergreen shrubs. It covers large areas in Malta and is found in various valleys, in parts too steep or inaccessible to be grazed, on steep slopes where carobs can be planted but arable farming is impossible.

#### *Garrigue*

This is the most abundant semi-natural type of habitat and has the most widespread distribution, especially on exposed ground. It is dominated by low shrubs usually less than half a metre in height but is also rich in geophytes and herbaceous species. Garrigue is the result of excessive degradation on the maquis, especially through grazing.

#### *Steppe*

Steppes are essentially the result of further degradation of woodland, maquis and garrigue through grazing, deforestation and fire. Large shrubs are completely lacking with grasses, geophytes, thistles and other herbaceous plants dominating. It should be noted that the Maltese term for the garrigue, and the steppe is *xaghari.*

## Conservation and use of genetic resources of Noble Hardwoods in Malta

### Definition of Noble Hardwoods

The use of the term Noble Hardwoods needs additional qualification. There seems to be a broad consensus in the EUFORGEN Network on which species belong to the Noble Hardwoods group, namely species of *Acer, Fraxinus, Ulmus, Tilia, Juglans, Sorbus, Prunus avium, Castanea sativa, Alnus glutinosa* and others. These species share a number of common characteristics, including their use in the timber industry, some providing very hard and durable wood. They are also deciduous trees physiologically adapted for a cold winter period before they restart growth in spring.

In Malta, *Fraxinus angustifolia, Pyrus amygdaliformis* and *Ulmus canescens* are three hardwood species present in the wild in very small numbers. The low population numbers dictate a high degree of urgency for their conservation. Pollen records show that these species are native, thus further increasing our interest in utilizing them for reforestation projects. All three species are listed in the National Red Data Book. There are a few specimens in the wild, all requiring urgent conservation work.

There are also records for the following: *Ulmus procera, Ulmus glabra, Pyrus pyraster* and *Sorbus aucuparia*. The latter is recorded in old literature as being present in Gozo, but has not been sighted for a number of decades and is therefore possibly extinct locally. Whether these are native or introduced still requires further study. The reason for inclusion of these species in conservation programmes is not for their timber value but more for their ecological importance and landscaping/restoration value.

The conservation of genetic resources of these species may still have some value considering that genotypes may express some degree of adaptation to dry environmental conditions. This consideration must be made irrespective of the degree of genetic erosion these remnant specimens have suffered. There is no forest industry in Malta but there is a growing pressure to increase the tree cover on the islands for a variety of ecological reasons.

Since no proper inventories of genetic diversity have been carried out in Malta, it is premature to say whether we have material which has distinctive characteristics from those of neighbouring countries. The need for standardized guidelines to compile these inventories of genetic diversity within a species has to be considered. Little research has been carried out on local trees, although there are indications of some interesting material, e.g. *P. halepensis* seedlings raised from particular stock show extreme resistance to drought and to coastal conditions.

For *Q. ilex*, two remnant populations offer scope for preservation of their genetic material. The scientific evidence that these populations are indeed remnant comes from the discovery of endemic endogeic beetles. The same may apply to the *Ulmus* and *Fraxinus* species under consideration.

### National conservation activities

As stated elsewhere there are a number of agencies involved in conservation work but it is time now to adopt more stringent and scientific methods of doing this. Mention must be made of the following:

1. Environment Protection Secretariat: action to preserve our natural environment is being stepped up.
2. Structure Plan: inclusion of studies on conservation of our natural resources.
3. The setting up of national tissue culture facilities within the Department of Agriculture.
4. Conservation working group as part of the Biodiversity Network within Malta Council for Science and Technology: this is in the process of being set up with the following objectives:
   - to bring together a number of officials from different Government Sectors, NGOs to formulate common policies and strategies for conservation in the Maltese islands
   - advise and assist central and local government on implementation of conservation projects
   - set guidelines for important conservation issues such as degradation assessment, the establishment of conservation areas, ecological restoration, re-introduction policies, etc.

***In situ* conservation activities:** Malta has a number of nature reserves, both coastal and inland. Government and NGOs are involved in their management.

*Ex situ* **conservation:** The Department of Agriculture, together with NGOs and the University Botanic Gardens, have started *ex situ* conservation measures but as yet these activities are not coordinated, which results in duplication of work in a number of instances. Documentation of source material has just started. The value of past conservation projects is severely impaired by the absence of documentation. There is also the additional problem of plant material imported from abroad resulting in additional dilution of our native plant genetic resources. The few specimens surviving in valleys need special conservation attention. The use of local material for reforestation work is being emphasized.

The following specific gene conservation activities need to be considered:

- Collecting of seed when this is present. When not present, other propagules must be chosen but care must be taken that these come from distinctive clones.
- Adequate sampling of populations to ensure that the genetic diversity within the population is sufficiently represented.
- Storage of propagules in the form of seeds, cryopreserved embryos or tissue cultures.

The conservation working group being set up within the MCST has the role of coordinating all future conservation activities as well as formulating such strategies as are required for a species or a group of species. Additionally, there are preparations to set up a genebank facility to complement the conservation process. The National Micropropagation Centre, which has been recently established, is showing interest in conservation of locally endangered species. Furthermore, there is also the Afforestation Section, within the Department of Agriculture, NGOs and the University Botanic Gardens which are involved in the conservation of a number of locally endangered species.

The adoption of a species-based approach is considered an effective means of covering all aspects of gene conservation of forest trees and their ecosystems. The following steps should be taken at the national and international levels:

- inventories of the native stands of each species
- inventories of the genetic diversity within species
- compilation of identification sheets and descriptor lists for the different clones of a species
- compilation of guidelines for *ex situ* field collections
- development of *in situ* conservation measures.

## Three remnant Noble Hardwood species in urgent need of conservation measures

### *Fraxinus angustifolia* Vahl. (Narrow-leaved ash)

#### *Description*

This is a medium-sized tree, up to 25 m high, with a tall and regular crown. It is similar to *F. excelsior* but less robust. The trunk can grow quite wide, up to 4 m after 100 years. Young growth is often glabrous although *F. angustifolia* var. *australis* (Gay) Schneid. has puberulous leaves beneath. The natural distribution of the species is southern Europe to northern Africa.

The leaves are 15-25 cm long with a glabrous rachis bearing 5-13 leaflets. The petiole is also glabrous. Each leaflet is 3-9 cm long, oblong-lanceolate to linear-lanceolate; long-pointed at the apex and with coarsely toothed margins; dark green above, paler beneath glabrous, rachis terete grooved only at the junction with pinnae.

As far as is known the flowers are hermaphrodite but unisexual forms may be present. The corolla and calyx are absent. A racemose inflorescence develops from the axis of 1-year-old wood. The flowering period is in May. The fruit consists of a samara with an oblong-lanceolate wing. They are found in clusters, each samara being 2-4.5 cm long, rounded at the base. The fruits ripen in October.

In the past this species was used as a source of tannins, where the bark was specifically used for tanning nets. Medicinally, the bark was once used to alleviate symptoms of intermittent fevers, agues, etc. The leaves are known for their purgative and diuretic activity. They are also used in arthritic and rheumatic complaints amongst others.

Writing in 1922, Professor J. Borg stated, in reference to this species, "Thrives in comparatively dry localities. Prefers a deep soil and cool situation sheltered from wind. Gigantic ash trees estimated to be even 350 years old. Hardly produced fertile seed; commenced to produce such seeds very abundantly in 1922 – possibly due to cross-pollination with recently imported smaller trees planted amongst them ... furnished a well-known timber."

In this treatment the species was wrongly identified as *F. excelsior* but the reference to the lack of seed production may be an indication that the specimens present at the time were infertile due to the lack of male flowers in the vicinity.

In Malta it grows well in wet and humid valleys. Out of all our native watercourse trees, it is the most tolerant to droughts. It is a fast-growing tree and can live up to 200 to 300 years. As regards its uses in landscaping and environmental management, it is considered a handsome tree, casting little shade and preferring calcareous soils. It is capable of withstanding coastal winds, and some atmospheric pollution, but roots can disturb foundations when planted near buildings. In landscaping, *F. angustifolia* is a valuable small tree for autumn colour.

#### *Present state*

The present occurrence of this species in Malta is very rare. It is found in only two localities, one in Gozo near Marsalforn and the other at Buskett in small stands which at present are unprotected. The one at Buskett is probably a native stand. Because of the limited watercourse habitats in Malta, there is hardly any use of this tree in afforestation. A number of NGOs, the Gardens Unit from the University of Malta, as well as the Afforestation Section within the Department of Agriculture, are at present involved in the conservation effort to try to increase stock with the intention of planting these in the wild in suitable habitats.

The following procedure for planting has been adopted: the fruit or samaras are collected from October all through the winter. The seeds have to be extracted from the samaras before being of any use. A cold treatment helps in their germination. They are placed in a freezer for at least 1 week but not more than 3 weeks. They will sprout after the frozen period is over.

After the cold treatment, they can be sown at a depth of 1-2 cm below the soil level. In each container, 1-2 seeds are placed and watered well. Sprouting usually occurs after 2 weeks, but may continue until the end of spring. About 90% germination is expected and frequent watering is required for container-grown trees, especially during the first summer. They are transplanted after 1 year unless shorter than 20 cm. Permanent watercourses form the optimum habitat. Temporary watercourses may also be used but the trees must be watered during the first summer.

### *Ulmus canescens* Melville (Grey-leaved elm; Sigra tan-Nemus or Nemmiesa)

This taxon was first recorded in Malta by Sommier and Caruana Gatto in 1915 as *Ulmus campestris*, a name which belongs to another species altogether. The true identity of our local elms was verified in 1981 by M. Briffa when two small stands of native elms were located. The Grey-leaved Elm is a rare tree and since it grows on very fertile land it has been persecuted by farmers. One of the population was accidentally burnt down in 1982.

It is an Eastern Mediterranean element of our flora. Its Maltese name has originated from large galls caused by the aphid *Scizoneura lanuginosa* Hartig. These galls may also be filled by hyperparasitic insects or inquilines. Other elms have been introduced for planting in moist places, e.g. *Ulmus minor* Miller (in Buskett Valley), *U. glabra* (Wied Qirda) and *U. procera* (Ghajn Rihana).

*Ulmus canescens* is found in valleys where water is available throughout the year. It is now found in three localities in Malta, namely Ghajn il-Kbira, Wied ir-Rum and Gnien il-Kbir. All populations are rather small in number and show signs of extensive cloning through suckering. Some have been reported to be in a poor state of health. Flowering occurs in February.

In the past (early this century), different species of the elm tree, both native and introduced, were naturalized in several valleys. This may be attributed to the ease of growing these species since they can be propagated by suckers which are thrown up abundantly, sometimes at considerable distance from the main trunk. A number were frequently planted alongside roads in moist situations or valleys, some surviving to this day. A fairly deep and moist soil is required but they also thrive in dry and poor soils.

This situation may in fact cause a number of problems in future conservation work, primarily because it introduces an element of uncertainty as to which material is derived from the native and which is derived from introduced material. The best option is to use material collected from localities cited in the oldest literature. More work has to be done to identify the genetic diversity within our populations of Grey-leaved Elm. As with the Narrow-leaved Ash there is as yet no conservation order to protect these specimens.

### ***Pyrus amygdaliformis*** **Villars (Almond-leaved pear)**

The Maltese populations have dwindled to one small copse at the bottom of Wied Zembaq and another small population at Wied Maqbul. Suckers from the wild trees have been used and are still used as stock for grafting pears. It is a shrub or small tree up to 6 m high with branches which are sometimes spiny. Twigs are grey, dull and tomentose while young. Leaves are narrowly lanceolate to obovate, usually entire with rounded or cuneate base. The species is associated with rocky valleys.

# Study and conservation of Noble Hardwoods in Italy

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## Introduction

Since the beginning of the 1980s, when strategies were developed to study and to give impetus to the cultivation of broadleaves, a strong interest in Noble Hardwoods has been shown in Italy. The main goal was the creation of new high-quality wood reserves mainly using abandoned agricultural or economically marginal lands.

The peculiar environmental situation of Italy plays two different roles in the conservation and breeding strategies of forest species. First, the high degree of variability of the environmental parameters is related to an extremely high level of genetic variability. Second, breeders have many difficulties in selecting materials at low levels of genotype by environment interaction.

Latitudinal and altitudinal variation, exposure and slope are very important in the determination of the distribution of the forest flora. The Mediterranean climate means that weather is unforeseeable in the short and long term, with rainfall peaks in autumn and spring.

## Hardwood species of common interest in Italy

In Italy about 5.2 million ha are covered by hardwoods: 1.5 million ha as high forests (Mediterranean or mixed mesophile forests) and 3.7 million ha as coppices over a total forest area of 8.4 million ha.

The main Noble Hardwoods come from the phytosociological range characterizing the high-elevation mesophile forests (10-1000 m asl in northern Italy; 500-2000 m in central and southern Italy).

The present prominence given to hardwoods is not only related to their use in intensive forestry farming, agroforestry or row plantations, but also to their great ecological significance. The hardwood species we are considering here belong to the range of temperate mesophile mixed forests. As these are not social species, this trait must also be considered when we want to use them whether for traditional afforestation programmes or for productive plantations.

Presently, because of their high timber value the main hardwood species having prominence in Italy are: *Juglans regia, Castanea sativa, Prunus avium* and *Alnus cordata*. Of these, chestnut seems to be most social because of the wide areas over which, until 40 years ago, it was intensively cultivated for fruit production. We are thus able to rank the hardwoods according to their importance in Italy (Table 1).

Noble Hardwoods, along with other dominant species such as oak, beech, silver fir or pine contribute to very complex forest communities (Susmel 1988). We can assume that all the species floristic communities migrated to the south during the different glacial periods. They are used, like conifers, on southern sites as refuge areas. In this way we can hypothesize that variability should also be higher. In southern Italy the presence of many endemic species or varieties is a clear sign of this variability.

**Table 1.** Hardwood species and their range in Italy.

| Intensively studied species | Range of distribution |
|---|---|
| *Juglans regia* L. | Exotic in Italy, even if cultivated over the long term. Scattered, in small populations or single trees on cultivated lands throughout Italy (10-1000 m asl). High-value timber. Considered the most important wood in Italy. |
| *Castanea sativa* L. | Intensively planted from the Alps to Sicily, cultivated for seed and for timber production (600-1200 m asl). Good-quality species, there is a well developed industry, not only for fruit but also for wood manufacturing. |
| *Prunus avium* L. | Range in northern Italy (quite widespread populations) and in mesophile forests of the Apennines (small groups or single trees) at 600-1500 m asl. Especially used as a high-quality wood in northern Italy. |
| *Alnus cordata* Lois. | Southern Apennines in beech forests, in groups or single trees, very fast growing. Used for timber production, but is also planted as accompanying species because of $N_2$-fixation. |
| *Ulmus carpinifolia* G. Sokkov<br>*U. minor* Mill.<br>*U. glabra* Huds | The first species occurs throughout Italy up to 500-600 m asl in Mediterranean forest communities. The second species occurs from 500 to 1600 m asl in the mixed mesophile forests. |
| **Species where more genetic information is needed** | |
| *Acer pseudoplatanus* L. | Occurs in all mountain ranges (700-1500 m asl) on the western side of Apennines. |
| *Acer platanoides* L. | The Alps and north-central Apennines; perhaps there is an isolated population in the southern beech forest of Gargano (Foresta Umbra). |
| *Acer obtusatum* Waldst. et Kit.<br>*A. opalus* Mill.<br>*A. neapolitanum* Tenore<br>*A. tomentosum* Koch<br>*A. velutinum* Boissier<br>*A. aetnense* | Similar to *A. opalus*. Central southern mixed forests. It has high variability in Italy, presenting several different varieties. |
| *Acer lobelii* Tenore | Endemic in the southern Apennines. |
| *Acer monspessolanum* L. | Sporadic in Mediterranean mixed forests (up to 500 m asl). |
| *Fraxinus excelsior* L. | It occurs in all the mixed forests between 700 and 1700 m asl from Alps to Sicily and Sardinia. |
| *Fraxinus angustifolia* Vahl. | Species adapted to humid areas. Mixed in plain oak forest areas, and can be found in the humid areas of the Po Valley and in Tuscany. |
| *Sorbus aucuparia* L.<br>*S. torminalis* L. (Crantz)<br>*S. aria* L. (Crantz) | Several species spread throughout all floristic ranges. |
| *Betula pendula* Roth. | Its range is theoretically along all the Apennines, but it is present only on the Alps, in some small and isolated populations in the Apennines. Very famous in Sicily. |
| *Platanus orientalis* L. | Southern Italy. |

Because of the species' less social behaviour, perhaps the interpopulation variability is lower, or more clinal than in the more social varieties, so we must consider these as a group of species which, from the ecological point of view, are quite exigent or specialized (they are mostly distributed over a European environment) and can be isolated where conditions are most suitable for them. An important aspect, related to the relatively low occurrence of these species in Italian forests, is the negative effect of the usual silvicultural treatments.

## Strategies for conservation systems

The national law on forest reproductive and propagative material (269/1973) indirectly involves the conservation of genetic resources with the establishment of a National Book of Forest Seed Stands (Morandini and Magini 1975). While conifers are highly considered, probably because of their social behaviour and diffusion in wide pure stands, hardwoods are strongly under-evaluated. Only dominant species, such as beech, Italian alder and oak are partially listed as seed stands (which are protected).

At the moment there is no integrated and clear national strategy for gene resource conservation of hardwoods. Some individual research is carried out, from the economic point of view, by single or small working party groups on the main species.

In the framework of a national project, a working group coordinated by ISSA on forestry farming and agroforestry is studying the genetic resources of wild cherry and walnut, and other research is being done over the long term by various institutions on chestnut, elm and alder.

### Traits for the characterization of Noble Hardwoods

Beginning and establishing a strategy for gene resource conservation means to first carry out a geographic survey of the species, recording the size and distribution of the different populations (Figs. 1-3).

With non-social species, presenting scattered populations in mixed stands, the delimitation of physiographic areas and the recording of the main environmental parameters is important.

The following steps should be devoted to investigating the natural intraspecific and intrapopulation variability. In this phase different traits should be studied by different specialists working within the framework of narrow integration.

Different traits should be evaluated together such as adaptive traits: anatomy, phenology, physiology and their genotype by environment interactions, as well as biochemical markers (isozymes, RAPDs, RFLP). These natural variations need to be investigated in order to create a basis for future germplasm conservation and breeding programmes.

The study of isozymes, indicating allele distribution, is an important and fairly efficient tool in evaluating variations in the main genetic parameters of the species, and molecular marker techniques, related to monogenic quantitative traits (QTL), could be useful in strategies for future breeding. Of course, during the first step importance should be given to the research on phylogenetic relations among species of the same genus and to study of the intraspecific variation. Work is being done on material from an extreme part of the natural range of this species, and many intrageneric hybrids are present. Given the wide transnational natural range it becomes obvious to compare results from different countries and to integrate genetic research activities.


1. Aspromonte
2. Sila piccola
3. Pollino
4. Sorrento
5. Valtiberina, Casentino
6. Valdarno
7. Appennino tosco-romagnolo
8. Appennino modenese
9. Appennino parmense
10. Valvestino
11. Bleggio
12. Bosco Fontana
13. Asiago
14. Alpago
15. Appennino marchigiano

**Fig. 1.** Main areas of sampling of *Juglans regia* L. plus trees by ISSA, 1985-93.

**Fig. 2.** Distribution of *Acer pseudoplatanus* in Italy.

Fig. 3. Distribution of *Alnus cordata* L. in Italy.

## Noble Hardwoods threatened in Italy

As mentioned above, one of the main problems affecting the consistency of hardwood species in Italy is related to silvicultural treatments applied to the forest communities where they are growing. Coppice treatments are very dangerous to forest biodiversity, as all the equilibria among species are completely manipulated, creating more possibilities for the eliophile and more aggressive species. Variability, in this case, is also severely reduced because of the long survival time of stumps which reduces the advantages of natural regeneration.

Resources are endangered for species growing in plain forests because of the dramatic reduction of forest areas through agriculture and industrial expansion. Mediterranean species are also endangered because of human pressure from exploitation, grazing and, more significantly, from forest fires.

There are signs of new dangers, which are related to increasing global environmental changes, such as pest and disease attack. Stress symptoms are also occurring more frequently, mostly in the Mediterranean areas where the forest climax communities are really sensitive.

Some peculiar phytosanitary problems are affecting species such as *C. sativa* (*Endothia parasitica, Phytophthora cambivora*) and elms (*Ophiostoma ulmi*). In the first species the main damage is in the selected resources (clones) for fruit and wood production; in the second, elms are practically destroyed or are transformed into shrubs.

Today at least 10% of the national territory is protected as national, regional or local parks. In this way some peculiar forest communities are at least protected *in* *situ*. An ever more important problem, even if underestimated, within the framework of activities concerning forest tree farming of high timber value hardwoods, is the increasing importation of propagative material from other countries. Because of this importation there is a severe risk of genetic pollution. European laws on the propagative material trade should distinguish between material to be used for traditional silviculture and material to be used outside forests, in forest tree farming, where the main aim is production.

## Breeding and genetic research

### Walnut (*Juglans regia*) and wild cherry (*Prunus avium*)

*Institutes: ISSA-Arezzo, CNR-Agroforestry, CSAF-Rome*

The main breeding programmes are carried out under the coordination of ISSA, involving at least 23 Italian research institutions. They are closely connected with the EU AIRCT920134 (Alternative use of agricultural lands with fast-growing trees) and AIRCT920142 (walnut) research programmes. Strategies are based on the establishment of a selected and wide genetic base to give impetus to the improvement and cultivation programmes.

Morphological, phenological and biochemical markers (isozymes, RFLP, RAPDs) are studied in order to determine the intraspecific variability and to select material for future programmes according to the following steps:

- direct phenotypic selection of basic material (walnut) with reference to stem form, branching, growth, bud break and phytosanitary aspects according to a physiographic area division
- studies on the intrapopulation genetic structure in both species
- establishment of an *ex situ* genetic base by clonal collections and their improvement through exchange with Italian and foreign colleagues
- establishment of provenance, progeny and clonal (cherry) multisite trials aimed at the genetic evaluation of selected material by the recurrent method
- interspecific and intraspecific hybridizations.

Presently, about 350 clones of wild cherry from all Italy, 10 from France, 10 from the UK and modified clones with radiation are conserved in the ISSA collections, 150 of them planted in trials. Seventy progenies from three main provenances are being tested.

About 100 grafted clones of walnut from all Italy are conserved at ISSA and progenies of half of them are being tested. In the framework of EU AIR3 CT920142, a network of experimental plots has been established with walnut common material throughout western Europe in order to evaluate its genotype by environment interaction value. Six trials have been planted in Italy.

A similar network has been established for wild cherry in the framework of AIR3CT920134 using the supposed best clonal material from the participating countries. A collection of several species is planted near the CSAF in Rome.

Cherry organogenesis and somatic embryogenesis are being studied to produce future transgenic individuals, modified with *Agrobacterium* sp. as a genic vector.

### Chestnut (*Castanea sativa*)

*Institutes: ISSA-Arezzo, CNR-Porano, University of Florence*

Many studies on the resistance and propagation of chestnut have been carried out by the University of Florence after severe damage of this species by parasites.

Good work on this species has been carried out in the past on genetic resources conservation. About 300 selected clones of fruit and wood have been collected, grafted and conserved at ISSA.

Studies have been carried out by CNR Porano on the variability and genetics of the above-mentioned cultivars and of natural populations from Italy and Turkey. Silvicultural treatments on coppices and their eventual conversion to high forest are being developed at ISSA.

**Elms (*Ulmus* sp.)**

*Institute: CNR-Pathology of Forest Species, Florence*

Particular studies have been carried out on *Ulmus* for 15 years. The main aim is to select clones resistant to *Ophiostoma ulmi*. Interspecific hybridizations and selection via inoculation of the mushroom are the main tool used in this strategy. Two clones give very good results and will be patented. One of them is characterized by good growth.

Germplasm collections and trials of *Ulmus minor* and of the main foreign produced clones are conserved at CNR. Also some samples from the main species are conserved: *U. japonica, U. wallichiana, U. chenmoui, U. wilsoniana, U. parvifolia, U. pumila, U. macrocarpa* and *U. villosa*.

Because of the major sensitivity of some of these species to the agents of "elm yellowing," research is being carried out on phytoplasmas of Ulmaceae.

**Italian alder (*Alnus cordata*)**

*Institute: Dept. of Silviculture, University of Florence*

This peculiar species has been widely investigated for genetic aspects by the Department of Silviculture, Chair of Forest Tree Breeding for the past 20 years. Main studies were on discrimination of populations using morphological and phenological traits.

Morphological, phenological and breeding traits have also been studied as a model for heritability and relations among characters. Several experimental trials and collections are being grown.

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# Country Reports: the Temperate Zone

## Present status of Noble Hardwoods in Croatia

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**Summary**
The paper presents relevant data on Croatian forests, present status of Noble Hardwoods (*Acer, Fraxinus, Ulmus, Tilia, Juglans, Castanea sativa, Alnus glutinosa* and *Prunus avium*), and activities aiming at the conservation of genetic resources of Noble Hardwood in Croatia.

### Introduction

Conservation of genetic resources of Noble Hardwoods should be given the highest priority in any extensive programme of forest resources management. It is very important to conserve the existing genetic diversity of forest stands in which Noble Hardwoods are present. The most important Noble Hardwoods belong to the genera *Acer, Fraxinus, Ulmus, Tilia* and *Juglans*. The national strategy for conservation of forest genetic resources is in a preparatory phase. Noble Hardwoods will be included as individual species.

### Forests in Croatia

Forests are the most valuable natural resource in Croatia. With 0.51 ha of forest per inhabitant, Croatia is a European country with significant forest area. Forests and forest land comprise 43.5% of Croatia. Out of 2 457 648 ha total forest land, 84% is stocked, while the remaining 16% (396 139 ha) is comprised of various groups of unstocked forest land.

Forests and forest land belong to: State forest (managed by a public enterprise 'Hrvatske šume'), 1 946 998 ha (79%); private, 458 342 ha (19%); other, 52 308 ha (2%). The total forest land is covered by 53% valuable high forests, 31% coppice forests and 11.5% different degraded forest forms (maquis, garrigue and brushwood), while 4.5% is covered by newly planted forest culture and plantations.

It is stated in the new General Management Plan of Forestry that the growing stock in all Croatian forests amounts to 300 million $m^3$, consisting of 84% broadleaved and 16% coniferous species.

Broadleaved species are represented by the following tree species: beech (35%), oak (27%), hornbeam (8%), ash (3%), other hard broadleaved (7%) and soft broadleaved (4%). The most important coniferous tree species are fir and spruce (13%), pine (2%) and other (1%).

The total annual current volume increment amounts to 8.8 million $m^3$ from which around 7.7 million $m^3$ belong to broadleaved and 1.1 million $m^3$ to coniferous species (Table 1). The annual allowable cut has been calculated according to the new Management Plan of Forestry for all Croatian forests in gross amounts of 5.5 million $m^3$. In the state forests the annual gross allowable cut amounts to 4.8 million $m^3$ (87% of broadleaved and 13% of conifers). The allowable cut in Croatian forests has been diminished to almost 40% in comparison with the removals before hostilities.

The forestry and wood industry contribute 3.7% to the gross national product of the Republic of Croatia. Although the contribution of the forestry and wood industry to the gross national product is less than 4%, the export of products amounts to 10% of the entire export of Croatia.

## Present status of Noble Hardwood

After some discussion with the forest and wood industry scientists it was suggested that Noble Hardwood genera or tree species in Croatia would be: *Acer, Fraxinus, Ulmus, Tilia, Juglans, Castanea sativa, Alnus glutinosa* and *Prunus avium* with other fruit trees. The following data on Noble Hardwoods are given in Table 2: growing stock, growing stock per ha, annual current increment, current increment per ha, total annual gross allowable cut and annual cut according to structure (saw logs, other roundwood, pulpwood and fuelwood). Relation to annual current increment and annual cut is given in Table 3. It can be seen that the allowable annual cut is only 61.4% of annual increment. This means that there is no uncontrolled cutting of Noble Hardwood species in Croatia.

The total hardwood and softwood production in 1993 was 741 000 $m^3$ (516 000 $m^3$ + 225 000 $m^3$) net, but the marketing structure of 1993 shows the total amount of 917 000 $m^3$ (687 000 $m^3$ hard broadleaved and 230 000 $m^3$ softwood) was sealed. This difference is from a reduction in marketing in 1992.

Noble Hardwoods in Croatia are present in the following areas:

- Lowland forests (*Fraxinus angustifolia, Alnus glutinosa, Ulmus carpinifolia, Ulmus laevis, Acer campestre, Acer tataricum*). The lowland forests of Croatia are located along the large rivers, in the areas of Podravina, Podunavlje, Posavina and Pokuplje. The entire lowland region of Croatia from 80 to 200 m above sea level belongs to the Pannonian vegetation zone. In this zone, forests of peduncled oak and common hornbeam predominate (*Carpino betuli – Quercetum roboris*).
- Forests on low and high hills and mountains (*Fraxinus parvifolia, Fraxinus excelsior, Ulmus minor, Acer platanoides, Acer pseudoplatanus, Castanea sativa, Prunus avium, Tilia* sp.). This region deals with the forests inhabiting low hills, high hills and mountains in Croatia from Slavonia in the east to the border with Slovenia in the west, and the Dinaric mountain range in the south, at altitudes from 150 to 1060 m.
- Forests of high hills and mountains in the Dinaric region (*Acer pseudoplatanus, Fraxinus excelsior, Tilia* sp.). The Dinaric beech–fir mixed forests (*Abieti – Fagetum dinaricum*) is the dominant ecological and economic base for the whole hilly and mountain range. Selective beech-fir forests developed at altitudes ranging between 700 and 1200 m above sea level. Beech forests encompass a very important belt of both economic and protective forests, especially at higher altitudes and on steep terrains.
- Forests of the Mediterranean region. These forests are divided into two belts: the eu-Mediterranean and the sub-Mediterranean belt from Istria to Dubrovnik (evergreen oak and flowering ash forests (*Orno - Quercetum ilicis*).
- Black walnut and locust are artificially planted mostly in Slavonia along the Drava and Danube rivers. Walnut (*Juglans regia*) is planted by farmers as individual trees. There are same small private or state plantations that originate from seeds or clones.

**Table 1.** The growing stock in all forests of Croatia (New General Management Plan of Forestry).

| | Even-aged forests | | | | Selection forests | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Growing stock ($m^3$) | | Increment ($m^3$) | | Growing stock ($m^3$) | | Increment ($m^3$) | | Growing stock ($m^3$) | | Increment ($m^3$) | |
| **Tree species** | **Total** | **Per ha** | **Total** | **Per ha** | **Total** | **Per ha** | **Total** | **Per ha** | **Total** | **Per ha** | **Total** | **Per ha** |
| Beech | 48 000 346 | 31.51 | 1 583 087 | 1.04 | 5 729 7266 | 106 | 1 364 592 | 2.54 | 105 297 612 | 51.08 | 2 947 679 | 1.43 |
| Oak | 83 059 227 | 54.52 | 2 301 342 | 1.51 | 752 833 | 1 | 33 890 | 0.07 | 83 812 060 | 40.65 | 2 335 232 | 1.13 |
| Ash | 9 494 804 | 6.23 | 305 435 | 0.20 | – | – | – | – | 9 494 804 | 4.61 | 305 435 | 0.15 |
| Elm | 341 027 | 0.22 | 13 504 | 0.01 | – | – | – | – | 341 027 | 0.17 | 13 504 | 0.01 |
| Hornbeam | 24 094 276 | 15.82 | 886 917 | 0.58 | 827 899 | 2 | 18 783 | 0.03 | 24 922 175 | 12.09 | | 0.44 |
| Maple | 911 764 | 0.60 | 28 679 | 0.02 | 106 000 | – | 2 610 | – | 1 017 764 | 0.49 | 31 289 | 0.02 |
| Chestnut | 2 824 255 | 1.85 | 132 025 | 0.09 | 1 600 | – | – | – | 2 825 855 | 1.37 | 132 025 | 0.06 |
| Locust | 2 139 496 | 1.40 | 116 231 | 0.08 | – | – | – | – | 2 139 496 | 1.04 | 116 231 | 0.06 |
| Black walnut | 209 836 | 0.14 | 6 447 | – | – | – | – | – | 209 836 | 0.10 | 6 447 | – |
| Fruit trees | 458 678 | 0.30 | 19 746 | 0.01 | – | – | – | – | 458 678 | 0.22 | 19 746 | 0.01 |
| Other hardwood | 4 846 290 | 3.18 | 195 217 | 0.13 | 4 111 914 | 8 | 137 583 | 0.26 | 8 958 204 | 4.35 | 332 800 | 0.16 |
| Lime trees | 2 067 872 | 1.36 | 87 393 | 0.06 | – | – | – | – | 2 067 872 | 1.00 | 87 393 | 0.04 |
| Other softwood | 9 590 476 | 6.30 | 484 252 | 0.32 | 3 742 | – | 165 | – | 9 594 218 | 4.65 | 484 417 | 0.23 |
| Conifers | 8 083 239 | 5.31 | 312 667 | 0.20 | 39 188 322 | 73 | 750 711 | 1.39 | 47 271 561 | 22.93 | 1 063 378 | 0.52 |
| **Total Volume** | 196 121 586 | 128.74 | 6 472 942 | 4.25 | 102 289 576 | 190 | 2 308 334 | 4.29 | 298 411 162 | 144.75 | 8 781 276 | 4.26 |
| **Total Area** | 1 523 361 | | | | 538 148 | | | | 2 061 509 | | | |

**Table 2.** Growing stock, increment and allowable cut of Noble Hardwood for state forests.

| Tree species | Vol. of growing stock ($m^3$) | | Increment ($m^3$) | | Allowable cut per year ($m^3$) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Per ha | Total | Per ha | Saw logs | Other roundwood | Fuel | Waste | Total |
| *Acer* | 1 017 764 | 0.49 | 31 289 | 0.02 | 978 | – | 8 556 | 1 953 | 11 487 |
| *Fraxinus* | 9 494 804 | 4.61 | 305 435 | 0.15 | 122 297 | 13 884 | 63 456 | 31 097 | 236 347 |
| *Ulmus* | 341 027 | 0.12 | 13 504 | 0.01 | 576 | – | 2 833 | 698 | 4 107 |
| *Tilia* | 2 167 872 | 1.00 | 87 393 | 0.04 | 21 248 | – | 1 932 | 7 818 | 52 522 |
| *Juglans* | 209 836 | 0.10 | 6 447 | – | 225 | 376 | 256 | 125 | 982 |
| *Castanea sativa* | 2 825 855 | 1.37 | 132 025 | 0.06 | 4 738 | 11 055 | 13 745 | 4 972 | 48 255 |
| *Alnus glutinosa* | 3 328 261 | 1.61 | 128 561 | 0.06 | 26 431 | – | 6 177 | 10 486 | 87 912 |
| *Prunus avium*, fruit trees | 458 678 | 0.22 | 19 746 | 0.01 | 459 | 92 | 2 160 | 525 | 3 978 |
| Total | 19 744 097 | 9.57 | 724 400 | 0.35 | 176 952 | 25 407 | 99 115 | 58 174 | 444 608 |

**Table 3.** Noble Hardwood species: relation of increment to allowable cut for state forests.

| Genera (or species) | Increment ($m^3$) | Allowable cut $m^3$/ha | $m^3$ | $m^3$/ha |
|---|---|---|---|---|
| *Acer* | 31 289 | 0.02 | 11 487 | 0.006 |
| *Fraxinus* | 305 435 | 0.15 | 236 347 | 0.115 |
| *Ulmus* | 13 504 | 0.01 | 4 107 | 0.002 |
| *Tilia* | 83 393 | 0.04 | 52 522 | 0.025 |
| *Juglans* | 6 447 | – | 982 | – |
| *Castanea sativa* | 132 025 | 0.06 | 48 255 | 0.023 |
| *Alnus glutinosa* | 128 561 | 0.06 | 187 912 | 0.043 |
| *Prunus avium* | 19 746 | 0.01 | 3 978 | 0.002 |
| Total | 724 400 | 0.35 | 444 608 | 0.216 |

## Conservation of Noble Hardwoods genetic resources in Croatia

The national strategy for conservation of forest genetic resources in Croatia is in the preparatory phase. Almost all the forests are naturally regenerated by silvicultural management (95%). Only 5% of forest are artificially regenerated using domestic (spruce, pine) and exotic species (eastern white pine, Douglas fir, European larch) and clones (poplars and willows). A permanent silvicultural treatment and protection of forests is enabled by this country's diverse landscape which continuously changes from lowland river valleys, through Slavonian oak forests, green hills of central Croatia, coniferous forests of Gorski Kotar, the Dinaric Alps with Velebit mountain down to the Adriatic sea with its thousand islands and evergreen vegetation.

The programme for Noble Hardwoods genetic resources conservation should take into account the preservation of variability, namely population variability, at the provenance and local population level and the family variability and individual variability within families.

The *in situ* preservation of Noble Hardwood genetic resources in Croatia could initially use selected seed stands of Noble Hardwood species (Table 4), including mixed and pure, even-aged and uneven-aged, well-managed forests and nature-protected stands where regular silvicultural operations such as care, cleaning and thinning should be carried out.

According to the Law on Nature Protection, all 746 nature areas in Croatia are protected, of which 322 reserves have a total area of 447 197 ha, almost 7.3% of the total Croatian territory. Protected objects of nature are divided into 10 categories (strict reserves, national parks, nature parks, special reserves, park forests, etc.).

There have been some improvement programmes for two Noble Hardwoods, black alder and chestnut. Two black alder clonal seed orchards were established with 30 and 32 clones and a provenance test of black alder was established from eight provenances. Chestnut progeny tests were established from 15 different families.

Research and inventory of forest tree species are needed in order to develop the national strategy for conservation of forest genetic resources in Croatia. The objective would be to maintain and improve variability, not only for Noble Hardwoods, but for all forest tree species, by monitoring genetic diversity as the basis for future activities.

**Table 4.** Forest seed stands of Noble Hardwood species.*

| Tree species | Forest administration | Locality | Area (ha) | Age (years) |
|---|---|---|---|---|
| *Fraxinus angustifolia* | Vinkovci | Desicevo | 5.77 | 97 |
| | Vinkovci | Desicevo | 101.73 | 105 |
| | Vinkovci | Slavir | 20.43 | 128 |
| | Vinkovci | Dobrinja | 143.71 | 110 |
| | Našice | Đurdevacke niz. šume | 77.12 | 91 |
| | Našice | Kapelacki lug | 108.88 | 101 |
| | Našice | Slatinske niz. šume | 7.09 | 101 |
| | Bjelovar | Cesma | 24.51 | 95 |
| | Koprivnica | Repaš | 5.35 | 99 |
| | Koprivnica | Đurdevacke šume | 15.95 | 65 |
| | Gradiška | Kapela | 47.06 | 98 |
| | Zagreb | Kutinske šume | 11.96 | 87 |
| | Zagreb | "Josip Kozarac" | 15.95 | 148 |
| | Zagreb | Turopoljski lug | 34.86 | 97 |
| | Karlovac | Jastrebarski lugovi | 66.12 | 106 |
| **Total** | | | **686.39** | |
| *Ulmus* sp. | only single trees are selected in mixed lowland forest | | | |
| *Tilia* sp. | Vinkovci | Vrbanjske šume | 60.23 | 101 |
| | Vinkovci | Otocke šume | 0.72 | 28 |
| | Našice | Kapelacki lugovi | 108.88 | 101 |
| | Pozega | Juzna Krndija II | 2.00 | 96 |
| | Bjelovar | Viroviticka Bilogora | 3.10 | 68 |
| **Total** | | | **171.83** | |
| *Juglans nigra* | Vinkovci | Jelaš | 14.40 | 82 |
| | Vinkovci | Dubrave | 20.38 | 75 |
| | Osijek | Haljevo | 4.00 | 68 |
| **Total** | | | **38.78** | |
| *Castanea sativa* | Pozega | Istocni Psunj | 21.44 | 78 |
| *Alnus glutinosa* | Našice | Krndija | 18.92 | 67 |
| | Koprivnica | Đurdevacke niz. šume | 13.17 | 59 |
| | Zagreb | Zutica | 5.50 | 94 |
| | Zagreb | Popovacke niz. šume | 7.33 | 70 |
| **Total** | | | **44.92** | |
| *Prunus avium* | Pozega | Juzna Krndija | 15.20 | 96 |
| **Total** | | | **978.56** | |

* For the genus *Acer* there are no selected seed stands yet.

# Noble broadleaves in Slovenia

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## Introduction

Forests cover 53% of Slovenia with a total growing stock of 208.5 million $m^3$. Sustainable management of forests on the basis of their multiple functions and close-to-nature forest management has a long tradition, owing to the large Karst area and labile forest ecosystems, in which any clearcutting would have resulted in degradation and erosion of deforested land.

Phytogeographically Slovenia is very diverse and is divided into six regions: Alpine, Pre-alpine, Subpannonian, Dinaric, Predinaric and Submediterranean. The ecological conditions and the forestry management in the past have resulted in the predominant forest types being coniferous, mainly of Norway spruce and silver fir, while among broadleaves the predominant species are beech and oak.

The potential forest types in 1990 (Anonymous 1990) included: beech forest on carbonate ground rock (26.9% of forest area), acidophilous beech forest (17%), forest of beech and silver fir (15.3%), forest of beech and oak (10.9%), forest of oak and hornbeam (7.9%), thermophilous broadleaves forest (5.1%), silver fir forest (4.5%), mountainous beech forest (3.9%), pine forest (3.5%), oak forest (3%), spruce forest (1.3%), forest of willow and alder (0.6%). Noble broadleaves comprised 0.1% of forest area.

## Noble broadleaf and overlooked tree species in Slovenia

In Slovenia the expression Noble Hardwoods is equal to **noble broadleaves,** which has been used for a group of six species: wild cherry *(Prunus avium),* broadleaved lime *(Tilia platyphyllos),* Wych elm *(Ulmus glabra),* common ash *(Fraxinus excelsior),* sycamore *(Acer pseudoplatanus)* and common walnut *(Juglans regia).* These are species which usually do not grow in stands comprised only of themselves, which have similar, usually high ecological demands and which can all produce wood of high quality.

There is, however, a long list of other tree species which should receive more attention. In Slovenia five of the economically most important tree species (Norway spruce, common beech, silver fir, common oak, Scots pine) constitute as much as 90% of the wood mass, while around 65 species represent a mere 10% (Anonymous 1996). However, neither an exact definition and characteristic traits nor an exact list of **overlooked tree species** has been accepted so far. A list of species which were not given any attention, and for which no efforts were made for their preservation or use, is difficult and subjective, but from our opinion around 2/3 of the 70 indigenous forest tree species can be considered as overlooked (Wraber and Skoberne 1989; Kotar 1995). The broadleaved species among these are listed in Table 1.

The species reaching their geographical borderline in Slovenia are particularly important for their role in increasing biodiversity, but unfortunately these are also the most vulnerable species which are difficult to preserve. None have been economically important or intensively studied or supported in the forests.

