OPTFORESTS
Multilevel BIODIVERSITY for RESILIENT forests in the face of climate change

Deliverable 6.1

Status report on the European forest nursery sector

Dissemination Level

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Sen	*Sensitive — limited under the conditions of the Grant Agreement*	☐
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Type

R	Document, Report	☒
DEM	Demonstrator, Pilot, Prototype	☐
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1. Executive Summary

In deliverable D6.1, developed within the EU Horizon Europe project OptFORESTS, we provide a first status report on the European forest nursery sector. To the best of our knowledge, this is the first such report made to gather and collate contemporary data about the forest nursery sector from a large part of the European countries. Based on questionnaires towards forest nurseries and seed providers from 30 European countries, semi-structured interviews with selected nurseries and feedback from national Forest Reproductive Material (FRM) authorities from 20 countries, as well as from additional data sources, an overview of the current forest nursery sector is described qualitatively and quantitatively. While the sample could not be fully representative and comprehensive of the entire sector across Europe, we believe our results provide the best available knowledge about the current overall situation, with deep insights in several countries with high participation.

The sector is structured in a complex way, which stems from differences among countries in the availability and intensity of use of national forest resources, i.e. the forested area and silvicultural systems applied, ownership structure and historical (political) development. Knowledge gaps were identified, i.e. for some countries no proper production statistics are available. In most cases, countries with high forestation and intense use of their forests (through artificial regeneration) harbour the highest capacity for FRM production; this is concentrated in Central Europe and Northern Europe, while less capacity is developed in South-Western and particularly Eastern Europe. Overall, the current annual production capacity of European forest nurseries lies within an estimated range of 2.5 to 3 billion plants.

During the last decades the number of forest nurseries has declined considerably especially in Central Europe due to various factors, but most prominent a general decrease in demand due to changes in silvicultural systems (lower planting density) and a general shift to natural regeneration, but also the risks associated with a spot market system. European forest nurseries work in a highly regulated workspace, producing a niche product, often under high economic risks. Production planning associated with long production times and insecure sales, problems in seed provision and staff availability, along with lack of specific or volatile subsidies, and rising production costs (staff, energy, consumables) were identified as the current main problems observed by the majority of forest nurseries which participated in our research, particularly in the private sector. To improve the sustainable development of forest nurseries in Europe market participants, policymakers and stakeholders need to be aware of the production environment.

In Northern Europe the market is differently structured with fewer but larger nurseries and production is mainly done on pre-order. This has resulted in higher stability of forest nurseries, but also here changes in general demand are impacting nurseries. In most South-Western and Eastern European countries, forest nurseries have a lower production capacity due to predominant reliance on natural regeneration, but artificial regeneration is becoming more important due to major calamities in the wake of climate change (e.g., storm damage, bark beetle outbreaks) and forest restoration efforts. In these regions, production capacity needs to build up to provide sufficient FRM to keep devastated areas forested. Rigid bureaucratic schemes at the national level often make the expansion of production capacity difficult, particularly for public nurseries, which are the most important in the region. Due to low production capacity, particularly in Southern and Eastern Europe, improved support and innovative solutions are needed to secure forest restoration.

Cooperation (also international) among nurseries is generally seen in a positive way by most of the nurseries which participated in our research, especially when it comes to knowledge sharing and lobbying for interests at the EU level. A relatively large proportion of the forest nurseries providing feedback were not familiar with EU policies affecting their daily work, so capacity building and involvement of these important stakeholders in policy development is

necessary. In many cases cooperation among nurseries on a national level already exists, but internationally the structure of the market (competition) and national policies often hinder the transfer of FRM.

The European Green Deal calls for the additional planting of 3 billion trees in Europe by 2030 to combat climate and biodiversity crises; realistically this would mean 20% more production for forest nurseries in a period of 5 years, which in principle could be achieved with the current production capacity, depending on the regions of deployment and proper planning guidelines: for sustainable business operations, nurseries need support in the decision of which species and provenances should be raised as production takes several years. Moreover, they will face various risks, uncertainties, and potential constraints associated with the crises they are expected to help mitigate (e.g. seed availability, worsening production conditions due to higher water scarcity, rising production costs). The majority of European forest nurseries intercepted by this research would welcome support from public forest administration in the provision of proper amounts of seeds (i.e., from seed stands and seed orchards). In consequence, a common strategy with clear guidelines for deployment of FRM is needed to support the adaptation of European forests to climate change and biodiversity decline through assisted migration. This needs to be developed based on sound scientific evidence. Such strategy also strongly depends on the proper collation and collection of national data (e.g. on the number and condition of seed sources, afforestation demand, and FRM production) and their analysis at the European level, which is currently lacking. This OptFORESTS Deliverable 6.1 is a starting point in this direction.

2. Introduction

2.1. Background

Forests are a cornerstone of Europe's bio-economy, providing essential ecosystem services and supporting diverse ecological systems with different levels of biodiversity. With climate change already a reality, forests and forest trees must adapt to increasingly extreme climate events, emerging pests and diseases, and shifting disturbance regimes, including forest fires, wind breakage as well as longer and more frequent drought periods. Urgent and targeted actions are required to enhance the resilience of European forests while maintaining their ecological, social, and economic functions sustainably. This imperative has been acknowledged in key EU policies, such as the EU Biodiversity Strategy for 2030 and the EU Forest Strategy for 2030, and at national level by many countries that have adapted or will adapt their strategies to those delineated at European level (Pecurul-Botines et al. 2023). The ambitious goals outlined in these strategies—such as ecosystem restoration and planting additional 3 billion trees in full respect of ecological principles through the 3 Billion Trees Pledge —align with broader environmental initiatives, including the European Green Deal, the Agenda 2030 Sustainable Development Goals (SDGs), the Convention on Biological Diversity and its targets as fixed at the Conference held in Kunming-Montreal in December 2022 (COP15) and the Ecosystem Restoration Decade of the United Nations. The 3 Billion Trees Pledge states that no alien invasive tree species should be planted and that the species used should be suitable for the projected climatic, soil and water conditions. Similar guidelines are provided in relation to non-native invasive species by other documents relevant at international level (e.g. Nelson et al. 2024).

Achieving these objectives hinges on the protection, sustainable management, and deployment of adequate Forest Genetic Resources (FGR). These resources, in the form of Forest Reproductive Material (FRM) such as seeds and plants, are foundational for plantation and restoration efforts, and they need to be supported by a robust forest nursery sector. In OptFORESTS we address these challenges by advancing knowledge, updating and organizing data, thus fostering collaborations for the conservation, production, deployment, and management of diverse, and adaptable FGR and FRM.

The European forest nursery sector plays a pivotal role in ensuring the availability and deployment of appropriate FRM, which is vital for building forest resilience to climate change. However, transforming, innovating and advancing the forest nursery sector is necessary to identify and meet future demands of the practitioners and land managers, including increasing species diversity and production scale. Supporting practitioners, managers and policy makers in understanding and overcoming current barriers to efficient production and sector expansion is a central focus of OptFORESTS, particularly within Work Package 6 (WP6). Task 6.1 aims to identify medium- and long-term challenges and propose actionable recommendations to support the nursery sector's sustainability and resilience. These efforts are essential for mitigating uncertainties, economic pressures, and other obstacles related to the provision of FRM.

A key objective of OptFORESTS and WP6 is to support the European forest nursery sector in efficient FRM production to adapt the European forest to climate-induced challenges. This involves developing regional pathways for expanding nursery production capacity and fostering collaboration among market participants (Task 6.4). Achieving this goal requires a comprehensive understanding of the European nursery sector, which is marked by significant heterogeneity among countries. Factors such as nursery numbers, production capacities, ownership structures, mechanization levels, workforce availability, legal frameworks, commercial structures, value chains and availability of subsidies vary widely across the continent, posing challenges for cross-country collaboration and transfer of FRM. Additionally,

forest tree seed availability—a critical aspect of plant production—is heavily influenced by climate change and its consequences, necessitating attention to seed production and associated limiting factors. Assisted migration is a key component of the adaptation of European forests to climate change, so cross-country exchange of FRM is essential. In this report, we also provide insights on the institutional and commercial implications related to the transfer of FRM among countries, which is expected to reinforce the international collaboration among nurseries, but we also report on the commercial or legal barriers for this to happen.

Deliverable D6.1 provides the first in-depth analysis of the European nursery sector, akin to the study by Fargione et al. (2021) on the US nursery sector. The US study highlighted obstacles such as seed collection, seedling production, and workforce challenges while emphasizing the need for public support and landowner incentives. Similarly, D6.1 offers a comprehensive examination of the European forest nursery and seed market, providing a foundation for regional strategies to optimize and diversify FRM production. The study also explores recent trends, such as the centralization of nursery production into fewer, larger businesses, as noted by Gömöry et al. (2021), and the need for subsidies and incentives to bolster the sector for sustainable afforestation and reforestation efforts.

Europe's complexity—stemming from its diverse political, legal, cultural, and social histories—is reflected in its nursery sector. The sector's evolution has been shaped by varying ownership structures, regeneration methods, silvicultural practices, and forestry objectives across countries (Pulla et al., 2013; Forest Europe 2020). Understanding these dynamics is essential to support the transformation of the European nursery sector and to ensure its capacity to meet the challenges of the future.

2.2. The legal framework for FRM production in the EU and in Europe

Due to the length of forest production cycles and due to the cost of plantations as a long-term forest investment, as well as to guarantee the stability and ecological functioning of forests, one of the most essential information that foresters depend on are fully reliable data on the origin and on the genetic characteristics of the FRM they use for reforestation/ afforestation. Therefore, specific regulations have been implemented by European countries to prevent negative effects of low quality or ill-adapted seeds and plants on sustainable forest management. The basic legal framework for FRM production in the European Union is defined in Council Directive 1999/105/EC) on the marketing of forest reproductive material; it is therefore the main legal guideline on which national legal instruments on FRM are based and under which all EU forest nurseries operate (see also Mataruga et al. 2023). The EU framework is closely associated with the OECD Forest Seed and Plant Scheme for FRM production and marketing (OECD 2024). All EU member states have to follow the EU Directive for marketing of FRM, while the closely related OECD Forest Seed and Plant scheme is the legal guideline for FRM collection and marketing for all non-EU OECD Forest Seed and Plant Scheme member countries (i.e., Canada, Norway, Serbia, Switzerland, Turkey, USA).

In the EU Directive it is demanded that only FRM can be imported into the EU that affords the same assurances (follows similarly strict rules) for collection and labelling as laid out in the Directive. Since the OECD Forest Seed and Plant scheme is very similar to the EU specifications (e.g. the same categories of FRM are used) in practice only FRM that has been collected following the OECD Forest Seed and Plant scheme can be imported from third countries (Council Decision 2008/971/EC). Therefore, in practice, European countries that are not member of either EU or OECD cannot market their FRM in other European countries (e.g., Albania, Bosnia-Herzegovina). Exemptions are possible thorough an application for a dispensation from this rule to make imports if a country can document a lack in the EU market on a specific species; inspections regarding for plant health issues remain of course valid also in these cases. For OECD Forest Seed and Plant Scheme Member states additional phytosanitary restrictions exist for the transfer of plants and seeds, e.g. phytosanitary permits

are needed for members of genera *Pinus* and *Prunus*, and it is basically also not possible to import plants of broadleaved species into the EU from third countries (Regulation (EU) 2016/2031 and Regulation (EU) 2018/2019).

Council Directive 1999/105/EC regulates the marketing and production for marketing purposes of FRM within the EU. In Article 3 (3. and 4.) it states that the measures contained in the directive "*shall neither apply to (a) forest reproductive material in the form of planting stock or parts of plants intended for purposes other than forestry (e.g., ornamentals, but also scientific purposes),* nor to *(b) "forest reproductive material intended for export or re-export to third countries."* Article 2 gives the definition of forest reproductive material, which is classified into the following categories: "*(i) source-identified; (ii) selected; (iii) qualified; (iv) tested (*details are provided in the Directive*). Forest reproductive material may be placed on the market only if it has been produced through approved basic material, to be included in the national register of the basic material of the various species drawn up by the Member State".*

In brief FRM categories are described in Council Directive 1999/105/EC as follows:

"(i) 'Source-identified' Reproductive material derived from basic material which may be either a seed source or stand located within a single region of provenance;

(ii) 'Selected' Reproductive material derived from basic material which shall be a stand located within a single region of provenance, which has been phenotypically selected at the population level;

(iii) 'Qualified' Reproductive material derived from basic material which shall be seed orchards, parents of families, clones or clonal mixtures, the components of which have been phenotypically selected at the individual level; […] Testing need not necessarily have been undertaken or completed;

(iv) 'Tested' Reproductive material derived from basic material which shall consist of stands, seed orchards, parents of families, clones or clonal mixtures. The superiority of the reproductive material must have been demonstrated by comparative testing or an estimate of the superiority of the reproductive material calculated from the genetic evaluation of the components of the basic material."

In the Directive (L11/18, (20)) it is also stated that: "*The Member States should establish lists of regions of provenance specifying, where known, the origin of basic material (national register or FRM sources, i.e. seed stands, seed orchards, stool bed for poplars). Member States should draw up maps showing the demarcations of the regions of provenance [seed zones]; i.e. for a species or sub-species, the region of provenance is the area or group of areas subject to sufficiently uniform ecological conditions in which stands or seed sources showing similar phenotypic or genetic characters are found, taking into account altitudinal boundaries where appropriate." (Article 2 [g]) (…) "Member States shall draw up and publish maps showing the demarcations of the regions of provenance. The maps shall be sent to the Commission and other Member States.*"

After the completion of a (seed or other basic materials) harvesting operation, a master certificate has to be issued by the official bodies for all reproductive material derived from the approved basic material; i.e. the number of this master certificate has to be used for labelling of the respective lot of FRM throughout the whole production process (Article 13-1a of Council Directive 1999/105/EC).

The Directive also foresees that Member States should in certain circumstances be allowed to prohibit the marketing to the end user of forest reproductive material which is unsuitable for use in their territory (point 28 in preamble). This exception is used in some countries which consider all foreign FRM of native species unfit for growing in their country.

Suppliers of FRM also need to be officially registered. Further provisions in the Directive also lay down the labelling and packaging requirements to be met by reproductive material and seed units (arts. 14 and 15). Moreover, FRM needs to comply with the relevant plant health

conditions laid down in Regulation (EU) 2016/2031. Nine Annexes are attached to the Directive.

Annex I of Directive 1999/105/EC lists the species that are regulated in all member countries; this list is comprised of the 47 most important tree species for European forests. For species which are not listed in the Directive in general, there are no legal regulations for collection and marketing foreseen. However, in some countries additional species have been added to the national list of regulated species, e.g. in Spain 71 species are listed in the national FRM act. Species that are listed in the act of one country but not of the other cannot be marketed as FRM in the former country, since no proper harvest certificate can be issued in the latter country.

Annexes II, III, IV and V of Council Directive 1999/105/EC lay down the minimum requirements for the approval of the basic material intended for the production of reproductive material to be certified as “source-identified”, “selected”, “qualified” and “tested”, respectively. While “source-identified” has the lowest requirements (no phenotypic selection necessary), the “tested” category has very high requirements in terms of selection and breeding efforts and is not available in several European countries (see country reports in 5.1.1).

Council Directive 1999/105/EC has been translated into national regulations on FRM production in all member states of the EU and respective national authorities are in charge of implementing these regulations including the control of their implementation (see collation in Mataruga et al. 2023, supplementary material). In practice, forest nurseries have to document all steps in the production of FRM from origin or source of seeds to production in the nursery (with proper labelling of seed and plant lots in all steps of production), to avoid wrong labels and to make sure that the proper materials are delivered to the final customer. All forest nurseries are subject to recurring controls by the national authorities or a designated authority at certain intervals, e.g. every or every second year. Sanctions and fines can be imposed if the production process is not transparent or if lots have been wrongly declared.

Since the legal status is that of a Directive, member states have the right to make certain modifications in the national implementation. For example, additional species can be added to the list of regulated species, and the trade can be restricted to certain categories of FRM, e.g. in some countries the use of the category “source identified” (the lowest demanding category) is restricted to certain, less common species or fully prohibited (see also above and Konnert et al. 2015). In this report, we also try to give an overview of the current implementation status for all countries that have made their data available.

A new regulation on FRM is being developed at present (see draft at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:415:FIN) and once adopted it will replace the current Directive. Other than a Directive, as a regulation the new legal text will be directly binding for all member states and will provide very detailed guidelines on the sourcing and marketing of FRM. This new regulation is being developed with a broad stakeholder involvement. The current draft is trying to regard all inputs of the different stakeholders (forest managers, nurseries, NGOs, policy makers, etc.) and is currently debated in the Council of the EU. Because the draft is still under review we cannot comment on it in this document.

In some countries, forest nurseries also have to (voluntarily) comply to certification schemes, i.e. PEFC and FSC standards in addition to the EU Directive. In Germany also (voluntary) genetic certification schemes (ZüF; https://www.zuef-forstpflanzen.de/; FfV; https://ffv-zertifikat.com/) are in place (Konnert & Hosius 2010). All nurseries are also subject to recurrent inspections by the phytosanitary service of the respective country.

For a better understanding of forest nursery production practices a short description of FRM production essentials is presented in Annex 1.

2.3. Forest management in Europe

The European forest nursery sector's evolution has been shaped by varying ownership structures, regeneration methods, silvicultural practices, and forestry policies and objectives across countries. Understanding these dynamics is essential to support the transformation of the European nursery sector and to ensure its capacity to meet the challenges of the future. A key data source about forest management and forest regeneration in Europe is the Forests Europe report on the State of Europe's Forests (Forest Europe 2020). According to this report, approximately 66% of the total forest area in Europe originates from natural regeneration or natural expansion, while 5% is coppiced (this estimate is based on the data from 35 European countries reporting this information, representing more than 95% of Europe's forested area). Afforestation and regeneration through planting and/or seeding account for 29% of the forest area (Schuck & Derks 2020).

Natural regeneration and expansion have established over 60% of the current total forest area in most regions, with the exception of Central-East Europe, where only 48.3% of forests result from these processes. In this region, forests established through afforestation or planting and/or seeding represent 43.8%, the highest proportion among all regions. Croatia, Estonia, Georgia, Italy, Latvia, Liechtenstein, Norway, Slovenia, Spain, Switzerland, and Turkey report that over 80% of their forest area has been established through natural regeneration or natural expansion, while more than 60% of the current forest cover stems from afforestation and planting and/or seeding in Belgium, the Czech Republic, Denmark, Iceland, Ireland, Poland, The Netherlands and the United Kingdom.

The proportion of forests established through natural regeneration and expansion is at present gradually increasing across all European regions, except in Northern Europe, where planting remains the predominant method of regeneration (at the time of reporting). Annual regeneration trends reported in the Forest Europe (2020) report indicate that at present planting and seeding dominate in Northern Europe (71.2%) and Central-East Europe (66%) (**Erreur ! Source du renvoi introuvable.**). In contrast, natural regeneration is the primary method in Central-West Europe. For example, at the time of reporting, 74.7% of annual regeneration in Germany and 85.3% in Switzerland occurred through natural regeneration. South-West Europe and South-East Europe reported the highest shares of artificial afforestation as a proportion of total regenerated area in 2015. In Iceland, Ireland, and the United Kingdom, artificial afforestation accounted for 78.4%, 41.3%, and 36%, respectively. Since the national forest nursery sector mostly has developed to fill the domestic demand, it is logical to assume that the biggest nurseries – in terms of capacity and actual plant production – have developed in countries with predominant artificial regeneration of forests.

