




THE SECOND REPORT
ON THE STATE
OF THE WORLD'S

FOREST GENETIC RESOURCES

COUNTRY REPORT

CROATIA



This country report was prepared as a contribution to the FAO publication, *The Second Report on the State of the World's Forest Genetic Resources*.

The country reports had two elements: (1) an online questionnaire to gather data and information on forest genetic resources; and (2) a complementary written report. For the written reports, countries were invited to follow the structure of the global report and reporting guidelines adopted by the Commission on Genetic Resources for Food and Agriculture at its Seventeenth Regular Session in 2019.

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The second report on the state of the world`s genetic resources

Croatia

2020

Summary

Croatian flora is one of the richest in Europe with around 4,500 plant species and subspecies. Of the total number of forest woody species, 260 are native species, of which 60 are economic tree species. Also, Croatia is geographically very diverse and therefore its forests formed various ecological types sensitive to habitat degradation, air and water pollution, excessive use of certain more valuable species of forest trees, as well as other anthropogenic effects and increasing impact of global climate changes. The basic principles of Croatian forestry are sustainable forest management, aiming to preserve the natural structure and diversity of forests, and the continuous increase of the stability and quality of forest ecosystem services. The use of natural resources is carried out on the basis of natural resource management plans and the conservation of biodiversity, landscape diversity and geodiversity are taken into account. Forest genetic resources in Croatia should be managed in a way that conserves their potential for adaptation to changed environmental conditions, especially considering the effects of climate changes and climate extremes that forests are increasingly subjected to. Several institutions deal with forest genetic resources conservation (Ministry of Agriculture, Croatian Forests LTD., Croatian Forest Research Institute and Faculty of Forestry Zagreb). These institutions are well equipped, both in human resources and equipment to fulfill major demands in FGR conservation. Major weaknesses, as identified by the authors of this report are: institutions involved in FGR conservation cooperate well but there are possibilities for further improvements, especially in coordination of their activities and resources. Unfortunately, public is not well informed (sometimes even misinformed) about FGR conservation efforts conducted by above mentioned institutions. Also, forestry practice is often not complied with FGR conservation theory though some traditional practices are useful (e.g. natural regeneration). There is a need for stronger implementation of genetic conservation theory into the forestry practice and for supporting that modified practice in long term. Financial support by government is not sufficient while private sector is not stimulated to voluntary support FGR conservation efforts. A permanent official body (e.g. commission for FGR within the Ministry of Agriculture) would help in correcting mentioned weaknesses.

List of abbreviations and acronyms used in the complementary report

CSO - clone seed orchards

LTD. - limited liability company

CFRI - Croatian Forest Research Institute

FGR - forest genetic resources

FSO - forest seed objects

FRM – forest reproductive material

EUFORGEN - European Forest Genetic Resources Programme

EUFGIS - European Information System on Forest Genetic Resources

OECD - Organisation for Economic Co-operation and Development

SPA - Special Protection Areas

Chapter 1. Value and importance of forest genetic resources

Since almost half of the Republic of Croatia's land area is forested, forests with their multiple functions are of great traditional and cultural and significant economical importance. Total area of forests and forest land in Croatia amounts to 2,759,039 ha which is 49.3 % of its total land area. Out of that, 2,097,318 ha is state-owned, whereas 661,721 ha are privately owned. Vast majority of state-owned forests is managed by Croatian Forest LTD. (2,024,461 ha). Considering the economic importance of the Forestry sector in Croatia, the percentage of gross value added of jointly Agriculture, Forestry and Fishing in the total gross value added of all sectors has been moving between 3.5 and 4 % in the last few years, which is higher than the EU average of approx. 1.6 %. Since the majority of natural protected areas (especially almost all National parks) are also covered in forests that determine much of their character and appeal, the forests in Croatia also have important turistic value.

The basic theory and principle of the Croatian forestry are the sustainable management, aiming to preserve the natural structure and biodiversity of forests (including the forest genetic resources of forest species as a component of the overall biodiversity) and the continuous rise of the stability and quality of the commercial and welfare functions of the forest.

The principle of sustainability has been officially incorporated in the main legislative document, the Forest Act. The Forest Act prescribes an integral forest-management area in the Republic of Croatia, which is further divided into management units. There are also a number of other laws and by-laws and regulations that are taken in account in the process of forest management. These include, for example, the Nature Protection Act, the Environment Protection Act, the Act on Forest Reproductive Material, the Hunting Act, the Forest Fire Protection Act, the Water Act, the Act on Roads, the Physical Planning and Building Act, the State Measurement and Land Registry Act, the Act on Sustainable Waste Management, and the Regulation on Remittance of Trees, Marking of the Timber and Forest Row, the Regulation on Forest Fire Protection, the Regulation on Strictly Protected Species, the Regulation on the Collection of Wild Plants, and the Regulation on the Ecological Network (4).

Forests and forest land in Croatia is managed in line with the Forest management plan, adopted for the period of 10 years. The Forest management plan defines the ecological, commercial and social basis for the biological improvement of forests and the growth of forest production.

Besides according to the ownership, forests are classified according to their purpose. The Forest Act states that according to their purpose, forests can be commercial, protective and those with a special purpose. By fulfilling all of their functions, all of the forests significantly contribute to the Sustainable Development Goals, especially those concerning Climate Action, Good health and well - being, Life on Land and Clean water. Genetic diversity and balanced state of forest genetic resources is a crucial prerequisite for forests to deliver those functions.

There are many challenges that the forestry sector and forest genetic resources are facing nowadays in Croatia. They are comparable to the challenges noted also in other European countries. Problems stressed by the experts include changed climate conditions occurring at the beginning of the 21st century that have inflicted major problems to the forests. Also, the general market globalisation contributed to the faster and easier spread of invasive diseases and pests. All the important forest tree species today in Croatia have problems. Forests of Gorski Kotar, which are composed of fir, beech, and spruce, have succumbed to climatic extremes and to attacks of bark beetles. Lowland forests of pedunculate oak are infested with the oak lace bug, while forests of narrow-leaved ash are rapidly deteriorating under the cumulative action of several factors. Dalmatian pine forests are severely

threatened by the pine bark beetle. Forest fires also cause extensive damage. The subsequent erosions lead to the loss of forest soils, which greatly hinders recovery and contributes to the degradation of forests.

There is increased interest of the general public in the state of the forests, resulting with pressure on forestry experts, which is also a situation recognized all over the world. At the same time the financial means needed for forest protection and reforestation are being decreased. In order to address the problems properly, funds from various sources (national and EU) are needed for relevant scientific research in the field of climate change conditions, adaptability and genetic and epigenetic variability of forest genetic resources.

Considering the raising of public awareness, the problem in Croatia is a lack of attractive communication tools with the public, to better inform them on the value and importance of forest genetic resources. Also, the forestry sector should communicate on forestry practices that possibly have been wrongly identified by the public, due to lack of knowledge. Since the right of the public to all available information on forest management has also been incorporated in the Forest Act, forestry needs to adapt to better communicate with the public and ensure availability of all forest functions, as determined by the Act. A useful tool for such communication is Forest Pedagogy, multi-functional and interdisciplinary activity widely used to bring forests and forestry closer to people. It is starting to develop also in Croatia and hopefully will play its role in developing awareness on importance of forest genetic resources.

Chapter 2. State of diversity in forests and wooded land in the Republic of Croatia

Croatian flora is one of the richest in Europe with around 4,500 plant species and subspecies. Of the total number of forest woody species, 260 are native species, of which 60 are economic tree species. There are around 100 different plant communities - phytocenosis established in Croatia. Shrubs, herbaceous plants and mosses significantly participate in the formation of phytocenoses. There are four biogeographical regions in the relatively small surface area of Croatia: Continental, Mediterranean, Pannonian and Alpine.

Croatia is specific because it is rich in natural forests that grow on 97% of the forest surface area in total. The natural character of forests is reflected in the dominance of autochthonous flora and fauna, abundance of endemic species, stand structure and other criteria. It is recognizable by its pedunculate oak forests and fir-beech forests that cover very large areas. In addition, Croatia is characterized by a high share of degraded forests forms, most of which are located in the Mediterranean area. Nevertheless, they fulfill the forest ecosystem services such as erosion protection, torrent prevention, absorption of carbon dioxide, release of oxygen, mitigation of climatic extremes, contribution to the beauty of the landscape, etc.