**Table 1.** Overlooked broadleaved species in Slovenia.

| Scientific name | Common name | Status[1] |
|---|---|---|
| *Acer campestre* | Field maple | |
| *Acer monspenssulanum* | Montpellier maple | + |
| *Acer obtusatum* | Coarse-leafed maple | + |
| *Acer tataricum* | Tartar maple | +* |
| *Alnus incana* | Grey alder | |
| *Betula pendula* | Silver birch | |
| *Betula pubescens* | Downy birch | |
| *Carpinus betulus* | Common hornbeam | |
| *Carpinus orientalis* | Oriental hornbeam | |
| *Celtis australis* | Southern nettle-tree | +* |
| *Cercis siliquastrum* | Judas tree | +* |
| *Ficus carica* | Common fig | + |
| *Fraxinus ornus* | Manna ash | |
| *Ilex aquifolium* | Common holly | |
| *Laburnum alpinum* | Scotch laburnum | |
| *Laburnum alschingeri* | Alschinger laburnum | |
| *Laburnum anagyroides* | Common laburnum | |
| *Laurus nobilis* | Bay laurel | +* |
| *Malus sylvestris* | Common crab apple | * |
| *Mespilus germanica* | Medlar | * |
| *Olea europaea* | Olive | + |
| *Ostrya carpinifolia* | European hop hornbeam | |
| *Phillyrea latifolia* | Phillyrea | +* |
| *Pistacia lentiscus* | Lentisc pistachio | + |
| *Pistacia terebinthus* | Terebinth pistachio | + |
| *Prunus mahaleb* | Mahaleb cherry | |
| *Prunus padus* | Bird cherry | |
| *Pyrus amygdaliformis* | Almond-leafed pear | * |
| *Pyrus pyraster* | Wild pear | * |
| *Quercus cerris* | Turkey oak | |
| *Quercus crenata* | False-cork oak | +* |
| *Quercus ilex* | Holm oak | +* |
| *Quercus pubescens* | Downy oak | |
| *Salix alba* | White willow | |
| *Salix caprea* | Goat willow | |
| *Salix daphnoides* | Violet willow | |
| *Salix elaeagnos* | Hoary willow | |
| *Salix fragilis* | Crack willow | |
| *Salix pentandra* | Bay willow | |
| *Salix viminalis* | Common osier | |
| *Sorbus aria* | Whitebeam | |
| *Sorbus aucuparia* | Rowan | |
| *Sorbus domestica* | True service tree | * |
| *Sorbus torminalis* | Wild service tree | * |

[1] * marks the endangered, vulnerable or rare species in terms of IUCN categories; + marks the species on the borderline and occurring in limited numbers in Slovenia.

Another specific expression is used to characterize a group of species – these are so-called minor tree species (also secondary tree species, subordinate species, accessory species or associated tree species). Minor tree species of forest stands were defined as "relative choice of tree species sharing a modest part in forest biomass structure and having apparently little influence on ecosystem processes" (Robic 1995). The choice is usually relative because the majority of tree species can take over different roles in different forest stands. Therefore, the same tree species, for example beech which dominates and is widespread in mountain beech forests, can be of minor (secondary) importance in spruce or oak forest types. In general, long-lived and shade-tolerant species are rarely among minor tree species, common yew being the exception that only confirms the rule. The number of minor tree species exceeds the number of overlooked tree species, because some minor tree species, for example our classical Noble Hardwoods, such as the wild cherry, have been given sufficient attention in silvicultural practice.

### Current importance of noble broadleaves in the forest sector of Slovenia

The growing stock in 1990 (Anonymous 1990) was 108.6 million $m^3$ for coniferous and 99.9 million $m^3$ for broadleaved species. For eight tree species this represented: spruce 68.7, silver fir 24.7, larch 2.4, pine and other conifers 12.8, beech 62.7, oak 16.5, noble broadleaves 6.0, other hardwood broadleaves 11.6, softwood broadleaves 3.1 million $m^3$. The current percentage of noble broadleaves in the growing stock in Slovenian forests is 3%, of other broadleaves (except beech and oak) it is 7%.

The growing stock of noble broadleaves and some overlooked tree species and their distribution in forestry units after the general inventory from 1990 (Anonymous 1990) are shown in Table 2.

Older forest management plans used to consider only conifers, beech, oak, sycamore and ash. All other noble broadleaved species, such as wild cherry, lime and elm, were included as 'other broadleaves'. The general forest inventory from 1990 has already divided this category into several individual tree species, which included the six noble broadleaves and 15 overlooked tree species.

The inventory is based partially on estimates and partially on measurements of forest tree species with their accompanying ecological descriptions in forest units (86 246 such forest units cover the whole forest area) for the 14 forest management districts in Slovenia. Six noble broadleaves and the overlooked autochthonous broadleaved tree species are included.

In Table 2 each tree species is presented with the total area of forest units in which it occurs, with the growing stock per area of forest units and per hectare, with the total growing stock of all broadleaves and coniferous trees per ha, the percentage of the tree species in relation to the total growing stock in the relevant forest units, and the number of forest units in which it grows. All data are linked to four altitudinal zones (below 400 m, 400-700 m, 700-1000 m and above 1000 m) and separated after their total area for carbonate and silicate soils. The percentage of broadleaves is bigger than it should be in the total growing stock of all forest trees in Slovenia, because it is related only to the forest units in which these broadleaves grow.

Irrespective of the great ecological diversity of Slovenia, the considered broadleaved tree species occur in almost all phytogeographical regions of Slovenia and in all forest management districts, the main restriction being the altitudinal zone.

**Sycamore** (*Acer pseudoplatanus*) grows in all forest management districts and in all altitudinal zones. Its largest areas belong to the second altitudinal zone and it grows mainly on carbonate soils.

**Norway maple** (*Acer platanoides*) grows in all forest management districts up to 1000 m high. In the fourth altitudinal zone it is very rare, while it predominates in the second zone. It grows mainly on carbonate soils and is rather limited in comparison with sycamore.

Table 2. The growing stock of noble broadleaves and some overlooked tree species.

| Tree species | Elevation (m) | Area of forest units (ha) | Stock/unit ($m^3$) | Stock/ha ($m^3$) | Stock/ha conif.+ brdl. ($m^3$) | Trees/ha (%) | No. units | Ground area (ha) on soils: Carbonate | Silicate |
|---|---|---|---|---|---|---|---|---|---|
| **Sweet chestnut** | to 400 | 88941 | 1210551 | 10.18 | 174.54 | 6.3 | 7523 | 72469 | 16480 |
| *(Castanea sativa)* | 400-700 | 87066 | 1216658 | 9.46 | 203.84 | 4.7 | 5260 | 60451 | 26616 |
| | 700-1000 | 12382 | 96500 | 5.45 | 200.81 | 3.4 | 692 | 6641 | 5741 |
| | >1000 | 32 | 94 | 3 | 292 | 1.0 | 1 | 32 | |
| | **Total** | **188420** | **2523803** | **8.27** | **196.41** | **4.7** | **13476** | **139584** | **48837** |
| **Walnut** | to 400 | 573 | 2902 | 3.70 | 169.40 | 2.2 | 38 | 445 | 128 |
| *(Juglans nigra)* | 400-700 | 795 | 782 | 1.12 | 225.87 | 0.5 | 33 | 585 | 209 |
| | 700-1000 | 377 | 570 | 2.25 | 201.75 | 1.3 | 16 | 166 | 211 |
| | >1000 | 11 | 177 | 16.00 | 313.00 | 5.1 | 1 | 11 | |
| | **Total** | **1756** | **4431** | **3.08** | **200.91** | **1.5** | **88** | **1208** | **548** |
| **Sycamore** | to 400 | 72629 | 561849 | 7.64 | 182.28 | 4.3 | 5375 | 66933 | 5686 |
| *(Acer pseudo-* | 400-700 | 225384 | 2038153 | 7.92 | 207.61 | 3.8 | 14497 | 193718 | 31676 |
| *platanus)* | 700-1000 | 134096 | 1548164 | 10.69 | 251.92 | 4.2 | 8526 | 117817 | 16279 |
| | >1000 | 61243 | 573284 | 11.90 | 297.45 | 3.9 | 3914 | 55493 | 5750 |
| | **Total** | **493352** | **4721450** | **9.41** | **231.33** | **4.1** | **32312** | **433961** | **59392** |
| **Norway maple** | to 400 | 5461 | 24364 | 3.55 | 183.66 | 1.9 | 338 | 4570 | 891 |
| *(Acer platanoides)* | 400-700 | 8933 | 28165 | 3.00 | 188.08 | 1.9 | 571 | 7452 | 1481 |
| | 700-1000 | 3808 | 10234 | 4.22 | 220.22 | 1.8 | 195 | 3087 | 721 |
| | >1000 | 299 | 286 | 2.00 | 221.00 | 0.9 | 13 | 238 | 61 |
| | **Total** | **18500** | **63049** | **3.35** | **199.29** | **1.8** | **1117** | **15347** | **3153** |
| **Field maple** | to 400 | 12034 | 16742 | 1.60 | 163.2 | 1.3 | 864 | 10860 | 1174 |
| *(Acer campestre)* | 400-700 | 16897 | 19224 | 1.09 | 194.45 | 0.6 | 813 | 15226 | 1671 |
| | 700-1000 | 5929 | 3985 | 0.90 | 209.27 | 0.5 | 239 | 5241 | 688 |
| | >1000 | 331 | 305 | 1.00 | 234.85 | 0.9 | 18 | 300 | 30 |
| | **Total** | **35190** | **40256** | **1.15** | **197.87** | **0.8** | **1934** | **31627** | **3564** |

| Tree species | Elevation (m) | Area of forest units (ha) | Stock/unit ($m^3$) | Stock/ha ($m^3$) | Stock/ha conif.+ brdl. ($m^3$) | Trees/ha (%) | No. units | Ground area (ha) on soils: Carbonate | Silicate |
|---|---|---|---|---|---|---|---|---|---|
| **Common ash** | to 400 | 19288 | 109447 | 6.07 | 177.15 | 3.9 | 1866 | 17352 | 1936 |
| *(Fraxinus* | 400-700 | 63871 | 287847 | 4.25 | 196.58 | 2.2 | 4137 | 47720 | 16151 |
| *excelsior)* | 700-1000 | 28781 | 104739 | 4.33 | 221.83 | 2.9 | 1626 | 22499 | 6282 |
| | >1000 | 9819 | 13221 | 2.88 | 245.00 | 1.2 | 449 | 9260 | 559 |
| | **Total** | **121759** | **515254** | **4.52** | **207.15** | **2.7** | **8078** | **96830** | **24929** |
| **Manna ash** | to 400 | 29687 | 112372 | 3.37 | 146.00 | 2.9 | 1542 | 29202 | 485 |
| *(Fraxinus ornus)* | 400-700 | 45795 | 147842 | 3.25 | 129.66 | 3.0 | 2263 | 43885 | 1910 |
| | 700-1000 | 17568 | 42919 | 2.16 | 138.00 | 1.8 | 793 | 16835 | 733 |
| | >1000 | 2712 | 5347 | 2.12 | 124.12 | 2.6 | 105 | 2659 | 53 |
| | **Total** | **95763** | **308480** | **2.72** | **134.32** | **2.5** | **4703** | **92581** | **3181** |
| **Narrow-leafed ash** | to 400 | 7831 | 186602 | 13.62 | 193 | 6.7 | 579 | 2304 | 5528 |
| *(Fraxinus* | 400-700 | 1443 | 5702 | 2.60 | 195.4 | 1.3 | 109 | 1062 | 381 |
| *angustifolia)* | 700-1000 | 823 | 1991 | 2.62 | 225.75 | 2.4 | 33 | 642 | 181 |
| | >1000 | 59 | 45 | 1.00 | 31.00 | 8.3 | 2 | 50 | 9 |
| | **Total** | **10156** | **194340** | **5.64** | **191.64** | **3.6** | **723** | **4058** | **6098** |
| **Wych elm** | to 400 | 7489 | 11345 | 2.80 | 192.1 | 2.2 | 464 | 6768 | 721 |
| *(Ulmus glabra)* | 400-700 | 31510 | 83778 | 2.91 | 228.75 | 1.3 | 1649 | 26131 | 5379 |
| | 700-100 | 19481 | 52679 | 3.00 | 258.00 | 1.1 | 910 | 17326 | 2155 |
| | >1000 | 2458 | 4292 | 3.50 | 287.25 | 1.1 | 110 | 2315 | 143 |
| | **Total** | **60938** | **152094** | **2.97** | **233.86** | **1.5** | **3133** | **52540** | **8397** |
| **Smooth-leafed elm** | to 400 | 2047 | 5112 | 2.37 | 178.62 | 1.4 | 120 | 1366 | 681 |
| *(Ulmus minor)* | 400-700 | 1128 | 4032 | 5.50 | 254.83 | 2.0 | 52 | 1072 | 56 |
| | 700-1000 | 481 | 890 | 1.50 | 187.16 | 0.8 | 22 | 474 | 8 |
| | >1000 | 44 | 38 | 3.50 | 76.50 | 4.6 | 2 | 44 | |
| | **Total** | **3700** | **10072** | **3.09** | **192.45** | **1.7** | **196** | **2955** | **745** |

| Tree species | Elevation (m) | Area of forest units (ha) | Stock/unit ($m^3$) | Stock/ha ($m^3$) | Stock/ha conif.+ brdl. ($m^3$) | Trees/ha (%) | No. units | Ground area (ha) on soils: Carbonate | Silicate |
|---|---|---|---|---|---|---|---|---|---|
| **Broad-leafed lime** | to 400 | 21931 | 73493 | 4.38 | 179.38 | 2.6 | 1637 | 18688 | 3243 |
| *(Tilia platyphyllos)* | 400-700 | 33208 | 128107 | 3.38 | 194.84 | 1.8 | 1771 | 27639 | 5569 |
| | 700-1000 | 12524 | 40385 | 2.58 | 225.25 | 1.5 | 563 | 10996 | 1528 |
| | >1000 | 778 | 1423 | 0.80 | 259.80 | 0.5 | 30 | 545 | 234 |
| | **Total** | **68440** | **243408** | **3.16** | **206.21** | **1.8** | **4001** | **57867** | **10573** |
| **Common hornbeam** | to 400 | 201471 | 4075245 | 15.21 | 162.5 | 10.2 | 17670 | 160489 | 40982 |
| *(Carpinus betulus)* | 400-700 | 237870 | 2932516 | 11.23 | 186.61 | 6.4 | 15305 | 211242 | 26628 |
| | 700-1000 | 60881 | 457193 | 7.61 | 221.07 | 3.9 | 3440 | 55003 | 5878 |
| | >1000 | 14779 | 37785 | 5.36 | 216.27 | 3.3 | 711 | 14105 | 674 |
| | **Total** | **515002** | **7502739** | **10.13** | **195.17** | **6.2** | **37126** | **440839** | **74162** |
| **Wild cherry** | to 400 | 42779 | 100190 | 2.25 | 172.66 | 1.2 | 3061 | 33650 | 9128 |
| *(Prunus avium)* | 400-700 | 53437 | 120863 | 2.08 | 188.66 | 1.2 | 3109 | 44411 | 9026 |
| | 700-1000 | 15955 | 23956 | 1.58 | 230.41 | 0.7 | 733 | 12900 | 3055 |
| | >1000 | 904 | 399 | 0.57 | 266.42 | 0.2 | 39 | 724 | 180 |
| | **Total** | **113075** | **245408** | **1.74** | **208.51** | **0.9** | **6942** | **91685** | **21389** |
| **Wild service tree** | to 400 | 9113 | 10266 | 1.12 | 178.50 | 0.7 | 520 | 8036 | 1078 |
| *(Sorbus torminalis)* | 400-700 | 8047 | 12331 | 1.60 | 162.50 | 1.2 | 445 | 7229 | 818 |
| | 700-1000 | 1337 | 1361 | 1.77 | 184.11 | 1.6 | 72 | 1079 | 258 |
| | >1000 | 1255 | 3753 | 3.66 | 186.00 | 4.0 | 94 | 378 | 877 |
| | **Total** | **19753** | **27711** | **1.73** | **175.60** | **1.5** | **1131** | **16722** | **3031** |
| **Whitebeam** | to 400 | 6622 | 14060 | 2.70 | 138.1 | 2.5 | 382 | 6246 | 376 |
| *(Sorbus aria)* | 400-700 | 35755 | 90148 | 2.00 | 156.53 | 1.3 | 1660 | 33225 | 2530 |
| | 700-1000 | 23267 | 60964 | 1.91 | 184.08 | 1.1 | 1057 | 21607 | 1661 |
| | >1000 | 9127 | 17739 | 1.87 | 157.62 | 1.5 | 456 | 8821 | 306 |
| | **Total** | **74771** | **182911** | **2.11** | **160.23** | **1.6** | **3555** | **69899** | **4873** |

| Tree species | Elevation (m) | Area of forest units (ha) | Stock/unit ($m^3$) | Stock/ha ($m^3$) | Stock/ha conif.+ brdl. ($m^3$) | Trees/ha (%) | No. units | Ground area (ha) on soils: | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Carbonate | Silicate |
| **Rowan** | to 400 | 26 | 4 | 0.00 | 171.00 | 0.0 | 1 | | 26 |
| *(Sorbus aucuparia)* | 400-700 | 64 | 57 | 1.00 | 224.00 | 0.5 | 3 | 64 | |
| | 700-1000 | 625 | 569 | 1.00 | 228.00 | 0.4 | 22 | | 625 |
| | >1000 | 650 | 730 | 1.00 | 192.00 | 0.5 | 36 | | 650 |
| | **Total** | **1365** | **1360** | **0.75** | **203.75** | **0.4** | **62** | **64** | **1302** |
| **Hop hornbeam** | to 400 | 37924 | 352311 | 6.50 | 140.00 | 5.5 | 2034 | 36970 | 954 |
| *(Ostrya* | 400-700 | 89056 | 922968 | 9.25 | 155.75 | 7.1 | 4482 | 82964 | 6092 |
| *carpinifolia)* | 700-1000 | 38820 | 373352 | 8.66 | 175.83 | 5.9 | 1822 | 36563 | 2257 |
| | >1000 | 6270 | 48374 | 6.10 | 138.10 | 7.5 | 230 | 5978 | 292 |
| | **Total** | **172070** | **1697005** | **7.69** | **153.04** | **6.5** | **8568** | **162475** | **9596** |
| **Common alder** | to 400 | 58289 | 767227 | 7.50 | 165.08 | 5.1 | 5427 | 34531 | 24758 |
| *(Alnus glutinosa)* | 400-700 | 46725 | 296828 | 4.61 | 182.15 | 3.9 | 3237 | 33641 | 13084 |
| | 700-1000 | 7601 | 21057 | 2.83 | 221.25 | 2.0 | 469 | 4708 | 2893 |
| | >1000 | 786 | 1396 | 2.33 | 205.16 | 1.5 | 45 | 448 | 338 |
| | **Total** | **113401** | **1086508** | **4.60** | **191.51** | **3.4** | **9178** | **73328** | **41072** |
| **Grey alder** | to 400 | 2109 | 10736 | 4.55 | 184.44 | 2.8 | 186 | 1508 | 602 |
| *(Alnus incana)* | 400-700 | 6272 | 21679 | 8.36 | 183.36 | 7.6 | 523 | 3292 | 2980 |
| | 700-1000 | 5236 | 13297 | 2.66 | 239.22 | 1.2 | 332 | 2007 | 3230 |
| | >1000 | 1627 | 3798 | 2.42 | 256.28 | 0.9 | 78 | 969 | 658 |
| | **Total** | **15245** | **49510** | **4.83** | **211.77** | **3.5** | **1119** | **7775** | **7470** |
| **Common** | to 400 | 0 | 0 | 0.00 | 0.00 | 0.0 | 0 | | |
| **laburnum** | 400-700 | 6 | 11 | 2.00 | 245.00 | 0.8 | 1 | 6 | |
| *(Laburnum* | 700-1000 | 0 | 0 | 0.00 | 0.00 | 0.0 | 0 | | |
| *anagyroides)* | >1000 | 36 | 13 | 0.00 | 180.00 | 0.0 | 1 | 36 | |
| | **Total** | **42** | **24** | **1.00** | **212.50** | **0.4** | **2** | **36** | |

**Field maple** (*Acer campestre*) grows equally in all forest management districts and in all altitudinal zones. It is most frequent in the first and second altitudinal zones, and more frequent on carbonate soils than on silicates.

**Common ash** (*Fraxinus excelsior*) grows in all forest districts and in all four altitudinal zones. It is most frequent in the second altitudinal zone and on carbonate soils, where its areas are largest. In comparison to other tree species its percentage occurrence is biggest in lower altitudes.

**Manna ash** (*Fraxinus ornus*) is less frequent than the common ash. It occurs most frequently and in the biggest percentage in the second altitudinal zone and more frequently on carbonate soils than on silicates.

**Narrow-leafed ash** (*Fraxinus angustifolia*) is relatively rare in comparison with the other two ash species. It grows in all altitudinal zones, mainly in the first one, on silicates, and in all forest management districts except in the Karst and Bled district.

**Wych elm** (*Ulmus glabra*) grows in all forest management districts except in the Karst district, in all altitudinal zones, most frequently in the second zone. It is far more frequent on carbonate soils than on silicates.

**Smooth-leafed elm** (*Ulmus minor*) is relatively rare in comparison with Wych elm. It grows in all districts, mainly in the first altitudinal zone and its occurrence is diminishing with altitude. It is rare in the third zone. It grows mainly on silicates.

**Lime** (*Tilia platyphyllos, T. cordata*) grows in all districts and in all altitudinal zones but it is less frequent in higher altitudes. It is most frequent and has the highest growing stock in the second, partially in the first altitudinal zone. It is more frequent on carbonate soils than on silicates.

**Common hornbeam** (*Carpinus betulus*) is a tree species which occurs in all forest management districts and in all altitudinal zones. Its largest areas and highest frequency of occurrence are in the second and the first altitudinal zones. Its distribution is larger on carbonate soils than on silicates.

**Hop hornbeam** (*Ostrya carpinifolia*) grows in all districts and in all altitudinal zones. Its largest distribution is in the Karst district, where its percentage occurrence is also biggest. Its largest area, growing stock and frequency are in the second altitudinal zone, mainly on carbonate soils.

**Common alder** (*Alnus glutinosa*) grows in all districts and in all altitudinal zones, but is rare in the fourth zone. It is most frequent and grows on the largest areas in the first and second altitudinal zones, where its growing stock per ha and its percentage occurrence are greatest. It grows more frequently on carbonate soils than on silicates.

**Grey alder** (*Alnus incana*) grows in all districts and in all altitudinal zones. Its biggest areas and frequency are in the second and third altitudinal zones, and it grows equally on carbonate and silicate soils.

**Wild cherry** (*Prunus avium*) grows in all districts and in all altitudinal zones, but is relatively rare in the fourth zone. It occurs mainly in the second and first altitudinal zones, more often on carbonate soils than on silicates.

**Wild service tree** (*Sorbus torminalis*) grows in small areas in all districts, in all altitudinal zones, mainly in the first and second zones, while its biggest growing stock per ha and percentage of trees per ha is in the fourth zone. It grows mainly on carbonate soils.

**Whitebeam** (*Sorbus aria*) grows in all districts in all altitudinal zones, most frequently in the second and third zones, more often on carbonate soils than on silicates.

**Rowan** (*Sorbus aucuparia*) grows individually in the whole of Slovenia, but data on its growing stock and number of trees are only available for the Tolmin district. It grows in all altitudinal zones, most frequently in the fourth and third zone, mostly on silicate soils.

**Walnut** (*Juglans nigra, J. regia*) can not be differentiated from the forest inventory data. It grows on small areas up to the fourth altitudinal zone, more often on carbonate soils than on silicates.

**Common laburnum** (*Laburnum anagyroides*) grows individually and relatively rarely in the whole of Slovenia, but the forest inventory data are only available for the Tolmin district, where its primary importance is linked to the protective forests. It grows in all altitudinal zones.

## Annual forest reproductive material requirements

The annual area of natural regeneration is ca. 6500 ha. Only 600-700 ha are regenerated annually with reproductive material from forest nurseries. In 1995, the following structure of seedlings was used:

| | | | |
|---|---|---|---|
| **All coniferous species:** | | 1 253 850 seedlings | |
| **All broadleaf species:** | | 704 485 seedlings | |
| **All seedlings:** | | | |
| 54% | Norway spruce | 3.7% | common alder |
| 0.7% | silver fir | 0.3% | wild cherry |
| 4.1% | larch | 0.1% | lime |
| 1.6% | Scots pine | 0.1% | rowan |
| 2.5% | Austrian pine | 0.1% | common walnut |
| 0.1% | Douglas fir | 0.2% | black walnut |
| 11.1% | beech | 0.3% | red oak |
| 2.9% | sessile oak | 0.1% | manna ash |
| 6.9% | common oak | 0.1% | grey alder |
| 4.7% | sycamore | 0.3% | poplars |
| 5.2% | common ash | a few hundred seedlings | horse chestnut, black locust and crab apple. |

The main sources for seeds and seedlings are registered seed stands, while material from seed orchards is very limited.

Registration of seed stands started in Slovenia in 1955. Following its phytogeographical diversity Slovenia was divided into seven seed districts. Seed collecting and application were only allowed within these seven seed districts.

In the past few years the seed districts have been replaced by seed units. These are groups of comparable forest sites or phytocenological associations, in which the comparability is based mainly on their altitudinal zones and soils. The seed units comprise four units in four different altitudinal zones on carbonate soils and four different seed units in four altitudinal zones on silicate soils.

Each tree species belongs to its seed unit (8 seed units are possible), which is marked with a capital letter (i.e. 'P' is used for noble broadleaves), a number, which represents the altitudinal zone on limestone (1-4) or silicate (5-8) ground rock material and small letters 'k' (for carbonate) or 's' (for silicates).

The Register of seed stands is constantly under consideration regarding inscriptions of new seed stands and abandoning of the inappropriate ones. Until 1987, when the first total revision of seed stands was finished, the Register contained 416 seed stands of conifers and 73 seed stands of broadleaved tree species. At the moment, it includes a total of 404 seed stands, 328 of which are conifers and 76 are broadleaves. Seed stands of selected broadleaved tree species (all except beech and oak seed stands) are listed in Table 3. Seed stands are chosen from the total genepool of growing trees on the basis of their phenotypical appearance. The silvicultural measurements on them are adapted to their function.

In 1995, the second revision of seed stands was started. It is planned to be finished in 1996. In this revision, the inadequate seed stands are being omitted. Furthermore, the greatest interest is on choice of new seed stands of broadleaf trees, especially noble broadleaves and overlooked tree species. The new selection is guided by the requirements of the Slovenian Forest Service for forest reproductive material.

**Table 3.** Seed stands of selected broadleaved tree species.

| Register no. | Tree species | Seed unit | Area (ha) | Register no. | Tree species | Seed unit | Area (ha) |
|---|---|---|---|---|---|---|---|
| 3 | lime | P 1k | 4.00 | 73 | walnut | P 5s | 0.60 |
| 4 | field maple | P 1k | 4.00 | 74 | sycamore | P 3k | 0.46 |
| 7 | common ash | P 3k | 0.01 | 75 | sycamore | P 1k | 1.00 |
| 9 | sycamore | P 6s | 18.70 | 77 | common ash | P 5s | 0.50 |
| 50 | common alder | H 5s | 21.00 | 78 | sycamore | P 5s | 0.50 |
| 59 | common ash | P 1k | 0.45 | 79 | lime | P 5s | 1.50 |
| 60 | sycamore | P 3k | 0.60 | 80 | lime | P 5s | 2.00 |
| 61 | common ash | P 1k | 2.70 | 81 | lime | P 5s | 0.50 |
| 63 | sycamore | P 4k | 5.60 | 82 | sycamore | P 5s | 4.00 |
| 64 | sycamore | P 3k | 3.50 | 84 | common ash | P 3k | 1.00 |
| 65 | sycamore | P 4k | 25.00 | 87 | walnut | P 5s | 0.01 |
| 66 | sycamore | P 3k | 0.12 | 89 | walnut | P 5s | 0.20 |
| 67 | narrow-leafed ash | P 5s | 30.80 | 90 | walnut | P 8s | 0.15 |
| 68 | walnut | P 6s | 0.13 | 93 | common ash | P 6s | 2.11 |
| 70 | lime | P 5s | 1.00 | 94 | common ash | P 6s | 8.28 |

P = noble broadleaves seed unit, k =carbonate, s = silicate,
altitude: 1, 5 = below 400 m; 2, 6 = 400-700 m; 3, 7 = 700-1000 m; 4, 8= >1000m.

Noble broadleaves and overlooked tree species belong to one collective seed unit, which comprises 10 seed stands for *Acer pseudoplatanus*, 1 for *A. campestris*, 5 for *Tilia* sp. (*T. platyphyllos* and *T. cordata* are considered),5 for *Juglans* sp. (*J. regia* and *J. nigra* are considered), 7 for *Fraxinus excelsior*, 1 for *F. angustifolia*, and 1 for *Alnus glutinosa* (see Fig. 1).

A limited number of seed orchards was established in Slovenia about 15-30 years ago, 13 for conifers and two for broadleaved tree species. Only the two seed orchards of common ash and common alder are used regularly for seed production (Table 4).

**Table 4.** Seed orchards of common ash and common alder.

| | *F. excelsior* | *A. glutinosa* |
|---|---|---|
| Location | Hrašcica | Murska šuma |
| Year of establishment | 1989 | 1988 |
| Source of material | Hrašcica | Murska šuma |
| Area (ha) | 1.80 | 2.00 |
| Clones /seedlings | 60/505 | 55/330 |

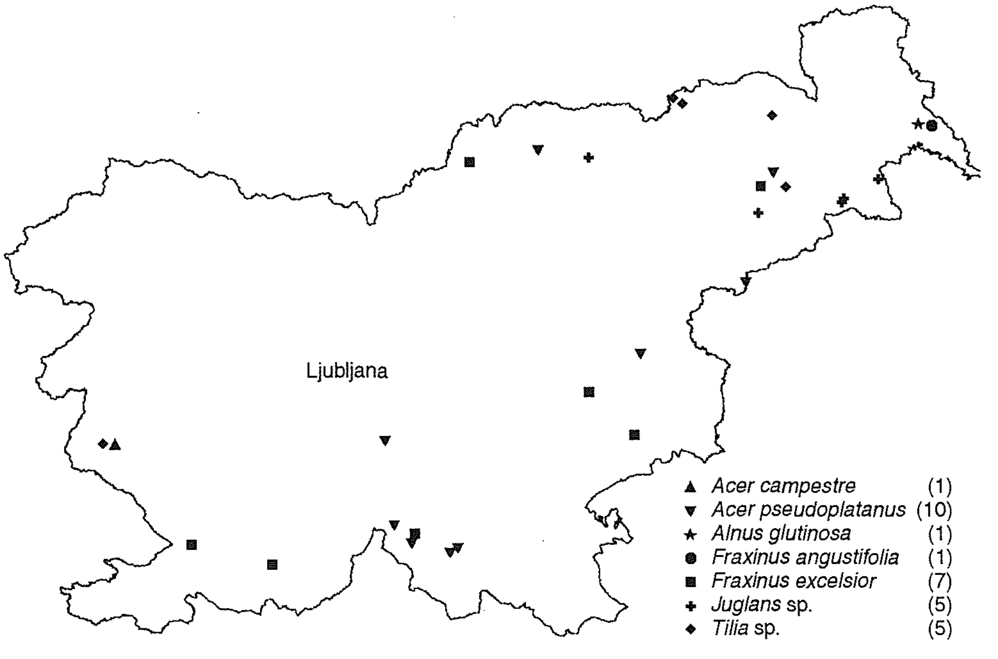


Fig. 1. Seed stands of noble broadleaved tree species in Slovenia.

## National strategy for the conservation of genetic resources of noble broadleaves

According to the Slovenian Forest Act of 1993 all forests are managed in a co-natural way, which can be classified as Category VI of the IUCN management categories: "protected area managed mainly for the sustainable use of natural ecosystems". The sustainable, close-to-nature and multifunctional forest management implies:

- small-scale flexible forest management, adapted easily to site characteristics and natural development of forests
- active protection of natural populations of forest trees
- protection and conservation of biological diversity in forests
- support of the bio-ecological and economical stability of forests by improving the growing stock
- tending of all developmental stages and all forest forms for support of vital and high-quality forest trees, which could fulfil optimally all functions of forests
- natural regeneration supported in all forests; if seedlings are used, they should derive from adequate seed sources/provenances, and only adequate species can be used.

Protected forest areas include forests in the National Park, regional parks, virgin forest reserves, protection forests and seed stands. Special attention and protection is given to sites of endangered plants (adequate to IUCN category IV of protection).

None of the six traditional noble broadleaf species is considered as threatened in Slovenia. The list, marking endangered overlooked tree species is given above. As most forest stands are regenerated naturally, while seeds are mostly collected from yearly re-certified seed stands, no special attention is given to *ex situ* conservation of forest genetic resources in Slovenia.

For the development of the national strategy for inventory, characterization, protection and utilization of genetic resources of broadleaved and overlooked tree species, more knowledge and therefore more support and efforts should be put towards studying:

- functions of different forest ecosystems
- genetic variability of forest trees and their physiological implications
- co-naturally oriented biotechnological methods in managing young forest and plant propagation materials
- possibilities of adaptation and use of ecosystem-oriented forest operations.

In regard to the protection and conservation of biological diversity in forests, especially of noble broadleaved and overlooked tree species, more efforts are being put towards studying their genetic, physiological and ecological characteristics, their natural rejuvenation, symbiotic and pathogenic relationships, as well as to studying their propagation from seed and other material. In 1995 a specific action of distribution of seedlings of endangered wild service tree and true service tree to all forest districts was initiated by the professional forestry meeting in Dolenjske Toplice (see Kotar 1995). The procedure for registration of seed stands in the past few years is inclined especially towards the selection of seed stands of noble broadleaves and overlooked tree species.

International collaboration in all above-mentioned aspects of studies is a prerequisite for development in our understanding and knowledge of Slovenian forest ecosystems and their genetic potentials.

The recommendations for the future comprise:

- further development of the existing scheme of sustainable forest management
- development of a national programme for management of forest genetic resources
- inventories of forest genetic resources
- characterization of forest genetic variability and its physiological evaluation
- complementarity of *in situ* and *ex situ* conservation activities
- international collaboration in research activities and approaches.

## Institutions working in the field of forest genetic resources

Within the national research programme called 'Forest' one single project, in which the two Slovenian forestry research institutions are collaborating – the Slovenian Forestry Institute and the Forestry Department of the Biotechnical Faculty, University of Ljubljana – was accepted in 1995 for the whole area of forest genetics, seeds and nursery-related studies. This project is financed jointly by the Slovenian Ministry for Science and Technology and the Ministry for Agriculture, Forestry and Food.

More applied work has been done through direct collaboration of the Slovenian Forestry Institute with the Slovenian Forest Service, as part of the Public Forest Service, financed by the Slovenian Ministry for Agriculture, Forestry and Food. This includes evaluation of seed stands and seed orchards, establishment of living archives of forest trees and preparation of the national strategy for conservation, characterization and utilization of forest genetic resources.

We hope to be formally included in the international programme on forest genetic resources, EUFORGEN, by the end of this year. We are included in the EEC scheme COST. All international joint research projects from the field of molecular characterization and physiological evaluation of forest genetic resources are welcome. The diversity in the Slovenian forests is our advantage, but it represents at the same time a highly demanding task for the relatively small team working on these subjects.

## Acknowledgements

This report was prepared as part of the Public Forest Service, done by the Slovenian Forestry Institute, financed by the Slovenian Ministry for Agriculture, Forestry and Food. We would like to thank Mr Vid Mikulic and Mr Branko Glavan from the Slovenian Forest Service for help in acquisition of data from the Forest Inventory 1990 and for preparation of the figure.

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# Gene conservation and silviculture of broadleaved mixture species in Hungary

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Over the past few years researchers and experts have begun to deal with the silviculture problems of forest fruit trees that provide valuable wood products in Hungary. The initiative of a European programme came at the best time and caused Hungarian forest authorities to focus on this field of silviculture, which had been overlooked until now.

Depending on the point of view, different definitions could be given as to what should be regarded respectively as Noble Hardwoods and (hard/soft) broadleaved mixture species, be it in silviculture or woodworking.

## Silviculture

In silviculture, we refer to hard and soft broadleaved mixture species. Their role is indispensable in the growth of stock in a natural way, because they improve the branch-clearing of the main species, provide shade, develop the soil and enrich the forest ecosystem. By their trade value, they also improve the economic returns of forest management.

Broadleaved mixture species according to this definition of silviculture are: *Acer campestris, A. platanoides, A. pseudoplatanus, Carpinus betulus, Castanea sativa, Cerasus avium, C. mahaleb, C. serotina, Corylus colurna, Fraxinus angustifolia* subsp. *pannonica, F. excelsior, F. ornus, Juglans nigra, Juglans* x hybrid, *J. regia, Malus sylvestris, Morus alba, Padus avium, Platanus* x hybrid, *Pyrus communis, Quercus frainetto, Q. pubescens, Q. virgiliana, Sorbus aria, S. aucuparia, S. domestica, S. torminalis, Ulmus campestris, U. glabra* and *U. laevis.*

## Woodworking

In woodworking, hard broadleaved species should be called Noble Hardwoods. Partially, this definition restricted the bund, which produces hardwood material that is processed economically in terms of volume and quality in the wood industry. On the other hand, the definition is broader because not only mixture species but hard broadleaved main species are listed. Furthermore, no distinction has been made between native and introduced species.

Lime trees and alders are considered soft broadleaved species by Hungarian wood processors.

Noble Hardwood broadleaved species from the aspect of woodworking are: *Acer campestris, A. platanoides, A. pseudoplatanus, Carpinus betulus, Castanea sativa, Cerasus avium, Corylus colurna, Fagus sylvatica, Fraxinus angustifolia* subsp. *pannonica, F. excelsior, Juglans nigra, J. regia, Quercus robur, Q. robur* f. *slavonica, Q. petraea, Q. rubra, Robinia pseudoacacia, Sorbus torminalis, Ulmus glabra* and *Ulmus laevis.*

There is some overlapping of the two definitions.

## Significance in forest management

Table 1 shows the area and type of important broadleaved species in Hungary.

**Table 1.** Total area of important broadleaved species and percentage of the total forest area in Hungary.

| | Area | | Volume | |
|---|---|---|---|---|
| **Species** | **ha** | % | **1000 m³** | % |
| *Quercus* sp. | 353 979 | 22 | 80 497 | 27 |
| *Fagus sylvatica* | 99 992 | 6 | 36 737 | 12 |
| *Carpinus betulus* | 95 582 | 6 | 17 394 | 6 |
| *Robinia pseudoacacia* | 310 877 | 20 | 35 448 | 12 |
| *Acer* sp. | 9 995 | 1 | 1 603 | 1 |
| *Ulmus* sp. | 2 003 | – | 320 | – |
| *Fraxinus* sp. | 20 251 | 1 | 5 890 | 2 |
| *Juglans* sp. | 4 003 | – | 756 | – |
| Forest fruit trees | 1 267 | – | 224 | – |
| Other species | 680 148 | 44 | 120 584 | 40 |
| Total | 1 578 097 | 100 | 299 453 | 100 |

Source: Forest Development Service (1994).

Exports of important hard broadleaved mixture species are shown in Table 2. Exports go towards western Europe where, since 1991, the importance of these species has increased.

**Table 2.** The export of important hard broadleaved mixture species in Hungary.

| | Export (m³) | | | | |
|---|---|---|---|---|---|
| **Wood species** | **1989** | **1990** | **1991** | **1992** | **1993** |
| **Logs for board industry** | | | | | |
| *Fraxinus* sp. | 66 | 131 | 513 | 119 | 709 |
| *Acer* sp. | – | – | – | – | – |
| *Juglans nigra* | 1 | – | 76 | 66 | 7 |
| Forest fruit trees | 232 | 148 | 514 | 968 | 532 |
| Other hard broadleafs | – | – | 8 | 24 | – |
| *Alnus glutinosa* | – | – | 1950 | 484 | 51 |
| Total | 299 | 279 | 3061 | 1661 | 1408 |
| **Saw logs** | | | | | |
| *Carpinus betulus* | 17 | 73 | 74 | 625 | 480 |
| *Fraxinus* sp. | 4687 | 5913 | 8676 | 9443 | 7396 |
| *Acer* sp. | 10 | 9 | 141 | 338 | 194 |
| *Juglans regia* | 454 | 1843 | 21 165 | 19 315 | 1897 |
| *Juglans nigra* | 1901 | 1791 | 1898 | 1881 | 2313 |
| Forest fruit trees | 3996 | 5664 | 5970 | 6814 | 6592 |
| *Alnus glutinosa* | – | 1892 | 10 351 | 21 200 | 13 372 |
| *Tilia* sp. | 1049 | 1305 | 696 | 1359 | 3443 |
| Total | 12 114 | 18 490 | 48 971 | 60 975 | 35 687 |

Source: Ministry of Agriculture (1995).

## Gene conservation activities and purposes

Two basic methods of gene conservation have been developed in Hungary (Table 3):

- *In situ* conservation: gene conservation takes place in seed-growing stocks and marked logs are chosen on the basis of phenotype characteristics.
- *Ex situ* conservation: from vegetative offsprings of chosen marked logs, a clone collection or seed orchard is created.

**Table 3.** Results of gene conservation of important hard broadleaved mixture species in Hungary, 1996.

| Wood species | Marked logs | Gene collections | Seed orchards |
|---|---|---|---|
| *Cerasus avium* | 180 | 2 | 1 |
| *Sorbus torminalis* | 60 | 1 | 1 |
| *Sorbus domestica* | 30 | 1 | 1 |
| *Fraxinus angustifolia* subsp. *pannonica* | 30 | 1 | 1 |
| *Juglans regia* | 27 | 1 | 1 |

There has been an increase in the interest in problems related to silviculture in Hungary over the past few years. The main reason is the continuous demand from abroad for logs from hard broadleaved trees. For example, *J. regia* has practically disappeared from Hungary and a prohibition on the export of walnut logs had to be introduced. Unfortunately, there seems to be some illegal export of this species.

Another reason for this interest is that certain foresters think there is much to recommend in the selling of seeds from seed orchards having selected genotypes or hard broadleaved trees. Initial steps to accomplish this were taken by several forestries, mostly in the case of *C. avium* and *S. torminalis*. Moreover, a private grower started a seed orchard for *C. avium*, *S. torminalis* and *S. domestica* in spring 1996. In addition, the Forest Research Institute has founded a walnut plantation (seed orchard), which is part of a European network.

Third, there is a trend towards ecological awareness. Concern has been expressed over the practice of monoculture rather than mixed species. This is mostly true of the hard broadleaved species. Silviculture, where preference is expressed for simple solutions and convenience, does not take into consideration the fact that mixed species should be regenerated in natural forests. Consequently, the soil composition of forests is becoming poor and there may be some trouble in the forest ecosystem.

The trend towards an ecological solution attempts to discover methods for practical silviculture regarding the regeneration of hard broadleaved species admixtures, which can be applied simply during natural forest renewal. In 1990 experiments were begun in Hungary on this subject. The University of Forestry and Wood Sciences, Sopron, together with the Forest Research Institute, started experiments on the regeneration of *C. avium* and *S. torminalis* and on the afforestation possibilities of *C. colurna.*

The fourth reason for the increasing interest may be the demand from agricultural private growers who are willing to invest in plantations growing valuable trees as an alternative use of ground. Presently the demand is low because field owners are not aware of the possibilities, although Hungarian researchers have to be ready to fill this demand by selecting genotypes of fast-growing, top-quality log shape. Selection work has been initiated at the University of Forestry and Wood Sciences.

On the basis of theories applied in the OECD, a plan to augment material has been made and there are approved standards concerning different types of seed orchards. An example of the regions of provenance for several broadleaved species admixtures is shown in Figure 1.

