THE SECOND REPORT ON THE STATE OF THE WORLD'S FOREST GENETIC RESOURCES

COUNTRY REPORT

UKRAINE

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.

2nd COUNTRY PROGRESS REPORT

UKRAINE

Monitoring the implementation of the *Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources*

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PREFACE

Forest genetic resources play an important role in the functioning of state forest management, they are a necessary component close to natural forestry. Conservation and use of genetic diversity of forest trees in Ukraine is carried out on forestry and ecological principles, taking into account the typological diversity of forests. The Second Report on the State of Forest Genetic Resources of Ukraine was prepared at the request of FAO and highlights the role of forest genetic resources in the functioning of state forestry, their state and approaches to conservation. Current data on the number and area of existing forest genetic resources conservation units, seed harvesting, planting material, current tree improvement programs are presented. Problems and prospects of activity on forest genetic resources conservation in the country are outlined.

The Report covers mainly the period of the last decade. Presented and analyzed current data on the number and area of forest genetic resources conservation units, seed harvesting, cultivation of planting material, tree improvement programs. Problems and prospects of activity on of the forest genetic resources conservation in the country are outlined. The Report prepared by employees of the State Forest Resources Agency of Ukraine, State organization “Ukrainian Forest Plant-Breeding Centre”, Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky, Ukrainian Research Institute of Mountain Forestry named after P. S. Pasternak, their research units and other institutions involved in the forest genetic resources conservation.

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ABBREVIATIONS AND ACRONYMS

CBGAU	Council of Botanical Gardens and Arboreta of Ukraine
CSO	Clonal seed orchard
DSTU	National standard (State standard of Ukraine)
FASU	Forestry Academy of Sciences of Ukraine
FSC	Forest Stewardship Council
GDP	Gross domestic product
ICBGI	Institute of Cell Biology and Genetic Engineering
IUCN	International Union for Conservation of Nature.
NAS	National Academy of Sciences
NULES	National University of Life and Environmental Sciences of Ukraine
PFSB	Permanent Foresr Seed Base
PCR	Polymerase chain reaction
SFRAU	State Forest Resources Agency of Ukraine
SSFPE	State specialized forest protection enterprise
UFPBS	State organization “Ukrainian Forest Plant-Breeding Centre”
UNFU	Ukrainian National Forestry University
UN ECE	United Nations Economic Commission for Europe
URIFFM	Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky
URIMF	Ukrainian Research Institute of Mountain Forestry named after P. S. Pasternak

EXECUTIVE SUMMARY

The total area of lands designated to forestry purpose in Ukraine is 10.4 million hectares, including 9.6 million hectares covered with forest vegetation. The forest cover of the country is 15.9%. Forests can be in state, communal and private ownership. According to the departmental subordination, the largest area of forest lands (about 73%) is used by state forestry enterprises which are coordinated by the State Forest Resources Agency of Ukraine (SFRAU). The share of forestry in the structure of Ukraine's GDP ranges from 0.26 % to 0.37 %.

In the last decade, the health condition of forests has severely deteriorated due to the negative effects of a complex of factors, mainly related to global climate change, which has led to an increase of dieback forests area and mass damage by pests and diseases. In 2019, the total area of dieback forests was 270 thousand hectares.

The dendroflora of Ukraine's forests includes 402 species of trees and shrubs. Among them, we can conditionally distinguish a group of the most common forest-forming species, which have industrial or agroforestry significance and are considered forest genetic resources. This group includes 58 species, of which 34 species are aboriginal and 24 are non-native. The Red Book of Ukraine [1] includes 50 species of trees and shrubs, including 11 species from the European Red List and 5 species from the IUCN list. Among forest trees, 16 species have a special status.

Thanks to the implementation of a number of sectorial programs coordinated by SFRAU in the last decade, the selection and certification of new plus trees and the creation of other forest genetic resources conservation units have been carried out. Currently, there are 702 gene reserves (23917.7 ha), 132 plus stands (2094.6 ha), and 1938 seed stands (15714 ha). In Ukraine, there are 48 plots of provenance tests of 16 species, covering an area of 24.4 hectares, as well as 116 plots of progeny test of 6 forest species, covering an area of 165 hectares. Clones of plus trees are conserved in 23 clonal archives with an area of 52.6 hectares.

In 2019, reforestation was carried out on an area of 42.0 thousand hectares, and afforestation – 2.2 thousand hectares. For this purpose, planting material obtained from seeds harvested at the storage in gene pool conservation units in the total amount of 234,122 kg, which is 37.5% of the total harvested seeds.

The main approaches used in forest tree improvement in Ukraine are the best individuals and populations selection in natural and artificial stands and their progeny testing. Work in ecotypes study in provenance tests, interspecific and intraspecific hybridization and testing of hybrids of I–III generations were carried out. Selection and assessment of improved material is carried out primarily on the basis of growth intensity (height, diameter, average annual growth by height and diameter), condition, straightness and fullness of the trunk. Reproduction intensity, resin productivity, biochemical, cytological, anatomical and morphological characteristics are used as additional features.

In Ukraine, a number of legal documents have been developed which regulate the implementation of measures for the forest genetic resources conservation. The most important of them are: The concept of conservation and sustainable use of forest genetic resources in Ukraine (The concept, 2011), Regulations on the allocation, conservation and sustainable use of the genetic fund of forest tree species in Ukraine (Regulations, 1982), Guidelines on forest seed production (Guidelines, 1993).

The main research institutions of the forest branch are the Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky (URIFFM) and Ukrainian Research Institute of Mountain Forestry named after P. S. Pasternak (URIMF). The Steppe (Kherson) and Polissia (Zhytomyr) branches, 6 research stations (Vinnytsia, Kyiv, Luhansk, Mariupol, Novhorod-Siversky, Kharkiv) and the Krasnotrostianets branch are subordinated to URIFFM.

Ukraine takes part in international activities on forest policy. The duties of a member of the joint office of the FAO European Forestry Commission and the UNECE Forest and Forestry Committee are being performed on an ongoing basis. Ukraine is not an associate member of EUFORGEN, but it participates in the European network, regularly providing information on the status of gene pool conservation units.

The following tasks in the field of conservation of forest genetic resources remain the most relevant and priority:

• monitoring and systematic inventory of the state of genetic conservation units, creation and maintenance of the electronic database;

• selection and creation of new genetic conservation units in accordance with differentiated strategies for conserving the genetic variability of certain forest species, including rare and shrub species;

• more rational use of genetic conservation units for tree improvement and seed production purposes;

• wider introduction of genetic variability of forest tree species research by modern methods;

• strengthening information activities in society on the importance and need for forest genetic resources conservation.

PART 1: THE CONTRIBUTION OF FOREST GENETIC RESOURCES TO SUSTAINABLE DEVELOPMENT

Chapter 1. Value and importance of forest genetic resources

The total area of forest lands designated to forestry purpose in Ukraine is 10.4 million hectares, including 9.6 million hectares covered by forest. The forest cover of the country is 15.9%. Due to the diversity of natural conditions, forests are distributed unevenly throughout the country. Forest cover in different natural areas has significant differences and does not reach the optimal level at which land resources are used most efficiently, an ecologically stable environment is formed and the whole complex of useful properties of the forest is most fully revealed. Forest stands are concentrated mainly in Polissia and in the Ukrainian Carpathians (Fig. 1) (Forestry, 2019; Public report, 2019).

Fig. 1. Forest cover of Ukraine in terms of regions

Forests of Ukraine are divided into four categories according to ecological and socio-economic significance and depending on the main functions they perform (Forest Code, 1994; About approval of the Procedure for division, 2007):

1) protective forests (perform mainly water protection, soil protection and other protective functions);

2) recreational and health forests (perform mainly recreational, sanitary, hygienic and health functions);

3) forests for environmental, scientific, historical and cultural purposes (perform special environmental, aesthetic, scientific functions, etc.);

4) commercial forests.

The distribution of forest areas by categories is given in Fig. 2.

According to the Land and Forest Codes (Land Code,2002; Forest Code, 1994), the forests of Ukraine may be in state, municipal and private ownership. All forests on the territory of Ukraine, regardless of the categories of lands on which they grow according to the main purpose, and regardless of the rights of ownership over them, constitute the forest fund of Ukraine and are under state protection.

The vast majority of forests are state-owned. In Ukraine, the situation is historically formed with the consolidation of state forests for numerous permanent forest users (for management, forests are given to permanent use to enterprises, institutions and organizations of several dozen ministries and

departments). According to the departmental subordination, the largest area of forest lands (about 73%) is used by forestry enterprises which are coordinated by the SFRAU (Fig. 3) (Public report, 2019).

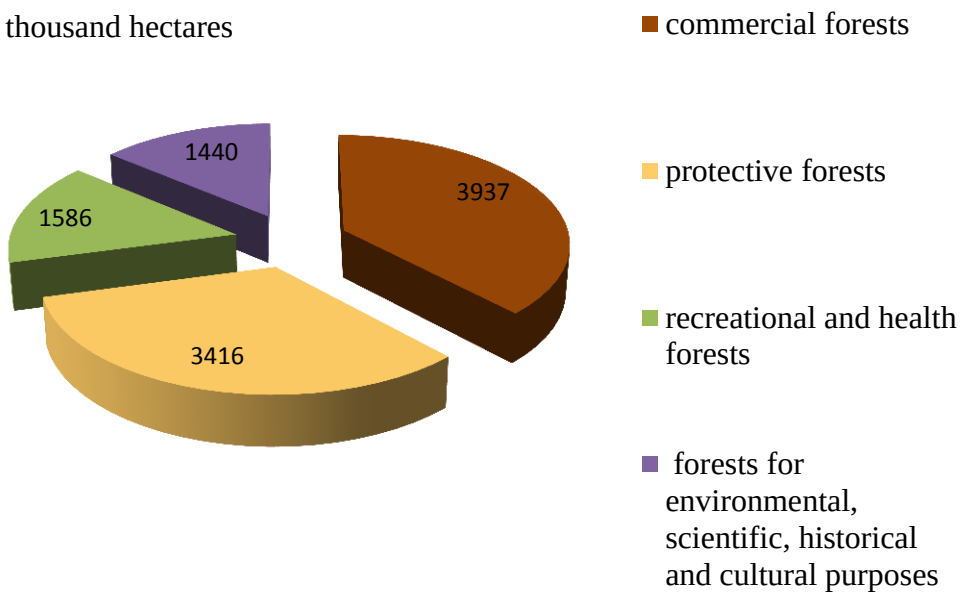

Fig.2. Distribution of the total areas of the forest fund of Ukraine by categories depending on the main performed functions, thousand hectares

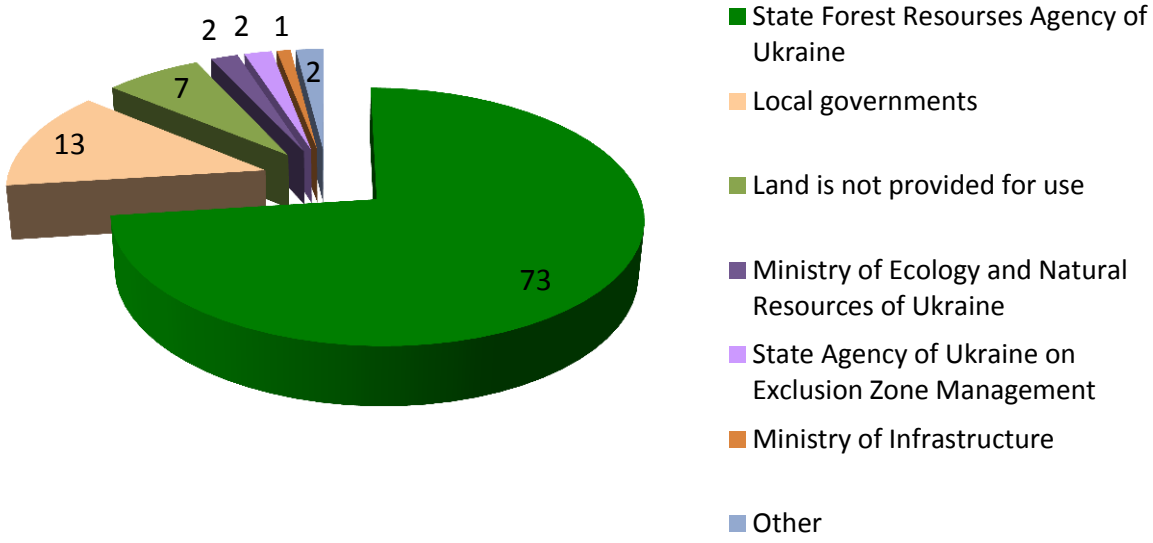

Fig.3. Distribution of the total forest fund area of Ukraine by departmental subordination as of 01.01.2020, %

In the process of delimitation of lands, about 1.3 million hectares (13%) of forest land plots are in communal ownership, which are in the permanent use of communal enterprises subordinated to local government. The share of private forests is less than 0.1% of the total forest land area. About 800,000 hectares of state-owned forest lands have not been provided for use and have been allocated to reserve lands. 2% of the forest area belongs to the Ministry of Ecology and Natural Resources of Ukraine and the State Agency of Ukraine on Exclusion Zone Management. In the latter case, it is a prohibited area for free access, which has been heavily contaminated with long-lived radionuclides as a result of the Chernobyl

accident. The zone was established in 1986, after the evacuation of the population from the 30-kilometer zone around the station

A set of institutional, organizational and managerial principles for the balanced development of forestry, which are simultaneously aimed to natural resources using, quality of human life improving and environment preserving is being formed in Ukraine.

Forest resources are the basis of the economic component of forestry, and the volume of their usage is set in such a way that it ensures the continuity of forest ecological and economic functions (environmental, protective, sanitary, health, resource ones). In terms of forest area and timber reserves, Ukraine is a forest-deficient country.

According to the Classification of Economic Activities (Classification, 2010) Forestry in Ukraine involves 4 groups: forestry and other activities in forestry (group 02.1), logging (02.2), harvesting of wild non-timber products (02.3) and provision of ancillary services in forestry (02.4). Forest enterprises also provide services in a number of other important industries, namely hunting, primary wood processing, food industry and some others. Thus, forestry is an important component of Ukraine's economy, because in addition to meeting the state needs for raw materials for many industries, it is also the basis for economic activity, which involves job creation and production, and hence the formation of gross domestic product (GDP) (Kichko, 2016). The share of forestry in the structure of Ukraine's GDP is insignificant and ranges from 0.26% to 0.37%. [Зелена книга «Регулювання].

However, regular forest users pay more than 3 billion annually in taxes and fees to the State Budget, and wood is one of the basic resources to form a number of subsectors of the economy and is widely used in industrial production, construction, agriculture, transport and chemical industry. Exports of wood and wood products bring in foreign exchange earnings of more than $ 1 billion a year (Green Book "Regulation, 2017).

During recent years, the forests of Ukraine have seen an increase in the special use of non-wood forest resources, in particular, the harvesting of secondary forest materials and forest by-products (harvesting wild fruits, mushrooms, berries, medicinal plants). In 2018, the State Forest Agency harvested: 20 tons of bark; 9 tons of nuts; 552 tons of mushrooms; 3,867 tons of berries; 43 tons of medicinal plants; 594 tons of wood sap (Fig.4).

Among the threats there are absence of adaptation strategy to climate change and systematic decisions aiming to mitigate its consequences, absence of reliable information about forests, necessity to update strict legislation, as well as non-compliance with afforestation programs due to insufficient funding of activities and motivation of forest users, reduction of state support for forest science and education (Green Book "Regulation, 2017).

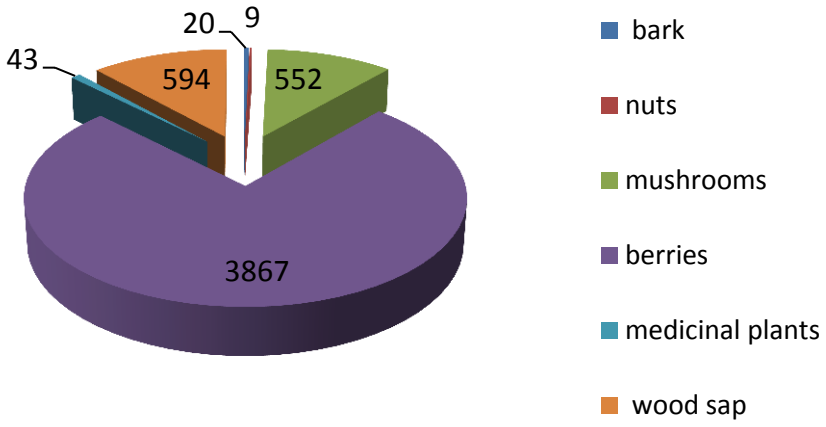

Fig.4. Harvesting of non-wood resources in the forests of Ukraine, tons

Among the priority needs are:

• Improving transparency on forest related information;

- Elaborating transparent timber trade rules (Law of Ukraine);
- Introduction of National Forest Inventory ;
- Improving financial support for SFM in south and eastern part of Ukraine and other forest related work of national significance as well as work on decreasing tax pressure;
- Increasing forest cover and strengthening work on forest landscape restoration;
- Paying more attention to research and activities on the conservation of forest genetic resources.

Awareness-raising activities on the forest genetic resources importance are carried out by SFRAU, forestry enterprises, research and educational forest institutions. Relevant information is covered on (Available at:s, in popular and scientific publications. At that, there is a lack of awareness among a large part of the society concerning the necessity of sustainble forest management, including forest landscape restoration and forest genetic resources conservation.

PART 2: STATE OF DIVERSITY IN FORESTS AND WOODLANDS

Chapter 2. State of forests

In the last decade, the forests health condition has severely deteriorated due to the negative effects of a complex of factors, which has led to an increase in the dieback forests area and mass damage by pests and diseases. The main influencing factors are global climate change that caused a rapid pests and diseases outbreakes.

Recently there has been a massive spruce dieback, ash, oak, hornbeam and birch stands throughout Ukraine, but especcialy of pine stands, where damage caused by stem pests, mainly bark beetles, has reached catastrophic proportions. The dynamics of forest dieback in Ukraine is presented in Fig.5. In 2018, the total area of forest dieback was over 413 thousand hectares, including 222 thousand hectares of Scots pine, 27 thousand hectares of European spruce, 100 thousand hectares of English oak and 64 thousand hectares of other stands. Thus, the massive damage of pine forests by stem pests, in particular apical and six-toothed bark beetles, continues to spread throughout the country (Bondar, 2019). In 2019, the total area of forests dieback by SFRAU data was 270 thousand hectares, which indicates a decline in outbreaks of bark beetle due to timely conducted measures to improve the forests health condition of (sanitary felling). The area of damaged forest stands by windbreaks amounted to 19.9 thousand hectares with a total weight of 670 thousand cubic meters. Measures to improve the forests health condition were carried out on an area of more than 217 thousand hectares, weighing almost 7.9 million cubic meters, which is 74% by area and 81% by weight respectively (Public report, 2019).

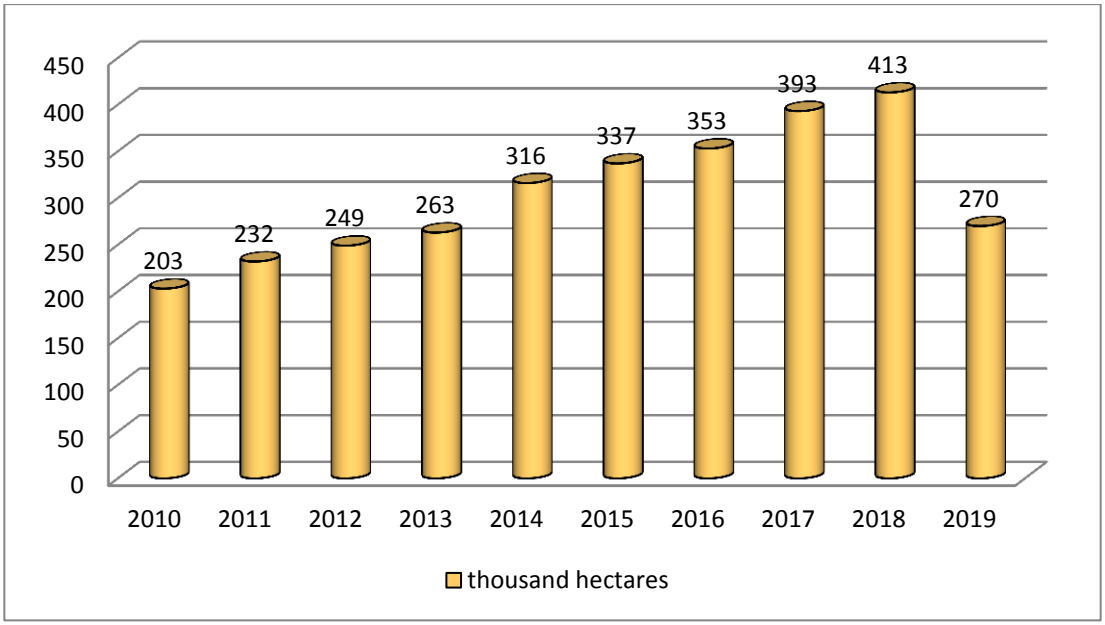

Fig. 5 Dynamics of forest dieback in Ukraine

Forest protection works are carried out by a specialized forest protection service, which is organized on the basis of 7 state specialized forest protection enterprises. The priority of the forest protection service is permanent forest pathological monitoring of stands, development and implementation of biological means of forest pest control. Such means do not have toxic influence on the people and environment and are applied in sanitary-protective stands and green plantings of Ukraine as well as in forests where the use of chemical pesticides is prohibited. The state specialized forest protection enterprise "Kharkiv Forest Protection" is actively engaged in this direction. In the laboratory of DSLP "Kharkiv Forest Protection" studies on artificial cultivation of an anteater (*Thanasimus formicarius*) against stem pests have been carried out. In 2019, biological material was produced on an area of 105 hectares (Public report, 2019).