General data on forests and wooded land in the Republic of Croatia according to the forest management plan of the Republic of Croatia for the period 2016 – 2025. The total surface area of forests and wooded land amounts to 2,759,039 ha, which is 49.3% of the land surface area of the country. Of that, 2,097,318 ha are owned by the Republic of Croatia, while 661,721 ha are owned by private forest owners.

The majority of state-owned forests are managed by the public forest owner Croatian Forest LTD. on a surface area of 2,024,461 ha. Data according to the ownership and purpose of forest areas and wooded land are indicated in Table 1 and Chart 1).

Table 1 - Forests and wooded land according to the ownership and purpose

Ownership	PURPOSE			TOTAL
	Productive	Protective	Special purpose	
	ha			
State forests Croatian Forest LTD.	981,665.33	650,631.34	392,163.95	2,024,460.62
State forests - other	721.21	0	72,136.33	72,857.54
Total state forests	982,386.54	650,631.34	464,300.28	2,097,318.16
Private forests	443,422.92	181,464.48	36,833.49	661,720.89
TOTAL	1,425,809.46	832,095.82	501,133.77	2,759,039.05



Chart 1. Forests and wooded land by ownership

Considering the growth and production potential, forests and wooded land are divided into the following categories: wooded land with tree cover (2,492,676 ha or 90% of the total forest and wooded land surface area), productive wooded land without tree cover (199,147 ha or 7% of the total forest and wooded land surface area), non-productive wooded land without tree cover (24,956 ha or 1% of the total forest and wooded land surface area) and infertile wooded land (42,260 ha or 2% of the total forest and wooded land surface area) (Chart 2). In relation to the land surface area of the Republic of Croatia, the wooded land with tree cover makes up for 44.5%, which is also the percentage of forest cover. Productive wooded land without tree cover occupies 3.6%, non-productive wooded land without tree cover occupies 0.4%, while infertile wooded land makes up for 0.8%.

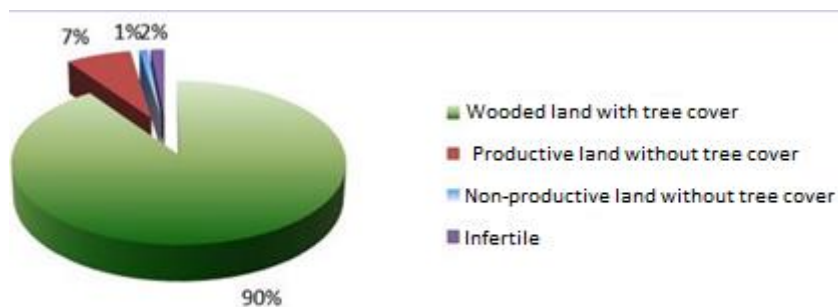


Chart 2: Categories of forests and wooded land

According to their purpose, forests can be productive, protective and special purpose forests. Special purpose forests are selected according to various criteria such as: protection of parts of nature due to their beauty and peculiarities, separation of forest parts for forest seed production, for scientific research, for defense, selection according to special criteria, and urban forests. In order to preserve the forest gene pool and conduct sustainable management, the focus is on forest stands, plantations and crops that are separated from regular management into the category of special purpose forests or established for the needs of forest seed production and for growing and restoring the forests.

In countries with advanced forestry, great importance is attributed to the origin of forest seeds because the genetic features of the future stand can usually be foreseen in advance, such as growth and increment rate, taper and bole length, crown and branch characteristics, vegetation duration, resistance to plant diseases and pests, etc. All over the world we are witnessing a progressive impoverishment of forest quality, where negative selections were carried through felling, which resulted in the loss of

specimens with the highest genetic quality in the stands, which in return led to impoverishment of the stands, as well as initiated a stage of thoughtful approach to forest seed production.

Forest management

The basic principles of Croatian forestry are sustainable forest management, aiming to preserve the natural structure and diversity of forests, and the continuous rise of the stability and quality of commercial and forest ecosystem services. Legislation prescribes that for the purpose of uniform and permanent forest management in the Republic of Croatia, a single forest management area is established, which is divided into management units. Forests and wooded land are managed on the basis of the Forest Management Plan adopted for the period of 10 years. The Forest Management Plan determines the environmental, commercial and social basis for the biological improvement of forests and increase of forest production. The objective of forest management in the Republic of Croatia is a sustainable and harmonious usage of all forest functions and the continuous improvement of their condition.

Growing stock and increment by tree species and ownership structure

According to current Forest Management Plan, the growing stock in the Republic of Croatia amounts to 418.6 million m³, of which 315.8 million m³ is in state-owned forests managed by Croatian Forest LTD.; 83.7 million m³ is in privately owned forests, and 19.1 million m³ in state-owned forests exploited by other legal entities.

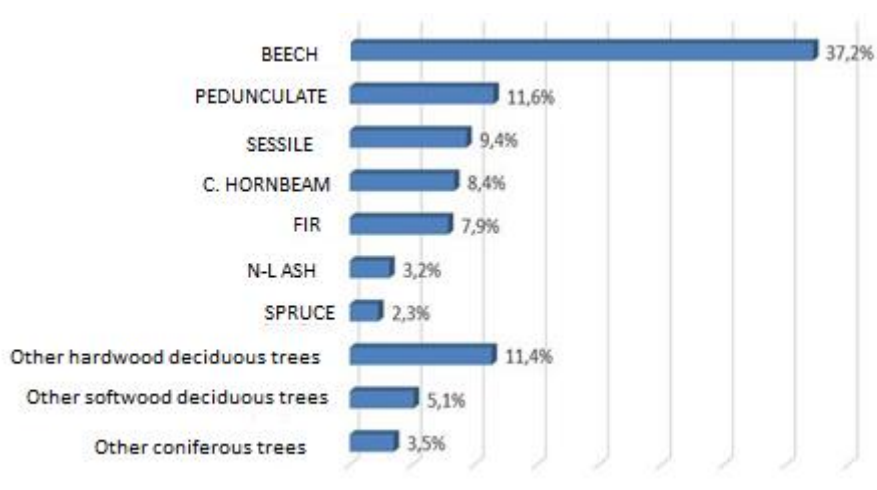


Chart 3: Percentage of growing stock share by tree species in the Republic of Croatia

Annual increment and yield

The annual increment of growing stock in the Republic of Croatia amounts to 10.1 million m³, whereof 7.5 million m³ is in forests managed by Croatian Forest LTD., and 2.2 million m³ in privately owned forests. Annually, in forests managed by Croatian Forest LTD., less wood than the total increment is exploited, which ensures the future of sustainable management.

Yield

Yield represents the allowable annual cut and determines the quantity of wood mass allowed to be exploited. Annual plans (annual yield) are adopted each year, while taking into account the increment which in recent years has generally been higher than the yield. The annual yield in forests managed by Croatian Forest LTD. amounts to an average of 6.4 million m³.

Table 2 indicates the data on forest areas managed by Croatian Forest LTD. in the period from 1996 to 2016. The table shows an increase in the surface area of special purpose forests by almost 10 times in 2016. One of the reasons for the increase is the increase in the forest area intended for the production of forest reproductive material of the category “source identified”. Seed collected in these forest seed stands (commercial stands) is of the lowest genetic quality and cannot meet the requirements related to the stated strains on the stability of forest ecosystems. The strategy for the development of forest reproductive material production in order to preserve the gene pool and biodiversity will require the attention to be placed on all negative facts and factors in order to define the needs, manner and volume of seed production and storage for the purpose of preserving the gene pool and restoring the forests.

Ecological network Natura 2000

Ecological network Natura 2000 comprises the areas significant for the conservation of endangered European species and habitats. It is the largest network of nature conservation areas in the world.

The ecological network of the Republic of Croatia covers 36.67% of the land territory and 16.26% of the sea shore. It consists of 745 conservation areas significant for species and habitat types (including pSCI, SCI and SAC) and 38 conservation areas significant for birds (SPA).

Public institutions are responsible for the management of ecological network areas. The basic manner of managing the ecological network area is to implement conservation measures for target species and habitat types. The measures are integrated into the management plans for the ecological network areas as well as the sectoral plans for the management of natural resources.