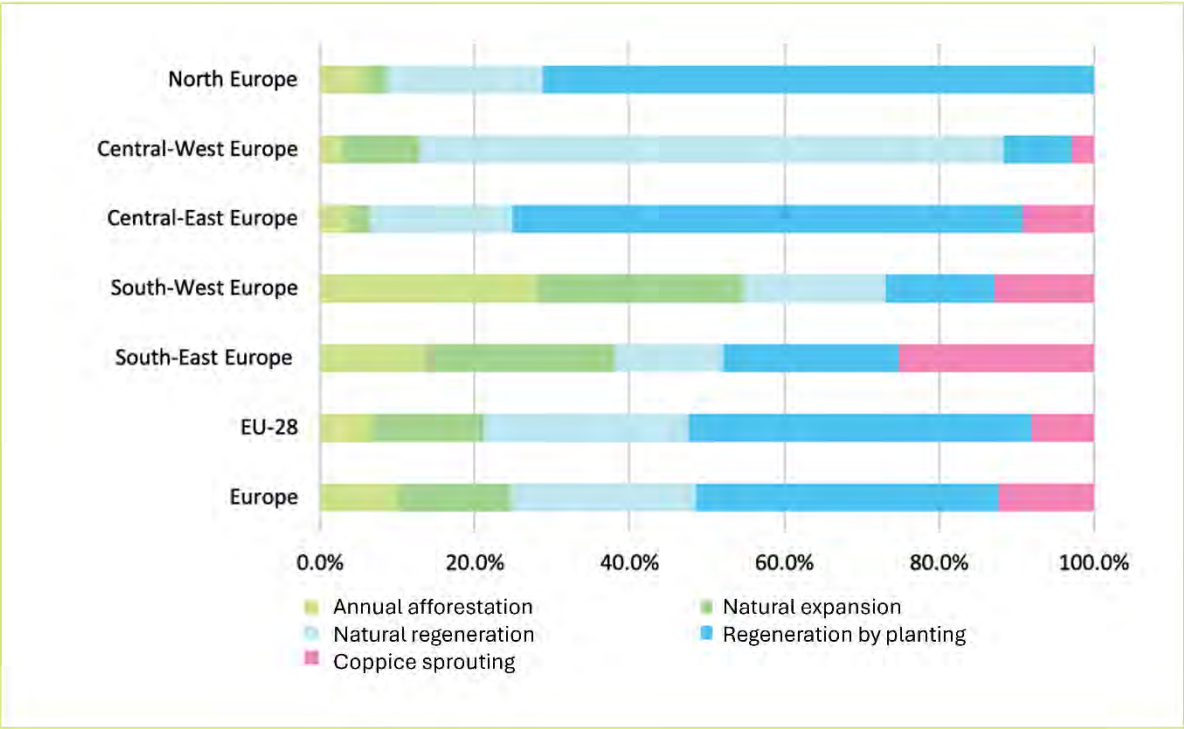

Figure 1 Share of forest expansion and regeneration types from the area regenerated, by region, in 2015. Note: Data coverage as % of total regional forest area: NE 83%, C-WE 43%, C-EE 26%, S-WE 11%, S-EE 71%, EU-28 60%, Europe 53%. Figure reproduced with kind permission from Forest Europe (2020; Figure 4.2-2).

The Forest Europe (2020) report also shows trends from 28 European countries providing data on origin of stands for the years 1990, 2000, 2005, 2010 and 2015 (Forest Europe 2020). Forest area originating from afforestation or regeneration by planting and/or seeding has increased and reached 53.2 million ha in Europe in 2015 (EU-28 45.0 million ha) as compared to 41.3 million ha (EU-28 34.6 million ha) in 1990. A marked increase of more than 29% in a relatively short period (25 years)! The raise from 2010 to 2015 alone amounted to 4% (Forest Europe 2020).

A more detailed analysis by European regions shows that the share of forest originating from natural regeneration and natural expansion in the period 1990-2015 has also increased in all regions except Northern Europe (Forest Europe 2020; Figure 2). In Northern Europe, the share of forest established by planting/ seeding has continually grown during the last 25 years. It can be observed that the share of forests originating from natural regeneration or natural expansion is rather stable in Central-East and Central-West Europe, whereas the trend in South-East Europe, and even more South-West Europe, has noticeably increased since 1990. These data indicate that most of the increase in planted forest has occurred in Northern Europe.

It needs to be stressed that the data from Forest Europe (2020) are depicting the state in 2015 and are already 10 years old, thus they might provide an incomplete picture of the current status following a strong increase in large scale forest disasters, e.g. wind throws, forest fires and insect damage (e.g., Lecina-Diaz et al. 2024; Seidl & Senf 2024). In the wake of climate change and the associated forest damage, an increase in areas to be reforested is to be expected. Therefore it may be anticipated that there is already and will be an even stronger increase in plant demand than has been observed in the 2020 report, considering also the efforts associated to assisted migration (Chakraborty et al. 2024). Unfortunately, no more recent comprehensive data are available at the time of this report.

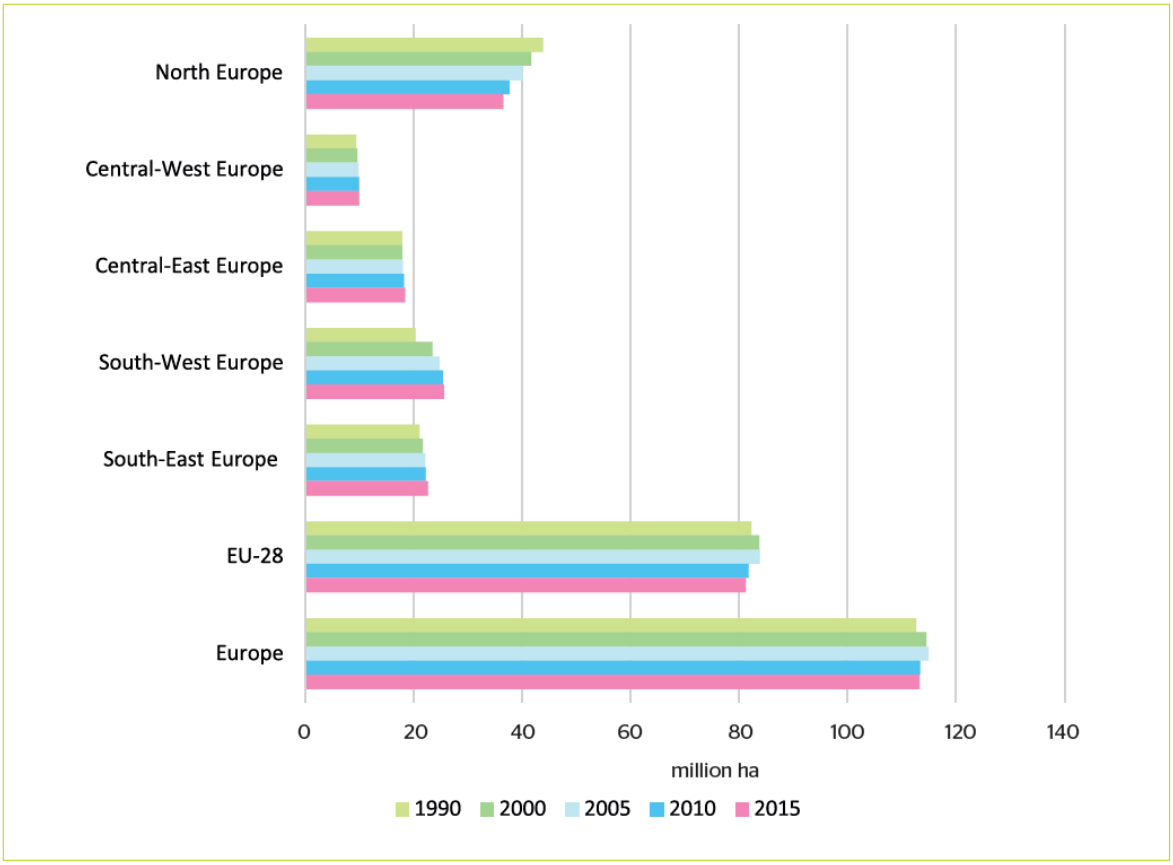

Figure 2. Trends in the area of forests originated from natural regeneration or natural expansion, by region, 1990-2015 (from Forest Europe 2020). Note: Data coverage as % of total regional forest area: NE 82%, C-WE 55%, C-EE 74%, S-WE 100%, S-EE 71%, EU-28 79%, Europe 76%. Figure reproduced with kind permission from Forest Europe (2020; Figure 4.2-3).

3. Objectives

Europe's complexity in terms of forests — stemming from its diverse landscapes, as well as political, legal, cultural, and social histories — is also reflected in its forest nursery sector. The sector's evolution has been shaped by varying ownership structures, regeneration methods, silvicultural practices, and forestry objectives across countries. Understanding these dynamics is essential to support the transformation of the European nursery sector and to ensure its capacity to meet the challenges of the future. To ensure the provision and deployment of adequate FRM, a transformation of the European forest nursery sector is needed in order to increase the diversity and quantity of plant production and to overcome the current obstacles to sector expansion, including those to an increased international collaboration.

This Deliverable D6.1 aims to provide an in-depth analysis of the way in which the market conditions, EU policies, climate change and other internal and external factors affect the forest nursery sector in Europe. Additionally, it identifies investment needs and barriers for extending production capacities that take into consideration not only the legal and institutional framework but also the labour conditions, the current knowledge and more. Deliverable 6.1 also investigates the possibilities and attitudes of the nurseries' managers who responded to the survey for the establishment of an EU network of forest nurseries assisting each other in the provision of FRM.

The sector is strongly structured at the national level, yet nurseries work under similar general legal frameworks. The objectives of this report are the characterization of the European nursery sector on various levels and in different regions, and the analysis of major obstacles and barriers for the nurseries to have sustainable business operations.

In short, the status survey presented in this Deliverable 6.1, supported by main sector actors such as the European Forest Nursery Association (EFNA; https://www.efna.eu/), has been carried out to assess whether European nurseries have the capacity for producing the necessary seedlings in terms of quality and quantity to meet European policy goals under the EU Green Deal (e.g. EU Biodiversity and New EU Forest Strategies for 2030), as well as to identify potential and real barriers to their expansion, innovation and overall governance improving.

The specific objectives were:

- To gain an overview on the structure of the sector in the different European countries, both in terms of ownership, production capacity, market situation and legal framework
- To obtain basic data on nursery production capacity on the European level; in particular it was interesting to identify available data sources but also gaps in data collection.
- To get an overview of the main impediments to successful business operations in terms of technical issues (e.g., availability of seeds), economic (market situation and demand) and in relation to policies and legal issues (e.g., views of nurseries towards legal regulations and incentives).
- To collect the views of nurseries on improved cooperation between nurseries and solutions to the identified problems, that would make their own business more sustainable and prosperous.

The results presented in Deliverable 6.1 also serve as the basis for the work to be performed in Task 6.3 (*Suggestions for strategic development for sustainable and long-term supply of FRM*). Based on the new-generation models produced in OptFORESTS and D6.1, under Task 6.3 WP6 aims to perform an innovative analysis of future seed and seedling demands in terms of species and provenances. Based on the results of D6.1 and using new generation modelling techniques, the modelling of the future demands for FRM on the regional level is to be implemented in the consecutive Task 6.3 by developing a deployment strategy. The results from T6.1 and T6.3 will be systematised into a catalogue of solutions to facilitate further

adoption and implementation in nurseries at the regional level, in a subsequent activity, T6.4 (*Regional pathways for expanding the production capacity of nurseries*).

4. Methods

This Section includes eight sub-sections, that illustrate in detail the methodological steps and materials used to develop and run the analysis. In particular, it reports: i) the target countries and responsible PPs (4.1); ii) the overall methodological approach, which is a quanti-qualitative mixed approach (4.2); iii) the overall study design (4.3); iv) the way how data have been statistically analysed (4.4); v) the path followed for developing and implementing the questionnaire targeted to the National Authorities (NA) in charge for FGR in the region (4.5); vi) the path followed in developing and implementing the online survey targeted to forest nurseries across Europe (4.6); vii) the path followed in developing and implementing the survey targeted to seed suppliers across Europe (4.7); and, finally, viii) the explanation of the development and implementation of semi-structured interviews targeted again to forest nurseries to complement the data from the online survey (4.8).

4.1. Target area and project partner roles

During the project development phase, four regional areas were defined (i.e., Northern Europe, Central Europe, Eastern Europe, and South-Western Europe), and respective project partners were assigned to each of them (Figure 3; Table 1). These partners were responsible for stakeholder communication and other project-related matters in the respective designated region (Table 1); details of partner tasks are provided in the respective subsequent sections.

Table 1. Partner roles and sharing of responsibilities in Deliverable 6.1.

WP6 Activity	General	Northern Europe	Central Europe	Eastern Europe	South-Western Europe
Identification of stakeholders	UNIPD, ETIFOR	Luke, NIBIO, CEH	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA
Dissemination of NA questionnaire	BFW	Luke, NIBIO, CEH	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, BFW, TRAGSA
Nursery survey revision	UNIPD, BFW	Luke, NIBIO	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA
Translation of nursery survey	UNIPD, BFW	Luke, NIBIO, CEH	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA
Dissemination of nursery survey	BFW	Luke, NIBIO	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA
Dissemination of seed supply survey	BFW	Luke, BFW	BFW, CZU	GIS, FSCS	BFW, TRAGSA
Semi-structured interviews to forest nurseries	BFW	Luke, NIBIO	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA
Cross-checking of results	BFW				
Revision of D6.1	UNIPD, INRAE, GIS	Luke, NIBIO, CEH	BFW, CZU	GIS, FSCS, INCDS	ONF, ETIFOR, TRAGSA

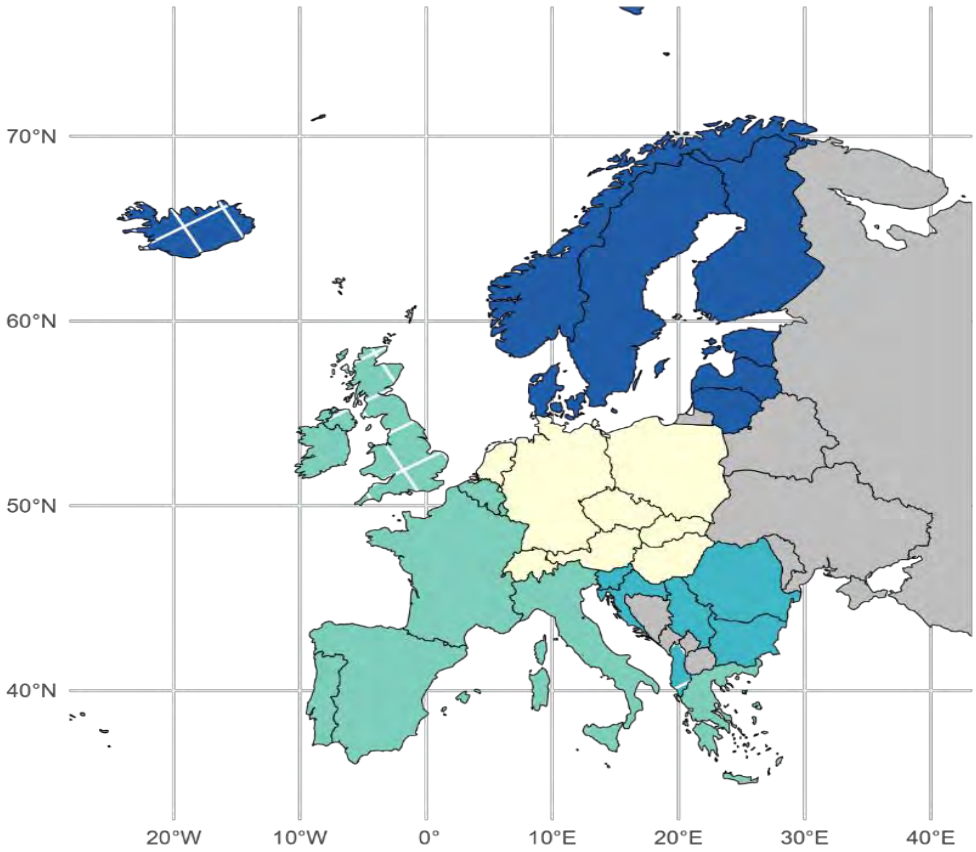

Figure 3. Definition of the target areas. Four country regions were defined: Northern Europe, displayed in blue, with Iceland volunteering to participate; Central Europe, displayed in yellow; Eastern Europe, displayed in light blue, with Albania volunteering to participate; and South-Western Europe, displayed in green, with the United Kingdom volunteering to participate. EU member countries: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden; OECD member countries: Norway, Switzerland, Serbia, United Kingdom; Others: Iceland, Albania.

For the South-Western European region, the project partners ONF, ETIFOR and TRAGSA were in charge, marked in teal. BFW and CZU were responsible for the Central Region, represented in light-yellow. The Northern Region was represented by Luke, NIBIO and CEH (blue), while the Eastern Region was represented by GIS, FSCS, and INCDS (light blue). The striped countries— Iceland, the United Kingdom, and Albania— represent those countries not initially included in the target but which volunteered to participate in the study during the interactions when developing the method. Cyprus and Malta were not included for data collection. So overall 31 European countries were included in the D6.1 data collection (Figure 3).

4.2. Mixed Methods Approach

To gain a comprehensive understanding of the nursery sector in Europe, we adopted a mixed methods approach, utilizing a combination of concurrent and sequential design elements in our study. Mixed methods research is the combination and integration of qualitative and quantitative methods in the same study. According to Molina-Azorin (2016), employing mixed methods in research can have the potential to enrich and provide a more comprehensive understanding of complex business problems and phenomena than either approach could

achieve alone (Creswell & Plano Clark, 2007, as cited in Molina-Azorin, 2016). The use of mixed methods creates the conditions for deeper understanding and cross-validation of results through triangulation, where one set of results is cross-validated with another, thereby enhancing the validity of the conclusions (Molina-Azorin, 2016).

Greene, Caracelli, and Graham (1989) highlight additional purposes and advantages of mixed methods research, including:

- Complementarity: Using one method to elaborate on or clarify the findings of another.
- Development: Employing the results from one method to inform or guide the application of the other method.
- Expansion: Extending the scope and range of the research by using different methods for distinct components of the inquiry.

Mixed methods approaches can be designed in various ways. These include concurrent designs, where data is collected simultaneously, and sequential designs, where data is gathered in stages (Molina-Azorin, 2016). Sequential designs offer the advantage of allowing one method to inform the other. For instance, the development of a qualitative method can be guided by insights already obtained from an online survey.

In this Deliverable 6.1, we present the specific methods, and the data collected with both quantitative and qualitative methods, i.e. the results as emerging from the different methodological steps. Triangulation is partially explained, and it will be further expanded in the scientific publications that are planned based on this report.

4.3. Study Design

As laid out in the objectives, the main aim of our data collection efforts were to get an overview on the structure of the forest nursery (and seed) sector in the different European countries, both in terms of ownership, production capacity, market situation and legal framework; to obtain basic data on nursery production capacity on the European level; to get an overview of the main impediments to successful business operations; and to collect the views of nurseries on improved cooperation between nurseries.

Four primary data collection methods were developed as part of Task 6.1. Two of these methods focused specifically on gathering data for describing the business conditions of forest nurseries: (a) an online questionnaire targeting nurseries to identify major impediments, views on subsidies and policies, and views on cooperation among nurseries, followed by (b) semi-structured interviews to obtain deeper insights into barriers for expansion of capacity and ways to improve cooperation. The other two methods — (c) a questionnaire sent by email directed at National Authorities (to gather country-level data on the FRM sector, information on ownership structure, and national production capacity) and (d) an online survey towards seed suppliers (to examine the current state and future prospects of seed supply in Europe) — addressed further key aspects of the sector.

The national authority (NA) questionnaire and the forest nursery survey were developed and released simultaneously (June 2023-May 2024). Insights gained from the forest nursery survey informed the development of both the semi-structured interviews and the seed supplier survey. The semi-structured interviews were conducted slightly before the release of the seed supplier survey. Additional data sources (e.g., e.g. technical reports, scientific papers, key informants and expert project partners who contributed with additional information) were explored throughout the entire data collection process (Figure 4).

Additional data sources included reports and previously published papers on the subject (e.g., the B4EST report on the legal FRM framework in Europe; Beuker et al. 2020), national plant statistics online (Spain, France, Hungary; see Table 6), and OECD reports (provided by that entity). Whenever possible plant statistics of the five last years (most current) were used for data collection, i.e. average plant production (number of marketed plants) during the last 5 years is presented.

These methods also provide critical data for projecting future FRM demand, a task planned for Task 6.3. The four approaches are described in detail below.

4.4. Statistical Analysis

In empirical research, the aim is often to make statements about large populations. If a study like ours seeks to draw conclusions about the European forest tree nursery sector, this refers to the population about which statements are to be made. As it is often not possible to survey the entire population as a whole, known as a census (Brosius et al., 2016), sampling strategies have to be applied (Brosius et al., 2016). An additional fundamental prerequisite, not only for a census but also for drawing a sample from it, is that the total population can be clearly defined in the first place as seen in Figure 4.