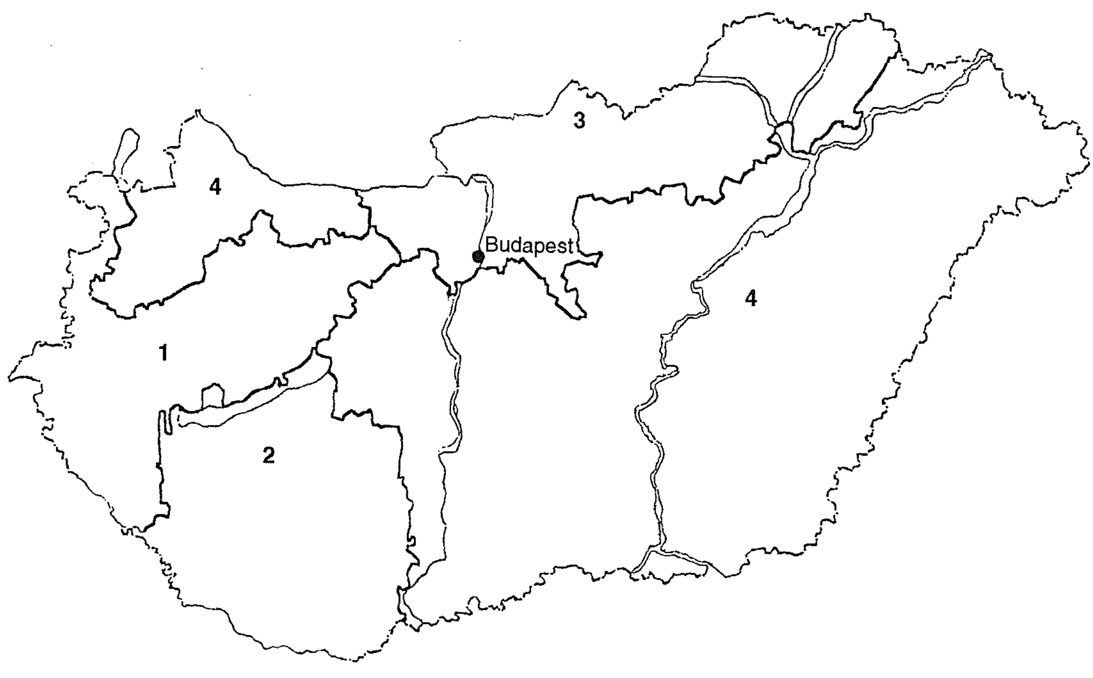


Fig. 1. Regions of provenance of several broadleaved species in Hungary: *Carpinus betulus, Cerasus avium, Acer pseudoplatanus, Tilia cordata, Tilia tomentosa.*

**Hungarian forestry research institutions and individuals**

| | |
|---|---|
| Forest Research Institute<br>Frankel L. utca 42-44<br>1023 Budapest | *Juglans regia* and *J. nigra* – research<br>*Cerasus avium, Corylus colurna, Sorbus* sp. – research with the University of Forestry and Wood Sciences |
| University of Forestry and Wood Sciences<br>Bajcsy-Zsilinsky utca 4<br>9400 Sopron | *Cerasus avium, Corylus colurna, Sorbus* sp. – research with the Forest Research Institute |
| National Institute for Agricultural Quality Control<br>Koloti K. utca 24<br>1024 Budapest | general gene conservation strategies, standards, participation in the planning of legislation |
| Mr Gábor Farkas<br>Szechényi utca 23<br>3300 Eger | *Cerasus avium, Sorbus torminalis, S. domestica* – seed orchards |
| Mr Sándor Bényi<br>Keselyus<br>7100 Szekszárd | *Fraxinus angustifolia* subsp. *pannonica* – seed orchard |

# Conservation of genetic resources of Noble Hardwoods in Austria

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## Distribution of Noble Hardwoods

According to the Austrian Forest Inventory the total forest area in Austria is 3.88 million ha, i.e. 46.2% of the federal territory. The proportion of Noble Hardwoods, calculated as percentage of the growing stock or stem number, is low (Table 1).

**Table 1.** Distribution of Noble Hardwoods (according to the Austrian Forest Inventory).

| Tree species | Growing stock (%) | Stem number (%) |
|---|---|---|
| *Fraxinus excelsior* | 1.3 | 2.0 |
| *Acer* sp. | 1.0 | 1.5 |
| *Ulmus* sp. | 0.1 | 0.2 |
| *Alnus glutinosa* | 0.5 | 1.0 |
| *Tilia* sp. | 0.2 | 0.4 |
| *Prunus avium* | ? | ? |
| *Sorbus* sp. | ? | ? |

In spite of this small proportion, the ecological value is considerable. It can be assumed that, with decreasing tropical hardwood resources, the native Noble Hardwoods have an increasingly high economic value.

Noble Hardwoods are mostly represented in the following natural forest communities in Austria:

- Beech forests: submontane to low mountain areas
- Oak - hornbeam forests: hilly to submontane areas on the outskirts and outside of the Alps
- Thermophile oak forests (pubescent oak - Turkey oak) on warm sites
- Lime-admixed forests: hilly to low mountain communities on boulder-fields and debris cones
- Sycamore maple and Sycamore maple with ash forests on specific sites with high atmospheric humidity
- Sycamore maple - beech forests: fragmentary associations on steep high mountainous sites with abundant snow
- Black alder - ash forests: low mountain to submontane associations on particular sites with water surplus
- Black alder swamp forests: submontane to low-montane communities with high groundwater level
- Riverside forests: various plant associations in the inundation areas of the Danube and other major rivers.

A preliminary evaluation of the 1992 survey of the Austrian Forest Inventory on regeneration provides information about the regeneration potential of Austrian forests. Fifteen percent of the forest area shows natural regeneration, 2% artificial regeneration and 83% no regeneration at all. The share of natural regeneration in the total regeneration is 87%, which is high.

The share of ash and maple in the natural regeneration is 22 and 27%, respectively, and around 14% in the artificial regeneration.

According to the available partial results of the Austrian Inventory most other Noble Hardwoods, such as *Ulmus*, *Sorbus* and *Prunus* species and also *Tilia*, regenerate exclusively naturally. If we consider the stands, however, from the pole-wood age onwards, these ecologically important admixed tree species have been largely eliminated. This is partly caused by lack of light and by competition, but the factors of game, forest pasture and silvicultural treatment of young growth play an essential role in this formation of demixed stands.

The existence of populations of the field elm (*Ulmus minor*) and European white elm (*Ulmus laevis*) is threatened by the dieback of elms (caused by the fungus *Ophiostoma ulmi*). Furthermore, wild pear (*Pyrus pyraster* Burgsd.) and crab apple (*Malus sylvestris* L.) are endangered. The yields of the fruits are increased by breeding and cultivation is widely spread. Secondary immigration of the modern cultivars into the forest, or hybridization with the still-existing wild varieties, threatens these species with displacement.

## Conservation of genetic diversity

In 1986, following expert talks of the Federal Forest Research Centre, a research project was commissioned by the Federal Ministry of Agriculture and Forestry, entitled "Contributions to the Conservation of Genetic Diversity". The project is unlimited in time and is jointly carried out by the Centre's Institutes of Silviculture and Forest Genetics in close cooperation with the services of the forest authorities and the forest owners.

The project is comprised of three groups of measures:

- gene reserves within natural forest communities
- seed bank for long-term conservation
- clone archives and seed orchards.

These *in situ* and *ex situ* measures are linked in an overall concept and complement each other in their effectiveness.

### *In situ* conservation measures

These measure are in line with the overall objective of gene preservation:

- to secure the full genetic diversity of the tree populations
- to guarantee their evolutionary development
- to preserve their full adaptability to changing environmental conditions.

The *in situ* conservation strategy is to be given priority.

Owing to the low number of virgin forests and, at present, of natural forest, genetic conservation under observance of certain requirements is practised in managed forests, which are integrated into the economic cycle.

Depending on the size of the conservation unit, we distinguish between gene reserves (large parts of forests from 30-50 to several 100 ha), and gene conservation stands (individual stands of more than 0.6 ha). The area size defines the independence and conservation properties of each unit.

As large coherent forest communities or combined communities (gene reserves) are assumed to be independent, *in situ* measures are sufficient for their conservation.

In the case of locally restricted, small forest communities (gene conservation stands), the transmission of genetic information to the next generation is more uncertain; for their conservation *ex situ* measures are, therefore, also required.

Conservation units with extended proportions of Noble Hardwoods are mostly forest associations that only rarely cover large areas (e.g. permanent associations, special sites, such as sycamore maple forests in narrow valleys or gorges, or black alder swamp forests). The reasons are mostly locally limited climatic extremes or peculiarities which may be based on relief or soil.

Specific small-scale silvicultural treatment, application of suitable natural regeneration procedures and creation of the preconditions for a permanent self-regulating balance enable sufficient continuation of genetic information even in small conservation units.

The presently registered gene conservation units (see Table 2) are stored with their characteristics in databanks at the Federal Forest Research Centre. Forest owners and authorities are furnished with summaries (documentation sheets), which serve as a basis for the implementation of operational and silvicultural measures and as information for applications for support.

At present international cooperation is limited to the exchange of information and attendance at pertinent events. A strengthened cooperation in Europe would, however, be useful for the preparation of common guidelines for the selection and treatment of gene reserves as well as for the establishment of a databank network. However, the importance of these international approaches must not be overestimated, since apart from generally valid guidelines, regional approaches which consider country-specific peculiarities have to be applied.

**Table 2.** Gene conservation units with at least 10% stem number proportion of hardwoods

| **Natural forest** | **Total area (ha) / number of conservation units** | | | | | | |
|---|---|---|---|---|---|---|---|
| **community** | *F.e* | *A.p.* | *U.g.* | *T.c.* | *T.p.* | *S.a.* | *A.pl.* |
| Riverside | 18.6/2 | | | | | | |
| Sycamore maple, and Sycamore maple - ash | 54.7/8 | 60.8/10 | 39.4/4 | | | | |
| Linden - mixed | 14.3/2 | 8.8/1 | 5.5/1 | | 18.3/4 | | |
| Oak - hornbeam | 27.3/4 | | | | 29.0/1 | | 5.0/1 |
| Beech | 14.7/2 | 52.6/5 | | | 4.4/1 | | |
| Sycamore - beech | | 1.2/1 | | | | | |
| Spruce - silver fir - beech | | 305.2/10 | | | | 7.5/1 | |
| Low sub-alpine spruce | | 88.2/2 | | | | | |
| Pine - oak on acid soils | 103.0/1 | 7.3/1 | 5.0/1 | 6.8/2 | 10.5/2 | | |
| Black pine | | | | | | 3.2/1 | |
| **Total** | 232.6/19 | 524.1/30 | 49.9/6 | 43.8/9 | 62.3/8 | 10.7/2 | 5.0/1 |

*F.e. = Fraxinus excelsior; A.p. = Acer pseudoplatanus; U.g. = Ulmus glabra; T.c. = Tilia cordata; T.p. = Tilia platyphyllos; S.a. = Sorbus aria; A.pl. = Acer platanoides.*

## Clone archives and seed orchards

Tree species that occur only as small-scale cells of a stand or individual trees may be preserved by means of clone archives and seed orchards. The plantations consist of a number (mostly 50 to 100) of selected trees, which are established on the basis of regional and vertical structure.

The Noble Hardwood plantations established by the Federal Forest Research Centre, the provincial governments and the Austrian Federal Forest Enterprise comprise a total of 22 units (Table 3), covering a total plantation area of 34.2 ha.

In the future, the plantation programme will concentrate on rare hardwood species and will also consider autochthonous bushes.

For plantation utilization, a draft contract was prepared between the Republic of Austria, represented by the Federal Ministry of Agriculture and Forestry, and forest seed producers united together into a working group, which regulates the marketing of the seed produced in state-owned plantations.

**Table 3.** Clone archives and seed orchards for Noble Hardwoods in Austria.

| Tree species | Provenance(s) | Altitudinal zone(s) | No. of orchards | No. of clones (single tree progenies) | No. of grafts (seedlings | Area (ha) |
|---|---|---|---|---|---|---|
| *Acer pseudoplatanus* | Northern rim of the Alps - East | sub- to low montane | 2 | 50/43 | 250/172 | 3.5 |
| | | medium to high montane | 1 | 55 | 220 | 1.3 |
| | Northern foothills of the Alps- West | submontane | 2 | 51/51 | 237/204 | 2.7 |
| | Eastern -Styrian mountains | sub- to low montane | 2 | 50/50 | 350/200 | 4.3 |
| *Alnus glutionosa* | Subillyrian hills and terraces | hilly - submontane | 2 | 65/50 | 200/200 | 3.1 |
| | Wald- und Mühlviertel | sub- to low montane | 2 | 50/50 | 200/200 | 3.1 |
| *Fraxinus excelsior* | Northern rim of the Alps - East | sub- to low montane | 1 | 53 | 265 | 1.9 |
| | Northern foothills of the Alps - West | submontane | 2 | 51/51 | 255/204 | 3.5 |
| *Prunus avium* | Pannonian lowlands and hilly country | hilly - submontane | 1 | 52 | 250 | 1.7 |
| | Northern foothills of the Alps | submontane | 1 | 51 | 204 | 1.0 |
| | East | hilly | 1 | 49 | 293 | 1.5 |
| *Sorbus torminalis* | Northern rim of the Alps - East | hilly - low montane | 1 | 45 | 225 | 1.4 |
| *Tilia cordata* | Pannonian lowlands and hilly country | hilly - submontane | 2 | 49/49 | 252/191 | 2.7 |
| | Northern foothills - Alps | low to medium montane | 1 | 51 | 255 | 1.5 |
| *Ulmus glabra* | Northern rim of the Alps | sub- to low montane | 1 | 26 | 130 | 1.0 |

**Seed stands of Noble Hardwoods**

In line with the regulations of the Forest Act, forest seed of some species of Noble Hardwoods is produced in stands approved for seed collection (Table 4).

Table 4. Selected seed stands of Noble Hardwoods (as of February 1996)

| Tree species | Number of stands | Total area (ha) * |
|---|---|---|
| *Acer pseudoplatanus* | 83 | 112.3 |
| *Alnus glutinosa* | 24 | 19.8 |
| *Fraxinus excelsior* | 77 | 116.3 |
| *Tilia cordata* | 23 | 33.2 |
| Total | 207 | 281.6 |

* Reduced area corresponding to the estimated tree species composition

The requirements for the approval of stands are apt to secure valuable reproductive material to increase forest production. At present, changes in the forest legislation at national level are intended, considering modern genetic results. For instance, for sites with increased protective function, where the preservation of the unlimited adaptability of tree populations is more important than the economic output, reproductive material with increased genetic diversity will have to be provided in the future. To propagate this material, only registered basic material may be used which meets the population genetic requirements and from which we can expect better adaptability.

**Measures to preserve the threatened elm species**

The long-term survival of elms can only be ensured if it is possible to maintain their entire genetic diversity and structure to evolve resistance properties against the causes of their decline. To preserve the threatened elm species the following measures have been realized:

- inventory of population sites and single-tree locations for *in situ* conservation, to provide population material for seed storage and to create clone archives in long-term perspective
- seed orchard with 26 half-sib families of *Ulmus scabra*
- clone archives to collect cuttings for vegetative propagation
- artificial stands, managed by coppice treatment; the aim is to create a rotation coppice system, preventing infection by the fungus.

## Research demand

The research demand is mainly in the following areas:

- Inventory of the structure of species by means of morphological, physiological and biochemical characteristics, to create a secure basis of decision on preservation measures.
- Survey of changes in genetic parameters as a consequence of anthropogenic influences.
- Examination of the impact of silvicultural measures in case of formation and tending of stands upon the genetic structures of populations.
- Investigations into the reproductive capacity of forests to survey impacts of climatic changes upon fructification and natural regeneration.
- Improvement of the preservation methods in seedbanks and investigations for potential changes of the genetic information during storage.

# Noble Hardwoods in Slovakia

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## Forests in Slovakia

Forests cover 19 990 km$^2$, which equals 41% of the total country's territory (49 036 km$^2$), in the western part of the Carpathian mountains. About 65% of the territory and thus a large proportion of forests has a mountainous character.

A breakdown of ownership follows: state-owned forests represent 45%, municipal, communal and church forests 38%, and private forests 17%. Categories of utilization are: 73% commercial forests, 14% protective forests, and 13% forests with special functions (watershed areas, nature conservation, recreation forests). The average growing stock is 190 m$^3$/ha, which has increased by 50% during the past 50 years. The mean total annual increment was 6.1 m$^3$/ha in 1987-93.

Eight forest vegetation zones are recognized in Slovakia (Table 1) according to the phytocenological classification of Zlatník (1959). Overall ecological characteristics of the vegetation zones are described in Paule (1995). According to management criteria and geomorphology, 47 forest regions have been delineated more recently.

Of the total forest area, 40-45% are semi-natural forests originating from natural regeneration and differing only slightly from natural forests in terms of species composition. More than 70 fragments of natural and virgin forests, with a total area of 18 000-20 000 ha, still exist in Slovakia (Korpel 1995). The broadleaves' share in the overall species composition is 56.9%, with beech dominating (29.6%) and oak second (13.7%). Conifers are represented by Norway spruce (27.5%), silver fir (4.6%) and pine (7.7%). The share of Noble Hardwoods (maple, ash, elm, alder, lime, wild fruit species) is 3.7%. More detailed information on Noble Hardwoods, including older reference data from 1953, is given in Table 2.

**Table 1.** Vegetation zones and their area in Slovakia.

| Vegetation zone | Area ha | Area % |
|---|---|---|
| Oak (swamp and dry lowland forests including *S. torminalis* and *F. angustifolia*) | 167 049 | 8.39 |
| Beech-oak (oaks, beech with Noble Hardwoods including *Sorbus torminalis*) | 306 365 | 15.39 |
| Oak-beech (beech, sessile oak with Noble Hardwoods) | 460 680 | 23.15 |
| Beech (beech with sessile oak, fir, Noble Hardwoods) | 387 050 | 19.45 |
| Fir-beech (beech, fir, spruce with Noble Hardwoods) | 414 314 | 20.82 |
| Spruce-beech-fir (spruce, beech, fir with sycamore, Wych elm, maple, ash) | 193 227 | 9.71 |
| Spruce (spruce with sycamore, ash, Wych elm, fir, rowan) | 41 381 | 2.08 |
| Dwarf pine (dwarf pine with spruce, rowan, Swiss stone pine) | 20 003 | 1.01 |

Many serious problems in Slovakia's forestry are associated with the mountainous topography. Mountain forests in elevations over 700 m represent 33% (641 000 ha) of the total forest area. These forests are apparently affected by the transboundary air pollution including surprisingly high heavy metal deposits. Fully 35% of forests are on slopes steeper than 18°, which makes them unsuitable for conventional logging technologies. Small-area clearcutting still dominates over shelterwood regeneration in the local forests. In addition, accidental fellings represent 65% of the total annual cut. In consequence, natural regeneration on the annually regenerated forest area has been only 15-25% in the last two decades.

## Status of Noble Hardwoods

The following species are referred to as Noble Hardwoods and are indigenous to Slovakia:

- sycamore (*Acer pseudoplatanus*)
- Norway maple (*A. platanoides*) and field maple (*A. campestris*)
- common ash (*Fraxinus excelsior*) and Hungarian ash (*F. angustifolia*)
- Wych elm (*Ulmus glabra*), field elm (*U. campestris*) and European white elm (*U. laevis*)
- rowan (*Sorbus aucuparia*)
- common whitebeam (*S. aria*)
- wild service tree (*S. torminalis*) and service tree (*S. domestica*)
- large-leaved lime (*Tilia platyphyllos*) and small-leaved lime (*T. cordata*)
- black alder (*Alnus glutinosa*) and grey alder (*A. incana*)
- wild cherry (*Prunus avium*)
- wild pear (*Pyrus nivalis* Jacq. and *P. pyraster* Burgsd.)
- wild apple tree (*Malus sylvestris*).

Horizontal ranges of most of the Noble Hardwoods cover the whole country with the exception of the highest mountains. Natural ranges of *S. torminalis* and rare, supposedly indigenous *S. domestica* are limited to the thermophilous plant associations in southern Slovakia. *Fraxinus angustifolia* occurs only in the riverain forests of the Danubian lowlands. *Tilia platyphyllos* and scattered occurrences of *Ulmus laevis* are not found in the northern part of the country.

The genera *Acer*, *Fraxinus* and *Tilia* have sufficiently high proportions to be considered economically important. The same is true for mountain and field elm. The share of maple, ash and lime trees has remained almost unchanged over the past 50 years (Table 2). However, the area of elm has decreased catastrophically over the past decades, from 9815 ha in 1953 to 953 ha in 1993. Dutch elm disease has been the principal factor in this unfavourable development. More precise data on actual distribution of 30 forest tree species are being collected in the forest inventory. Overall information on the distribution of Noble Hardwoods, according to forest regions, is presented in Table 3 and is based only on management surveys.

Most Noble Hardwoods in local forests are naturally regenerated and indigenous. In semi-natural forests, they are only slightly affected by competition from artificially planted species or intensive selection.

**Table 2.** Total area and proportion of Noble Hardwoods in the species composition according to management inventories in Slovakia.

| Year | *Acer* | *Fraxinus* | *Ulmus* | *Alnus* | *Tilia* | Other species |
|---|---|---|---|---|---|---|
| 1953 | 15 456 ha (0.928%) | 15 075 ha (0.905%) | 9815 ha (0.229%) | 7779 ha (0.468%) | 1620 ha (0.097%) | 830 ha (0.113%) |
| 1993 | 30 140 ha (1.58%) | 20 657 ha (1.08%) | 953 ha (0.05%) | 12 617 ha (0.6%) | 6122 ha (0.34%) | 3898 ha (0.2%) |

**Table 3.** Area of Noble Hardwoods by age classes and their proportion (%) on area of respective age classes.

| | Area of age class (ha, %) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **Total** |
| *Acer* | 6852 | 4745 | 2709 | 1936 | 2223 | 1901 | 1368 | 1308 | 1359 | 1409 | 1242 | 864 | 693 | 630 | 901 | 30,140 |
| | 3.97 | 3.14 | 2.02 | 1.38 | 1.09 | 0.94 | 0.71 | 0.63 | 0.77 | 1.25 | 1.68 | 1.89 | 2.09 | 2.55 | 2.82 | 1.58 |
| *Fraxinus* | 3177 | 2179 | 1548 | 2240 | 3182 | 2576 | 1637 | 1275 | 980 | 675 | 483 | 259 | 170 | 160 | 116 | 20,657 |
| | 1.84 | 1.44 | 1.16 | 1.59 | 1.55 | 1.27 | 0.84 | 0.62 | 0.56 | 0.60 | 0.65 | 0.57 | 0.51 | 0.65 | 0.36 | 1.08 |
| *Ulmus* | 55 | 74 | 50 | 97 | 87 | 103 | 81 | 44 | 50 | 91 | 69 | 44 | 39 | 40 | 29 | 953 |
| | 0.03 | 0.05 | 0.04 | 0.07 | 0.04 | 0.05 | 0.04 | 0.02 | 0.03 | 0.08 | 0.09 | 0.10 | 0.12 | 0.16 | 0.09 | 0.05 |
| *Alnus* | 1087 | 1820 | 2745 | 1944 | 1964 | 1019 | 784 | 525 | 299 | 180 | 138 | 63 | 31 | 11 | 7 | 12,617 |
| | 0.63 | 1.21 | 2.05 | 1.38 | 0.96 | 0.50 | 0.40 | 0.25 | 0.17 | 0.16 | 0.19 | 0.14 | 0.09 | 0.04 | 0.02 | 0.66 |
| *Tilia* | 823 | 1118 | 862 | 387 | 439 | 414 | 559 | 411 | 338 | 268 | 219 | 78 | 103 | 51 | 52 | 6122 |
| | 0.48 | 0.74 | 0.64 | 0.28 | 0.21 | 0.20 | 0.29 | 0.20 | 0,19 | 0.24 | 0.30 | 0.17 | 0.31 | 0.21 | 0.16 | 0.32 |
| Other broad-leaves | 612 | 673 | 695 | 420 | 358 | 201 | 205 | 135 | 110 | 98 | 140 | 80 | 66 | 46 | 59 | 3898 |
| | 0.35 | 0.45 | 0.52 | 0.30 | 0.17 | 0.10 | 0.11 | 0.07 | 0.06 | 0.09 | 0.19 | 0.18 | 0.20 | 0.19 | 0.18 | 0.20 |

## Conservation of Noble Hardwoods

### Strict forest reserves

Strict forest nature reserves occupy 69 560 ha in Slovakia, which equals 3.5% of the total forest area (Vološcuk 1994). In spite of their uneven vertical and horizontal distribution, they provide good opportunity for the conservation of genetic information *in situ*. Of 296 strict forests reserves, 161 are larger than 50 ha. Area of individual tree species and information on representation of forest associations in the forest reserves is given in Table 4.

### Forest gene reserves

The programme for forest gene reserves was begun in 1988 (Lafférs *et al.* 1988). The actual area of 66 forest gene reserves is 22 110 ha. Their establishment was preceded by the necessary field inventories, evaluation of phenotypical variation of main tree species and historical research. Modified management has already been implemented in the proposed gene reserves, although official regulation has been postponed owing to preparation of the new Forest Act. In the past, network design has focused on Norway spruce, silver fir, Scots pine, European larch, beech and sessile oak. Noble Hardwoods usually represent an accessory element and surpass 5% proportion only in 11 gene reserves. Current area of Noble Hardwoods in the forest gene reserves is, according to the forest survey of December 1995, as follows: ash, 92.37 ha; black alder, 29.46 ha; Wych elm, 22.65 ha; sycamore, 134.17 ha; small-leaved lime, 4.13 ha.

### Registered seed stands, plus trees, seed orchards

There are 110 registered seed collection stands with an area of 144 ha for: black alder (2 stands, 1 ha), common and Hungarian ash (35 stands, 57 ha), sycamore (60 stands, 60 ha), large and small-leaved lime (2 stands, 6 ha) and mountain elm (11 stands, 20 ha). Registration of more seed stands is intended in the next few years.

Plus trees have been registered for black alder (83), Hungarian and common ash (98), sycamore (35), mountain elm (5), large-leaved and small-leaved lime (91 trees). Regional seed orchards are being established for small-leaved lime in central Slovakia (55 clones/ha), ash and sycamore in eastern Slovakia (35 clones/0.6 ha and 35 clones/0.5 ha, respectively), black alder in eastern Slovakia (60 clones/ha). The total number of plus trees as well as clones in the seed orchards has been gradually increasing. A clonal archive is being established for black alder in southern Slovakia.

**Table 4.** Forest tree species composition of strict nature reserves on forest lands (from Vološcuk 1994).

| | In nature reserves | | In protected sites | | Forests of |
|---|---|---|---|---|---|
| **Tree species** | **Area (ha)** | **%** | **Area (ha)** | **%** | **Slovakia (%)** |
| **Coniferous tree species** | | | | | |
| Norway spruce | 26 253.96 | 37.74 | 149.54 | 20.64 | 27.0 |
| Silver fir | 13 249.98 | 19.05 | 17.22 | 2.38 | 5.0 |
| Scots pine | 2 012.69 | 2.89 | 43.45 | 6.00 | 8.0 |
| Larch | 1 892.13 | 8.72 | 21.23 | 2.93 | 1.9 |
| Dwarf pine | 1 182.69 | 1.70 | – | – | 1.0 |
| Stone pine | 1 072.74 | 1.54 | – | – | 0.1 |
| Total coniferous | 45 664.19 | 65.64 | 231.44 | 31.95 | 43.0 |
| **Deciduous tree species** | | | | | |
| Beech | 14 644.34 | 21.05 | 201.34 | 27.80 | 29.1 |
| Oak | 4 365.64 | 6.28 | 229.28 | 31.65 | 13.7 |
| Maple | 1 751.99 | 2.52 | 12.85 | 1.77 | 1.5 |
| Alder | 523.84 | 0.75 | 21.11 | 2.91 | 0.6 |
| Poplar | 859.53 | 1.24 | – | – | 1.5 |
| Willow | 334.61 | 0.48 | 0.50 | 0.07 | 0.1 |
| Elm | 41.48 | 0.06 | – | – | 0.1 |
| Hornbeam | 338.08 | 0.49 | 17.50 | 2.42 | 5.5 |
| Rowan | 585.33 | 0.84 | – | – | 0.7 |
| Service tree | 4.58 | 0.01 | 0.39 | 0.05 | – |
| Birch | 21.11 | 0.03 | 10.00 | 1.38 | 1.2 |
| Ash | 143.02 | 0.21 | – | – | 1.0 |
| Linden | 183.07 | 0.26 | – | – | 0.3 |
| Black locust | 31.02 | 0.05 | – | – | 1.7 |
| Dogwood, hazel and other deciduous shrubs | 67.07 | 0.09 | – | – | – |
| Total deciduous | 23 895.07 | 34.36 | 492.97 | 68.05 | 57.0 |
| **Total conifers and broadleaves** | 69 559.26 | 100% | 724.41 | 100% | 100% |

### Protective forests

Protective forests with special management plans occupy 268 657 ha in Slovakia. The intensity of management has been substantially reduced during the last 50 years. In many cases, however, low-intensity management caused deterioration of their functional efficiency. On the other hand, forests on exposed sites (steep slopes, ridges, forest steppes) totalling 137 865 ha represent, without a doubt, invaluable conservation areas for the majority of Noble Hardwoods which occur there with much higher frequency than in the commercial forests. Unfortunately, no detailed information on species composition in this particular type of protective forests is yet available.

## Survey of recent research on distribution and variability of Noble Hardwoods

Research on distribution, as well as analysis of phenotypical variation, has been carried out mainly within the institutional research programmes at the Forestry Faculty of the Technical University Zvolen, Institute of Forest Ecology of the Slovak Academy of Sciences, and the Forest Research Institute Zvolen.

The inventories have focused on the distribution mapping, ecological amplitude of a species, evaluation of morphological variation (leaf, fruit and bark morphology, habitus), and surveys of commercially valuable subpopulations. The following species have been studied:

*Acer pseudoplatanus* (Pagan 1994, Forestry Faculty, Technical University Zvolen): study of morphological variation (leaf, fruit, bark traits), growth and habitus; inventory of commercially valuable traits (curly and 'birds-eye' forms) and populations; provenance experiment with 20 provenances (9 from Slovakia, 3 from the Czech Republic, 3 from Romania, 3 from Austria, 2 from Switzerland).

*Alnus glutinosa* (Varga 1993, Forest Research Institute; Lukácik 1995, Forestry Faculty): analysis of phenotypic variation; mapping commercially valuable forms and populations; selection of plus trees.

*Fraxinus angustifolia* (Varga 1993, Forest Research Institute Zvolen): mapping of remnant populations in the Slovak part of the Danubian Basin; analysis of species' phenotypical variation (leaf, fruit and bark morphology, growth); selection of plus trees and agenda for registration of seed stands.

*Prunus avium* (Škvareninová 1995, Forestry Faculty, Technical University Zvolen): vertical and horizontal distribution mapping according to the forest regions; analysis of phenotypical variation (leaf and bark traits, habitus, growth); selection of plus trees.

*Sorbus domestica* (Bencat 1995, Arboretum Mlynany of the Slovak Academy of Sciences): review of earlier studies, evaluation of the native origin; mapping horizontal and vertical range, and morphological variation; detailed inventory of distribution.

*Tilia platyphyllos* and *T. cordata* (Labanc 1994, Forestry Faculty, Technical University Zvolen): inventory of horizontal and vertical distribution according to the forest regions, vegetation zones, parent rock, site topography; analysis of morphological variation based on 15 quantitative and 4 qualitative morphological traits (leaf, fruit, bark) – 1317 individuals were surveyed in 78 subpopulations; analysis of ecological amplitude of *T. platyphyllos* and *T. cordata*; mapping the distribution of intermediary individuals (putative hybrids); selection of plus trees.

*Ulmus sp.* (Greguss *et al.* 1994, Forest Research Institute): inventory of horizontal and vertical distribution according to the forest regions and vegetation zones; selection of plus trees; mapping vertical distribution of Dutch elm disease (DED) in the mountain elm populations; study of flowering phenology; field tests with native and Dutch hybrid elms; micropropagation.

*Juglans nigra, Castanea sativa* (Bencat 1982, Arboretum Mlynany): detailled inventory of their occurrence in forests, agricultural lands and parks.

## Relevant research projects

*Variability and Genetic Diversity of Forest Tree Species*
(Operating 1990-96, Faculty of Forestry, Technical University Zvolen)
- inventory and morphological variation of wild cherry in Slovakia
- *in situ* and *ex situ* conservation of wild cherry and lime
- breeding programme of curly birch and sycamore, including micro-propagation
- genetic variability of forest trees studied by means of isozyme gene markers.

*Breeding of Forest Tree Species for Deteriorated Sites*
(Operating 1995-98 in the Forest Research Institute Zvolen)
Subproject II: *Breeding Programme of Elms*
- Field testing for growth and resistance to DED of indigenous elms, Siberian elm, and Dutch elm hybrids
- Mapping remnant populations of indigenous elms, selection of plus trees and establishment of clonal orchards
- Micropropagation of Dutch elm hybrids, anther cultures of *U. campestris.*

*Afforestation of Agricultural Lands*
(Operating 1995-97 in the Forest Research Institute Zvolen)
Subproject III: *Afforestation Methods and Plantations,* inter alia
- Plantations and siliviculture of black walnut, wild cherry, sugar maple and red oak.

## Threats to Noble Hardwoods

The following threats have been identified:
- decline and isolation of *U. glabra* populations due to Dutch elm disease
- skimming-off by forest owners and neglected regeneration of *Prunus avium*
- low population density and isolation in *Sorbus torminalis*
- low population density, geneflow from domesticated cultivars, absence of regeneration in *Pyrus* sp. and *Malus sylvestris.*

Positive trends have been observed in the occurrence of Noble Hardwoods on agricultural lands which have been abandoned over the last 50 years. This is true for *Prunus avium, Pyrus* sp., *Acer campestris, Fraxinus excelsior, Sorbus torminalis,* and on wet sites also for *Alnus glutinosa* and *A. incana.* Thanks to low-intensity management, wooded belts along the rivers are frequently settled by *Ulmus campestris* and *U. laevis.* However, there is a risk of losing these habitats through reforestation of agricultural lands or inappropriate amelioration.

### Intended *in situ* and *ex situ* conservation activities

Ongoing activities to be completed within the next few years:
- selection of more plus trees for *Acer, Fraxinus* and *Ulmus* spp.
- regional clonal orchards for *U. glabra*
- regional clonal seed orchards for *A. pseudoplatanus, A. platanoides, F. excelsior, F. angustifolia, A. glutinosa*
- network of small-size conservation areas/gene reserves aimed at Noble Hardwoods.

Intended activities within the next 5 years:
- clonal orchard of *Prunus avium, Sorbus torminalis, Sorbus domestica*
- inventory of distribution and clonal orchards for *Pyrus* sp. and *Malus sylvestris.*

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# State of genetic resources and gene conservation of Noble Hardwoods in the Czech Republic

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## Introduction

Forests cover about 2 630 000 ha of the Czech Republic; broadleaved tree species cover 21% of that area. The tree species composition changed considerably in the past two and half centuries owing to the effects of intensive forest management. Planting of coniferous tree species has been given priority since the 18th century.

Past management methods and other effects of human activities in general damaged forests and markedly reduced their species composition and biodiversity. Serious problems are caused by air pollution and high game populations (red deer). Also of importance are the present transformation and changes in forestry, and tracheomycotic diseases, which affect hardwood species. It seems that privatization of forests could negatively affect certain efforts for genepool conservation.

## Broadleaved tree species and the occurrence of Noble Hardwoods

According to the results of forest inventories and data of the General Forest Management Plan for 1993, forests in the Czech Republic consist of 77% coniferous and 21% broadleaved stands (about 1% are cleared areas). Tree species composition is as shown below (Noble Hardwoods are marked in bold).

| | | | Recommended | |
|---|---|---|---|---|
| Species | Natural | Actual | 1985 | 1994 |
| Norway spruce | 11.2 | 54.3 | 52 | 30 |
| Silver fir | 19.8 | 1.0 | 8 | 5 |
| Scots pine | 3.4 | 17.6 | 10 | 20 |
| European larch | – | 3.4 | 2 | 5 |
| Mountain pine | 0.2 | 0.3 | – | 0.2 |
| Other coniferous species | – | 0.7 | – | 0.8 |
| **Oak** | 19.3 | 6.1 | 8.5 | 8 |
| **European beech** | 40.1 | 5.5 | 16 | 18 |
| Hornbeam | 1.5 | 1.2 | – | – |
| **Ash** | 0.6 | 0.9 | 0.5 | – |
| **Maple** | 0.7 | 0.7 | 0.7 | – |
| **Elm** | 0.3 | – | – | – |
| Birch | 0.8 | 2.9 | 0.3 | – |
| **Lime** | 0.8 | 0.9 | 1.2 | – |
| **Alder** | 0.6 | 1.4 | 0.5 | – |
| Aspen | 0.4 | – | – | – |
| Poplar | 0.5 | 0.1 | – | – |
| Other broadleaved species | 0.2 | 1.0 | 0.1 | 14 |

The monocultures of Norway spruce and Scots pine, located on sites originally covered by broadleaved or mixed-forest stands, are less stable and may be affected more seriously (e.g. by air pollution or insect pest outbreaks). Deciduous species show a much higher overall resistance. Because of this, one of the long-term aims of the Czech forest policy is to increase species diversity and to approach natural composition of forests with adequate application of suitable productive species. It is particularly important to increase the share of deciduous tree species, because of the forecasted climatic changes.

A critical proportion of broadleaved tree species used to form the basis of natural forests species composition, particularly in the Forest Vegetation Zones (FVZ) 1 to 6 (Table 1). The proportion of other broadleaved species is negligible. They had never been numerous in original stands, with the exception of lime and hornbeam in FVZs 1 to 3.

Elm, ash, maple, lime, oak and beech are considered the main Noble Hardwood tree species in the Czech Republic. Alder, service tree and wild fruit tree species are also very important.

**Table 1.** Characteristics of forest vegetation zones in the Czech Republic.

| Vegetation zone | % of total forest area | Altitude (m asl) | Mean annual temp. (°C) | Annual precip. (mm) | Vegetation period (days) |
|---|---|---|---|---|---|
| 0. Pine | 3.73 | | | | |
| 1. Oak | 8.31 | < 350 | > 8.0 | < 600 | > 165 |
| 2. Beech-oak | 14.89 | 350-400 | 7.5-8.5 | 600-650 | 160-165 |
| 3. Oak-beech | 18.41 | 400-550 | 6.5-7.5 | 650-700 | 150-160 |
| 4. Beech | 5.69 | 550-600 | 6.0-6.5 | 700-800 | 140-150 |
| 5. Fir-beech | 30.04 | 600-700 | 5.5-6.0 | 800-900 | 130-140 |
| 6. Spruce-beech | 11.95 | 700-900 | 4.5-5.5 | 900-1050 | 115-130 |
| 7. Beech-spruce | 5.00 | 900-1050 | 4.0-4.5 | 1050-1200 | 100-115 |
| 8. Spruce | 1.69 | 1050-1350 | 2.5-4.0 | 1200-1500 | 60-100 |
| 9. Mountain pine | 0.29 | > 1350 | < 2.5 | > 1500 | < 60 |

## Status of genetic resources

### Service tree (*Sorbus*)

Seven *Sorbus* species are native in the Czech Republic, the most frequent being *S. aucuparia*, *S. torminalis* and *S. aria.*

### Wild fruit trees (Rosaceae)

These are represented by *Pyrus pyraster*, *Malus sylvestris* and *Prunus avium.*

### European beech (*Fagus sylvatica* L.)

This is the main tree species of FVZ 4, in which it reaches the productive optimum. The best stands can be found on rich and humus soils with fresh moisture, from hilly regions to mountainous ones. This species frequently creates monocultural shady stands, aged 200-400 years.

### Oak (*Quercus*)

Seven species of this genus are reported in the Czech Republic, five of them only in a limited area of southern Moravia.

- *Quercus robur* L.: a frequent species, centre of occurrence is in lowland, floodplain forests, on nutrient-rich, heavy and wet soils. The species is also found on poorer and acid soils in submontane localities.

- *Quercus petraea* Liebl: most frequent species, also on poor and acid soils of upland and submontane sites. Resistant to drought and late frosts.
- *Quercus dalechampii* Ten: predominantly occurring in southern Moravia.
- *Quercus polycarpa* Schur.: predominantly occurring in southern Moravia.
- *Quercus pubescens* Willd.: sometimes in bushy form, resistant to drought, mainly on basic maternal rocks.
- *Quercus virgiliana* Ten.: very rare, more mesophilic than the previously listed species.
- *Quercus cerris* L.: native only in southern Moravia.

The most important and frequent introduced tree species is *Q. rubra* L.; *Q. palustris* Muenchh. is rare.

It seems that the worst problem from the past, which still persists, is that the differences between English *(Q. robur)* and durmast *(Q. petraea)* oaks are not sufficiently taken into consideration.

## Natural forest regions

Altogether, 41 Natural Forest Regions (NFRs, see Fig. 1) are demarcated in the territory of the Czech Republic. The NFRs are areas defined by the similarity of geographical, geomorphological and climatic conditions. Their ecological conditions predetermine the representation of and give rise to adapted regional populations (topodems).

In the framework of NFRs there are supraregional populations merged into seed zones. Tree seed zones are proposed for several reasons: to prevent unproductive mixing of current regional populations; to compensate for insufficient knowledge and to make sure that possibly occurring various species or varieties are not contaminated by unsuitable material from other populations or species.

Unfortunately, it seems that some representatives of forestry now prefer not to have seed zones that offer the possibility of arbitrary handling of reproductive material.

## Tree Seed Zones

The Tree Seed Zones are being proposed for the following tree species.

### Small-leaved lime tree (*Tilia cordata*)

The species does not occur naturally, only in the highest elevations of mountains (see Fig. 2). Five Tree Seed Zones were proposed.

### Large-leaved lime tree (*Tilia platyphyllos*)

This species is missing in the lowest part of the country, and three Tree Seed Zones were proposed (Fig. 3).

Similarly to beech, there are demarcated 'core zones' for both lime species (8a Ceský kras, 8b Krivoklátsko, 13 Šumava, 30b Moravský kras, 38 Bílé Karpaty a Vizovické vrchy) with recommended prohibited transfer of reproductive material.