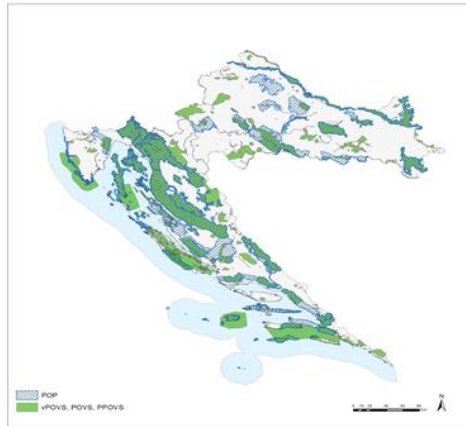


Figure 1. Areas of ecological network conservation

Protected areas at the national level

Data on protected areas in the Republic of Croatia are indicated in the Register of Protected Areas kept by the Directorate for Nature Protection of the Ministry of Environment and Energy. According to the Register of Protected Areas, there are 409 protected areas in the Republic of Croatia in different categories. Protected areas today cover 8.61% of the total surface area of the Republic of Croatia, i.e. 12.32% of the land territory and 1.95% of the territorial sea. The largest part of the protected surface area are nature parks, which amount to 4.90% of the total state territory (Table 3).

Table 3. Protected areas by category, number and surface area in the Republic of Croatia

Category	Number of protected areas	Surface area (km²)	% of the surface area of the Republic of Croatia
Strict reserve	2	24.19	0.03
National park	8	979.63	1.1
Special reserve	77	400.11	0.45
Nature park	11	4,320.48	4.55
Regional park	2	1,025.56	1.16
Nature monument	79	2.04	0.002
Significant landscape	83	1,387.61	1.35
Park forest	27	29.62	0.03
Park architecture monument	120	10.01	0.01
Surface area of protected areas within other protected areas*		593.23	0.67
Total	409	7,585.97	8.61

* surface area refers to protected areas that are located within another, larger protected area, and thus their surface areas overlap

Internationally protected areas

In Croatia, some areas are under the international protection of UNESCO due to their value, preservation and exceptional beauty (Table 4).

Table 4. List of protected areas under international protection

International protection	Area name	Year of designation	National protection
UNESCO – List of World Heritage Sites	Plitvice Lakes	1979	Plitvice Lakes National Park
UNESCO – List of World Heritage Sites	Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe	2017	Northern Velebit National Park
			Paklenica National Park
MAB - Biosphere reserve	Velebit Mountain	1977	Paklenica National Park
			Northern Velebit National Park
			Velebit Nature Park
MAB - Biosphere reserve	Mura-Drava-Danube	2012	Regional park
List of Wetlands of International Importance as defined by the Ramsar Convention	Crna Mlaka	1993	Special ornithological reserve Crna Mlaka
	Kopački Rit	1993	Kopački Rit Nature Park
	Lonjsko Polje and Mokro Polje, including Krapje Đol	1993	Lonjsko Polje Nature Park
			Special ornithological reserve Krapje Đol
	Neretva Delta	1993	-
Vransko Jezero	1999	Vransko Jezero Nature Park	
UNESCO Global Geoparks Network	Papuk	2007	Papuk Nature Park
	Vis Archipelago	2019	

The tentative list for the UNESCO List of World Heritage Sites includes three more areas: [Kornati National Park and Telašćica Nature Park](#), [Velebit Mountain](#) and [Lonjsko Polje Nature Park](#), which in 2005 submitted their candidacy for inclusion in the list as a mixed area of cultural and natural heritage, which is also the first Croatian candidacy for a mixed World Heritage Site.

The basic manner of managing the ecological network area and protected areas is to implement conservation measures for target species and habitat types. The measures are integrated into the management plans for the ecological network areas as well as the sectoral plans for the management of natural resources.

Drivers of change

Climate change, and as its consequence, reduced forest vitality and disturbed natural restoration represent new challenges in forest management, forest restoration and conservation of forest genetic resources. In order to preserve the gene pool and increase the vitality of forests, the use of adapted

seeds and seeds of genetically higher quality, in the category of qualified or tested, will be increasingly important.

New trends

Climate change is more and more present and visible in the forestry of the Republic of Croatia and requires a new approach in the restoration and management of forests, as well as new knowledge about the forest reproductive material and its adaptation to habitat conditions. In order to collect information and supplement the knowledge on the adaptability of species to changed environmental conditions, it will be necessary to intensify research through the establishment of provenance trials and progeny tests that will have a dual function. It will serve to collect and supplement the knowledge about intrapopulation and interpopulation variability and adaptability. It will also serve the purpose of preserving the gene pool by using the '*ex situ*' method, as well as for the production of seeds for the needs of growing and restoring the forests. It will also be necessary to intensify research on how to store seeds in seed banks by using conventional '*ex situ*' methods as well as new technologies and methods (cryopreservation, germplasm conservation, DNA sequence storage, etc.), depending on the seed species, storage duration and seed type according to the storage method. At the same time, it will be necessary to investigate the health status and the method of protecting the stored seeds. This especially refers to the species of deciduous trees with large fruits (large seeds) from the genera *Quercus* spp., *Aesculus* spp., *Castanea* sp., as well as the most endangered tree species in Croatia, with regard to the degree of crown defoliation and the occurrence of new pathogenic organisms, which include the silver fir, narrow-leafed ash, common beech and some Mediterranean coniferous species of the genus *Pinus* spp.

The consequences of climate change, rising air temperature and decreased precipitation, especially in the growing season, as well as anthropogenic impact have a stressful effect on physiological processes in trees, which in return has an adverse impact on the fruiting periodicity, and the quantity and quality of seeds. In addition, the frequent occurrence of extreme weather conditions (storms, hurricanes, waterspouts, strong winds, large amount of precipitation in a short time, geomagnetic storms), floods, fires, etc. is a visible consequence of climate change due to global warming. Examples of such adverse phenomena are still visible in the Republic of Croatia to this day. The consequences of the freezing rain in the area of Gorski Kotar in 2014 were vast. According to the estimate of the company "Croatian Forest LTD." the damage occurred on 43,025 ha of state-owned (including Risnjak NP) and 9,723 ha of privately owned forests, and the wood mass in the amount of 2,494,651 m³ of industrial wood and 1,774,426 m³ of firewood was damaged. The consequences of the fire that occurred in 2018 on the section from Omiš to Split ravaged 4,500 hectares of dense pine forest, maquis, grass, low vegetation and olive groves. Remediation of such disasters continues even to this day.

Chapter 3. State of other wooded land

Chapter 4. State of diversity between trees and other woody plant species

According to the Act on Forest Reproductive Material (OG 75/09, 61/11, 56/13, 14/14, 32/19 and 98/19), forest species of commercial importance and rare forest species have been identified in the Republic of Croatia (Table 5).

Table 5. List of forest species of commercial significance and rare forest species

Forest species of commercial significance

Number	Botanical name	English name
1.	<i>Abies alba</i> Mill.	silver fir
2.	<i>Alnus glutinosa</i> (L.) Gaertn.	black alder
3.	<i>Fagus sylvatica</i> L.	common beech
4.	<i>Fraxinus angustifolia</i> Vahl	narrow-leafed ash
5.	<i>Fraxinus excelsior</i> L.	common ash
6.	<i>Picea abies</i> (L.) H. Karst.	European spruce
7.	<i>Pinus brutia</i> Ten.	Turkish pine
8.	<i>Pinus halepensis</i> Mill.	Aleppo pine
9.	<i>Pinus nigra</i> J. F. Arnold	black pine
10.	<i>Pinus sylvestris</i> L.	Scots pine
11.	<i>Populus</i> L. i njihovih križanci	poplars and their hybrids
12.	<i>Quercus ilex</i> L.	evergreen oak
13.	<i>Quercus petraea</i> (Matt.) Liebl.	sessile oak
14.	<i>Quercus pubescens</i> Willd.	downy oak
15.	<i>Quercus robur</i> L.	pedunculate oak
16.	<i>Salix</i> L. i njihovih križanci	willows and their hybrids