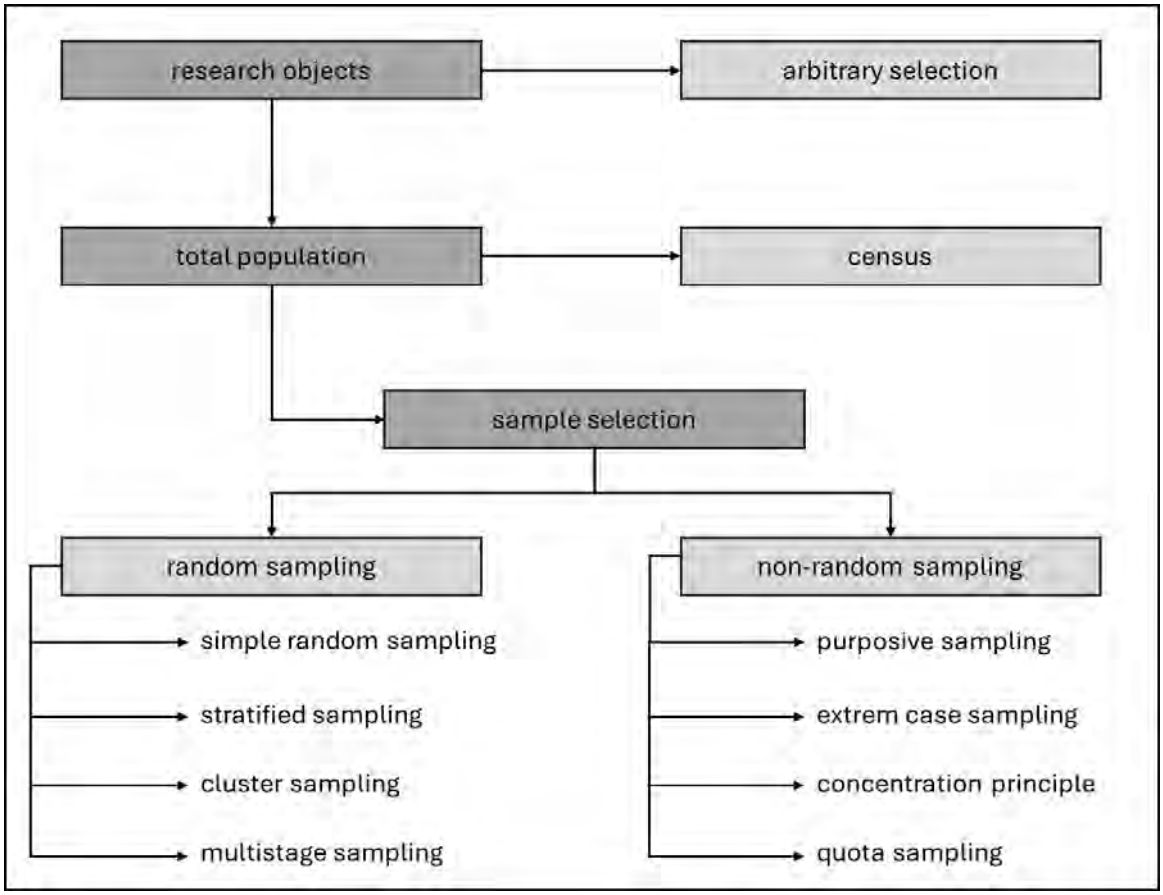

Figure 4. Different sampling methods (adapted and translated from Brosius et al., 2016).

According to von der Lippe and Kladroba (2002), a "true" random sample cannot be achieved in many empirical studies. In such cases, it becomes necessary to forego the use of methods from inferential statistics and rely solely on descriptive methods. However, for the purposes of this Deliverable 6.1 this is not necessarily a disadvantage, as descriptive statistical methods can also lead to a wealth of relevant insights (von der Lippe & Kladroba, 2002).

Because complete or updated lists of forest nurseries at national level that include both public and private nurseries do not exist in many countries, it was not possible to clearly define the total population. These limitations forced to apply non-random sampling strategies. In consequence, in our study the sampling strategies differ depending on the data collection instrument. Therefore, the sampling strategy are individually addressed in the description of each data collection instrument, targeted to different groups, as described in the following sections 4.5, 4.6, 4.7 and 4.8.

4.5. Questionnaire to National Authorities

National Authorities are responsible for implementing national legislation and data collection on Forest Reproductive Material (FRM) in their respective countries; therefore, they have a very good overview of the national rules and the market organisation in the country in question. These national authorities for all 31 target countries therefore were contacted to gather data and primarily obtain a verbal overview on different aspects of the overall national FRM sector and market across various European nations, e.g. the most important FRM producers, the organisation of seed harvests, and implementation of FRM legislation.

A detailed questionnaire was developed primarily by BFW and with the support from Task 6.1 partners; partners were also responsible to identify the respective National Authority and for contacting and sending the questionnaire to them by email.

4.5.1. Sampling Strategy

The objective was to collect existing data at national level, by engaging National Authorities from all 31 target countries. Task partners were responsible for identifying available national data sources on forest nurseries (national registers of FRM producers) and communication with National Authorities to assist in contacting forest nurseries, translation of data collection tools, and collection of data. The questionnaire was distributed via email to the respective National Authorities, through task partners. The questionnaire had not been translated into the respective national languages under the assumption that National Authorities are proficient in English as part of their professional responsibilities. The WP6 leader applied the ordinary procedures to guarantee the protection of the National Authorities data, following the GDPR regulation.

Eventually 20 countries provided a full response: Austria, Belgium (Flanders), Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Germany, Ireland, Italy, Latvia, Lithuania, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, and Switzerland. Partial answers were provided by Poland. No answers were provided by National Authorities of France, Greece, Hungary, Portugal, Norway, and the UK. All national authorities were informed on the project and task goals and written consent was obtained from all responding National Authorities for publication of country reports in this Deliverable.

4.5.2. National Authority Questionnaire

The questionnaire consisted of a MS Word document containing a series of questions to provide textual descriptions about the national forest nursery market, the national seed market, seed collection organization, categories of FRM used in the respective countries, the status of forest tree breeding in the country, the situation of contract production in forest nurseries and how the official FRM controls are organised in the respective countries. In addition, detailed numerical answers were requested, to provide an overview of the national forest nursery market (see Annex 2) and any current updates to the national implementation of the FRM Directive in the national legislation.

The National Authority Questionnaire was accordingly divided into three main sections, each detailed in the following:

Section 1: Overview of the Forest Nursery Market Structure

This section comprised seven open-ended questions covering topics such as the national market structure, organizational frameworks, key industry players, primary tree species, and notable market changes over time. Respondents were also asked to provide a brief description of the national seed market and its organizational structure. Additional details were sought on the use of FRM categories, the significance of tree breeding, and the role of official controls.

Section 2: Detailed Information about the Local Forest Nursery Market

This section was further divided into three parts:

1. The first part consisting of eight closed-ended questions to collect data on the total number of registered nurseries, their sizes, and annual sales. It also covered information about seed suppliers, seed stands, orchards, and similar resources. Separate responses were required for the private and public sectors.
2. The second part contained nine binary (yes/no) questions related to topics such as workforce, seed collection, FRM governance, certification schemes, digitalization efforts, the FOREMATIS database, and the status of seed stands.
3. The third part included seven questions. The first three questions required approximate percentage responses regarding the proportion of unused stands and the use of different production methods (bareroot vs. containerized seedlings). Questions 4–7 involved selecting percentage ranges (0–25%, 26–50%, 51–75%, or 76–100%) to describe the national market supply of broadleaf and conifer species.

Section 3: Legal Framework on FRM

This section presented a table summarizing the legal framework, guidelines, and recommendations on FRM in the respective country. The table, originally developed during the B4EST project, required respondents to verify its accuracy or update any outdated information. For countries not included in the B4EST project, National Authorities were asked to fill in the respective fields to address this gap. Since there were no major changes reported, the results of this part are not shown in this report.

The entire questionnaire is included in the Annex 2 for reference.

4.6. Online survey of forest nurseries in Europe

The Forest Nursery Survey was designed as an online questionnaire to gain insights into the current situation of the sector and identify potential obstacles that could arise during production expansion and in facing the emerging climate change and biodiversity crises. The survey was developed over a period of 6 months, involving all Task 6.1 partners and some external stakeholders (i.e., interested forest nurseries) to tackle all necessary areas of interest and to use the technical language of forest nurseries. The final version of the survey was created in English and then translated into 24 national languages by project partners or other national contacts (particularly national focal points of the EUFORGEN network, but also National Authorities, see Acknowledgments). Specific guidelines were developed and meetings organised to explain how project partners should achieve and guarantee the alignment among translations. In most cases, it was possible to have two or three translators to obtain a consensus version of the translation. The translations were done by native speakers (or were checked by a native speaker for English). The English version of the questionnaire is attached

in Annex 3, the other language versions are available on request from the first author. Translation contributions are shown in Table 2 below.

Table 2. Contributions to translation of online nursery survey to 24 languages.

Language	Translator(s)
Albanian	Leonidha Peri
Bulgarian	Maria Belovarska, Denitsa Pandeva, Dolores Belorechka
Croatian	Martina Đodan, Darjan Prugovečki
Czech	Jan Steskal, Jiri Korecky
Danish	Bent Leonhard, Erik Dahl Kjær
Dutch	Joukje Bouiteveld
English	Heino Konrad, Margarita Stockert Martin Braun
Estonian	Tiit Maaten
Finnish	Katri Himanen, Mikko Tikkinnen
French	Brigitte Musch, Philippe Proudhom
German	Margarita Stockert, Martin Braun, Heino Konrad
Greek	Evangelia Avramidou, Ermioni Malliarou
Hungarian	Gyula Kovacs, György Molnar
Italian	Jacopo Giacomoni
Latvian	Arnis Gailis
Lithuanian	Darius Kavaliauskas
Norwegian	Inger Floidstad
Polish	Marcin Beza
Portuguese	Andreia Afonso, Isabel Carrasquinho
Romanian	Georgeta Mihai, Alin Alexandru
Schwedish	Johan Kroon, Astrid Bygge
Serbian	Vladan Popović, Aleksandar Lučić, Vladan Ivetić
Slovak	Dagmar Bednarova, Julia Matejcikova, Zlatica Melichová
Slovenian	Gregor Bozic, Anže Japel,j Marjana Westergren
Spanish	Alicia Fernandez Calvo, Beatriz Cuenca Valera, Eloisa Pérez Carrión

The online survey towards forest nurseries was then made available online via EUSurvey starting in May 2023 until May 2024; the long data collection period was necessary because for some languages translations were delayed or it was difficult to obtain forest nursery contacts and responses.

4.6.1. Sampling Strategy

The goal was to collect the data needed to provide an update and comprehensive overview of the situation of the forest nursery sector across Europe. To fulfil this goal, it was initially planned to conduct a full census of the European forest nursery sector. However, due to the sector's highly heterogeneous organization and the significant variation in available information, determining the total population was challenging and carrying out a census was not possible. For example, in some countries, the structure of the public sector is well-documented, but there is little to no contact information for the private sector; in other instances, many nurseries still listed in the national directory of FRM producers have gone out of business, i.e. the actual number of active forest nurseries is not known. This posed a challenge from the outset. In some cases, we had access to national contacts through our project partners or national FRM authorities, while in others, potential contacts had to be identified through internet searches. In several instances, national FRM authorities also

provided support by directly distributing the online survey to FRM producers (e.g., in Austria or Czech Republic).

Potential participants were contacted via email, and those interested and available self-selected, i.e. they decided to join the survey. Self-selection sampling, also known as voluntary response sampling, is a non-probability sampling method where individuals choose to participate in a study on their own accord. Project partners also disseminated survey invitations through various channels, such as emails, meetings, and other public announcements (e.g., a publication in a nursery journal), but in this way they could not control or know the total number of individuals reached. Consequently, only those interested responded, and it was not possible to determine the exact number of people contacted or the response rate.

Measures undertaken to mitigate the risk of a low response rate were implemented through early and continuous communication with stakeholders. This was achieved by subcontracting the technical secretary of the European Forest Nursery Association (EFNA), to support communication with EFNA and forest nurseries through his established contacts. The project and the online survey were presented at specific meetings with forest nurseries, as well as at national-level meetings by various partners. Additionally, since the response rate in Germany was particularly low during the early phase of the Forest Nursery Survey, an article about the project and the survey was published in the German journal *Deutsche Baumschule*. German nurseries were also contacted by phone to encourage participation in the online survey.

It is worthwhile mentioning that this self-selection sampling has pros and cons. The pros are that it is straightforward and cost-effective, especially because it allows reaching contemporarily a large potential audience in various languages through a digital platform. As individuals decided autonomously and voluntarily to participate, they are often genuinely interested in the study topic, and therefore potentially provide more thoughtful and detailed responses. The cons are that it is impossible to know the total population exposed to the survey invitation and thus is it impossible to calculate response rates or assess the representativeness of the sample. In other words, the resulting sample may not represent the broad population, as it might over-represent individuals with strong opinions or specific characteristics related to the survey goals, while under-representing other categories of forest nurseries (for example, small-scale private forest nurseries which are not part of larger networks or associations and thus may neither have been invited nor got informed about the survey). As a consequence, the results have a limited generalizability and without knowledge of how many individuals were invited versus how many responded, assessing non-response bias become challenging. Nonetheless, considering the current situation in terms of information on the sector in many countries, this was the only and best applicable approach, which limitations are considered in the results interpretation.

Targeted countries were (see also Figure 3): the EU member countries Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden; the OECD member countries: Norway, Switzerland, Serbia, United Kingdom; other targeted countries: Iceland, Albania. Answers were obtained from all countries except from Greece.

4.6.2. Forest Nursery Questionnaire

The questionnaire consisted of seven sections, each detailed below. It primarily included closed questions, with response formats varying between single choice, multiple choice, and ranking. Some sections included fields for written responses or additional comments. Filter questions, which trigger sub-questions based on specific answers, were also used. Instructions for answering were provided with each question.

In the introduction to the survey a privacy note was included, informing respondents on the anonymity of their response; in case the respondent was interested to learn more about the survey's outcome or was willing to participate in a follow-up survey, it was voluntary possible to provide Name, Organisation, City/Town, Country and Email Address. Encrypted connections (HTTPS) were used for data transmission and data are stored on a secure, access-controlled platform (OptFORESTS SharePoint hosted by INRAE). Strong password protection and access restrictions were implemented and GDPR was followed. Contact details of the WP leader were made available in case of requests and complaints.

Section 1: Instructions

This section introduced the survey, providing information about its context, instructions for responding, and an estimated completion time. A link to the project website was included, along with details on data protection, processing, and complaint management. For details on the handling of general data protection regulations (GDPR) see the privacy notice in Annex 3: Online forest nursery survey.

Section 2: Demographic Data

Participants were asked about demographic information such as age, gender, and their role within the nursery. In this section, three questions were included.

Section 3: General Information

This section gathered general details about the nursery to understand its operational framework. Questions covered ownership structure, location (state, country), registration year as a professional operator, and employment composition. In this section, five questions were included.

Section 4: Nursery Production and Capacity

This section focused on production practices, including methods used, whether plant trading is part of operations, production outputs, and disposal rates. Participants were also asked about potential production increases over the next five years and perceived obstacles to achieving these goals. In this section, eight questions are included.

Section 5: Origin of Seeds

This section explored seed availability, seed sources, and challenges regarding the quantity and quality of both self-harvested and purchased seeds. Topics such as seed pre-treatment and contract production were also addressed. In this section, six questions were included.

Section 6: Market Situation and Demand

Participants provided insights into key species currently and prospectively in demand. Questions covered investment needs to adapt to shifting market demands, information about end customers and export activities, and challenges related to market conditions and demand. In this section, seven questions are included.

Participants were asked which countries they transfer seedlings to. A total of 27 countries were listed, along with two additional options: one indicating that participants do not export seedlings, and another allowing them to add other countries. The countries provided were as follows in **Erreur ! Source du renvoi introuvable.**.

Table 3. Countries provided in question on target countries for transfer of seedlings in online Forest Nursery Survey.

Austria	Estonia	Ireland	Norway	Slovenia
Belgium	Finland	Italy	Poland	Spain
Bulgaria	France	Latvia	Portugal	Sweden
Croatia	Germany	Lithuania	Romania	Others
Czechia	Greece	Luxembourg	Serbia	
Denmark	Hungary	Netherlands	Slovakia	

Section 7: Legal Regulations and Incentives

This section examined satisfaction with public incentives and administrative procedures. It assessed the awareness and relevance of key policies and regulations for the sector, both current and future. Participants were also asked about existing collaborations with other nurseries and their outlook on future collaborations in various areas. Finally, they were asked about their interest in free-to-use guidelines for specific topics. In this section, ten questions were included.

The entire questionnaire is included in Annex 3 for reference.

4.7. Survey of seed suppliers

The seed supplier survey was also developed as an online questionnaire and made available through EUSurvey from March to September 2024. It was based on the Forest Nursery Survey but was partially operationally refined, drawing from lessons learned during the implementation of the Forest Nursery Survey. While some sections were identical in content, others differed, being targeted to management and market aspects related to the seed collection, quality check, distribution and use. These distinctions are described in more detail below. Privacy and GDPR were the same as described for the online forest nursery survey (see 4.6.2). The full survey is available in Annex 5.

4.7.1. Sampling Strategy

A full census of the seed sector was originally planned. However, the seed sector seems to be even more opaque than the forestry nursery sector. From the information we obtained through semi-structured interviews and other stakeholder contacts, it became clear that the sector is significantly smaller, and in particular, many seed traders have closed their businesses in recent years. As a result, the total population is unknown. Also in this case, the only possible approach and, therefore the best one, was a self-selected non-probability sampling, which pros and cons have been described in the previous section 4.6. The survey was distributed via email and through project partners to 30 seed providers from all investigated regions. The selection was based on the knowledge of project partners on the main seed providers in the respective regions or countries, however, as explained before, no estimate can be given of the percentage of the seed market covered by the responses.

In total 18 seed providers from 9 European countries answered the OptFORESTS seed sector survey; these were comprised of one respondent form Austria, two from Bulgaria, two from Czechia, one from Germany, four from Denmark, one from Spain, one from Finland, two from France and four from Slovenia. It has to be stressed again, that the resulting data are probably not a representative sample but rather reflect the opinions of the 18 respondents from nine countries. The response rate was very high compared to the response rate of forest nurseries to the respective online survey.

4.7.2. Seed Supplier Questionnaire

This questionnaire consisted of seven sections, primarily comprising closed-ended questions. Response options included single-choice, multiple-choice, and ranking responses. There were also fields for open-ended written input and supplementary free comments. Filter questions were included, where sub-questions were displayed only for specific answers. The instructions for answering were provided directly within the text of each question. Privacy and GDPR were equivalent to the measures described for the nursery survey (see 4.6.2). The full survey is available in Annex 4.

Section 1: Instructions

While the content of this section was fully adopted from the Forest Nursery Survey, the parts regarding data protection, data handling, and complaint management were made available as downloadable file. The introduction also provided information about the survey and its context. Additionally, brief answer instructions and an approximate completion time were provided. A link to the project homepage was included. For details on the handling of general data protection regulations (GDPR) see the privacy notice in Annex 2: Forest Nursery Survey.

Section 2: Demographic Data and Section 3: General Information

These two sections were identical to those of the Forest Nursery Survey. In these sections, eight questions were included.

Section 4: Seed Procurement and Processing

This section addressed challenges related to seed availability, harvesting conditions, seed trade, and seed quality. In addition to seed sources, it examined potential capacity increases and associated obstacles. Topics such as seed cleaning, seed testing, seed pre-treatment, and seed storage were also covered. In this section, five questions were included.

Section 5: Production and Capacity

This section focused on annual total production. It surveyed the annual harvested quantities for key tree species (both conifers and broadleaves), the traded seed quantities, and the amount of unsold and discarded seeds (data not shown here, but will be used for Deliverable 6.2). In this section, 20 questions were included.

Section 6: Market Situation and Demand and Section 7: Legal Regulations and Incentives

These last two sections corresponded to those of the Forest Nursery Survey. In these sections, nine and ten questions were included, respectively.