In 2019, according to the observation results of SSFPE “Kharkiv Forest Protection” and the Laboratory of Forest Protection of URIFFM, a dangerous quarantine species, namely Emerald ash borer (*Agrilus planipennis*) was found in Luhansk region. It is an aggressive trunk pest which invades Pennsylvania ash trees (*Fraxinus pennsylvanica*) without visible signs of their weakening, which in turn accelerates disappearance of the trees.

According to the State Consumer Service, the quarantine regime is currently in force in four districts of Luhansk region, and trees inhabited by a quarantine pest are being cut down and burned. Against the background of mass destruction of ash stands in Ukraine by invasive disease – halar necrosis of ash and given the overregulated requirements of the Sanitary Rules in the forests of Ukraine, all this can lead to the rapid spread of this pest and loss of ash stands in Ukraine (Public report, 2019) and many species of animals and plants and microorganisms that have close constitutive links with ash.

Forest fires have a negative impact upon the forests health, in particular on forest genetic resources and their conservation. The main causes of fires (85%) are human factors. A network of 507 fire watchtowers has been set up in the SFRAU forests, of which 337 are equipped with television surveillance systems. In order to prevent forest fires and minimize their consequences, enterprises arrange in the forests fire breaks, barriers and mineralized strips. Forest enterprises systematically carry out preventive and explanatory work with the population regarding compliance with the fire safety requirements in forests (Forestry of Ukraine, 2019).

Due to the increase in xerophytization of the climate, there are negative trends in reducing a reproductive capacity and deterioration of condition of native species natural regeneration. Unsatisfactory reproductive processes are observed mainly in deciduous trees, in particular, oak. Among the local species of the Right Bank, forest beech and white fir are the most successfully restored. Deterioration of stands is mainly characteristic of local coniferous species, in particular, European spruce and Scots pine. Among deciduous species, the Common ash is distinguished by intensive dieback. Most of the non-native species are in good condition (Douglas fir, Red oak, Locust) (Neyko, 2019).

Genetic resources, especially *in situ*, are at risk of destruction by fire or illegal logging, disease, and pest damage. The deterioration of aboriginal species populations due to climate change, reduced reproductive capacity and the ability to regenerate naturally is a matter of concern and requires constructive solutions on moving the most valuable *in situ* gene pool consevation units to *ex situ* conditions.

Agroforestry stands include systems of protective forest stands in fields, watersheds, along reservoirs, highways, railways, afforestation and consolidation of sands, ravines.Currently in Ukraine, on the fields of agricultural enterprises, there are about 1.4 million hectares of protective stands for various purposes, including 150 thousand hectares of water protection stands and 440 thousand hectares of protective forest belts (General characteristics).

In 2013, the Government of Ukraine approved the "Concept for the development of agroforestry in Ukraine" (About approval, 2013). The document emphasizes the aggravation of environmental problems in the functioning of existent agricultural landscapes. Protective forest stands of linear type create an ecological framework of agrolandscapes, but their number, condition and unsystematic placement do not conform the actual requirements.

The problem of ineffective protection of agricultural lands by protective forest stands of linear type is caused by the following factors:

- unbalanced ratio of arable land, natural hayfields and pastures, forests;
- increasing the negative impact on agricultural landscapes and their biological component (climate change, aridization, man-caused load, etc.);
- deterioration of forestry condition of protective forest stands of linear type, reduction of their area, weakening of protective and melioration functions;
- inefficiency of constructions that reduces their reclamation impact on agricultural lands;
- lack of completed systems of protective forest stands of linear type;
- use of simplified technologies in agriculture which weaken the reclamation impact of protective forest stands of the linear type on agricultural lands;
- reduction of agroforestry reclamation stands in recent decades.

The aim of the Concept is to identify line for institutional change and improve legislation that will optimize the area of protective forest stands of the linear type on a zonal basis, efficient management and will be an ecological prerequisite for sustainable development of agricultural landscapes. This will solve the problem of protecting soils from degradation and pollution, increasing crop yields and production of environmentally friendly products, ensuring food security, preserving landscape and biological diversity, creating environmentally safe living conditions (About approval, 2013).

Resolution of the Cabinet of Ministers of Ukraine of July 22, 2020 № 650 approved the "Rules for maintenance and preservation of protective forest belts located on agricultural lands" (About approval, 2020), which define the basic requirements for the maintenance of forest belts and a set of measures to ensure performance of functions on agroforestry melioration.

Given that the country's agroforestry stands are dominated by aboriginal and non-native forest tree species, forest genetic resources play an important role in the formation and maintenance of sustainable agroforestry stands.

Chapter 3. State of other wooded lands

According to the Forest Code of Ukraine [Forest code, 1994), there are forest areas covered with forest vegetation, as well as permanently or temporarily not covered with forest vegetation but given to forestry related purpose (due to the heterogeneity of forest natural complexes, forestry or natural disasters, etc.). Non-forested forest areas cover forest nurseries and seed orchards, forest ways and forest clearing, forest firebreaks, forest drainage ditches and drainage systems.

The other wooded lands as well includes perennial stands for various purposes. These are gardens, vineyards, greenery and agroforestry. Perennial stands (orchards and vineyards) cover an area of 0.9 million hectares, which is 1.5% of the country's territory (Land Handbook, 2020). These stands have nothing to do with forest genetic resources.

As well there are urban forests on area, cover an area of about 500 thousand hectares (Zibtseva, 2017) and are characterized by significant species and cultivars diversity with a high proportion of non-native forest tree species.

Chapter 4. State of diversity between forest trees species

Dendroflora of Ukraine forests according to M. Kohno et al. (Dendroflora, 2001, 2005) has 402 species of trees and shrubs. Among them, we can conditionally distinguish a group of the most widespread forest-forming species that have industrial or agroforestry value and are considered forest genetic resources. This group includes 58 species, of which 33 species are indigenous and 25 non-native (Table 1). It should be noted that 11 species have small areas of natural stands in the country. The species number has not changed over the last 10 years.

The distribution of areas by genera of forest trees spesies is given on Figure 6. (Forestry of Ukraine. 2019.). The representatives of *Pinus, Quercus, Picea, Fagus, Alnus, Betula, Robinia, Gleditsia, Fraxinus, Carpinus, Abies, Acer, Populus, Salix* genera dominate. *Pinus sylvestris, Pinus nigra, Picea abies, Abies alba, Larix decidua,Quercus robur, Quercus petraea, Fagus silvatica, Betula pendula, Alnus glutinosa, Fraxinus excelsior, Populus nigra, Tilia cordata, Acer platanoides, Acer campestre, Acer pseudoplatanus, Ulmus glabra, Carpinus betulus* dominate among the species.

Scots pine (*Pinus sylvestris* L.) is the most widespread forest-forming species (about 35% of the forest area of Ukraine), which is most widespread in Ukrainian Polissya and in the northern part of the Forest-Steppe, sometimes growing on sandy terraces in the northern part of the Steppe. This species forms mostly pure, sometimes mixed forests. Natural relict micropopulations of Scots pine have been conserved in the Ukrainian Carpathians. Numerous steppe insular populations of pine, located along the southern border of native range, are of great value.

1. List of species that are considered forest genetic resources.

Indigenous species	Species are indigenous on part of territory and non-native in another	Non-native species
Abies alba	*Castanea sativa*	*Arbutus andrachne*
Acer platanoides	*Ceracus avium*	*Aronia melanocarpa*
Acer pseudoplatanus	*Cornus mas*	*Cedrus atlantica*
Alnus glutinosa	*Fraxinus angustifolia*	*Cedrus libani*
Betula pendula	*Larix decidua*	*Cedrus deodara*
Carpinus betulus	*Picea abies*	*Corylus colurna*
Corylus avellana	*Pinus cembra*	*Fraxinus pennsylvanica var. lanceolata*
Fagus sylvatica	*Pinus nigra ssp. pallasiana*	*Gleditsia triacanthos*
Fagus taurica	*Taxus baccata*	*Juglans ailantifolia*
Fraxinus excelsior	*Sorbus torminalis*	*Juglans nigra*
Juniperus excelsa		*Juglans regia*
Pinus brutia var. stankewiczii		*Juniperus virginiana*
Pinus mugo		*Larix kaempferi*
Pinus sylvestris		*Larix occidentalis*
Populus alba		*Larix sibirica*
Populus nigra		*Phellodendron amurense*
Populus tremula		*Picea glauca*
Prunus serotina		*Picea pungens*
Quercus petraea		*Pinus strobus*
Quercus pubescens		*Pseudotsuga Menziesii*
Quercus robur		*Quercus castaneifolia*
Tilia cordata		*Quercus rubra*
Ulmus glabra		*Robinia pseudoacacia*
		Tilia platyphyllos
		Pinus nigra ssp.nigra var. austriaca

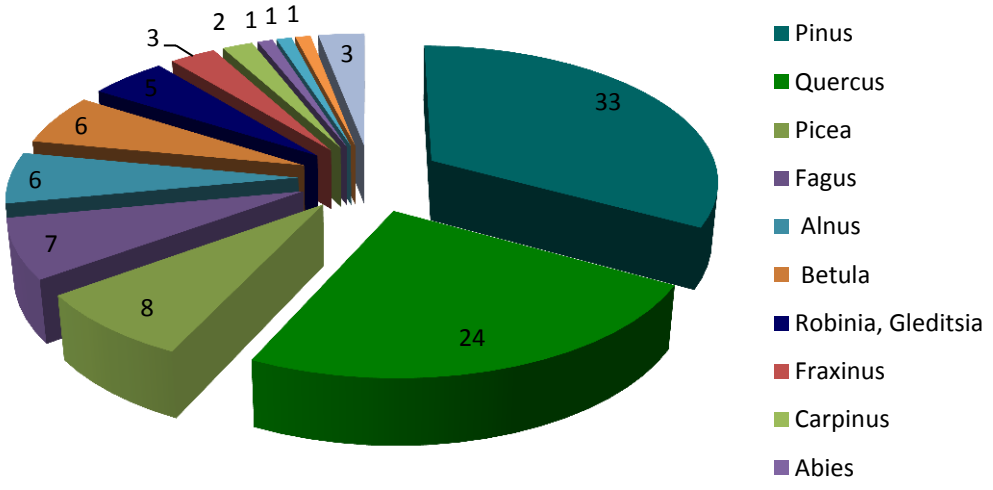

Fig. 6 Distribution of areas by genera of forest tree species, %

The adaptation of Scots pine to a wide range of forest growing conditions causes a high level of intraspecific variability, as evidenced by provenance tests (Patlay, 1984; Tereshchenko et al., 2008., Kokhany et al., 2014) and natural populations study (Yatsyk, 1981) results. Population-genetic analysis

confirms the hypothesis of a large stock of genetic variability in Scots pine in the Ukrainian part of its range (Korshikov et al., 2005)

The species is undemanding to soil conditions, every year forms seeds, propagates by self-seeding and expand on new territories, including lands withdrawn from agricultural use, and fire-damaged areas. Artificial stands of this species are created annually on large areas (see section 8). At the same time, stands mortality is observed every year on large areas as a result of root rot and pine bark beetles damage, and forest fires. There are serious threats to species population size decline and stands areas reduction. Research on study of the resistance mechanisms are conducted and it is planned to take into account resistance to diseases and pests while gene pool conservation.

The natural forests of **Crimean black pine (*Pinus nigra* ssp. *pallasiana (Lamb.) Holmboe*.)** occur on the Crimean Peninsula. As a result of large-scale forest melioration works in Crimea in the 60-80s of the twentieth century the area of artificial forests of Crimean black pine is more than 3 times larger than the area of natural ones, which are about 8.5 thousand hectares (Plugatar et al., 2010). Natural stands are non-even-aged, multilayered, while artificial ones are pure by composition, created mainly in poor and too dry forest conditions, not typical for this tree species. Crimean black pine is one of the main forest-forming species of the country's steppe regions.

The first artificial stands of **Austrian black pine** (***Pinus nigra ssp.nigra var. austriaca Hoess***) in Ukraine were created in the late XIX – early XX centuries, mainly in the Forest-Steppe and Steppe (Dobrovolsky V.I. 1956). It was found out that in harsh conditions of eroded slopes Austrian black pine prefers soils on loess deposits. On soils lined with granites and sands with layers of carbonate clays, its growth rates deteriorate slightly, but resistance is maintained (Orlovska & Marchuk, 2008). Austrian black pine is able to form drought-resistant and, at the same time, highly ornamental stands in the Forest-Steppe and Steppe (Tereshchenko et al. 2019). In forest stands of the western region of Ukraine Austrian black pine grows on 290 plots with a total area of 706.2 hectares, and stands with the participation of Crimean black pine were found on 250 plots with a total area of 1276, 8 hectares. However, the issue of the distribution of black pines in the forest stands of Ukraine has not been definitively clarified and data on it is contradictory due to inaccurate identification of these species by forest inventory. Often Austrian black pine stands are accounted as Crimean or Scots pine stands.

Natural forest stands of **European spruce (*Picea abies* (L.) H.Karst.**) grow mostly in the Carpathians in the altitude range of 900-1650 m above sea level. Natural localities of spruce also occur in some places in the northern regions of Polissya. Natural spruce forests in the conditions of wet relatively poor (subir) and relatively fertile (suramen) forest type conditions of Novgorod-Siversky Polissya form ”island” spruce stands (Porokhnyach, 2017).

White fir (*Abies alba* Mill) on the territory of Ukraine grows in the Carpathians at altitude of 200 to 1300 m, as well as in the west of the Ukrainian Rostochcha (Lviv region) [Dendroflora].

European larch (*Larix decidua* Mill) is a non-native species for Ukraine, except some natural location in the Carpathians (Debrinyuk & Belelya, 2012). In Ukraine, larch has been the object of forest growing activity for over 200 years (Belelya & Debrynyuk, 2016). It is planted in the western, northern and central parts of Ukraine (Carpathians, Polissya, Forest-Steppe). The spread of larch in the southern direction is limited by lack of moisture. The largest area of larch stands is in the Carpathian region and the Western Forest-Steppe. The most widespread species is European larch (*Larix decidua* Mill.). Less widespread is the **Polish larch - *Larix polonica* Racib. (*Larix decidua* var. *polonica* Ostenf. Et Syrach**). Among other larch species cultivated in stands of Ukraine there are **Japanese larch (*Larix leptolepis* Gord)** and **Siberian larch (*Larix sibirica* ledeb.). *Larix eurolepis* Henry,** which is characterized by intermediate features between European and **Japanese larch** is also quite widespread in forest stands of Ukraine.

English oak (*Quercus robur* L.) is one of the most important main forest-forming species in Ukraine. This species grows in most of the plain part of Ukraine, the main forest-forming species of the Forest-Steppe. Forests in which this species predominates occupy 26.3% of the total land area of the country's forest fund. The current distribution of oak forests in Ukraine was determined by the postglacial

migration of oak from secondary refugia, which were most likely located in the Carpathian region and adjacent territories of Western Ukraine.

The risks of reducing the genetic diversity of English oak are, first of all, in a significant reduction in the area of oak forests in the past. There was a process of fragmentation of the oak population and the formation of the disjunctive structure of its actual range in Ukraine. Significant fruiting periodicity of English oak is one of the limiting factors for successful natural regeneration of oaks and a factor of significant transfers of reproductive material for reforestation and afforestation. Global climate change may accelerate the succession of oak species: English oak, as a ”pioneer species”, can be replaced by Sessile oak, which better tolerates drought and poor soils. This scenario is most probable for Western Ukraine, where the habitats of these species overlap. Selective sanitary felling and the last stages of thinning with selection of the best biotypes also essentially reduce genetic potential of oaks. Periodic dieback, due to a complex of abiotic and biotic factors, also indicate a decrease in the viability of English oak populations and the need for urgent implementation of measures on conservation of its genetic variability.

Sessile oak (*Quercus petraea* (Matt.) Liebl.) is widespread in the western part of Ukraine and in Crimea. The range of Sessile oak in Ukraine is limited by the southern slopes of the Ukrainian Carpathians; forests in the Mountain Crimea. According to S. M. Stoyko research (1969), this species grows at an altitude of 150–1090 m above sea level, mainly on rocky shallow soils, where it forms pure stands. It rarely occurs as an admixture in beech forests of Lviv region. It occurs in the southwest of the Forest-Steppe (Vinnytsia region), and very rarely – in Polissya (Rivne, Zhytomyr regions).

Two beech species grow naturally in Ukraine – **European beech (*Fagus sylvatica* L.)** and **Crimean beech (*Fagus taurica* Popl.)**. Beech forests occupy 34,637 hectares here, which is 13.8% of the forested area. The natural range of the first of them is located in the Carpathian Mountains, where it has the great ecological and industrial importance. In the Carpathians, beech grows in a wide altitude range from 300 to 1300 m above sea level, with an optimum at 600-900 m above sea level. In the Carpathian Biosphere Reserve and Uzhansky National Nature Park unique primeval beech forests have been conserved. Primeval beech forests of the Carpathians in 2017 received the status of a UNESCO World Natural Heritage Site ”Ancient and primeval beech forests of the Carpathians and other regions of Europe“ (Stoyko, S. M. 2018.). In the plain part of its range in the Eastern Carpathian Foothills, Opillia, Rostochchcha and Podillia European beech is most often represented by isolated populations at altitudes of 300-400 m above sea level.

Crimean beech is naturally distributed on the Crimean peninsula, it is often considered a subspecies of eastern beech (Dendroflora, 2005). Crimean beech was separated out by G.I. Poplavskaya as an independent species, which is an intermediate form (introgressive hybrid) between Eastern and European beech (Poplavskaya, 1927).

According to studies of beech forest stands outside of the natural range, it is winter- and frost- and drought-resistant [Korinko 2007]. In experimental plantation of SE «Trostyanets Forestry» in Sumy region this species exceeds by growth intensity English oak of local origin (Los et al. 2020).

The forest fund of the plain part of Ukraine includes 7 species of poplar sections *Aigeiros* Dubi, *Populus* L. (syn. *Leuce* Dubi), *Tacamahaca* Spach, in particular, **Black poplar (Populus nigra L.)**, **Deltoid poplar (*P. deltoides* Marsh.), White poplar (*P. alba* L.)., Balsam poplar (*P. balsamifera* L.), Laurel poplar (*P. laurifolia* Ledeb.), Chinese poplar (*P. simonii* Carr.), Trembling poplar (P. tremula L.**), and also three cultivars: pyramidal poplar (***P. nigra* var. *pyramidalis* Spach**), **Bolle poplar (*P. albavar. Bolleana* Lauche.)** and **Gray poplar (*P.* x *canescens* Smith.)**. The total area of poplar forests of the SFRAU reaches 29,071.1 hectares. The distribution of poplar stands in different natural and climatic zones is uneven. Thus, poplars occupy the largest areas in the Steppe and Forest-Steppe zones – 13877.0 and 11580.3 hectares, respectively. In Polissya, poplar stands are represented only by 3616.8 hectares (Vysotska, & Tkach, 2016).

In the plain part of Ukraine, only 2% of poplar forests are available for wood supply to meet the needs of the national economy in wood. Such stands are concentrated mainly in the Forest-Steppe (59%) and Polissya (41%). There are no poplar forests of this category in the Steppe.

The share of poplar forests, which perform mainly the protective functions as well as engineering facilities from the negative impact of natural and anthropogenic factors, reaches 27%. Most of them are concentrated in the Steppe (47%) and Forest-Steppe (49%) (Vysotska, & Tkach, 2016).

The share of poplar stands, which mainly perform nature conservation, aesthetic function, or are objects for the long term research, contribute to the protection of unique and other especially valuable natural complexes, historical and cultural sites, is 26%. They are represented in all natural and climatic zones of the plain part of the country – Polissya (34%), Forest-Steppe (45%), Steppe (21%).

Almost half (45%) of the poplar stands of the forest fund of the plain part of Ukraine are located in the forests of green zones around settlements and within the districts of sanitary protection of medical and recreation territories and sanitary protection zones of water bodies. Most of these forests perform recreational, sanitary and health functions in the Steppe (66%) and Forest-Steppe (30%).

Natural forest formations are ecologically more stable, and the predominant tree species are characterized by significant genetic variability, which leads to their high resistance to adverse factors. The area of poplar stands of natural origin in the forest fund of the plain part of Ukraine reaches 15,522.7 hectares. The area of artificial stands is 13,551.4 hectares. Three poplars species –*P. tremula, P. nigra, P. alba* and their natural hybrids, in particular a hybrid of Trembling poplar with White poplar - Gray poplar (P. x canescens) form natural stands (Vysotska, & Tkach, 2016).

Silver birch (*Betula pendula* Roth) in Ukraine is the most widespread in Polissya, Forest-Steppe, in the Steppe along the banks of large rivers, in the Carpathians, in the Eastern Carpathian Foothills and Zakarpattia. In Polisya Silver birch often grows along with **Downy birch (*Betula pubescens* Ehrh.)**, they often hybridize. Birches occupy 5.4% of the forest fund of Ukraine. Silver birch is undemanding to soil conditions, annually forms many of seeds, easily propagated by self-seeding and expand on new areas, including withdrawn from agricultural use, and fire-damaged areas. Recently, the health condition of birch stands in forests of Polissya has been steadily deteriorating. The main factors deteriorating resilience of the forest ecosystems with the birch participation are adverse climatic conditions, pathogens and pests. Due to the lack of precipitation and high air temperature during the growing season, weakened stands become a favourable environment for the successful development of bacteria *Enterobacter nimipressuralis*.and other microorganisms that cause bacteriosis of birch trunks. With a significant reduction in the physiological functions of silver birch various species of insect pests infestation in stems are occurred. Currently, this problem in the forests of Ukraine, in particular in Polissya, needs to be solved at the state level (Goychuk et al. 2018).