Rare forest species

Number	Botanical name	English name
1.	<i>Abies cephalonica</i> Loudon	Greek fir
2.	<i>Abies grandis</i> (Douglas ex. D. Don) Lindl.	grand fir
3.	<i>Abies pinsapo</i> Boiss.	Spanish fir
4.	<i>Acer campestre</i> L.	field maple
5.	<i>Acer monspessulanum</i> L.	Montpellier maple
6.	<i>Acer platanoides</i> L.	Norway maple
7.	<i>Acer obtusatum</i> Waldst. et Kit. ex Willd.	Bosnian maple
8.	<i>Acer pseudoplatanus</i> L.	sycamore
9.	<i>Alnus incana</i> (L.) Moench.	grey alder
10.	<i>Acer tataricum</i> L.	Tatar maple
11.	<i>Betula pendula</i> Roth	silver birch
12.	<i>Betula pubescens</i> Ehrh	downy birch
13.	<i>Carpinus betulus</i> L.	common hornbeam
14.	<i>Carpinus orientalis</i> Mill.	Oriental hornbeam
15.	<i>Castanea sativa</i> Mill.	sweet chestnut
16.	<i>Cedrus atlantica</i> (Endl.) Manetti ex Carrière	Atlas cedar
17.	<i>Cedrus libani</i> A. Rich.	Lebanon cedar
18.	<i>Celtis australis</i> L.	European nettle tree
19.	<i>Cupressus sempervirens</i> L.	Mediterranean cypress
20.	<i>Fraxinus ornus</i> L.	manna ash
21.	<i>Juglans nigra</i> L.	eastern American black walnut
22.	<i>Larix decidua</i> Mill.	European larch

23.	<i>Larix x eurolepis</i> A. Henry	hybrid larch
24.	<i>Larix kaempferi</i> (Lamb.) Carrière	Japanese larch
25.	<i>Larix sibirica</i> (Münchh) Ledeb.	Siberian larch
26.	<i>Malus sylvestris</i> Mill.	European crab apple
27.	<i>Morus</i> L.	mulberry
28.	<i>Ostrya carpinifolia</i> Scop.	European hop-hornbeam
29.	<i>Picea sitchensis</i> (Bong.) Carr.	Sitka spruce
30.	<i>Pinus canariensis</i> C. Smith	Canary Island pine
31.	<i>Pinus cembra</i> L.	Swiss pine
32.	<i>Pinus contorta</i> Loud.	lodgepole pine
33.	<i>Pinus heldreichii</i> H. Christ	Bosnian pine
34.	<i>Pinus mugo</i> Turra	mountain pine
35.	<i>Pinus pinaster</i> Aiton	maritime pine
36.	<i>Pinus pinea</i> L.	stone pine
37.	<i>Pinus radiata</i> D. Don	Monterey pine
38.	<i>Pinus strobus</i> L.	eastern white pine
39.	<i>Prunus avium</i> (L.) L.	wild cherry
40.	<i>Pseudotsuga menziesii</i> (Mirb.) Franco	Douglas fir
41.	<i>Pyrus pyraster</i> Burgsd.	European wild pear
42.	<i>Quercus cerris</i> L.	Turkey oak
43.	<i>Quercus coccifera</i> L.	kermes oak
44.	<i>Quercus frainetto</i> Ten.	Hungarian oak
45.	<i>Quercus rubra</i> L.	northern red oak
46.	<i>Quercus suber</i> L.	cork oak
47.	<i>Robinia pseudoacacia</i> L.	black locust
48.	<i>Sorbus aria</i> (L.) Crantz	whitebeam

49.	<i>Sorbus aucuparia</i> L.	rowan
50.	<i>Sorbus domestica</i> L.	service tree
51.	<i>Sorbus torminalis</i> (L.) Crantz	wild service tree
52.	<i>Taxus baccata</i> L.	common yew
53.	<i>Tilia cordata</i> Mill.	small-leaved linden
54.	<i>Tilia platyphyllos</i> Scop.	large-leaved linden
55.	<i>Tilia tomentosa</i> Moench	silver linden
56.	<i>Ulmus glabra</i> Huds.	wych elm
57.	<i>Ulmus laevis</i> Pall.	European white elm
58.	<i>Ulmus minor</i> Mill. emend. Richens	field elm

The ordinance on provenances of forest tree species (OG 147/11, 96/12, 115/14 and 114/15) prescribes the provenances for forest tree species of commercial significance, as well as for rare forest species. Provenances of forest tree species of commercial significance are divided into the following seed units: seed areas, seed zones and seed regions. For rare forest tree species, the provenance is not determined by seed units for each taxon separately, but for them the entire territory of the Republic of Croatia is determined as one provenance.

Basic material for the production of forest reproductive material (forest seed objects) were separated from regular management into the category of special purpose forests (Tables 2, 6). The largest area and the largest number of forest seed objects refers to our commercially most important tree species - the pedunculate oak. Such a large surface area of isolated forest seed objects is a consequence of the need for forest reproductive material due to the disturbed natural regeneration of pedunculate oak forests in the lowland area of the Republic of Croatia. The negative side of these isolated facilities is that they belong to the lowest category of forest reproductive material "source identified". The area of seed stands in the "selected" category is relatively small given the need for forest reproductive material of higher quality. In the "qualified" category, 8 clone seed orchards were established, with a total surface area of 96.67 ha for the following tree species: *Fraxinus angustifolia* Vahl, *Prunus avium* L., *Quercus petraea* (Matt.) Liebl. I *Quercus robur* L. and *Pinus nigra* J.F. Arnold. In the category tested, two localities with a total surface area of 5.48 ha were entered, one for the production of recognized poplar clones, *Populus* sp. (Barje S-6-20, Danube (S-1-8), Sava (S-6-36), I-214, I-45/51, Bl. Constanzo, Triplo (I-37/61), M-1 (59-3), Panonia (H490-3), Villafranca), and one for the production of recognized clones of willows, *Salix* sp. (107/65/7, 378, V 158, V 160, B 44, B 72, B 84, 107/65/1, V 99, V 093, V 052, V 95, V374, V461 i V578).

Table 6. Data on forest seed objects in the Republic of Croatia

Type of forest seed object	Number (pcs.)	Surface area (ha)
Seed source – source identified	236	119.479,24
Seed stand - selected	114	3,755.29
Clone seed orchards - qualified	8	77.74
Clones - tested	4	5.48

Table 7 lists the types of forest species of deciduous and coniferous trees with the surface areas of extracted forest seed objects in individual categories.

Table 7. List of forest tree species by categories of forest seed objects in the Republic of Croatia.

No.	Species	Category				TOTAL
		SI	SEL	QFD	TEST	
1.	<i>Abies alba</i> Mill.	1,512.8	205.85			1,718.65
2.	<i>Acer platanoides</i> L.	479.94				479.94
3.	<i>Acer pseudoplatanus</i> L.	522.84	21.75			544.59
4.	<i>Alnus glutinosa</i> Gaertn.		89.96			89.96
5.	<i>Carpinus betulus</i> L.	423.39	24.81			448.2
6.	<i>Castanea sativa</i> Mill.	171.23	22.83			194.06
7.	<i>Cedrus atlantica</i> Man.					0.00
8.	<i>Cedrus deodara</i> G.Don.	16.25				16.25
9.	<i>Fraxinus angustifolia</i> Vahl.	30,613.3	117.33	3.53		30,734.16
10.	<i>Fraxinus excelsior</i> L.		21.75			21.75
11.	<i>Fraxinus ornus</i> L.	11.31				11.31
12.	<i>Juglans nigra</i> L.	350.84	51.62			402.46
13.	<i>Larix decidua</i> Mill.	119.94				119.94
14.	<i>Malus sylvestris</i> L.	11.76				11.76
15.	<i>Picea abies</i> Karst.	1,869.52	158.15			2,027.67
16.	<i>Pinus brutia</i> Ten.		20.95			20.95
17.	<i>Pinus halepensis</i> Mill.	94.01				94.01
18.	<i>Pinus nigra</i> Arn.	211.78	43.18	2.00		259.96
19.	<i>Pinus pinaster</i> Sol.	11.50				11.50
20.	<i>Pinus pinea</i> L.	16.50				16.50
21.	<i>Pinus sylvestris</i> L.		40.33			40.33
22.	<i>Pirus pyraeaster</i> (L.) Burgst.)	11.76				11.76
23.	<i>Populus nigra</i> L.		8.06			8.06
24.	<i>Populus</i> sp.				4.20	4.20
25.	<i>Prunus avium</i> L.	239.15	35.86	3.89		278.90
26.	<i>Pseudotsuga menziesii</i> Mirb. Fra.	71.86	0.20			72.06
27.	<i>Quercus cerris</i> L.	106.32				106.32
28.	<i>Quercus ilex</i> L.		14.96			14.96
29.	<i>Quercus petraea</i> (Matt.) Liebl.	13,084.98	512.78	10.28		13,608.04
30.	<i>Quercus pubescens</i> Willd.	30.44	39.91			70.35
31.	<i>Quercus robur</i> L.	52,826.86	1,828.47	50.74		54,706.07
32.	<i>Quercus rubra</i> L.	5.91				5.91
33.	<i>Robinia pseudoaccacia</i> L.	115.12				115.12
34.	<i>Salix</i> sp.				1.28	1.28
35.	<i>Taxodium distichum</i> Rich.	63.00				63.00
36.	<i>Tilia platyphyllos</i> Scop.		3.07			3.07
37.	<i>Tilia tomentosa</i> Moench		39.08			39.08
	Total	119,479.24	3,755.29	77.74	5.48	123,317.75