The entire questionnaire is included in the Annex 4 for reference.

4.8. Semi-structured Interviews with selected forest nursery managers

Semi-structured interviews (SSIs) are particularly valuable for collecting rich data that would otherwise be difficult to obtain. They are typical tools for qualitative data collection and analysis. Because they allow researchers to explore complex topics in greater depth, this method was chosen to gain a better understanding of the often-intricate challenges forest nurseries face in their daily operations. The qualitative data from the SSIs were compared and triangulated with the data collected in the online questionnaires to nurseries and seed providers (e.g. compared and cross-checked with views on subsidies and main barriers

identified for expansion of production) as well as to data from NAs and additional sources, e.g. on plant production and changes in the number of active forest nurseries.

In contrast to fully structured interviews based on questionnaires, where all respondents are asked the same questions in the same wording and sequence (Corbetta, 2003, as cited in Torkar, Zimmermann & Willebrand, 2011), and many are close questions (i.e. binary, Likert scales or selection from a pre-defined list of items), semi-structured interviews are based on guiding questions that guarantee that a common set of key topics are touched in each interview, while offering the advantage of being more versatile and flexible (Kallio et al., 2016). This flexibility allows for the exploration of additional topics that emerge from the interviewees themselves. However, they are also more challenging to conduct and analyze. To support PPs, who served as interviewers, detailed interview guidelines were developed by BFW, and a training workshop to align the methodology was held online by BFW for PPs doing the interviews.

4.8.1. Sampling Strategy

One of the fundamental qualitative sampling strategies is stratified purposive sampling (also known as quota sampling). In this approach, the researcher first divides the group of interest into strata and then selects a small number of cases within each stratum to study intensively, using purposive sampling techniques (Teddlie & Yu, 2007). This method allows the researcher to explore and describe in detail the characteristics that are either similar or different across the strata or subgroups; in our case strata were equivalent to the four designated regions and subgroups were equivalent to countries; the number of planned and performed semi-structured interviews and assigned partners is shown in Table 4. We believe that the approach chosen was adequate to describe the persisting differences among countries within regions.

In the online Forest Nursery Survey, participants were able to voluntarily provide their contact information and indicate if they were interested in providing additional insights. In our case, we filtered all participants who expressed willingness to participate in further data collection, categorized them into nursery size groups, and then purposely selected contacts, primarily from large nurseries and paying attention in having a balanced distribution amongst countries. The rationale was that large nurseries play a critical role in the market and could provide particularly valuable insights. They also have a bigger influence on future production enhancement and the obstacles associated with it. In cases where invited forest nurseries did not agree to participate in an interview or did not reply when contacted, project partners—who have expert knowledge and insight of the respective national sector—were asked to identify a key national nursery with significant market influence as a substitute.

Unfortunately, it was not possible within the timeframe of the deliverable to conduct all interviews as planned. Although interviews were also planned in Poland and France, these were not conducted, also a third interview in Germany could not be done due to time constraints. As a substitute, two interviews instead of one each were done in Denmark and the Netherlands. In summary, 25 SSIs were conducted in 16 countries. Details are given below in **Erreur ! Source du renvoi introuvable.**

Table 4. The number of planned and performed semi-structured interviews and assigned partners.

Country region	Country	Planned no. of interviews	Interviews performed/ ownership	Partner assigned
Northern Europe	Denmark	1	2 private	BFW
	Finland	2	2 private	Luke

	Norway	1	1 private	NIBIO
	Sweden	2	1 private	Luke/ NIBIO
	Total	**6**	**6**	
Eastern Europe	Bulgaria	2	2 public	FSCS
	Croatia	1	1 public	GIS
	Romania	2	2 (1 priv./1 publ.)	INCDS
	Slovenia	1	1 private	GIS
	Total	**6**	**6**	
South-Western Europe	France	2	0	ONF
	Italy	2	2 public	ETIFOR
	Spain	2	2 (1 publ., 1 priv.)	TRAGSA
	Total	**6**	**4**	
Central Europe	Austria	2	2 private	BFW
	Czech Republic	2	2 private	CZU
	Germany	3	2 private	BFW
	Hungary	1	1 private	BFW
	Poland	1	0	BFW
	The Netherlands	1	2 private	BFW
	Total	**10**	**9**	
	Total all regions	**28**	**25**	

4.8.2. Interview Structure

The interview was structured into three sections, following the approach suggested by Bearman (2019):

- Introduction: This section included explanatory material and a discussion of the consent form. It also featured the initial questions, which were designed to be simple and easy to answer.
- Exploration of the Core Phenomenon: This is the heart of the interview, containing all the important topics we aimed to cover.
- Final Reflections: This section allowed for the most abstract questions, provided an opportunity for the interviewee to offer any additional comments, and facilitated the exploration of new topics or the conclusion of the interview.

An overview of the entire interview structure is depicted as an arc in Figure 5. Interview topic arc used in the D6.1 semi-structured interviews. A topic arc allows for flexible thinking when determining the sequence of topics. (adapted from Knott et al., 2022).. The interview had fixed beginning and end positions but required flexibility during the exploration of the core phenomenon. For instance, if an interviewee identifies economic barriers as the most significant issue, the interviewer continued exploring economics-related questions before returning to other main barriers.

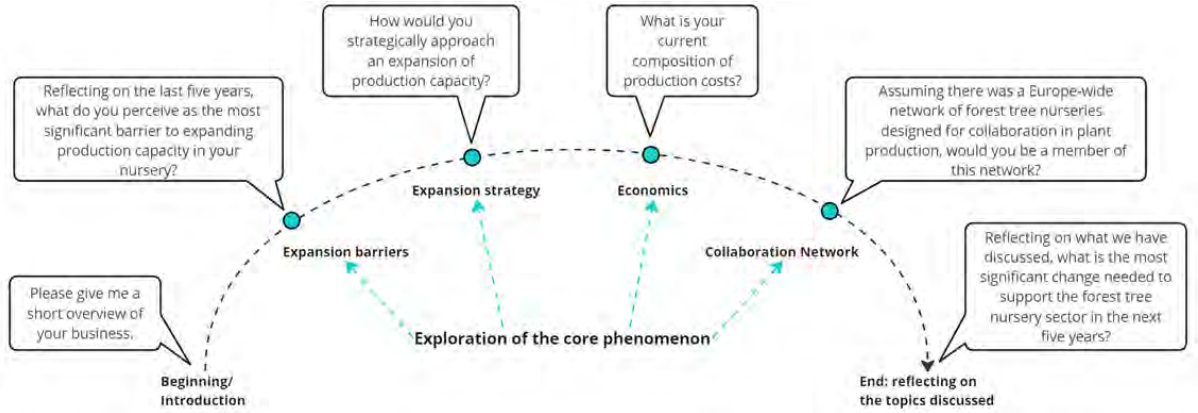

Figure 5. Interview topic arc used in the D6.1 semi-structured interviews. A topic arc allows for flexible thinking when determining the sequence of topics. (adapted from Knott et al., 2022).

The interview structure comprised main questions (numbered and bold) as well as 'interviewer cues' and sub-questions (numbered but not bold), which serve as 'probes'. Probes are optional expansions designed to prompt participants to provide concrete details and examples (Bearman, 2019; Knott et al., 2022). While probes may not always be used, they are included to facilitate the improvisation necessary for eliciting rich, detailed descriptions (Bearman, 2019). The key guiding questions are provided to guide the interviewee to be sure that all the relevant information is collected, and that all interviews provide a certain set of minimum contents that can be aggregated and interpreted together. Interviewer cues are even less prescriptive, merely suggesting potential topics for participants who may not fully understand the question or feel uncertain about how to respond.

An interview consent form was prepared, discussed with and explained to respondents before the interview, so that they knew precisely what they were agreeing to. Before the interview the respondent's signature of consent was collected. Interviews were recorded on audio or video in case of online meetings (Sweden, Finland). The average duration of each interview was one hour. The transcript of the interview was done by the interviewer and then shared with respondents and consent to use the transcript for the analysis was requested. In case the consent for recording was not obtained interviewers provided a transcript based on their notes during the interview.

The main structure of the interview was as follows:

1. Description of business and role of respondent.
2. Most significant barrier to expanding production capacity perceived by respondent.
3. Detailed description of main barrier
4. Possible solutions for this barrier
5. Detailed description of second main barrier (if applicable).
6. Possible solutions for this barrier
7. How to strategically approach an expansion of production capacity
8. Specific support required for production expansion process in the next five years
9. Does the respondent currently reach out for subsidies?
10. View on collaboration and participation in a European network of forest nurseries
11. Respondents' views on the most significant change needed to support the forest nursery sector in the next five years

For further full details, the entire interview guideline and consent form are included in Annex 5. After the interview project partners transcribed the interviews and translated it to English; the translation then was transferred to BFW for content analysis.

Content analysis was done by reading each interview at least two times, by two members of the BFW team. Following a deductive approach relevant segments of text were manually labelled with short descriptive codes (e.g. “challenges with production planning”, problems with subsidies for afforestation”, “climate change”, “changes in general demand”, “staff education”) and were then grouped into broader categories and themes based on the observed patterns, e.g. “production risk”, “staff availability”. These themes are equivalent to the main challenges described in the results section, respective quotes were selected for illustration of the different topics raised.

5. Results and discussion

In the following the results of the different data collection approaches are reported. First an overview on the structure and organisation of FRM production in the different countries is provided. Then we give an overview of the production capacity of European forest nurseries (5.1.2). Though there are gaps in the data due to lack of responsiveness or non-availability of data in some countries, we believe that a comprehensive overview of the sector and the production capacity could be achieved. In the subsequent sections we report on the findings of the forest nursery and seed sector surveys, and finally the results of the semi-structured interviews towards forest nurseries are reported. In the last section also the main part of the discussion is provided, bringing together all the information from the different data sources. By this, we provide an overview of the main impediments to successful business operations and collect the views of nurseries on improved cooperation between nurseries, as well as solutions to the identified problems.

5.1. National structures and production capacity of European forest nurseries

In OptFORESTS' Task 6.1, 31 National Authorities from EU and non-EU countries were requested to fill in a targeted questionnaire to provide information about the FRM sector in their respective countries. Eventually 21 countries provided full feedback. Unfortunately, it was not possible to obtain complete answers from several countries, e.g. Poland and Hungary (no clearance of supervisors was obtained), other countries did not reply to our request (France, Greece, Portugal, Norway, UK). For Belgium it was only possible to obtain an answer from the Flanders region. Further, some of the National Authorities were not able to provide figures of annual sales or produced plants - e.g., due to the pronounced federal organisation of Germany no official figures are available for production capacity at national level for this country. Country reports are shown on the following pages with the obtained permission from National Authorities that provided the reports. The results were also aggregated and used to produce graphical representations of the sector organisation for a subset of the countries (see Figures 6 to 14: Bulgaria, Czechia, Denmark, Estonia, Germany, Latvia, Lithuania, Slovakia, Sweden).

As expected, there is large variation in the number of the nurseries per country and the distribution of production capacity among them (Table 5). Also, the ownership of the nurseries (private or public) varied greatly among countries, as well as seed provision (seed collection, seed origin – seed stands vs. orchards) and the categories of FRM permitted and mainly used at the national level (source identified, selected, qualified, tested).

5.1.1. Country reports on the market structure of the national FRM sector

In the following the country reports are provided in alphabetical order.

AUSTRIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
There are currently 111 registered forest nurseries in Austria. The majority of these companies are private, in addition there are 5 forest nurseries that are operated by the federal provinces. Many of the nurseries produce mainly for the local market, while a few produce supra-regionally or internationally. The main tree species according to the quantity sold in the 2021/2022 production year are, in descending order: *Picea abies, Larix decidua, Abies alba, Quercus robur, Acer pseudoplatanus, Fagus sylvatica, Pinus sylvestris*. Besides the nurseries there also many companies that only operate in trade.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
In Austria there is currently one major private seed trading company that sells seed from Austria as well as other countries. There are currently 4610 approved seed stands (mainly privately owned) and an additional 71 approved seed orchards, most of the latter are state-owned. The federal seed orchards are managed by BFW (in some cases together with the provincial forest administration or provincial forest nursery). Seeds from the from the federal seed orchards are marketed by BFW.
Overview of organization of seed collection, seed cleaning, and seed storage.
In Austria, seed collection is either carried out by the registered operators themselves or by so-called harvesting contractors. The registered companies are both private and public enterprises. Before the planned seed harvest, the local authority is informed, which then inspects the harvest and compliance with the minimum standards. After that, the local authority and issues the Master Certificate. During the harvest, single tree samples are collected (with the exception of source-identified material) and sent to the Federal Forest Office accompanied by a copy of the Master Certificate. Seed cleaning is either carried out by the operators themselves or outsourced to professional companies. Most of the storage takes place at the tree nurseries or seed providers.
Categories of FRM used in the country:
Austria produces FRM in the categories source-identified, selected and qualified. There is currently no material in the tested category produced in Austria. However, some of this material is brought to Austria from abroad and used here.
Status of forest tree breeding in the country:
With ongoing climate change, the sustainable forest management in Austria is under significant pressure as the ecological, social and economic functions of the forests are threatened. Forest tree breeding in Austria is vital for conserving biodiversity, adapting forest to climate change, supporting the economy, maintaining ecosystem services, advancing research, preserving cultural heritage, and managing forests sustainably. More recent achievements of the breeding program include – among others – breeding activities in pedunculate oak, European larch, common ash and Norway spruce. In pedunculate oak, a series of combined provenance-progeny tests has been established, which resulted – after 15 years of testing – into the establishment of three new oak seed orchards. For European larch, for which Austria already managed 16 first-generation seed orchards, the implementation of the breeding-without-breeding approach resulted into the establish of second-generation seed orchards. The most urgent and wide-ranging gene conservation

and breeding activities have been implemented for common ash, which is under severe pressure from ash dieback. Here, Austrian scientists established large gene conservation and selection trials with more than 700 progenies and established three seed orchards with disease resistant genotypes. Breeding activities on Norway spruce focus on identifying individuals that survive bark beetle, identifying genes involved in bark beetle defence, improving drought tolerance, and developing large-scale early screening procedures to enhance provenance selection for specific abiotic stresses.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country.
Larger companies outsource some of their seedling production to other EU countries. Smaller companies do not use these practices at the moment.
Description of official controlling of FRM of legislation
In Austria, inspections are carried out by the authorities, with smaller businesses being inspected by the local authorities and larger businesses by the federal authority. The inspections take place at regular intervals, with forest nurseries being inspected at least once every three years and forest plant and seed traders as well as processing companies once a year. As part of the inspections, relevant papers, records, storage and production facilities are checked. In addition to these controls, the plant health authority also carries out inspections at regular intervals.

BELGIUM (Flemish part)
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
The national forest nursery market only includes private companies. There are two main producers of forest reproductive material and in addition there are about 15 smaller producers. The annual production of seedlings (one year) is around 25 million trees, the overall production (all ages) is around 45 million trees. The main species are ***Quercus petraea***, ***Fagus sylvatica***, ***Quercus robur***, ***Carpinus betulus*** for the broad leaves and ***Pseudotsuga menziesii***, ***Picea abies*** and ***Picea sitchensis*** for the coniferous trees. There is also production of poplar clones, around 85.000 one year old seedlings per year. The production is not only for the national market, but also for other EU member states and the United Kingdom. The last few years, there was an increased demand of forest reproductive material for both seeds and seedlings. However, there is a shortage of seeds and plants for a number of important species, both in Belgium and abroad. As nurseries in Flanders also buy seed/trees in other EU member states, this causes problems for the supply of FRM.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
The vast majority of the seed orchards/seed stands are owned by a public authority: the Agency for Nature and Forests. Each year, that Agency announces publicly in which seed orchards/seed stands can be harvested by recognized harvesters. A small amount of seed orchards/seed stands is private. In that case, the recognized harvesters make individual agreements with the private owner. The main species harvested in Flanders are *Quercus* ***petraea***, *Fagus sylvatica*, *Quercus robur* and *Carpinus betulus*. The forest nurseries also buy seeds abroad, mainly from other EU countries, sometimes from third countries (mainly *Pseudotsuga menziesii* from the US - equivalence regulation on EU level). In some cases, it concerns contract farming: the

seeds are delivered by an EU forest nursery, grown here and the seedlings go back to the nursery that delivered the seed.
Overview of organization of seed collection, seed cleaning, and seed storage.
Private harvesters, who are recognized by the competent authority and who also include forest nurseries, can subscribe for harvesting in the seed orchards/seeds stands of the Agency for Nature and Forests. After harvest, the harvesters need to pay a fee per kg harvested seed. The collection of seed is supervised by the Agency of Agriculture and Fisheries. At the moment there are 5 companies who are also harvesters of seed. Normally, the harvesters clean their own seed. Occasionally, seed (especially from conifer species) is cleaned by a specialized company. Normally, the seed harvested is only stored for a short period between harvest and sowing. If the seed needs to be stored for more than one season, it is often sent to specialized companies in the Netherlands.
Categories of FRM used in the country:
The material of the tested category concerns only the poplar clones. There are no tested seed orchards/seed stands. There is a list of recommended origins, not category for the most important tree species. Subsidies are only given for (re)forestation if FRM from this list is used. This does not mean that there is no other material used for (re)forestation. The most important broadleaves (*Quercus robur, Quercus petraea* and *Fagus sylvatica*) are from the selected category. In a minority of the cases, it concerns source-identified material. For *Quercus robur*, there is also tested material from the Netherlands on the list of recommended origins. There are also a lot of shrub species on the list of recommended species (species not regulated on EU level but on regional level). These are almost all from the source-identified category.
Status of forest tree breeding in the country:
The forestry sector in Flanders aims to market high-quality FRM. There are no values available regarding the economic value created by the FRM sector in Flanders. Nevertheless, the added value for forest trees was around 47 million in 2019.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
Not all forest tree growers who grow FRM start from seed. Some turn to Dutch specialized companies for certain species initially sown in plugs.
Description of official controlling of FRM of legislation:
All inspections are carried out by inspectors of the Agency of Agriculture and Fisheries. The first step is the inspection of the harvest of the seed in approved units. Harvesters need to notify the Agency at least 2 working days prior to the harvest. For the notification, an electronic platform is used (in that platform all the data of all the inspections are also stored). After harvesting, a Master Certificate is issued digitally by the platform according to Directive 1999/105/EC. Cleaning of the seed must be notified. Inspections take place at random to verify the weight of the seed after cleaning. Also, the mixing of seed lots needs to be notified. Again, random inspections are carried out. When a seed lot or a lot of plants are coming from another member state, the supplier document needs to be uploaded in the electronic platform. Each lot receives a unique reference code. When a seed lot is imported from a third country, the documents also need to be uploaded in the electronic platform. As foreseen in the Directive 1999/105/EG, a new master certificate is issued. The lot also receives a unique reference code. The nurseries need to keep a plan of all lots that have been sown/planted with the number of seedlings produced per seed lot. They also need to register all these lots in the field in the electronic platform. First a documentary check is performed: does the number of

seedlings mentioned correspond with the number of seeds in the seed lot. After that, a field inspection is carried out to verify the number of seedlings in the field. When seeds or plants are sold, the nursery can generate a supplier's document using the electronic platform. As the system keeps records of the original amount of the lot and every amount that has been sold, it is for a nursery not possible to sell more seed/plants than the original amount. Finally, random checks are made at the nurseries to verify if the lots that have been sold correspond with the lots harvested in the field.

BULGARIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years
For the production of saplings for forestry purposes, 174 forest nurseries have been registered on the territory of the Republic of Bulgaria, of which 151 are state owned. In recent years, on the territory of two nurseries in the South-West State Forest Enterprise, production lines for automated container production of saplings have been built, which have a total production capacity of 3 million saplings per year. Two more production lines for container saplings are under construction. The main producers of poplar cuttings in Bulgaria are Vardim nursery on the territory of Svishtov and Nakov Chiflik nursery on the territory of SFE Pazardzhik. Of the coniferous species, black pine is the most preferred, with 2 41.9 ha of reforestations in 2022, representing 75.8 % of the 1-year-old coniferous crops, other coniferous species – Scots pine, Norway spruce and Atlas cedar. Of the deciduous tree species, the most used for afforestation are Euro-American poplars – 56.6 %. The preferred poplar cultivars for forestation are P.cv. I-214-73 % followed by P.cv. Agate – 7.2 %, P.cv. BL – 7.1 %, P.cv. I 45/51-5.8 %, etc. Oaks are frequently used too for reforestation.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
Seven natural persons and 218 legal entities are registered in the national register of forest reproductive material suppliers, of which 151 are branches of state forestry enterprises, 2 educational holdings at the Forestry University. Main suppliers are private producers - “Introduction” and “Uber” Ltd. There are 56 registered seed orchards (51 state-owned and 5 municipal property) of 12 tree species were approved and registered – *Robinia pseudoacacia*, Scots pine, Black pine, etc. Basic material of the category “selected” are 274 832 666 ha, of which 236 828 801 ha are state-owned, 2 342 495 ha municipal, 22 141 ha private, and 1 241 222 ha other property. The main tree species are Scots pine, spruce, beech and oak.
Overview of organization of seed collection, seed cleaning, and seed storage:
Seed harvesting is carried out by registered natural and legal persons in the public register of the Executive Forest Agency for the performance of the activity “Planning and organization of afforestation activities” or “planning of forest areas”. The extraction of seeds from cones and fruits and their cleaning is carried out in seed production stations, and on the territory of Bulgaria there are two such stations – “Chepelare” and “Razlog”, which, on a regional basis, process seeds mainly for the state forest and hunting enterprises. Forest seed control stations Sofia and Plovdiv carry out preliminary control of the collected seeds lots of deciduous and coniferous species. The conservation and storage of seeds is also on a regional basis and is organized by the State through the two seed control stations, which operate a seed storage facility for long-term seed storage and a “gene bank”. 986.53 kg of seeds from 225 seed lots of coniferous and 9 lots of deciduous species were stored in the long-term storage facility in the FSCS

Plovdiv by 31 December 2022. For “Genna Bank” as a seed collection in FSCS Sofia by 31 December 2022, 220.62 kg of seeds of different origins of 44 tree and shrub species were stored. In the FSCS Plovdiv are preserved 18.5 kg of 7 tree species.
Categories of FRM used in the country:
The production of FRM is carried out under control of FSCS or specialists from regional forest directorates on the terrain, including also the cases of production for self-use for non-commercial purposes. Vegetative production of forest reproductive material intended for marketing shall be carried out only from basic material that meets the harvesting requirements of the categories ‘selected’, ‘qualified’ and ‘tested’. Artificial production by hybridization of forest reproductive material for marketing shall be carried out only from sources originating from sources eligible for extraction of the category ‘tested’.
Status of forest tree breeding in the country:
There is no breeding in the country.
Importance of contract production of small seedling, i.e. the outsourcing of the initial stages of seedling production in the country:
There is no information of contracting for outsourcing.
Description of official controlling of FRM of legislation:
The monitoring of the implementation of the activities in the forest nurseries and compliance with the regulations is carried out by the EFA, RFD, FSCS, FPS (Forest health protection) in their designated area of activity. Controls are carried out through unannounced, planned and ongoing checks.

CROATIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
Main players in producing and putting forest planting material (FPM) on the market in Croatia are nurseries of the public enterprise Croatian Forests Ltd. Even though there are some small companies that are officially registered to be able to produce and put on the market FRM they do not officially have production (or they break the law and do not report they production as they are obliged to according to Law on FRM). In total there is one major player (Croatian forests Ltd.) with ca 20 nurseries. The exact number of active nurseries varies annually, even though the official database of registered nurseries has more than 40 nurseries listed (outdated). Major production in Croatia is production of broadleaves, mostly pedunculate and sessile oak, European beech, and up to few years back when it is forbidden for production, narrow leaved ash. Any changes in production/marketing of tree species follows major needs from practical forestry, mostly public forests, since Croatian forests produce FRM for their own needs (only some portion for other stakeholders, and neglectable portion for other countries).
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
The situation for the seed market is very similar to the already described FRM market. One main player (Croatian forests Ltd.) who is collecting seeds for their own purposes, both for artificial regeneration by seeding or for nursery production. FRM in general falls under the national Law on forest reproductive material (in accordance with Directive of EU on FRM) and under expert supervision. Collected seeds must be tested and its origin must be determined (Master certificate), while produced seedlings/cuttings/wildings must also be

checked for quality and origin (traceability of origin from collection to final customer, mostly again Croatian forests Ltd.). For both supervisions are conducted by national authority prescribed by the Law on FRM, and that is Croatian Forest Research Institute. The official list of seed orchards/stands is publicly available on the webpage of Ministry of agriculture where one can find all basic data (not frequently updated). There is a relatively small amount of seeds introduced from abroad annually, up to recently mostly of NNTS. Nowadays, due to problems in seed production of oaks there has been more introduction of these species.
Overview of organization of seed collection, seed cleaning, and seed storage:
Seed collection, seed processing and storage are done by Croatian Forests Ltd. and partially by the Croatian Forest Research Institute (also for purposes of Croatian Forests Ltd.). Processing and storage of conifer tree species (for purposes of Croatian forests, i.e. for public forests in Croatia is done by the Croatian Forest Research Institute (CFRI). The whole seed testing (for forest tree species) in Croatia is done in the seed testing laboratory of CFRI which is the reference laboratory for this kind of service in Croatia.
Categories of FRM used in the country:
Not answered.
Status of forest tree breeding in the country:
Moderate.
Importance of contract production of small seedling, i.e. the outsourcing of the initial stages of seedling production in the country:
No outsourcing, as explained previously.
Description of official controlling of FRM of legislation:
Expert supervision is done by official body determined by the FRM law (i.e., Croatian Forest Research Institute). It is conducted annually in all nurseries prior to shipment of FRM to the market or to the forest stands. This applies only to seedlings which are shipped to forests (not horticultural purposes/species or seedlings aimed for these purposes).

CZECH REPUBLIC
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
As of 31.12.2022, 237 licensed entities were engaged in forest nursery production on 278 nursery sites; 84% of nursery sites were involved in the marketing (i.e. distribution/sale to other entities) of planting material. Nurseries run by public and state-owned entities produce planting material mainly for their own use and market very small, insignificant, quantities of seedlings; only one state-owned entity participates in the market for planting material to a greater extent. The most common species of planting material placed on the market in 2022 at a seedling age of 1 to 3 years were: *Picea abies, Scots pine, Larix decidua, Abies alba, Pseudotsuga menziesii, Fagus sylvatica, Quercus robur, Quercus petraea, Acer pseudoplatanus, Tillia cordata, Alnus glutinosa*. The year-on-year variation in the total quantity of planting material placed on the market tends to range from about minus 20 million to plus 50 million seedlings, the average is 232 million seedlings per year (data collected end of 2022). It needs to be noted that since then

the proportion of natural regeneration has increased substantially and production has accordingly decreased.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
A significant proportion of the ownership of recognized sources (approved basic material by competent authority) of forest reproductive material (hereinafter referred to as FRM) of the categories identified source and selected is in the administration of institutions having the right to manage forests owned by the state, namely 81% in the case of identified FRM and about 72% of selected FRM. Thus, the weight of approved sources of forest reproductive material for reforestation and afforestation lies mainly in the public sector. The number of seed orchards approved for seed collection is 72 for coniferous trees (for *Pinus sylvestris, Picea abies, Larix decidua*, and others) and 40 for broadleaved tree species (mostly for *Prunus avium, Ulmus glabra, Acer pseudoplatanus, Sorbus torminalis*, and others). 80 % of the total number of seed orchards are owned by state entities. Of the introduced tree species, the most approved sources for seed collection are *Pseudotsuga meziesii, Pinus strobus, Pinus nigra, Abies grandis, Quercus rubra, Quercus robur subsp. slavonica, Robinia pseudoacacia and Aesculus hippocastanum*. Seed orchards approved for seed collection of the introduced tree species are recorded only for *Pseudotsuga meziesii, Abies grandis, and Pinus cembra*. The cultivation of planting material of domestic origin in foreign forest nurseries is carried out in the form of contract cultivation; seedlings grown from seed originating from Czech sources are grown abroad and returned to the Czech Republic in the form of seedlings. Planting material from foreign sources, apart from the use of *Pseudotsuga menziesii* and *Abies grandis* seed imported from the USA and Canada, is not allowed in the Czech Republic for reforestation and afforestation. Approval of all sources for the collection of seed material is always carried out by the government competent authority (Czech Forestry Institute, CFI).
Overview of organization of seed collection, seed cleaning, and seed storage:
The holder of a forest reproductive material license may collect seed material from approved sources of FRM with the consent of the source owner. A Master Certificate of identity shall be issued by the competent authority (Czech Forestry Institute, CFI, former Forest Management Institute, FMI) for the collected seed material. Seed stock is usually processed into seed commercially, as the license holder uses other public or private providers if it does not have its own facilities for this purpose. The same applies to the storage and pre-sowing preparation of the seed material or seed obtained from it. Seed material from state forests is processed and stored in a seed factory operated by the Forests of the Czech Republic, a state enterprise, which also provides these services for seed material from other entities commercially.
Categories of FRM used in the country:
In the Czech Republic, the FRM categories used are identified source, selected, qualified, and tested. We register the source of FRM of the tested category for hybrid poplar clones used for stands with a short rotation period.
Status of forest tree breeding in the country:
The importance of the genetic quality of the FRM resource is increasing with the extremes of habitat conditions, increasing pressure from pollutants, climate change and the rising costs of remedial actions. Therefore, the quality of the source, provenance and transfer of FRM will influence the production and stability of the stands being established more than the application of breeding, since the main operational sources of FRM are approved forest stands.

Importance of contract production of small seedling, i.e. the outsourcing of the initial stages of seedling production in the country:
Planting FRM of domestic origin in foreign nurseries in EU countries takes place in the form of contractual cultivation in nurseries; seedlings grown from seed originating from Czech sources are grown abroad and returned to the Czech Republic in the form of seedlings. In 2022, this amount accounted for 3,65 % of the quantity of planting material placed on the market in the Czech Republic. Planting material from foreign sources within the EU or from non-EU countries, apart from the use of *Pseudotsuga menziesii* and *Abies grandis* seed imported from the USA and Canada, is not allowed in the Czech Republic for reforestation and afforestation.
Description of official controlling of FRM of legislation:
License holders are inspected by the competent authority (Czech Forestry Institute, CFI, former Forest Management Institute, FMI) both at the time of FRM collection and also at the nurseries. In both cases, compliance with the Act on the Management of Reproductive Material and its implementing decrees, as amended, is checked in accordance with the Control Act. In 2022, 31 suppliers out of a total of 704 license holders were inspected, of which 12 inspections were in cooperation with another government body. Inspections during FRM collection were carried out in 313 cases, representing 17% of the collections. The frequency of inspections is not given.

DENMARK
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
The Danish forest nursery market is private, there is but one public producer of basic material [seeds, no public nurseries]. What The Danish Agricultural Agency does know about the forest nursery market is what is of trade of seed internally in Denmark, and plants to other countries. The Danish Agricultural agency has registered 42 private companies that trade forest reproductive material, not all are nurseries some just trade the material.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
Regarding seed trade there are only very few (3) companies in the marked. One is the state forest and the others are private. Both the state forest and the private seed companies do own seed sources them self, but many seed sources are owned by forest owners. In Denmark there are 328 registered sources of FRM. 230 are seed stands, 91 are seed orchard and five are clones. *Quercus robur* is the most common with 70 listed areas, *Abies nordmanniana* 28, *Fagus sylvatica* 25, *Larix* sp. (*L. decidua*, *L. kaempferi*, *L. x eurolepis*) are the most common by number of stands. The harvested species vary among years, mostly related to the weather. There is mainly an import of ***Quercus*** from Norway, and of *Abies nordmanniana* from Georgia, but import of other species from other countries does also occur.
Overview of organization of seed collection, seed cleaning, and seed storage:
These activities are carried out mainly by private companies.
Categories of FRM used in the country:

The main part of the approved units of basic material is selected, which by number of areas is 208, then comes qualified which counts for 50 and 68 are tested.

Status of forest tree breeding in the country:

Denmark has a long tradition for tree breeding with the oldest seed orchards of larch and ash established in the 1940'ties. Today seed orchards play a significant role in the seed procurement of many conifers including the most frequently planted conifers in forests: *Picea abies, Picea sitchensis, Abies alba, Abies nordmanianna, Abies procera, Pseudotsuga menziesii, Pinus sylvestris , Larix x eurolepis,* and *Larix kaempferi.*

Seed orchards have also been established for several broadleaved species, but have so-far only played a major role in the procurement of *Fraxinus excelsior* seed. However, almost all major forest plantation species are targeted in Danish breeding activities although with different level of intensity. Various types of improved seed sources have thus been established based on selection and testing native species including *Prunus avium*, *Quercus robur, Quercus petraea, Alnus glutinosa, Acer pseudoplatanus, Acer platanoides, Acer campestre,* and *Tilia cordata*. Among the broadleaved species, intensive breeding activities are implemented for *Fraxinus excelsior* to develop ADB tolerant tree and *Quercus robur* to develop trees with high climate resilience and wood quality'

At present, *Fagus sylvatica* is probably the only major plantation species in Denmark where trees breeding are not applied to develop improved seed sources.

Importance of contract production of small seedling, i.e. the outsourcing of the initial stages of seedling production in the country:

Not known.

Description of official controlling of FRM of legislation:

Nurseries are under official control depending on the culture, for most forest nurseries it is one annual control. The control includes both a plant health and a documentary control. The control is conducted by the Danish Agriculture Agency's official plant health inspectors.

ESTONIA

Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:

Forest plants are mainly grown for reforestation, to a lesser extent for the afforestation of fields. The national plant producer mainly grows plants for the renewal of the national forest, to a lesser extent for trade. The main tree species are *Picea abies, Pinus sylvestris, Betula pendula* and *Alnus glutinosa.* On average, 1% of the annual plant production is exported from Estonia. 4 to 5 million plants are brought to Estonia from other member states per year.

Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):

Stored forest tree seeds are used for growing plants and for forest seeding. 54% of the stands suitable for seed storage are state forests and 46% are private forests. The national seed store collects 95% of the seeds, which are also traded to the private sector. The most important tree species are *Picea abies, Pinus sylvestris, Betula pendula* and *Alnus glutinosa*. On average, 63% of the seeds collected annually are collected from stands, 35%

from seed orchards and 2% from individual trees. Forest tree seeds are exported on average 81 kg per year and imported on average 8.8 kg per year.
Overview of organization of seed collection, seed cleaning, and seed storage:
The seed collectors are registered, and the work is carried out under the supervision of the Environmental Board. Most of the seeds of forest trees are collected by the state company, private companies collect seeds for growing plants. The seeds are processed and stored in a state-owned enterprise. The state enterprise also manages the seed stock of forest trees. The state-owned company calculates that *Pinus sylvestris* has a 3-year seed reserve, *Picea abies* has a 6-year seed reserve, and *Betula pendula* has a 2-year seed reserve. Only certified FRM is marketed.
Categories of FRM used in the country:
Categories 'source identified' and 'qualified' are used. Marginally the category 'selected'. Category 'tested' is not used.
Status of forest tree breeding in the country:
505 plus trees of *Picea abies*, 572 of *Pinus sylvestris*, 394 *Betula pendula*, and 174 of *Alnus glutinosa* have been selected. Since 2012, succession experiments with the mentioned tree species have been conducted. Forest tree breeding is led by the Estonian University of Life Sciences.
Importance of contract production of small seedling, i.e. the outsourcing of the initial stages of seedling production in the country:
Associations of forest owners order plants from plant producers or suppliers on the basis of a contract. Short-term contracts (1 year) or longer ones (5 years) are common. Contracts are not very important. Tree seeds from us are taken to other member states, and the plants grown from them are brought back to Estonia.
Description of official controlling of FRM of legislation:
The Environmental Board supervises the producers of FRM. The frequency of inspection depends on risk assessments. Quality control of plant batches in spring (up to 20% of marketed plant batches) and planned supervision of suppliers (July to October) are usual. Planned supervision covers all suppliers holding activity permits for issuing plant passports and growers of Scots pine plants. The frequency of inspection depends on the findings.

FINLAND
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
There are 23 registered private nursery companies in Finland. Two companies have a total of seven nurseries, each registered separately. As of the end of the year 2022, the total number of nurseries in Finland is 30. The number of nurseries has decreased from 57 to 32 over the past decade. The greenhouse area used for seedling production in 2022 was 99 hectares and it has increased slightly in recent years. In 2022, Finnish nurseries delivered more than 174 million seedlings for reforestation. Of these, the shares of Norway spruce, Scots pine, silver birch and other species were 65%, 30%, 4%, and 0.2%, respectively. Only container seedlings are produced. Over the last ten years, the amount of seedling production has ranged from 155 to 174 million per year, with a mean of 161 million.

In 2022, Finnish nurseries market 18,5 million seedlings mainly to Sweden and Estonia. The marketing of seedlings to other EU countries has seen a substantial increase. Over the last five years, the number marketed seedling has grown from 3.6 to 18.5 million.

Most of the seedlings are delivered to private forest owners by forest management associations or companies. In 2022, there were 99 registered marketing companies with a total of 310 registered local offices (branches).

Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):

In 2022, Finnish nurseries used 956 kg of Norway spruce, 531 kg of Scots pine and 5 kg of silver birch seed for nursery sowings. For Norway spruce, the share of Swedish seed was 5.5% and Estonian seeds accounted for 0.2%. In Scots pine, the share of foreign seed was 7%. Additionally, for direct seeding, we required 6,250 kg (± 500 kg) of Scots pine seeds.

We have two companies, which produce almost all of the seed orchard seeds (bred seeds, qualified and tested category) in Finland. Siemen Forelia Oy is a limited company and a subsidiary of by Metsähallitus, which is a state-owned enterprise. Tapio Palvelut Oy is a limited company owned by Tapio Oy, which is in turn owned by Government of Finland. Both companies are own separate legal entities. In addition, we have two private companies which produce conifer seeds and a few companies which produce small quantities of broadleaf seeds.

For northern Finland we maintain a long-term security seed storage of category source-identified seed. The harvesting and security storage of forest tree seeds in Lapland is a public administration duty of Metsähallitus (State Forest Enterprise). In Northern Finland (Lapland with a land area 100, 366 km2), a large amount of pine seeds are needed for direct seeding, but the harsh climatic conditions prevent sufficient seed orchard seed production there. The main tree species of Lapland (spruce and pine) are flowering there approximately once in a decade.

The primary opportunity for source-identified seed collection in Finland arises after final harvesting (felled trees). This means that we do not have permanent basic material for the “source-identified” category; new stands need to be selected in each case. The selection is carried out by local foresters (operators) working in that region. The authority has the ability to inspect the collection at any stage, but it is impossible to inspect each place beforehand. The inspections are conducted using a risk-based basis. The material is classified into the “source-identified” category, and the collection is mainly done within one municipality or smaller administrative unit, within a narrow latitudinal range and according to altitudinal ranges. The material clearly meets the requirements of the “source-identified” category, with at least hundreds or thousands of collected trees. The material is genetically diverse due to the large number of collected trees and open pollination with pollen from a wide range of father trees.

Since seed harvesting has to be done during the wintertime, there are harsh climatic conditions for seed collection (very short days, lots of snow, cold weather, strenuous work and sometimes a shortage of labor). For these reasons, the collecting of cones from standing trees is very hazardous for labor and, in many cases, practically impossible.

Most of the seeds used for direct seeding are delivered to private forest owners by forest management associations or companies. In 2022, there were 99 registered marketing companies and they had 310 registered local offices (branches).

Overview of organization of seed collection, seed cleaning, and seed storage:

Seed collection, cleaning and seed storage is done by registered companies described above under supervision of the competent authority. The operators submit cone collection notifications to the competent authority through an extranet information system (MEVI).

They receive combined plant passports and cone labels with identifiers (lot numbers), including all necessary information required by the Plant Health Regulation ((EU) 2016/2031) and Council Directive 1999/105/EC. All cone and seed packages or containers must be labelled. The cones are extracted in the seed extraction plants. The Master Certificate can be applied for only based on the identifier. The Master Certificate is applied for in the MEVI information system after seed cleaning, and it is issued for the seeds if they fulfil the requirements. Inspectors carry out inspections in all stages of cone collection and seed harvesting on a risk-based basis.