Small-leaved lime *(Tilia cordata* L.) is widespread almost all over Ukraine, except for the extreme Steppe. In Polissya it occurs less often. As an accompanying species it is distributed in oak and mixed forests of the Forest-Steppe. In Ukraine, 77% of the area of small-leaved lime stands is natural, in particular, 58% of stands are of coppice origin, 19% – of seed origin. Artificial linden stands grow on 23% of area. Last decades, the share of small-leaved lime in forests of Ukraine has decreased significantly. **European linden (*Tilia europaea* L.).** and **Broad-leaved linden *(Tilia platyphyllos* Scop.*)*** grow in mixed and deciduous forests in the western regions of Ukraine. ***Tilia tomentosa*** occurs only in the southwestern part of Ukraine. **Crimean linden (*Tilia x euchlora* K. Koch**) is widespread in oak forests of the mountainous part of Crimea.

Three species of the genus ***Alnus*** are naturally distributed in Ukraine: ***A. glutinosa* (L.) Gaerth**., ***A. alnobetula* a (Ehrh.) K. Koch** and ***A. incana* (L.) Moench.** and a natural hybrid of ***A. x pubescens* (*A. glutinosa x A. incana*).** *Alnus glutinosa* stands are widespread almost throughout Ukraine, especially in Polissya, less in the Forest-Steppe and the Carpathians. In the Steppe zone, alder forests are formed, as a rule, on microdepressions and ravines. Alder forest ecosystems occupy almost 3.9% (237 thousand hectares) of the forest area of Ukraine. Increased anthropogenic impact, especially changes in the hydrological regime has a negative impact on the condition, productivity and natural regeneration of alder. In alder forest types on site of seed stands mainly coppice secondary stands are formed, which have a simplified structure, reduced resistance and productivity.

Norway maple (*Acer platanoides* L.) grows naturally in the second floor of deciduous and mixed forests, mainly with oak, ash and linden almost all over Ukraine, except the extreme northern regions. In the culture it is often used in protective belts and parks. **Field maple *(Acer campestre* L.)** occurs in the second floor or undergrowth of deciduous forests, in clearings almost throughout Ukraine. Both species in

forests often grow side by side in the same stands. **Tatar maple (*Acer tataricum* L.)** occurs in the undergrowth or third floor of deciduous and mixed forests, mainly in the Forest-Steppe and northern Steppe. Field and tatar maples are often used in field protection belts and for steppe afforestation. **Sycamore maple (*Acer pseudoplaianus* L.)** is widespread in the right-bank Forest-Steppe and the Carpathians, it grows in the first, rarely in the second floor of deciduous, mostly oak forests. In the Crimean forests there is a **Steven maple (*Acer stevenii* Pojark.),** which grows naturally only on the southern coast of Crimea. This plant is an endemic to Crimea, and it is included in the list of rare and endangered species of the IUCN (Dendroflora, 2005).

Forest stands with the participation of **Common ash (*Fraxinus excelsior* L.)** are one of the most widespread and least studied formations of deciduous forests in Ukraine. Common ash is the most valuable species of the genus *Fraxinus* in forestry, protective afforestation and landscaping (Kuznetsova, 2009). **Sharp-fruited ash *(Fraxinus oxycarpa Willd.)*** (Dendroflora, 2005) or a subspecies of **Narrow-leaved ash (*Fraxinus angustifolia* subsp. *Oxycarpa* (M.Bieb. Ex Willd.)** Franco & Rocha Afonso) [Fraxinus angustifolia] grows naturally in forests of Crimea and often occurs in Steppe part of Ukraine in landscaping. These species are recommended as the main species for creation of stands in dry steppe of Ukraine, in particular on saline soils [Recommendations].

Hornbeam (*Carpinus betulus* L.) grows naturally in the second floor of oak and beech forests, in some places it forms pure stands of coppice origin. In Ukraine it is spread in the Forest-Steppe and Polissya on the Right Bank and partly on the Left Bank, sometimes in the Steppe. In Crimea it is widespread in the zone of beech forests, in the mountains up to an altitude of 700 m above sea level. Forests with hornbeam occupy 3.7% of the area of the forest fund of Ukraine (Dendroflora, 2005).

Different Elms species (***Ulmus***) have different boundaries of natural distribution in Ukraine. Thus, European white elm (***U. laevis)*** and wych elm (***U. glabra)*** are part of deciduous oak forests. They occur in the second floor, often grow on the edges and clearings. The **Field Elm (*U. minor*)** is a accompanying species in mixed oak stands of the Forest-Steppe zone, in the Steppe zone it occurs in ravine forests. In the last century it was one of the main tree species for steppe afforestation. Along the banks of the Dniester River a **Siberian elm (*U. pumila*) grows,** which, however, does not play a significant forest-forming role for the forest stands of the Western Forest-Steppe (Maslovata, 2017). It was revealed that the dieback of elm stands occurs with a certain cyclicity, which is associated with the periodicity of the impact of adverse environmental factors that significantly weaken the plants. Mortality due to Dutch elm disease, necrosis-cancer and bacterial disease are most often observed in elm stands (Iavniy & Puzrina, 2018). The pathogen causing bacterial disease of wych elm in Kyiv Polissya of Ukraine has been identified as *Enterobacter nimipressuralis.*

According to Order № 312 of the Ministry of Environmental Protection of Ukraine of 17.06.2009 “On approval of lists of species of plants and fungi listed in the Red Book of Ukraine”, 50 species of trees and shrubs were included to the Red Book of Ukraine (Red Book of Ukraine. Flora. 2009), among them – 11 species from The European Red List, and 5 species from the IUCN list. A new edition of the Red Book of Ukraine is currently being prepared. The book hasn’t been published, but the proposals of the NAS of Ukraine M.G. Kholodny Institute of Botany was applied only to herbaceous plants. Thus, among forest trees in Ukraine, 16 species have a special status:

***Juniperus excelsa* M. Bieb.** – Mediterranean relict species on the northern border of the range. Association of the *Junipereta excelsae* is included in the «Green Book of Ukraine». It is protected in the Yalta Mountain and Forest Nature Reserve, Nature Reserves “Mys Martian” and Karadag, in the national nature reserves (zakaznik) “Ayu-Dag”, “Karaul-Oba”, “Novyi Svit”, “Kanaka” and others.

***Juniperus foetidissima* Willd**. – Mediterranean species on the northern border of the range. Associations of this species are included in the “Green Book of Ukraine”. It is protected in the Crimean Natural Reserve.

***Larix polonica* Racib. (L. decidua Mill. subsp. *polonica* (Racib.) Domin)** is an endemic species with a disjunctive range, listed to the IUCN Red List. Forest associations with larch co-dominance are included in the “Green Book of Ukraine”. It is protected on the territory of the botanical nature reserve of national importance “Kedrin” and the forest reserve of national importance “Urochyshhe Skyt Manyavskyi”.

***Pinus cembra* L**. is a Central European mountain Pleistocene relict. Associations of this species are included in the “Green Book of Ukraine”. It is protected in the “Horgany” Nature Reserve, the Carpathian

National Nature Park, in the botanical nature reserves of national importance “Kedrinskyi”, “Tavpishyrskyi”, “Yaykivskyi”, in the landscape reserves of national importance “Bredulets”, “Hrofa”.

***Pinus cretacea* (Kalenicz.) Kondr. (*Pinus sylvestris* L. var. *cretacea* Kalenicz. ex Kom.)** is a relict disjunctive species included in the IUCN Red List. It is protected in the “Svyati Hory” National Nature Park and the Ukrainian Steppe Nature Reserve (Cretaceous Flora Department, Donetsk region).

***Pinus stankewiczii* (Sukacz.) Fomin (*P. brutia* Ten. *var. pityusa* (Steven) Silba pp, *P. brutia* subsp. *Stankewiczii* (Sukacz.) Nahal, P. *pityusa Steven* var. *stankewiczii* Sukacz.)** – is an endemic race of thermophilic Mediterranean species *P. brutia*, located on the northern border of the range, included in the IUCN Red List. Associations of this species are included in the “Green Book of Ukraine”. The species is protected in the landscape reserve of national importance “Mys Aya” and the botanical reserve of national importance “Novy Svit”, a complex landmark of nature “Hirskyi massif Karaul-Oba” in Crimea.

***Taxus baccata* L.** is a rare relict species with a disjunctive range. Forest associations with its co-dominance in subordinate layers are included in the “Green Book of Ukraine”. It is protected in the Carpathian Biosphere Reserve, the Crimean and Yalta Mountain and Forest Natural Reserves, National Natural Parks “Karpatskyi” and “Skolivsky Beskydy”, the landscape nature reserve of national importance “Velykyi kanyon Krymu”, the botanical nature reserve of national importance “Tysovyi Yar”.

***Pistachio mutica* Fisch. et C.A.Mey. (*P. atlantica* Desf. subsp. *mutica* (Fisch. Et C.A.Mey.) Rech.f.)** is a Mediterranean relict species on the northern border of the range. Associations of this species are included in the “Green Book of Ukraine”. It is protected in the Yalta Mountain and Forest Natural Reserve, Nature Reserves Karadag and “Mys Martian”, landscape reserves of national importance “Ayu-Dag”, “Mys Aya”, “Baydarskyi”, “Mys Fiolent”, botanical reserves of national importance “Novyi svit”, “Kanaka”, complex landmark of nature “Hora Kishka”.

***Betula borysthenica* Klokov** is a Black Sea-Volga psammophilous-valley neoendemic. Associations of *Betuleta borysthenica* are included in the “Green Book of Ukraine”. It is protected in the Black Sea Biosphere Reserve, the Regional Landscape Park “Kinburnska kosa” , and the National Forest Reserve “Berezovi kolky”.

***Betula klokovii* Zaverucha** is a niche endemic. It is protected in the Nature Reserve “Medobory”.

***Betula obscura* A.Kotula (incl. *B. kotulae* Zaverucha; *B. pendula Roth subsp. obscura* (A.Kotula) Á.Löve, B. *verrucosa* Ehrh. subsp. *obscura* (A.Kotula) Á.Löve et D.Löve)** - Central European species with unclear taxonomic status. It is protected in Nature reserves “Roztochchya”, “Medobory”, “Horgany”, landmark of nature “Bukovynka”.

***Arbutus andrachne* L**. is a relict Mediterranean species on the northern border of the range. The only evergreen deciduous tree in Ukraine. Associations of this species are included in the “Green Book of Ukraine”. It is protected in the Natural Reserve “Mys Martian”, the Yalta Mountain and Forest Nature Reserve, and landscape reserves of national importance “Mys Aya” and “Ayudag”.

***Quercus cerris* L. (*Q. austriaca* Willd.)** is an eastern Mediterranean-southern European disjunctively distributed species on the northeastern border of the range. Forest associations with its co-dominance are included in the “Green Book of Ukraine”. It is protected in the Carpathian biosphere reserve, the botanical nature landmark “Velykyi lis”, and regional landscape park “Prytysyanskyi”.

***Fraxinus ornus* L.** is a relict sub-Mediterranean species on the northern border of the range in an isolated locality. Forest associations with its co-dominance are included in the “Green Book of Ukraine”. It is protected in the Carpathian Biosphere Reserve, and regional landscape park “Prytysyanskyi”.

***Tilia dasystyla* Steven** is a relict species with a disjunctive range included in the European Red List. It is protected in the Crimean, Yalta mountain-forest and Karadag nature reserves, the nature reserve of national importance “Kubalach”, the landmark of nature of local importance “Hora Kastel”.

***Sorbus torminalis* (L.) Crantz (*Crataegus torminalis* L., *Pyrus torminalis* (L.) Ehrh.)** is an endangered species. It is protected on the territory of Yalta mountain-forest, Karadag, Crimean and “Medobory” nature reserves, national nature parks “Podilsky Tovtry”, “Dniestrovskyi kanyon” and “Karmelyukove Podillya”, “Zacharovanyi Kray”, regional landscape park “Chernivetsky”, in protected tracts and landmarks of nature.

Four species (***Tilia argentea* Desf ex DC, *Quercus dalechampii* Ten., *Quercus polycarpa* Schur. *Fraxinus syriaca* Boiss.)** are protected only at the regional level in the Carpathian region or in Crimea and would require a nature protection status at the national level.

Chapter 5. State of intraspecific diversity of forest tree species

Information on the genetic diversity of forest forest tree species in Ukraine is fragmentary and based on studies conducted by different institutions using different methods. Systematic studies using the harmonized methodological approach have not been carried out.

One of the first study of the genetic variability of natural beech populations in Ukraine by using genetic methods (isoenzyme method) was conducted by I. M. Shvadchak (Shvadchak, 1994) and study of relict island populations of Scots pine in the Ukrainian Carpathians was conducted by R. T. Volosyanchuk (Volosyanchuk, 1996). At the beginning of the XXI century, isoenzyme method was successfully used by a scientific group led by I. I. Korshikov at the Donetsk Botanical Garden to study the genetic variability and population structure of indigenous species of the family *Pinaceae* Lindl. within their natural habitats in Ukraine (Korshikov, 2007).

Molecular genetic markers allow understanding the genome structure of the plant organisms, its organization and functioning. The most effective in studying the variability of forest trees species using DNA markers is the laboratory of genetic markers of the Department of Forestry of Ukrainian National Forestry University (UNFU) organized by prof. R. T. Gut (Gut, 2004, 2006, 2009). The study of 15 populations of *Pinus sylvestris* L. in the main forest regions of Ukraine at 22 isoinzyme loci showed that values of the main parameters of polymorphism are the lowest for relict populations in the Ukrainian Carpathians and the highest in Steppe and Forest-Steppe populations. At the same time, cluster analysis could not show clear trends in the distribution of populations according to their geographical location (Korshikov, 2007). Significant genetic variability of foothill and mountain populations of *Pinus sylvestris* L., as well as the average genetic distance between groups of these populations were revealed. Differentiation between groups of populations isolated by spurs of the ridges corresponds to the rank of geographical groups of populations. The obtained results are sufficient grounds for isolating the Carpathian mountain geographical race of *Pinus sylvestris* L. - *var. carpatica* Klika [Sannikov].

Analysis of individual heterozygosity of Scots pine (*Pinus sylvestris* L.) 35 plus trees selected in the north of Donetsk region using 14 polymorphic isozymes and 5 microsatellite DNA loci showed that the individual heterozygosity of trees is markedly different. However, microsatellite loci provide a more exact determination of allele diversity and heterozygosity of plus trees (Korshikov et al., 2013).

The results of the study of 196 Scots pine (*Pinus sylvestris* L.) trees genotypes using molecular markers based on genetic intron gene polymorphism (ILP) of PsDef1-4 defensins revealed high informativeness of markers based on PsDef2 gene intron (IPL-PsDef2) for study the intraspecific polymorphism of the species (Kovaleva et al., 2018)

Study of isolated populations of the easternmost part of *Pinus cembra* L. native range in the Carpathians revealed a higher level of expected heterozygosity and differentiation compared to the alpine populations, caused by the fragmentation of their distribution in the region. The level of genetic variation confirmed by microsatellite analysis was higher than previously obtained by allozyme method (Mudrik et al. 2008). The distinct genetic structure of Ukrainian populations comparing to the Alpine and South Carpathian ones indicates the validity of the development of strategies for genetic resources' conservation of the species and in parallel with the gene pool conservation, it is necessary to invent opportunities to facilitate migration for this species (Mohytych et al., 2019**).**

Comparative study of genetic variation of seeds and mother plants from marginal populations of *Abies alba* Mill., *Pinus pallasiana* D. Don and *Pinus sylvestris* var. *cretacea* Kalenicz. ex Com. in Ukraine showed that the allele frequencies of the analysed loci were maintained in the generations of mother plants of these populations. However, the population structure of the seed embryo genotype shifted towards an excess of homozygous genotypes. The most variable loci of mother plants make the greatest contribution to the homozygosity of the progenies (Korshikov, 2007).

For White fir (*Abies alba*) the morphological forms of trees by crown shape, colour and type of bark were revealed. The estimation of genetic variability and differentiation of its populations was also carried out (Korshikov et al., 2005).

European spruce is characterized by phenological forms, in which the difference between the dates of bud burst can reach 10-20 days. The intraspecific variability by colour of the young female cones, character of branching, type of bark and morphology of seed scales is revealed (Shvadchak., 1989). Based

on the analysis of 20 allozyme loci variability, genetic differences of plain, island, small population (2 ha) from Polissya and two different-altitude populations of European spruce from the Ukrainian Carpathians (1000–1500 m above sea level) were revealed (Korshikov et al., 2008).

Intraspecific variability of English oak in Ukraine is mostly studied in provenance tests (Patlay, 1984; Hayda, 1989). However, in natural populations, this species is characterized by exceptionally broad polymorphism (Molotkov et al., 1989). Phenological, morphological, ecological forms are distinguished for the English oak. For example, according to the morphology of vegetative and generative organs, there are forms by the length of the peduncle, the length of the petiole, the size and form of the leaves, the type of crown and bark. Methodical approaches to the study of oak variability have been developed (Los, 2002, 2018, 2020).

The study of small isolated populations of *Q. robur* in the south-east of Ukraine revealed a relatively high level of genetic diversity with weak differentiation (Korshikov & Slepykh, 2014).

Early and late phenological forms of *Quercus robur (Fagaceae*) were studied using microsatellite markers and DNA markers system on the base of the intron duration of β-tubulin genes (TBP markers) polymorphism study. Relatively low values of genetic variability were found (HO = 0.342 ± 0.208, HE = 0.566 ± 0.199 for the early and HO = 0.288 ± 0.136, HE = 0.461 ± 0.216 for the late phenological groups). Genetic differences between early and late *Q. robur* forms were determined. 9 unique alleles for microsatellite loci and 4 fragments for TBP loci for early form trees and 5 unique alleles for microsatellite loci and 5 fragments for TBP markers for late form were identified (Pirko et al. 2018).

Early, late and intermediate phenological forms are clearly distinguished for European beech. Numerous morphological forms by crown, bark, leaf blades characteristics have also been identified (Molotkov et al., 1989). Genetic variability and differentiation of European beech populations has been studied by a group of Slovak and Ukrainian scientists (Vyshny et al., 1995; Krynytskyj et al., 2017). Studies carried out in 2013 in the Crimean beech genetic reserves revealed high intrapopulation and medium and low interpopulation diversity, which in turn indicates the possibility of successful preservation of the gene pool in a small number of sites. Also, it was confirmed intermediate position of Crimean beech between European beech and Eastern beech by the leaves morphological characteristics (Los et. al., 2014).

Species of the genus *Alnus* are morphologically variable. Thus, for *A. glutinosa* in Ukraine there are at least five forms (Olshansky, 2014).

Work to study the phenotypic variability of forest tree species over the past 10 years has been part of tree improvement investigations. Particular attention was paid to phenological development, reproductive intensity, pollen viability, morphological characteristics of clones and progenies, in particular part of well-formed seeds and yield from Scots pine cones (Tereshchenko, 2002; Mitrochenko 2009; Mazhula & Dyshko, 2014). The spectrum of disorders in the meiosis of microsporogenesis of clones of Scots pine plus trees was revealed, which was caused by the influence of genetic factors and weather conditions during meiosis (Mitrochenko, 2007).

In order to predict the tree species growth rate, the method of the mitotic activity of poplar and coniferous species study has been improved. A method for studying the mitotic activity of apical meristems of vegetative buds of English oak has been developed (Torosova L.O. 2012).

The study of genetic variability of plus trees progenies is indirectly carried out in progeny tests of Scots pine (Tereshchenko, 2011, Tereshchenko et al., 2011; Mitrochenko, 2010), English and Sessile oak (Hayda et al., 2010; Los 2016; Los, Tereshchenko, Kolchanova, 2016).

Provenance tests, as one of the oldest tools for studying the variability are characterized by exceptional multifunctionality. In particular, the results of their study serve as an information base for the development and improvement of forest seed zoning. Progeny tests of geographically distant populations, subject to certain conditions, can be used for varietal testing of forest tree species. An important function of provenance tests is the conservation of forest genetic resources' ex situ. Recently, provenance tests have been considered as a very informative tool for determining the climatic boundaries of adaptation of forest species (Hayda, 1989, 2014), which is especially relevant in today's global warming.

Stages of The strategy and technology of valuable gene pool conservation of certain forest tree species elaboration are proposed by Yu.I. Gaida using EUFORGEN approaches (Fig. 7) (Krynytskyj et. al., 2017). Thus, the process of elaboration of the strategy and technology of valuable gene pool conservation of a certain forest tree species begins with an assessment of the nature of the species distribution in the

country The boundaries of the natural range, its size, degree of fragmentation, the distribution patterns (solid, sparse) are determined. The size and number of required gene conservation units depend on these parameters.