In the Republic of Croatia, forest seed objects were extracted for a total of 37 different autochthonous and domesticated species of deciduous and coniferous trees. Of this number, 4 are domesticated species of forest trees: *Juglans nigra* L., *Cedrus libani* A. Rich., *Larix decidua* Mill., *Pseudotsuga menziesii* (Mirb.) Franco. Trends in the last 30 years record an increase in the number of deciduous forest seed objects and a large decrease in the number of coniferous forest seed objects. The reason for this is the manner of management and disturbed natural restoration, as well as a significant need for pedunculate oak seeds. Regarding the preservation of the gene pool in the Republic of Croatia, the highest quality forest seed objects of different species of deciduous and coniferous trees were selected and entered in the list of species in the gene bank for the preservation of the gene pool through 'in situ' method.

Chapter 5. State of diversity within trees and other woody plants species

In the last decade, research on the intraspecific diversity of the main forest tree species in the Republic of Croatia has been significantly increased. The largest number of studies referred to pedunculate oak, followed by studies of narrow-leafed ash, common beech, silver fir, wild cherry, sweet chestnut and field elm. Study on sessile oak has been initiated recently.

According to current knowledge, the studied species of forest trees are generally characterized by a high level of intraspecific diversity and, in some cases, a significant differentiation between populations. However, it is worrying that in a certain number of populations of pedunculate oak and narrow-leafed ash, high levels of inbreeding coefficient were found, i.e. significantly lower heterozygosity was observed. Recently, there has been a major problem with the desiccation of narrow-leafed ash due to an epidemic of the pathogenic fungus *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz, Hosoya (basionym: *Chalara fraxinea*), but also the interaction of various abiotic and biotic factors. The pedunculate oak is faced with the spread of the introduced insect species - the oak lace bug (*Corythucha arcuata*). Furthermore, an increase in the frequency of extreme weather phenomena as a result of climate change (e.g. long drought periods, prolonged floods, stormy winds, etc.) have an extremely adverse impact on the effective size of forest tree populations and thus on their genetic diversity. Species that have not traditionally exhibited issues in fruiting and restoration (e.g. common beech) have had them lately.

We can only assume that the intraspecific diversity of forest trees is relatively stable for now, given that natural population restoration is traditionally applied in the Republic of Croatia as well as additional measures to preserve genetic diversity in forest management (e.g. regeneration in full yield years or care for effective population size). However, it is not possible to know what the actual trends are because research is generally not conducted periodically in the same populations. We also assume that a variety of issues, which we consider to be the consequences of climate change, adversely affect the stability of intraspecific genetic diversity.

To determine the intraspecific diversity of forest tree species in the Republic of Croatia, methods of analyzing phenotypic traits in natural populations, analyses of phenotypic traits in specially designed genetic tests (e.g. provenance tests) and analyses of various DNA markers are used, separately or in combination.

In order to better understand, and thus more effectively preserve, the genetic diversity of forest tree species, research needs to be extended to more species, especially those species that live in habitats that are potentially endangered by climate change (e.g. typical species of the Adriatic region). In addition, the species covered by the research so far should be continuously monitored in order to understand the trends in the state of genetic diversity and the possibility of conducting timely conservation measures. The latter is particularly important for seed facilities (seed stands) of the most main species (e.g. pedunculate oak), as they represent an increasingly significant source of forest reproductive material for stand restoration. The most significant challenge in this process arises from financial reasons, i.e. lack of financial resources to support the research, while the greatest potential thereof is in human resources, given that in recent years the number of researchers dealing with forest tree genetic diversity has increased.

Chapter 6. *In situ* conservation of forest genetic resources

Preservation of the gene pool of forest species in the Republic of Croatia is carried out on the basis of the Act on Forest Reproductive Material. The Croatian Forest Research Institute, as an Official body under the subject Act, is in charge of carrying out these tasks. In accordance with the Act on FRM, conservation refers to forest seed objects (FSO), of which there are now more than 350, with around 50 of them contributing to the gene bank, which are distributed by seed units for a particular species. The audit of registered facilities is performed every year, as well as the registration of new objects.

In situ conservation of forest genetic resources in the territory of the Republic of Croatia is progressively improving every year. Due to the rising awareness of users of forest reproductive material in the territory of the Republic of Croatia, new forest seed objects are registered every year due to the collection of seeds on ever-increasing forest areas. Forest seed objects for rare forest tree species are also being registered, which will be of exceptional significance for the preservation of the gene pool of rare forest tree species.

During the *in situ* conservation of forest genetic resources in the Republic of Croatia, the approach of sustainable forest management in forest seed objects of category “source identified” is used, while forest seed objects in category “selected” are excluded from regular management and are generally not felled at the end of the rotation (they have no rotation and become special purpose forests). After forest owners have consulted with forestry experts from the Official body, new forest seed objects are registered according to the recommendations and guidelines, with genetically ameliorative measures implemented therein to improve the structure, increase the number of seed trees and genetically superior specimens (phenotypic assessment).

Forest owners register new forest seed objects at their own request. When registering a new forest seed object, CFRI experts visit the location and as representatives of the Official body issue an expert opinion on meeting the criteria for registration of new FSO in the National list of forest seed objects, after which they send an application for registration to the Ministry of Agriculture, competent for the National List of Forest seed objects. If it is assessed that the new FSO is of exceptional quality or in some respect an interesting and significant facility, it is entered in the gene bank of forest trees of the Republic of Croatia. For the time being, private entities did not express a desire for their facilities to be entered in such a list (*probably due to the opinion that they will be imposed with some type of management restriction*).

In the territory of the Republic of Croatia, there is currently no long-term monitoring of the yield of forest reproductive material and it is not possible to accurately determine the actual production potential of an individual forest stand. Long-term scientific research and yield monitoring (at least 10 consecutive years) in forest seed objects of the category “source identified” and “selected” could in the future result in predicting the amount of yield before collection and thus affect the Croatian economy because it would emphasize the species that will produce a plentiful yield that year (greater than the needs of forest owners), which could ultimately encourage the export and movement of forest reproductive material outside the Republic of Croatia. Apart from the economic point of view, this would provide better guidelines for the *in situ* preservation of the gene pool, a better insight into diversity and thus more precisely what is necessary for registration in order to preserve diversity.

Priorities for capacity building and research in this area should emphasize the main tree species (oak, beech, fir, spruce) because in addition to natural changes in habitat, they also have a great human impact. On the other hand, some rare forest species should also be one of the priorities in order to

preserve the genetic diversity and gene pool of rare forest species: fruit trees, sorb, poplars (black poplar), and species that are especially endangered today, e.g. field elm, narrow-leafed ash.

It is necessary to perform scientific research that would lead to better and more accurate insights into the genetic diversity of forest species, which might also give a better insight into the zoning of a seed unit.