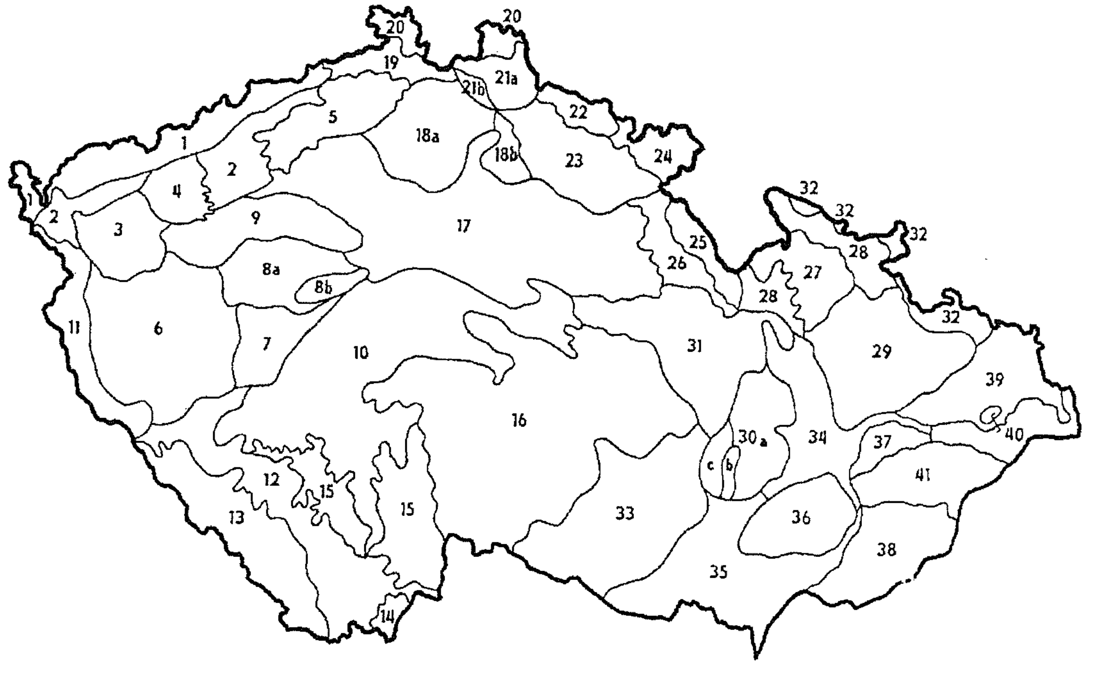


**Fig. 1.** Natural forest regions of the Czech Republic (Hynek 1996a).

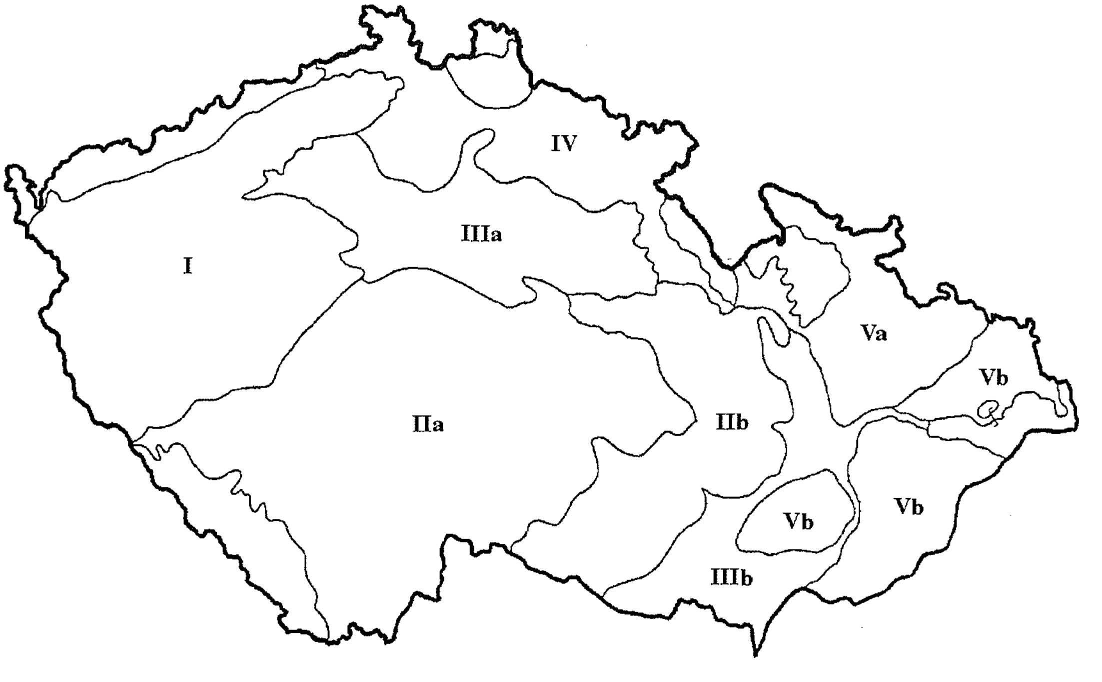


**Fig. 2.** Map of proposed Tree Seed Zones for *Tilia cordata* Mill. (Hynek 1996a).

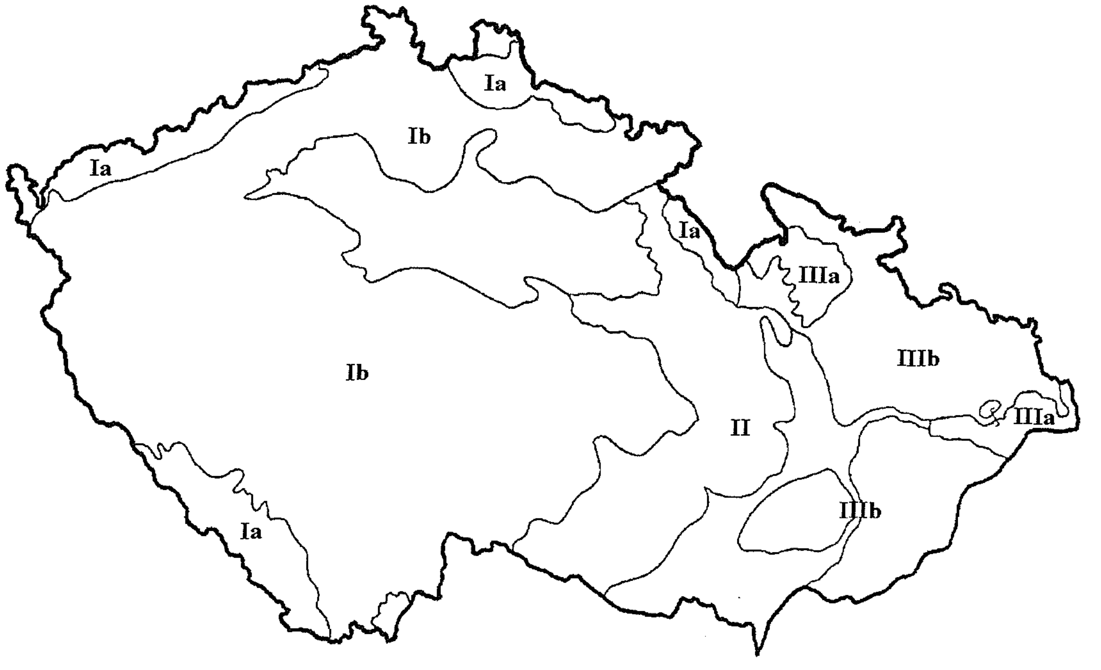


**Fig. 3.** Map of proposed Tree Seed Zones for *Tilia platyphyllos* Scop. (Hynek 1996a).

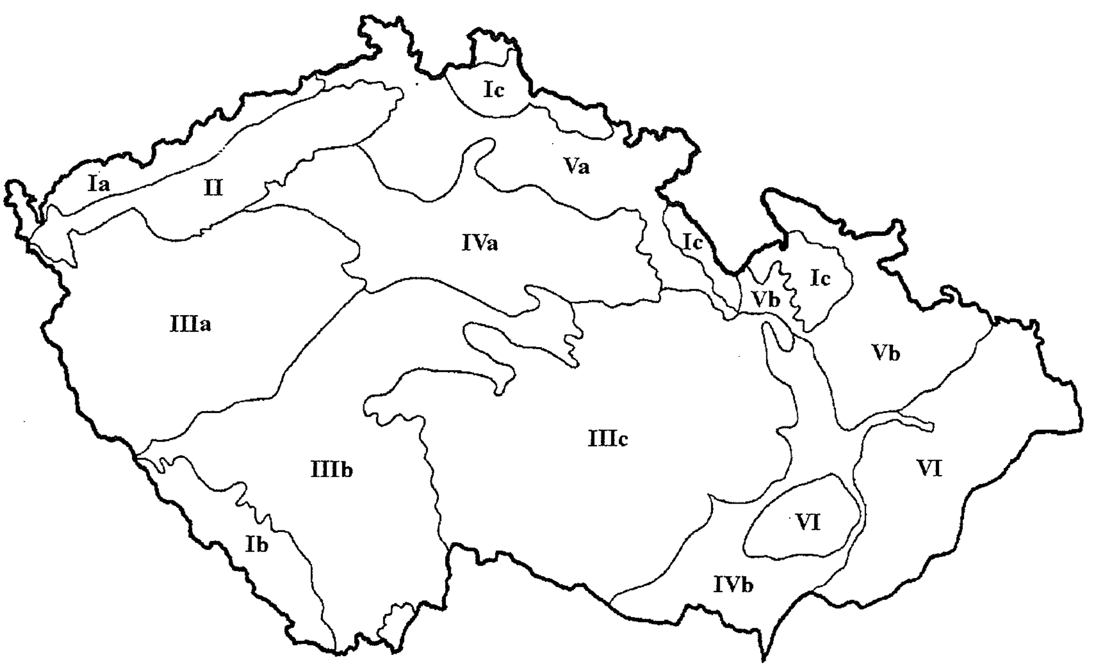


**Fig. 4.** Map of proposed Tree Seed Zones for *Fraxinus excelsior* L., *Acer platanoides* L. and *Acer pseudoplatanus* L. (Hynek 1996a).

**Ash (*Fraxinus excelsior*), Norway maple (*Acer platanoides*) and sycamore (*Acer pseudoplatanus*)**
All three species originally occurred in all Natural Forest Regions (Fig. 4). Sycamore transfer is restricted to FVZ 7. Transfer of seed material among the NFZs is not necessary because of the abundant fruit crop of these species.

**European beech (*Fagus sylvatica* L.)**
Occurs naturally in all 41 NFRs. Designation of all 10 Tree Seed Zones together is proposed. There is a proposal to prohibit any transfer of reproductive material from outside into so-called 'core NFRs' (8 Ceský kras and Krivoklátsko, 13 Šumava, 21a Jizerské hory, 27 Hrubý Jeseník, 30b Moravský kras, 36 Stredomoravské Karpaty, 38 Bílé Karpaty a Vizovické vrchy, 40 Moravskoslezské Beskydy and 41 Hostýnsko-Vsetínská vrchovina a Javorníky).

**Oak (*Quercus*)**
Four Tree Seed Zones are proposed for durmast oak in its natural distribution area. Transfer of reproductive material among the proposed Seed Zones is not recommended. In the case of English oak, three Tree Seed Zones are proposed, and the transfer of reproductive material is not recommended.

## Contamination of native genepool of broadleaved tree species

**European beech (*Fagus sylvatica* L.)**
It is assumed that the prevailing majority of beech stands in the Czech Republic are of local origin. Artificial afforestation of beech was exceptional (e.g. in the area of forest enterprise Luzná). Beech imports to the Czech Republic have occurred in the last 30-40 years. Many seeds and transplants were imported from Slovakia and illegally from the Ukraine and officially declared as material of local origin.

**Oak (*Quercus*)**
Contamination of native species by unsuitable populations has not reached significant levels, but the natural oak areas were often not considered. Forestry practice in the past has not differentiated between the two main species (*Q. robur* and *Q. petraea*). Fortunately, oak acorn importation was not implemented to a great extent. Also, the so called 'Slavonic' oak represents another uncertain entry to the list of approved forest stands. Usually, there is no certainty as to its origin. Less important oak species are easily reproduced vegetatively through coppices.

Other tree species were not imported as the main timber tree species were represented by beech, oak and conifers.

## Transfer of reproductive material

Development of respective regulations is based on the 'Licensed forest tree species reproductive material transfer rules in various periods in the present Czech Republic territory', and is shown in the 'New proposal of forest tree species reproductive material transfer rules' in Figure 5 (after Hynek 1996b).

Former legislative limitations enabled the transfer of reproductive material from other parts of the state (e.g. Slovakia). The reason was usually not the crop failure but the low price.

The basic precondition for any future transfer of forest reproductive material should be only lack of local seeds and/or other material. In such a case the material from relevant Tree Seed Zone or Natural Forest Regions should be used. Transfer between individual Seed Zones or importation should be an exception justified by very good reasons because it is necessary to respect the known ecotypes. There is a general prohibition of the transfer of reproductive material into FVZ 7 from lower vegetation zones. With the exception of FVZ 7, the transfer of broadleaved tree species is without limitation within Natural Forest Regions. The transfer between NFRs is qualified by a shift through one FVZ up or down (see Hynek 1996b).

| Forest Vegetation Zone | | Vegetative | Noble Hardwoods | |
|---|---|---|---|---|
| **No.** | **Name** | **period (days)** | | |
| 8 | Spruce | 60-100 | | |
| 7 | Beech - spruce | 100-115 | | |
| 6 | Spruce - beech | 115-130 | Transfer within natural forest regions without restrictions | Transfer between natural forest regions ±1 FVZ |
| 5 | Fir - beech | 130-140 | | |
| 4 | Beech | 140-150 | | |
| 3 | Oak - beech | 150-160 | | |
| 2 | Beech - oak | 160-165 | | |
| 1 | Oak | >165 | | |

**Fig. 5.** Proposal of rules for transfer of reproductive material of forest tree species (after Hynek 1996b).

## Current conservation activities

### Legal framework

The New Forestry Act (in force since 1 January 1996) and implementation guidelines provide the general framework for preservation of gene sources for all forest tree species, including Noble Hardwoods. A decree on genetic classification, forest regeneration and afforestation is currently under preparation by the Ministry of Agriculture.

From the point of view of conservation activities, the Forest Act has several important chapters regarding Classification of Forests (Protection and Special Purpose Forests), Forest Preservation (Prohibition of Certain Activities, e.g. to lift seedlings and transplants, to collect seeds, etc.), Forestry Activities (Certified Forest Stands and Plus Trees, Handling of Seeds and Plants, Regeneration and Tending, and Special Requirements for the Issue of Licences). It is supposed that our Forestry and Game Management Research Institute will be appointed as a legal entity entrusted with the documentation of the reproductive material sources as well as with the approval of plus trees, forest stands suitable for seed collection, seed orchards, etc.

For the sake of forest management promotion, the state offered funds which may be provided, in particular, for increasing the share of stabilizing and soil-improving tree species, mainly broadleaves.

### Conservation aims and measures

The following means for genepool conservation are undertaken in general:

- *In situ*: gene bases, approved stands for seed collection and procurement; protected areas of various levels (national parks, landscape protected areas, nature reserves)
- *Ex situ*: seed orchards, clonal archives, seedbanks, trials and testing plots, reproductive plantations.

### Gene bases

Gene bases are considered to be the basic measure for the preservation of gene sources of forest tree species *in situ*. They are defined as complexes of presumably original forest stands or stands with a high extent of genetic variability to be preserved. Gene bases represent reserves of long-term significance. They are established in various forest regions, and are being gradually declared in Forestry Management Plans. Their preferably natural reproduction must be provided by suitable, special ways of management. The area of gene bases ranges from 100 to 2000 ha. In comparison with currently applied silvicultural measures, forest management in the gene bases should aim at longer rotation and regeneration periods. They represent the type of forests with special ecological and environmental functions.

### Seed stands

This is a special category of forest stands for reproduction of mother stands with highest genetic variability. They represent planted stands that mainly originated from seeds of stands approved for seed collection of the best category (A). Natural regeneration of these artificially established stands is desirable, and vegetative regeneration is also possible. Sometimes seed stands were, in the past, planted outside the respective NFR, and even ecotypes were disregarded in the framework of the NFR, in which case these plantations lost their meaning.

### Ecotypes of forest tree species

There is an overall lack of information on ecotypes of the various broadleaved tree species because breeding and cultivation methods were not determined until a relatively short time ago.

Considering climatic zones (see FVZ), it is possible to differentiate beech and sycamore ecotypes of FVZ 7 (above 900 m elevation). However, there is a serious lack of information on zonal ecotypes of other species. In the framework of the natural forest regions, it is presumed that regional ecotypes do exist. Theoretical super-regional ecotypes originated from the fusion of regional ecotypes with similar ecological conditions which are demarcated into newly proposed Tree Seed Zones (Hynek 1996a, 1996b).

The available means for the preservation of the genepool are shown below and in Tables 2 to 6.

| Means | Maple | Ash | Elm | Lime | Oak | Beech |
|---|---|---|---|---|---|---|
| Gene bases[1] | 62 | 21 | 7 | 25 | 52 | 172 |
| Selected plus trees | 245 | 69 | 170 | 328 | 187 | 327 |
| Approved stands (ha) | 138 | 723 | 13 | 158 | 5425 | 12 524 |
| Seed orchards (ha) | 2 | – | 8 | – | 4 | 16 |
| 'Seed stands' (ha) | – | – | – | – | 275 | 168 |

[1] The number and area of gene bases for all concerned species including beech and oaks:

| | | |
|---|---|---|
| • already delared | 163 | 82 095.90 ha |
| • proposed | 108 | 45 066.63 ha |
| **Total** | **271** | **127 162.53 ha** |

**Table 2.** Number of gene bases decreed for broadleaved tree species.

| Species | Number of gene bases | Of total area (ha) |
|---|---|---|
| European beech | 172 | 79 498.17 |
| English oak | 16 | 8 257.43 |
| Durmast oak | 36 | 23 721.65 |
| Sycamore maple | 61 | 33 012.93 |
| Norway maple | 1 | 525.00 |
| Wych elm | 7 | 2 168.22 |
| Black alder | 5 | 1 149.27 |
| European ash | 21 | 8 486.25 |
| Small-leaved lime | 13 | 6 415.27 |
| Large-leaved lime | 12 | 5 718.99 |
| Hornbeam | 6 | 6 316.70 |

**Table 3.** Certified (selected) plus trees.

| Species | Number |
|---|---|
| English oak | 10 |
| Slavonic oak | 99 |
| Durmast oak | 78 |
| European beech | 327 |
| Norway maple | 9 |
| Sycamore maple | 236 |
| European ash | 69 |
| Wych elm | 170 |
| European white elm | 86 |
| Birch species | 147 |
| Service tree | 50 |
| Mazzard | 223 |
| Small-leaved lime | 314 |
| Large-leaved lime | 14 |
| Black alder | 80 |
| Total | 1 912 |

**Table 4.** Seed orchards (broadleaved tree species).

| Species | Area | Number | Seed already obtained for commercial use |
|---|---|---|---|
| European beech | 15.66 | 7 | yes |
| Slavonic oak | 3.60 | 1 | ? |
| Wych elm | 7.73 | 4 | yes |
| Service tree | 0.78 | 1 | no |
| Black alder | 1.33 | 1 | ? |
| Sycamore maple | 1.90 | 1 | no |
| Total | 31.00 | 15 | |

**Table 5.** Seed stands (area, ha).

| Species | Natural regeneration | Planting | Total |
|---|---|---|---|
| English oak | 20.15 | 64.02 | 84.17 |
| Slavonic oak | – | 183.91 | 183.91 |
| Durmast oak | – | 7.05 | 7.05 |
| European beech | 136.19 | 32.26 | 168.45 |
| Total | 156.34 | 287.24 | 443.58 |

**Table 6.** Certified Forest Stands approved for seed collection.

| Species | A category | B category | A + B |
|---|---|---|---|
| English oak | 434.18 | 3 974.47 | 4 408.65 |
| Slavonic oak | 211.20 | 212.47 | 423.67 |
| Durmast oak | 69.84 | 523.31 | 593.15 |
| European beech | 2 459.96 | 10 064.24 | 12 524.20 |
| European hornbeam | 6.34 | 29.45 | 35.79 |
| Norway maple | - | 5.91 | 5.91 |
| Sycamore maple | 15.86 | 116.34 | 132.20 |
| European ash | 117.97 | 605.28 | 723.25 |
| Smooth-leaved elm | 5.16 | 4.40 | 9.56 |
| Wych elm | 0.35 | 3.28 | 3.63 |
| Birch species | 4.49 | 201.09 | 205.58 |
| Rowan tree | - | 14.68 | 14.68 |
| Small-leaved lime | 26.33 | 131.84 | 158.17 |
| Black alder | 22.10 | 164.32 | 186.42 |
| Speckled alder | - | 0.52 | 0.52 |
| European aspen | - | 7.10 | 7.10 |
| **Total** | 3 375.76 | 16 108.33 | 19 484.09 |

Oaks = 3.6% of the total area; beech = 8.4% of certified stands in the Czech Republic.

### Progressive methods

New methods of vegetative propagation and tree breeding are being developed. Presently, cultures of several species are grown using *in vitro* techniques at the FGMRI: oak, beech, lime, elm, mountain ash, aspen, poplar and black locust.

The cultures from these species were prepared from approved trees certified for seed collection. The cultivation of 20 beech clones is important from the point of view of methodology. These were multiplied successfully and complete transplants were made. Methodologies for genetic manipulations of oak and aspen are under preparation. Complete transplants from extracted tissues have been growing successfully in outdoor trial plots for several years.

Using extracted tissues for forest tree breeding is not a dream of the future. Following forest practice and nature protection requests, primary explantate cultures of oak and elm clones were founded. Cultivation methods were prepared by our laboratory of biotechnology.

Stands of 200-year-old oak in Kardašova Recice locality are not yet reproducing, which is also due to the massive outbreak of tortricide budworm. Primary cultures for *in vitro* propagation were founded from winter buds of 18 oak clones in 1995. The number of clones from approved trees of this locality will be further improved this year.

For the past 2 years material from 60 to 80-year-old elm trees has been unsuccessfully grafted for seed orchard purposes. One of the last possibilities of saving chosen and/or rare clones is to cultivate transplants using *in vitro* cultures. Success was achieved with primary cultures of all clones in 1995. The same methodology was used for chosen clones of Wych elm. The preservation programme of smooth-leaved elm started in 1996. Multiplication of at least 40 clones of this species is foreseen.

## Needs in the genetic conservation of broadleaved tree species

National networks of *in situ* gene conservation stands, as well as tree improvement programmes and facilities for storage of forest reproductive material, are in place.

Structural changes and the overall transformation of the economy resulted in budget cuts at institutions responsible for the respective research. It is necessary to stress that conservation of genetic sources should generally be considered as a public service and sufficient attention should be paid continuously to this important task. As the forest decline in the Czech Republic is caused not only by industrial pollution but also by various pests, climatic excesses and unsuitable, badly adapted tree species composition, the importance of broadleaves is increasing.

In the past much more attention was paid to coniferous trees than to broadleaved species. The monospecific conifer plantations were planted in areas of natural mixed-stands distribution, particularly in lower forest vegetation zones. Coniferous monocultures usually have been damaged by abiotic agents (wind, snow and ice) in higher zones. Industrial pollution is another cause of serious damage. The stands have also been affected by drought in the last decade. Lowering of stability and reproductive ability of conifers was the reason for the change of view in regard to the necessity of increasing the proportion of broadleaved tree species. The importance of broadleaves, which are more resistant to abiotic and air pollution damage, is increasing in FVZs 1 to 7 (i.e. 93% of the total forest land). At higher elevations it is important to plant mainly mixed-forest stands, and the European beech should be the main tree species. At lower elevations Norway spruce stands could be replaced gradually by oaks. An indispensable precondition is to reduce the deer population.

Although all forest stands in the country are covered by forestry management plans, there is a strong need for a detailed inventory, mainly of minor or rare species and especially of Noble Hardwoods. At the present time there is a small project dealing with this matter in southern Moravia. Also desirable is isoenzyme testing.

There is a serious need for the improvement of public awareness on genetic resources and forests in general, seminars and training courses for new forest owners and forest managers.

As to the question of gene sources and their sufficiency, there is a need to carefully monitor possible trade with forest tree seeds or transplants. We could face problems due to the influence of market behaviour in this field in the short term. But, if the change in thinking toward the more natural composition of our forests should represent a long-term process (350 years if we consider the present trend of broadleaved annual planting), then there would not be any hurry to buy seeds and other reproductive material from elsewhere. Responsible forest management regarding this topic needs support through subsidies and additional funding.

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## Noble Hardwoods in Switzerland

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### Importance and current situation of Noble Hardwoods in Switzerland

Switzerland has a wide variety of site conditions. In the lower elevations (below 800 m asl), sites are very fertile and provide excellent conditions for high-value timber production of different Noble Hardwoods. Young soils, rich in minerals, combined with moderate temperatures and high precipitation provide extraordinary growing conditions for most broadleaf species. On these sites, mixtures of nearly all indigenous species are possible and the objective of silvicultural management is to create highly structured, economically valuable and biologically diverse forest. The excellent site conditions allow for highly intensive forestry, high productivity, short rotations for most species and a broad variety of different objectives.

Swiss forestry has a long tradition of sustainable management and a close-to-nature silviculture. Diversity of species is an important aspect in the context of sustainable management. Diversity in species, mixtures, age class and rotation ages helps to minimize all risks caused by insects, pests and other non-biological factors, such as wind and snow damage. In addition, a high species diversity allows for a flexible, market oriented timber harvest and a sustainable source of income. Furthermore, diversities in species, stand structures and age classes play an important role in the context of nature conservation and overall biodiversity of the ecosystem.

Despite the long tradition of a close-to-nature silviculture, only about one-third of the lowland forests may be called natural in terms of species composition. In the past, production-oriented forestry has favoured conifers such as spruce (*Picea abies*), fir (*Abies alba*), larch (*Larix decidua*) and pine (*Pinus sylvestris*) on these sites typical for broadleaves. Conversions of coppice with standard-type structures into more productive stands, which was the silvicultural practice for many decades, have led to unnaturally high proportions of cultivated conifer forests. Proportions of most Noble Hardwoods are thus lower than what would be potentially possible. Some species were probably affected more than others. Light-demanding, slower-growing species such as the service trees (*Sorbus* spp.) or the fruit trees (*Pyrus, Malus*) were most likely not competitive enough to survive in plantations of conifers. The change in the silvicultural system had yet another negative effect on Noble Hardwoods, especially on all the light-demanding species. As a consequence of degraded and overexploited forests at the end of the last century, silviculture and management were primarily governed by the need to restore these exploited forests. Consequently, interventions were made conservatively, allowing for a permanent increase in standing volumes.

Dense, overstocked and dark stands, however, were unfavourable for all the light-demanding species which eventually disappeared because of insufficient growing space. The result of decades of conservative cuttings and the consequent policy to restore growing stocks is reflected in an extremely high average stand volume of 333 $m^3$/ha which is by far the highest found in Europe. On the lowland sites of the Swiss Plateau, average stand volume is even 409 $m^3$/ha.

Table 1 gives an overview of the current proportions of some Noble Hardwoods in Switzerland as evaluated by the Swiss Forest inventory between 1982 and 1986. The category 'other broadleaves' includes several species which commonly are not regarded as Noble Hardwoods. Although volumes and stem numbers of all species are available in more detail, the values for rare and disseminated species may be regarded as only rough estimates since sampling density was too small for such species. If we take *Juglans regia, Malus sylvestris, Pyrus malus, Prunus avium, Quercus rubra, Robinia pseudoacacia, Alnus glutinosa, Sorbus torminalis, Tilia cordata, Tilia platyphyllos* and *Ulmus* sp. as Noble Hardwoods, then roughly half of the category 'other broadleaves' in Switzerland is made up of these species. Regardless of the insufficient database and regardless of the question of which species shall be considered Noble Hardwoods, the data in Table 1 clearly demonstrate that Noble Hardwoods make up less than 10% of total standing volume. The proportion is only slightly higher on the low-elevation sites where growing conditions would be ideal. A higher proportion of Noble Hardwood is found on the southern side of the Alps. In this part of Switzerland, chestnut (*Castanea sativa*) is the dominant species. Chestnut, however, mainly grows in coppice-like stands and therefore it is neither very productive nor economically very valuable.

**Table 1.** Species composition in Switzerland (in % of standing volume).

| Species | Switzer-land | Swiss Plateau | Swiss Jura | Pre-Alps | Alps | Southern Switzerland |
|---|---|---|---|---|---|---|
| Conifers | 73.5 | 65.3 | 57.1 | 80.9 | 88.9 | 58.1 |
| *Fagus* | 16.2 | 20.4 | 30.0 | 13.3 | 6.6 | 13.1 |
| *Acer* | 2.1 | 2.1 | 3.4 | 2.2 | 1.4 | 0.4 |
| *Fraxinus* | 2.5 | 4.7 | 3.1 | 2.1 | 0.7 | 1.3. |
| *Quercus* | 2.1 | 4.6 | 3.3 | 0.3 | 0.3 | 3.0 |
| *Castanea* | 0.9 | – | – | – | 0.1 | 14.3 |
| Other broadleaves | 2.7 | 2.8 | 3.1 | 1.1 | 2.0 | 9.8 |
| Total 'hardwoods' | 10.3 | 14.2 | 12.9 | 5.7 | 4.5 | 28.8 |

From these low proportions of Noble Hardwoods in our forests one might conclude that they are of minor importance for Swiss forestry. Several other aspects must be considered, however, in order to fully appreciate their role and overall importance.

Although their contribution to timber harvests is of minor importance, these species are highly important for their contribution to value production. Unfortunately, we have no information about their contribution to the financial revenues of our forest enterprises. From current market prices, however, it may be speculated that their contribution to the financial revenues is well above 10%.

We are persuaded that Noble Hardwoods will be of even greater importance to Swiss forestry in the future. Several considerations lead us to such a view. First, lowland sites offer ideal conditions for the production of high-quality timber of these species. Since only a few European countries have the site conditions to grow the highest quality Noble Hardwoods, prices most likely will be less affected by the increasingly internationalized market than the prices for conifers, which will be determined by an overabundance on the market. Second, the high cost of labour and restricted possibilities to reduce production cost by new harvesting technologies (owing to topography and other constraints) will force Swiss forestry to produce a maximum amount of high-quality timber with the highest possible revenues to stay competitive. As a consequence, two major changes in management strategies may be anticipated.

Wood production will, most likely, have to be concentrated on the very productive and easily accessible sites. Second, tending and silvicultural interventions will probably be restricted to only the most valuable and most productive individuals within each stand. Because of their high-value production, Noble Hardwoods will thus certainly play a more important role in the future than they do today.

As a third aspect, compositions of stands are gradually changing to a natural state. Although it has been an objective of silviculture for several decades, site-adapted species compositions will eventually be realized on most sites. As a consequence, conifers will be replaced by productive broadleaved species on all lowland sites. This modification is clearly apparent in all younger stands where Noble Hardwoods are present in much higher proportions than in the overall composition (Table 2). It may be anticipated that this trend will become even more pronounced in the future. Today, decisions on species compositions in newly regenerated stands are mainly based on the natural plant communities (vegetation maps). Moreover, stands are regenerated mainly by natural regeneration which likewise favours site-adapted species.

In particular, maple (*Acer)* and ash (*Fraxinus)* will be much more important in the future, primarily on the productive lowland sites of the Swiss Plateau where their proportion is four times higher in the young stands than in the overall compositions. Oak (*Quercus)* and chestnut (*Castanea)* show a decline, however. Since oak usually has to be planted, especially on beech-dominated sites, high investments for the plantations as well as the tending are necessary. This could be the prime reason for the decreasing proportion in young stands. It may be anticipated that the proportion of oak will drop even more in the future owing to financial constraints. Chestnut, on the other hand, shows a decline due to the pathogen *Endothia parasitica* and the insufficient productivity (small dimension, ring shake). Decreasing virulence of the pathogen (hypovirulence) and newly developed technologies in wood-processing may bring about a change in this trend.

Unfortunately, we have no detailed information on the proportions of other Noble Hardwoods found in young stands since the forest inventory summarizes them in the category 'other broadleaves'. Overall, however, the data in Table 2 clearly indicate the high natural potential of our sites for Noble Hardwoods. Moreover, they show that the young stands offer an excellent basis for silvicultural interventions in favour of these species.

## Threatened species and gene conservation

Deciding on the status of menace to Noble Hardwood species in Switzerland is a rather complex task. First, we lack information on the overall population size or the distribution of rare and disseminated species. Second, the problem is complex since genetic diversity may be in danger even if the overall population size is still large enough. Fragmentation, insufficient geneflow, drift and other processes such as inbreeding may lead to a gradual, hardly noticeable loss of genetic diversity. Local extinctions may be identical to loss of unique genetic variants. For the conservation of rare and disseminated species, plantations will be necessary since in many cases natural regeneration is not possible or not successful enough.

In the case of plantations, however, genetic diversity in the planting material depends largely on the seed source and the seed-collecting practice used. In disseminated and rare species, it is common practice to collect seed from only a few trees. Consequently, the genetic diversity found in the planting material is governed by chance, most likely representing only a small fraction of total diversity found within the species. Another important problem is the replacement of local genepools by foreign material. On the basis of the number of imported plants and the amount of imported seed we estimate that every second to third plant in our broadleaves plantations is of foreign origin.

Currently we may only speculate on the possible processes that are going on in such species. Lack of information leaves us with a lot of uncertainty regarding the scope of threat as well as the actions to be taken to conserve this species. In Switzerland, the situation is unsatisfactory since we lack the basic information on population size, distribution and distribution patterns of most Noble Hardwoods. Hence, effective gene-conservation measures are not possible as long as such information is not available. For the same reason we are unable to quantify or to qualify the menace to most species in question. We may at best speculate on the basis of the very incomplete overview we have at the moment.

*Sorbus domestica, M. sylvestris, P. malus, Ulmus minor and Ulmus laevis* do have to be considered threatened, because of their very small number of remaining individuals. *Sorbus domestica* is extremely rare (with a total of less than 300 estimated individuals) and its population consists mainly of old trees. No regeneration has been going on for the last 60-80 years, most likely because of insufficient light conditions in our dense stands. Moreover, owing to the large distances between single individuals, geneflow is likely low and inbreeding is high. A large variability in vigour and survival may be observed in descendants of indigenous trees which may be largely a consequence of inbreeding.

*Malus* and *Pyrus* are most frequently found on less productive sites or on the margin of the forest. Absolute numbers of individuals are unknown. From a few regional surveys we may state that the number of remaining individuals is small for both species. *Pyrus* seems to be more threatened than *Malus*. In addition, we may have to consider that a rather high proportion of remaining individuals in both species (but especially in *Malus*) are not truly wild genotypes.

The two elm species (*Ulmus*) are rare for two reasons. Since both species were most abundant in riparian ecosystems, their populations were reduced as a consequence of the disappearance of this type of forest. A further, and drastic, decrease of population size was caused by the Dutch elm disease.

*Sorbus torminalis, T. cordata, T. platyphyllos, J. regia, Acer platanoides* and *P. avium* may be regarded as moderately threatened. Although the number of individuals may still be sufficient, genetic diversity of all these species most likely is threatened by fragmentation, restricted geneflow, drift, reduced genetic diversity in cultivated plant material and loss of local material due to high imports of foreign genotypes.

*Fraxinus excelsior, A. pseudoplatanus, Quercus robur, Quercus petraea* and *C. sativa* may be regarded as the least threatened Noble Hardwoods since they still appear in moderately large populations or in higher proportions within mixed stands.

Measures to preserve genetic diversity of tree species in Switzerland were initiated in 1987. A national programme to establish gene reserves was started in 1988. First priority in this programme was given to the establishment of *in situ* gene reserves for spruce (*Picea abies*) and fir (*Abies alba*). Based on the results of a genetic survey of 20 autochthonous populations a first network of 10 gene reserves was set up for spruce. A genetic inventory of fir (21 autochthonous populations) has been completed recently. As in the case of spruce, these genetic data will be used to select the populations to be included in a network of gene reserves for fir. In 1993, a first gene reserve for oak (*Q. petraea*) was established and genetically described. Genetic inventories are currently underway to extend the gene reserve network for oak species (*Q. petraea, Q. robur* and *Quercus pubescens*).

**Table 2.** Comparison of species composition in young stands (<20 years) with overall composition (in % of number of stems per ha).

| | Switzerland | | Swiss Plateau | | Swiss Jura | | Pre-Alps | | Alps | | South Switzerland | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Total** | **<20** | **Total** | **<20** | **Total** | **<20** | **Total** | **<20** | **Total** | **<20** | **Total** | **<20** |
| Conifers | 60.7 | 35.8 | 53.7 | 26.9 | 45.8 | 20.4 | 69.9 | 54.5 | 79.3 | 49.7 | 31.0 | 23.3 |
| *Fagus* | 19.2 | 15.5 | 23.9 | 15.6 | 33.6 | 31.8 | 17.1 | 9.4 | 8.9 | 7.4 | 18.7 | 17.2 |
| *Acer* | 3.6 | 10.6 | 4.0 | 16.8 | 5.0 | 14.9 | 4.4 | 7.4 | 2.7 | 3.5 | 0.9 | 2.4 |
| *Fraxinus* | 3.6 | 14.9 | 6.3 | 23.8 | 4.4 | 20.4 | 3.8 | 9.9 | 1.5 | 3.5 | 2.7 | 9.9 |
| *Quercus* | 2.5 | 1.3 | 4.9 | 1.3 | 3.6 | 1.3 | 0.4 | 0.3 | 0.7 | 1.4 | 4.5 | 2.9 |
| *Castanea* | 2.4 | 0.3 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 21.0 | 3.7 |
| Other broadleaves | 8.0 | 21.7 | 7.0 | 15.5 | 7.6 | 11.3 | 4.4 | 18.5 | 6.8 | 34.4 | 21.2 | 40.7 |
| Total 'hardwoods' | 20.1 | 48.8 | 22.4 | 57.5 | 20.6 | 47.9 | 13.0 | 36.1 | 11.8 | 42.9 | 50.3 | 59.5 |

In spite of the alarming situation for several broadleaved species, no coordinated and nationwide programme exists for other Noble Hardwoods in Switzerland. Several factorsare responsible for this unsatisfactory situation. First of all, when the first gene conservation programme was initiated in 1988, conifers were threatened more by air pollutants than broadleaves. From the development of coniferous forests in eastern Europe, the prospects seemed rather bleak for all our alpine forests. Moreover, spruce and fir are the most important species in terms of their proportion as well as their importance for the stability of protective forests in the higher elevations. Consequently, financial resources were concentrated primarily on the preservation of genetic diversity of these two most important conifer species. Secondly, information on the population structure of most Noble Hardwoods was missing, thus genetic monitoring was hardly possible. In addition, gene conservation measures of rare and disseminated species need other strategies than *in situ* gene reserves. Without information and clear conservation strategies, however, no coordinated and systematic measures were possible. Finally, in Switzerland the implementation and practical realization of all conservation measures largely depend on the regional forest services. Experience has shown that most of these regional forest services currently are dealing with problems that they consider more important than gene conservation programmes. While *in situ* gene reserves may still be realized under these circumstance, *ex situ* measures are much harder to implement since they can not be accomplished without the support and input (land, financing) of the forest service. In 1990, for example, an effort to establish seed orchards for the most important hardwoods on a nation-wide level was unsuccessful for this reason.

The following efforts for gene conservation of Noble Hardwoods have been realized so far or are in the process of realization:

1. The Chair of Silviculture has established a collection of 78 clones of *Ulmus laevis*. Strong and virulent attacks by Dutch elm disease during the last couple of years were threatening the already small and local populations of this species. Thus, no time could be spent to collect systematic data on the distribution of the species in Switzerland. Instead, all available individuals from the different and known populations were collected and grafted into a conservation orchard.
2. On the other hand, a rather systematic survey was carried out for the extremely rare *S. domestica*, before conservation measures were initiated. The Chair of Silviculture is planning a collection of grafting material, including all currently known individuals (±200), for the winter 1996/97. Clones will be put into a seed and conservation orchard which will be established in collaboration with a regional forest service. At the same time, trees will be genetically assessed and diversity will be compared with populations in Germany. Genetic information will be used to find answers to several questions regarding conservation strategies for this extremely rare and disseminated species. The conservation of *S. domestica* has also been supported by propagating planting material of local genotypes.
3. The Chair of Silviculture has also started a survey of *S. torminalis* plus trees in northeastern Switzerland. So far about 150 individuals have been localized and assessed for important traits. The best 70-80 clones will be grafted into a seed orchard in winter 1996/97. This orchard should provide genetically diverse seed and planting material with improved form characteristics. At the same time, phenotypically extraordinary genotypes will be preserved.
4. A survey of *Malus* and *Pyrus* has been started. The available number of clones, however, does not allow the establishment of conservation orchards yet.

We are confident that Noble Hardwoods will get much more attention in the future. These species will certainly benefit from the increasing importance which is given to nature conservation aspects within forest management and silviculture. The national gene conservation programme, for example, is now financially supported by the nature conservation agency. As a consequence, objectives have already been changed to include rare and disseminated broadleaved species. Apart from oak, which will be the major species for the programme over the next 4 years, *S. torminalis* has been chosen as a 'pilot species' to study genetic diversity and to develop gene conservation strategies for a rare and disseminated species. Moreover, a project to survey the population sizes, population structures and distribution patterns of all disseminated species has been formulated and will start this coming spring. The resulting inventory will finally supply the necessary data which are needed to quantify the status of threat to these species. Furthermore, it will provide the basic information needed for genetic surveys and for the collecting of grafting material for conservation and seed production orchards. In addition, a regional forest service has plans to establish seed orchards of rare Noble Hardwoods and a conservation plantation of endangered shrub species. Primarily rare species such as *Malus, Pyrus, Juglans* and *Sorbus* shall be conserved for the northwestern parts of Switzerland. Although these are independent programmes, a maximum benefit may be achieved when these different efforts are well coordinated and integrated with each other and with the existing conservation measures.

## Research and breeding programmes

Noble Hardwoods are prime candidates for breeding since excellent form and quality are prerequisites for their high-value production. Excellent form may partly be realized by an appropriate silvicultural management. The traditional silvicultural conditions to favour good form and stem characteristics are small spacings in the plantations and dense, highly overstocked stands in the first 20-30 years. High investments are necessary to produce the desired quality of Noble Hardwood timber. Alternatively, high-quality timber may be achieved by using excellent genetic material with an above-average phenotypic expression of the desired traits. In broadleaved species where quality and form is much more important than in conifers, amazing differences in quality traits have been found at the level of provenances. As an example, the best oak provenance showed a net value at rotation age that was 170% higher than the net value produced by an average provenance.

Family selection within good provenances may produce an additional gain in the average values of the desired traits since heritabilities of some of these traits are moderately high. Improved form characteristics may also be achieved by family selection of traits which often have a negative effect on axis formation such as phenology traits, frost resistance or low apical dominance characteristics in the case of damage to the terminal bud.

If our objective is production of the highest quality Noble Hardwood timber with a minimum amount of investment, then the genetic material which is used for plantations is absolutely decisive for the desired results. The genetic value of planting material will become even more important owing to the wider spacings which are used in plantations and the necessary reduction of tending and thinning measures to the absolute minimum. Breeding Noble Hardwoods thus seems highly profitable. We may, however, have to differentiate the potential of breeding for single species. At present, no breeding programmes for Noble Hardwoods exist in Switzerland. Two activities with a breeding aspect do exist, however. A seed orchard of *J. regia*, containing the best 62 clones selected in our provenance trial of original provenances from Himalayan countries, was established in 1995. The objective of this orchard is the production of genetic material with improved form characteristics. The planned seed orchards of *S. torminalis* and *S. domestica* will also contain material of phenotypically selected plus trees, mainly based on form traits.

Not all Noble Hardwoods have the same potential for breeding and thus priorities for breeding differ according to the species. In our opinion, the following criteria must be considered:

- the importance of form traits for the final product
- the variation of form traits within the species (populations)
- the average phenotypic expression of these traits found in the average planting material
- the population structure of the species, which strongly influences seed collection
- genetic quality of the propagation material and the need for conservation measures
- the number of plants used for plantations.

A high priority for breeding should, in our opinion, be given to the following species: *P. avium, J. regia, S. torminalis, T. cordata* and *T. platyphyllos*.