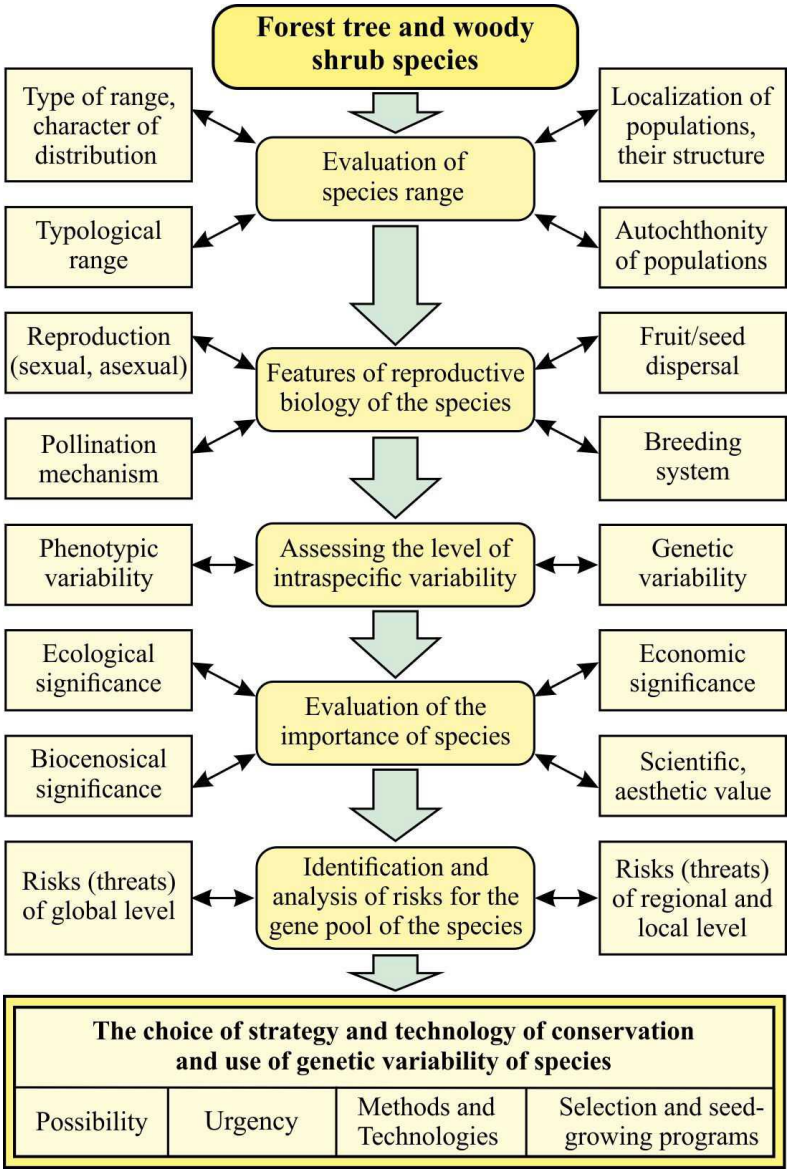

Fig 7. Schematic diagram of development of the strategy and technology for conservation of the genetic diversity of forest tree species (Krynytskyj et. al., 2017)

An important characteristic that determines the feasibility and possibility of preserving the genetic variability of a certain species is the autochthony of its populations. Deviation from the principle of autochthony of gene conservation objects is allowed for the best artificial populations outside the natural range of the species, well adapted to the new conditions of growth, as well as for the situation of critical depletion of the gene pool and lack of natural populations within the native range.

For many forest species, the level of genetic variability of populations is different in central and marginal parts of native range, and therefore for their conservation slightly different methods might be used.

It is required to study the ecological conditions within the range, to identify factors that may give rise to isolation barriers to gene migration. It is advisable to study the forest typological range of the species, and identification of forest types for which this species is a native. This is necessary to determine the scale and representation of gene conservation units in forest typological spectrum of the species' range.

Features of the reproductive biology of the species determine the minimum and maximum size and density of gene conservation units. That is why information about the plant's sexualization type (monoecious, dioecious), the pollination method (anemophilic, entomophilic), the fruits and seeds distribution method (anemochoric, zoochoric, hydrochoric) is taken into account.

The presence of introgressive hybridization zones at the points of contact or overlapping of ranges makes certain adjustments to the strategy and technology of gene pool conservation. Therefore, it is always valuable to search the literature for information on the location of natural hybrid populations. Such searches are complemented by field observation and research. Significant assistance in choosing the optimal strategy for gene conservation is provided by an array of scientific data on the level of phenotypic and genotypic variability of the species. The data received at studies of native population, and progeny tests are informative. For many forest tree species there is enough information about the form diversity, but of particular value there are the data on the level of genetic variability and population differentiation, obtained using genetic markers (isoenzymes, microsatellite and other DNA markers). Unfortunately, molecular methods for studying forest tree plants are not used enough.

Expert assessment of ecological, biocoenotic, economic, aesthetic value of the species is used as one of the factors (but not the only one) for determining the priority (urgency) of implementation of the strategy of its gene conservation.

Having complete information on the species distribution, biology, ecology and genetics, the identification of risks (threats) to its gene pool is carried out. Qualitative and quantitative analysis of such risks allows to rank all species of arboriflora according to the integrated risk indicator and assign them an index of urgency of the strategy of their valuable gene pool conservation.

After passing all stages of the development of the strategy for gene pool conservation, it is to proceed to formulation of the strategy basic elements. The following items are defined in it: possibility of conservation procedure, the level of its urgency, *in situ* and *ex situ* methods, most suitable for this species, the most effective ways to combine procedures for the conservation and use of genetic variability for breeding and seed purposes. At the same time special attention is paid to quantitative and qualitative parameters of the gene conservation units – the minimum number of trees of the target species, their area and structural and spatial organization.

One of the most important problems that hinders the development of forest tree species genetic variability research is the lack of technical capabilities for molecular genetic research in research institutions of forestry profile. The molecular genetic methods use is a necessary condition for modern scientific developments on forest tree improvement and forest genetic resources conservation. An important component for the effective forest genetic resources' conservation in Ukraine and their sustainable use is the availability of information on the genetic variability of forest trees at both the population and individual levels. Data on interpopulation and intrapopulation genetic diversity and the intensity of gene exchange between populations are needed to prioritize populations for conservation. An important issue is genetic identification of the plus trees and their clones at clonal seed orchards.

PART 3: STATE OF FOREST GENETIC RESOURCES CONSERVATION

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

In situ forest genetic resources conservation activity in Ukraine involves the conservation of rare and endangered species listed in the Red Book (2009), natural communities listed in the Green Book (2009) on the territory of natural reserve fund (NRF) and gene pool conservation units of widespread, economically significant forest-forming species on the territory of the forest fund. Conservation of biodiversity in forests is carried out by their owners and permanent forest users at the genetic, species, population and ecosystem levels by (Forest Code, 1994):

- creation and announcement of objects of natural reserve fund in the manner prescribed by law in the most valuable forest sites, the development of the ecological network;
- allocation, creation and conservation of units of valuable gene pool of forest species (genetic reserves, plus stands and trees, clonal archives, seed stands and seed orchards, experimental and progeny tests, etc.);
- prevention of genetic contamination of gene pools of aboriginal species and invasions of non-native species into natural ecosystems;
- application of ecologically oriented reforestation methods and use of forest resources;
- ensuring the protection of rare and endangered species of fauna and flora, plant communities, primeval forests and other valuable natural complexes in accordance with environmental legislation.

NRF facilities are under the state administration of the Ministry of Environmental Protection and Natural Resources of Ukraine. Studies of these species are carried out mainly by ecological and botanical institutions of the Academy of Sciences of Ukraine, in particular botanical gardens.

50 species of trees and shrubs are listed in the Red Book of Ukraine, including 16 forest trees. Most of them are not of great economic importance, but are valuable in the melioration, protection, ecological sense and are an integral part of forest cenosis. They are conserved on the territory of natural and biosphere reserves, national nature parks, botanical and forest reserves, protected tracts, landmarks of nature, etc.

As of 01.01.2020, the natural reserve fund of Ukraine consists of 8512 territories and units with a total area of 4.418 million hectares within the territory of Ukraine (actual area 4.085 million hectares) and 402500.0 hectares within the Black Sea (Territories and objects) (table.2).

72 natural forest plant communities are registered in The Green Book of Ukraine. Their protection is ensured by their special legal status, taking into account the requirements for the protection of these communities during the development of regulations; creation of biosphere reserves, other territories and objects of the natural reserve fund, including transboundary; monitoring their condition and research; introduction of conservation regime. Reproduction of natural plant communities is carried out on the basis of scientifically sound measures by: promoting their natural regeneration; prevention of undesirable changes and negative anthropogenic impact; their formation on artificially created objects of the natural reserve fund.

Within the forest sites, which belong to one of the forests categories (About approval of the Procedure 2007 p.), specially protected forest areas can be allocated, for which a regime of limited forest use is established. Such areas include unique forest sites in terms of species composition, productivity and genetic properties, on which relict, endemic tree species of great scientific importance (forest seeds, nuts, fruits and berries, honey, permanent research and other forest sites, having special economic importance) grow.

State control over compliance with the requirements for the protection, reproduction and use of plant communities is carried out by the State Ecological Inspection and its territorial offices (Regulations, 2002). Monitoring of soils of forest lands, forest vegetation and hunting fauna is entrusted to SFRAU.

In situ conservation of widespread, economically important forest-forming species, the number and size of natural populations of which is declining, is currently controlled by the SFRAU. Research of these species will be carried out by researcher of the Ukrainian Research Institute of Forestry and Forest

Melioration (URIFFM), the Ukrainian Research Institute of Mountain Forestry (URIMF) and forest universities.

2. The units of natural reserve fund of Ukraine

Category	**Units number**	**Area, ha**
String reserves:	23	445,1
natural (IUCN–Ia)	19	198,7
biosphere (IUCN–II)	4	246,4
National natural parks (IUCN–II)	45	1 239 958
Reserves:	1429	417806,9
state significance (IUCN–IV)	207	221086,9
forest	30	23593
botanic	89	43813,8
landscape	88	153680,1
local significance (IUCN–IV)	1222	196720
forest	246	14424
botanic	639	22968
landscape	337	159328
Natural monuments:		
state significance (IUCN–III)	43	1973,1
local significance (IUCN–III)	1506	
Botanical gardens	30	
Arboretums (registred by CBGAU)	19	
Parks-monuments of garden-park art:	79	4608,6
state significance	79	3774,6
local significance	409	834
Regional landscape parks (IUCN–II)	26	278361
Protected tracts (IUCN–Ib)	743	301073

Work on the selection and *in situ* forest genetic resources conservation of these species began in 1983 on the basis of "Regulations on the allocation and conservation of the gene pool of tree species in the forests of the USSR" (1982). The main units of *in situ* forest genetic resources conservation in the country are genetic reserves, plus stands, seed stands and plus trees.

At the beginning of the XXI century (2000-2005) in the framework of the international project "Genetic Resources of Broadleaved Species in Southeastern Europe" in the country a large-scale inventory of valuable gene pool of broadleaves species was conducted. In the Carpathian region and adjacent territories, the gene pool conservation units of coniferous tree species were also observed. The method of comprehensive assessment of the state of forest genetic reserves was used for inventory (Volosyanchuk et al., 2003). In the western region of Ukraine to characterize the state of gene reserves also a multifactor index of their functionality was used (Gaida & Jacyk, 2013), which comprehensively illustrates the various characteristics of gene pool conservation units, namely autochthony of populations; the number of individuals of the target species, which will ensure the preservation of a high level of allelic diversity; the level of potential for natural regeneration; stability and lifetime of stands. It was revealed that by the single (single-vector) integral indicator sometimes it is difficult to illustrate a wide range of diverse features of gene pool conservation unit, as each of them has its own objective weighting factor and a different number of gradations of manifestation. In addition, a single integral indicator can mask the achievement of critical values by gene pool conservation unit for certain of its characteristics. The multi-factor index of the functionality of gene pool conservation units has another advantage in that it is an open indicator, if necessary, it can be expanded by additional factors. For example, with the accumulation of sufficient

information about the level of allelic variability of populations, the overall index can be supplemented by another factor index, which assesses the genetic variability of the target species.

The results of inventory showed that 5-15% of genetic reserves of different forest tree species have lost their functional capacity and need to be replaced. Such a replacement has taken place, but the selection of new genetic reserves is often faced the problem of reducing the area of natural forests. There was also a decrease in the area of plus stands and plus trees number. Thus, from 885 plus trees of the main forest-forming species, which were covered by the inventory in the western region of Ukraine (Ivano-Frankivsk, Lviv, Ternopil and Chernivtsi regions), state and parameters of 584 plus biotypes (66.9%) were detected and described in detail. The most critical situation with the gene pool of plus trees was noted for European spruce (35.9% of trees remained). The situation is better for white fir and Scots pine (remained 64.4 and 69.1%, respectively). In deciduous tree species, the preservation of plus biotypes was the highest (more than 80%).

In the last decade, thanks to the implementation of a number of sectoral programs (Sectoral Forest, 2010, 2016; The concept, 2011), coordinated by the SFRAU, in all regions selection and certification of new plus trees of forest trees species was carried out and other gene pool conservation units were created. Currently (as of 01.01.20) the area of *in situ* gene pool conservation units is registered as follows: genetic reserves – 23917.7 ha (702 units), plus stands – 2094.6 ha (132 units), seed stands – 15714 ha (1938 units). Areas and number of units by species are given in tables 3 and 4. It should be noted that most of these units are selected in forests subordinate the SFRAU (fig. 8).

3. Areas and number of *in situ* forest genetic resources conservation units by species

Scientific name	Gene reserves		Plus stands		Seed stands	
	area, ha	units number	area, ha	units number	area, ha	units number
1	2	3	4	5	6	7
Abies alba	1286,6	27	16,7	3	126,5	18
Cedrus libani	0	0	0	0	0,9	1
Cedrus deodara	0	0	0	0	0,9	1
Juniperus virginiana	0	0	0	0	27,6	8
Juniperus excelsa	208,6	2	0	0	0	0
Larix decidua	39,7	4	12,5	3	180,1	78
Larix kaempferi	0	0	0	0	3,5	1
Larix x	0	0	0	0	5,6	2
Larix occidentalis	0	0	0	0	0,1	1
Picea abies	2098	46	21,9	3	321	70
Picea glauca	0	0	0	0	1,6	1
Picea pungens	0	0	0	0	3	2
Pinus cembra	632,1	5	0	0	22,2	1
Pinus nigra	0	0	4,5	1	2,1	1
Pinus nigra ssp. Pallasiana	133,8	7	7,3	2	454,9	60
Pinus stankewiczii	42,1	2	0	0	4,5	1
Pinus mugo	1,2	1	0	0	0	0
Pinus strobus	1,6	1	0	0	4,9	5
Pinus sylvestris	6038,9	222	566,4	49	1220	219
Pseudotsuga Menziesii	23,7	3	1,2	1	67,4	29
Taxus baccata	97,1	3	0	0	0	0
Conoferous	**10603,4**	**323**	**630,5**	**62**	**2446,8**	**499**
Aronia melanocarpa	0	0	0	0	0,3	1
Phellodendron amurense	0	0	0	0	2,3	2

continuation of table 3

1	2	3	4	5	6	7
Betula pendula	3,2	1	0	0	26,4	5
Sorbus torminalis	6,1	1	0	0	0	0
Fagus taurica	140,8	7	0	0	15	2
Fagus sylvatica	4298,6	62	83,2	6	1224,1	138
Alnus glutinosa	179,6	25	0	0	49,2	16
Ulmus glabra	2,5	1	0	0	0	0
Gleditsia triacanthos	0	0	0	0	6,4	4
Carpinus betulus	53,8	5	0	0	0	0
Juglans regia	0	0	0	0	45,4	5
Juglans ailantifolia	0	0	0	0	1	1
Juglans nigra	0	0	0	0	33,4	12
Cornus mas	0	0	0	0	4,5	1
Quercus robur	7831,1	250	1364	62	10981	1058
Quercus castaneifolia	0	0	0	0	0,3	1
Quercus rubra	48,7	3	11	1	315,1	114
Quercus pubescens	129	1	0	0	0	0
Quercus petraea	220,4	16	0	0	304,3	22
Castanea sativa	0	0	0	0	6,2	5
Acer platanoides	0	0	0	0	1,5	1
Acer pseudoplatanus	1,8	1	0	0	21,6	3
Corylus colurna	0	0	0	0	15,7	2
Corylus avellana	0	0	0	0	54,6	7
Tilia cordata	0	0	0	0	38,5	10
Tilia platyphyllos	0	0	0	0	0,4	1
Robinia pseudoacacia	10	1	0	0	79,4	19
Arbutus andrachne	196	1	0	0	0	0
Prunus serotina	0	0	0	0	1,3	1
Fraxinus excelsior	192,7	4	0	0	39,3	8
Fraxinus angustifolia	0	0	5,5	1	0	0
Broadleaves	**13314,3**	**379**	**1464**	**70**	**13267,2**	**1439**
Total	**23917,7**	**702**	**2095**	**132**	**15714**	**1938**

4. The number of plus trees by species

Scientific name	Native (N) or Exotic (E)	Plus trees number	
		total	Selected in 2012-2019
1	2	3	4
Pinus sylvestris	N	1330	165
Pinus pallasiana (Pinus nigra ssp. pallasiana)	N	222	43
Pinus nigra (*Pinus nigra ssp. nigra)*	N	44	2
Pinus cembra	N	19	0
Pinus sylvestris ssp. cretacea	N	10	0
Pinus stankewiczii	N	20	0
Pinus strobus	E	31	0
Cedrus libani	E	4	0
Cedrus atlantica	E	11	0

continuation of table 4

1	2	3	4
Cedrus deodara	E	2	0
Picea abies	N	213	3
Larix kaempferi	E	30	0
Larix decidua	N/E	331	51
Abies alba	N	291	58
Pseudotsuga Menziesii	E	138	70
Juniperus excelsa	N	28	0
Populus nigra	N	6	0
Quercus robur	N	1515	330
Quercus petraea	N	209	46
Quercus rubra	E	15	0
Quercus pubescens	N	12	0
Fagus sylvatica	N	190	1
Fagus taurica	N	44	0
Acer platanoides	N	1	0
Acer pseudoplatanus	N	2	0
Ceracus avium	N	1	0
Fraxinus excelsior	N	29	0
Fraxinus lanceolata	E	6	1
Total		4754	770

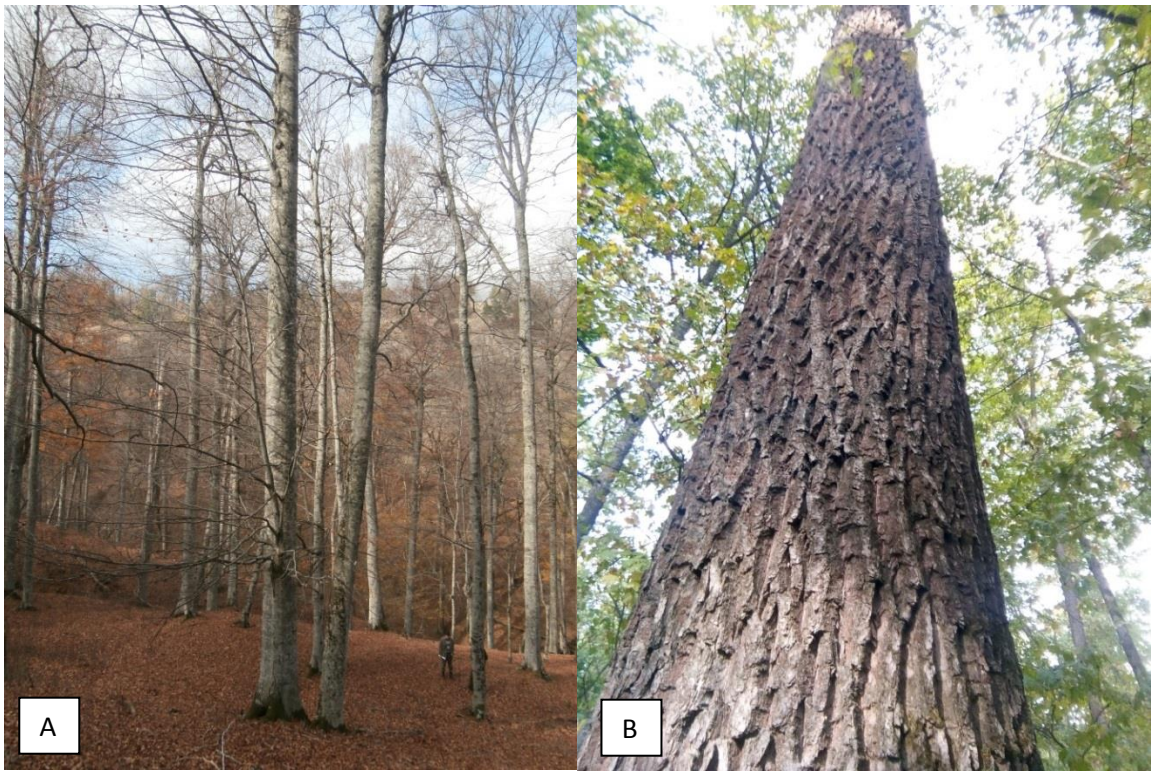

Figure 8. A – *Fagus sylvatica* gene reserve in Krimea, 2013; B – *Quercus robur* plus tree in Kharkiv region, 2019 (photos S. Los)

In Ukraine, a number of regulatory documents have been developed and put into effect, which regulate the implementation of measures for the forest genetic resources conservation, including *in situ*. The most important of them are:

- The concept of conservation and sustainable use of forest genetic resources in Ukraine (2011);
- Regulations on the allocation, conservation and sustainable use of the genetic fund of forest tree species in Ukraine (2012);
- Guidelines on forest seed production (2017).