Chapter 7. *Ex situ* conservation of forest genetic resources

Ex situ conservation of genetic resources in the Republic of Croatia is carried out in clonal seed orchards owned by Croatian Forest LTD. (pedunculate oak, narrow-leafed ash, wild cherry, black pine) and through provenance experiments conducted by employees of the Croatian Forest Research Institute, Faculty of Forestry in Zagreb and Croatian Forest LTD. Furthermore, within the CFRI, there is a living archive founded in the 70s, which contains clones produced from the most superior plants from the entire former Yugoslavia (black pine, Scots pine, larch). With the funds from the Ministry of Agriculture, two years ago the Laboratory for Tissue Culture was established and started operating at the Croatian Forest Research Institute, in which there is a collection of tissues that is continuously replenished.

The main idea of *ex situ* conservation of genetic resources in the Republic of Croatia was initially the production of the highest quality forest reproductive material, gaining scientific knowledge on genetics through clone seed orchards and research into the diversity of domestic and foreign forest tree provenances, and today the main basis for the *ex situ* conservation of forest tree gene pool in the Republic of Croatia are CSOs, genetic tests of provenance plantations and established living archives with the laboratory for tissue culture.

Clone seed orchards are owned by Croatian Forest LTD., but there are also indications that private forest owners will establish clone seed orchards in the future for the purpose of producing quality forest reproductive material. Initiated provenance experiments take place on the land owned by Croatian Forest LTD., and were established by employees of the Croatian Forest Research Institute and the University of Zagreb, Faculty of Forestry.

Due to the increasing climate extremes, there is a need for *ex situ* conservation of genetic resources in controlled conditions. The establishment of new clone seed orchards with species not currently included in the *ex situ* conservation of genetic resources is commendable and necessary. Furthermore, the establishment of living archives with clones of all trees from clone seed orchards in one place would allow for easier and more accurate research of genetic diversity, physiology and fruiting of these forest species.

Chapter 8. The state of use

Conservation of forest genetic resources is carried out within programmes that include *in situ* and *ex situ* methods of gene pool conservation, and the objective thereof is to ensure the production of the highest quality forest reproductive material and to preserve the genetic diversity of forest tree species. In the territory of the Republic of Croatia, the current situation is satisfactory, but the need for its continuous improvement should not be neglected. Due to the need for high-quality FRM, regular monitoring of forest seed objects (FSO) is carried out and every year new facilities are entered in the National List of Forest seed objects in order to enable collection of FRM on as large surface areas as possible, while ensuring that seed objects of forest species are evenly distributed in all seed zones. Preservation of the genetic pool of forest species in the Republic of Croatia is carried out on the basis of the Act on Forest Reproductive Material. The Croatian Forest Research Institute (CFRI), as an Official Body under the subject Act, is in charge of carrying out these tasks.

According to the current National list of forest seed objects in Croatia, there are a total of 366 FSOs on the surface area of 123,428.9 ha, with around 50 of them contributing to the gene bank. The audit of registered facilities is performed every year, as well as the registration of new facilities. The *in situ* method is carried out on a total surface area of 123,345.65 ha in 354 FSOs in the categories “source identified” and “selected”, while the *ex situ* method is carried out on the surface area of 83.22 ha in 12 FSOs in the categories “qualified” and “tested”. In order to preserve the genetic diversity of forest tree species and their genetic sources, the Official body established a gene bank of forest tree species, consisting of a collection of tissues, living archives, forest seed objects, as well as controlled or cultivated populations. Seed material used for research or scientific purposes in forestry is stored in the seed bank of forest tree species by the Official body with the consent of the Ministry of Agriculture.

Forests in the Republic of Croatia managed by Croatian Forest LTD. have been holders of the FSC certification for forest management since 2002. With the adoption of the National Forestry Strategy and Policy (2003), adoption of the Forest Act (2005, 2006, 2008 and 2018) and the Act on Forest Reproductive Material (2009), as well as bylaws, the strategies, guidelines and recommendations for the use of forest genetic resources have been introduced.

The role of forest seed objects is the production of highest quality FRM (seed material, plant parts and propagation material).

Seed stands are managed in a manner to meet the criteria for obtaining quality FRM. Forest seed objects in the “source identified” category are regularly managed, while seed facilities in the “selected” category are excluded from regular management and special management programmes are developed therefor, which prescribe genetic amelioration measures for improvement of the structure of forest seed objects in order to obtain a larger number of seed trees and genetically superior specimens. The improvement of the structure of the forest seed object is obtained by selective thinning, which is inspected and approved before felling by the Croatian Forest Research Institute as the Official body. CFRI also inspects and approves sanitary marking that is performed as a result of specimen desiccation and adverse weather conditions (wind, snow, ice ...).

In clone seed orchards, established from selected plus trees, the objective is to produce frequent and abundant yields of genetically superior seed. Clone seed orchards are an example of *ex situ* conservation of the gene pool and when they are established, care is taken to ensure that they are isolated from external impacts (e.g. planting a buffer zone around the CSO to avoid and reduce pollination by trees from the surrounding stands).

FRM production in the Republic of Croatia is generally satisfactory. The quantities of FRM collected by generally refer to quantities sufficient for national needs. It so happens that in today's conditions of disturbed ecological balance the forest species do not tolerate changes in habitat conditions that occur due to unfavourable biotic and abiotic factors, and thus the ability to bear fruit and the periodicity of yields are disturbed. In that case, if they fail to meet their own needs, it is possible to relocate FRM within the Republic of Croatia and the EU or import it from third countries. FRM must be used in accordance with the Ordinance on provenances of forest tree species.

In the forests of the Republic of Croatia managed by Croatian Forest LTD., movement to the EU or export to third countries of forest tree species FRM of commercial significance is not performed (oak, beech, fir, spruce, etc.), and neither the movement of rare forest species (linden, walnut, Douglas fir, larch, etc.). In practice, imports are not common (it is mainly related to nursery production), but if it is necessary (e.g. due to the absence of seed yield), it is used in forestry only if it is established that unique ecological relations which take into account the altitude and phenotypic and genotypic features of the provenance from which the FRM originates, correspond to unique ecological relations which take into account the altitude and phenotypic and genotypic features of the provenance in which the FRM is intended to be used. The Official body approves the provenance in which this material may be used. Furthermore, scientific research institutions are allowed to import or relocate limited quantities of FRM intended for research, scientific work and conservation of genetic resources.

FRM in the Republic of Croatia is used in a way to meet the needs of biological forest restoration and sustainable forest management. According to the Act on FRM, CFRI is designated as the Official Body that performs activities and is responsible for performing the tasks of production control, placing on the market and quality of FRM, and is under the supervision of the Ministry of Agriculture.

In order to conserve the forest genetic resources, it is necessary to protect and conserve the existing genetic variability, its adaptation to the processes of natural evolution, and to improve the knowledge and identification of specimens resistant to certain diseases and pests. Research should be complemented by data covering the inventory, legislation, practical application, and coordination at the national and European level.

The diversity of geographical regions in the Republic of Croatia has created various ecological conditions, and thus diverse communities, which are directly affected by climate change, various anthropogenic impacts and habitat degradation. The need to preserve genetic diversity is related to commercially significant species (oak, beech, fir, spruce). Furthermore, one of the priorities are the rare and especially endangered forest species (narrow-leafed ash, field elm, black poplar, etc.). Along with the aforementioned, scientific research is needed that would lead to better and more accurate insights into the genetic diversity of forest species.

Chapter 9. The state of genetic improvement and breeding programmes

Breeding programmes for pedunculate oak (*Quercus robur* L.), wild cherry (*Prunus avium* L.), narrow-leafed ash (*Fraxinus angustifolia* Vahl.) and sessile oak (*Quercus petraea* (Matt.) Liebl.) were initiated in the 1990s with the aim of production of genetically high-quality forest reproductive material (FRM) of these species in the category “qualified”. This programme was established and is being implemented in cooperation between three institutions: Croatian Forest LTD. d.o.o., the Croatian Forest Research Institute (CFRI) and the University of Zagreb, Faculty of Forestry.