Our two main producers have high-quality seed orchards for our main tree species. In Finland, the establishment of the seed orchards has been carried out systematically for several decades. We have a new long-term seed orchard establishment program that has recently been published (Benefits of Forest Breeding into Use – the Seed Orchard Establishment Programme 2060 http://urn.fi/URN:ISBN:978-952-366-719-8). The goal of the Seed Orchard Establishment Programme is to ensure statutory forest regeneration by securing an adequate supply of forest reproductive material of appropriate genetic quality. The Programme will transfer genetic gains from operational tree breeding, which involves improvements in growth, quality, and field fitness, into practice.

In Finland, a research institute (Natural Resources Institute Finland) is responsible for the selection of clones for seed orchards and designing the layouts of seed orchards. The companies establish the orchards according to the plan. After establishment, the orchards are inspected and registered by the competent authority. Thinning must be done in accordance with a thinning plan designed by the Natural Resource Institute Finland and approved by the competent authority. After thinning the orchards are inspected, and any changes are registered by the competent authority.

Companies are responsible for fertilizing, crown cutting of clones, plant protection measures, and promotion of flowering, as well as other treatments procedures for seed orchards. Before collecting the seeds, the companies take enough samples to ensure the sufficient quality of the seed crop. Cone collection is usually carried out by external contractors under supervision of the registered company. Both of our major seed producers have seed extraction plants with modern and effective machines, their own seed laboratories for seed testing, and professional personnel.

Categories of FRM used in the country:

In 2022, nearly all Scots pine nursery sowings in southern Finland were conducted using bred seeds. In northern Finland, the percentage was lower at 89%. The proportion of pine seeds categorized as tested was 81% in the south and 50% in the north. The proportion of seeds processed for Norway spruce was slightly lower, especially in northern Finland. The share of bred seeds was 97% in the south and 78% in the north. In the case of spruce, only a small percentage of seeds belonged to the “tested” category. For silver birch, nearly all (97%) nursery sowings were done using bred seeds, most of which fell into the tested category.

We do not have precise annual statistics regarding the categories of seeds used for direct seeding. According to our seed producers, the use of bred seeds in Southern Finland is close to 100%. In central and northern Finland, it is lower. According to an unpublished survey of operators conducted in 2020, the national average for the use of bred seeds (“qualified” and “tested” categories) in forest plantings was approximately 60%. This proportion decreased from south to north.

Status of forest tree breeding in the country:

In Finland, Natural Resources Institute carries out intensive and long-term forest tree breeding program for Scots pine, Norway spruce, and silver birch. Additionally, black alder, Siberian larch and hybrid aspen have been bred with narrower breeding materials than the main tree species. The goal of forest tree breeding is to ensure the availability of genetically

improved materials for reforestation, including planting and direct seeding, throughout Finland. Seed orchard materials are currently widely used in forest regeneration, covering tens of thousands of hectares every year. Breeding programs will provide new improved materials to be used in 1.5- and 2nd-generation seed orchards and vegetative mass propagation over the coming decades. The genetic gains achieved in adaptability, hardiness, stem quality, and productivity of the reforestation materials add value to the entire forest sector.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country
In Savonlinna, the Natural Resources Institute Finland (Luke) has a research and development platform for vegetative propagation. The laboratory for vegetative propagation can produce several million somatic embryos per year. The associated greenhouse is used to develop and pilot methods for somatic embryogenesis and cryopreservation of forest trees, facilitating a more efficient transfer of tree improvement results into practice. This laboratory produces somatic seedlings (somatic emblings) and SE-plants, which are sold to commercial nurseries where they are grown to a marketable size. Commercial production started a couple of years ago, and it is expected to expand in the coming years.
Description of official controlling of FRM of legislation:
Large nurseries are inspected annually, while smaller ones are inspected every two years. The inspections are conducted by inspectors from the Finnish Food Authority. Both the requirements of the Council Directive 1999/105/EC and the Plant Health Regulation ((EU) 2016/2031) are assessed during the same inspection visit.

GERMANY
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
The forest nursery sector in Germany is predominantly privately owned. In recent years, there has been a decline in the number of small tree nurseries, accompanied by a concentration on a few large companies. For cost reasons, the public sector has withdrawn more and more from this business. Generally, there are only 1-2 state-run tree nurseries per federal state, which also strive not to compete with the private sector. Currently, approximately 1,900 forestry seed/forest plant enterprises are registered. Of these, around 280 are registered as tree nurseries, 500 forest owners harvest or market seeds themselves, 450 are traders and seed and planting enterprises, and over 500 are other companies without precise classification. There are 11 seed kilns, mainly in public hands. (Figures on seed harvests as well as imports and exports of seeds and plants can be found at https://fgrdeu.genres.de/erntehandel).
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
Seed collection is done by a few specialized operators, which carry out a large part of harvests either themselves or with subcontractors. These are partly state owned, but also private seed kilns. In Germany, approximately 14.500 seed stands with an area of 100.000 ha are registered in the category "selected"(for a total overview see https://fgrdeu.genres.de/zulassungsregister).
Overview of organization of seed collection, seed cleaning, and seed storage:

In almost every federal state, there is a state-run seed kiln, but some of them are managed as independent business entities. Additionally, there are several private seed kilns, as well as larger tree nurseries with their own seed departments and seed storage facilities.
Categories of FRM used in the country:
In Germany, only FRM of the category “selected” or higher categories (“qualified” and “tested”,) is to be used in the forest. The category “source identified” is prohibited to be offered and sold to end-users in the forestry sector. The category “selected” also has by far largest proportion both in the certified basic material as well as in harvested seeds. For some tree species, however, the proportion of seeds in the categories “qualified” and “tested” is used to a considerable extent, because these categories are given priority during harvesting operations (see also https://fgrdeu.genres.de/erhaltung/in-situ-und-ex-situ-erhaltung).
Status of forest tree breeding in the country:
While the importance of forest tree breeding has decreased over the last two decades (due to a strong focus on natural regeneration), efforts have intensified again in the face of climate change. Tree breeding is mainly done by the public sector. In almost every federal state there is a forest research institute, which is dealing with tree breeding, or this effort is done in cooperation with other federal states. In addition, there is the Thünen Institute of Forest Genetics, which is financed by the federal government.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
As part of the concentration process towards larger forest nursery operations, specialization has also occurred. There are specialized nurseries (mainly in Schleswig-Holstein) that produce only one-year-old seedlings for other nurseries in Germany and abroad. Similarly, contract cultivation is carried out for state forestry administrations or other European member states (e.g., Sweden). On the other hand, German nurseries have their plants produced in Eastern European member states.
Description of official controlling of FRM of legislation:
The responsibility for control of forest seed and plant companies lies with the federal states. Each federal state has one or more inspectors who conduct on-site inspections of the businesses. Depending on the scope of the business's activities, inspections are carried out once or twice a year or on a risk basis. This involves an exchange of information between the inspectors on suspicious circumstances. Once a year, inspectors from all federal states meet for a working session. Coordination with other European member states is carried out through the Federal Office for Agriculture and Food (BLE). The BLE handles inquiries to and from other European member states and maintains the national list of registered forestry seed and plant companies.

IRELAND
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
Ireland's forests are expanding and now stand at 11.6% of the total land area, with a wide variety of forest types present. Ireland is home to a range of native, non-native and naturalised tree species. There are approximately 36 native tree species (including some shrub species). The number of native tree species managed or utilised in a forestry context is much smaller, mainly *Betula* spp., *Quercus* spp. and *Pinus sylvestris*. Traditionally non-native tree species have played an important role in the forestry context. Sitka spruce

(*Picea sitchensis*) is the most common tree species, occupying 44.6% of the total forest area. Over one-quarter of the forest estate contains broadleaves. One-third (33.6%) of the broadleaves are 'Other broadleaf species' (both long-living and short-living), of which over half are *Salix* spp. The next largest broadleaf species group are *Betula* spp. (24.4%), followed by *Fraxinus excelsior* (13.1%) and *Quercus* spp. (9.2%).

Planting is the predominant method of forest establishment, most of it on former agricultural land. Regeneration is almost always by planting. The country is classified as one region of provenance. Forest reproductive material is identified and utilised according to the regulations as prescribed by EU Council Directive 1999/105/EC. Seed is the most used reproductive material apart from a small amount of cuttings material from the Sitka spruce improvement programme.

The forest nursery market is a combination of both public and private entities, which reflects the ownership structure of the forests in Ireland more generally. Approximately 50 % of the forest area of Ireland is owned publicly, managed by the State forestry company, Coillte. This company has its own nursery to serve to forestation needs. Forests in private ownership generally source FRM from the private nursery sector. The private nursery sector is characterizsed by a small number of dominant nurseries supplying the commercial forestry sector, supplemented with a number of smaller specialized nurseries, generally focused on specific markets, for example production of native species for establishment and restoration of native woodland.

Seed comes from two home sources: seed stands and seed orchards, the greater proportion of which comes from seed stands. The seed stands selection and registration programme is carried out by the Department of Agriculture, Food and the Marine; it is an ongoing programme to fulfil the requirements of the EU Directive 1999/105/EC.

Main broadleaves species planted include, *Alnus glutinosa, Fagus sylvatica, Betula pendula, Betula pubescens, Prunus avium, Querus Petraea, Quercus Robur, Acer pseudoplatanus*. The main conifer species planted include: *Picea sitchensis, Pseudotsuga menziesii, Pinus sylvestris, Pinus contorta, Thuja plicata*.

To meet afforestation and reforestation requirements, a secure supply of appropriate reproductive material is required. In the medium to long term, it is likely that there will be a continued demand for the main commercial tree species, as well as an increasing demand for native species to serve native woodland establishment and rehabilitation programmes. An indigenous resource of high-quality reproductive material from home sources is a priority. Seed stands will remain a major source of seed, especially for broadleaf trees for the foreseeable future, while strategies to increase the production of 'Qualified' and 'Tested' FRM are also being prioritized, which has resulted in the establishment of a number of seed orchards in recent years.

There are however operational and environmental limitations to the production of seed in Ireland. This can include practical challenges such as the limited number of seed collectors, to the periodicity of seed years for some species. Furthermore, for species with an active tree improvement programme, it will take time for seed-producing orchards to come into production. While for some potential species recommended for use in the context of climate change, there are few stands in Ireland to serve as potential seed sources.

Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):

The national seed market is characterised by a small number of operators who are responsible for over 95 % of indigenous seed collections. There are four private seed orchards. There are 18 public seed orchards. There are 240 publicly owned seed stands, and 49 private seed stands. Species diversity (16 different species) in publicly owned stands is greater than privately owned (8 species). The species in publicly owned seed orchards are: *Acer pseudoplatanus, Alnus glutinosa, Betula pendula, Betula pubescens,*

Fraxinus excelsior, Larix x euroleptis, Picea sitchensis, Pinus contorta, and Pinus sylvestris. The species in privately owned seed orchards are: Acer pseudoplatanus, Betula pendula, Betula pubescens, Castanea sativa. The species in privately owned seed stands are: *Alnus glutinosa, Betula pubescens, Fagus sylvatica, Picea sitchensis, Pinus nigra, Pinus sylvestris, Quercus petraea, and Quercus robur. The species in publicly owned seed stands are: Acer pseudoplatanus, Alnus glutinosa, Betula pubescens, Castanea sativa, Fagus sylvatica, Fraxinus excelsior, Larix decidua, Larix kaempferi, Picea abies, Picea sitchensis, Pinus contorta, Pinus radiata, Pinus sylvestris, Pseudotsuga menziesii, Quercus petraea,* and *Quercus robur*.

Overview of organization of seed collection, seed cleaning, and seed storage**:**

Seed collection is undertaken by registered seed collectors. All seed collectors, seed suppliers, nurseries, plant suppliers/brokers etc. must be registered with the Department of Agriculture, Food and the Marine. All seed collections must be notified in advance following which a Seed Collection Permit is issued. Following the collection the seed collector applies for a Master Certificate of Provenance for the collection. Where seed or plants are subsequently marketed the material must be accompanied by a Supplier's Document which incorporates the Master Certificate of Provenance number and the national register reference number for the basic material. Where seed is marketed the supplier, in addition to supplying specified provenance details, must also provide information on seed purity, germination percentage, weight per 1,000 seeds and germinable seeds per kg.

Seed collection is carried out by a number of public and private entities. On the public side this includes Coillte Nurseries, and the National Parks and Wildlife Service (Government Agency with responsibility for National Parks). Seed collection is also carried out by private entities.

In 2022, 283 Seed Collection Permits were issued – an increase on the previous year (242 issued in 2021). During 2022, 64 Master Certificates of Provenance were issued (91 issued in 2021). These figures vary from year to year depending on availability of suitable seed and levels of demand.
Coillte Nurseries manages Ireland's National Tree Seed centre. This facility includes cone drying and storage, seed kiln, seed processing and extractory facilities, cold storage and other related facilities.

Categories of FRM used in the country:

The figures given below detail the FRM that were sown in forest nurseries in Ireland in 2023. These figures include FRM collected from Basic Material situated in Ireland, and FRM imports.

In 2023, source identified FRM of the following species, with estimated number of plants, were grown in Irish nursery beds: *Acer pseudoplatanus* 98,000, *Betula pendula* 38,000, *Betula pubescens* 1,674,000, *Prunus avium* 35,000, *Quercus petraea* 83,000, *Quercus robur* 317,000.

In 2023, FRM of the selected category of the following species, with estimated number of plants, were grown in Irish nursery beds: *Alnus glutinosa* 2,481,000, *Betula pubescens* 942,000, *Fagus sylvatica* 229,000, *Picea abies* 870,000, *Picea sitchensis* 4,850,000, *Pinus contorta* 2,014,000, *Pinus sylvestris* 200,000, *Pseudotsuga menziesii* 500,000, *Quercus petraea* 719,000, *Quercus robur* 2,061,000, *Tsuga heterophylla* 16,000.

In 2023, FRM of the Qualified category of the following species, with estimated number of plants, were grown in Irish nursery beds: *Acer pseudoplatanus* 22,000 plants, *Alnus glutinosa* 24,000 plants, *Betula pendula* 369,000 plants, *Betula pubescens* 882,000 plants, *Larix* spp. 8,000 plants, *Picea abies* 970,000 plants, *Pinus contorta* 473,000 plants, *Pinus sylvestris* 1,259,000 plants, *Pseudotsuga menziesii* 268,000 plants.

In 2023, FRM of the Tested category of the following species, with estimated number of plants, were used in Irish nursery beds: *Picea sitchensis* 19,465,000 plants, *Pinus sylvestris* 2,004,000 plants, *Pseudotsuga menziesii* 325,000 plants, *Quercus robur* 1,110,000 plants.

Status of forest tree breeding in the country:

Progress has been made in the genetic improvement of many of the species used in Irish forestry over the last 70 years. Information from provenance trials has been used as the basis of seed source recommendations and tree breeding work has produced genetically improved planting stock for certain tree species.

Tree breeding programmes were established in Sitka spruce and for a number of broadleaf species, including birch (*Betula pubescens* & *Betula pendula*) and alder (*Alnus glutinosa*), oak (*Quercus robur* & *Quercus petraea*). Breeding programmes were also established for pines, however, the programme for lodgepole pine (*Pinus contorta*) was suspended due to reduced peatland planting and the Monterey pine (*Pinus radiata*) programme was terminated due to limited suitability of the species. There is also ongoing work to improve the quality of pedunculate and sessile oak (*Quercus robur*, *Quercus petraea*), wild cherry (*Prunus avium*), sweet chestnut (*Castanea sativa*) and sycamore (*Acer pseudoplatanus*). "Qualified" orchards for all of these species have been established.

Sitka spruce has been the focus for conifer tree improvement and is the only species for which 'Tested' FRM has been developed. Sitka spruce is not a regular seed producer under Irish climatic conditions, as a result, seed orchards were not considered initially to be a feasible production strategy for producing improved FRM. Instead, deployment was initially through vegetative methods, using a process of somatic embryogenesis to provide copies of full-sib crosses, and then establishing hedges of this material, from which cuttings could be then taken. The theoretical advantage of this approach is that individuals with superior traits can be reproduced. The disadvantage is that the techniques result in higher per plant costs than plants propagated from seed. Largely for this reason, the micropropagation facilities were closed in 2016. Resources have instead been directed towards the establishment of seed orchards. The first "tested" seed orchards were established in 2011 and expanded in 2018, 2020 & 2023. Seed was collected for the first time in 2014, with the first major collection occurring in 2019.

Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:

Figures on the extent of such practices are not available at the national level.

Description of official controlling of FRM of legislation:

The Department of Agriculture, Food and the Marine (DAFM) is Ireland's National Plant Protection Organization (NPPO) and is responsible for the implementation of the Plant Health Regulation (Regulation (EU)2016/2031) and the Official Controls Regulation (Regulation(EU)2017/625). Annual forest health surveys in forests and forest nurseries are carried out as part of its responsibilities. In addition, DAFM is responsible for implementing EU Council Directive 1999/105/EC on the marketing of forest reproductive material and carries out compliance checks on suppliers of forest reproductive material - seed collectors, nurseries, seed and plant importers and brokers.

ITALY

Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:

In Italy, the forestry nursery sector for the production and marketing for forestry purposes of the species included in Annex 1 of Legislative Decree no. 386/2003 is the responsibility of the official regional bodies and the autonomous provinces of Trento and Bolzano. Following the changes introduced by Legislative Decree no. 34/2018, the coordination of the national nursery supply chain is entrusted to a Technical Commission established at the MASAF (Ministry of Agriculture, Food Sovereignty and Forestry). The need for coordination, especially at a regulatory level, emerged due to the notable heterogeneity found at the administrative level between the 21 official bodies and also demonstrated by studies on the sector. Almost all official bodies have one or more public nurseries in their territory of competence. Following the increase in demand, private forest nurseries are also finding interest in the production of forest reproductive materials for forestry purposes. From both categories emerges the need for planning to adequately deal with requests from public and private entities. Among the most produced species we find maples (*Acer campestre* and *A. pseudoplatanus*), spruce, oaks (*Q. ilex, Q. cerris* and *Q. pubescens*), black hornbeam (*Ostrya carpinifolia*) and manna ash (*Fraxinus ornus*). Currently, public and private forest nurseries that intend to produce forest reproductive material (FRM) to be used for forestry purposes must be equipped with a license pursuant to article 4 of Legislative Decree no. 386/2003, issued by the competent regional official bodies. Furthermore, they must comply with current national phytosanitary regulations. In recent years, with the approval of the Green Deal and the related strategies, there has been a sudden increase in the demand for forest reproductive materials and, at the same time, in the identification of further basic materials of regulated species. The sector is undergoing reorganization, both to adapt the regulatory aspects and to deal with the demand for reproductive materials in an adequate and coherent way with the new strategies and with the indications of scientific research. To overcome the fragmented nature of data collection relating to the sector, a management indicator has been introduced within the SINFor database (National Forestry Information System) which will be fed by data provided by official bodies. The objective is to have unique data useful for planning and evaluating any regulatory and/or organizational interventions also in order to introduce concepts characterizing the new strategies in the sector even before they are implemented by European standards. This approach was applied to the definition of the forestry purposes named in Directive 1999/105/EC, declining them on the basis of what was already considered forest management activities by Legislative Decree no. 386/2003 and other specific activities for which the use of certified propagation materials is considered of fundamental importance for the success of the interventions.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
The forest seed market has seen a significant boost since the approval of the Green Deal. In particular, the demand for seedlings to be used for forestry purposes has increased greatly, consequently the demand for seed has also seen a notable increase. Public nurseries are often specialized in sourcing seeds and supplying seedlings of the most significant species of the area in which they are located. The National Centers for Biodiversity, in addition to this objective, often extend the availability of FRM to many species even from regions of origin distant from the centers themselves.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
Depending on their production capacity, private nurseries source certified seed from the National Centers for Biodiversity or, very often, carry out all the phases on their own, from harvesting to the sale of certified seedlings to be planted. It depends on the characteristics of each nursery and the ability to invest in training and equipment. This aspect is also being studied in depth with the current Centers for Biodiversity and with the Technical Commission responsible for coordination with the aim of evaluating the possibility of separating the harvest and first germination phase from the breeding phase: the first is in

fact often too burdensome for some nurseries which would be facilitated if a few public centers were able to provide certified and quality FRM to be raised and sold at the appropriate time.
Categories of FRM used in the country:
Regarding forest seeds, the most used category is the Source Identified category, followed by Selected. The controlled category concerns exclusively poplar cuttings used for poplar cultivation.
Status of forest tree breeding in the country:
Improved seed in Italy is produced by seed orchards which contain best parental trees selected on growth performances. To date, 14 seed orchards are registered in the National FRM Register and belong to the species *Castanea sativa, Fraxinus excelsior, Juglans regia, Prunus avium, Populus alba, Populus nigra* and *Pinus brutia*. Established during breeding programs several years ago, they are mainly managed by CREA the Council for Agricultural Research and Economics. The most important forest tree considered as model species for forest genetics, genomics and breeding in Italy is poplar. Breeding programs on poplar, willow and eucalyptus produced improved reproductive materials which are used for fast-growing trees plantations. Tree breeding programs focused on best genetic resources for reforestations in the context of climate change are carried out by several research institutions (e.g., Universities, CNR – National Research Council and CREA).
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
Since the competence in the matter is attributed to the official regional bodies and the Autonomous Provinces, in order to have a complete picture of all aspects, including the outsourcing of some phases, a reorganization is underway to improve sharing at national level of aspects relating to production and marketing of FRMs. At present we know that the practice is not very widespread and that it has been used in an emergency to support nursery facilities on the border with another Member State following a natural disaster.
Description of official controlling of FRM of legislation:
Based on legislative decree no. 386/2003, forest nurseries in Italy must comply with current phytosanitary legislation. Therefore, forest nurseries are subject to phytosanitary controls (approximately one per year), for aspects related to the FRM legislation the organization of the controls is delegated to each official body but the control normally takes place during the harvesting phase, before the issuing of the identity certificate. Forest reproductive material from individual admission units or consignments, must be clearly identifiable throughout the entire process, from collection to delivery to the end user, otherwise the sanctions set out in article 16 of Legislative Decree no. 386/2003.

LATVIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
In Latvia we have 10 state nurseries and 29 private nurseries. In 2022, state nurseries produced 62.7 million seedlings and private nurseries 6.4 million seedlings. The main tree species grown in the nursery are spruce (*Picea abies*), pine (*Pinus sylvestris*), birch (*Betula pendula*) and black alder (*Alnus glutinosa*). One of the structures of Latvian state forests is the maintenance of seed orchards, seed extraction. With the aim of growing forest seedlings of the highest category and quality. The company Latvian state forests is a company owned by the Latvian state, and one of the company's structures is the production

of seeds and seedlings. Market trend: For about the last 3 years, birch (*Betula pendula* Roth.) seeds and forest seedlings have been lacking in Latvia. Therefore, FRM material is imported from other EU countries. This year, a couple of nurseries bought *Fagus sylvatica* seeds with the aim of growing forest seedlings and selling them in Latvia.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
Latvia's largest producers of forest seeds are the Latvian state forests. Latvian state forests have 61 seed orchards with the "qualified" category and 11 seed orchards with the "tested" category. There is one municipality that owns six seed orchards ("qualified" and "tested"), but what is produced is used for its forest nursery. And the 2 seed orchards are private. The state forests of Latvia have a structure that processes forest seeds and maintains seed reserves in cold chambers. Forest seeds are imported every year. Imports seeds that are lacking in Latvia or for commercial purposes - grows forest seedlings and takes the seedlings back. When importing seeds, they must have the categories "qualified" and "tested". The seed orchards main species are spruce (*Picea abies*), pine (*Pinus sylvestris*), birch (*Betula pendula*) and black alder (*Alnus glutinosa*).
Overview of organization of seed collection, seed cleaning, and seed storage**:**
In Latvia, there is a State Forest Service that controls and supervises FRM producers and are 4 FRM inspectors. Before collecting the seeds, the producer reports the activity and predicts the harvest in the State Forest Service system. When the collection takes place, the FRM inspector measures the collection. Latvian state forests have a structure that processes and stores seeds. Private owners also take the collected seeds to the Latvian state forest seed processing place, which is a paid service. Latvian State Forests cooperates with the Latvian State Research Institute "Silava" to maintain and develop forest seed orchards.
Categories of FRM used in the country:
All categories are used in Latvia. Yes, material of the "tested" category are available.
Status of forest tree breeding in the country:
Forest tree breeding in Latvia began in the second half of the 1950s, when the best stands of the main tree species began to be identified. The achieved result of the work today is the scientifically proven opinion that trees grown from seeds of local origin are the most suitable for Latvia. Using higher grade FRM, the forest will grow with better quality wood and at least 15 years faster. In 2022 the forest was restored with 45.0 million forest seedlings categories "tested" and "qualified", which is 83% of the total amount grown. The tree breeding is highly valued in Latvia.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
Yes, it is important. Swedish firms use such an outsourcing service. Latvian state forests offer the following outsourcing service. Latvia's state forests sell 23% of the total grown volume in outsourcing. Private nurseries also sell to other EU countries, but there is no information whether this is an outsourcing service.
Description of official controlling of FRM of legislation:
There are four FRM inspectors operating in Latvia, who control tree nurseries (check the volume, compliance with legislation, check payment documents and advise on the FRM State Forest Service system, etc.); inspect seed orchards and assess their yield; checks the amount collected in the seed plantations; conducts inspections at seed processing sites; take forest seed samples, which the producer sends to the forest seed control laboratory; etc. tasks performed by FRM inspectors. Inspectors carry out official controls

two times a year in each nursery (this is the minimum). If the nursery has a large production, there is import and export, then there is more control. For large nurseries, even 10 times a year.

LITHUNIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
Annually, about 50 million plants are grown in public forest nurseries (State Forest Enterprise), of which about 30 million are used for the reforestation and afforestation of state forests, about 15 million are sold within the country to private forest owners and about 4-5 million are sold to other EU countries (most of them - according to preliminary agreements). The number of state nurseries decreased from 26 in 2019 to 16 in 2023 and their general area decreased from 1232 ha to 558 ha, while maintaining a similar quantity of cultivated plants due to container planting technologies. In Lithuania in 2019, 22 private FRM suppliers were registered as plant growers, but only 19 of them had small nurseries. Currently, many of them do not grow forest plants anymore, only two private nurseries grow very small amounts. Realized production of private nurseries fell from 0,3 million in 2019 to 0,008 million plants in 2023. The main species are *Picea abies* (L.) H. Karst, *Pinus sylvestris* L., *Betula pendula* Roth, *Alnus glutinosa* (L.) Gaertn. and *Quercus robur* L.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
From 150 kg to 400 kg of Picea abies seeds were sold to Sweden annually until 2019. Seed trade has decreased significantly since 2019. During the last 5 years, only 5,1 kg of *Betula pendula* seeds were sold to Latvia and 7 kg of *Fagus sylvatica* L. seeds were bought from Denmark. From 2019 private nurseries prepared only 2 kg of *Tilia cordata* Mill. seeds. Seed preparation is carried out by the State Forest Enterprise.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
Seed collection, seed cleaning and seed storage are organized by State Forest Enterprise. One modernized seed kiln is operating in Lithuania. The seeds of coniferous and deciduous trees are stored in a seed storage fridge. There is also an oak acorn thermotherapy line and a separate seed storage fridge for oak acorns.
Categories of FRM used in the country:
FRM of the following categories are used in Lithuania: “selected”, “qualified” and “tested”, rare tree species are rarely used thus provided in the “source-identified” category.
Status of forest tree breeding in the country:
In Lithuania forest tree breeding is very important - in the strategic documents, it is planned to increase the country's forest cover to 35 % (about 89 000 ha new forests being planted in the future).
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
The practice of contracting with specialized nurseries for outsourcing is not significant.
Description of official controlling of FRM of legislation:

In Lithuania the State Forest Service is responsible for the control of forest reproductive material. This institution issues documents confirming the origin and quality of forest reproductive material and registers suppliers of forest reproductive material. Control of forest propagating material and nurseries is carried out by the Department of Environmental Protection under the Ministry of the Environment.

THE NETHERLANDS
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
The majority of the nursery sector grows material for FRM. About 10 companies grow a wide range, including many “source identified” Directive and non-Directive species. These are species that are mostly autochthonous. Species from the category selected, qualified and tested such as pedunculate oak and beech, hornbeam, birch, lime, *Prunus* and maple are species that are important for the Dutch nursery sector. There is a shift in the conifer-like species. *Picea abies* has been grown less and less in recent years, it is being replaced by *Pseudotsuga menziesii*. Furthermore, the demand for sessile oak seeds is increasing notably.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
There are 7 specialized companies that only trade in seeds. Three companies that have specialized in only collecting oak, castanea and beech seeds. Three companies carry a wider range of seeds, originating from the Netherlands as well as from other EU countries. Occasionally, seeds are also purchased from other OECD countries (USA and UK). One company (SBB-state forestry department) is responsible for the seed orchards and stands FRM for both directive and non-directive species. The most important species that are collected and traded are: *Quercus robur, Quercus rubra, Castanea sativa, Acer pseudoplatanus, Acer platanoides, Betula pendula, Betula pubescens, Alnus glutinosa, Pinus sylvestris, Pinus nigra subsp. laricio, Prunus avium, Pseudotsuga menziesii, Fagus sylvatica.* Purchases material from other EU member states are *Carpinus betulus, Quercus petraea, Prunus avium, Acer pseudoplatanus, Betula pendula, Betula pubescens, Pinus nigra, Larix x marschlinsii, Tilia cordata, Tila platyphyllos, Abies alba, Abies grandis, Pseudotsuga menziesii* Purchase via OECD from the UK: *Betula pendula, Alnus glutinosa*. From the USA: *Pseudotsuga menziesii*
Overview of organization of seed collection, seed cleaning, and seed storage.
The collection of seeds (FRM) must be reported via the digital program for collecting tree seeds. Seed trade indicates per day where the collection is taking place, the time period of collection and how many people are collecting. Naktuinbouw checks these collections of tree seeds. It is checked whether the collection is taking place on the correct stand, how many people there are and the expected amount of seeds to be collected for that day. This expected amount is entered into the program after which the seed trade must supplement the correct amount of kilograms. A master certificate is drawn up for this collection, if the collection is fully completed, the certificate becomes final. Oak, *Castanea* and beech seeds are sorted by vitality and delivered directly to the tree nursery sector. Sometimes beech seeds are stored refrigerated for a longer period as strategic stock. All other species are cleaned, pulped and then frozen for storage.
Categories of FRM used in the country:

All four categories: source identified, selected, qualified and tested are available. Tested material is available for the species *Fagus sylvativa* and *Quercus robur.*

Status of forest tree breeding in the country:

For a description of the importance of forest tree breeding we refer to Chapter 9 in the Country report of the Netherlands for the state of the world's forest genetic resources for food and agriculture 2021 Most tree improvement programmes were discontinued in the 1990s. Tree breeding activities on *Populus* and *Ulmus* spp., have been carried out in the past, but these breeding programmes are currently on hold, and only selections are being carried out on earlier breeding material. For *Ulmus* spp. the aim of the breeding programme is to develop elm disease resistant hybrid clones for urban green and landscapes, by crossing native and Asian elm species. As a result, more recently, four varieties with good to very good resistance to Dutch elm disease ('Fagel', 'Klondike', 'Nikko' and 'Europa') were released for the Dutch and European market (Buiteveld et al. 2015). Eight experimental clones of Populus x canadensis were selected from the Populus breeding programme, and were recently planted in a clonal trial for further testing.

New clonal collections of *Fraxinus excelsior* (200 clones) were established that showed field tolerance to ash dieback (Figure 9.1). These collections can serve as breeding material for a future tree improvement programme for ash.

Provenance testing is continued in the past decade with a focus on broad leaved species. Since 2012, several new provenance trials have been established. New provenance trials of Prunus avium were established in cooperation with the German Thünen-Institute of Forest Genetics and the Belgian Research Institute for Nature and Forests (INBO). Special attention was paid to the inclusion of both local and climate matched provenances. Two trials of Juglans spp. were established to compare species and hybrids. Currently, provenance trials of Quercus petraea are being prepared in cooperation with the INBO with the aim to compare autochthonous local provenances with provenances originating from more southern regions.

In general, provenance testing objectives are related to good quality timber production, adaptation to Dutch climatic conditions and resistance to pest and diseases. Testing for production and wood quality focusses on growth, stem straightness and branching habits. Testing for adaptation takes survival and leaf flushing into account. Late flushing is seen as an especially valuable trait because of risks of late frosts.

In the Netherlands, provenance, progeny and clone testing are performed by the CGN and mainly related to Value for Cultivation and Use (VCU) research, which is commissioned and funded by the Board for Plant Varieties. The focus is on species relevant for Dutch forestry and subjected to the Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material. Provenance testing of non-directive species (*Juglans* spp.) is carried out in cooperation with the State Forest Service and other forest owners. Wageningen Environmental Research (WENR) holds collections of clones from earlier breeding activities (mainly *Populus* and *Ulmus* spp.).

Tree breeding activities are almost absent in the Netherlands. For *Fraxinus excelsior*, a clonal collection has been set up to be used for future breeding activities in relation to ash dieback caused by the *Hymenoscyphus fraxineus* fungus. The development of adaptive breeding strategies for Fraxinus excelsior is part of the EU-funded H2020 project B4EST (Adaptive BREEDING for productive, sustainable and resilient FORESTs under climate change). One of the main outcomes of this project is the genotyping tool '4TREES' that would allow breeders to evaluate tolerance to ash dieback at an early stage of growth. In this project, in addition to using genomics, inoculation experiments in combination with the use of NIR spectroscopy are being developed to detect tolerance to ash dieback.

Most seed orchards in the Netherlands were established between 1960s and the 1990s. There is a need to consider renewing existing seed orchards and establishing new ones for new species. There is a need to continue provenance testing, particularly because forest managers have an interest in applying climate assisted migration and introducing new species. Besides looking at production traits, provenance testing could also focus more on drought tolerance, bud phenology and resistance to new emerging pests and diseases linked to climate change. The development of tree improvement and breeding programmes that focus on pest and disease resistance needs more attention. For example, in the *Fraxinus excelsior* tree improvement programme, resistance to ash dieback will remain the main target for selecting plus trees. Genomic technologies and advanced genotyping tools will provide new opportunities for selecting desirable traits and maximising genetic diversity in FRM.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country.
This is being done in the Netherlands, although not so much, also batches of seeds are sent to Belgium and Poland. Control is then done by the national authorities of those countries.
Description of official controlling of FRM of legislation
The inspection is carried out by Naktuinbouw. The inspectors check the sown and planted nurseries at least once. And more often if necessary. The inspection is carried out on the basis of the plant book issued by the company. The batches intended for FRM certification must be correctly specified with all relevant information and correctly labelled at the nursery. During the field inspection, a check is carried out on the quantity of plants per batch, for both sown and planted planting material. The certificates are also checked. An administrative check follows during the delivery season, this check not only includes checking the written documents but also a check is carried out on the labelling of the batches that are ready or stored in a cold store. Purchased certified FRM that is sold on is checked to see whether the correct documents have been delivered with the batch.

POLAND
Below the most important information about the forest nurseries of the State Forests National Forest Holding (PGL LP) are provided:
Currently, 334 forest districts have a network of forest nurseries covering the entire country. The nurseries produce planting material for the purposes of reforestation and afforestation works, for both: the State Forests and private forest owners. In addition, State Forests nurseries have modern technical facilities necessary for the acquisition, storage and testing of seeds. The production area of forest nurseries in 2022 was 1752 ha. Seedling production in PGL LP is carried out in field, container and tunnel systems. In 2022, a total of 672 million seedlings of forest trees and shrubs were produced (all ages), and annually approximately 420-430 million plants delivered to the forest. Pine accounted for 44%, oak 22%, beech 16%, spruce 4%, birch 4%, fir 3% and alder 2%. The State Forests National Forest Holding also has a network of container nurseries, which enable the cultivation of container seedlings under controlled conditions. Container nurseries enable a rapid response to cyclically recurring disaster phenomena occurring in forests: large-scale fires, hurricanes and insect outbreaks causing the forest area to be exposed or stands to be thinned. Seedlings from the State Forest nurseries are characterised by good quality, known and controlled origin from our own selected seed base. The seedlings guarantee the intended breeding and economic effect. In terms of the

production of forest reproductive material, the State Forest nurseries are fully self-sufficient.

ROMANIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
According to the "Register of Authorized Producers for the Production of Forest Reproductive Material", in Romania there are 320 state forest nurseries and 450 private forest nurseries. In 2022, forest regeneration carried out on 27,981 hectares. Of the total area, 70.7% was natural regenerated and 29.3% (8,181 ha) through artificial regenerations (plantations and field sowing). The average area of the artificial regenerations over last five years was 8,000 ha. In average, 55% of the total number of used seedlings are coniferous species and 45% broadleaf species. According to the Recovery and Resilience Plan, 27,600 ha will be planted through afforestation and reforestation during 2024-2026. Therefore, the amount of FRM will increase in the coming years.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
In Romania there are four categories of the basic material: “identified”, “selected”, “qualified” and “tested”. The most FRM comes from the “selected” and “qualified” categories. The area of the “selected” category is 37,461 ha and of the “qualified” category is 680 ha, from which 625 ha are seed orchards. The main species used in afforestation and reforestation are: *Picea abies*, *Abies alba* and *Larix decidua* for coniferous species and *Quercus robur, Quercus petraea, Tilia spp, Fraxinus spp, Acer pseudoplatanus, Acer platanoides, Prunus avium,* and *Robinia pseudoacacia* for deciduous species.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
The harvesting activity is organized and carried out by each producer individually. They must notify the territorial Forest Guards within MMAP (Ministry of Environment, Waters and Forests) before harvesting begins. The territorial Forest Guards have the obligation to verify the origin/provenance and quantity of fructification in the respective year. They also will issue the provenance certificate. At national level we have a center for the conservation of the coniferous seeds, which belongs to INCDS (National Institute for Research and Development in Forestry). Also, Romsilva has its own seeds conservation warehouses.
Categories of FRM used in the country:
The most used FRM are from the selected category followed by qualified category (seed orchards and culture to produce poplar and willow cuttings). We also use FRM from tested category (provenance tested in provenance trials).
Status of forest tree breeding in the country:
Research on tree breeding is important both to increase yield and adaptation of the forest species to climate change. The Forest Department from the MMAP collaborates with the Department of Forest Genetics within INCDS on projects regarding the revision of the National Catalog of the basic materials, the revision of the provenance regions, elaboration of the Catalog of the Genetic Resources, elaboration of the legislation on FRM and recommendations for forest practice.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:

This does not fall within the ministry tasks.
Description of official controlling of FRM of legislation:
All control activities regarding production and use of the FRM is carried out by the Forest Guards within the Ministry of Environment, Waters and Forests (MMAP) based on its internal procedures, in both public and private forests. Also, the National Forest Administration (Romsilva) carries out controls in the forests administrated by themselves.

SERBIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
In Serbia, nurseries are either public or private ownership. At the moment, there are 55 public nurseries and 30 private nurseries. In the last few years, the number of private nurseries decreased. The main species that are being produced are *Fagus sylvatica, Quercus robur*, *Quercus petraea, Prunus avium, Acer pseudoplatanus, Picea abies, Pinus nigra,* and *Pinus sylvestris*.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
The main providers are public enterprises. The main species are *Fagus sylvatica, Quercus robur, Quercus petraea, Prunus avium, Acer pseudoplatanus, Picea abies, Pinus nigra, and Pinus syilvestrus*.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
These activities are carried out exclusively in public institutions. There are two seed facilities, one in Central Serbia, and another one in autonomous province of Vojvodina.
Categories of FRM used in the country:
In our country, forest seeds of the categories “source identified”, “selected”, and “qualified” are being used. Material of the “tested” category is not available.
Status of forest tree breeding in the country:
Breeding gets more and more significance in our country, especially in the means of climate change.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
These practices do not apply in my country.
Description of official controlling of FRM of legislation:
Inspection is done by republic hunting and forestry inspection, and reproductive material quality is controlled by authorized institutions (e.g. Institute of Forestry).