According to these documents, the recommended area of genetic reserves for the main forest-forming species should be 8-12 ha, for valuable rare and non-native – 5 ha, for relict, endemic and endangered species – not less than 0.5 ha. When selecting reserves, it is also necessary to allocate a buffer zone and a transition zone. The minimum width of the buffer zone is 50 m, and the maximum – 500 m. The transition zone includes artificial stands of the target species, created from planting material of unknown or non-local origin, which are located within the core and buffer zone. It should be noted that in the regulatory documents of the 90s there was a requirement for the allocation of a buffer zone around genetic reserves; however, in practice such allocations were not made everywhere. Not always the boundaries of genetic reserves are marked. In most cases, the on site arrangement of reserves is limited to the installation of information board.

In general, the method of passive *in situ* gene pool cconservation dominates in Ukraine. Namely, the genetic reserve is protected from unauthorized cutting and other types of forest use, and forestry workers monitor the presence of pests and diseases. In cases of trees mortality on the territory of the genetic reserve sanitary fellings are carried out.

Research in genetic reserves is mainly limited to the study of the variability of phenotypic traits. Estimation of the level of allelic variability of the target species in genetic reserves by molecular methods was performed quite rarely. The reason is the lack of genetic laboratories in forest research institutions due to their extremely limited financial capabilities.

For accounting of genetic reserves and plus stands and analyze their distribution, area, structure and growing conditions, the International Forest Biodiversity Institute, with the assistance of the EUFORGEN (European forest genetic resources program), European database EUFGIS was created (http://www.eufgis.org). Ukraine has joined the initiative to create a database that includes basic information on the location and characteristics of *in situ* units. At present, this database is constantly updated, information on the gene pool conservation units of deciduous species of the Right-Bank Forest-Steppe of Ukraine is entered. The information system is currently maintained and developed under the EUFORGEN. (Neyko, 2019) (Fig. 9).

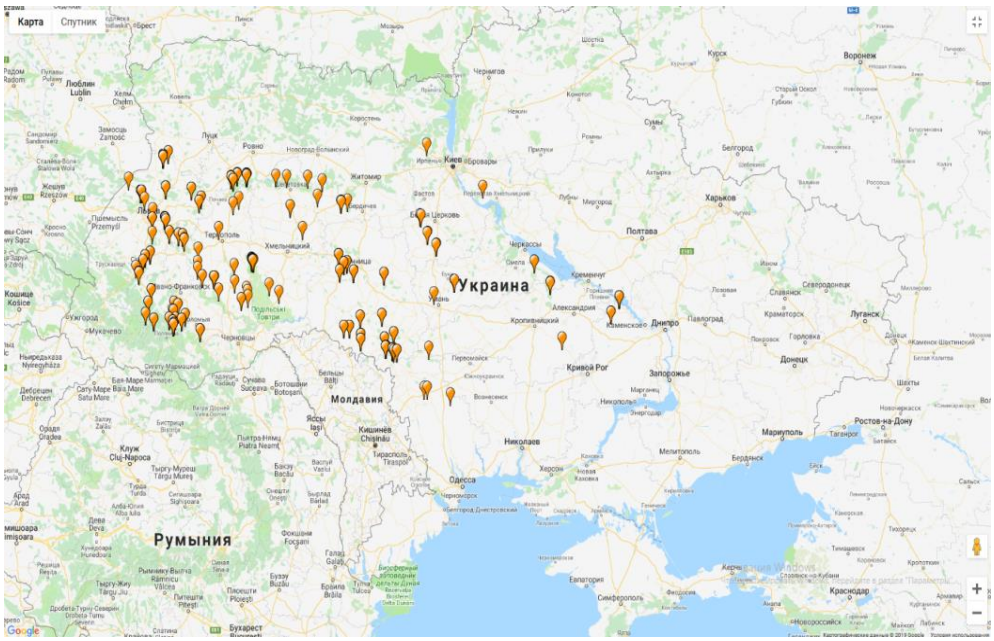

Fig. 9. Forest genetic reserves and plus trees id deciduous trees, Right-Bank Forest-Steppe (http://www.eufgis.org)

The most interested parties on the forest genetic resources conservation, including *in situ* are scientific and educational-scientific institutions: Ukrainian Research Institute of Forestry and Forest Melioration (Kharkiv), Ukrainian Research Institute of Mountain Forestry (Ivano-Frankivsk), educational-scientific institutes (faculties) of forestry of universities in Kyiv, Lviv, Kharkiv. In most cases they are initiators of selection and conservation of units. Forest enterprises are less active in this regard. Their main task is to protect and maintain the functionality of forest genetic reserves. State registration of gene conservation units, including *in situ,* and general control over their state is carried out by the State Organization "Ukrainian Forest Tree Improvement Center" (Boyarka, Kyiv region) through its regional laboratories (Kyiv, Lviv, Uzhhorod, Vinnytsia, Kharkiv). Selection, registration (attestation), write-off, replacement of gene pool conservation units is carried out by attestation commissions, whose members are representatives of all the above-mentioned stakeholders.

The aging of forest gene pool conservation stands is a serious problem in the country. At the same time, the dominant practice is to write-off such unit and select another, not less area. Under such circumstances, all previous research and development loses its weight, and the new object's genetic characteristics may differ significantly from the previous one. Unfortunately, there are no measures to aging units regeneration (natural or artificial).

Significant potential for the *in situ* forest genetic resources conservation of have the objects of natural reserve fund - forest reserves, national nature parks, state reserves, landmarks of nature. It is necessary to assess the forests conditions in such objects and the possibility of allocating areas for gene conservation in them.

The following tasks in the field of forest genetic resources conservation, including *in situ,* remain relevant and a priority:

- selection and creation of new gene pool conservation units in accordance with differentiated strategies for the genetic variability conservation of forest tree species, including not wide spread and shrubs;
- more rational use of gene pool conservation units for tree improvement and seed production purposes;
- creation and maintenance of an electronic database of gene pool conservation units;
- extensive research of genetic variability of forest tree species by modern methods and technologies;
- monitoring and systematic inventory of the state of gene pool conservation units;
- strengthening information activities in society on the importance and need for the genetic resources conservation;
- search and diversification of funding sources for forest genetic resources conservation measures, including *in situ.*

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

Measures for *ex situ* forest genetic resources conservation are regulated by regulations mentioned in the previous chapters: Forest Code (1994), The concept of conservation and sustainable use of forest genetic resources in Ukraine (2011), Regulations on the allocation, conservation and sustainable use of the genetic fund of forest tree species in Ukraine (2012), Guidelines on forest seed production (2017). The guidelines set out the rules on the technology of creation and use of clonal archives, clonal and seedling seed orchards, provenance and progeny tests as units of conservation and reproduction of valuable gene pool. The separate chapters are devoted to the conservation of improved material in collections and genetic banks.

During the last 10 years, " Sectoral forest seed production development programs for 2010-2015" and “Sectoral forest seed production development program for 2016-2020”, which provided for the plus trees selection, new seed orchards and seed stands creation. At the same time, the programs do not provide progeny and provenance tests creation, and there are no systematic measures to identify, conserve and reproduce the valuable gene pool of populations of related species of forest trees.

Among the *ex situ* conservation units in Ukraine there are: 1) field gene banks (clonal archive, seed orchards, provenance and progeny tests; 2) *in vitro* plants banks 3) genetic seed banks.

The oldest in Ukraine provenance tests of Scots pine and English oak were created in 1912 – 1916, the youngest – of Crimean black pine – in 2012. Currently in Ukraine there are 48 provenance tests plots of 16 species, covering an area of 244.4 hectares (Table 5).

Among the most valuable provenance tests there are plots of Scots pine, created by V.D. Ogievsky in 1912-1916, which presents more than 25 geographical origins from Ukraine, Russia, Belarus, the Baltics, Poland. In 1975-76, an all-Union (the former USSR) network of provenance tests was created. In Ukraine 4 plots of Scots pine provenance tests, which presents 45 origins of the former USSR (1 in Polissya, 1 in the Carpathian region, 2 in the Steppe) were carried out under guidance of I. M.Patlay. One of the sites was surveyed in 2020. Among the valuable units of geographical crops of introduced species are the of yellow pine and Blu spruce in the Kharkiv region and the geographical cultures of cedar pines in the Carpathians.

The clonal archives of pine of different geographical origins are established both by grafting on special rootstock and by planting grafted seedlings with a closed root system. The oldest clonal archive was created in 1964.

Table 5. Provenance tests and clonal archives of different geographic origin

Scentific name	Native (N) or Exotic (E)	Provenance tests		Clonal archives	
		Number	Area, ha	Number	Area, ha
Pinus sylvestris	N	18	155,6	4	4,2
Pinus pallasiana (Pinus nigra ssp. pallasiana)	N, E	1	0,5	1	0,5
Pinus sibirica	E	1	9,2	0	0
Pinus korainsis	E	1	1,8	0	0
Pinus pumila	E	1	2,6	0	0
Pinus ponderosa	E	2	3,8	0	0
Larix decidua	N	2	1,5	0	0
Larix x *czekanowskii*	E	2	0,7	0	0
Larix sibirica	E	2	0,8	0	0
Picea pungens	E	1	1,95	0	0
Picea abies	E	1	2,0	0	0
Juniperus virginiana	E	2	0,4	0	0
Quercus robur	N	11	57,15	0	0
Fagus sylvatica	N	1	4,2	0	0
Fraxinus excelsior	N	1	2,2	0	0
Fraxinus oxycarpa	N	1	0,04	0	0
Total		**48**	**244,44**	**5**	**4,7**

Work on the conservation of plus trees on clonal archives, clonal and seedling seed orchards, as well as testing of their progenies began in Ukraine in the 50s of the XX century.

As of January 1, 2020, in the country there are 37 clonal archives with an area of 71 hectares. At the largest Scots pine clone bank, located in Kyiv region clones of 511 plus trees from Polissia and Forest-steppe zones are represented.

During 2010-2020, the clonal archives of forest tree species were not established, although 770 plus trees (Scots and Crimean pines, English and Sessile oaks, and Larch) were selected. Selection was carried out mainly in forestry enterprises of the Steppe zone, plus trees are not vegetative propagated and are not tested by progenies due to the difficult economic situation of forestry enterprises. The decrease of Scots pine clone archives number is due to the aging of trees and their mortality. Some plots was written off or not certified, some was transferred to another category of forests.

For conservation, comprehensive study and use of plus trees selection material of forest- forming tree species about 1.2 thousand hectares ha of seed orchards have been created of which 80.5% have been certified (fig. 10).

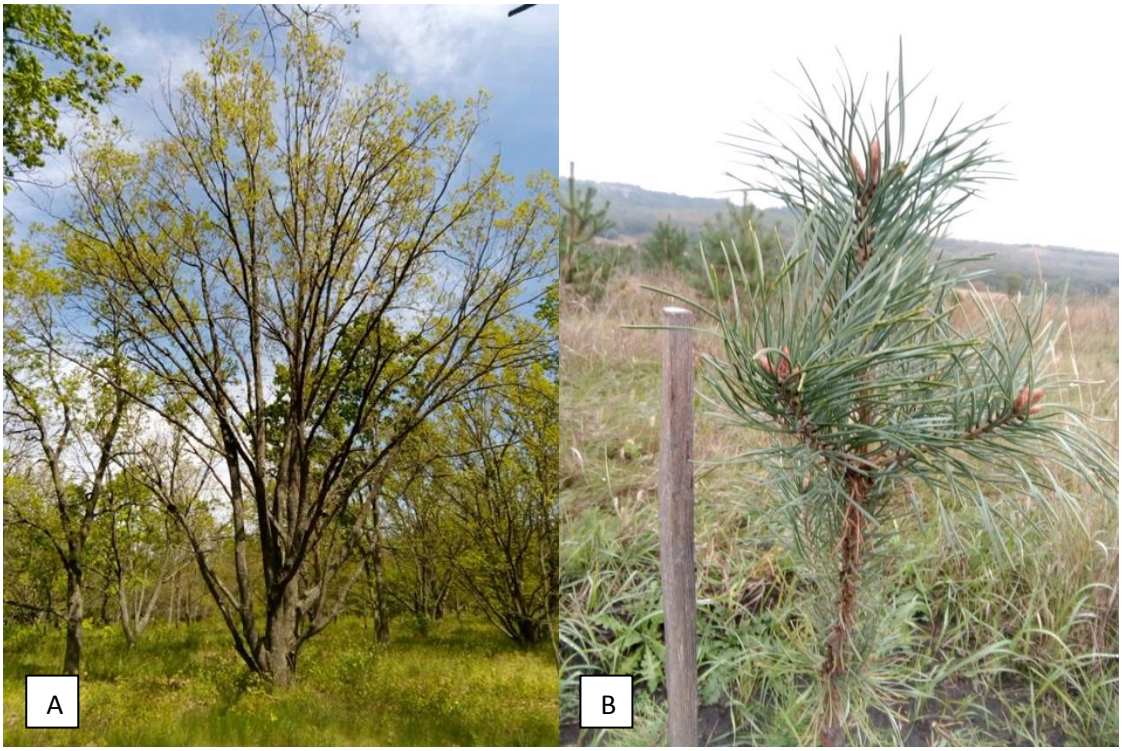

Figure 10. Clonal seed orchards:
A – 40-year old cloal seed orchards of *Quercus robur* in Kharkiv region, 2019 (photo S. Los);
B – 3-years old grafterd planf of *Pinus sylvestris* in Kirovograd region, 2018 (photos L. Tershchenko)

Yielding ability, seed quality, and heritability are the main criteria for the effectiveness of the seed orchards. In Kyiv region, the Scots pine clonal seed orchard (CSO) with 400 trees per ha at the age of 11–15 years-old may produce from 8.8 to 12.0 kg of seeds per ha. At the age of 20–25 years, with the quantity of 200 trees per ha, the seed yield reaches 17.8–18.2 kg per ha. The production potential of the best clones at the age of 20 years can reach even 36 kg per ha. (Shlonchak & Shlonchak, 2009).

In the early 90s, the CSO of Scots pine and European spruce of Finnish origin were established in the area of 5.0 ha in the Vinnytsia region (Neyko et al. 2016).

As of 01.01.2020, there are 118 plots of progeny test of 8 forest species in the country, which cover an area of 165.5 hectares (Table 6). Among them 7 plots of progeny test of Scots pine, English oak and Douglas fir with an area of 3.6 hectares was created in 4 regions of Ukraine during the last decade. Among the most valuable there is the oldest progeny test of Scots pine (1962), where 28 the best trees were selected and vegetatively propagated (Tereshchenko, 2011).

In general, 77% of plus trees of Scots pine and 36% of English oak are represented on clonal archive and seed orchards (Fig. 11). So, for example, from 106 registered in Kharkiv region plus trees of an English oak 50 are presented on seed orchards, and from 126 registered in Vinnytsia region –30. In other regions indicators are lower. Therefore, forestry enterprises spend money on their selection but do not use them properly.

Currently, 40% of plus trees of Scots pine and 24% of English oak are tested for progenies (see Fig. 11). Testing of plus trees of Crimean pine, White fir and Sessile oak is limited. Thus, only 7% of plus trees of European spruce are tested for progenies. Progeny tests of other species, including larch and beech, are absent.

6. Progeny tests and clonal archives

Species		Progeny tests		Clonal archives	
scientific name	**native (N) or Exotic (E)**	**Number**	**Area, ha**	**Number**	**Area, ha**
Pinus sylvestris	N	81	111,1	9	20,4
Pinus pallasiana (Pinus nigra ssp. pallasiana)	N	4	13,6	1	6,4
Picea abies	N	1	0,5	-	-
Quercus robur	N	28	36,5	8	17,2
Quercus petraea	N	1	2	-	-
Juglans regia	E	-	-	3	10,5
Corylus avellana	N	-	-	3	4,5
Fraxinus excelsior	N	1	1	-	-
Gleditsia triacanthos f. inermis	E	-	-	2	3,74
Robinia psevdoakacia (mast form)	E	-	-	3	4,36
Populus ssp	N	1	0,3	8	3,9
Betula pendula var. carelica	E	1	0,5	-	-
Total		**118**	**165,5**	**37**	**71,0**

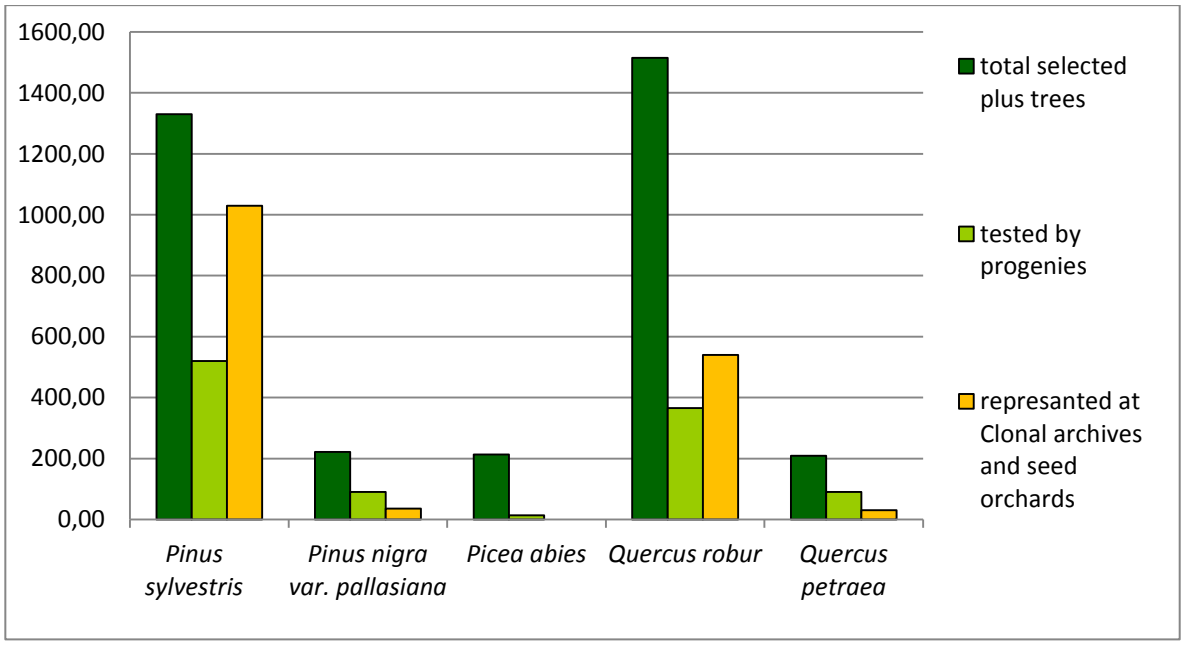

Fig. 11. Representation of plus trees on clonal archive and progeny tests

Aboriginal and non-native species, which are not widespread in the country (about 10–12%) (Sixth National Report, 2018), are conserved in botanical gardens, arboretums, in the collection plots of higher education institutions, research institutes, research stations in the field of forestry and medicinal plants, green farms. For example, the plant collection of the “Sofiyivka” National Arboretum includes 1,911 taxonomic units of tree and shrubby plants. The collection of the State Arboretums “Trostyanets” includes 467 species of trees, 431 – shrubs, 3 – semi-shrubs, 17 – lianas. The collection fund of the arboretum

"Alexandria" of the National Academy of Sciences of Ukraine includes more than 2632 taxonomic units of tree species, including 244 taxa of conifers (http://logos-ukraine.com.ua/project/nued5/s2.pdf).

According to the results of the inventory of *ex situ* conserved dendroflora species of different administrative regions and natural zones of Ukraine (Polissya, Forest-Steppe and Steppe) conducted by National University of Life and Environmental Sciences of Ukraine (NULES) scientists in 2014 - 2019, a list of tree and shrub species of different conservation status in protected parks of Ukraine (botanical gardens, parks-monuments of garden and park of landscaping art) of autochthonous and introduced dendroflora was draw up [Savoskina, 2019; Vlasenko & Popovych, 2016; Stepanenko & Popovych, 2015).

An effective form of species biodiversity conservation is the gene banks creation. The Institute of Cell Biology and Genetic Engineering (ICBGI) in Kyiv has created a collection of germplasm of plants of Ukraine's and world's flora, which has a seed bank of about 5,000 specimens (more than 130 families) and more than 2,000 cell lines in *in vitro* cell culture bank. The collection consists mainly of wild species, among which a separate part is occupied by protected species in different regions of the world, and endemic species. In 1999, the collection was included in the list of objects that make up the national scientific heritage (http://logos-ukraine.com.ua/project/nued5/s2.pdf). The National Genetic Bank (The Plant Production Institute nd. a. V. Ya. Yuryev, Kharkiv) presents more than 200 samples of forest trees and ornamental plants (Lytvynchuk, 2015). There is no especial genetic bank of forest seeds in Ukraine yet, as well as the state reserve fund of forest seeds. In case of a barren year, some large state forestry enterprises (in particular the Lviv Forest Breeding and Seed Center) have a three- to five-year seed supply. In forestry enterprises, the seeds reserve fund of the main forest-forming species is usually in the amount of one- or two-year needs of the enterprise.

In addition to seed banks and live collections, the *ex situ* forest gene pool conservation is carried out using *in vitro* cultivation and cryopreservation. At present, biotechnological laboratories operate in Ukraine at research institutions and private organizations, but only a small number of them study the application of *in vitro* technologies for effective cloning of forest tree species, especially aged ones.

The Research Laboratory of Plant Biotechnology of NULES "Boyarska Forest research station" is developing the latest methods for obtaining virus-free planting material, including forest tree species. There is a *in vitro* plants collection, which is represented by forest-forming tree species (English oak, Norway spruce, Small leaved lime, aspen, etc.), ornamental plants for landscaping and living quarters; fast-growing species of forest trees for bioenergy; plants listed in the Red Book of Ukraine in the status of rare and endangered; berry species. The laboratory's own bank of plants includes 40 species and more than 160 varieties (https://nubip.edu.ua/node/32255/1).