Selection of plus trees was carried out with respect to the usual growth and form traits (height, diameter at breast height, stem straightness, taper, forking, etc). Their cloning was carried out using the method of grafting and the establishment of clone seed orchards (CSOs). 3 CSOs of pedunculate oak, 2 CSOs of narrow-leafed ash and one CSO of sessile oak and wild cherry were established. Studies on clones in CSOs of pedunculate oak, narrow-leafed ash and wild cherry were conducted, which established a high level of their phenotypic and genetic diversity, as well as the absence of genetic structure (difference between CSOs of the same species). However, the aforementioned studies also indicated a potentially small effective size of populations in pedunculate oak CSOs due to phenological asynchronization of clones. In CSOs of narrow-leafed ash, the issue of gender imbalance as well as variability of gender structure was observed. Recently, narrow-leafed ash CSOs have been affected by an epidemic of the fungus *Hymenoscyphus fraxineus* (T. Kowalski) Baral, Queloz, Hosoya, which showed that the selected clones were mostly susceptible to pathogens, although a small number of clones showed resistance. Today, significant amounts of FRM are already being produced in 8 CSOs on a total surface area of 77.74 ha. This FRM is used in the assisted reforestation. However, the annual needs of Croatian forestry still far exceed the production in CSOs, so the share of the FRM in the “qualified” category is low. Tests of progeny from pedunculate oak and narrow-leafed ash CSOs have been established, and genetic testing of plus trees is ongoing. With the cooperation of individuals from CFRI and University of Zagreb, Faculty of Forestry, the beginning of breeding of Norway spruce (*Picea abies* Karst.) and silver fir (*Abies alba* Mill.) as Christmas trees has been initiated. Plus trees were selected with regard to the phenotypic properties of ornamental value (e.g. crown density, arrangement of needles on the shoot, etc.). Initial research on the possibility of cloning plus trees for their mass propagation was conducted.

The main disadvantage of all breeding programmes initiated is the absence of an organizational structure that would effectively respond to the existing challenges, form strategic objectives and manage them in the long term. For now, all breeding activities are carried out by poorly coordinated individuals without significant systematic support. This issue is present from the level of maintenance of CSOs, through the level of targeted use of the produced FRM, to the level of research. Currently, the most important priority is the selection of specimens resistant to pathogenic fungus and their introduction into the breeding programme of narrow-leafed ash.

Chapter 10. Management of forest genetic resources

Conservation of genetic diversity of forest tree species in Croatia mostly relies on maintaining sustainable forest management and conserving the structure of natural forest stands, currently making around 95 % of the total woodland area. Croatia is geographically very diverse and therefore its forests formed various ecological types sensitive to habitat degradation, air and water pollution, excessive use of certain more valuable species of forest trees, as well as other anthropogenic effects, increasing impact of global climate changes. The majority of forests are state owned and managed by Croatian Forests LTD., which were previously financing research conducted by Faculty of Forestry, University of Zagreb and Croatian Forestry Research Institute, within the Research Work Programme on Management and Conservation of forest genetic resources. The genetic conservation of forest tree species was further initiated by the EUFORGEN programme, which started in 1994.

In principle, conservation of genetic diversity is incorporated in management of major broadleaves species (*Quercus robur*, *Quercus petraea*, *Fagus sylvatica*) and, for example, the preliminary delineation of seed units that was based on ecological parameters has been adjusted according to the more recent research and recommendations. However, some current issues considering certain species, like *Fraxinus angustifolia*, are not being properly addressed in practice, from the point of conservation of important genetic diversity. In sanitation of stands affected by popularly called *Chalara* and other problematic issues, resistant genotypes are not being conserved for *ex situ* collections and further research, which is strongly suggested. Such practises are limited to the scope of scientific research and in this way important diversity could be lost. The scientists from the Faculty of Forestry and Croatian Forestry Research Institute regularly communicate the recommendations based on research to the Croatian Forests LTD. managers and relevant authorities. The Genetic diversity of economically most significant species (like *Quercus robur* and *Fraxinus angustifolia*) has been investigated in several studies, using various molecular markers and analysis of quantitative traits. The state of diversity was satisfactory in continuous populations and complexes and narrowed in isolated and fragmented populations, as expected. Since the beginning of 2000s, there have been important efforts in establishing clonal seed orchards of important species, as well as clonal archives of endangered species such as *Ulmus minor*, which are also managed by Croatian Forests, but due to the lack of allocated funds and workforce, their management, and consequently their usability is not optimal. Considering the species with less economic importance, conservation of the noble broadleaves should encompass a larger number of species from various genera (*Fraxinus*, *Alnus*, *Ulmus*, *Prunus*, *Juglans*, *Castanea*, *Sorbus*, *Acer*, *Malus*, *Pyrus*, *Tilia*). These are partially endangered because of their exposure to different diseases and pests and their presence in natural stands is very important for forest ecosystems stability and biodiversity. Changes in hydrological conditions of main rivers have brought about difficulties in regeneration of the riparian forests, and decreased genetic variability of European black and white poplar (*Populus nigra*, *P. alba*) in their habitats. In Croatia's coastal areas, there is a need for conservation of genetic resources of Dalmatian black pine (*P. nigra ssp. dalmatica*) and Mediterranean oaks. As previously mentioned, there are many challenges that almost all species are facing because of climate extremes and pests. Funds available for quality research of genetic and genomic diversity of forest tree species and ecosystems in the context of climate change and subsequently good communication and understanding between science and practice is crucial for overcoming these difficulties and ensuring appropriate management of forest genetic resources.

Chapter 11. Institutional framework for the conservation, use and development of forest genetic resources

Forest genetic resources management in Croatia involves few institutions: Ministry of Agriculture, Croatian Forests LTD., which are managing state owned forests in Croatia, Faculty of Forestry of University of Zagreb and Croatian Forestry Research Institute. Other Agencies and Ministries, like the Ministry of Environment are also partially involved. The Croatian Forest Research Institute is the official body for supervision of management and trade of forest reproductive material. They are also in charge of the seed bank, control of seed stands and seed quality. The Faculty of Forestry is conducting expert supervision of the implementation of Forest Seed Objects management programs in the category "qualified" (clonal seed orchards) with the aim of producing qualified forest reproductive material and providing professional supervision services in the production of forest reproductive material in the category "tested" under the Act on Forest Reproductive Material. The main documents relevant for Management of FGR are the Forest Act, the Act on Forest Reproductive Material and the Ordinance on provenances of forest tree species, but there are numerous other laws and bylaws that are indirectly connected to the FGR. These include, for example, the national Climate change adaptation strategy, the Nature Protection Act, the Environment Protection Act, the Regulation on Strictly Protected Species, the Regulation on the Collection of Wild Plants, and the Regulation on the Ecological Network. The number of projects investigating genetic, genomic and epigenetic diversity of forest tree species is rising and should be encouraged, since the knowledge of the state of FGR is crucial prerequisite for efficient FGR programmes. The research is mainly conducted at the Faculty of Forestry and Croatian Forest Research Institute, but in cooperation with many other institution, both in Croatia and abroad. It is very important to establish and maintain scientific cooperation and networking with relevant institutions and keep track with the new methodology and state of the art research. We also need to make maximal use of EU funding for research projects. In the last few years there have been several projects dealing with genetic diversity and its connection to the effects of climate change (especially drought), with the final goal of providing recommendations for use and transfer of FGR in order to ensure adaptability of forest trees species to changing environment. The importance of genetic diversity and adaptability is still understated and not recognized enough in the forestry circles. It is crucial to strengthen communication between science and practice in Croatian forestry and also to coordinate activities between all the institutions dealing with FGR management in the common strategy.

Chapter 12. International and regional cooperation on forest genetic resources

The Republic of Croatia has been an active member of the EUFORGEN (European Forest Genetic Resources Programme) since 1994. As part of this programme, we participated in the EUFGIS Project (Establishment of a European Information System on Forest Genetic Resources). Furthermore, the Republic of Croatia is a member of the OECD scheme for the certification of forest reproductive material moving in international trade, and CFRI is the Designated Authority.

In addition, representatives of the Croatian Forest Research Institute (CFRI) and the University of Zagreb, Faculty of Forestry have collaborated with colleagues from various foreign institutions in joint research projects, of which we can single out the following:

2013-2014: Bilateral Project, Croatia - Germany (MSES-DAAD) - Identification of drought-tolerant beech provenances (*Fagus sylvatica* L.) by using molecular and physiological markers; CFRI and Albert-Ludwig University of Freiburg, Institute of Forest Botany and Tree Physiology, Department of Tree Physiology and the Forest Research Institute Baden-Wuerttemberg (FVA), Freiburg, Germany.