For *P. avium* form traits are decisive for the final product; apical dominance, internodal length and branching characteristics are highly variable. Phenotypic provenance or family selection allow for a considerable genetic gain regarding such form traits. Planting material used in Switzerland very often is of insufficient genetic quality. High proportions of forking and high numbers of branches per whorl as well as thick branches are frequently observed in the plantations. Phenotypic selection of superior provenances is difficult since populations with a sufficient population size and a superior phenotypic quality are extremely rare. As a consequence, more than 50% of the yearly amount of seed must be imported. In addition, genetic quality and genetic diversity of the seed collected in Switzerland is clearly deficient in most cases. Even if the yearly demand for planting material is relatively low (250 000 plants), breeding activities should have a high priority since *P. avium* is one of the most interesting and most abundant Noble Hardwood species in Switzerland. The production of a sufficient amount of seed may easily be combined with breeding activities for form traits. If seed orchards contain a large number of superior clones, the produced seed will not only be genetically improved, it may at the same time have a higher genetic diversity than what is currently found in the available material. Thus, breeding may partly be combined with conservation activities.

*Juglans regia* is a prime candidate for breeding activities. We believe that this species has the highest future potential and the highest possible value production of all Noble Hardwoods. The available resources of timber in Europe are decreasing while the demand is increasing. Walnut is an excellent species that may be used to replace several tropical hardwoods. We thus believe that the future market perspectives are excellent. Over 90% of raw timber used in Switzerland is currently imported; 9% of the inland production comes from agricultural lands where the number of trees is decreasing steadily. Only 1% of the timber is produced on forest lands. This proportion may be much higher and walnut thus is a very interesting species for our excellent lowland woodland sites where the rotation is estimated to be only 60 years.

The main constraint for successful cultivation of walnut on forest land is the lack of provenances or seed sources which are suitable for high-value production timber. Regarding the indigenous genepool, *Juglans* is a special case since it is not native to Europe. Walnut colonized Europe in the course of human cultivation. If we consider that *Juglans* was cultivated for its fruits and thus was selected over more than 2000 years for fruit traits only, we may speculate that form characteristics have been negatively influenced. We are persuaded that unsatisfactory results of plantations on woodland sites are mainly the result of insufficient genetic material that is available in Europe. Thus, breeding indigenous sources may not be very efficient nor very successful.

For this reason, the Chair of Silviculture has initiated a research programme, testing provenances from the original area of distribution in Asia. The main objective of these provenance trials is a first step to find autochthonous populations with above-average form characteristics, sufficient frost resistance and an excellent ability to re-establish the main axis after damage to the terminal bud. In a second step, family selections within the best provenances are possible to achieve an additional improvement of traits. Seed orchards combining the best families of the best provenances will produce seed that should allow a successful cultivation of walnut in forest environment. A first orchard containing 62 families, selected within two provenances from India and Pakistan, has been established. Further provenance trials are planned and breeding will be pursued. Breeding hybrid walnuts (*Juglans intermedia*) may be another interesting objective. At present, however, no priority is given to hybridization or selection of suitable hybrid genotypes. First of all, we have no information about the number of existing hybrid walnuts in Switzerland. Secondly, vegetative propagation techniques do have to be improved before programmes may be started. Finally, questions regarding wood properties and future market perspectives of hybrid walnuts are still unclear.

*Sorbus torminalis* is a species with an excellent potential on site conditions where the available number of species is clearly reduced. Shorter rotations than needed for oak combined with an excellent market price make this species extremely interesting for forestry. Resources of *Sorbus* will gradually decrease owing to a lower proportion found in even-aged stands than in the ancient coppice with standard-type stands, which are gradually disappearing. It may thus be anticipated that market prices most likely will increase in the future. Consequently, *Sorbus* may become a species that is not only interesting for nature conservation but also for value production. An increasing interest for this species may clearly be observed during the last several years. We already notice a demand for planting material that may not always be satisfied. For long-term conservation of the species, the planting material should be genetically diverse. Genetically diverse seed may, however, only be produced in seed orchards since seed collections *in situ* representing a sufficient number of parents are practically impossible. Phenotypic selection of superior families (form traits, spiral grain) grafted into seed orchards containing 100 or more clones thus will improve not only the genetic quality but also the genetic diversity of the planting material. In *Sorbus*, we believe that breeding and conservation may easily be integrated.

The proportion of *Tilia* makes roughly 13% of standing volume of the category 'other broadleaves'. This is higher than the proportion of *P. avium* (7.5%). Since natural regeneration is hardly successful, both species of *Tilia* do have to be planted on most sites. Plantations, however, are often unsatisfactory in their quality (forking, stem form) even when narrow spacings are used. Available seed sources are quantitatively as well as qualitatively (phenotypic expression of desired traits as well as genetic diversity) insufficient for both species. More than half of the seed is imported. The situation of *Tilia* is thus very similar to *Prunus* except that *Tilia* may still be found, at least regionally, in small populations. Genetically diverse seed might be collected in these stands if genetic considerations were respected. Consequently, in a first step, suitable indigenous provenances must be identified and assessed for their phenotypic values. The best populations may then be used as seed sources. In a second step, a family selection may be performed and production orchards established. Gene conservation of *Tilia* may partly be realized *in situ*;

production orchards may be an additional *ex situ* reservoir for excellent genotypes.

Breeding programmes for *F. excelsior* and *A. pseudoplatanus* are less essential. Ash and maple are mainly regenerated naturally. In general, the large number of individuals in such regenerations provides a sufficient basis for tending and silvicultural selection. Moreover, stem form of both species is normally good. If forking occurs, it is mainly for biotic or abiotic reasons and not primarily due to genetic background. Thus breeding for form is less important than in other species.

For *Quercus* species, we have to consider the problem of propagating selected and possibly improved genotypes at least by ways of generative propagation. The alternative of multiclone selections of superior genotypes seems not to be a valuable option for us, at least not for the moment. Especially for long-living oak, we believe that clonal forestry bears too many risks to be an alternative. Moreover, many excellent provenances are available in Europe which may be used instead of indigenous material. High phenotypic gains may be achieved by carefully selecting the right provenances. The few provenance trials which are available clearly indicate the high potential of provenance selection. Our information is scarce, however. Consequently, we need more information on the performance of indigenous and potential foreign provenances.

# Noble Hardwood species in Germany: occurrence and gene conservation measures

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## Introduction

The last forest inventory in Germany is dated 1990. The main results are shown in Table 1. Forests cover about 30% of Germany with 10.8 million ha. The proportion of broadleaves in the forest area is 33.9%; the main species are beech, 1.4 million ha (14.0%) and oak, about 0.8 million ha (8.6%).

**Table 1.** Area (in 1000 ha) of forest (source: BML 1990, 1994).

| Region[1] | Oak | Beech | Alh[2] | Aln[2] | Broad-leaves | Conifers | All |
|---|---|---|---|---|---|---|---|
| NW Germany | 227 | 312 | 54 (2.7%) | 267 | 859 | 1140 | 1 999 |
| E Germany | 171 | 208 | 88 (3.1%) | 238 | 705 | 2111 | 2 816 |
| S Germany | 479 | 904 | 257 (4.8%) | 240 | 1879 | 3450 | 5 329 |
| Total | 876 (8.6%) | 1424 (14.0%) | 398 (3.9%) | 745 (7.3%) | 3443 (33.9%) | 6701 (66.1%) | 10 144[3] (100%) |

[1]

| Regions | Federal States |
|---|---|
| Northwest Germany | Bremen, Hamburg, Niedersachsen, Nordrhein-Westfalen, Schleswig-Holstein |
| East Germany | Berlin, Brandenburg, Mecklenburg-Vorpommern, Sachsen, Sachsen-Anhalt, Thüringen |
| South Germany | Baden-Württemberg, Bayern, Hessen, Rheinland-Pfalz, Saarland |

[2] Alh = long-lived broadleaved species; Aln = short-lived broadleaved species.

[3] Without unstocked forest land and non-forest land (total sum plus about 0.7 million ha).

Other broadleaved species are combined in the two groups 'Alh' (long-lived broadleaved species) and 'Aln' (short-lived broadleaved species). In the group 'Alh' the broadleaved species hornbeam, ash, sycamore, Norway maple, field maple, lime, elm, wild cherry, false acacia, sweet chestnut and wild service tree are pooled. The group 'Aln' contains the species birch, alder, poplar, willow, mountain ash and all other broadleaved species. In reference to the Noble Hardwood species, the group 'Alh' is of particular interest (Table 2), as are nut tree species, *Sorbus* sp. and wild fruit species, which are registered in the group 'Aln'.

In general, Noble Hardwoods can be defined as relatively rare tree species which were often neglected in the past; produce a highly valuable timber; and need relatively better site conditions for optimal growth (Puchert 1974). The proportion of Noble Hardwoods increases from 2.7% of the total forest area in northwestern Germany to 3.1% in eastern Germany and up to 4.8% in southern Germany (see Table 1).

**Table 2.** Importance, seed legislation and endangering of Noble Hardwoods in Germany.

| | | | | Cause of endangering | | | |
|---|---|---|---|---|---|---|---|
| **Species** | **Importance** | **Seed legislation** | **Unregulated seed import** | **Hybridization with other species** | **Hybridization with cultivars** | **Small population size ⇒Inbreeding, genetic drift** | **Diseases** |
| **Native species** | | | | | | | |
| *Acer pseudoplatanus* | ***** | * | | | | | |
| *Acer platanoides* | ** | | * | | | ** | |
| *Acer campestre* | *** | | * | | | ** | |
| *Alnus glutinosa* | **** | * | | | | | |
| *Fraxinus excelsior* | ****** | * | | | | | |
| *Ulmus glabra* | *** | | * | * | | ** | *** |
| *Ulmus laevis* | ** | | * | * | | * | *** |
| *Ulmus minor* | ** | | * | * | | ** | **** |
| *Tilia cordata* | *** | * | | * | | | |
| *Tilia platyphyllos* | ** | | * | * | | * | |
| *Prunus avium* | **** | | * | | * | * | * |
| *Sorbus torminalis* | ** | | * | | | ** | |
| *Sorbus domestica* | * | | * | | * | *** | |
| *Pyrus pyraster* | * | | * | | *** | *** | |
| *Malus sylvestris* | * | | * | | *** | *** | |
| **Non-native species** | | | | | | | |
| *Juglans regia* | * | | | * | | * | |
| *Juglans nigra* | * | | | * | | * | |

More than 90% of the stands within the group 'Alh' are mixed forests, mainly mixed with beech and/or oak and they often occur only in small relicts, not forming reproductive populations. Recently interest has been focused on Noble Hardwoods because of their rarity, value and, therefore, the necessity to maintain these species with gene-conservation measures.

The climatic and edaphic conditions of most German forests favour beech. Therefore, the competitive power of beech is very strong. In the colline and submontane zones, the proportion of Noble Hardwoods increases on drier or wetter sites (Fig. 1), and in the montane zone, where the soils are neutral or not too acid (Ellenberg 1982).

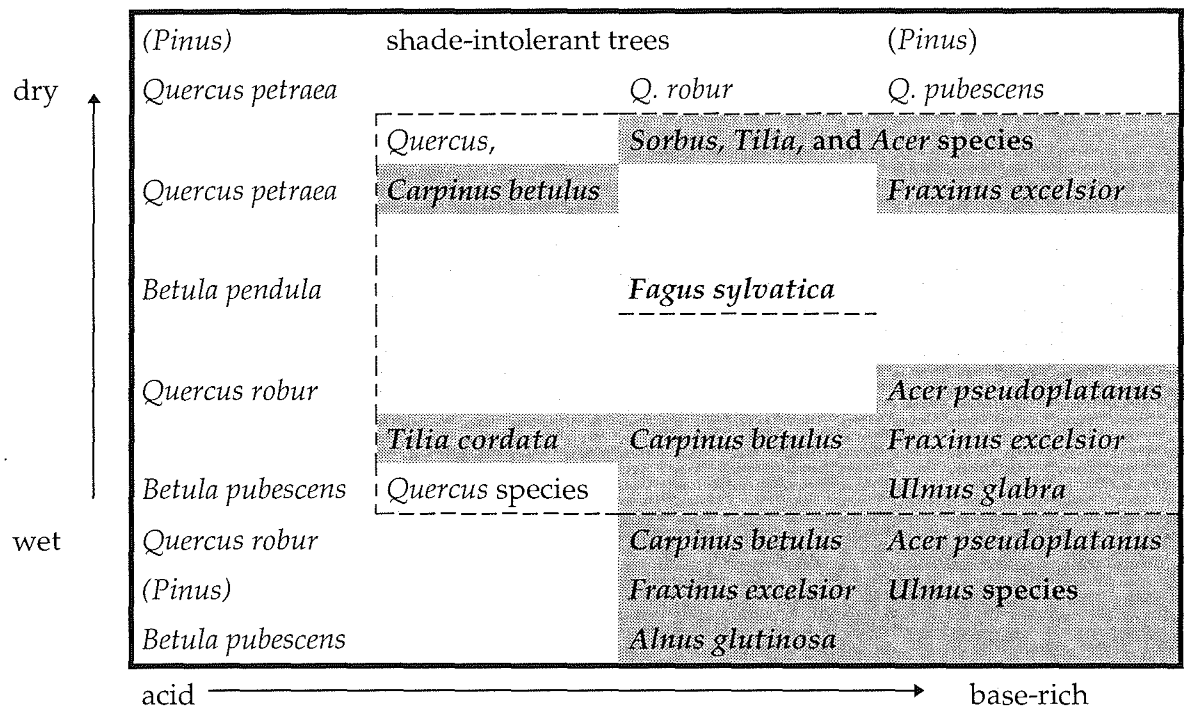


**Fig. 1.** Water and nutrient site requirements of main tree species in submontane regions (modified from Ellenberg 1982); dark shaded area = Noble Hardwoods.

Most of the Noble Hardwoods grow on sites having a good water and nutrient situation. Some Noble Hardwood species inhabit moist sites along rivers or in valleys, from the lowland up to the submontane zones. A few other species, e.g. of the genus *Sorbus*, prefer climatically warmer regions. Usually those sites are less suited to beech.

The rotation length for Noble Hardwoods is 80-180 years, depending on the species (Otto 1989). Figure 2 shows the age-class distribution of 'Alh' high forest in Germany. Broadleaves, even more than conifers, have relatively rigid lower diameter limits for particular end uses. The large minimum diameter limits to attain high timber and veneer qualities, combined with relatively low diameter increments give rise to the long rotations associated with growing high-quality broadleaves. However, in recent years there has been a tendency towards higher prices, even with small diameters, in many of these species; obviously a reaction of the market to the decreasing quantity and quality of tropical hardwood timber.

The fruits of most of the Noble Hardwoods provide food for wild animals.

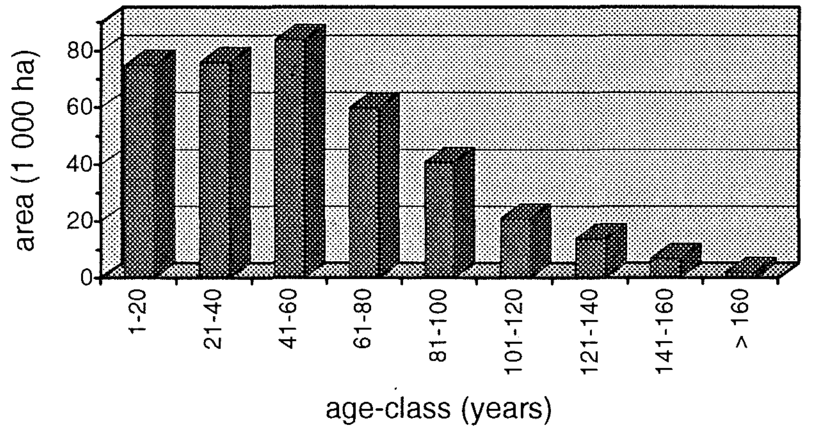


**Fig. 2.** Age-class (years) distribution of 'Alh' high forest in Germany (1000 ha) (source: BML 1990, 1994).

## Noble Hardwood tree species

### Maple

The maples include one important timber-producing tree, sycamore (*Acer pseudoplatanus* L.), and two of considerable potential, Norway maple (*Acer platanoides* L.), and field maple (*Acer campestre* L.). Sycamore is well known as a submontane and montane woodland tree, and thrives on a wide range of soils except those that are very dry and infertile. Sycamore is a longer-lived tree species than other maples. It is the only maple considered by legal and administrative regulations in Germany. In the 'Regulation on the Regions of Provenance for Forest Reproductive Material' 11 forest seed provenance regions for sycamore are defined (Anonymous 1994).

The ecological optimum of Norway maple is a more continental climate. The field maple prefers warmer temperatures. Norway maple and field maple often grow in forest edges, field hedges and on open land.

### Ash

Ash (*Fraxinus excelsior* L.) is a widely occurring broadleaved species that, when well grown on fertile sites, produces a fine-quality timber. Ash grows in the lowlands beside water, and in the mountains on fertile and moist sites. Ash is considered in the legal and administrative regulations of Germany. In the 'Regulation on the Regions of Provenance for Forest Reproductive Material' eight forest seed provenance regions for ash are defined (Anonymous 1994).

### Lime

Both large-leaved lime (*Tilia platyphyllos* Scop.) and small-leaved lime (*Tilia cordata* Mill.) occur mostly in mixed forests. In the lowlands, human activities have made lime a rare forest tree species. In the mountainous regions of southern Germany there are still a few native stands mixed with maple, ash and elm. Like hornbeam, both lime species are important components of accompanying species in oak forests, and also in ash and larch forests. Small-leaved lime is considered in the legal and administrative regulations of Germany. In the 'Regulation on the Regions of Provenance for Forest Reproductive Material' eight forest seed provenance regions for small-leaved lime are defined (Anonymous 1994).

The two native lime species can hybridize with other lime species or other provenances planted in the landscape, and are, therefore, endangered.

### Elm

Elms are common woodland tree species. The species are severely endangered owing to their high susceptibility to Dutch elm disease, caused by the fungus *Ophiostoma ulmi*. Since 1970, in particular, the last widespread epidemic of the very aggressive fungal strain has caused high losses of the mature and also middle-aged populations of mountain elm (*Ulmus glabra* Huds.) and field elm (*Ulmus minor* Mill.). The large-leaved elm (*Ulmus laevis* Pallas) is less susceptible. The field elm belongs to the most precious broadleaved tree species in Germany.

### Cherry

Wild cherry (*Prunus avium* L.) is an important minor species on fertile and warm sites and on forest edges. Wild cherry is a valuable addition to a stand, both for timber production and, as part of the landscape in spring, for its flowers. There are only a few stands and seed plantations able to produce valuable seed. Wild cherry is not considered in the German 'Act on Forest Seed and Planting Stock' (Anonymous 1979). There exists no guarantee of obtaining proper seed, and the risk of hybridization with cherries from plantations established for fruit production is also high. Generally population sizes are small.

### Sweet chestnut

Sweet chestnut (*Castanea sativa* Mill.) was probably introduced by the Romans and is now growing very well on lighter, limeless soils mainly in southern Germany. Most sweet chestnuts will be found on forest edges, parks and in landscapes where they are used as fruit trees.

### Hornbeam

The ecological optimum of hornbeam (*Carpinus betulus* L.) is the warmer lowland. In the past hornbeam was an important component in coppice silviculture. This forest type is changed mostly after clearcutting into high forest with other tree species. Nowadays, it is a frequent component of the understorey, for example in oak forests. It is also used for hedges in gardens, parks and landscape. The origin of this material is mostly unknown. It is necessary to discuss if this species should belong to Noble Hardwoods.

### Mountain ash species

The wild service tree (*Sorbus torminalis* [L.] Crantz) prefers fertile soils over limestone or chalk and a warmer climate. The presence of the wild service tree is a useful indicator of an ancient woodland site. In the past *S. torminalis* was often neglected in the forests and could not compete with the more dominant broadleaved species.

Whitebeam (*Sorbus aria* L.) occurs on fertile sites in mixed broadleaved forests of warmer regions in western and southern Germany. The northern distribution limit of service tree (*Sorbus domestica* L.) is in southern Germany. The species grows individually on limestone in mixed forests and in the landscape there are only 6000 old trees alive. The fruit is still used as an addition in fruit juices. Both whitebeam and service tree have slow growth rates.

These mountain ash species are very sensitive to competition from other trees.

European mountain ash (*Sorbus aucuparia* L.) is a sub-boreal element and has the widest natural distribution in Germany. It can grow on soil with lower nutritional value and is resistant to frost. It is used at higher elevations for reforestation, forest edges, hedges, and in landscape. In the past, *S. aucuparia* was not regarded as a Noble Hardwood species.

### Walnut

Common walnut (*Juglans regia* L.) is extremely susceptible to frost damage, particularly late spring frosts. It is spread and cultivated in the warmer regions of Germany. Common walnut is not damaged by extreme cold in winter. Walnut produces a high-quality timber. Some of the most attractive wood comes from the root crown area from which fine burr walnut veneers can be obtained. Most of the trees are grown in the landscape (Fleder 1986).

Black walnut (*Juglans nigra* L.) is native in North America and cultivated on fertile sites in the lowlands along water in southern Germany. Initial growth of black walnut is rapid. It produces an appreciated high-value wood.

### Wild apple tree, wild pear tree

The wild apple tree (*Malus sylvestris* [L.] Mill.), and particularly the wild pear tree (*Pyrus pyraster* [L.] Burgsd.), are rare in forests. They are still on forest edges, in remaining coppice and composite forests. But the coppice and composite forests have changed, mostly after clearcutting into high forest with other tree species. Wild fruit trees can not compete with the more dominant species and their existence is, therefore, extremely endangered.

In addition, and as a consequence of, the long breeding history of wild apple and wild pear trees, and their easy hybridization, the identification of wild species is extremely difficult. On account of their rarity today, they are important subjects for gene conservation (Wagner 1995).

### Alder

The black alder (*Alnus glutinosa* [L.] Gaertn.) is widely distributed throughout northern Europe. The species is a light-demanding pioneer which naturally regenerates easily to form small pure stands on areas of freshly exposed soil in wet localities. Natural and semi-natural stands occur predominantly on wet ground almost regardless of the parent material of the soil, being found both in regions where acid rocks and in regions where limestones predominate. Black alder is able to fix atmospheric nitrogen and, therefore, is an important species for reclamation work and plantings where the soils are poor in organic matter and nitrogen. In the 'Regulation on the Regions of Provenance for Forest Reproductive Material' (Anonymous 1994), eight forest seed provenance regions for black alder are defined.

## Conservation of genetic resources of Noble Hardwoods

The conservation of indigenous material is significantly influenced by the use of material for commercial trade. Only the species *A. pseudoplatanus*, *A. glutinosa*, *F. excelsior* and *Tilia cordata* are written into the national law. The selected stands for these species are summarized in Table 3. A private organization, with public participation (Deutsche Kontrollvereinigung für Forstliches Saat- und Pflanzgut e.V.), has selected additional stands of those species that are not under the national law. These stands are summarized in Table 4.

**Table 3.** Selected stands of Noble Hardwoods under the national law.

| Species | No. of stands | Total area (ha) |
|---|---|---|
| *Fraxinus excelsior* | 1120 | 2333 |
| *Alnus glutinosa* | 427 | 1247 |
| *Acer pseudoplatanus* | 705 | 855 |
| *Tilia cordata* | 453 | 705 |

**Table 4.** Selected stands of Noble Hardwood not included under the national law.

| Species | No. of stands | Total area (ha) |
|---|---|---|
| *Acer campestre* | 2 | 5.1 |
| *Acer platanoides* | 1 | 0.4 |
| *Castanea sativa* | 1 | 3.5 |
| *Juglans nigra* | 1 | 7.5 |
| *Prunus avium* | 42 | 68.3 |
| *Robinia pseudoacacia* | 3 | 12.2 |
| *Sorbus torminalis* | 8 | 44.9 |
| *Sorbus aria* | 1 | 6.0 |
| *Sorbus domestica* | 3 | 0.9 |
| *Tilia platyphyllos* | 7 | 4.6 |
| *Ulmus glabra* | 10 | 15.6 |

## *In situ* measures

*In situ* conservation has priority for most of the major tree species. However, in Noble Hardwoods the relict populations are often too small to really form reproductive populations. A higher number of stands of sufficient size could be detected only for *A. pseudoplatanus*, *F. excelsior*, *C. betulus* and *T. cordata*. The present stage of *in situ* conservation is summarized in Table 5. From this it is obvious that for some species only very few stands can be found; however, quite a high number of single trees are collected into seed orchards.

**Table 5.** *In situ* conservation measures for Noble Hardwood species in Germany at 31 December 1995 (source: BLAG 1996).

| | *In situ* stands | | *In situ* single trees |
|---|---|---|---|
| Species | Number | Area (ha) | Number |
| *Acer campestre* | 11 | 20.0 | 654 |
| *Acer platanoides* | 11 | 4.5 | 384 |
| *Acer pseudoplatanus* | 46 | 47.2 | 750 |
| *Carpinus betulus* | 56 | 73.2 | 322 |
| *Castanea sativa* | 1 | 2.8 | 26 |
| *Fraxinus excelsior* | 66 | 118.7 | 710 |
| *Juglans nigra* | | | 100 |
| *Juglans regia* | 1 | 0.1 | 329 |
| *Malus sylvestris* | 1 | 1.0 | 880 |
| *Prunus avium* | 34 | 19.6 | 1164 |
| *Pyrus pyraster* | 1 | 0.2 | 579 |
| *Sorbus aria* | 1 | 0.2 | 78 |
| *Sorbus aucuparia* | 2 | 2.2 | 229 |
| *Sorbus domestica* | 1 | 0.1 | 2137 |
| *Sorbus torminalis* | 244 | 4.8 | 1149 |
| *Tilia cordata* | 113 | 111.8 | 283 |
| *Tilia platyphyllos* | 122 | 19.0 | 302 |
| *Ulmus glabra* | 79 | 46.1 | 1242 |
| *Ulmus laevis* | 71 | 43.0 | 425 |
| *Ulmus minor* | 26 | 9.0 | 514 |

**Table 6.** *Ex situ* conservation measures (stands, single trees, seed orchards, clone archives) for Noble Hardwood species in Germany (status: 31.12.1995) (source: BLAG 1996).

| | *Ex situ* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stands | | No. single | Seed orchards | | No. of | No. of | Clone archives | |
| Species | No. | Area (ha) | trees | No. | Area (ha) | families | clones | No. | No. of clones |
| *Acer campestre* | – | – | – | – | – | – | – | – | – |
| *Acer platanoides* | – | – | – | 2 | 4.4 | – | 110 | 1 | 50 |
| *Acer pseudoplatanus* | 38 | 16.45 | – | 14 | 27.6 | – | 465 | 2 | 21 |
| *Carpinus betulus* | 12 | 9.07 | – | – | – | – | – | – | – |
| *Castanea sativa* | – | – | – | – | – | – | – | 1 | 20 |
| *Fraxinus excelsior* | 10 | 17.28 | – | 9 | 21.8 | – | 519 | 1 | 52 |
| *Juglans nigra* | 9 | 2.53 | – | – | – | – | – | – | – |
| *Juglans regia* | 17 | 8.29 | – | 3 | 14.2 | – | 15 | – | – |
| *Malus sylvestris* | 227 | 37.23 | 1985 | 18 | 18.8 | 157 | 312 | – | – |
| *Prunus avium* | 48 | 38.95 | – | 17 | 25.3 | 1 | 700 | 4 | 120 |
| *Pyrus pyraster* | 3 | 0.34 | 400 | 13 | 10.5 | 53 | 305 | – | – |
| *Sorbus aria* | 8 | 1.00 | – | 3 | 0.9 | 50 | – | – | – |
| *Sorbus aucuparia* | 13 | 4.01 | – | 3 | 1.9 | 48 | – | – | – |
| *Sorbus domestica* | 21 | 6.51 | 2733 | 5 | 3.1 | 128 | 186 | 2 | 76 |
| *Sorbus torminalis* | 13 | 4.56 | 3077 | 7 | 9.0 | – | 202 | 1 | 71 |
| *Tilia cordata* | 19 | 15.64 | – | 19 | 39.3 | – | 501 | 2 | 85 |
| *Tilia platyphyllos* | – | – | – | – | – | – | – | 1 | 11 |
| *Ulmus glabra* | 14 | 8.20 | 4525 | 8 | 10.1 | – | 146 | 8 | 116 |
| *Ulmus laevis* | 54 | 5.60 | 20 | 2 | 2.7 | – | – | 1 | 9 |
| *Ulmus minor* | – | – | 20 | 1 | 2.5 | – | 50 | 1 | – |

**Table 7.** *Ex situ* conservation measures (seed and pollen storage) for Noble Hardwood species in Germany (status: 31.12.1995) (source: BLAG 1996).

| | Seed storage | | | | Pollen storage | |
|---|---|---|---|---|---|---|
| | Stands/seed orchards | | Single trees | | | |
| Species | No. | Quantity (kg) | No. | Quantity (kg) | No. | Quantity ($cm^3$) |
| *Acer campestre* | – | – | – | – | – | – |
| *Acer platanoides* | 3 | 17.49 | 10 | 2.49 | – | – |
| *Acer pseudoplatanus* | 28 | 224.77 | – | – | – | – |
| *Carpinus betulus* | 8 | 88.32 | 140 | 22.49 | – | – |
| *Castanea sativa* | – | – | – | – | – | – |
| *Fraxinus excelsior* | 17 | 106.17 | 295 | 178.08 | – | – |
| *Juglans nigra* | – | – | – | – | 8 | 3.9 |
| *Juglans regia* | – | – | – | – | 10 | 16.0 |
| *Malus sylvestris* | 38 | 17.75 | 39 | 0.78 | – | – |
| *Prunus avium* | 9 | 212.90 | 5 | 0.03 | 4 | 0.4 |
| *Pyrus pyraster* | 11 | 1.50 | 51 | 2.52 | – | – |
| *Sorbus aria* | 3 | 42.08 | – | – | – | – |
| *Sorbus aucuparia* | 31 | 110.86 | 155 | 4.06 | – | – |
| *Sorbus domestica* | 17 | 6.45 | 22 | 0.72 | – | – |
| *Sorbus torminalis* | 21 | 17.82 | 16 | 0.53 | – | – |
| *Tilia cordata* | 7 | 74.76 | 2 | 0.55 | – | – |
| *Tilia platyphyllos* | – | – | – | – | – | – |
| *Ulmus glabra* | 10 | 37.37 | 21 | 0.78 | – | – |
| *Ulmus laevis* | 7 | 4.32 | 15 | 0.45 | – | – |
| *Ulmus minor* | 7 | 8.00 | 74 | 10.18 | – | – |

### *Ex situ* measures

For most of the species the material has to be collected in seed orchards and then made available to forest owners. *Ex situ* measures include seed orchards, plantations, seed storage, pollen storage and propagation. The *ex situ* measures are summarized in Tables 6 and 7. During the last few years a considerable number of *ex situ* stands and seed orchards have been established for most of the Noble Hardwoods and, since these stands will come into production soon, they produce a good base for further seed procurement as well as for gene-conservation purposes. However, only part of the total region of Germany has up to now been covered. These activities will have to be continued.

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# Conservation strategy for Noble Hardwoods in Belgium

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## Introduction

During the last two decades, Belgian foresters have shown a growing awareness of the potential of certain indigenous hardwood species to significantly contribute to forest practices. The acknowledgement of their high silvicultural, economic and ecological value and, thus, the consequent upgrading from secondary tree species to the present ranking of Noble Hardwoods, can be seen as a logical outcome of multiple considerations:

- Despite their confinement to more fertile sites, the distribution of Noble Hardwoods still covers a fairly broad spectrum, allowing high expectations for their involvement as stand-building elements for the conversion of homogeneous stands. Considering the large tolerance towards other tree species, creation of mixed stands becomes possible, thus increasing the biodiversity of the forest ecosystem.
- The species considered represent an undisputable economic potential as they can be ranked among the faster-growing hardwoods and produce wood of the highest quality.
- The name Noble Hardwoods partly evolves from a certain aspect of the rarity of these tree species, for they do not occur in vast homogeneous stands and have a limited range of distribution (narrow pedological amplitude).

In 1981, the National Forest Service in Belgium was federalized in accordance with a general policy of regionalizing most of the national administrations. This division was partly inspired and justified by the different physical manifestation of forests in Flanders and Wallonia (i.e. species composition, soil, topography, etc.) and gave way to a somewhat divergent concept of forest policy, forest management and silvicultural research.

Although the concept of preservation of the genetic resources of Noble Hardwoods is very similar in both regions, the regionalization necessitates separate discussion of conservation strategies in Flanders and Wallonia.

## Conservation strategy in Flanders

### Present situation

In Flanders, the species admitted to the level of Noble Hardwoods are: wild cherry (*Prunus avium* L.), European ash (*Fraxinus excelsior* L.), sycamore maple (*Acer pseudoplatanus* L.), black alder (*Alnus glutinosa* (L.) Gaertn.) and elm (*Ulmus* spp.).

Exact figures on the current importance of Noble Hardwoods in Flanders are not yet available. As the species most often occur as isolated individuals or small groups, their share in mixed hardwood stands, representing 20% of total forest cover (i.e. 155 000 ha), is highly variable and hard to assess. In addition, owing to their former labeling as secondary tree species, they usually were disregarded in former forest inventories.

More accurate data will become available in 1997, as an overall forest inventory will then be initiated by the Flemish Forest Service. This inventory is to be based on some 2500 circular sampling plots of about 10 are each, centred at the intersections of a 2 x 1.5 km grid, thus representing a sampling density of 0.15%.

## Threats

### *Pathogens*

Pathogens present a prime threat to the elm species, taking into account their marked susceptibility to Dutch elm disease, caused by *Ophiostoma ulmi*. A similar problem, to a lesser extent, arises from the susceptibility of European ash to ash canker, caused by *Pseudomonas syringae* subsp. *savastanoi* pv. *fraxini*. Although the survival of ash as a species is not directly jeopardized by this pathogen, it still constitutes a problem to be reckoned with, as the number of infected individuals often exceeds 50% of the population.

In both cases, solutions can be offered by including resistance as a main criterion of the breeding programme for the species concerned (selection of resistant basic material).

### *Unplanned forest management*

Noble Hardwood species can be endangered by 'skimming off' natural populations through the excessive felling of trees of high economic value.

### *Trace keeping*

Any genetic resource of Noble Hardwoods, selected or created within the scope of a breeding or conservation programme, should be entered in a well-managed, accessible database. Permanent and frequent updating of the database is essential to prevent valuable genetic elements from passing into oblivion. In addition, lack of follow-up inevitably entails ignorance of possible critical threats (felling, game damage, pests), eventually leading to accidental loss.

## Conservation strategy

Conservation of the genetic resources of Noble Hardwoods has mainly been a logical spin-off of breeding and selection programmes, strongly economically motivated.

Only recently have efforts been made to preserve genetic elements (local populations or relics) with no direct economic importance, either through actual protection (forest reserves), or through vegetative or generative propagation (conservation *ex situ*).

The choice of genetic resources to preserve (*in situ* or *ex situ*) is determined by the desire to conserve populations and/or individuals:

- of different geographic locations, with special reference to provenance area (six provenance areas are distinguished in Belgium)
- of different site and growth (i.e. ecological) conditions (soil, topography)
- with different genetic and physiological traits (phenology, growth, form, pest resistance)
- with low phylogenic affinity, assessed through biotechnological markers (DNA, isozymes).

## Conservation *in situ*

### *Seed stands*

Seed stands are defined as stands which are phenotypically superior to most forest characteristics (see OECD/EEC regulations). These stands are officially selected and included in an official Register of Basic Materials.

In Flanders, Noble Hardwoods are seldom managed as homogeneous stands. The species concerned most often occur as isolated individuals or small groups and contribute in only a minor way to stand structure (on average 2% of stand basal area). As this offers very few prospects for designating seed stands, efforts are concentrated on the selection of individual plus trees.

### *Plus trees*
Plus trees are selected on the basis of their outstanding phenotype. Depending on the developmental stage, plus trees are classified as:

- mature clones: selection at forest stage after sexual maturity
- juvenile clones: selection in early forest stage
- infantile clones: selection in nursery, mostly among the progeny of plus trees and seed orchards.

Until now, the only plus trees selected and registered were European ash (10 mature clones) and wild cherry (81 mature, 10 juvenile and 75 infantile clones). In view of the continuous extension of this collection and the entering of sycamore maple in the selection programme, a scouting campaign is resumed every year, mainly based on an inquiry addressed to all local forest services.

Conservation *ex situ* of selected clones is compulsory as plus trees are not only subject to the normal exploitation term, but are, in some cases, threatened by premature felling, especially in privately owned forests. *Ex situ* conservation can be achieved with creation of seed orchards, clone parks and/or multiclonal experimental plantations (see below).

### *Forest reserves*
The Flemish Forest Decree of 1990 provides a legal framework for designating forest reserves, aiming at a final overall surface of some 2000 ha. A major criterion for selecting forest reserves is the presence of autochthonous tree species, with special attention to Noble Hardwoods.

This policy assures the preservation of Noble Hardwoods as the majority of the reserves is assigned the status of 'integral reserve', meaning that "doing nothing" is adopted as a management option, except for averting external threats.

### *Natural regeneration*
Natural regeneration of Noble Hardwoods, as a natural strategy of survival and/or proliferation, generally does not encounter major problems.

However, whenever unfavourable site conditions occur – high game pressure, overgrowing herbaceous vegetation – chances of a successful regeneration can be increased by raising seedlings in optimal, highly controlled nursery conditions, after harvesting of seeds and/or saplings in the original stand. Once plants are fully developed, they can be re-introduced to the area of origin, thus ensuring conservation of local populations.

## Conservation *ex situ*

### *Provenance trials*
The main and initial motive for setting out provenance trials is to trace those provenances which, through their adaptation and performances (growth, form, pest resistance), can contribute in a significant way to forest practice in Flanders. This will finally result in the drawing up of a list of 'recommendable' provenances. In a further stage, the best individuals will be selected within the most promising provenances, thus offering the prospect of creating provenance seedling seed orchards.

A major spin-off of these experiments is the conservation of provenances outside their range, assuring the possibility of restoring the original populations should they be lost.

Provenance trials of Noble Hardwoods have been included only recently in the research programme of the Flemish Institute for Forestry and Game Management and therefore are still rather limited in the number of provenances present: five and four provenances for ash and maple, respectively.

Yearly efforts will be made to broaden this spectrum, either by using the offer of reliable and reputable professional nurseries, or through future collaboration with other foreign research institutes (e.g. exchange of basic material). Whenever possible, the highest level of accuracy for identifying provenances will be obtained (e.g. identification at stand level).

### *Seed orchards*

Grafted clonal seed orchards for wild cherry were created in the 1970s and 1980s and have already reached a phase of productivity (Table 1). Once sufficient plus trees have been selected, the same strategy will be adopted for sycamore maple and European ash.

Although conservation of the component clones is inherent to the existence of a seed orchard, seed production still remains the prime motive for its creation. Thus, whenever productivity should prove to be insufficient, the normal lifespan of such an orchard (50 to 100 years) could be severely shortened by either felling or mere neglect, as the orchard's further maintenance loses its economic justification.

**Table 1.** Clonal seed orchards of sweet cherry (*Prunus avium* L.) in Flanders.

| | | Clones | | | Surface | First |
|---|---|---|---|---|---|---|
| Name | Creation | No. | Type | Proven. | (ha) | harvest |
| Moustier I | 1978 | 7 | Juv | 1 | 0.19 | 1983 |
| Moustier II | 1986 | 3 | Mat/Inf | 5 | 0.18 | 1995 |
| Brabant | 1980 | 4 | Mat | 1 | 0.41 | 1985 |
| Meerdaal | 1988 | 65 | Mat/Inf | 2 | 0.78 | – |

### *Progeny and clone tests*

Comparative progeny and clone trials have only been established for wild cherry, covering a total surface of about 5.9 and 1.6 ha, respectively. Within the scope of the breeding strategy, plantations of different progenies constitute a major source for additional selection of infantile and juvenile clones. The lifespan of these trials equals the current stand rotation.

### *Clone parks*

No projects have been conceived for the creation of propagation clone parks of Noble Hardwoods, aiming at the mass production of cuttings harvested on ortets or ramets of selected infantile clones. This breeding strategy is indeed regarded as being less expedient as a general consensus exists on the insufficient genetic diversity of the vegetative offspring emerging from such a synthetic variety.

Clone parks of European ash and elm species (*Ulmus campestris* Mill., *U. glabra* Mill., *U. laevis* Pall.) have been laid out as a way of safeguarding local relics. These genebanks are still rather limited as their building-up was only started in 1995 (ash, 5 clones; elm, 40 clones).

In the case of elm, selected clones will be involved in a strategy for selection for resistance to Dutch elm disease. Through controlled crossings of clones with various degrees of susceptibility (assessed through artificial inoculation), biotechnological markers for resistance will be sought.

#### *Seed banks*

Since the late 1970s, a seed bank of black alder has been built up. It now consists of 360 seedlots (provenances), stored at –17°C and originating from 21 different countries. Total weight amounts to 11 kg, representing a potential plantation of about 600 ha.

#### *Pollen banks*

No pollen has yet been stored.

### Prospects for further conservation

Besides actual preservation *in situ* (forest reserves) and *ex situ* (through vegetative and generative propagation of selected and valuable elements), any future conservation programme urges and will benefit from the following.

- Identification and registering of all plantations by means of a certificate of provenance, to be provided by each nursery (state or private).
- The use of plants of known and certified origin is still not compulsory, though it is strongly encouraged by the present policy of subsidizing afforestation projects, as financial support is only granted to private forest owners to the extent that a certificate of provenance can be presented. However, present regulations are still not watertight as subventions are granted even when the certified planting material is not of indigenous origin.
- In anticipation of a stricter policy, use of autochthonous material can be promoted by further extension of the activities of the Flemish seed kiln, situated in Groenendaal (harvesting, treatment, storing, certifying, marketing of Noble Hardwood seeds).
- Trace-keeping through frequent updating of a well-managed database including all registered genetic resources as well as all further plantations emerging from them.

Sensitization of persons and authorities involved in forest management in order to prevent accidental loss (e.g. lucrative felling) and to assure frequent reporting of critical threats.

## Conservation strategy in Wallonia

### Present situation

The conservation of indigenous Noble Hardwoods is focused mainly on four species: wild cherry (*Prunus avium* L.), sycamore maple (*Acer pseudoplatanus* L.), common ash (*Fraxinus excelsior* L.) and black alder (*Alnus glutinosa* (L.) Gaertn.). The other possible species (*Sorbus, Pyrus, Malus)* are not considered in the present paper.

The above four species are commonly present on relatively rich and humid to moderately humid soils. However, their optima vary. The natural distribution of black alder covers Wallonia entirely and its optimum conditions correspond to wet and rich soils. The other three species, and especially wild cherry, are relatively sensitive to wet soils and are not as well represented in the Ardennes (eastern part of Wallonia) where they are often concentrated in the valleys.

Except for European ash, which could be planted by private owners, these species are mainly present in naturally regenerated mixed stands. For this reason, it is particularly difficult to estimate the real area of the Noble Hardwoods and to split information by species.

Based on the regional forest inventory, detailed in Anonymous (1996), we can evaluate a significant presence of Noble Hardwoods on about 80 000 ha (15% of the total forest area). The share of Noble Hardwoods can be rougly estimated at 25% on the basis of the number of stems.

**Threats**

Noble Hardwoods are threatened at two levels in Wallonia and these threats are directly in relation to the behaviour of the forest plant users.

The first one is the risk of the loss of genetic diversity, caused by systematic felling of the best trees due to high price of such wood ('genetic creaming').

The second risk is the gene pollution linked with imported seeds coming from very different countries without any control and with utilization of horticultural origins (cherry stones from kirsch, or jam, industries). This is possible because the law has not foreseen a compulsory check on these species.