In URIFFM works on microclonal propagation have been carried out for almost 20 years. During this time, micropropagation of *Quercus robur*, *Picea* spp., *Populus* spp., *Fraxinus exelsior*, *Larix decidua, Sorbus domestica, Cerasus avium, Betula pendula var. carelica* was conducted. Work is underway to reproduction methods of tree species improve, testing of plants propagated by microcloning in open ground.

In UNFU experimental researches are held on *Pinus sylvestris* L., *Larix decidua* Mill., *Abies alba* Mill., *Pisea abies* (L.) Karsten reproduction by microcloning (Lisovy& Guz, 2017).

The Laboratory of Plants Microclonal Propagation of the "Sofiyivka" National Arboretum has developed a full cycle of technological methods of micropropagation from *in vitro* introduction to *ex vitro*-adapted planting material *Corylus* L., *Crataegus* L., *Malus* Mill., *Pyrus* L., *Cercis* L., *Sorbus* L., *Tsuga canadensis* (L.) Carrière, *Diospyros virginiana* L. and others (Kosenko, 2018).

Ex situ conservation activities are supervised by SFRAU and closely linked to forest seed production. The study and creation of *ex situ* gene pool conservation and seed production units of forest tree species for direct conservation of certain micropopulations and genotypes outside natural range, intended for reproduction of forests (clonal and seedling seed orchards) and progeny testing (progeny and provenance testing) are carried out by research institutions - URIFFM, URIMF and their subdivisions. Research covers dendrological collections created with the participation of scientists and located on the territory of these institutions or their subdivisions.

The activity of *ex situ* gene pool conservation of tree species in botanical gardens and arboretums is supervised by the Council of Botanical Gardens and Arboreta of Ukraine (CBGAU) at the Department of General Biology of the National Academy of Sciences of Ukraine. Council solves a wide range of issues, in

particular (Zaimenko, 2019): makes legislative initiatives and proposals to various branches of government on the protection and conservation of botanical gardens and arboretums collections; organizes work on creation of the uniform database of collection funds of these institutions; implements measures for the protection of rare, endangered and endemic plant species.

The current needs and challenges of improving *ex situ* conservation of forest genetic resources are:

• insufficient involvement of professional specialists in making policy decisions on *ex situ* gene pool conservation units;

• insufficient state funding for *ex situ* conservation of genetic resources of, in particular forestry enterprises, botanical gardens and environmental protection institutions;

• unsystematic monitoring (inventory) of the conditions of forest species gene conservation units;

• insufficient representation of plus trees in progeny and provenance tests, in the clonal archives, lack of genetic banks of forest seeds;

• the complexity of creating and management of units on the lands of different land users and different forms of ownership;

• problems with the adjustment of measures for the units care, collection of samples and research carrying out at units;

• lack of laboratories for molecular genetic research in scientific institutions of forestry profile;

• insufficient use of vegetative propagation methods of forest genetic resources of valuable species and forms, in particular *in vitro*;

• insufficient use of GIS technologies in the accounting of clonal archives and other units of preservation of the gene pool *ex situ* with the gradual formation of the database.

Priorities for capacity building and research are as follows:

• Involvement of professional specialists in making political decisions on *ex situ* gene pool conservation units;

• providing state funding for genetic resources ex situ conservation of, in particular forestry enterprises, botanical gardens and environmental protection institutions;

• ensuring periodic monitoring (inventory) of the conditions of forest species gene conservation units;

• expansion of the network of plus trees in progeny and provenance tests, in the clonal archives, genetic banks of forest seeds;

• search for opportunities of creating and mangements of units on the lands of different land users and different forms of ownership, subject to compliance with certain environmental requirements;

• mandatory adjustment of measures for the care of units, created on the initiative and with the participation of research institutions with these institutions;

• mandatory adjustment of sample collection and research at units, established on the initiative and with the participation of research institutions with these institutions;

• simplification of the procedure on approval of permits for conducting scientific research by forestry scientists and procurement of samples at NRF objects of another subordination;

• organization of laboratories of molecular genetic research in scientific institutions of forestry profile;

• further improvement of methods of forest genetic resources reproduction of valuable species and forms, in particular *in vitro*;

• wider use of GIS technologies in the accounting of clonal archives and other units of the gene pool *ex situ* conservation with the gradual formation of a database.

PART 4: STATE OF USE, DEVELOPMENT AND MANAGEMENT OF FOREST GENETIC RESOURCES

Chapter 8. The state of use of forest genetic resources

The state and procedure for the use of forest genetic resources in Ukraine is regulated by the legal document “Forest Seed Management System” and new edition of the “Guidelines for forest seed production” (2017). According to this document, activities on forest seed production should be based on the following priority principles:

- conservation and reproduction of the valuable gene pool of local natural populations;
- effective use of seed production units, valuable hybrids and varieties;
- abidance of forest seed zoning when moving of the reproductive material;
- cultivation of non-native species in limited areas and only in the case of their reasonable advantages by certain characteristics over local populations of indigenous species;
- use of seeds with high sowing quality;
- use of the improved seeds, mainly for the creation of forest plantations.

In 2019, the Ukrainian Forest Breeding Center developed a draft Law of Ukraine “On Forest Reproductive Resources”, which aims to determine the basic principles and conditions of production, marketing and use of forest reproductive material. The law aims to implement the provisions of Directives 1999/66/EC, 1999/105/EC 2006/123/EC regarding the fulfillment of the terms of the Ukraine–European Union Association Agreement of September 16, 2014 and further prospects of accession to the EU. The adoption of the law will make it possible to regulate the use and conservation of forest genetic resources for certain species of forest trees and shrubs under Directive 1999/105 / EC and in accordance with those adopted under the Forest Seed Management System (1996) for forestry in Ukraine. This will provide an opportunity to improve and adopt new programs on forest tree improvement and seed production in the country, as well as to optimize the needs and opportunities for the use of forest genetic resources in the forest sector.

In 2020, the Ukrainian Forest Seed Center is developing a bylaw - a new version of the "Forest Seed and Nursery System", as well as completes work on state standards for technical conditions for seeds of trees and shrubs, trees and shrubs seedlings that regulate certification of forest seeds and planting material and ensure the development of compliance of forest reproductive material and its introduction into circulation.

Forest genetic resources are used in Ukraine for reforestation and afforestation. According to the SFRAU data in 2019, using the potential of forest genetic resources, reforestation was carried out on an area of 42.0 thousand hectares (including 14.4 thousand hectares to ensure reliable natural regeneration), and afforestation - on an area of 2.2 thousand hectares.

The scope of work on reforestation and afforestation is determined on the basis of forest management materials or a special observation, taking into account the actual changes in the forest fund of Ukraine and the condition of lands subject to afforestation. Reforestation is carried out in ways that ensure the creation of highly productive forests of economically valuable tree and shrub species [Rules of forest reproduction].

The dynamics of reforestation and afforestation for 2011 - 2019 (Fig. 12) shows that reforestation rates ranged from 39.2 thousand hectares in 2011 to 51.5 thousand hectares in 2017 and averaged 44.4 thousand hectares. The largest volumes of reforestation were noted in the period 2015 - 2017. Indicators of afforestation (creation of new forests) over the last decade averaged 7.8 thousand hectares (from 1.7 thousand hectares in 2017 to 22.3 thousand hectares in 2011). In general, there is a tendency to gradually reduce the area of new forests in the reporting period. During the last five years, these figures decreased to 1.9 (2018) - 2.6 thousand hectares (2016). It should be noted that the vast majority of afforestation plots are located in the steppe and forest-steppe parts of the country, where forests perform mainly ecological functions. One of the reasons for the decline is a significant reduction in budget funding, which, in turn, affected primarily the steppe and forest-steppe forests, whose activities are low-profit.

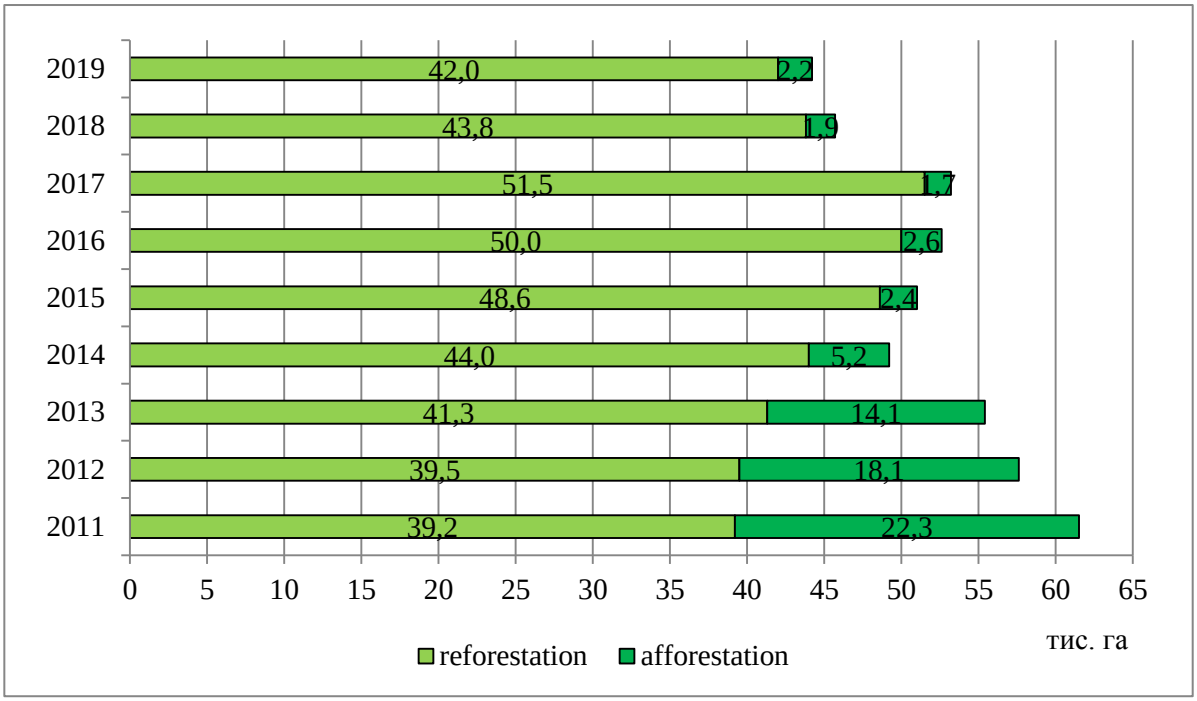

Fig. 12. Volumes of reforestation and afforestation for 2011 - 2019 (Forestry of Ukraine, 2019)

In 2019, 264,606.5 thousand standard seedlings were used to create artificial forest stands (Table 7). The vast majority of coniferous planting material (more than 80%) is represented by Scots pine. The share of other species does not exceed 10%. Thus, the share of planting material of Norway spruce is on average 6.3%, Black pine – 2.5%, White fir 2.3%, Larch – 1.4%. Among deciduous species, more than half (54.8%) of planting material is represented by English and Sessile oaks. The share of Northern red oak is 14.0%. The share of other species does not exceed 10% (Black locust - 6.1%, Maples - 4.6%, Birches - 4.0%, Common ash - 3.4%, European beech - 2.8%).

7. Number of standard seedlings grown in 2015-2019 (thousand pieces)

Scientific name	**Years**					**Average**
	2015	**2016**	**2017**	**2018**	**2019**	
1	2	3	4	5	6	7
Pinus sylvestris L.	177024,3	178936,8	192784,2	153580,6	143556,2	**169176,4**
Pinus nigra ssp. Pallasiana (Lamb.) Holmboe.	12054,0	5372,3	35576,0	1773,9	2066,1	**4964,6**
Picea ssp.	9506,9	11344,2	12690,7	13868,3	14002,2	**12282,5**
Abies alba Mill.	5280,6	4100,4	5227,9	4507,5	3033,5	**4430**
Larix ssp.	984,3	2814,3	3244,3	3441,3	3052,6	**2707,3**
Tuja ssp.	85,8	58,6	17,4	26,2	24,2	**42,4**
Juniperus ssp.	28,0	19,7	19,5	6,5	3,9	**15,5**
Other Coniferous	200,9	166,0	381,1	552,4	432,4	**346,6**
Total Coniferous	**205165**	**202812**	**217922**	**177757**	**166171**	**193965,3**
Quercus robur L. and *Quercus petraea* Liebl.	31369,3	40838,4	30519,2	31778,0	58964,8	**38694,0**
Quercus rubra L.	11031,1	5576,5	12420,5	12828,0	7756,0	**9922,4**
Fraxinus excelsior L.	3734,7	2660,4	2407,3	1634,6	1497,2	**2386,9**
Fagus sylvatica L.	2275,1	2422,7	2408,7	1646,7	1173,7	**1985,4**
Tilia ssp.	1013,1	1048,4	853,7	685,1	685,0	**857,1**

continuation of table 7

1	2	3	4	5	6	7
Acer ssp.	3461,4	3694,5	3611,7	2871,5	2738,6	**3275,5**
Betula ssp.	1851,2	1551,7	3000,2	3869,8	4021,7	**2858,9**
Juglans ssp.	1241,3	938,7	1044,2	1168,6	1283,2	**1135,2**
Populus ssp.	10,0	16,4	25,9	8,7	13	**14,8**
Salix ssp.	0	0	0	6,0	0	**1,2**
Alnus ssp.	1346,2	891	771,2	1054,5	747,5	**962,1**
Robinia pseudoacacia L.	6691,9	4747,4	3204,2	2731,4	4292,0	**4333,4**
Gleditsia triacanthos L.	1371,4	666,6	156,3	171,4	94,7	**492,1**
Carpinus betulus L.	18,1	8	15	36,2	6,02	**16,7**
Ulmus ssp.	208,4	167,5	19,6	52,9	89,3	**107,5**
Morus alba L.	89,7	10	19,6	5,1	4,9	**25,9**
Sorbus ssp.	112,6	108,4	110,7	75,9	87,2	**99,0**
Malus sylvestris Mill.	376,3	339,3	292,2	264,5	248,5	**304,1**
Pyrus communis L.	418,0	596, 8	440,2	548,1	486,1	**497,9**
Prunus ssp.	2503,5	2388,1	1437,4	1381,3	1210,9	**1784,2**
Other broadleaves	1317,2	1319,6	741,8	459,8	596,6	**887,0**
Total Broadleaves	**70440,4**	**69990,4**	**63499,7**	**63278,4**	**85996,9**	**70641,1**

The seed of more than 130 species of trees and shrubs, including ornamental, are harvested annually in Ukraine. In the period from 2011 to 2019, the annual weight of harvested seeds ranged from 682.5 thousand kg (2019) to 1407.8 thousand kg (2018). The annual volumes of harvest seed depend on both the planned volumes of the required planting material and the weather conditions of the year. Thus, the low rate in 2019 is related with poor seed yields of many species due to prolonged drought (Table 8). 2018, on the contrary, was favourable, which was reflected in the amount of harvested seeds.

8. Dynamics of forest tree seed harvesting volumes in Ukraine in 2011-2019

Years	**Total amount of harvested seeds, kg**	**Amound of seeds harvested from seed production units, kg**	**Part os seed harvested from seed production units, %**
2011	1007843	255248	25,3
2012	1130408	384795	34,0
2013	977776	310400	31,7
2014	479592	127781	26,7
2015	955204	374594	39,2
2016	690626	228486	33,1
2017	7207854	264409	36,7
2018	14077854	555771	39,5
2019	682526	249122	36,5
Середнє	3023298,1	305622,9	33,6

More than 50 species of forest trees are used in forestry (Table 9). Seeds of species distributed only on the Crimean Peninsula (*Quercus pubescens* Willd., *Amygdalus communis* L., *Pinus stankewiczii* (Sukaczev) Fomin and *Fraxinus ornus* L.) have not been harvested since 2014.

9. Volumes of obtained seeds of forest species used in forestry of Ukraine in 2019

№	Species		Total amount of seeds, kg	Amound of seeds from seed production units, kg
	scientific name	Native (N) or Exotic (E)		
1	*Betula pendula* Roth	E	771	4
2	*Sorbus torminalis* (L.) Crantz	N	26	0
3	*Fagus sylvatica* L.	N	727	77
4	*Alnus glutinosa* (L.) P.Gaertn.	N	196	10
5	*Ulmus glabra* Huds.	N	5	0
6	*Ulmus parvifolia* Jacq.	E	50	0
7	*Aesculus hippocastanum* L.	E	6110	0
8	*Gleditsia triacanthos* L.	E	456	55
9	*Juglans regia* L.	E	4633	0
10	*Juglans mandshurica* Maxim.	E	152	0
11	*Juglans cinerea* L.	E	720	0
12	*Juglans nigra* L.	E	65627	8448
13	*Sorbus aucuparia* L.	N	26	0
14	*Carpinus betulus* L.	N	3	0
15	*Pyrus communis* L.	N	162	0
16	*Cornus mas* L.	N	95	0
17	*Quercus robur* L.	N	451750	224217
18	*Quercus rubra* L.	E	71135	12505
19	*Quercus petraea* Liebl.	N	3196	394
20	*Castanea sativa* Mill.	E	391	70
21	*Acer platanoides* L	N	951	0
22	*Acer pseudoplatanus* L.	N	1299	135
23	*Acer saccharinum* L.	E	69	0
24	*Acer tataricum* L.	N	196	0
25	*Acer negundo* L.	E	15	0
26	*Tilia platyphyllos* Scop.	N	611	30
27	*Tilia cordata* Mill.	N	899	0
28	*Larix decidua* Mill.	M/I	275	138
29	*Robinia pseudoacacia* L.	E	2840	210
30	*Prunus domestica* L.	N	77	0
31	*Prunus spinosa* L.	N	30	0
32	*Prunus divaricata* Ledeb.	E	512	0
33	*Pinus sylvestris* L.	N	8300	2258
34	*Pinus pallasiana* D. Don *(Pinus nigra ssp. pallasiana)*	N	680	214
35	*Sophora japonica* L.	E	14	0
36	*Chaenomeles japonica* (Thunb.) Lindl.	E	48	0
37	*Padus avium* Mill.	N	13	0
38	*Padus serotina* (Ehrh.) Ag.	E	121	0
39	*Cerasus avium* (L.) Moench	N	744	0
40	*Malus sylvestris* Mill.	N	104	0
41	*Picea abies* (L.) H.Karst.	N /I	528	136
42	*Abies alba* Mill.	N	897	140
43	*Juniperus virginiana* L.	E	14	5
44	*Fraxinus excelsior* L.	N	1060	5
45	*Fraxinus lanceolata* Borkh	E	526	0
46	Other		55472	71

The share of seeds harvested from seed production units ranged from 25.3% in 2011 to 39.5% in 2018. There is a tendency to increase the volume of seeds harvested from seed production units. Unfortunately, current reporting does not provide for the distribution of seeds by harvesting units. The volume of seeds harvesting of certain species varies slightly over the years, due to the biological properties of the species and weather conditions. Thus the share of improved seeds of the main forest-forming species, according to the Ukrainian Forest Breeding Center is on average 22.1% for Scots pine and 15.8% for Norway spruce, 32.4% for White fir, 42.5% for English oak, and 27.6% for European beech. (Fig. 13).

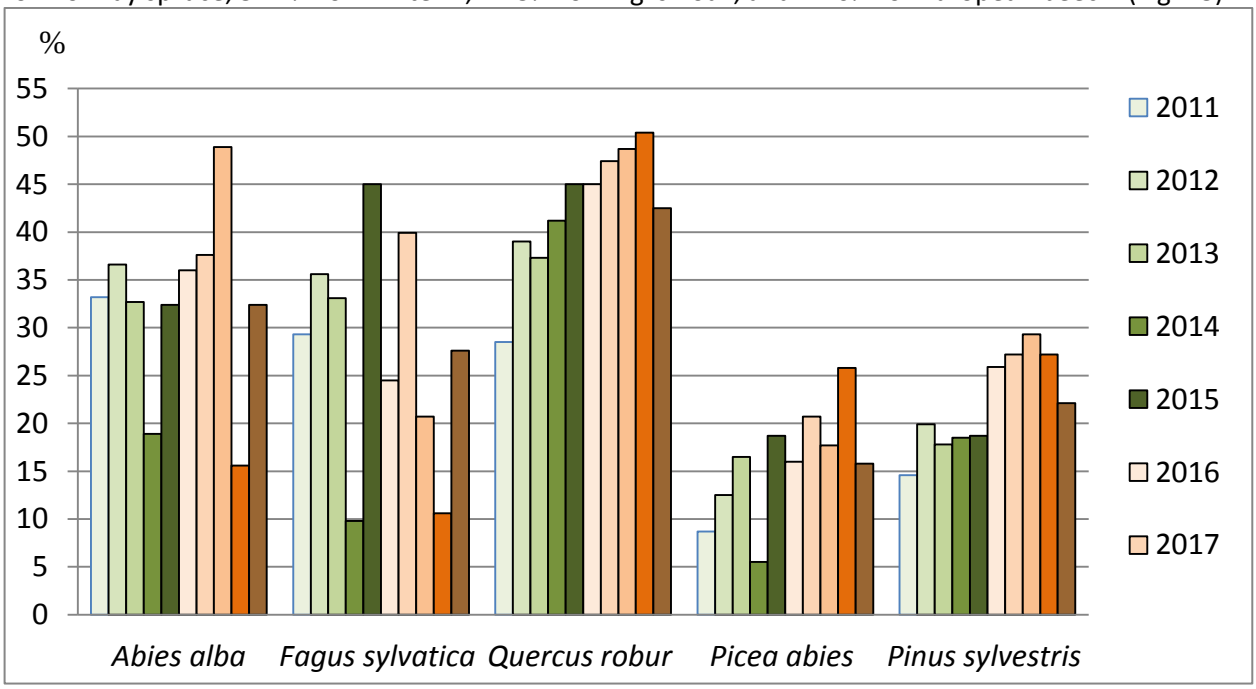

Fig. 13. Dynamics of seed harvesting of the main forest-forming species (2011-2019)

All forest reproductive material intended for use in forestry is inspected for origin, quality, which is determined by the Ukrainian Forest Seed Center and its separate subdivisions – 7 regional forest seed laboratories. Information about the origin of the seeds is fixed in journals and cards. Sowing qualities of seeds are determined by analyzing the average sample in accordance with current state standards. This determines the moisture content, purity of the seeds, the weight of 1000 seeds, germination energy and germination (or viability or good quality), infection by diseases and pest damage (Guidelines, 2017). Thus, in 2019, zonal forest seed laboratories analyzed 4022 samples from batches of forest seeds of 408 enterprises, including 300 enterprises of the SFRAU and 108 organizations of other departments.