2018-2021: REFOCuS - Resilient riparian forests as ecological corridors in the Mura-Drava-Danube Biosphere Reserve; INTERREG Danube Transnational Program; CFRI Partner, principal investigator Forestry Institute of Ljubljana, as well as Austria, Hungary and Serbia as partners.

LIFE SySTEMIC – Close-to-nature forest sustainable management practices under climate changes. It is a project in which CFRI participates as a project partner, while the remaining partners (as well as project coordinators) are from Slovenia and Italy. LIFE18 ENV/IT/000124.

2014-2018: CSF - Conservation of genetic resources of forest trees in light of climate changes; (German colleagues as project partners: Albert-Ludwig University of Freiburg, Institute of Forest Botany and Tree Physiology, Department of Tree Physiology, and the Forest Research Institute Baden-Wuerttemberg (FVA), Freiburg, Germany).

In recent years, successful cooperation has been established between CFRI and related German institutions, which has resulted in numerous trainings of our junior researchers, as well as exchange of experience and good practices. Some of the most important institutions for this type of cooperation are: Albert-Ludwig University of Freiburg, Institute of Forest Sciences, Department of Tree Physiology; Laboratory for Molecular Genetics, Forest Research Institute Baden-Württemberg, Freiburg; University of Göttingen Faculty of Forest Sciences and Forest Ecology, and Thünen Institute of Forest Genetics. Regional cooperation between related institutions dealing with forest genetic resources has been ongoing since 2016 within the regular conferences with informal name “inter-departmental SEEFORGEN (South-East European Forest Genetics) conference”. This informal organization consists of researchers employed at the departments of forest research institutes and faculties of forestry from the region of Southeast Europe, who deal with forest genetic resources. These conferences are held every 2 years, but the researchers involved meet more often through expert visits, working meetings, workshops, etc.

Chapter 13. Recommended actions for the future

Availability of information on forest genetic resources

The availability of information on forest genetic resources in the Republic of Croatia should be improved. Information is presented within the forestry profession, in professional and scientific journals or at scientific conferences, and not easily accessible to general public.

Today, only data related to marketing or trade in forest reproductive material can be found on the website of Ministry of Agriculture (National list of forest seed objects and the Register of suppliers of forest reproductive material).

In order to better understand and improve information, it would be necessary to explain to the general public what the term 'forest genetic resources' means and why their conservation is important, especially today when forest ecosystems are exposed to great negative pressures of abiotic and biotic factors. In addition, it would be necessary to establish a stronger link with the determinants prescribed by the Nature Protection Act. Pursuant to this Act, 9 different categories of protected areas in the area of 8.61 % of the total area of the Republic of Croatia have been excluded from regular management in order to preserve natural ecosystems. Furthermore, the Natura 2000 ecological network has been declared, covering 36.67 % of the terrestrial territory and 16.26 % of the coastal sea of the Republic of Croatia.

The main goal of the protection of forest genetic resources is to improve the conservation and use of genetic diversity of plant resources for present and future generations. Therefore, it is necessary to develop a national strategy for the conservation of forest genetic resources of our economically important, rare and endangered species of forest trees, and provide funds for the implementation of the strategy to increase the number of species and areas for conservation, and to explore new methods for their conservation.

It is recommended that information on the state of forest genetic resources and the national strategy for the conservation of forest genetic resources be available on the website of the relevant ministry, that funding for the implementation of measures from the national strategy for the conservation of forest genetic resources be provided and implemented through the Official body for forest reproductive material.

Conservation of forest genetic resources

Forest genetic resources in Croatia should be managed in a way that conserves their potential for adaptation to changing environmental conditions, especially considering the effects of climate change and climate extremes that forests are increasingly subjected to. That implies the maximal conservation of genetic diversity of forest tree species and also biodiversity of forest ecosystems in order to preserve their stability, as prescribed in the Forest Act. This should include, besides the natural regeneration in forest stands, the use of most appropriate and adapted forest reproductive material for certain existing, but also anticipated environmental conditions. The transfer of forest reproductive material should therefore, whenever possible, take into consideration the results of scientific research (experimental trials), pointing to genotypes and/or provenances that have proven their quality for certain conditions in the experimental trials. Certain rules and recommendations should be reconsidered, according to the available research. For concrete example, the *Quercus robur* stands in Motovunska šuma that belong to the submediterranean seed area are by the current Ordinance on provenances of forest tree species

(NN 147/11, 96/12, 115/14 and 114/15) treated as a separate seed area in which only local FRM is used for regeneration. It is true that these stands are genetically (by some markers) differentiated from the main complex of *Quercus robur* in Croatia (Morić 2016). But the research also showed that their genetic diversity is narrowed, due to their isolation, which hinders their adaptive potential in the face of climate change. In this particular case, the transfer of FRM from other areas should be considered to increase the genetic diversity of these stands. Sustainable forest management is often highlighted in Croatia as a main tool for conservation and stability of forest genetic resources, but in some cases this is not sufficient to conserve valuable genotypes. Since almost all main forest tree species in Croatia and the big part of Europe face certain difficulties in the form of pests or diseases, it is necessary to make efforts to identify and preserve resistant genotypes in the form of Ex situ collections (for example reproductive material of *Fraxinus angustifolia* individuals that are in good shape in affected stands). Specific stands and species like *Pinus nigra* var. *dalmatica* should also be conserved both In situ and Ex situ. Efforts should also be put in conservation of scattered species (like for example forest fruit trees *Prunus* sp., *Sorbus* sp.) in forest ecosystems and overall biodiversity of species, to ensure the ecosystem stability.

Use, development and management of forest genetic resources

The forest tree gene bank is one of the most important factors in the conservation of forest genetic resources. In the following period, the Croatian Forestry Research Institute will review the existing FSO registered in the Forest Species Gene Bank and select new high-quality FSO for registration in the Forest Species Gene Bank.

In the bank of genes of forest traits, it is necessary to improve FSO with an emphasis on economic species of trees, while satisfying the correct distribution within all proven forest traits. If the current number of SCOs does not meet the quality and number of the schedule by provenances, the Official body will review potential FSO and make recommendations to forest owners for entry of FSO in the FSO Register.

Also, in the future it is necessary to more intensively collect FRM in facilities registered in the Bank of forest species genes and create larger seed stocks in the Seed savings bank, also paying attention to the distribution of seeds by provenance and with emphasis on forest species, although rare forest species should not be neglected.

Policies, institutions and capacity building

The fundamental paradigm of Croatian forestry is sustainable forest management which incorporates preserving forest biodiversity as one of its main objectives. This paradigm is strongly supported by existing legislation (Forest Act, Ordinance on Provenances of Forest Tree Species, Nature Protection Act). Several institutions deal with FGR conservation efforts (Ministry of Agriculture, Croatian Forests LTD., Croatian Forest Research Institute and Faculty of Forestry Zagreb). These institutions are well equipped, both in human resources and equipment to fulfill major demands in FGR conservation. Major weaknesses, as identified by the authors of this report are: institutions involved in FGR conservation cooperate well but there are possibilities for further improvements, especially in coordination of their activities and resources. Unfortunately, public is not well informed (sometimes even misinformed) about FGR conservation efforts conducted by above mentioned institutions. Also, forestry practice is often not complied with FGR conservation theory though some traditional practices are useful (e.g. natural regeneration). There is a need for stronger implementation of genetic conservation theory into the forestry practice and for supporting that modified practice in long term.

Financial support by government is not sufficient while private sector is not stimulated to voluntary support FGR conservation efforts.

A permanent official body (e.g. commission for FGR within the Ministry of Agriculture) would help in correcting above mentioned weaknesses. Although there is a working group within the commission for FRM which may serve this purpose, it should be refreshed and more proactive. Thus, proactive commission for FGR (consisting representatives of all stake holders) would set up common strategic objectives, would serve as a bridge between scientists and forestry practitioners and forest owners thus improving coordination among various stake holders, increasing public awareness (i.e. visibility) for FGR conservation efforts and needs etc.

14. List of references used in text

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