Fortunately, as subventions for plantation are linked with the utilization of good provenances in Wallonia, this problem could be reduced in the future. Moreover, the starting of a regional kiln will give the opportunity to every forester to get plants which will be well adapted to this ecological territory, an objective which has been practically impossible to reach up to now, owing to the lack of such material. Furthermore, these two elements are not indispensable in trying to improve the law in the future.

**Conservation strategy**

In Wallonia, no specific conservation programme has yet been perfectly established. However, a general breeding programme, in which a part of the strategy in relation with gene conservation, is starting.

Therefore, the presentation will follow the classical steps of a general forest tree breeding programme (Table 2).

Table 2. Present situation of the genetic conservation of Noble Hardwoods.

| Kind of population or individual | *Fraxinus excelsior* | *Prunus avium* | *Acer pseudoplatanus* | *Alnus glutinosa* |
|---|---|---|---|---|
| *In situ* | | | | |
| Seed stands | | | | |
| Number | 1 | 2 | 0 | 1 |
| Area (ha) | 14 | 6 | 0 | 1 |
| Plus trees | 10 | 121 | 107 | 17 |
| *Ex situ* | | | | |
| Seed orchards | | | | |
| Number | 0 | 2 | 1 | 0 |
| Area (ha) | 0 | 4.5 | 3.0 | 0 |
| Progeny or clone tests | | | | |
| Number | 0 | 16 | 0 | 0 |
| Area (ha) | 0 | 4.3 | 0 | 0 |
| Clone parks | | | | |
| Number | 0 | 1 | 1 | 0 |
| Number of clones | 0 | 97 | ~30 | 0 |
| Seed/pollen | 0 | 0 | 0 | 0 |

## Conservation *in situ*

### *Seed stands*
Natural hardwood seed stands are very limited in number and acreage. This situation is simply in relation to the existing low needs for plantation, at least so far. In fact, until the 1980s, only a few artificial plantations were established and natural regeneration was the only method in practice. But, with the increasing price of Noble Hardwood over the last 15 years, and furthermore, the regional subventions and the increasing interest for biodiversity, artificial plantations have increased, thereby increasing the need for seed.

For these reasons, a new programme of seed stand selection has begun to fill the need for seeds for the majority of hardwoods, and to avoid the systematic massive importation of seed from other countries having completely different ecological conditions.

### *Individual selection*
During recent years, the main effort was concentrated on wild cherry and sycamore maple for which 121 and 108 plus trees were selected (Table 2). The selection is based on:

- quality of the stem and the bole
- good adaptation and phenotypic resistances to diseases
- growth characteristics
- good coverage of the different ecological conditions; good regional distribution.

## Conservation *ex situ*

### *Provenance trials*
The only hardwood provenance trial done in Wallonia concerns European ash. This international trial was organized by Kleinschmit who distributed 1-year-old plants to different research stations. It is composed of 259 provenance/progeny lots, originating from five European countries, and was planted in the winter of 1987.

### *Seed orchards*
Grafted clonal seed orchards of plus trees of respectively 4.5 ha for wild cherry and 3.0 ha for sycamore maple are settled. They now contain around 100 plus trees for each species. These seed orchards have, besides a seed production goal, also an objective of genetic conservation. Thus, they can also serve as conservation clone parks.

### *Clonal tests*
These tests exist only for wild cherry. About 60 clones, mainly multiplied by *in vitro* techniques, are compared in 16 small trials covering about 3 ha. These tests are distributed all over Wallonia.

### *Clone parks*
Since 1988, a wild cherry clone park has been established at close spacing (0.5 x 1.0 m). It contains 97 clones with a maximum of 10 ramets. It is pruned and top-cut every year to maintain the plant height below 1 m and to preserve physiological juvenility in view of possible cutting propagation.

### *Seed banks*
No seeds have been stored yet.

#### *Pollen*

No pollen has been stored yet.

#### **In vitro *conservation***

It is potentially possible to store *in vitro* material of wild cherry for several years, but this option is not used in our programme as we ensure conservation through clone parks, seed orchards and maintaining the ortet (plus tree) *in situ*.

Moreover, these Noble Hardwood species are generally easy to graft or propagate with cuttings. Under these conditions, *in vitro* conservation and even cryoconservation are not absolutely necessary in our strategy of gene conservation.

### Prospects for further conservation

A general programme, based on the identification of genetic material present in forests, completed with practical action in the long term for specific genetic materials, is already partly in place in public forests and should be improved in the near future.

#### *Promotion of the use of highly diversified reproductive material*

With the increased need for reproductive material for artificial plantations, it is necessary to promote harvesting in a larger number of seed stands and to be able to check that a minimum number of trees per stand is collected.

The present Walloon programme will try to meet these two important points. A new programme is in fact concentrated on the identification of new seed stands and the new Walloon kiln is beginning to harvest a maximum number of seed stands following strict rules for having a minimum number of trees per collection.

#### *Trace-keeping in forest management*

When trying to put in place a long-term genetic resources management plan at a regional level, it is important to state the genetic constitution of the forests and to follow their evolution over the years.

In principle, this procedure is now in use in the Walloon public forest management where, for each stand, indication of the kind of regeneration (natural, artificial, coppicing) and the name of the provenance used for the artificial plantations are indicated.

As Nanson (1995) mentioned for Norway spruce, the idea of the level of reliability must be applied and could be used in the same way for all the species in Wallonia.

Three levels of reliability in ascending order are foreseen:

- identification through the standard EU certificate of provenance for commercial plantation made with plants provided by private nurseries
- identification through a State certificate of provenance for plantations made with plants provided by State nurseries
- identification through the direct control of the Forest Research Station.

#### *Construction and management of databases*

When identification is realized, the second step involves the utilization of these data. A partial database connected to a specific programme exists for Douglas fir. It originates in the Forest EEC Research Project which involved France, Germany and Belgium (Riboux 1993; Servais 1993; Servais and Riboux 1993). With some adaptations, this database could be extended to meet our present needs for hardwoods.

#### *Improvement of knowledge about forest genetic resources*

A better knowledge of the genetic structure of populations is essential to elaborate a comprehensive genetic conservation programme.

It is obvious that the genetic diversity at different levels of the natural range (ecological territory, geographical variation, natural stand) must be studied to build up a rational programme (Galoux and Falkenhagen 1965). But, at the present time, only a little information is available (Frascaria *et al.* 1993) and it must be completed in the future. In this way, European programmes could be a useful means to answer these needs.

## Conclusion

Although precise figures on the current importance of Noble Hardwoods are not yet available, in terms of area occupied, their potential for forestry practice is beyond any doubt. The motivation for a conservation programme on Noble Hardwoods originates from the awareness of their economic and ecological value as well as of their relative rarity.

Although preservation evolves to a large extent from former and current breeding programmes (seed stands, plus trees, seed orchards, clone parks, provenance trials, etc.), recent efforts are made for conservation of genetic resources without any direct economic importance.

Threats to Noble Hardwoods, which were important during the past 30 years, are now weakening thanks to the new forest policy (subventions to hardwoods in general, promotion of local, autochthonous provenances through the activities of the regional seed kilns and the growing awareness among public and private forest owners).

Any further conservation programme should focus on:

- promoting the involvement of highly diversified autochthonous forest reproductive material
- data collection and storage of genetic resources and plantations emerging from it (trace-keeping)
- A better scientific knowledge through basic research of forest genetic resources, i.e. a better understanding of genetic diversity mechanisms within the species.

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# Activities on genetic resources of Noble Hardwoods in the Netherlands

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## Introduction

The importance of Noble Hardwoods in the Netherlands is increasing rapidly, both within the forestry sector and in landscaping.

Threats to Noble Hardwoods do not occur so much on the species level, since there is an increase in the use of different species, but they do occur in the genetic resources of the species. Autochthonous material is scarce, often located on private estates or nature reserves and therefore less accessible, and the price of seeds and plants is higher. As a result of very often negative selection, it appears that the quality of trees from these rare sources is not really of the desired forestry standards.

Specifically, for *Ulmus* species there is the increasing threat from Dutch elm disease (*Ophiostoma ulmi*); which has been the cause of eradication of numerous elms in the country at both species and clonal level.

A few years ago, a beginning was made on a national strategy for the conservation of forest genetic resources, including inventories and background research on diversity. However, this does not include Noble Hardwoods as a group of species, but treats them like all other species, as individual species.

Besides *in situ* gene conservation of ecosystems, every species is having, or is going to have, some sort of gene conservation strategy.

## General situation for indigenous woody species

Of the approximately 80 indigenous species of trees and shrubs present in the Netherlands about 9% have almost disappeared; 33% are very rare; 36% are rare and only 21% are more or less common, though possibly locally threatened (Maes 1993).

*Juniperus communis* is the only species protected by law. A number of regulations and incentives favouring genetic resources do exist, however. Following the International Union for the Conservation of Nature and Natural Resources (IUCN) a Red List has been constructed for the Netherlands containing eight woody species. Besides protection of species it is very important to be able to protect environments and locations containing the species. Restoration of typical forest types and reintroduction of autochthonous forest material takes place at forestry level and in landscaping.

Inventories have taken place since 1992, whereas seeds and plant material are collected and grown on a contract basis to serve special purposes and plantations.

A proposal for a nation-wide inventory, drawn up by Maes (1993), included a time schedule. Some of the inventories in this proposal have been carried out, while others await funding (see Figure 1 for the proposal of inventories).

Some of the species have been introduced into clonal genebanks, seed orchards, or both. In this way rare individuals can be combined in order to increase genetic variability.

Collection of the material, maintenance of the genebanks and the lay-out of seed orchards has so far been carried out by the Institute for Forestry and Nature Research (IBN). Establishment and maintenance of the seed orchards was conducted by the State Forest Service (SBB).

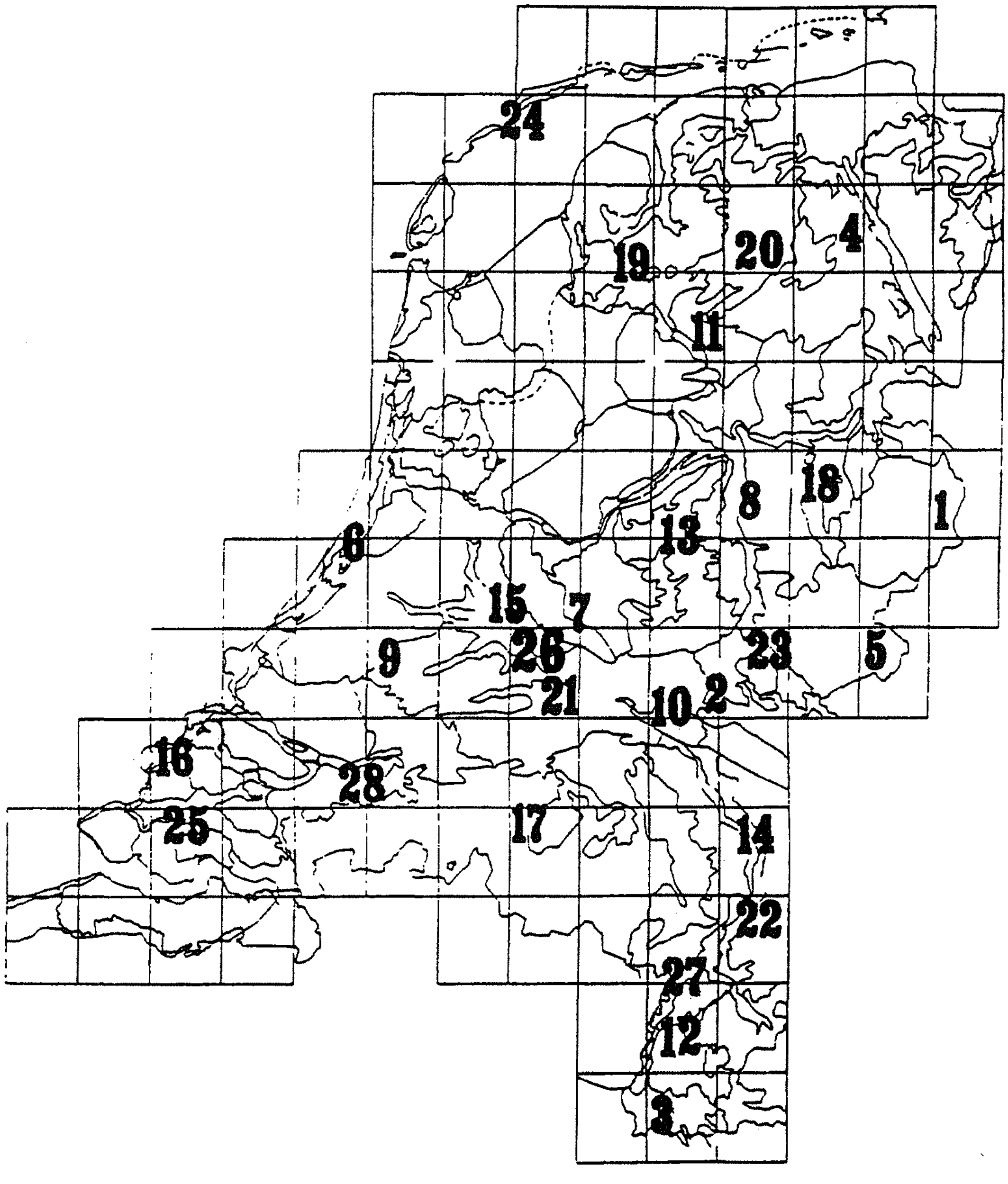


**Fig. 1.** Proposal for a nation-wide inventory of indigenous species of trees and shrubs (after Maes 1993).

## Value of Noble Hardwoods

Only a relatively small number of the previously mentioned 80 species of trees and shrubs are considered to belong to the group of Noble Hardwoods in the Netherlands. The following are considered indigenous Noble Hardwoods species: *Acer campestre* and *A. pseudoplatanus* (v.r.)[2], *Alnus glutinosa* (c), *Carpinus betulus, Fraxinus excelsior, Prunus avium, Sorbus aucuparia* (c), *Tilia cordata* and *T. platyphyllos* (v.r.), *Ulmus glabra, U. laevis* (v.r.) and *U. minor*.

[2] v.r. = very rare, c = common.

In general, these species occur with oak (*Quercus petraea* and *Q. robur*) and beech (*Fagus sylvatica*), which are the leading tree species in different types of forests. They have a high value, not only as dominant trees but because the wood is of a high, and sometimes extremely high, value (e.g. *Prunus avium*). Dispersion and occurrence for the 12 species is as follows.

*Acer camprestre*
As a species it is rather common but, as an autochthonous tree, it is rare in most parts of the country except for the most southern part of the Netherlands (Zuid-Limburg).

*Acer pseudoplatanus*
Very rare. Difficult to trace in inventories; trees in some parts of old coppice areas in the most southern part of the country are possibly autochthonous. Most of these are in nature reserves. Introduction from populations in Germany and Belgium, just across the border, could be a positive solution in adding to genetic variability.

*Alnus glutionosa*
At least two different ecotypes are known of this species ('tree-type' in climax vegetations and 'shrub-type' in pioneer vegetations). It is very common, although autochthonous character is often unknown.

*Carpinus betulus*
Rare, although in some locations quite common. Many old populations are saved as former coppice trees and in hedgerows. A number of populations grow in nature reserves. However, not many seed trees are available. A larger genetic variability is needed.

*Fraxinus excelsior*
Rare as autochthonous material, but common as tree species. Indigenous trees are often saved as coppice or as pollarded trees. Further genetic research is justified by the importance of this tree species for the Netherlands. A genebank of ash is maintained by IBN.

*Prunus avium*
Rare. A number of sites suitable for *P. avium* are located in the south in nature reserves and in the eastern part of the country. Difficult to distinguish between autochthonous trees and artificial plantings. A seed orchard was established from indigenous material by the Institute for Forestry and Nature Research (IBN). Seeds are supplied by the State Forest Service to Dutch forestry. Research at IBN showed a wide morphological variation between the collected clones.

*Sorbus aucuparia*
Very common outside the coastal areas. Regenerates very easily. A large variation in morphological characters (leaves, fruit) exists. It is a valuable species for landscaping purposes.

*Tilia cordata*
Rare. Autochthonous populations exist in brook valleys, in the east of the country, as well as in the forests on the slopes of hills in the southernmost part of the country. In the past this species vanished through lack of economic interest and restricted regeneration. Small populations are threatened by browsing and by wood harvesting. This is a priority species in the Nature policy plan.

*Tilia platyphyllos*

Very rare. *T. platyphyllos* is one of the priority species in the Nature policy plan. Only a few autochthonous populations are known. In the past this species vanished for the same reasons as did *T. cordata*.

*Ulmus glabra*

Rare. Has, like the other *Ulmus* species, ecological importance in the forest structure. The wood is of high value. Autochthonous populations exist in the east and the south of the country and possibly along the river Oude IJssel.

*Ulmus laevis*

Very rare; only a few populations in the south (Zuid Limburg), along the river Rhine, in the river valley of 'the Dommel' and in the very east on the borderline with Germany. This species seems to be less attractive to the elm bark beetle (*Scolytus scolytus*) which spreads the spores of the fungus *O. ulmi*, the cause of Dutch elm disease. This species therefore suffers less from the disease than other species, although it is just as susceptible to the fungus when artificially inoculated.

*Ulmus minor*

Rare. This species' natural dispersion area reaches the northwest borderline of the Netherlands. Natural occurrence is mainly along the drainage of main rivers and within the dunes of the coastal area. Has suffered, and continues to suffer, from campaigns against Dutch elm disease. On a species level the fungus on its own is not a real problem, because of the species' capability to form many rootsuckers. Adult trees, however, suffer from the disease itself.

## Conclusions and recommendations

At the national level, as well as at the international level, conservation of forest genetic resources is recognized to be of major importance (Heybroek 1992). By signing the Strasbourg Resolution 2 on the protection of forests in Europe, countries committed themselves to implementing a policy for the conservation of forest genetic resources in their own countries. The follow-up Committee to Resolution 2 initiated the creation of four species-specific conservation networks, which were presented at the Geneva II meeting and are steered by EUFORGEN.

Within the EUFORGEN context one of these networks was devoted to Noble Hardwoods. The Netherlands decided to join this network as an attending member. Following activities mentioned in the National Forest Policy Plan and the Nature Policy Plan, a number of inventories took place in the Netherlands to register areas and localities of importance for forest genetic resources. Through these inventories a broad picture can be given on where genetic resources of Noble Hardwoods are located. There exists a strong need for the continuation and even enlargement of the nation-wide inventory proposed by Maes (1993).

Registration of forest genetic resources is needed as is control on the harvesting of seeds and plant material. Growing and trading of plantlets must be controlled in the same way, to keep track of valuable material. Again, registration of traded material is foreseen by the Dutch Government, in order to create new sources of genetically valuable material. A registration project has been planned.

Additional money from the Dutch Government for research purposes is presently dedicated to gain further knowledge on genetic diversity within and between populations of *Populus nigra* and *Q. petraea*. It would be very useful to find the funds to execute the same type of work on the species belonging to the group of Noble Hardwoods.

Genebanks and seed orchards are one way of maintaining a genepool of indigenous species. Genebanks are created and kept by the Institute for Forestry and Nature Research (IBN) for *F. excelsior*, *P. nigra* and *Salix* spp. A seed orchard of *P. avium* has been laid out by IBN and is maintained by the State Forest Service.

It is recommended that material be collected to establish seed orchards and/or genebanks of the other Noble Hardwoods to initiate *ex situ* gene conservation. Protection of known sites and localities, resulting from previous and future inventories within the country, is needed for *in situ* gene conservation.

For those species where genetic variability is too low and inadequate to restore the biodiversity it is recommended that material from populations in Germany and Belgium be introduced from just across the border (e.g. *A. pseudoplatanus*, *C. betulus*, *T. platyphyllos*).

To promote public awareness, a number of symposia have been organized, and a leaflet and video were created and distributed to explain the importance of our forest genetic resources. The public should be kept informed, whenever possible, in order to keep the momentum going.

It is recommended that provenances of autochthonous tree species and other forest genetic resources should be included in the national catalogue, avoiding regulations specifically meant for high-quality forest reproductive material, by mentioning the ecological characters of the sources.

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# Country Reports: the Boreal Zone

## Genetic resources of Noble Hardwoods and their conservation in Lithuania, with special emphasis on *Fraxinus excelsior* L. and *Quercus robur* L.

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**Summary**
In Lithuania hardwood deciduous forests make up 4.7% of the total forest area, including ash (*Fraxinus excelsior* L.), 2.7%, and oak (*Quercus robur* L.), 1.7%. The rest is comprised of: *Carpinus betulus, Ulmus campestris* L., *Ulmus laevis* Pall., *Ulmus glabra* Huds., *Acer platanoides* L., *Pyrus communis* L. and *Malus sylvestris* (L.) Mill. Both ash and oak species form mixed stands, often together with softwood deciduous trees, and not many pure stands. In the course of evolution, populations of different phenotypic structures were formed. These can be divided into three groups according to a variety of traits. In Lithuania there are 31 oak genetic reserves with a total area of 422 ha, 10 ash reserves of 98 ha and an ash reserve with strict protection covering an area of 296 ha. The protected oak stands make up 1.7% and ash stands 0.6% of the total area.

### Introduction

Lithuania has an area of 65 300 km$^2$ and a total population of about 3.8 million people. The landscape is hilly with lowland planes with podzolic soils. The average elevation is 99 m asl (35-292 m). The climate is transitional between maritime and continental, affected to a large extent by the Baltic sea, which creates a comparatively mild climate. Average annual temperature is +6°C (in January -4.8°C, in July +17°C) with an average annual precipitation of 650 mm (540-930 mm). The vegetation period lasts for 175 days. Lithuania is crossed by the northern boundary of the distribution area of *Carpinus betulus* L. Behind the northern boundary, *Quercus petraea* (Matusha) Liebl. grows on 70 ha in the Trako forest of the southeastern part of the country.

Forest areas comprise 30.1% of the country, with 0.5 ha of forests per capita.

Complex management is applied to Lithuanian forestry, for state forests make up 92.4%. The greatest forest tract is that of Dainavos covering 150 000 ha. Five tracts cover 30 000-60 000 ha, nine tracts 10 000-27 000 ha, and the rest are small woodlots. Scattered small woodlots create favourable conditions for microclimate formation and recreation.

Coniferous stands make up 61.6% for a total 1 860 000 ha of forest. Hardwood deciduous forest comprises 4.7%, while the rest (33.7%) is covered by softwood deciduous trees. Almost all mature stands are of natural origin, productive and of good quality. The productivity of mixed stands reaches 650 m$^3$/ha of timber. Mature stands make up 9.6%.

Lithuanian forests fall into four groups according to purpose:

- strict forest reserves (2%)
- special forests (5.8%)
- protective forests (14.9%)
- commercial forests (77.3%).

Strict forest reserves are left for natural development. The objective of special forests is to preserve ecosystems, genetic resources, landscape and recreational functions. Forest genetic resources are preserved *in situ* in genetic strict reserves and reserved areas, by individual (plus) trees and *ex situ* in clonal archives, special plantations and seed orchards.

### Hardwood deciduous species native to Lithuania

The following are considered hardwood deciduous species, having timber hardness and relative weight greater than that of birch. Harwood species in Lithuania are: *Quercus robur* L., *Fraxinus excelsior* L., *Carpinus betulus* L., *Ulmus campestris* L., *Ulmus laevis* Pall., *Ulmus glabra* Huds., *Acer platanoides* L., *Pyrus communis* L. and *Malus sylvestris* (L.) Mill. Those having the greatest ecological commercial value are oak and ash.

The pedunculate oak has two forms, according to the time of coming into leaf and flowering: early (*Quercus robur* L. *praccox* Czern.) and late (*Quercus robur* L. *tardiflora* Czern.). The time of coming into leaf between these forms differs from 9 to 12 days; time to flowering, 5-10 days. Flowering duration is 4-7 days. Sometimes the hybrids of these forms become ripe at the same time and therefore they are mixed when collecting. Early (f. *precorior* Soc.) and late (f. *tardiuscula* Soc.) forms (Dendrology 1963) are distinguished according to the time of shedding which varies from 15 to 20 days. The early oak form suffers to a large extent from late frosts.

The following crown forms for oak are found in Lithuanian forests: oval, circular, mop-like and dichotomic form. Bark morphology is narrow-chinked, deep-chinked and individuals with vertically cracked bark are found. There are also other signs of individual variability, such as blossom colour, receptacle size, form of clusters, acorns and leaves as well as the duration of their stay on parent trees. Both the physical and chemical wood properties of oak trees differ (Baliuckas *et al.* 1994).

As mentioned, *Q. petraea* grows naturally on an area of 70 ha in Trako forest behind the boundary of the northern distribution area. Two phenological forms are also found. During the first growth year it lags behind the pedunculate oak, but at the age of 40-50 years it overcomes the latter. At 60 years the oak in Lithuania reaches an average height of 18-20 m and 21-23 cm in diameter, which corresponds to the indices of the pedunculate oak.

More attention to the fate and distribution of oak stands was paid after the Second World War, for in the 18th and 19th centuries they were felled without subsequent regeneration. According to Lukinas (1967), in the 16th century Lithuania had 15-20% of oak stands, while in 1895 only 2-3% of them were left. Despite great efforts, oak stands failed to increase (Fig. 1). Over the last 20-year period the infestation of oak roller moth (*Tortrix viridana* L.) has been observed as well as the die-off of individual oak trees and their groups. In 1993-95 the Lithuanian Forest Research Institute carried out a complex study on the state of oak stands. Some data of the study are presented in this paper.

Since 1994 a research programme to inventory and study plant genetic resources, financed by the Lithuanian Open State Science and Education Fund, has been initiated.

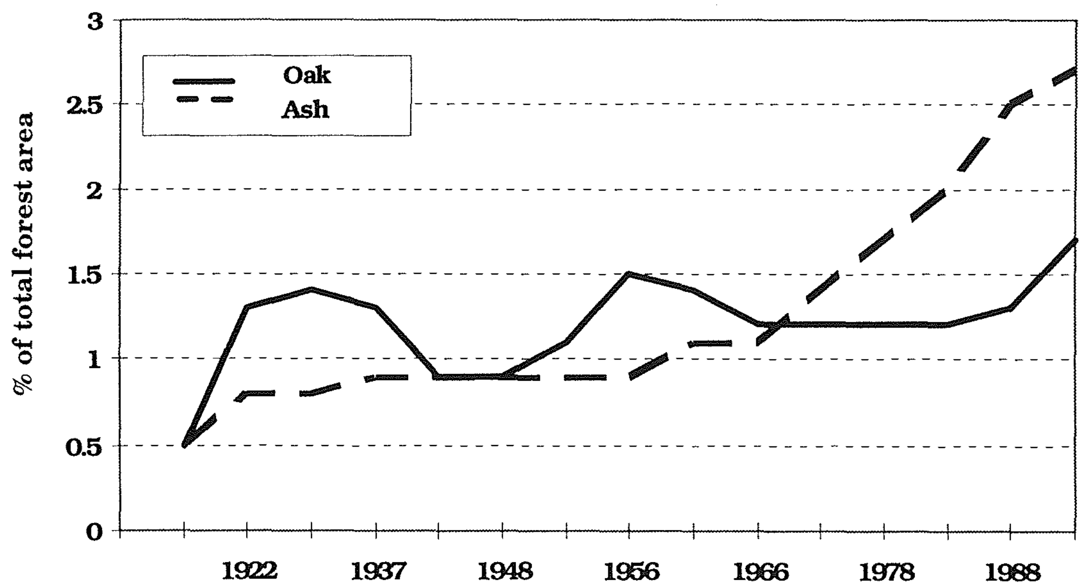


**Fig. 1.** Dynamics of oak (*Quercus robur* L.) and ash (*Fraxinus excelsior* L.) stand areas in Lithuania by years.

Phenological forms of *F. excelsior* have not been recorded. However, the onset of coming into leaf of different ash trees differs from 2 to 4 weeks. Observations show that 2-3% of individuals have one or another stable form (Narbutas 1975). The stands of seed and sprout origin are detected. The former ones live for over 300 years. The age of sprout origin stands is shorter. Ash trees grow on humus, carbonaceous, moist gleyic loam soils. The forms of dry and wet edaphotypes have been determined. In the last decade an increase in natural ash regeneration has been observed.

*Carpinus betulus* grows on fertile sites together with oak, ash and maple. Hornbeam stands cover about 1500 ha in Lithuania, at the northern boundary of its distribution area. Commercial value of hornbeam is insignificant, but its ecological role is considerable, as its presence in the understorey makes stands much more dense and is valuable in establishing protective plantations. At the age of 90 years the tree reaches 16 m in height.

As mentioned, there are three representatives of Ulmaceae having similar growth rates. These are most often found on slopes, have deep root systems and are, therefore, suitable for establishing wind-resistant stands. Elm has a cork-like form (var. *suberosa* (Moench) Rehd.) and lives up to 250-300 years. As a result of elm disease a great number of them have declined.

*Acer platanoides* grows in mixed deciduous stands, has a high-value timber and is durable. The species is very resistant to air nitrogen pollution, therefore, it is suitable for establishing protective belts and plantations. In Lithuania several decorative forms exist.

*Pyrus communis* and *Malus sylvestris*are found individually in the composition of deciduous stands. The former species is resistant to air pollution.

## Distribution of hardwood deciduous and their significance

Table 1 shows that hardwood species make up 4.7% of the total forest area, including 4.4% for oak and ash. The average age of oak stands is 80 years., while that of ash stands is 44 years (Lithuanian Forest Resources 1994). Pure oak and ash stands in Lithuania are rare. The species grow mostly in stands mixed with aspen, birch, spruce and other species. Stands with more than 50% oak make up 7% of the total area of oak stands, stands with 25-50% oak form 8% of total area, 5-25% oak mixtures comprise 36% of the total, and stands with less than 5% oak make up 49% of the total area. As noted, most stands have a comparatively small proportion of oak trees.

**Table 1.** The structure of Lithuanian forests by species and age.

| Stands of prevailing species | Total | % | Distribution by maturity groups, % | | | |
|---|---|---|---|---|---|---|
| | | | Juvenile | Middle-aged | Premature | Mature |
| **Conifers** | | | | | | |
| Scots pine | 695.3 | 37.4 | 37.0 | 47.7 | 11.7 | 3.6 |
| Norway spruce | 450.2 | 24.2 | 39.0 | 26.3 | 26.2 | 8.5 |
| Other | 0.8 | – | 87.6 | 12.4 | | |
| **Hard deciduous** | | | | | | |
| English oak | 32.4 | 1.7 | 17.3 | 58.0 | 8.7 | 16.0 |
| Ash | 49.3 | 2.7 | 48.9 | 44.4 | 4.9 | 1.8 |
| Other | 5.1 | 0.3 | 25.5 | 57.2 | 11.4 | 5.9 |
| **Soft deciduous** | | | | | | |
| Birch | 363.4 | 19.5 | 7.2 | 65.9 | 15.5 | 11.4 |
| Black alder | 104.0 | 5.6 | 7.0 | 56.4 | 15.7 | 13.4 |
| Aspen | 50.4 | 2.7 | 6.9 | 12.7 | 25.0 | 55.4 |
| Grey alder | 103.8 | 5.6 | 6.5 | 29.0 | 40.3 | 24.2 |
| Other | 5.6 | 0.3 | 10.1 | 51.8 | 17.9 | 20.2 |
| **Total** | **1860.3** | **100** | | | | |

The distribution of oak and ash stands is different in various regions. Although oak, and especially ash stands, occupy the most fertile sites the greatest part of ash stands grows in the northern part of Central Lithuania, while that of oak stands is on coastal lowlands and the central part of the country. Pure pine stands are found in Kauno, Kėdainiu, Alytaus, Vilniaus and other districts. Very often productive stands are comprised of oak with ash, elm, maple and lime, also stands with oak trees prevailing in the first and spruce trees in the understorey.

Hardwood deciduous make stands that are resistant against storms (especially in the zone of the Baltic Sea), droughts and industrial pollution. They are also favourable for recreation and are commercially valuable for timber production.

Mature oak stands, on an average, produce 246 $m^3$/ha of timber, while ash stands produce 244 $m^3$/ha. However, Lithuania has highly productive oak stands. For instance, Jûravos oak stand (though the area is very small) at the age of 110 years produces 660 $m^3$/ha, the 80-year-old Dušnioniu oak stand in Alytus produces 343 $m^3$/ha, 120-year-old Kûlupěnu oak stand in Kretinga, 354 $m^3$/ha.

Every year 1560 $m^3$ (or 1.1% from the total amount of timber harvested) of mature and overmature hardwood deciduous, mainly oak and ash, are felled (Kenstavicius and Brukas 1993). The felling age for oak is 121-141 years, for ash 101-121 years. Comparing the productivity of mature oak stands in 1937 and 1993, it can be seen that the productivity has remained about the same; oak stands increased by 2.5%. The productivity of ash stands during the same period has decreased by 9.6% (Judickas 1993).

All oak stands older than middle-aged during inventory were distributed into selection groups (Table 2). Comparison of oak and ash stands of different genetic quality shows that they are far better than those of other deciduous species. The number of high-quality ash stands is greater (32%).

**Table 2.** Selection assessment of oak and ash stands, in % (older than middle aged 1993).

| | Selection (genetic) groups (according to quality and productivity) | | |
|---|---|---|---|
| Species | I (good stands) | II (average stands) | III (bad stands) |
| Oak | 22 | 63 | 15 |
| Ash | 32 | 57 | 11 |
| Other deciduous | 15 | 66 | 19 |

## Strategy for the conservation of genetic resources

In 1970-80 oak seed reserves with a total area of 172 ha as well as 72 plus trees were selected. In 1992-95, 31 oak genetic reserves on an area of 422 ha were singled out. Total protected oak stand area comprises 563 ha (1.7% of the total area of oak stands), while that of ash stands is 313 ha (0.6% of their total area).

The condition of oak stands and all forests is being observed according to international forest monitoring programme methods (Ozolincius 1994). Based on 1994 data, defoliation of oak stands comprises 21%, ash 27%, while the rest, hardwood deciduous, is 25%. Defoliation of softwood deciduous makes up 22%. Greater defoliation is observed in older stands.

The state of oak stands is improved by draining wet growth sites, which raises their productivity. Oak stands on mineral soil are stable and productive when groundwater level is about 2 m (Ruseckas 1994).

Young oak stands are, to a large extent, damaged by deer. Older oak stands are heavily infected by wood rot fungi (*Phellinus robustus* and *Laetiporus sulphureus*) and therefore these stands are unhealthy. An outbreak of oak roller-moth (*Tortrix viridana* L.) was observed around 1980.

One negative phenomenon in oak stands is that their natural regeneration is rather weak. The factor preventing this is considered to be the presence of undergrowth and underbrush of other species. Especially poor regeneration of oak trees is observed under the spruce storey. Corresponding measures could improve natural regeneration of oak stands.

Sixteen plus trees of European ash were selected; 10 genetic reserves with a total area of 98 ha and one strict genetic reserve covering 296 ha were allotted. More detailed information is available from a publication issued by the Lithuanian Forest Research Institute. The existing strict genetic reserves involve quite a large portion of oak stands. For instance, Azvincio strict reserve has 5 ha, Punios 124 ha and Survilu 12 ha.

Characteristics of protected stands of all species are shown in Table 3.

Two main principles for the conservation of populations and genotypes are foreseen:

- **necessity**, when the objects mentioned are threatened with extinction, being representative of ecotypes of a natural region
- **value**, when the objects are unique or possess valuable geographical, ecological, physiological, phylogenical and genetic properties.

The programme of conservation of Lithuanian oak and ash genetic resources includes:

- additional allocation of genetic reserves in all natural regions
- allocation of seed stands and seed reserves of basic populations
- selection of plus trees
- establishment of plus trees clonal archives
- recommendations for the rotation of biologically mature stands
- recommendations to establish population and family plantations
- regionalization of seed material.

## Research

Research on oak stands has been reported by Lukinas *et al.* (1955). In his monograph, Lukinas (1967) summarized all studies on oak stands carried out in Lithuania up to 1965. He has described the historical development of oak stands, prepared typological and ecological fundamentals for singling out the fund of oak stands as well as ways for occasional afforestation, described oak phenology and reforestation characteristics in Lithuania and studied the growth of geographic provenances (Lukinas 1956, 1962). Sessile oak (*Quercus petraea*) was studied by S. Tuminauskas (1957).

Extensive research was carried out by K. Narbutas (1975). He studied the distribution of *Fraxinus excelsior*, its biological and ecological peculiarities, productivity, quality and worked out stem volume tables. He prepared recommendations to regenerate ash stands, and substantiated final felling age.

Genetic resources of oak and ash stands have been studied more thoroughly since 1963. The staff of the Lithuanian Forest Research Institute in 1993-95 carried out complex studies on oak stands and prepared theoretical background for their regeneration. The studies involved the historical development of oak stands in Lithuania, characteristics of current stands, their state and its causes, assessment and usage of the genebank, as well as recreation and management of oak stands.

In 1994 studies on the genetic resources of oak were initiated. They cover the inventory of genetic resources, testing and identification of genotypes, accumulation of valuable resources, and preparation of ways and criteria for their conservation.

To develop and practically implement research results, it is necessary to:

- carry out genetic studies of present populations, including at the DNA level and select the most valuable populations and genotypes to be preserved *in situ* and *ex situ*
- prepare and implement the projects of preservation of hardwood deciduous species in different geographical regions by reducing anthropogenic stresses
- work out genetic and ecological fundamentals for oak stand regeneration, including the creation of seed bases
- develop practical selection methods and provide a basis for growing reproductive material
- train specialists in countries with greater experience
- support international and national initiatives
- attain free exchange of information and genetic material for the sake of science.

**Table 3.** The main characteristics of genetic reserves in Lithuania.

| Prevailing species | Age (years) | Selectional groups | Site index | Stocking level | Height of trees (m) | Diam. of trees (cm) | Stand vol. ($m^3$/ha) | Annual increase of vol. ($m^3$/ha) | Area of gen. res. from total forest area (%)[1] |
|---|---|---|---|---|---|---|---|---|---|
| *Pinus sylvestris* | 89 | 1.7 | 1.5 | 0.7 | 26.3 | 30.8 | 327 | 3.9 | 0.60/0.76 |
| *Picea abies* | 83 | 1.6 | 1.8 | 0.8 | 27.3 | 30.5 | 366 | 5.6 | 0.35/0.44 |
| *Larix* sp. | 79 | 2.5 | 0.8 | 0.5 | 23.5 | 26.5 | 243 | 4.1 | 1.69/1.69 |
| *Quercus robur* | 125 | 1.8 | 1.7 | 0.7 | 26.4 | 45.1 | 268 | 2.2 | 1.59/1.69 |
| *Fraxinus exelsor* | 98 | 1.3 | 0.9 | 0.8 | 27.2 | 33.2 | 286 | 2.2 | 0.50/0.71 |
| *Alnus glutinosa* | 64 | 1.8 | 0.7 | 0.8 | 23.1 | 25.1 | 332 | 3.2 | 0.30/0.34 |
| *Betula pendula* | 62 | 1.9 | 0.5 | 0.8 | 24.7 | 25.1 | 237 | 4.6 | 0.18/0.24 |
| *Tilia cordata* | 79 | 2.5 | 0.8 | 0.5 | 23.5 | 26.5 | 243 | 4.1 | 0.50/0.50 |
| *Ulmus glabra* | 55 | – | 1.0 | 0.5 | 21.0 | 24.0 | 130 | 2.4 | 0.24/0.24 |
| *Populus tremula* | 55 | 1.9 | 0.4 | 0.9 | 24.9 | 26.4 | 333 | 8.3 | 0.32/0.38 |
| Average | 87 | 1.7 | 1.3 | 0.7 | 26.1 | 31.4 | 313 | 3.3 | 0.44/0.55 |

[1] The area of premature and older conserved stands / area of conserved stands, as a percentage of the total area of stands.

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# Genetic resources of Noble Hardwoods in Latvia and their conservation

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**Summary**
Latvia's forests cover 2.87 million ha or 44% of the country's land area. The tree species composition is native coniferous 60.5%; broadleaves 39.5% including the typical boreal species; two birch species 28.4%, grey alder 5.3%, aspen 2.5% and common alder 2.4%. The rest are native broadleaves: oak, ash, small-leaved lime, Norway maple, Wych elm, white elm, hornbeam and white poplar, which together occupy only 1.2% of land area or 1.3% of standing volume. Their occurrence is determined by their location at the northern boundary of their natural range. Indigenous Noble Hardwoods in Latvia having commercial value are common alder and ash. The economic value of timber of the other native Noble Hardwoods is insignificant, but in terms of forest biodiversity, ecosystem stability and forest environmental protection, their significance for the country's forestry is considerable. However, their principal role is in and landscaping, where their use has a long-standing tradition. Conservation of Noble Hardwood genetic resources in Latvia has been attempted *in situ* in: protected forests, the total area of which is 309 500 ha, restricted management forests, 225 700 ha and protected forest areas within commercial forests, 248 000 ha. The total area of common alder and small-leaved lime genetic reserves at present is 68 ha. The development of an appropriate strategy for conservation and enhancement of the potential of Noble Hardwood forests requires a deep understanding of the genetic structure and biology of the species, and geographical variability of the populations. The EUFORGEN Network on Noble Hardwoods could play an important role in that development.

## Introduction

To gain an insight into broadleaved species composition and current distribution in Latvia, it is useful to have some information on the country's location and climate.

### Geography

Latvia is located on the edge of eastern European near the Atlantic Ocean on the shores of the Baltic Sea and Gulf of Riga. Its coastline is nearly 500 km long. Total land area is about 6.46 million ha, bordering Estonia to the north, the Russian Federation to the east, Belarus to the southeast and Lithuania to the south, between 55°40' - 58°05' N latitude and 21°00' - 28°15' E longitude. Latvia is a typical lowland with relatively flat countryside, the average elevation being about 87 m asl. The highest point of the Vidzeme Upland is 312 m asl. The land area includes 26% arable land, 3.9% inland waters, 4.9% bogs and about 44% forest. Land surface and soils are mostly influenced and formed by the last glacial period.

### Climate

The Gulf Stream of the Atlantic gives Latvia a milder climate than other areas equally far north. The climate is between east Europe continental and west Europe maritime. In spite of Latvia's small area there are important differences in climatic conditions between the following four zones: northeastern, southeastern, central and western.

The growing season lasts from 175 days in the east to 200 days at the Baltic Sea. Mean temperatures range from 16 to 18°C in July to –4 to –7.5°C from January to February. The sum of active temperatures (above 5°C) is 2020-2460°. The cold period (below 0°C) lasts from 100 days in the coastal regions to 145 on uplands. Annual precipitation ranges from 500 to 800 mm. Evaporation is relatively low, about 40-70%, which contributes to the abundance of wetlands, lakes and waterways.

These climate characteristics create a highly variable mosaic of forest-growing conditions which are subdivided into five edaphic groups: dry mineral (54.4%), wet mineral (10.3%), wet peat (11.9%), drained mineral (9.6%) and drained peat soils (13.8%) and the extent of forest cover. According to the forest tree species composition Latvia's forests belong to the hemi-boreal zone, where indigenous boreal conifer tree species, Scots pine and Norway spruce predominate (60.5%). Climatic conditions in the west and southwest cause features of a temperate zone to appear.

## Forests and forestry

The forest is one of the Latvia's major assets, its most important and valuable natural resource, covering 2.87 million ha or about 44% of the total land area. This illustrates the great importance of the forest for economy, landscape, environment, flora and fauna of Latvia. For many the forest also means the place for leisure activities, recreation and hunting.