Ukraine does not import or export forest reproductive material. The sale and purchase of seeds and planting material takes place between forestry enterprises within the forest seed zoning of the country and is regulated by the "Forest Seed Management System" (1996).

Needs, challenges and opportunities related to the use of forest genetic resources:

• imperfection and insufficient level of compliance with existing legislation on the use of forest genetic resources;

• imperfect reporting system for seeds harvested (does not distinguish between types of seed orchards and often provides for the differentiation of seeds only by genus and not by species);

• insufficient volumes of seeds harvesting from gene pool conservation units, in particular, the inefficient use of seed production units.

• insufficient volumes of seed harvesting from CSO of higher levels, which is due to insufficient volumes of work on plus trees progeny testing.

• lack of conditions for long-term storage of seeds at regional level;

• zonal forest seed laboratories need re-equipment, use of more modern equipment and opportunities to use more modern seed analysis methods, including molecular genetic;

• insufficient attention is paid to research on forest tree improvement and gene pool conservation and use.

Priorities for capacity-building of use and research in this area are as follows:

• completion, development and implementation of laws and recommendations on the use of forest genetic resources;

• improving the reporting system for volume of seeds harvesting, taking into account the types of seed orchards and forest tree species;

• increasing the volume of seed production from the gene pool conservation units, increasing the efficiency of seed production units, the use of methods to stimulate fruiting on them;

• intensification of work on plus trees progeny testing not only by biometric, morphological, anatomical and cytological methods, but also with DNA markers and other modern methods;

• increase in the area of CSO of higher level with the involvement of elite tree clones for their creation;

• providing conditions for long-term seeds storage, creation of a gene bank of seeds of forest tree species;

• re-equipment the zonal forest seed laboratories, creating opportunities for the application of new methods, in particular molecular genetic;

• increasing attention to research on forest tree improvement and gene pool conservation and use.

Chapter 9. The state of genetic improvement and breeding programmes

The main approaches used in forest tree improvement in Ukraine are the selection of the best individuals and populations in natural and artificial stands and their testing by progenies. Creation of CSO and SSO is carried out both with the use of plus trees selected by phenotype (level I) and by the results of their progenies testing (level 2). The best populations are given the status of plus stands. Work is underway to selection of the best ecotypes in provenance tests, as well as on interspecific and intraspecific hybridization and I-III generations hybrids testing. The most promising individuals and populations that have shown significant advantages over control when tested by progenies are given the status of the variety and included to the State Register of Varieties.

Selection and assessment of improved material is carried out on the basis of: indexes of growth intensity (height, diameter, average annual increment by height and diameter), condition, straightness and form-adjusted solid volume of the trunk. Reproduction intensity, resin productivity, biochemical, cytological, anatomical and morphological characteristics are used as additional features (Methods of varietal testing of forest trees, 2019). Morphological characteristics of vegetative and reproductive organs are used for identification of plus trees and their clones (Los & Smashnuk, 2020). The results are processed using the methods of quantitative genetics and statistics.

The research is carried out at stationary tree improvement and silviculture units in different natural zones of Ukraine. Attention is paid to the main forest-forming aboriginal species: *Pinus sylvestris* L., *Picea abies* L., *Abies alba* Mill., *Quercus robur* L., *Quercus petraea* L., *Fagus sylvatica* L., as well as non-native species of genera *Pinus, Larix, Pseudotsuga, Juniperus, Juglans, Corylus, Caria, Cedrus* and hybrids of genera *Pinus, Larix, Quercus, Populus, Salix, Juglans, Corylus.*

Customers of budget research on forest tree improvement in Ukraine are State Forest Resources Agency of Ukraine (http://dklg.kmu.gov.ua) and the National Academy of Sciences of Ukraine (http://www.nas.gov.ua). The research is carried out mainly by the laboratory of tree improvement of URIFFM (https://uriffm.org.ua), laboratory of reforestation and tree improvement of the URIMF (http://ukrrimf.org.ua/uk/golovna-2) and by research stations and departments of these institutes. Each project is worked out for 5 years. Table 9 provides a list of budget projects on tree improvement in 2010 - 2024.

The project № 7 was devoted to the conservation and reproduction of forest gene recourses. During the period of 2010-2014, the genetic reserves of Scots pine, English oak, Sessile oak and Crimean

beech in 5 regions of Ukraine and in the Autonomous Republic of Crimea were observed. The method of genetic reserves condition assessing has been improved.

9. List of research projects on tree improvement, developed during the last decade in Ukraine

Project number	Project name	Years	Institu-tion	Project manager
7	Forest genetic resources conservation and getting of genetically improved reproductive material for forest stands and bioenergy plantations	2010-2014	URIFFM	Roman Volosyan-chuk (2010–2011), Svitlana Los (2012–2014)
14	To develop improved recommendations for the formation and exploitation of forest seed base in current conditions on the basis of population and plus tree improvement	2010-2014	URIFFM	Svitlana Los (2010–2011), L.I. Larisa Tereshchenko (2012–2014)
23	To analyse the current state of clonal forest seed production in the Carpathian region and develop the recommendations for its effective use and creation of seed orchards of higher genetic level	2010-2014	URIMF	Roman Jatsyk
13	To develop scientific approaches to obtaining, propagating and studying promising forms and varieties of forest trees species to create the forest stands for different purposes	2015-2019	URIFFM	Svitlana Los
12	To develop program-targeted methods of reforestation on cutting areas by using aboriginal and non-native tree species and genetic tree improvement achievements in the Carpathian region	2015-2019	URIMF	Yury Katsylyak
4	To improve the methodological approaches to the selection and assessment of improved material of native and non-native forest tree species based on the study of their intraspecific variability and adaptive response, including climate change	2020-2024	URIFFM	Svitlana Los
17	To study the effectiveness of reforestation in the Carpathian region on the basis of tree improvement and introduction	2020-2024	URIMF	Yury Katsylyak

According to study of 10 provenance tests plots of Scots pine, English oak, Yellow pine, Blue spruce and European beech promising origin for regional conditions were revealed. The adaptability of non-native species (*Larix ssp., Pseudotsuga Mensiesii* and *Corylus colurna* L.) was studied in arboretums, experimental and forest stanfs. The hybrid plants from the best individuals of the genera *Pinus, Quercus* and *Corylus* were obtained as results of work, the pollen viability of these species was studied and methodological approaches to the study of variability of *Quercus and Corylus* species by morphological characteristics of reproductive organs was proposed.

About 50 clones of *Populus* were propagated and clonal collection was created. Variety testing of poplars for the bioenergy needs were created and observed. The level of mitotic activity of cells in the roots of grafts of 6 poplar clones was studied.

The research on elaboration of *in vitro* methods of reproduction of plants of *Populus, Quercus, Corylus, Sorbus* genera was continued. “Improved methods of in vitro reproduction of valuable species and hybrids of forest tree species” were proposed as a source document by the research findings.

During the study of the project № 14 the partly inventory of plus trees of *Pinus sylvestris, Pinus pallasiana Pinus strobus, Larix sibirica, Larix decidua, Quercus robur* and *Quercus petreae* was conducted in 5 regions of Ukraine and Crimea. An additional selection of about 800 plus trees of Scots pine, Crimean black pine, English oak, Sessile oak, European and hybrid larch, European spruce was carried out. More than 400 candidates to plus trees of second generation were selected in progeny and variety tests of Scots pine. The need for a differentiated approach to plus trees selection for different species, natural zones and site conditions was emphasized (Los et al., 2015).

The study of clone reproduction was continued at 30 CSO and clonal archives of Scots pine and English oak in 6 regions of Ukraine, in particular, the meiosis passing of microsporogenesis of 60 Scots pine clones from 4 regions was studied. Seed forming intensity of 17 species of pines on pinetum was determined.

The generalization of data on the growth of 10 - 35-year-old progenies of the Scots pine plus trees allowed determining 32 promising plus trees - candidates to the elite trees (Shlonchak Get al., 2015). For the English oak 4 such trees are proposed, for the Sessile oak - 7 trees (Los, 2012).

The results of the work on the project were reflected in the document “Guidelines for forest seed production”(2017).

Project №23 was devoted to the study of the structure and state of CSO of aboriginal and non-native species and the study of the adaptability of the latter to new environmental conditions. During 2010-2014, the study was carried out in 5 regions of Ukraine.

The reproduction intensity and seed quality of European larch, Douglas fir, White fir and European spruce clones, on the CSO in Eastern Carpathian Foothills on the area of 25.0 ha, as well as relict Scots pine, English oak, Common and Pennsylvanian ash on the CSO in Zakarpattia were studied. The best clones for the creation of seed orchards of higher genetic level were recommended, the variability of fertility of clones was quantified and the dynamics of genetic variability of seed material from CSO was assessed.

The current state and characteristics of 150 European larch and Douglas fir plus trees at the Carpathian region were presented.

Experimental plantations on an area of almost 20 hectares were studied: progeny test of English oak; provenance tests of English oak and Cedar pines; altitude-introductory of 20 non-native species at different altitude of growth in the mountainous conditions of the region.

The current state and taxonomic and spatial structure of arboretums on the northeastern mega slope of the Ukrainian Carpathians were determined. Quantitative and qualitative characteristics of non-native plants at different altitudes were determined, the analysis of their adaptation, prediction of their growth, development, biological resilience and ability to reproduction were carried out. Phenological observations and studies of seasonal biorhythms were performed for 36 coniferous species.

The research materials became the basis for the development of “Recommendations for the effective use of clonal forest seed production in the Carpathian region and the creation of seed orchards of high genetic level” (2018).

In the course of development of the project № 13 scientific approaches to the selection and complex assessment of forms and varieties of forest wood species to create standss for different purposes have been improved.

The genetic reserves, plus and seed stands of Scots pine, Black Crimean pine and English oak were studied in 6 regions of Ukraine and their condition and the prospects of use for tree improvement were assessed. The current state and prospects of conservation of poplar genetic resources in Ukraine were determined.

Plus trees suitable for the creation of higher-level CSO have been detected according to the results of the assessment of the growth and development of progenies more than 300 plus trees of Scots pine of and more than 100 plus trees of English oak. Comparison by the complex of indicators of 20-year-old progenies of CSO from different regions of Ukraine allowed identifying those that give the most stable and productive progenies. The suitability of poplar and willow clones for the needs of bioenergy was assessed based on the study results of the varietal test and clone collection.

The reproduction intensity of Scots pine, English oak and Norway spruce clones on CSO was evaluated. The studies of disorders in the process of meiosis of microsporogenesis of Scots pine plus trees clones from 3 regions were continued.

The growth and development of origins in 5 plots of provenance tests of Scots pine and English oak were studied. The experimental and forest stands and arboretums of 14 coniferous and 14 deciduous non-native species were studied and perspective of their use for creation of different purpose stands was determined.

Experiments on micropropagation of old oak trees were continued. Methods of sterilization of explants and introduction of Bolle poplar and Hazelnut to *in vitro* culture have been improved. Bolle poplar plants propagated *in vitro* have been transferred to soil.

The results of the work on the project were reflected in two documents: “Methods of variety testing of forest treespecies. Departmental testing (new edition) (Methods, 2020) and “Program for varietal testing of forest tree species in Ukraine (Program, 2020).

During the research on the project № 12 the grouping of state forests of the Carpathian region by the main purpose was carried out, the state of reforestation on cutting areas in different formations of oak, fir, beech and spruce forests was assessed.

The efficiency of seed production units use of aboriginal and non-native species was evaluated, the volumes of seeds that can be obtained from them were calculated. It was defined that forestry enterprises of the Carpathian region is potentially able to provide 80% of its needs in improved European, Japanese and hybrid larch seeds, partly in White fir, European spruce, English oak and Sessile oak (up to 40%). Only 30-50% of the plus trees in the region were used to create the CSO.

The frequency of reproduction of the main forest-forming tree species was studied. The age of onset, frequency and intensity of fruiting (seed bearing) and potential yield of clones of different species on CSO, the volumes of seed losses due to damage by pests and diseases.

Methods of obtaining and use of improved high-quality Cedar pine seeds, the technology and agrotechnics of planting material growing and artifisial forest stands creating were proposed.

The following non-native species are promising for introduction into the forests of the Carpathian region: Sitka and Eastern spruce, Grand and Balsamic firs, Atlas cedar (for the plains of Zakarpattia), Northern red oak, Persian, Manchurian, Gray, Black walnuts, Amur cork tree, Sweet chestnut and Austrian oak (for lowland conditions of Zakarpattia).

The results of the research became the basis for the development of "Recommendations for program-targeted methods of reforestation on cutting areas in the forests of the Carpathians for various purposes using genetic and trees improvement achievements", textbook "Fundamentals of introduction and adaptation of tree and shrub species" (Yatsyk, Hayda, Gudima, 2017), monographs “Main wood introduction units in the forests of Ivano-Frankivsk region: characteristics, condition, arrangement measures” (Golubchak et al., 2018)

In processing of project №4 (2019-2024) it is planned to select and evaluate the improved material of aboriginal and non-native forest tree species on a set of characteristics of productivity and resistance to adverse environmental factors, including climate change, to investigate the mechanism of resistance and response of forest tree to climate change and identify the most representative criteria for selection and assessment of improved material, analyze the results of research on provenance tests of aboriginal and non-native species of forest tree species and improve methods of reproduction of forest trees, in particular *in vitro*. It is planned to develop the following documents:

1. Instructions for carrying out of seed production units inventory.

2. Methodical recommendations for early diagnosis of growth intensity of forest tree species by cytological methods.

4. Propositions to specification of forest seed zoning.

5. Methodical recommendations on selection and assessment of improved material of aboriginal and non-native forest tree species.

During the project №17 it is planned to study the effectiveness of reforestation in the Carpathian region on the basis of selection and introduction through the use of improved seeds and planting material of promising non-native species in reforestation and afforestation, which provides high adaptability of forests to changing environmental conditions, and guarantees proper performance of forest ecosystems of a wide range of environmental, social, economic functions.

It is planned the detailed study of the unic 50-year-old provenance tests of Cedar pines in Ukraine: European, Korean, Siberian and Cedar stalks in the highlands (1250-1350 m above sea level), where more

than 50 of their provenances are tested to determine the best origins for afforestation of mountain steep slopes and particularly secondary rocky placers.

It is planned to study premature and mature forests with the participation of the most promising non-native species (primarily Larch and Douglas fir species), which exceed the productivity of aboriginal species (spruce, fir) by 2-4 times. The condition, structure, growth, development, resistance to adverse environmental factors, diseases and pests of mixed forest stands of different species composition of aboriginal and non-native forest-forming species throughout the growing cycle will be analyzed.

It is planned to develop the following documents:

1. Assessment of the state and productivity of artificial plan communities created with the participation of promising non-native species.

2. Recommendations for increasing the genetic value of permanent forest seed base of tree species in the Carpathian region.

3. Recommendations for improving reforestation in the Carpathian region using trees improvement and introduction methods.

In addition to budget projects, URIFFM and URIMF are working on small projects, the customers of which are forestry enterprises. These works are mainly aimed at determining the current state of forest seed production units, creation of new one and providing recommendations for their management. Such recent studies became the basis for the development of “Practical recommendations for the arrangement of genetic improvement units and the creation of forest stands in the Ivano-Frankivsk region” (Golubchak et al., 2018), “Proposals for the use of cedar pines to create highly productive forests in the Carpathian highlands” [Sishchuk, 2020].

There is a laboratory of micropropagation of forest tree species in the laboratory of tree improvement of URIFFM. Over the last 10 years, methods of micropropagation of *Quercus robur, Quercus petraea, Quercus pubescens, Quercus* x (oak hybrids of SS Pyatnytsky F3) *Corylus avellana, Corylus colurna, Populus* species and varieties, in particular *P.alba*.var. *bolleana, Morus alba*. were developed and improved. In 2020, research on micropropagation of *Juniperus virginiana* L. was started (Obozny, Kolchanova, 2014; Vysotska, 2018)

Cytological investigations are carried out in the laboratory of tree improvement of URIFFM and at the Kyiv Forest Research Station, in particular, detection of disorders during meiosis (Mitrochenko, 2007, 2009). To predict the growth rate of Poplars clones as an additional feature, it is recommended to use indicators of mitotic activity of root cells (Torosova, 2014).

In URIMF an analytical laboratory is at the stage of formation, where it is planned to create a sector of forest tree species micropropagation.

Among the problems hindering the development of the tree improvement direction of research are:

- the volume of forest tree improving research work has significantly decreased due to reduced funding;
- difficulties in creating and caring for new research units (allocation of areas, non-compliance of selected areas with the established requirements and insufficient or untimely care);
- lack of possibility to conduct molecular genetic research in branch research institutions.

Priorities for capacity development and research in this area:

- expansion of tree improvement research works with appropriate targeted funding;
- allocating suitable areas for the creation of new research units and their management;
- establishment and maintenance of molecular genetic research laboratories in branch research institutions;
- elaboration of forest tree improving, conservation and assessment of units taking into consideration species and regional features, and adaptation potential, genetic characteristics of trees, etc.

Chapter 10. Management of forest genetic resources

To the greatest extent, genetic approaches in the management of forest genetic resources in Ukraine are displayed in the “Concept of conservation and sustainable use of forest genetic resources in Ukraine” (2011). In the Concept the relevance and necessity of forest genetic resources conservation are characterized; the classification of threats of reduction of genetic diversity of forest tree species is given; the legal bases of the process of forest genetic resources conservation are analyzed; methods and strategies for the genetic variability of forest tree species conservation are proposed; attention is paid to the sustainable use of the benefits of forest genetic resources conservation; the scientific support of this process is pointed out and the ways to implement this Concept, which was developed in Ukraine for the first time were proposed. The document use will serve as a basis for the development of new and improvement of existing legislation, regulations and organizational and administrative acts that ensure various aspects of biodiversity conservation in forests - programs, regulations, guidelines, instructions, recommendations and more.

Principles and mechanisms for the implementation of close to nature forestry determine the management system. The prevalence of artificial stands in the forest fund is about 55% by area. Such stands have a simplified age, species and spatial structure, require intensive care and, compared to natural forests, are characterized by lower biodiversity and biological resilience. The mechanism of implementation of close to nature forestry in Ukraine is based on the main principles of the Forest Code of Ukraine (1994).

An important tool for forest genetic resources management in the country is the forest seed zoning. The first scheme of such zoning for Scots pine and English oak in Ukraine was developed by I.M. Patlay (Prokazin et al., 1982; Patlay, 1984). Later it was extended to other forest tree species and integrated into the All-Union Forest Seed Zoning in 1982 (Guideline, 1993). The second edition of The Guidelines of Forest Seed production the zoning regulations currently in force in Ukraine are given for eight species of forest tree species: Scots pine, Europeancedar pine, European spruce, European cedar pine, White fir, European larch, European and Crimean beech (Guideline, 2017). The number and name of forest seed districts and subdistricts, the list of forestry enterprises that are part of these districts and subdistricts, as well as the list of forestry enterprises from which seed transfer is allowed are determined for each species.

The current forest seed zoning was developed mainly by the method of superimposing schemes of natural-geographical, climatic, soil, forest-typological, forestry, silviculture zoning, as well as taking into account the results of long-term studies of provenance tests of forest trees species. It should be emphasized that the existing forest seed zoning needs to be clarified, and therefore the urgent task is to establish new provenance tests of main forest tree species with a wide representation of Ukrainian provenances, which will fully characterize the habitats of these forest tree species within Ukraine.

Management of forest genetic resources also involves monitoring and inventory of valuable gene pool units.

In general, it should be noted that in Ukraine today, the requirements of the genetic diversity conservation are insufficiently taken into account in the management of natural and artificial forests, as well as other forest lands. Due to the inconsistency of definitions, international and national methods of inventory and monitoring of genetic resources, it is sometimes difficult to adequately assess the component of conservation of genetic variability in the forest certification system [30]. In Ukraine, forest certification is conducted according to the international scheme of the Forest Stewardship Council® (FSC) – an international non-profit non-governmental organization whose goal is to promote responsible forest management around the world. In Ukraine as of 01.11.2020 there are 4.55 million hectares of FSC-certified forests or 44% of forest areas of the country (http://ivano-frankivskelg.in.ua/images/FC-STD-02-V1-2_-_UKR.pdf).