During the last 70 years the forest cover has had a stable trend of growth, from 25% in year 1923 to 44% in 1994. Despite this, there are significant regional variations, for example the higher forest coverage is in the northeast as well as in the west, where forests cover 50-60% of land area. The lowest percent (25.8%) in Latvia is in districts where the best agricultural soils are situated and where the purposeful substitution of native broadleaved species woodlands has been taking place for centuries. The total growing stock of Latvia forests has increased from 176 million $m^3$ in 1935 to 489 million $m^3$ in 1994. The net annual increment is 16.5 million $m^3$ but the annual allowable cut, determined mainly by age structure and the rotation period of the species, for 1995-99 accepted by the Parliament, is 8.4 million $m^3$ or 51% of the annual increment. The above figures indicate a sustainable management approach.

## Broadleaved species in Latvia

The share of boreal coniferous species is 60.5% of the total forest covered area. The rest, 39.5%, is broadleaved species (see Table 1) which are divided into four groups according to their origin and economic value.

Native silver birch, downy birch, common alder, grey alder, aspen, rowan, about 20 willow species and bird cherry are typical boreal species and are situated in the optimum of their natural range.

Other indigenous broadleaved species – oak, ash, small-leaved lime, Norway maple, Wych elm, white elm, hornbeam and white poplar – belong to or could be referred to the temperate forest zone. For them, Latvia is the north end of their natural range. For this reason the occurrence of these species is scattered and fragmented.

**Table 1.** Native and exotic broadleaved species in Latvia.

| | Commercial | Non-commercial |
|---|---|---|
| **Indigenous** | *Betula pendula* Roth | *Tilia cordata* Mill. |
| | *Betula pubescens* Ehrh. | *Acer platanoides* L |
| | *Alnus glutinosa* L.(Gaertn.) | *Ulmus glabra* Huds |
| | *Alnus incana* L.(Moench.) | *Ulmus laevis* Pall |
| | *Populus tremula* L. | *Sorbus aucuparia* L. |
| | *Quercus robur* L. | *Salix* spp. (20 species) |
| | *Fraxinus excelsior* L. | *Carpinus betulus* L |
| | | *Populus alba* L. |
| | | *Prunus padus* L. |
| **Exotic** | *Fagus sylvatica* L. | *Tilia platyphyllos* Scop. |
| | | *Acer pseudoplatanus* L. |
| | | *Acer negundo* L. |
| | | *Acer tataricum* L. |
| | | *Acer ginnala* Maxim. |
| | | *Acer campestre* L. |
| | | *Fraxinus pennsylvanica* Marsch |
| | | *Populus* spp. (about 15 species) |
| | | *Prunus avium* L.(Moench.) |
| | | *Juglans cinerea* L. |
| | | *Juglans mandshurica* Maxim. |
| | | *Juglans ailanthifolia* Carr. |
| | | *Quercus rubra* L. |

## The role of Noble Hardwood species in the forest sector of Latvia

Although species included on the list of Noble Hardwoods may be the cause of some dispute, native species included are: *Alnus glutinosa* L. (Gaertn.), species of genera *Fraxinus, Tilia, Acer, Sorbus,* as well as exotic species *Prunus avium* L. (Moench.) and species of genera *Juglans.*

### Commercial species

**Common alder,** *Alnus glutinosa* L.(Gaertn.)
The importance of this species to Latvia's forestry is obvious, although the area occupied is relatively insignificant. According to the inventory data, the area covered is about 64 000 ha (2.4% of total forest area) and growing stock of the species is 14.5 million $m^3$ (3.5% of total growing stock).

A characteristic feature of the species is its specific adaptation to growing conditions. Common alder is mainly associated with fertile mineral wetlands, *Myrtiloso-politrichosa, Dryopteriosa;* wet peatlands, *Dryopterioso-caricosa, Filipendulosa* and their drained derivatives, *Mercuriarilosa mel., Oxalidosa turf. mel.* The share and occurrence of those forest land types determine the distribution of common alder woodlands throughout the country (see Fig. 1). Despite the fact that Latvia's forested wetlands or potentially wet areas occupy almost half (45%) of the total forest area, the above-mentioned land types do not exceed 10% and are distributed unevenly.

In some administrative districts in the northeast, common alder woodlands comprise 7.5% of the total forest area. The distribution of the species is linked to the distribution of wetlands and is not influenced by climate differences.

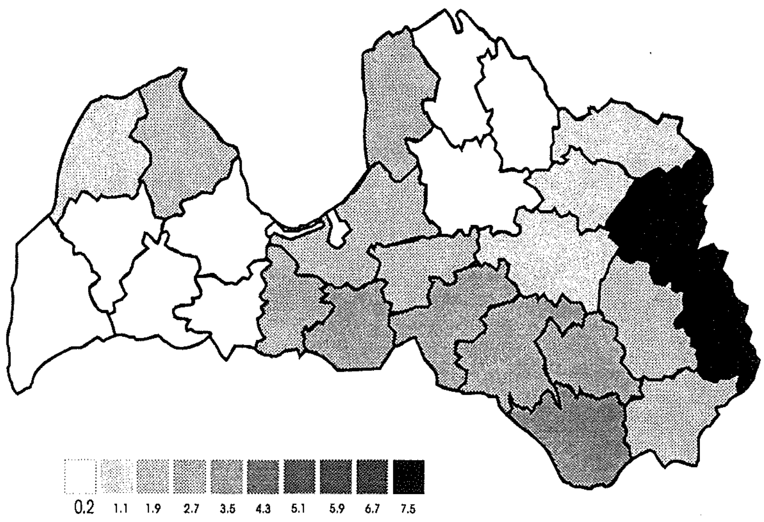


**Fig. 1.** Distribution of common alder woodlands in administrative districts.

The next characteristic feature of the species is that the areas cut during the last 50 years have been regenerated naturally, either from seeds or coppice shoots. The decrease in the area of young stands may be related to the decrease in the cut area of common alder (Fig. 2), caused by mild winters in the past decades.

As mentioned, *Alnus* sp., common and grey alder are in the optimum of their natural range in Latvia. Both are fast-growing species with mean annual increments of 5.7 $m^3$ $ha^{-1}$ $yr^{-1}$ and 4.9 $m^3$ $ha^{-1}$ $yr^{-1}$ respectively. They have found a specific ecological niche and in future should play a more significant role in the country's forestry as a timber source, as well as in wetland ecology and forest environment protection.

In accordance with the forestry development programme for the years 1992-2000 and 2030 the optimal distribution of common alder would increase by about 20 000 ha or up to 3.0% of the forest area. The species could be suitable for afforestation of marginal wet farmlands.

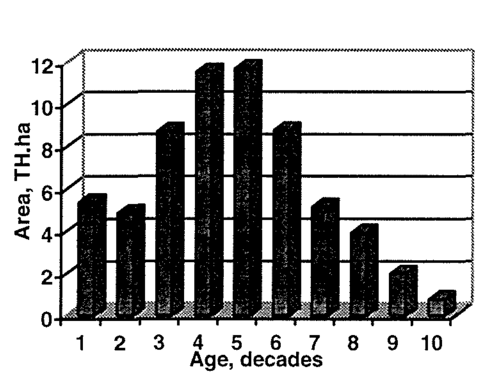


**Fig. 2.** Age structure of common alder woodlands.

**Ash,** *Fraxinus excelsior* L.

The area taken up by this species is about 19 300 ha (0.8% of total forested area) and the species growing stock is 2.4 million $m^3$ (0.6% of total growing stock). Ash is associated with the nutrient-rich, reduced soil acidity, dry mineral forest land types: *Aegopodiosa* and *Oxalidosa*. In some forest districts pure or mixed ash woodlands constitute almost 30% of all forests (Fig. 3).

Most fertile forest land types in the past were mainly converted to arable lands. Ash forests were overharvested because of the species' excellent timber quality. Analysis of age structure of ash woodlands has shown that their depletion has continued from 100-200 years ago (Fig. 4).

During the last 30-50 years ash woodlands have mostly regenerated naturally. The share of plantations is insignificant because the increased populations of red deer and moose have prevented any regeneration. Only the unmanaged, naturally regenerated, very dense young stands have survived.

Ash makes up good-quality stems and is relatively fast growing. The mean annual increment for ash is 6.95 $m^3$/ha. The best pure ash stand at the mature age reaches a standing volume of 500 $m^3$/ha. It is expected that the area under the species will increase in both state and private forests when land reform is completed.

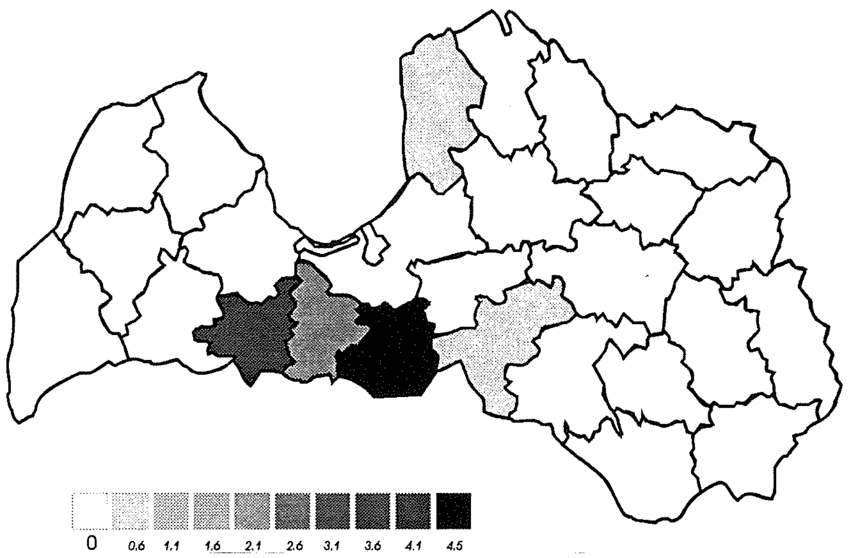


**Fig. 3.** Distribution of ash woodlands in administrative districts.

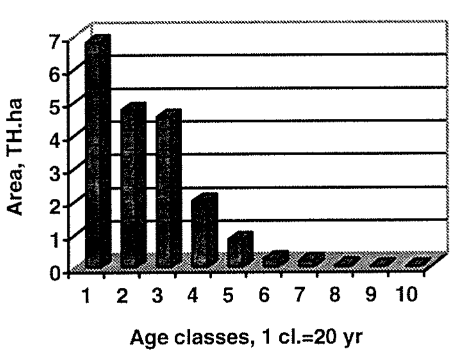


**Fig. 4.** Age structure of ash forests.

### Non-commercial Noble Hardwood species

Lime (*Tilia cordata* Mill.) is Latvia's most famous native broadleaved species. Lime woodlands are consistent with the same growing conditions as ash, and thus the species has suffered from human impact during the past centuries. Pure lime stands are now rare. The remaining mature stands reach 180-200 $m^3$/ha of standing volume. Lime can mostly be found on fertile soils in mixed oak and birch woodlands, often in the understorey or in mixtures with Norway spruce. According to inventory data, the total area of lime woodlands is about 1300 ha, which has been regenerated mostly naturally. Young stands have been damaged by game animals. If compared with the situation of 100 years ago, the total area of lime woodland at present could be about 300 ha. Many areas of felled lime woodlands have since become Norway spruce plantations. This is the main reason why during the last 40 years naturally regenerated areas do not exceed 50 ha per decade.

It is important to note that lime trees in the future should be ranked higher in the country's forestry, as it is a significant element of the diversity of forest ecosystem. However, its principal role is in landscaping, where the use of lime has a long tradition.

Norway maple (*Acer platanoides* L.), elm (*Ulmus glabra* Huds), white elm (*Ulmus laevis* Pall.) and rowan (*Sorbus aucuparia* L.) are native Noble Hardwoods species. Their share in the forest-covered area or in formation of growing-stock is insignificant. Sometimes pure small scale elm stands can be found on fertile dry or wet mineral soils along rivers and lakes. Norway maple, white elm and especially rowan are associated species making up an integral part of mixed broadleaved woodlands by occupying mainly the woodlands understorey. They are very important in landscaping, where the use of these species has a long tradition.

### Exotic Noble Hardwood species

Since the beginning of the last century many Noble Hardwood species have been introduced from western Europe and, since the end of last century, from America. Among them are:

- genus *Fraxinus* is represented by Pennsylvanian ash, *Fraxinus pennsylvanica* Marsch, cold resistant, used in landscaping
- wild cherry, *Prunus avium* L.(Moench.) initially introduced for fruit gardens, at present can be found in broadleaved woodlands in the west of the country where it is completely cold resistant and is a potential species for agroforestry because it is relatively fast growing
- genus *Tilia: Tilia platyphyllos* Scop., *Tilia* x *vulgaris* Hayne mainly are used in urban areas because of their tolerance to emissions and their resistance to cold; they also have medicinal properties
- genus *Acer*: *Acer pseudoplatanus* L., *Acer negundo* L., *Acer tataricum* L. *Acer sacharinum* L., *Acer ginnala* Maxim., *Acer campestre* L. are completely adapted to Latvia's climate; mainly used for landscaping
- genus *Juglans: Juglans cinerea* L., *Juglans mandshurica* Maxim. *Juglans ailanthifolia* Carr.
- genus *Sorbus*: one representative species, *Sorbus intermedia* (Ehrh.) Pers.

Exotic Noble Hardwood species have become an integral part of Latvia's flora. Adapted to the harsh climate, genotypes could be used in their original range. *Ex situ* collections of about 2000 taxons and varieties have been maintained in the Forestry Research Station 'Kalsnava' since 1975. The arboretum has harvested the first seed crops.

## Forest genetic resources conservation and utilization strategies and programmes

There is no common national conservation programme or strategy for plant genetic resources in Latvia. According to the Law on Environment Protection adopted in 1991, one of the goals of the protected areas (Table 2) is the maintenance of natural genetic resources, although they have been established mainly for ecosystem and species conservation. The oldest strict nature reserve – Moricsala – was founded in 1912; on an area covering 818 ha, there are 563 plant species, including about 20 broadleaves.

It is hoped that the system of protected areas will be useful for conservation *in situ* of non-commercial (in lesser degree for commercial) tree species genetic resources until the demand for seed appears.

**Table 2.** Forest and environment protection in Latvia.

| Forest category and subcategory | Number | Forest covered area ('000 ha) | Percent of total area |
|---|---|---|---|
| Protected forests | | | |
| 1.1 Strict nature reserves | 5 | 38.2 | 1.2 |
| 1.2 National park forests | 1 | 51.6 | 1.6 |
| 1.3 Nature parks | 11 | 15.0 | 0.5 |
| 1.4 Nature reserves | 180 | 87.6 | 2.7 |
| 1.5 Anti-erosion forests | 28 | 44.4 | 1.4 |
| 1.6 Suburban parks | 76 | 72.5 | 2.2 |
| **Total** | | **309.3** | **9.4** |
| Restricted management forests | | | |
| 2.1 Protected landscape forests | 6 | 55.2 | 1.7 |
| 2.2 Suburban forests | 15 | 244.0 | 7.6 |
| 2.3 Forests for environmental protection | 31 | 224.4 | 6.9 |
| **Total** | | **523.6** | **16.2** |
| Commercial forests | | 2394.1 | 74.1 |
| **Total** | | **3227.0** | **100** |

Specially protected forest areas covering 248 200 ha or 7.7% of total forest area are designated under restricted management and exploitable forests with special management regulations. The most important of them are:

| | Area ('000 ha) |
|---|---|
| Forests along rivers and lakes | 138.0 |
| Forests along roads and railways | 44.4 |
| Forests around cock-capercaille rut places | 20.5 |
| Specially preserved forest compartments | 11.8 |
| Forests of culture monuments | 5.4 |
| **Genetic reserves** | **4.5** |
| Protected landscape forests | 4.3 |
| Forests around protected water bodies | 3.8 |
| Forests of scientific research and monitoring | 3.8 |
| Parks and dendrological plantations | 3.6 |
| Protected margins and edges | 3.4 |

Obviously some subcategories have contributed considerably to both associated and target broadleaved species gene resources conservation. These are forests along rivers and lakes and other water bodies, specially preserved forest compartments, parks and dendrological plantations, etc.

Although a considerable area is under protection only forests of genetic reserves are suitable for, or create, good conditions for future evolution, because they are situated within commercial forests where all (sustainable) management activities are allowed.

According to the Law on Forest Management and Utilization and regulations on the protection of the forest environment, the State Forest Service is responsible for maintenance of biological diversity in Latvia's forests and the decision-making body for acceptance of genetic reserves. The existing officially established genetic reserves of Noble Hardwoods are listed in Table 3.

**Table 3.** Genetic reserves of Noble Hardwoods in Latvia.

| | *Alnus incana* | *Tilia cordata* |
|---|---|---|
| Administrative District | Aluksne | Balvi |
| Area (ha) | 35 | 33 |
| Mean height (m) | 26 | 26 |
| DBH (cm) | 32 | 28 |
| Volume ($m^3$/ha) | 190 | 340 |
| Latitude | 57° 20′ | 57° 10′ |
| Longitude | 27° 30′ | 27° 50′ |

## Tree breeding and genetic research projects

The department of tree breeding and genetics within the Latvian Forestry Research Institute 'Silava' has two research projects on native coniferous and broadleaved tree species. Genetic resource projects concerning Noble Hardwoods have, so far, touched upon a rather detailed exploration of common alder and ash woodlands, their ecological characteristics and some metric characteristics such as stand health, adaptability to local conditions and seed productivity. A provenance trial for common alder is expected to be established in cooperation with Sweden and the Baltic countries. This would serve as a notable input for research of species provenance variability.

## Genetic resources of Noble Hardwoods in Denmark

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### Noble Hardwood species of importance for the forest sector in Denmark

Given that the common consensus of the Noble Hardwoods Network under EUFORGEN covers the genera *Acer, Alnus, Fraxinus, Ulmus, Tilia, Juglans, Pyrus, Sorbus*, and *Prunus avium, Castanea sativa* and *Malus sylvestris*, the following species can be considered Noble Hardwood species of importance to the forest sector in Denmark: *Acer pseudoplatanus, Alnus glutinosa, Fraxinus excelsior, Prunus avium, Tilia cordata* and *Ulmus glabra.*

The Noble Hardwoods area of Denmark can roughly be set at 30 000 ha, corresponding to approximately 7% of the total forest area according to the 1990 forestry census (Danmarks Statistik og Skov- og Naturstyrelsen 1994). Considering the proportion of the total forest area covered by Noble Hardwoods, they obviously do not have great importance for the sector today. Nevertheless, several Noble Hardwood species are, for various reasons, becoming increasingly important. Large areas of naturally regenerated beech (*Fagus sylvatica*) contain a considerable proportion of *A. pseudoplatanus*. *Fraxinus excelsior* is mainly located on specific site types (fertile, moist, but well-drained soils), and here it is considered an important species with a large per area production value. Also, several of the other species mentioned play an important role as raw material for the Danish furniture industry. For this reason interest in planting, for example, *P. avium* is growing.

In addition to the species listed above, a number of other species which are covered by the network occur in Denmark: *Acer campestre, Acer platanoides, Ulmus carpinifolia, Ulmus laevis, Sorbus aria* var. *rupicola, Sorbus aucuparia, Sorbus intermedia, Sorbus torminalis* and *Tilia platyphyllos.*

These species are not used for silvicultural purposes, but a few of them are widely used for planting in outer forest belts, shelterbelts, hedgerows and small game coverts.

With the exception of *T. platyphyllos*, all of the species mentioned above are included in national plans for conservation and management of genetic resources.

The rest of this paper will, however, mainly focus on the Noble Hardwood species of importance to the forest sector in Denmark.

### Characterization of Noble Hardwoods: geographic, ecological, phylogenic and genetic traits

Conservation activities are based on gene-ecological zoning (Graudal *et al.* 1995). Zoning is established on the basis of geographical, edaphological and climatic data. Ideally, to conserve genetic variation, we should know this variation. However, our knowledge of the genetic variation of Noble Hardwood species is very limited, or non-existent, for some of the species in question. For lack of the necessary knowledge, it is assumed that the similarity of ecological conditions implies similarity of genetic constitution. A comparison of species distribution, with well-defined ecological zones, thus provides a framework for selection of conservation stands.

Phenological and morphological data have been used to discriminate between species in *Sorbus* and *Tilia* genera and to some extent to detect hybrids and introgression complexes. Leaf colour has been used to detect *Acer* sp. of non-local origin and hybrids/introgression where no record of origin exists.

Danish stands of *Tilia* sp. have been examined by allozyme markers, but this technique did not prove useful in separating populations or species owing to low allozyme differentiation. Biochemical markers have not been applied for any of the other Noble Hardwood species in Denmark.

## Occurrence, origin and distribution of Noble Hardwood species and their genetic resources in Denmark

***Acer pseudoplatanus***, according to the latest Danish forestry census, is an important forest species in Denmark. It covers approximately 8000 ha, but is present as a non-dominant species in a much larger area. The species was probably introduced to Danish forestry in the 1760s, and *A. pseudoplatanus* is, therefore, not considered a native species. Today the species is widespread and regenerates very easily. The early imported plant material has presumably adapted to local environmental conditions. Differentiation between occurrences of *A. pseudoplatanus* can be expected as a result of founder effects, since local origins often can be traced back to seed dispersal from a few old trees in the vicinity of the stands.

***Alnus glutinosa*** is a native species with widespread, but fragmented distribution in Denmark. Reproductive material from the southern part of the species' natural distribution area is not suitable for planting in Denmark (Møller 1965). Hence, only material of Danish origin is used. Differentiation between Danish populations has only been examined in field trials, and variation between provenances was revealed (Kromann 1994).

***Fraxinus excelsior*** is an important broadleaved forest species in Denmark (approximately 10 000 ha). The species occurs normally in patches within broadleaved stands of *Fagus sylvatica*, *Quercus* sp. or *Alnus glutinosa*. Many of the existing stands originate from imported seed. The occurrence of genetic differentiation within Denmark has not been examined, but vigorous seedlings with good stem form have been obtained from seed orchards based on selected clones. Substantial variation within populations may therefore be present.

***Prunus avium*** is not native to Denmark. The species was introduced at least several hundred years ago, and it is likely that the early imported material has adapted to local environmental conditions. It occurs commonly in small individual stands or in mixed broadleaved stands in the southeastern part of Denmark. Today *P. avium* has limited importance; however, it may gain attention if the currently growing demand for its wood from the furniture industry continues.

***Tilia cordata:*** the distribution of *T. cordata* is scattered in the southern parts of Denmark. The capacity to produce viable progeny is very poor in Denmark, mainly due to unsuccessful development of fruit. The physiological and/or genetic background for this problem is unknown, but climatic conditions may be the most important factor, since pollen analysis has shown a general decrease in the species' distribution following the decrease in mean temperature 3000 years ago (Huntley and Birks 1983). Most of the planted stands are based on imported seed, partly because of the above-mentioned problems regarding lack of viable seed. Over the last 5 years interest in using *T. cordata* in forests has grown considerably.

*Ulmus glabra* occurs in most Danish forests, particularly on forest edges or as single trees in broadleaved stands. During the past century, the species has presumably been spread from park trees of unknown origin to natural habitats. It has limited importance to the forest sector as its wood is often flawed and new forest plantings are not established, owing to the Dutch elm disease. However, it is used for planting in semi-natural habitats in open landscape such as shelterbelts, and *U. glabra* is therefore of some importance here.

## Legal measures and strategies aimed at conservation and/or management of species

### Legal measures

A new Forest Act, adopted in 1989, includes special rules to protect indigenous species. These rules are particularly concerned with the conservation of outer forest belts of deciduous trees, natural oak forests (scrub) and small biotopes. The Act provides a legal framework for policies and strategies for the conservation of forest genetic resources.

### The Danish strategy for natural forests

A Strategy for the Natural Forests and Other Forest Types of High Conservation Value in Denmark, in short the Danish Strategy for Natural Forests, was adopted in 1992 (Ministry of the Environment 1994). This strategy focuses on ecosystem conservation and the overall objective of the strategy is to conserve the biodiversity of the Danish forests including the gene resources present in these areas. The strategy will contribute to gene resource conservation, but it will not systematically address the conservation of forest genetic resources.

The natural forest area in Denmark is estimated at 35 000 ha. The strategy defines the term "natural forest" as forest that is established spontaneously on a site and consists of naturally occurring species or provenances. Some natural forests remain untouched, but today most Danish natural forests are subject to forest management through logging and regeneration. According to the strategy, before the year 2000, at least 9000 ha of natural forest should be strictly protected, of which at least 5000 ha should be kept untouched. Within the next 50 years the aim is to maintain 10% of the present forest cover as natural forest.

### Strategy for the conservation of genetic resources of trees and shrubs in Denmark

Closely linked to the Danish Strategy for Natural Forests is a strategy specifically aimed at the conservation of genetic resources of trees and shrubs prepared in 1991/93 (Skov- og Naturstyrelsen 1994a, 1994b). The objective of this strategy is to secure the ability of the species covered to adapt to environmental changes and to maintain the basis for future improvement work.

The strategy includes 75 tree and shrub species of actual or potential use for planting in Denmark. The genetic resources in Denmark will, in general, be conserved in evolutionary conservation stands, *in situ* or *ex situ*. For most species a network of conservation stands is required to cover the spectrum of assumed gene-ecological variability. An estimate of the required number and distribution of conservation stands was made from a preliminary gene-ecological zoning, combined with information on the biology and distribution of each species. From 2 to 15 conservation stands are considered adequate for the different species.

The approach to gene resource conservation within the Strategy is described in greater detail by Graudal *et al.* (1995).

A summary of the most important Noble Hardwood species covered by the strategy is shown in Table 1.

**Table 1.** Number of stands proposed for the conservation of genetic resources of Noble Hardwood species used in forests in Denmark; and the number of existing approved/selected seed stands and seed production areas for use in forestry and the open landscape (sources: Plantedirektoratet 1995; Brander *et al.* 1993, Skov-og Naturstyrelsen 1994a).

| | Stands proposed for conservation of forest genetic resources | | | Existing selected seed-production areas in 1993 | |
|---|---|---|---|---|---|
| Species | *In situ* | *Ex situ* | Clonal collections | Forest | Open landscape |
| *Acer pseudoplatanus* | 2-4 | | | 9 | 5 |
| *Alnus glutinosa* | 11-15 | 1 | | 9 | |
| *Fraxinus excelsior* | 8-10 | 2 | | 13 | |
| *Prunus avium* | 11-15 | 4 | 1 | | 9 |
| *Tilia cordata* | 11-15 | | 1 | 2 | 2 |
| *Ulmus glabra* | 8-10 | | | | 2 |

The strategy for the conservation of genetic resources of trees and shrubs is planned to be implemented within the next 10 years. Implementation will include:

- collection and mapping of existing information on distribution and genetic variation of each species covered by the strategy
- development of guidelines for preparation of management prescriptions and management protocols
- field inspection, selection and demarcation of *in situ* stands and existing *ex situ* stands
- field inspection, selection and collecting of reproductive material for the establishment of new *ex situ* stands
- establishment of new *ex situ* stands.

At present, potential gene resource conservation stands of broadleaved species have been identified within the state forest areas that are protected as a result of the above-mentioned strategy for natural forests. During the summer of 1996 a number of the identified stands will be inspected and demarcated and management protocols will be prepared for each stand.

## Other programmes and measures

Finally, a strategy for utilization of genetic resources of trees and shrubs in Denmark is currently under preparation. This strategy shall serve as a guide for the individual user's choice of woody plant material from each species and for specific purposes and specific sites. The strategy shall also guide activities concerning genetic improvement and mass production of genetically improved plant material, so that the best possible plant material, according to the user's interests, is available at any time. Also, the strategy will include necessary measures for regulation of the use of genetic resources, for instance possibly a minimum acceptable number of clones to be used in clonal forest stands.

Currently, some of the existing tree seed-production areas and breeding populations also serve as *ex situ* gene conservation areas. The many provenance seed stands in Denmark also serve as *ex situ* (or in some cases *in situ*) conservation stands of specific populations. They are, however, not gene conservation stands in the strict sense, because they generally are selectively thinned.

## Threatened Noble Hardwood species in Denmark

The following species are, in line with the IUCN Red List categories, considered as rare in Denmark (Skov- og Naturstyrelsen 1991): *Ulmus laevis, Ulmus carpinifolia* and *Tilia platyphyllos.*

In broad terms, the main threats to these species are intensive forest management practices such as drainage of moist areas in the forests and clearing of natural regrowth. No special measures have so far been taken to specifically protect the three species mentioned. Denmark lies at the fringe of their natural distribution area and they are widely distributed in other parts of Europe. However, as is well known, the two species of *Ulmus* are threatened throughout their area of distribution by Dutch elm disease. Within a few years, measures to conserve genetic variation of *U. laevis* and *U. carpinifolia* in Denmark will be taken, as they are included in the Strategy for the Conservation of Genetic Resources of Trees and Shrubs in Denmark.

## Programmes for tree breeding or genetic research on Noble Hardwoods in Denmark

### Tree breeding

The tree breeding programmes in Denmark have so far focused on exotic plantation species and recently also on *Quercus robur* and *Quercus petraea*.

However, low-level tree-improvement activities have also included *F. excelsior*, and extensive work on *A. pseudoplatanus, A. campestre* and *P. avium* has been initiated.

Finally, the Danish programme for mass production of tree seed includes all of the important Noble Hardwood species mentioned[3] in Section 1 with the exception of *U. glabra*. The Tree Improvement Station of the National Forest and Nature Agency is responsible for the implementation of the programme.

### Research into genetic variation/gene resource conservation

Research into genetic variation of *T. cordata*, based on morphological studies and allozymes, is currently being carried out by the Arboretum (Department of Botany, Dendrology and Forest Genetics, Royal Veterinary and Agricultural University). Also measurement of hybridization between *T. cordata* and *T. platyphyllos* is part of the Arboretum's research project on *Tilia* sp.

The Arboretum will initiate a study in 1996 on determination of selfing rates in *A. pseudoplatanus* based on allozyme markers.

The Danish Institute of Plant and Soil Science (Ministry of Agriculture and Fisheries) is currently carrying out studies on genetic variation of *Acer* sp., *P. avium* and *Tilia* sp. based on their phenological and morphological performance.

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# A policy suggestion for conservation of Noble Hardwoods genetic resources in Sweden

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**Summary**
The group of species referred to as Noble Hardwoods is rather heterogeneous: patterns of pollination vectors differ, some species reproduce asexually, some have small populations at the margin of their distribution. There are some common features: none belong to the climax-type of species nor have they a continuous distribution, and they grow in the southern part of the country. The prime objective of forest management is to create good conditions for future evolution, which includes low-intensity improvement for some of the species. The rare species *Acer campestre* and *Tilia platyphyllos* must be saved. Tolerance against Dutch elm disease is an important objective in the three elm species. An *in situ* multiple population breeding system is suggested for the majority of species with more subpopulations for those that are insect-pollinated. To avoid genetic drift, *A. campestre* and *T. platyphyllos* should be crossed with non-domestic trees. Crosses with eastern elm trees are suggested to introduce tolerance against Dutch elm disease in *Ulmus glabra*.

## Introduction

In the late 1970s a committee carried out an investigation on conservation of forest genetic resources in Sweden (Ministry of Agriculture 1978). Since then a large number of scientific papers have been devoted to conservation of forest genetic resources. A full issue of the Forest Ecology and Management journal addressed that subject in 1990. Suggestions for the best methods for conservation vary considerably, probably because the objectives are not clearly expressed.

It has been argued that there are three cornerstones for sound gene conservation: objectives, genetic knowledge, and methods (Eriksson *et al.* 1993). The methods should ensure that the objectives are fulfilled while considering the structure and dynamics of the species to be conserved.

The purpose of this paper is to formulate a policy for conservation of genetic resources of Swedish Noble Hardwoods. Even if tree species do not recognize country borders, Sweden like many other countries has signed agreements on conservation of biodiversity. Therefore, the following discussion is on gene conservation from a Swedish perspective, although that may be regarded as somewhat unbiological. Moreover, since Noble Hardwoods do not constitute a homogeneous group, it is useful to examine some of their features.

## Features of importance for the conservation of Noble Hardwoods in Sweden

Common to these species is that knowledge of genetic structure for metric traits is almost totally lacking (Jonsson and Eriksson 1989). This is a consequence of the absence of any substantial breeding efforts in these species.

With the exception of *Sorbus aucuparia*, Noble Hardwoods are restricted to the southern part of the country, south of latitude 61°, and thus many populations grow at the margin of their distribution (Table 1). *Acer campestre, Tilia platyphyllos, Ulmus laevis* and *U. minor* are good examples of species with only marginal populations in Sweden. Some species have relict populations north of latitude 61°, but only on south-facing hill slopes with a much warmer microclimate than the surrounding area. In these cases they never become tall trees but are mostly of a shrubby character.

These species never form continuous forests like *Picea abies* or *Pinus sylvestris*. Rather they frequently occur as scattered trees in mixed stands and must be regarded as secondary species in their respective ecosystems. Another difference from the conifers is that some of them are insect-pollinated (*Acer, Prunus, Sorbus* and *Tilia*). *Sorbus* species are characterized by both sexual and asexual propagation. The elm species face a great threat from the Dutch elm disease (DED).

In summary there is no uniformity within the group of Noble Hardwoods, which means that both objectives and methods for gene conservation will vary. Rather than pooling the trees designated as Noble Hardwoods in this context it might be preferable to classify trees according to their ecological characteristics and to the objectives of gene conservation. Characteristics such as distribution, mating pattern, dispersal of pollen and propagules, and stage in ecosystem might be a more sensible way to group tree species (see Eriksson, this volume).

## Objectives

There is a widespread misconception that evolution has led to perfect adaptedness as defined by Endler (1986). This can probably be attributed to a belief that natural selection is the sole evolutionary force, which is not the case as elaborated elsewhere (Eriksson *et al.* 1993; Kleinschmit 1994a). Natural selection will favour the individuals with the highest fitness, i.e. the individuals that at the time of selection have the best combination of traits. When the environment changes, individuals with other trait combinations will be favoured. Over time there will be shifts between progress and recession of a trait. Therefore, it is a misconception to believe that what exists in nature is an ideal genetic constitution that ought to be the target for gene conservation actions. Even if there were no environmental variation over generations, another prerequisite must be fulfilled to obtain the perfect genetic constitution, namely the total independence of all traits. There is no such independence.

The prime objective in gene conservation is to create good conditions for the future evolution of the species. This is in full agreement with the statement of Soulé, one of the leading conservationists, that conservation genetics is justified for one reason only: to promote the fitness of targeted populations (Soulé and Mills 1992). This is also in line with the decision taken in the Swedish parliament that all existing species should be guaranteed a continued existence in vital populations. The meaning of the objective of creating good conditions for future evolution is that maximum genetic adaptability should be aimed at. Expressed in other words the target should be to maximize additive variance. During the last decades global change, due to the increased level of greenhouse gases, has been much discussed. Some researchers hold the opinion that the global change has already happened (Roberts 1987). If the changes are as drastic as projected in some models, the objective of creating good conditions for future evolution is even more urgent.

At present, strong forces oppose buying products from tropical tree species. If this is not just a passing fashion there will be an increased demand for wood from some species like ash, elm, lime tree and maple. This suggests that a joint breeding and gene conservation objective is justified for these species. Since the area covered by these species is fairly limited, any intensive breeding efforts are excluded.

**Table 1.** Distribution and some features of Swedish Noble Hardwoods, objectives and methods for genetic resources conservation.

| Species | Distribution (latitude or area) | Features | Conservation Objectives | Conservation Methods |
|---|---|---|---|---|
| *Acer campestre* | 56° | insect pollination endangered | CGCFE[1] | introduction and crosses to avoid genetic drift |
| *Acer platanoides* | 61° | insect pollination | CGCFE, improvement | 10 *in situ* subpopulations – culling of poor phenotypes, 1 *ex situ* plantation |
| *Fraxinus excelsior* | 61° | wind pollination | CGCFE, improvement | 5 *in situ* subpopulations – culling of poor phenotypes, 1 *ex situ* plantation |
| *Prunus avium* | 60° | insect pollination | CGCFE, improvement | 10 *in situ* subpopulations – culling of poor phenotypes, 1 *ex situ* plantation |
| *Sorbus aucuparia* | 68° | insect pollination? | CGCFE | jointly with other species |
| *Sorbus hybrida* | Baltic Sea | facultative apomict | CGCFE | 5 *in situ* subpopulations |
| *Sorbus intermedia* | 61° | facultative apomict | CGCFE | 5 *in situ* subpopulations |
| *Tilia cordata* | ~61° | insect pollination | CGCFE, improvement | 10 *in situ* subpopulations – culling of poor phenotypes, 1 *ex situ* plantation |
| *Tilia platyphyllos* | few trees | insect pollination endangered | saving, CGCFE | introduction and crosses to avoid genetic drift |
| *Ulmus glabra* | 65° | wind pollination | CGCFE, improvement, tolerance to DED[2] | 5 *in situ* subpopulations, crosses with DED-tolerant trees from exotic populations |
| *Ulmus laevis* | Öland | wind pollination endangered | saving, CGCFE, tolerance to DED | protection and crosses with DED-tolerant trees from exotic populations |
| *Ulmus minor* | Öland, Gotland | wind pollination endangered | saving, CGCFE, tolerance to DED | protection and crosses with DED-tolerant trees from exotic populations |

[1] CGCFE = **C**reation of **G**ood **C**onditions for **F**uture **E**volution.
[2] DED = Dutch elm disease.

Another incentive for some breeding efforts is the increased demand for many of these trees in landscaping. This increase is caused by a reluctance among landscape architects to use exotics for landscaping. The main objective of breeding will be to match the bred material to the site conditions such that frost exposure at frost-sensitive stages is avoided. For landscaping purposes it is important that frequent die-backs of the leader are avoided; otherwise, the habitus of the trees will deviate from the aesthetic qualities expected from a certain species. The need for joint breeding and gene conservation is also strongly stressed by Kleinschmit (1994b).

As a safeguard against future uncertainties, conservation should aim at capturing genes with frequencies above 0.01.

Preservation of the existing genetic constitution might be identified as one objective so as to have a reference for future comparisons.

Saving of endangered populations might be a final objective. This is valid for two of the elm species, *A. campestre* and *T. platyphyllos*.

## Genetic structure

As stated in the Introduction, little is known about the genetic structure for traits of adaptive significance. There is a clinal variation in growth rhythm with latitude for most Noble Hardwoods with the exception of *S. aucuparia* (Håbjørg 1978). In Figure 1 the relationship between latitudinal origin and mean critical night-length for growth cessation (when 50% of the plants had stopped their growth) is illustrated for the trees and shrubs studied by Håbjørg (1978). Since day- and night-length change so dramatically at the latitudes in Sweden it is expected that adaptation has taken place to match the growth cessation at a certain latitude to avoid autumn frost exposure. In consequence, most tree species will probably show a clinal variation with respect to growth cessation. It is not the latitude *per se* that is of importance, but rather the climatic conditions that change gradually from south to north in Sweden.

## Methods

As stated, the prime objective must be met by capturing maximum additive variance. The methods must be designed such that we not only keep the existing genetic variance but also increase the variance beyond what exists today. For that purpose we have to utilize the Multiple Population Breeding System (MPBS) developed by Namkoong (1984) for joint breeding and gene conservation. The MPBS means that the joint breeding and gene conservation population is split into subpopulations each with an effective population ($N_e$) size of at least 50 entries. This number will not lead to any large reduction in the additive variance within a subpopulation (= 1 - 1/2 $N_e$ = 1%). Such a loss may even be compensated for by new mutations at loci regulating the various quantitative traits. Moreover, in other organisms improvement has continued over many generations, even at population sizes of 20-50 individuals (Hill and Keithley 1988; Namkoong 1989). To fulfil the objective of capturing genes at frequencies above 0.01, the $N_e$ in the entire gene resource population ought to be 1000.

The subpopulations should be distributed over a great range of site conditions. Plantations outside the present range of the species may also be considered to maximize the among-population additive variance (Namkoong 1989). The advantage of distribution of the subpopulations over a great span of site conditions may be evident from Figure 2. The subpopulations are distributed over the 64 combinations of temperature climate, photoperiod and nutrient availability. Intuitively it is realized that the subpopulation located to one particular combination of these three environmental factors will have the largest probability of adaptation to that particular combination of factors. In contrast, one single large gene resource population would lead to lower adaptation for most combinations of these three environmental factors. The number 64 should not be regarded as a recommended number.

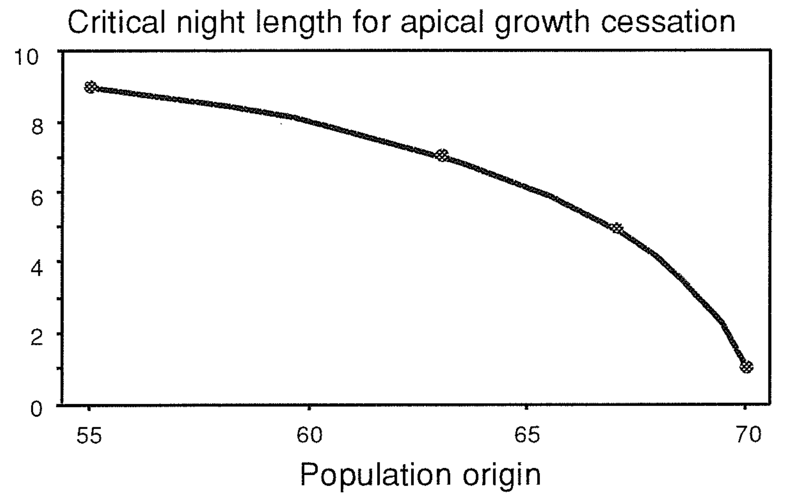


**Fig. 1.** The relationship between estimated critical night-length for growth cessation (when 50% of the plants had stopped their growth) in some Scandinavian trees and shrubs; modified from the original data by Håbjørg (1978).

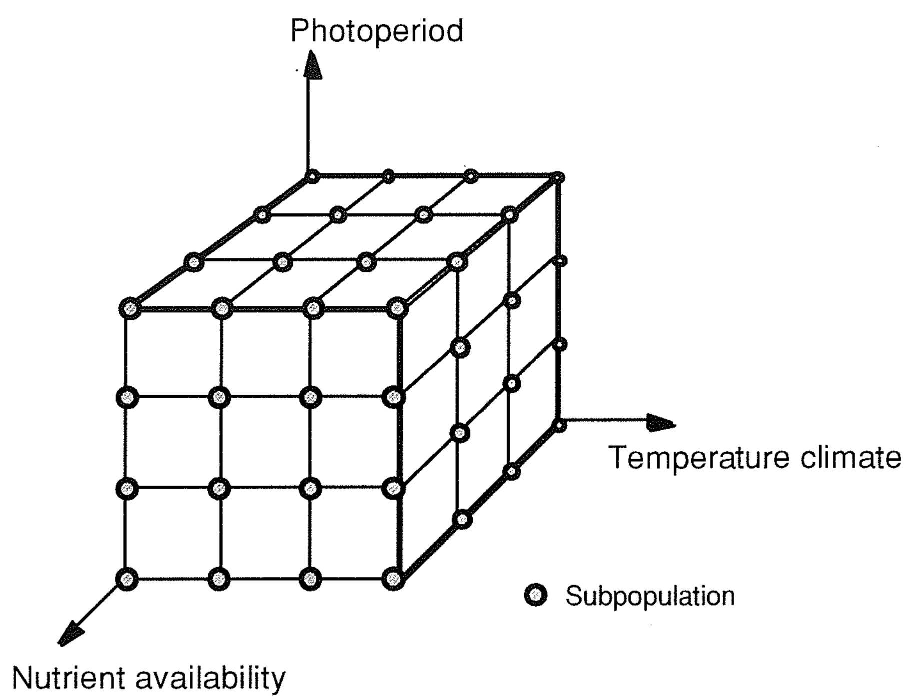


**Fig. 2.** The principles of conservation of genetic resources by splitting the gene resource populations into subpopulations, which will be exposed to different combinations of three environmental factors of significance for adaptation under Swedish conditions.