Problems and challenges:

- Insufficiently efficient methods of forest management and promotion of natural regeneration of forests;
- slow implementation of the close-to-nature forestry principles;
- use of non-local reproductive material due to insufficiently forest seed base;

• uncontrolled spread of invasive species in forests;
• insufficiently efficient technology for creating and caring of forest stands;
• insufficiently developed provisions related to forest genetic resources in the forest certification system.

Development priorities:

It is necessary to use more widely the methods of conservation of forest genetic resources, integrated into forestry practice [Concept]:

• giving preference to the natural way (in favorable conditions) of reforestation over artificial;
• wider implementation of close-to-nature forestry methods into forestry practice;
• use in forestry of reproductive material of local origin with the involvement of reproductive material obtained from the gene pool conservation units;
• prevention of the spread of invasive species in forests;
• creation of forest stands of optimal density for each forest site conditions in order to promote natural processes of self-thinning of stands and increase their biological stability;
• preservation of form (genetic) diversity in stands during thinning;
• implementation of a gradual transition from a system of clear final felling, to gradual and selective fellings.

PART 5: STATE OF CAPACITIES AND POLICES

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

Ukraine is forming a set of institutional, organizational and management principles for the sustainable forest management, which are simultaneously aimed at using natural resources, improving the quality of human life and preserving the environment. The legal status of genetic resources is attributed to the status of the country's natural resources, which are coordinated by the Ministry of Ecology and Natural Resources of Ukraine. The main tasks of the Ministry are to ensure the formation and implementation of state policy in the field of rational use, reproduction and sustainable use of biological and landscape diversity, formation, conservation and use of ecological network, organization, protection and use of NRF (About approval of the Procedure, 2007).

NRF units are subordinated the Department of Protected Areas of the Ministry, the State Forest Resources Agency of of Ukraine and a number of other state institution. The general guidance of activities for the conservation, use and development of forest genetic resources on forest lands is carried out by the State Forest Resources Agency of Ukraine. The protection and conservation of natural complexes, gene pool conservation units are entrusted to the forestry enterprises on the territory of which they are located. There is no support from the state and local authorities for their maintenance. No special funding is allocated for the genetic resources conservation.

The holder of the State registers of gene pool conservation units (genetic reserves, plus stands, plus trees, seed orchards) is the State Organization “Ukrainian Forest Seed Center” of the SFRAU.

Conservation and research of rare and endangered species are carried out mainly by ecological and biological institutions of The National Academy of Sciences of Ukraine, in particular by botanical gardens.

Botanical gardens and arboretums of Ukraine play an important role in gene pool conservation the of forest tree species. To determine the main directions of research work of botanical gardens and arboretums in Ukraine in 1952, the Council of Botanical Gardens and Arboretums of Ukraine was established at the Department of General Biology of the National Academy of Sciences of Ukraine. The Council includes 31 botanical gardens (17 of them of national importance) and 19 arboretums (13 of them of national importance) of different subordination (Zaimenko, 2019).

The issues of forest genetic resources conservation are regulated, in addition to the Forest Code (1994), by the legal documents mentioned in the previous sections: “Concept of conservation and sustainable use of forest genetic resources in Ukraine” (2011); “Regulations on the allocation, conservation and sustainable use of the gene pool of forest tree species in Ukraine” (2012); “Guidelines on forest seed production” (2017), “The Law on the Red Book” (2009), “The Regulations on the Green Book” (2002). One of the main documents that guide the enterprise on forestry measures, including and felling, is the Law of Ukraine “On Environmental Impact Assessment” (2017).

The SFRAU coordinates and funds research related to the forest genetic resources conservation. The main scientific institutions of the forest industry are the Ukrainian Research Institute of Forestry and Forest Melioration named after G. M. Vysotsky (URIFFM) and Ukrainian Research Institute of Mountain Forestry named after P. S. Pasternak (URIMF), as well as the Ukrainian National Forestry University (UNFU), the National University of Life and Environmental Sciences of Ukraine (NULES) and other educational institutions and research institutions.

In 2004 URIFFM and URIMF received the status of scientific institutions of dual subordination - SFRAU, in terms of financial plan) and the NAS of Ukraine (in scientific and methodological terms).

The research network of URIFFM and URIMF covers all natural and climatic zones of Ukraine, as well as unique units of forestry science, many of which were created more than 150 years ago. The Steppe (Kherson) and Polissya (Zhytomyr) branches, 7 research stations (Vinnytsia, Kyiv, Crimea, Luhansk, Mariupol, Novhorod-Siversky, Kharkiv) and the Krasnotrokstyanets department are subordinated to URIFFM (Kharkiv). Scientific activity of URIMF (Ivano-Frankivsk) is carried out on the territory of the Carpathian region (Ivano-Frankivsk, Zakarpattia, Lviv and Chernivtsi regions). Research and experimental

subunits function here, which include the Transcarpathian department of URIMF (Mukacheve), the Mountain research department (Zelena).

The research of URIFFM and URIMF covers fundamental and applied aspectsThe research works are carried out at the expense of the state budget. In addition to budget, the institutes conduct research on the creation of scientific and technical products under agreements with sectoral organizations and enterprises, and enterprises of related agencies. About a third of the total amount of research is carried out on permanent stationary research units, which are located not only on the lands of the research network of institutes, but also in the forests of enterprises of the forest sector. Today, there are about 1,100 such objects with a total area of almost 4,000 hectares. (Forestry of Ukraine, 2019).

The education process of students of forestry colleges and universities involves the provision of knowledge on the forest genetic resources conservation. The need for mid-level specialists for forestry production in Ukraine is provided by 17 higher educational institutions of I-II levels of accreditation (educational and qualification level “junior specialist”), which are located in all natural zones of Ukraine. These educational institutions train junior specialists in the following specialties: “Forestry”, “Hunting”, “Operation and repair of forest equipment”, “Logging and primary wood processing”, “Wood processing”, “Accounting”, “Landscaping and garden and park management“. The traditions of secondary forest education are well formed in Ukraine and college graduates most often enter forest faculties.

Specialists and masters for forestry production are trained in higher educational institutions of III-IV levels of accreditation: NULES, UNFU, Kharkiv National Agrarian University named after V. V. Dokuchaev, Zhytomyr National Agroecological University, Kherson State Agrarian University and others. Students have internships in state forest enterprises and experimental forest enterprises. Unfortunately, in recent years, due to the declining prestige of forest professions, the number of students has significantly decreased.

Postgraduate studies in forest specialties have been opened at the URIFFM, URIMF, UNFU, NULES, Prykarpattia National University. URIFFM, UNFU, NULES have specialized scientific councils for the defense of dissertations: 06.03.01 – forest planting and phytomelioration, 06.03.03 - sylvics and sylviculture.

Collections of scientific works included in the international scientific and technical base Index Copernicus International (ICI) are published by URIFFM (Forestry and Forest Melioration), NULES (Scientific reports of NULES of Ukraine) and UNFU (Scientific Bulletin of UNFU), Forestry Academy of Sciences of Ukraine (Proceedings of the Forest Academy of Sciences of Ukraine).

“Ukrcentrkadrylis” is a specialized institution of postgraduate education in the field of forestry. Up to 2,000 employees of forest sector are trained there annually. Educational activities to improve the skills of forest masters are carried out by two branches - the Carpathian Regional Training Center and Chornolis Forest School.

Given that forestry science in Ukraine is divided both territorially and by different Ministries and departments, a public organization “Forestry Academy of Sciences of Ukraine” (FASU) was established to inform the public about the possible negative consequences of ill-considered exploitation of forest resources, the need for their sustainable and planned use, to intensify the process of reforestation, to promote the idea of their conservation, to clarify the policy of forest use and reforestation. FASU is a scientific and creative, methodological and coordinating public center in the field of forestry, forest management, wood-processing technology and forest economy. Another important activity of FASU is the publication of original scientific papers (Proceedings of the Forest Academy of Sciences of Ukraine) [http://nltu.edu.ua/lanu/].

In actual conditions, the role of public organizations of scientists, whose activities are aimed at coordinating and uniting the efforts of researchers, for example, by holding scientific conferences, meetings, publishing scientific papers on the preservation of plant gene pool. A number of such scientific organizations, which unite scientists in the field of natural sciences are: the All-Ukrainian Association of Plant Biologists (1995), the All-Ukrainian Botanical Society (1925), and the Ukrainian Society of Plant Physiologists (1988), Vavilov Society of Geneticists and Breeders of Ukraine (1967), Society of Foresters of Ukraine (1990).

The development of the forest sector requires scientific support for the implementation of state policy on the implementations of sustainable forest management; increase of forest resource potential, as well as forest cover of Ukraine to the optimal level; increasing the efficiency of forestry production through

the use of modern scientifically sound methods of reforestation, afforestation and the rational use of various forest functions; protection and conservation of forests from fires, pests and diseases.

Problems and challenges:

• lack of special funding aimed at forest genetic resources conservation

• insufficient coverage of regulations and developments related to forest genetic resources in educational institutions

• loss of prestige of the forestry profession

Development priorities:

• providing special funding aimed at conserving forest genetic resources

• coverage of regulations and developments related to forest genetic resources in educational institutions

• awareness rising and improving coomunication and public relation in forestry

Chapter 12. International and regional cooperation on forest genetic resources

Scientists of URIFFM and URIMF participate in the activities of the European working networks EUFORGEN for the genetic resources conservation. In 2018 and 2020, the representative of Ukraine (Svitlana Los) participated in EUFORGEN Steering Committee Meetings. Ukraine has joined the initiative to create a database that includes basic information on the location and characteristics of *in situ* genetic conservation units. National coordinators of the forest genetic resources database participated in meetings and seminars held in Zagreb (Croatia, 2012) and Rome (Italy, 2017).

In the context of joint research with scientists from Finland (Natural Resources Institute Finland (Luke)), the study of adaptation mechanisms to the environment of Scots pine sib progenies, obtained from controlled crossing on clonal seed orchards of Finnish origin of European spruce and Scots pine, created in the central part of Ukraine (Vinnytsia region)

In recent years, contacts and cooperation have been established with the Department of Silviculture and Genetics of Forest Trees of the Forest Research Institute (Poland). In October 2018, a Polish colleagues delegation led by prof. Jan Kovalczyk took part in the international scientific-practical conference “Main problems and tendencies of further development of forestry in the Ukrainian Carpathians”, held at the URIMF.

In March 2019, prof. Yuriy Gaida participated in the conference “Assessment of the productive potential of seed orchards and optimization of their use in the planning of silvicultural production” (Ocena potencjału produkcyjnego plantacji nasiennych i optymalizacja ich wykorzystania w planowaniu hodowlanym), which was organized by the Forest Research Institute (Poland, Szczekocin Stary). Cooperation between Ukrainian and Polish scientists is carried out in the course of exchange of scientific information experience and preparation of joint scientific publications.

Among the problems are the lacks of active participation of the country in international cooperation on the genetic resources conservation. Due to non-payment of annual fees, Ukraine is not an associate member of EUFORGEN and does not have the opportunity to join international projects.

In the future, mutually beneficial scientific and technical international cooperation in the field of harvesting, storage, study and use of the gene pool of forest plants should be promoted in order to implement tree improvement programs. In particular, participation in international projects and conferences, exchange of experience and information are relevant.

PART 6: CHALLENGES AND OPPORTUNITIES

Chapter 13. Recommended actions for the future

Among the priorities for the future regarding the availability of information on forest genetic resources, first of all, it is necessary to name the importance of obtaining sufficiently complete information on the available genetic resources in the country, which requires:

• systematic monitoring of the state of gene conservation units, creation and maintenance of an electronic database of units, wider use of GIS technologies;

• harmonization of international and national methods of inventory and monitoring of genetic resources;

• providing promotion in the establishment and maintenance of molecular genetic research laboratories in forest research institutions and conducting research on the genetic variability of forest tree species by modern methods;

• improvement of the reporting system on the volume of seed harvesting, taking into account the types of seed orchards and forest tree species;

• search for and diversification of sources of funding for measures to forest genetic resources monitoring, including genetic monitoring;

It is also important to strengthen public information on the importance and need for forest genetic resources conservation, dissemination of information on the distribution and use, biology and genetic variability of species and populations of forest trees, and promote international cooperation on conservation, study and use of forest plants improvement programs.

Priorities for the conservation of forest genetic resources are primarily related to the development and implementation of strategies and the relevant regulatory framework for the gene pool conservation of forest tree species. The most important tasks for the future include:

• selection and creation of new gene conservation units in accordance with differentiated strategies for genetic variability conservation of certain forest species, including uncommon and shrub species, in particular the expansion of the network of progeny and provenance tests, clonal archives;

• intensification of works on creation of gene banks of forest seeds;

• certification of new units, including DNA identification;

• providing support from SFRAU in allocating appropriate areas for the creation and maintenance of new experimental units;

• providing special funding aimed at forest genetic resources conservation.

To better forest genetic resources use and management, it is necessary to:

• more rational use of genetic conservation units for improvement and seed production purposes;

• increasing of seed harvesting volume from the gene pool conservation units, increasing the efficiency of the seed production units use, application of methods to stimulate fruiting on them;

• intensification of work on plus trees testing by progenies not only by biometric, morphological, anatomical and cytological methods, but also with the DNA markers and other modern methods;

• increasing the area of higher-level CSO with the involvement of elite tree clones for their creation;

• providing conditions for long-term seeds storage, creation of a seeds gene bank of forest tree species;

• re-equipment of zonal forest seed laboratories, creation of opportunities for application of modern methods, in particular molecular genetic;

• increasing attention to research on forest improvement, gene pool conservation and use.

Priorities for policy, institutions and capacity building should take into account the importance of:

• involvement of professional experts to making political decisions on the gene pool conservation.

• finalization, development and implementation of laws and recommendations on the use of forest genetic resources.

• providing state funding for *ex situ* forest genetic resources conservation, including forestry enterprises, botanical gardens and environmental protection institutions;

• coordination of measures for the care of units created on the initiative and with the participation of research institutions with these institutions;

• coordination of sample collection and conducting research at units created on the initiative and with the participation of research institutions with these institutions;

• simplification of the procedure for approval of permits for forest scientists on scientific research and sample collection at NRF objects of another subordination.

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ANNEX 1

Part B: State of conservation, use and development of forest genetic resources

6.5	National distribution available	Non-molecular characterization	Molecular characterization	*In situ* programme	No. of *in situ* units	Area of *in situ* (ha)	*Ex situ* programme	No. of *ex situ* units	Area of *ex situ* (ha)	No. of *ex situ* accessions	National tree seed programmes	Tree breeding programmes	Area of seed stands (ha)	No. of seed stands	Area of seed orchards (ha)	No. of seed orchards	Amount of planting stock produced per year	State of tree breeding programme (generation)
Abies alba	0	0	0	1	48	1429.8	0	6	25.3	0	0	1	126.5	18	25.3	6	4429979	1
Acer platanoides	0	1	0	1	1	1.5	0	0	0	0	1	0	1.5	1	0	0	3275532	1
Acer pseudoplatanus	0	1	0	1	4	23.4	0	0	0	0	1	0	21.6	3	0	0	0	1
Alnus glutinosa	0	1	0	1	41	228.8	0	0	0	0	1	0	49.2	16	0	0	962080	n. a
Arbutus andrachne	0	1	0	1	1	196	0	0	0	0	0	0	0	0	0	0	0	n. a
Betula pendula	0	1	0	1	6	29.6	0	0	0	0	1	0	26.4	5	0	0	2858907	1
Carpinus betulus	0	1	0	1	5	53.8	0	0	0	0	0	0	0	0	0	0	16654	n. a
Castanea sativa	0	1	0	1	5	6.2	0	0	0	0	1	0	6.2	5	0	0	0	n. a
Cedrus deodara	0	1	0	0	1	0.9	0	0	0	0	0	1	0.9	1	0	0	0	n. a
Cedrus libani	0	1	0	1	1	0.9	0	0	0	0	0	1	0.9	1	0	0	0	n. a
Cornus mas	0	1	0	1	1	4.5	0	0	0	0	1	1	4.5	1	0	0	0	n. a
Corylus avellana	0	1	0	1	7	54.6	1	3	4.5	0	1	1	54.6	7	0	0	64638	n. a
Corylus colurna	0	1	0	1	2	15.7	0	0	0	0	1	1	15.7	2	0	0	0	n. a
Fagus sylvatica	0	1	0	1	207	5610.1	1	1	4.2	0	1	1	1224.1	138	0	0	1985386	n. a
Fagus x taurica	0	1	0	1	9	155.8	0	0	0	0	1	1	15	2	0	0	0	n. a
Fraxinus angustifolia	0	1	0	1	1	5.5	1	1	0.04	0	1	0	0	0	0	0	0	n. a
Fraxinus excelsior	0	1	0	1	12	232	1	4	5.1	0	1	1	39.3	8	1.9	2	2386861	n. a
Gleditsia triacanthos	0	1	0	1	4	6.4	0	0	0	0	1	0	6.4	4	0	0	492094	n. a
Juglans ailanthifolia	0	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	0	n. a
Juglans nigra	0	1	0	1	12	33.4	0	0	0	0	1	1	33.4	12	0	0	0	n. a
Juglans regia	0	1	0	0	5	45.4	1	3	10.5	0	1	1	45.4	5	0	0	1135188	n. a
Juniperus excelsa	0	1	0	1	2	208.6	0	0	0	0	0	0	0	0	0	0	0	n. a
Juniperus virginiana	0	1	0	0	8	27.6	1	2	0.4	1	1	0	27.6	8	0	0	15510	n. a
Larix czekanowskii	0	1	0	0	0	0	1	2	0.7	0	0	0	0	0	0	0	0	n. a
Larix decidua	0	1	0	1	85	232.3	1	34	79.7	6	1	1	180.1	78	53.6	26	2707343	1
Larix kaempferi	0	1	0	1	1	3.5	1	9	32.9	0	1	1	3.5	1	32.9	9	0	n. a
Larix occidentalis	0	1	0	0	0	0	1	1	0.1	0	1	0	0.1	1	0	0	0	n. a
Larix sibirica	0	1	0	0	0	0	1	2	0.74	0	0	0	0	0	0	0	0	n. a
Larix x eurolepis	0	1	0	1	2	5.6	0	0	0	0	1	1	5.6	2	0	0	0	n. a
Phellodendron amurense	0	1	0	0	0	0	1	2	2.3	0	1	0	2.3	2	0	0	0	n. a
Picea abies	0	1	0	1	119	2440.9	1	13	22.9	0	1	1	321	70	20.4	11	12282468	1
Picea glauca	0	1	0	1	1	16	0	0	0	0	1	0	1.6	1	0	0	0	n. a

Picea pungens	0	1	0	0	0	0	1	3	4.95	0	1	1	3	2	0	0	0	n.a
Pinus cembra	0	1	0	0	6	654.3	0	0	0	0	1	0	22.2	1	0	0	0	n.a
Pinus koraiensis	0	1	0	0	0	0	1	1	1.8	0	0	0	0	0	0	0	0	n.a
Pinus mugo	0	1	0	1	1	1.2	0	0	0	0	0	0	0	0	0	0	0	n.a
Pinus nigra	0	1	0	1	71	602.6	1	9	23.5	0	1	1	457	61	9.4	4	4964646	1
Pinus ponderosa	0	1	0	0	0	0	0	2	3.8	0	0	1	0	0	0	0	0	n.a
Pinus pumila	0	1	0	0	0	0	1	1	2.6	0	0	0	0	0	0	0	0	n.a
Pinus sibirica	0	1	0	0	0	0	1	1	9.2	0	0	0	0	0	0	0	0	n.a
Pinus strobus	0	1	0	0	6	6.5	0	0	0	0	1	1	4.9	5	0	0	0	n.a
Pinus sylvestris	0	1	0	1	490	7825.3	1	257	1003.1	23	1	1	1220	219	716	149	169176406	1
Populus canadensis	0	1	0	0	0	0	1	8	3.9	0	0	1	0	0	0	0	14800	n.a
Prunus serotina	0	1	0	0	1	1.3	0	0	0	0	1	0	1.3	1	0	0	0	n.a
Pseudotsuga menziesii	0	1	0	1	39	112.3	1	3	10	1	1	1	67.4	29	10	3	0	n.a
Quercus castaneifolia	0	1	0	1	1	0.3	0	0	0	0	1	0	0.3	1	0	0	0	n.a
Quercus petraea	0	1	0	1	38	524.7	1	2	1	0	1	1	304.3	22	0	0	0	n.a
Quercus pubescens	0	1	0	1	1	129	0	0	0	0	0	0	0	0	0	0	0	n.a
Quercus robur	0	1	0	1	1370	20176.5	1	154	580.4	17	1	1	10981	1058	469.5	107	38693967	2
Quercus rubra	0	1	0	0	118	374.8	0	0	0	0	1	0	315.1	114	0	0	9922409	n.a
Robinia pseudoacacia	0	1	0	1	20	89.4	0	0	0	0	1	1	79.4	19	0	0	4333379	n.a
Salix alba	0	1	0	0	0	0	0	3	3.25	0	0	1	0	0	0	0	1200	n.a
Sorbus torminalis	0	1	0	1	1	6.1	0	0	0	0	0	0	0	0	0	0	98958	n.a
Taxus baccata	0	1	0	1	3	97.1	0	0	0	0	0	0	0	0	0	0	0	n.a
Tilia cordata	0	1	0	1	10	38.5	0	0	0	0	1	0	38.5	10	0	0	857087	n.a
Tilia platyphyllos	0	1	0	1	1	0.4	0	0	0	0	1	0	0.4	1	0	0	0	n.a
Ulmus glabra	0	1	0	0	1	2.5	0	0	0	0	0	0	0	0	0	0	107530	n.a