If some genes are at low frequency in the species as a whole but higher in some populations, the probability of capturing such genes is higher with the MPBS than if conservation is restricted to one large population. Another advantage with the MPBS is that evolution may be faster in a small population than in one large population. It should be remembered that segregation of homozygous individuals for rare alleles is much lower in one large population than in a small population that contains this allele.

Three levels of intensity of MPBS may be distinguished.

- Highest level: *ex situ* populations are distributed over a broad span of site conditions and active management, including selection, is used.
- Second level: *in situ* populations are selected over a broad span of site conditions and some management and selection are done.
- Lowest level: appointment of *in situ* stands as gene resources without management and selection.

As stressed by Eriksson *et al.* (1993), even low-intensity versions of MPBS may be used when the financial support for conservation is limited. For the species with a wide distribution the second level of intensity has been suggested. This means that the gene conservation should mainly be of *in situ* character complemented with *ex situ* plantations outside the present range of the species. The existing adaptedness will thus be capitalized as the starting material for future evolution rather than being the goal for gene conservation.

Any kind of genetic field trials or genetic archive must be regarded as one form of gene resource. Varela and Eriksson (1995) discussed the merits of various populations for gene conservation purposes and concluded that they all may have some merit but they are always inferior to the MPBS.

In agriculture, seed storage is the dominant method for gene conservation. The main objective of agricultural gene conservation is to have a large variation available once the breeders want to change their varieties in any direction. In many instances it is also a question of incorporating individual genes with large effects in a highly bred variety. To accomplish this, a crop breeder may need 7-8 generations of backcrosses. This is time consuming and impossible for most species with long generation times. Seed banks are of value only to match the objective of preserving the existing adaptedness. Even for this objective there is a constraint on its value since it is time consuming to raise the plants and trees to get progenies from the gene resource.

Kleinschmit (1994b) has strongly argued for *ex situ* gene resource plantations as necessary complements to *in situ* conservation. The reasons for this are the low $N_e$, the risks for outcompetition of the species, and the risks for loss owing to human interventions including forest fires. Hedrick (1994) examined the effect of inbreeding following repeated full-sib mating in small populations with different numbers of lethal equivalents and strength of the effect of deleterious alleles. One important observation was that such close inbreeding may lead to fixation of alleles with slight deleterious effects. As a consequence, the probability for extinction is increased. From a genetic as well as a safety point of view there are good reasons for such *ex situ* plantations as a foundation to generate new populations with a satisfactory additive variance.

As outlined elsewhere we have to rely on educated guesses about how the sampling should be carried out. However, we expect that there is a gradient from south to north with respect to growth rhythm (see above). Therefore, sampling ought to take place along the latitudinal gradient. Besides, the climate in the western part of southern Sweden is different from that in the eastern part. The wind-pollinated species are expected to show less differentiation than the insect-pollinated ones since geneflow is probably lower in the latter type of species. Therefore, five subpopulations have been suggested for the wind-pollinated tree species of common occurrence and 10 subpopulations for the corresponding insect-pollinated species. Equal numbers of populations from the eastern and western parts of the country will be selected. It is assumed that measures are taken in other countries for conservation of these three species. Therefore, the Swedish subpopulations may become part of an international network.

If any of these species grows under some extreme site conditions, sampling of such populations might be valuable since such a population might have acquired adaptedness to those particular site conditions. The same level of adaptedness, even if far from perfect, might take some generations to reach for a population previously not exposed to that extreme site.

To match the objective of improvement it is suggested that culling of inferior phenotypes be carried out. To guarantee regeneration, measures to promote flowering by thinning should be taken. If it is a species that grows in mixtures with other species, then thinning should encompass the other species as well. Thinning has to be done in such a way that the objective of allowing the subpopulation to adapt to the prevailing conditions is not lost.

Two species, *A. campestre* and *T. platyphyllos*, have low numbers of individuals. This means that genetic drift has probably played a great role in these species. The only way to match the prime objective of gene conservation is to initiate a crossing programme to increase the additive variance that must have been lost during previous generations with low $N_e$ (Frankel 1983).

The threat of extinction of the three elm species due to the Dutch elm disease is a special problem for design of gene conservation. Much effort has been made to obtain DED-tolerant elms in the Netherlands, UK and USA with some success. It can be speculated whether the existing elm species in Sweden have passed several bottlenecks which might have caused a decrease of the Swedish populations. In contrast, eastern populations have not passed such bottlenecks and therefore seem to be more resistant to DED. Therefore, at least for research purposes, crosses with trees from exotic populations ought to be carried out to possibly improve the tolerance against DED.

In Table 1 relevant information for the species has been summarized: the objectives and the suggested methods for gene conservation. As stated above the methods suggested are not ideal but are a low-cost alternative to match the prime objective of gene conservation by creating good conditions for future evolution, in some cases combined with an improvement objective. The number of populations should be looked upon as functional rather than physical. If some tree species grow jointly in the same stands, separate gene resource populations are not needed. Therefore, the actual number of gene resource populations will probably be less than the functional number.

If one or two gene resource populations could be extended to cover a few hundred hectares this would make them useful for the gene conservation of many associated species dependent on the tree species for their survival.

If the suggested programme is extended to become part of an international network, in which the entire distribution of the species is considered, the number of functional populations in Sweden may be reduced.

## Research needs

There is a need for more information on genetic variation among and within populations in respect to traits of adaptive significance. Studies should be designed so that an understanding of the evolutionary processes that have led to the existing population structure are revealed. Studies of geneflow are critical in this connection. It is important to carry out studies of inbreeding depression for species that always consist of small populations. Molecular markers as tools for early selection may be tested. Finally, there will never be funding for research on all Noble Hardwood species. We have to take either of two approaches. The first is to select species with different ecological characteristics, the second is selection of ecological keystone species for the studies. The justification for the latter approach is to be able to design conservation is such a way that species associated with the keystone species will also be conserved.

**Acknowledgements**
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# Noble Hardwoods genetic resources and their conservation in Finland

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## Introduction

Finland has 20 million ha of forests, mostly Scots pine and Norway spruce stands with some birch growing admixed. Only 0.5% of forest land area is dominated by Noble Hardwoods, including English oak. Most of this area is alder, which in Finland is called a 'semi noble hardwood' species. Moreover, in the Finnish grouping, English oak belongs to Noble Hardwoods and, indeed, is the main species of interest for forestry.

Noble Hardwoods entered Finland some 9000 years ago, principally from the east, partly across the Finnish Bay from the Baltic and later on from the west. Their distribution was largest about 8000-5000 years ago, in the Atlantic period when the climate was warm and humid. When the climate started to become cooler and drier Norway spruce spread vigorously from the east and the hardwoods withdrew to the south. Later on these species also suffered from human action. Agricultural activities split the forests into small fragments and, for example, oak was used for ship-building and lime for fibre, and was even subject to taxation. In the last decades forest management practices have been unfavourable to Noble Hardwoods; many areas which used to be rich in maple have been turned into pure spruce plantations.

The natural distribution of Noble Hardwoods is limited to southern Finland, except for common alder, which reaches southern Lapland. Elms have no continuous distribution; only some thousand individuals are found. Cultivated individuals of all species can be grown successfully north from their natural distribution in favourable environments.

## Activities with Noble Hardwoods

Some activities with Noble Hardwoods are summarized in Table 1. Altogether, six seed orchards have been established, but so far they have produced very little seed. Good natural stands for seed sources are needed and some new selections are underway. The wood of Noble Hardwoods has traditionally been used for several special purposes and some new interest for traditional carpentry has developed recently. For example, rowan tree became very popular when it was successfully used in the furniture of the new residence of the president of Finland.

## Importance for forest sector

Noble Hardwoods have only minor importance in forestry in Finland. The proportion of broadleaved species other than birch in the growing stock in 1994 was only 3.1%. The total area of cultivated Noble Hardwoods, oak included, is about 500 ha plus about 1000 ha of common alder stands, while the yearly regeneration areas amount to 180 000 ha. Valkonen *et al.* (1995) made an inventory of Noble Hardwood cultures in Finland and compared the profitability of species. Their conclusion was that among Noble Hardwoods common alder is the easiest, cheapest and safest choice for cultivation.

**Table 1.** A summary of the activities with Noble Hardwoods in Finland.

| Species | Seed orchards | Seed collection stands | Gene reserve forests | Used for: |
|---|---|---|---|---|
| *Acer platanoides* | | | 1 | parquet, musical instruments |
| *Alnus glutinosa* | | 9 | | sawn timber, furniture, panels |
| *Fraxinus excelsior* | 1 | 2 | 1 | parquet, boats, furniture |
| *Sorbus aucuparia* | 1 (+1) | | | furniture, berries |
| *Tilia cordata* | 2 | | 3 | sculptures (fibre) |
| *Ulmus glabra* | 1 | 1 | | ornaments |
| *Ulmus laevis* | 1 | | | |

Louna and Valkonen (1995) made a survey on the state of domestic raw material in the industrial use of hardwoods (Table 2).

**Table 2.** Some hardwoods used in Finland.

| Species | Usage $m^3$ | Usage %[1] |
|---|---|---|
| Common alder | 4 000 | 1.6 |
| Rowan tree | 110 | – |
| Ash | 5 350 | – |
| Maple | 8 520 | – |
| Lime | 100 | – |
| Elm | 100 | – |

[1] Percentage of total forest resources of each species.

Almost all wood of Noble Hardwoods used in Finland is imported, with the exception of rowan tree and common alder. In 1993 the value of imports was 150 million Fmk. Cultivation of Noble Hardwoods in Finland is a small-scale activity and the natural stands are poor in usable wood. The quality of stems is often inferior, the stands are small and many of them are protected. In any case the present native resources correspond to only a few years' consumption (Valkonen *et al.* 1995).

## Conservation

Probably none of the Noble Hardwoods is threatened as a species in Finland, although mountain elm and European white elm are rather rare and protected by law. However, most of the small populations are vulnerable to both external and internal threats. Road construction and expansion of settlements are the most common external threats. The severity of internal threats such as inbreeding and genetic erosion is difficult to estimate without intensive genetic research.

The increasing public interest in these species can be of advantage to the conservation programme, since the value of the species is recognized. On the other hand it may increase the importation of foreign forest regeneration material in the near future and thus create a threat to native populations.

Establishment of a network of *in situ* gene reserve forests started in 1992. The target of this programme is to select 10 gene reserve forests for pine, spruce and birch according to the biogeographical zones. The idea has been to store them as dynamic units, which are allowed to evolve. So far, 33 gene reserve forests have been selected, four of them specifically for Noble Hardwoods (Table 3). In these forests the actual coverage of the conserved species is much less than the reserved area. The minimum area of the gene reserve forests for main species is 100 ha and they are managed according to accepted forestry practices. Noble Hardwoods, on the other hand, require small-scale silvicultural working plans and active measures to help natural regeneration. Often the forests in southern Finland are protected as such, which does not necessarily promote the conservation and regeneration of tree species.

**Table 3.** Gene reserve forests of Noble Hardwoods in Finland[1].

| Species | Name | Owner | Area (ha) |
|---|---|---|---|
| Lime | Niinisaari | FFRI[2] | 17 |
| Maple + lime | Haarikonmäki | FFRI | 5 |
| Lime | Muukonsaari | Enso-Gutzeit | 10 |
| Ash | Kalkkivuori | Enso-Gutzeit | 30 |

[1] Source: Statistical Yearbook of Forestry, 1995.
[2] Finnish Forest Research Institute.

The population structure of Noble Hardwoods is, in many ways, different from that of the main species. Populations are small and isolated and they have gone through severe pressures during their life history. The preliminary results from genetic studies indicate that the populations are differentiated from each other to a notable extent. Therefore *ex situ* collections have been selected for the main strategy of conservation of Noble Hardwoods.

Collections will be established with individuals from several populations with the intention to catch wider variation. Both grafting and sowing can be used. The work has been started by seed collections in 1995 and will last 6-10 years. The programme will be expensive compared with *in situ* conservation, since collections have to be fenced and the plants need intensive care in the first years. However, an additional advantage is that collections can later on be used to produce regeneration material. This would be especially profitable with species that express a high degree of inbreeding in natural populations.

## Breeding and research

There is no intensive breeding programme in Finland for Noble Hardwoods. Some seed orchards have been established with selected plus trees, but they have met with setbacks and generally they have not produced much seed. However, now there is some interest in new seed orchards.

In 1995 one of national forest district boards started a project for the establishment of a new rowan seed orchard. Selections were based on the stem form or the sweetness of the berries. This project is now interrupted because of lack of funding.

The phenology of rowan was studied quite intensively in the Finnish climatic change programme together with 11 other plant species. As a result of this project phenological maps were made, which predict the onset of flowering in heterogeneous climatic conditions. Also a phenological observation network has been established with rowan tree.

The Finnish Forest Research Institute and the Foundation for Forest Tree Breeding started a common research project on Noble Hardwoods in 1995. The aim of the project is to characterize the main features of the Noble Hardwood populations in Finland in the genetic sense. Isoenzymes are used to measure the neutral genetic variation and its distribution within each species. So far the main interest has concentrated on oak, maple and white elm. The preliminary results have supported the expectation that rare and scattered species would differ from the main species in their genetic pattern. This research will help to make the operative plan for genetic conservation and will also help to make recommendations for the selection of seed sources for forest regeneration.

## Public awareness of forest genetic resources

Traditionally forests are important to almost every Finn. More than 60% of the forest land is owned by private persons and the 25% that is state owned is very clearly taken for common property. In Finland the so-called everymans' right affords everybody unrestricted movement and recreation in the forests. The general interest in forests shows in the genetic register where there are 1200 observations of special trees (*forms*, etc.), reported often by laymen.

In the 1990s several projects were started to increase the interest in rare forest species. The year 1996 has been declared a special year for wood. Connected to this theme there are courses and seminars on the utilization of wood for special purposes as well as on the forest cultivation and management of Noble Hardwoods. The possible climatic change has also raised interest in hardwoods to the north of their natural distribution. As 'green' values and nature conservation in general have been popular in recent years, it has been rather easy to advertise the idea of genetic conservation. However, since the strategy is different from that of general nature protection, it is sometimes difficult to introduce the special needs of genetic conservation.

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# Evolutionary genetics and conservation of forest tree genetic resources

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**Summary**
In addition to natural selection other evolutionary forces, such as mutation, genetic drift, geneflow and phenotypic plasticity, influence evolution. The strength of and interaction among these forces will influence the magnitude of among-population differentiation. It is concluded that we can never expect any perfection in natural populations. The need for additive variance to make natural selection operative is stressed. It is shown that the number of individuals required to capture low-frequency alleles rises sharply when the frequency drops below 0.01. This increase is fairly independent of the number of loci with rare alleles. It is graphically shown that the increase of the remaining additive variance for traits that are independent of the traits selected for in breeding does not increase much beyond random sampling of 100 individuals.

It is stressed that the methods of gene conservation should ensure that the objectives in gene conservation are fulfilled while taking the structure and the dynamics of the gene resource into account. The creation of good conditions for future evolution is the prime objective of gene conservation in most instances. As a safeguard, the capture of alleles at frequencies above 0.01 should be aimed at. Since the present genetic constitution is not perfect, its maintenance should not be a goal in gene conservation. Rather it is good starting material for future evolution. The Multiple Population Breeding System and its merits are presented here. Sampling of gene resource populations in the absence of knowledge of the genetic structure of a species has to be based on informed guesses based on what is known of the structure of the ecological characteristics of the species such as pattern of distribution, stage in ecosystem and potential for geneflow.

## Evolutionary forces

For gene conservation it is important to understand how the evolutionary forces influence population differentiation. In Figure 1 it is illustrated that selection, genetic drift and mutation act to increase the population differentiation, whereas geneflow and phenotypic plasticity tend to reduce the among-population variation.

It is assumed that different mutations appear in different populations, which means that these mutations increase the differentiation among populations. However, the effect is low owing to the low mutation frequencies, which are estimated at approximately $10^{-5}$ at individual loci. However, the pooled mutation frequency at loci influencing a trait may be considerably higher, between $10^{-2}$ and $10^{-3}$ (Lande and Burrowclough 1987). Kärkkäinen *et al.* (1995) reported a mutation frequency for chlorophyll mutants in *Pinus sylvestris* of $10^{-2}$ based on data published by Eiche (1955).

According to the survey of the strength of natural selection in the wild carried out by Endler (1986) natural selection can vary from weak to as strong as in breeding. It cannot be over-stressed that without additive variance natural selection cannot operate, as is well known from the textbook formula for genetic response (*DG*) to selection:

$$DG = (s_a)^2 \times i \times (s_p)^{-1}$$

$(s_a)^2$ is the additive variance;
$i$ is the selection intensity;
$s_p$ is the phenotypic standard deviation.

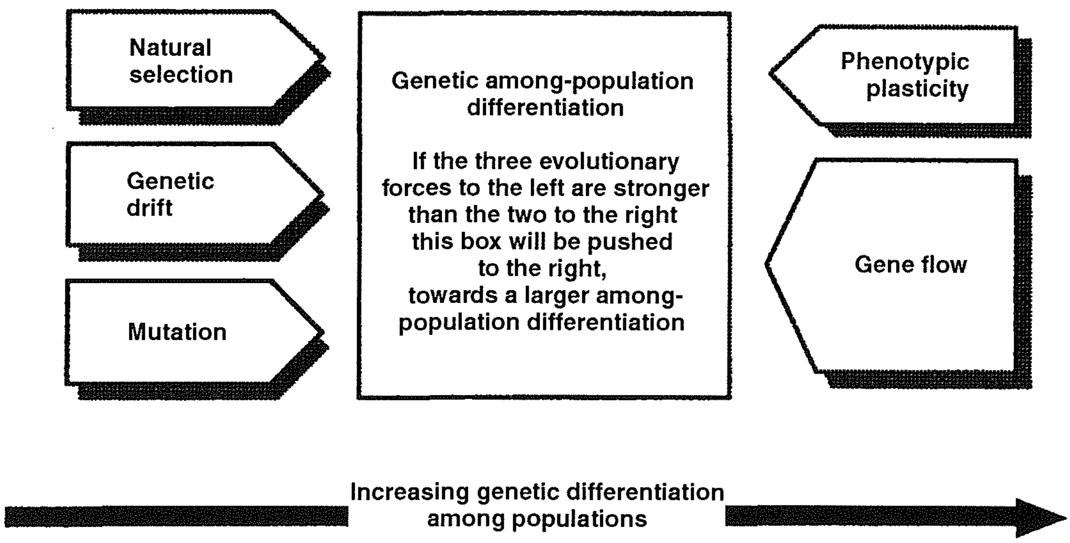


**Fig. 1.** When the pooled effects of the forces to the left outweigh the forces to the right, the among-population differentiation will increase

Since additive variance is fundamental for the success of natural selection, it is important to emphasize that additive variance is dependent on gene frequencies. In Figure 2 the relationship between amount of additive variance and gene frequency is visualized for a situation assuming no dominance deviation. Figure 2 illustrates that genes at extremely low or extremely high frequencies do not contribute substantially to the additive variance. This in turn means that rare alleles below a frequency of 0.01 do not contribute much to the additive variance. Even if they contribute to the fitness of its carriers their continued presence in a population is a matter of random events and not an effect of natural selection.

Phenotypic plasticity is the amplitude a genetic entry shows when studied in two or more environments. Plants with their indeterminate growth can express a large phenotypic plasticity for many traits with the probable exception of floral organs. Certain ecological characteristics contribute to the development of phenotypic plasticity:

- longevity
- wide and continuous distribution
- large geneflow among populations growing under various site conditions.

Tree species with long generations cannot respond genetically to selection caused by annual variation in weather conditions. Instead, such a species has to cope with varying conditions by adjusting its phenotype, i.e. by phenotypic plasticity. Short-generation plant species can respond to selection genetically and are thus not expected to have as much phenotypic plasticity as long-lived trees.

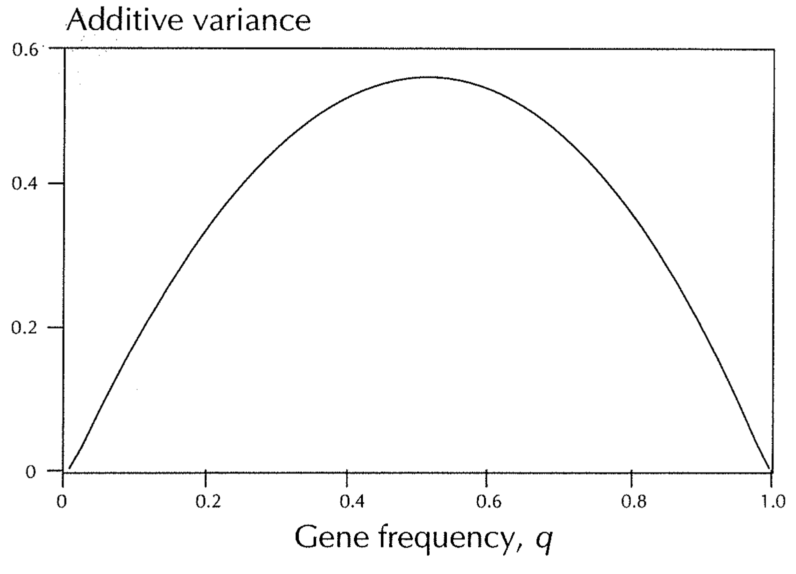


**Fig. 2.** The relationship between the additive genetic variance and gene frequency in the absence of non-additive gene action.

A combination of the two latter criteria will strongly promote development of phenotypic plasticity. If the pollen from a tree has a high probability of fertilizing egg cells of other trees growing under other site conditions and thus with some difference in adaptedness to these other growth conditions, it will probably not be advantageous with specialization. Rather an adjustment dependent on the site conditions, i.e. phenotypic plasticity, will probably contribute to fitness. Phenotypic plasticity can be thought of as a disguise of the genotype. In this way the possibility for natural selection to exert its force is reduced. Phenotypic plasticity has not been discussed much as an evolutionary force, although it prevents the full effect of natural selection.

Random genetic drift is a strong force in populations with low effective population size ($N_e$) while it is negligible in large populations. For forest trees it might be of interest to examine the loss of additive variance owing to drift over 10 generations in populations with varying $N_e$. The loss is proportional to $1/2\ N_e$ in the absence of other evolutionary forces. As seen in Figure 3 the effect of drift is relatively limited at $N_e$ above 20. For tree species with small and scattered populations, like many of the ones under discussion during this conference, drift may play a great role.

Geneflow is a strong evolutionary force preventing among-population differentiation. It suffices with one migrant per generation to prevent fixation of neutral alleles in the two populations. Geneflow takes place by pollen, seeds, nuts, acorns and other propagules. The physical dissipation of these organs is dependent on their vectors. It is generally considered that wind pollination is an efficient means for long-distance transfer while heavy propagules like acorns will be distributed over more limited areas even if jays may carry acorns over some kilometers (Demesure 1996).

To summarize, there are several evolutionary forces which interact in a complex way which means that the belief that natural selection is the only evolutionary force is a misconception. There are certainly many examples of natural selection as an important force in forest trees such as the adaptation of growth rhythm to the climate at different latitudes (e.g. Ekberg *et al.* 1979).

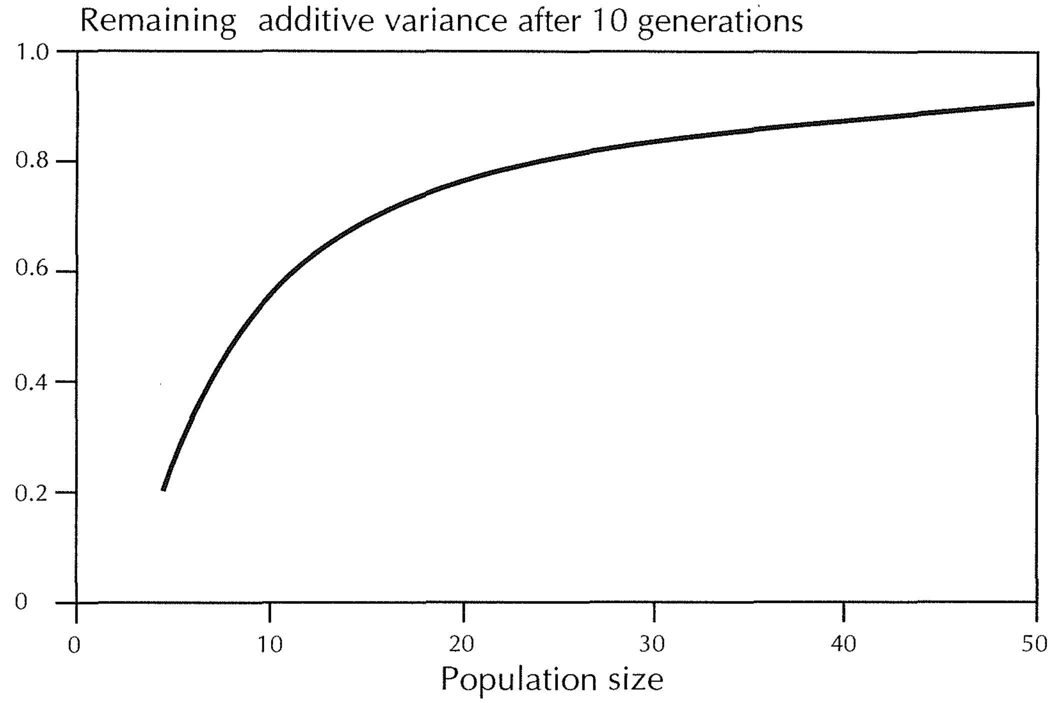


**Fig. 3.** Loss of additive variance owing to genetic drift during 10 generations with different effective population sizes.

The implication of this for gene conservation is that the existing genetic constitution of a population may not be the best adapted to the conditions but rather is one of many possible. Therefore, the existing adaptedness should not be regarded as sacred and should not be the final goal in a dynamic gene conservation programme. However, it constitutes good starting material in such a programme.

One consequence of the discussion above is that genes at low frequencies should not be targeted for conservation since they do not contribute to fitness. In Figure 4 the number of individuals required to capture alleles at different frequencies and in varying numbers of loci are illustrated. At allele frequencies lower than 0.01 the number of individuals required rises sharply. It should also be noted that the number of loci does not influence the numbers required as much as the low allele frequencies. Down to frequencies of 0.01, a gene resource population of 500 is satisfactorily large.

## Cornerstones in the conservation of genetic resources

The methods of gene conservation should ensure that the objectives are fulfilled while taking the structure and the dynamics of the gene resource into account. The cornerstones are thus objectives, genetic structure and methods.

### Objectives

In a series of papers (Namkoong 1984; Eriksson *et al.* 1993, 1995; Varela and Eriksson 1995) we have strongly argued for creation of good conditions for future evolution as the prime objective of gene conservation. This means that high adaptability is of greatest concern. This in turn means that we should develop methods of gene conservation that keep or even increase the additive variance.

One way to do this is to capture the existing adaptedness in the species. Finally as a safeguard we should aim at saving alleles at frequencies ≥0.01. If low-frequency alleles are more common in some populations an inclusion of populations from a broad span of site conditions will increase the probability of saving these low-frequency alleles.

There are other objectives of gene conservation that are justified but none are of equal importance to the dynamic one as defined above. One that has great merit is the conservation of associated species. Associated species are those dependent on a tree species for its survival.

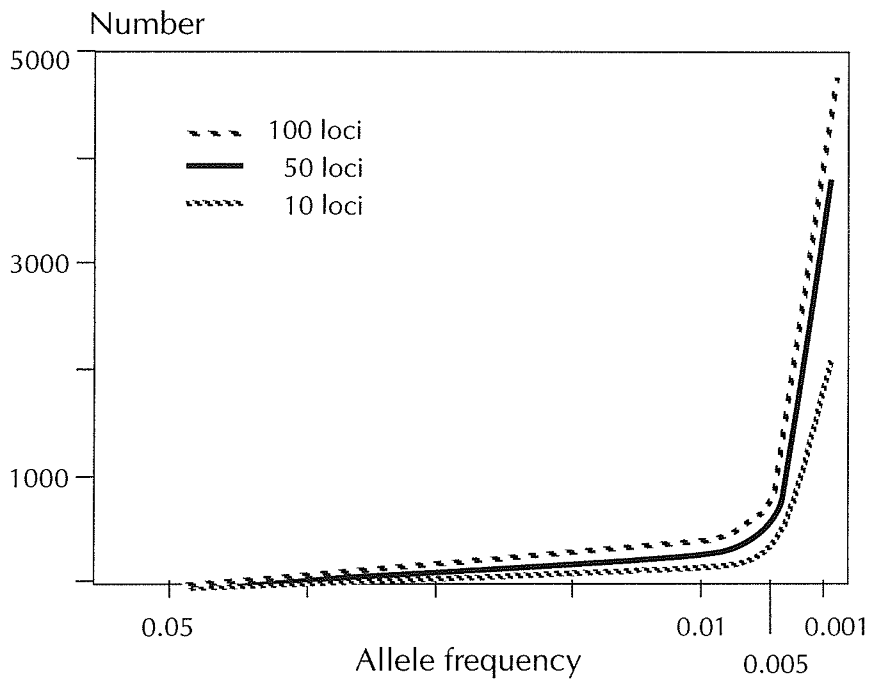


**Fig. 4.** The number of individuals needed to capture alleles at different frequencies.

## Methods

### *Sampling*

A central issue is sampling of genetic resources. If the genetic structure is known, it is a simple matter to select genetically representative samples of gene resource populations. However, in most cases the genetic structure is unknown. The discussion in the section **Evolutionary forces** may be helpful in these cases. A prime prerequisite for among-population differentiation is that the environment occupied by a species is experienced as heterogeneous by this species. The concept of selective environmental neighbourhood (SEN) introduced by Brandon (1990) is useful for the discussion of this prerequisite. Within a SEN there is no ranking changes of the genotypes with respect to fitness, conferring a degree of homogeneity to a SEN. Thus several selective environmental neighbourhoods are required for among-population differentiation. As emphasized before, geneflow is a strong evolutionary force. Therefore, the relationship between the strength of the geneflow and the number of SENs is crucial for among-population differentiation. In the absence of a strong disruptive selection there will be limited among-population differentiation. With increasing strength of the disruptive selection we expect a larger among-population differentiation. Figure 5 is an attempt to illustrate how these three factors interact in large random mating populations.

The question is how estimates of the strength of the geneflow and numbers of SENs should be made. The best guesses are probably obtained from the ecological characteristics of a species. Examples of such characteristics are:

- patterns of distribution
- pollen and propagule distribution mechanisms
- stage in the ecosystem.

A species with a wide distribution over climatic or edaphic conditions will probably occupy more SENs than a species with a limited distribution. Scattered small populations will probably have less geneflow than continuously distributed species. For discontinuously distributed species with low $N_e$, we expect a larger population differentiation. However, this differentiation has been brought about mostly without any accompanying adaptation which means that the adaptedness is not high. If the geneflow is strongly limited we anticipate a large within-population variation among small cohorts (Fig. 6).

It is supposed that wind pollination favours geneflow among populations. This will operate against among-population differentiation. As pointed out earlier, heavy propagules and pollen vectors which do not transport pollen over wide areas will reduce geneflow and promote among-population differentiation. For the latter type of situation, sampling should encompass a larger number of populations than for wind-pollinated species since we do not count on much levelling owing to geneflow.

It is generally believed that pioneer species which invade open ground are genetically rather uniform. This means that sampling in such species should be focused on sampling of several populations rather than many individuals in the selected populations. Contrary to this, climax species probably house a larger within-population variation than pioneer species. The sampling should therefore be different for the two types of species.

Generally, if we expect that natural disruptive selection has been of some importance our sampling should take place along ecological gradients.

### *Dynamic gene conservation*

Eriksson (1995) discussed dynamic gene conservation and the next section is an excerpt from that paper.

The great uncertainty about the future calls for a dynamic approach in forest tree gene conservation (Namkoong 1984; Hattemer and Gregorius 1990; Eriksson *et al.* 1993; Finkeldey and Hattemer 1993). The gene resources themselves are most dynamic (Eriksson *et al.* 1993). This means that growing populations must be included in the gene resource populations. To cope with these problems Namkoong (1976 and later) developed the Multiple Population Breeding System (MPBS). The MPBS means that the allied breeding/gene resource population consists of approximately 20 subpopulations, each with an effective population size ($N_e$) of 50 genetic entries. These figures are based on the probability of saving genes at frequencies above 0.01 and of avoiding severe inbreeding in the subpopulations. With an effective population size of 50 individuals the rate of inbreeding will be 1% per generation ($1/2\ N_e$) which might be regarded as satisfactorily low. The most intensive form of MPBS includes planting of regular progeny trials; less intensive forms are utilized for species not included in any breeding programme (see Eriksson *et al.* 1993; Varela and Eriksson 1995).

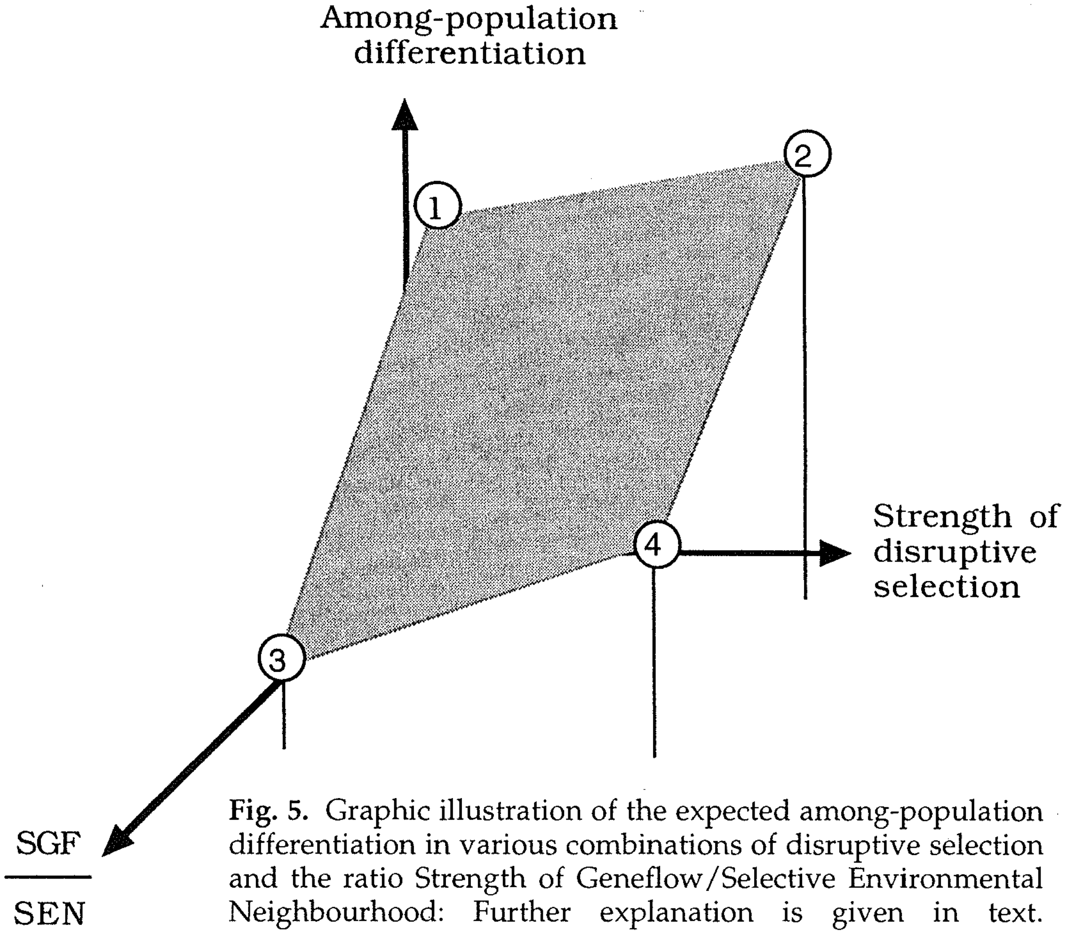


**Fig. 5.** Graphic illustration of the expected among-population differentiation in various combinations of disruptive selection and the ratio Strength of Geneflow/Selective Environmental Neighbourhood: Further explanation is given in text.

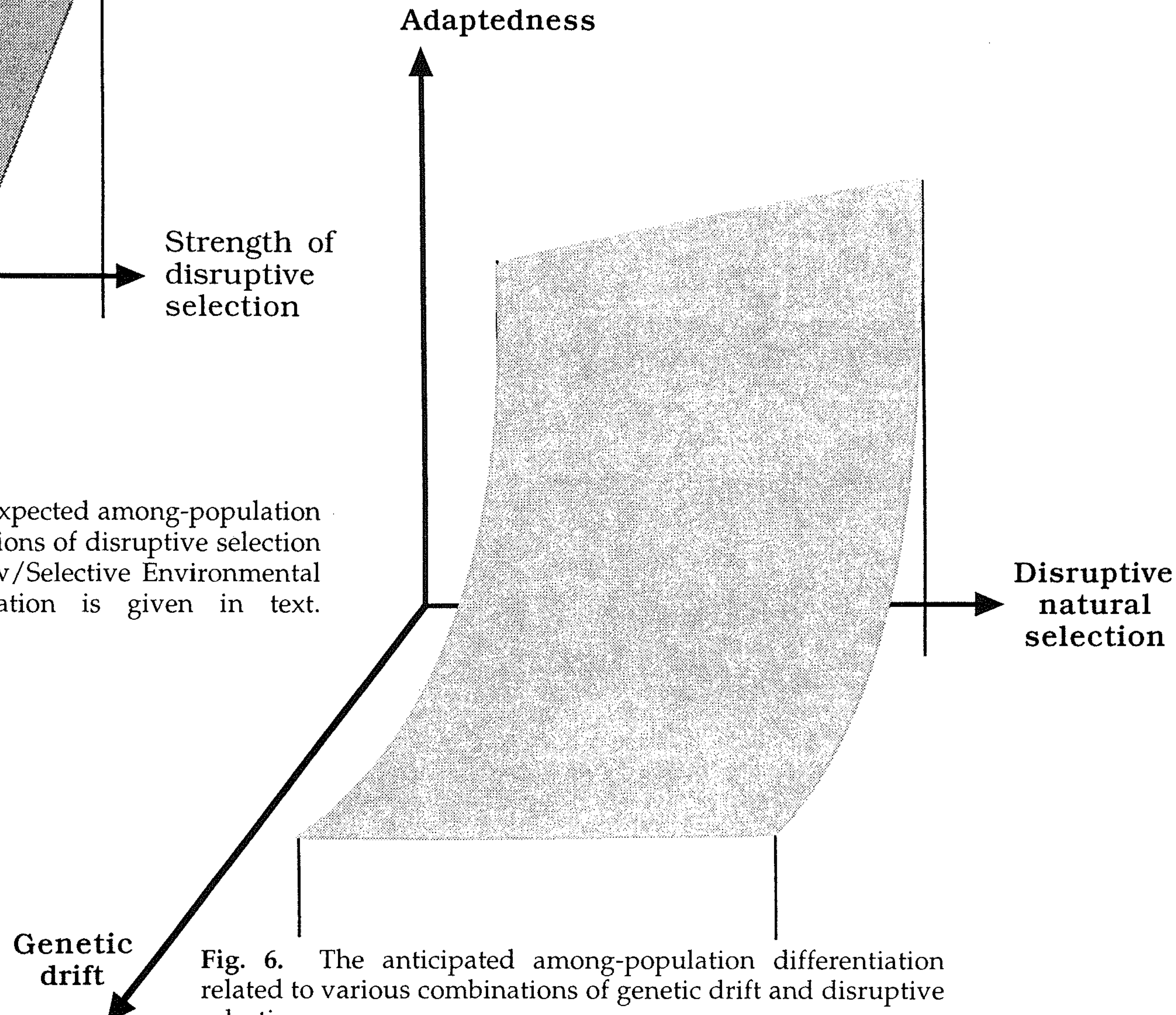


**Fig. 6.** The anticipated among-population differentiation related to various combinations of genetic drift and disruptive selection.

The advantages of splitting the population into subpopulations can be summarized as follows:

- among-population additive variance can be increased while keeping the within-population additive variance
- the chance of obtaining a segregation of homozygotes for low-frequency fitness-contributing alleles is much greater in small populations than in large ones
- the speed of evolution is mostly greater in small populations than in large ones
- the probability of saving low-frequence alleles is increased if sampling among subpopulations is carried out over the span of existing adaptedness, partly because a gene might be at low frequency in the species as a whole but more prevalent in particular subpopulations.

These advantages are reflected as plus signs in Table 1 in which a schematic illustration of advantages (+) and disadvantages (-) of different gene conservation methods are given. The recommendation by Varela and Eriksson (1995) was followed in that such a classification should have its starting point in the possibilities of the methods to fulfil important gene conservation objectives. Thus to fulfil the objective "to create good conditions for future evolution", there is a need to have a series of small populations. Establishment of these small populations stratified over the span of site conditions accompanied with desired selections in each subpopulation is the best guarantee for fulfilment of the prime objective. Large managed and unmanaged multiple populations have lower merits than the previous. One single population would be satisfactory for species consisting of one SEN (in the sense of Brandon) only. The probability of including genes at frequencies above 0.01 and existing adaptedness is good for multiple populations but low for a single population. Species having just one SEN are exceptions to this.

**Table 1.** Merits of different *in vivo* methods of gene resource conservation of target and associated species.

| | No. of populations | | | | |
|---|---|---|---|---|---|
| | Single | | Multiple | | |
| | | | Managed | | |
| **Objectives** | **Managed** | **Unmanaged** | **Small** | **Large** | **Unmanaged** |
| **Target species** | | | | | |
| Good conditions for future evolution | –[1] | – | + | $0^2$ | $0^2$ |
| Capture existing: | | | | | |
| adaptedness | –[1] | – | + | + | + |
| genes ≥0.01 | –[1] | – | + | + | + |
| **Associated species** | | | | | |
| Good conditions for future evolution | – | – | – | + | – |

To match the objective of gene conservation of associated species, Varela and Eriksson (1995) suggested a modification of the MPBS by enlarging some strategically selected subpopulations to comprise a few hundred hectares. Moreover, these huge subpopulations should be managed to create maximum habitat diversity. One way of creating habitat diversity is to have large areas of all the different age classes from the juvenile to the over-mature stages with snags and fallen logs. The reason for maximizing habitat diversity is that many threatened species are restricted to certain habitats (Berg *et al.* 1994). Such an application of the MPBS has a high probability of taking care of the gene conservation of the majority of the associated species with the possible exception of some large animals. This modified version of the MPBS method satisfies the requirements of the associated species in the best way (see Table 1). Large unmanaged nature reserves will not contain all the habitats demanded by the associated species and therefore will not be satisfactory for gene conservation of some of the associated species.

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# Agenda

Introduction
Welcome address — J. Kleinschmit
Welcome address — J. Turok

Evolutionary genetics and conservation of forest tree genetic resources — G. Eriksson

Reports on activities by participants

Future activities in EU research and EUFORGEN

Genetic resources of Noble Hardwoods under the aspect of seed legislation — S. de Vries

History of the Noble Hardwoods gene conservation Network and definition of the Network's objectives — G. Eriksson

Coordination of the development of European databases: needs and priorities

Agreement on Network tasks and development of a workplan

Excursion in Forstamt Escherode: 'Conservation of Noble Hardwoods and production of valuable timber'

Final wrap-up session: approval of the Report

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