SLOVAKIA

Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
There are 19 public and 82 private nurseries active in plant production in Slovakia. There are 6 public and 4 private large nurseries, who each are producing more than 5 million plants annually. Trading is a matter of agreement between the producer and the customer. The most used trees are *Picea abies, Abies alba, Fagus sylvatica, Quercus petraea, Acer pseudoplatanus, Larix decidua* and *Pinus sylvestris*.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
We do not import seed to Slovakia; the main producers of seed are state forests and about 3 private entities. The structure of seed orchards are: 93% state, 7% non-state entities. The most represented trees in seed orchards are *Pinus sylvestris* L. and *Larix decidua* Mill...
Overview of organization of seed collection, seed cleaning, and seed storage**:**
Seed collection is carried out by state entities and private entities on the basis of framework agreements, natural persons organize them individually as needed. Everyone who carries out seed collection must hold a certificate of professional competence for activities with forest reproductive material.
Categories of FRM used in the country:
All FRM categories are used in Slovakia, including the “tested” one.
Status of forest tree breeding in the country:
We cannot comment on that.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
We do not know whether some nurseries enter into contracts.
Description of official controlling of FRM of legislation:
Inspections of all forest nurseries are carried out once a year and the state inspection is carried out by the National Forest Centre Zvolen.

SLOVENIA
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
In the Republic Slovenia (from 1990 - 2024) production forest nurseries are mainly privately owned. Currently there are six private forest nurseries registered in Slovenia (t.i. Omorika, Štivan, Gozdarstvo Turnisce, Trgovina z lesom, BLS Gozd, Cornus) and one public forest nursery. Among private registered nurseries the Trgovina z lesom forms a part of the Gozdarstvo Turnisce nursery in the same region. Last FRM marketing was reported in 2020 while Cornus is a new nursery with experience in container seedlings (for vegetables) registered in February 2024 and is not yet operational in FRM market. Apart from private forest nurseries also a state SLOVENIA FOREST SERVICE (SFS) is registered for FRM

marketing and was operational only in the year 2019. All mentioned forest nurseries are small size nurseries in broader EU view. Two (Štivan, Omorika) cover the majority of the forest regeneration seedlings needs in Slovenia, while two others (Gozdarstvo Turnisce and BLS Gozd) are regional and cover mostly the needs of FRM for reforestation in NE Slovenia and partly in the other part of the same provenance region. Since 1997 seedling production has been decreasing steadily (except for a few years following a major disturbance in 2014), from approximately 1.5 million annually in 1997 to around 0.5 million annually in 2013. Over the last five years when disturbances have occurred almost on a yearly basis the nursery production increased to approximately 2 million in 2020 and decreased to 1 million in 2023. The main stock type is bare root seedlings. Generally, around half of the seedlings produced are conifers and half broadleaves. The produced seedlings in the last 30 years belong mainly to *Picea abies, Larix decidua, Abies alba, Fagus sylvatica, Quercus robur, Quercus petraea* and noble hardwoods (*Acer pseudoplatanus, Prunus avium*). Relative shares of species were more or less constant over the years. Despite small numbers, seedlings are produced for more than 25 species annually on average. The non-native species produced is mainly *Pseudotsuga menziensii*. The Ministry of Agriculture, Forestry and Food of the Republic of Slovenia provides funding for Slovenia Forest Service (SFS) from the state budget and EU funds. The public body SFS procures the seedlings in forest nurseries for all private forests (80% of all forests in Slovenia) through multi-annual public tender and distributes them to private forest owners free of charge on the basis of a signed document in accordance to forest management plans while state owned company Slovenia State Forests directly purchases seedlings from forest nurseries for all state forests (20%) according to an annual plan based on forest management plans in close coordination with the Slovenia Forest Service.

Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):

In Slovenia there are 7 officially registered private suppliers of FRM and 1 public institution (Slovenia Forest Service - SFS) which is registered to distribute FRM paid by state to private landowners according to forest management plans. Among 7 private suppliers of FRM are the 6 forest nurseries already mentioned under question 1) and one specialized seed trading company. Forest nurseries and seed trading companies mainly collect seed for their own needs in approved seed stands; the last operator is specialized in seed production for other nurseries. There is currently no import of seeds from countries outside the EU for use in forestry. The Slovenia Forest Service (SFS), which manages the seed storage, is also registered for seed collection. One seed trader (GJ2 company) who collects and sells seed in Slovenia and exports it abroad, carries out international trade. As on the 1st of January 2024, a total of 477 Forest Seed Objects (FSO) including 47 plus trees and 125 'not for forestry use' objects were registered. All together 305 forest seed stands in the category of “source identified” and in category “selected” and 1 clonal seed orchard (“qualified”) have been approved for forest seed production in Slovenia. We have registered plus trees of wild cherry, indigenous poplars (white and black) and white willow. Seed is collected mainly for *Fagus sylvatica, Quercus robur and Quercus petraea, Abies alba, Picea abies, Acer pseudoplatanus*. In addition to these main tree species, seed is collected also from approx. 30 ecologically important and pioneering tree species. In the period 2019-2023, a total of 128 Master Certificates (MC) were issued from 73 different FSOs; of these 128 Master Certificates, 20 were issued with the purpose 'not for forestry use'. For multi-purpose forestry (i.e. without 'not for use' and plus trees) 108 MC from 67 FSOs was issued over a last 5 year period. 28 FSOs have had multiple seed collection ranging from 2 to 5 times (median = 2). It is possible to import seed and seedlings from other EU Member states, but each time the import is subject to the expert opinion of the competent authority (which is the Slovenian Forestry Institute, GIS). In most cases, such transfer among EU countries constitutes introduction/transfer of container seedlings from Slovenian seed grown in an Austrian nursey, or the introduction/transfer of seedlings from Croatia (Croatian seed), if there is a lack of FRM of a certain species in Slovenian

nurseries, primarily as a result of sudden increase in the need for rapid forest restoration after large scale disturbances such as fire. Since 2023 these seedlings are subject also to phytopathological survey of soil substrates (primarily for *Phythopthora* spp) prior to transfer into Slovenia.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
Seed harvesting in approved seed stands: Suppliers notify the intention to harvest to the Local unit of the Slovenia Forest Service - SFS one week before the start of harvesting (start of production) in order to secure the issuance of a Master Certificate of Origin. The SFS supervises the harvesting and issues a certificate of harvesting of the in situ FRM. A sample from each tree harvested is sent to the Slovenian Forestry Institute (SFI) for analysis, together with a copy of the Proof of Harvesting. On the basis of the SFS report and the Proof of Harvesting, SFI issues a Master Certificate to the supplier, checking beforehand, if necessary, the seed declared on the SFS proof and the number of trees (following the guidelines for collection as set out in the Decree on the Approval of the FSO) from which the seed has been collected. Cleaning and storage are done by every operational forest nursery itself while long-term storage (for emergency needs) is organized in the frame of the Seed Storage managed by SFS (SFS is a public institution). Genetic diversity in seed collection is ensured by prescribing the minimum number of tress from which seeds have to be harvested. This number depends on the tree species and is determined by a regulation on the conditions for the approval of forest seed object in the categories “source identified” and “selected”. Forest nurseries in Slovenia collect seeds and cuttings for their own needs in officially approved forest seed objects. The Regulation on the conditions for the approval of forest seed object in the categories “source identified” and “selected” recommend collecting seed from 25 (or at least 10) unrelated trees for scattered forest tree species and from 50 trees (or at least 25) for stand-forming tree species which are distributed over the entire seed stand. Equal quantities of seed should be collected from each tree. Mixing seed lots is permitted and even supported if the source material comes from the same region (and elevation) of origin and the process of mixing is controlled by the inspectorate and documented.
Categories of FRM used in the country:
In Slovenia, most of FRM is of the “selected” category. If there is not enough seed, also the “source identified” category is collected and used. Every year, seed is collected in the*Alnus glutinosa* seed orchard (qualified category). No FRM of category “tested” is available in Slovenia. For restoration of lowland forests with native poplar and white willow, FRM is grown in nurseries (“qualified” category derived from in situ seed / seedling objects).
Status of forest tree breeding in the country:
The majority of forest regeneration in Slovenia is natural (95%), the rest is via artificial regeneration. Breeding has not been a priority in Slovenia, but with the increasing impacts of climate change we expect the share of artificial regeneration to increase, possibly also including breeding.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
Initial stages of seedling production are not outsourced. Nurseries do it themselves, except for one approved forest seed owner, who produces seedlings *of Malus, Pyrus, Prunus* and *Juglans* within his farm as a cooperative of one nursery. However, in special cases Slovenian seed is exported abroad and seedlings raised from this seed transferred back into Slovenia (thus far only happened between Slovenia and an Austrian nursery), while two Croatian nurseries have provided oaks seedlings for from their basic material for use in Slovenian forests.

Description of official controlling of FRM of legislation:
The health status of all reproductive material (regarding the requirements about FRM health status by the Council Directive 1999/105/EC of 22 December 1999 on the marketing of forest reproductive material) is inspected twice a year by the Slovenian Forestry Institute, which is authorized by the ministry responsible for the forestry sector to officially supervise the health of all reproductive materials for forest plantings; the inspection is carried out in cooperation with forest inspection. The prescribed phytosanitary measures are mandatory for nursery managers. The implementation of the measures prescribed is monitored by forest inspectors. In addition, the presence/absence of quarantine pests and RNQP for the EU has to be regularly checked by the nursery, and is under supervision of forest inspection Regulation (EU) 2016/2031 on protective measures against plant pests. The presence/absence of quarantine pests and RNQP for the EU has to be regularly checked by the nursery and is under supervision of forest inspection Regulation (EU) 2016/2031 on protective measures against plant pests. The infected plants must be removed and destroyed.

SPAIN
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
There are many small private forest nurseries and a few public belonging to regional governments. Primary tree species (according to production of FRM in the last statistics): *Quercus ilex, Quercus suber*, other *Quercus* spp., *Pinus pinaster*, *Pinus pinea*, *Pinus halepensis, Pinus sylvestris*, *Pinus radiata*, other *Pinus*, *Populus*, spp. (no data of *Eucalyptus*, as it is not a regulated genus).
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
In relation with companies devoted to collect forest fruits and seeds there are a few and mainly the Central Government (the most important seed supplier to the sector) and some of them in the Autonomous regions. Seed orchards are mainly public (33% from the Central Government, the rest from the autonomous regions, with a total of 32 of seed orchards). For basic material of qualified and tested categories there are around 20% private and 80% public). Seed stands have diverse ownership, depending on the regions and the species (for example for *Quercus ilex* is mainly private), and for *Pinus* it depends on the region, but public is predominant. The introduction of seeds from abroad is uncommon (more with plants: e.g. *Eucalyptus*). Some plants of *Pinus radiata* were imported in the last years.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
All these activities are mainly carried out for the public administration and the whole process with the help of public companies.
Categories of FRM used in the country:
All categories are used, but much less quantity of the superior categories (less than 10% of the production in seeds and plants); category “source-identified”: 61.5% (seeds), 37.9% (plants); “selected”: 29.4% (seeds); 54.4% (plants); “qualified” 7,8% (seeds), 7,1% (plants); “tested”: 1,4% (seeds) 0.6% (plants)
Status of forest tree breeding in the country:
There was a national plan of seed orchards (pine species) focused on timber production. There are some seed orchards in the North (mainly Galicia) of *Pinus pinaster* and *Pinus*

radiata. Forest tree breeding with the aim to tolerances to pests and diseases have become increasingly important in the last years (e.g. *Quercus ilex* and *Q. suber* against *Phytophthora* and drought). There are other older examples: elms, chestnut.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
This practice is not significant in Spain, and it occurs rarely.
Description of official controlling of FRM of legislation:
The inspections are carried on by the control authorities of the regions. Each region decides on how to carry out the inspections and how often they are necessary based on the risk for misconduct.

SWEDEN
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
FRM production is not organized or managed on authority level. Five big actors produce the vast majority of seed (seed orchard seed) and plants; the four biggest forest owning companies SCA, Holmen, Stora Enso (Finnish-Swedish) that are listed companies owned by private shareholders, Sveaskog that is limited company 100% state ownership, and Södra skogsägarna that is the biggest forest owners association, owned by forest owners in southern part of Sweden. A couple (around 10) of smaller privately owned companies with nurseries in Sweden or with established contract grower agreements in Germany and other countries around the Baltic Sea also produce a significant proportion of plants for the Swedish market. Also, the big five grow plants by contract nurseries abroad to some extent. Around 10% of the plants reaching the Swedish market has been produced abroad. Sweden lacks capacity or interest to grow minor species, and a significant proportion of broadleaved plants come from Denmark and other European countries, mainly for use in southern Sweden. *Picea abies* and *Pinus sylvestris* represent more than 95% of the plants (54% pine and 41% spruce). Lodgepole pine, *P contorta*, *Larix* spp. (hybrid and Siberian) and *Betula pendula* are 2-7 million. plants each on an annual basis. Almost all Pine seed and around 70% spruce seed is from improved seed orchards (“qualified” or “tested” categories). The trend is towards fewer small producers as they tend to close when managers retire.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
Please see above. There are 152 entries of seed orchard basic material in the Swedish register. Some of the Scots pine SO are in fact so called fractions of seed orchards, sorting high genetic value clones and clones of less high genetic values; one physical SO can comprise three entries: the whole SO, the high genetic value fraction and the lower genetic value fraction. 37 spruce and 71 pine, 13 *P. contorta*, 16 broadleaved tree, and 13 exotic species except contorta (hybrid larch, Douglas, Sitka spruce) entries. Many SO have shared ownerships among the big five, and one of them is appointed management and responsibility in relation to the authority (Swedish Forest Agency). Stand seed is not common but every year some collection of stand seed of oak, spruce and pine and occasionally other species is applied for master certificate. Sweden is divided in five seed sources (corresponding the five Regions of provenance) for collection of the “source-identified” category. So the whole country is open to harvest any species. Between approx. 2005 and 2019 large quantities of Norway spruce seed were imported from Belarus due to shortcomings in Sweden, but probably also competitive pricing, and in particular because

Belarusian provenances produce better than local seed. Today a certain amount of seeds come from neighboring countries. The Forest Research Institute of Sweden (Skogforsk) is responsible for forest tree breeding, 50% state and 50% private forestry financing.
Overview of organization of seed collection, seed cleaning, and seed storage**:**
All steps are managed by private actors (including state owned Sveaskog that is the largest actor). Contractors perform harvest. Forest companies or one single private kiln perform seed extraction. Skogforsk (Sävar close to Umeå) is a main player and service provider in seed cleaning and testing. Companies have their own seed storage. No official control on amounts of seed in storage are done.
Categories of FRM used in the country:
Statistics can be extracted from https://pxweb.skogsstyrelsen.se/pxweb/en/ In 2023 for *Pinus sylvestris* 96% of seeds came from national seed orchards; in *Picea abies* 82% came from national seed orchards, 11% from foreign seed orchards, 6% from foreign stands; in ***Pinus contorta*** 98% of seeds came from Swedish seed orchards; in ***Larix decidua*** 58% come from foreign seed orchards18% from Swedish seed orchards; in ***Betula pendula*** 38% of seeds came from Swedish plantations, 56% from foreign plantations. So seed orchard material (categories “qualified” and ”tested”) account for a very large amount of FRM used in Swedish forestry.
Status of forest tree breeding in the country:
When it comes to the proportion of FRM tree breeding is very important. Forest companies rely on expected increase in growth due to breeding when calculating cutting levels, so it is important from a forest industry point of view. Increasing threats from pests may increase the need for resistance breeding and in the case of ash dieback it is already the case. Also, the pest ***Cronartium pini*** on Scots pine requires resistance breeding to be included in breeding programme. Climate change will increase the need for assisted migration that will probably include steps of breeding or at least plus tree selection.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country:
Please see above. To complement, small proportion of contract growing outside EU (Norway and maybe the UK). Not aware of domestic contract growers as this is not notified by the authority. Probably the actors buy plants and/or nursery capacity from each other when needed. The biggest contract growers I am aware of are situated in Northern Germany.
Description of official controlling of FRM of legislation:
The Swedish Forest Agency is the competent authority in FRM control, including approval of basic material, import permits (import from outside EU needs a permit, not just notification), MC issuance, official documents, import from EU notification (Sweden requires that import from both third countries and other MS is notified), and risk-based control/inspections. Every registered actor (or facility if the actor has more than one facility) shall be inspected regularly and not more seldom than every fourth year. The frequency is risk based and depends on previous findings and noted deviations from rules. The forest seedling market is very diverse and fragmented as it consists of large numbers of service providers (independent silviculture contractors, sawmills and other buyers of timber) offering reforestation services, sometimes the offer includes the seedings and sometimes only delivering and planting the seedings is included as a contractor under the nursery or plant dealer. All these service providers are not registered but can be under the scope of inspection and control via the providers of seedlings, except contractors only working with seedlings bought from other MS. This is a grey area that needs to be revisited.

SWITZERLAND
Overview of the national forest nursery market, including its organizational structure (public or private), key industry players, primary tree species, and any notable changes in the market over recent years:
The forest nursery market in Switzerland consists of both public (5) and private sectors (3). The organizational structure reflects a mix of small to medium-sized enterprises (SMEs). Key industry players include specialized nurseries and government agencies involved in forest management. Primary tree species cultivated on different altitude include spruce (*Picea abies*), fir (*Abies alba*), and beech (*Fagus sylvatica*). Over recent years, the market has increased a lot and the focus has switched to sustainability and climate-resilient species to address changing environmental conditions.
Short description of the national seed market (e.g. main providers, ownership structure seed orchards/seed stands, introduction from abroad, main species, etc.):
The seed market in Switzerland is primarily composed of both public and private seed orchards and stands. Both can be harvested with the approval of the owner. The ownership structure emphasizes local seed sources to maintain genetic diversity. Limited introduction of seeds from abroad is permitted under strict regulations, mainly for non-native but climate-adaptive species. Key species include spruce, fir, and other native broadleaf trees.
Overview of organization of seed collection, seed cleaning, and seed storage.
Seed-related activities in Switzerland are predominantly managed by public institutions, with some private-sector involvement. Seed collection follows strict guidelines to ensure sustainability and the best genetic difference possible. Cleaning and prepping of seed within the cones are done in a special facility in Rodels. The other seeds are processed from "normal" forest nursery. The storage, however, is centralized in specialized facilities (e.g. WSL) to maintain high quality and longevity. Public institutions play a critical role, but private nurseries contribute significantly to the operations.
Categories of FRM used in the country:
All four categories of FRM (“source-identified”, “selected”, “qualified”, and “tested”) are utilized in Switzerland. In Switzerland we don't have any seed stands labelled as “tested” material.
Status of forest tree breeding in the country:
Forest tree breeding is moderately emphasized in Switzerland. Most of the plants are planted on mountains regions, where a fast growth is needed in order to protect as soon as possible against natural hazards. Otherwise, the focus is on maintaining genetic diversity, the use of natural regeneration and developing climate-resilient species. Breeding programs prioritize both native and adaptive non-native species.
Importance of contract production of small seedlings, i.e. the outsourcing of the initial stages of seedling production in the country.
Contracting specialized nurseries is a significant practice in Switzerland, mainly within domestic borders. Once a year we have a meeting, where all the big key players can exchange their own seeds. However, some collaborations exist with EU countries, even if most of those exchanges are based on the trade of young plants. This outsourcing helps ensure high-quality seedling production.
Description of official controlling of FRM of legislation

In Switzerland at the moment, we don't do any FRM special inspection which take place in the forest nursery. However, due to the new agreements with the EU, we are keen to implement such an inspection system in the near future. Official phytosanitary inspections are conducted annually by national authorities. Those ensure compliance with national and regional forestry regulations.

In synthesis, the available 21 country reports show the diverse range of the structure and organization of the FRM market in Europe. An overview of main characteristics is shown in Table 5. The FRM production in Central and Northern Europe (particularly in Scandinavia) is dominated by private enterprises; while there is still a relatively high number of nurseries in Central Europe the market is dominated by few very large privately owned nurseries in Scandinavia. In Scandinavia FRM production is done with high technological effort with almost exclusive production of container plants (see also Mataruga et al. 2023). Public nurseries strongly dominate the market in Poland, Latvia, Lithuania, and Croatia. In the other regions and countries public participation via public nurseries in the market is also common.

Except in Scandinavia public involvement is also strong in seed provision, as many seed stands and in particularly seed orchards are publicly owned. The importance of tree breeding varies among countries and is most evident in the availability of FRM in the “tested” category. Outsourcing of early stages of seedling production could become more important in the future to increase the regional production capacity. This practice is already common and developing in the majority of countries. Controls on the implementation of FRM production regulations is done by the respective national authorities.

Effects on assisted migration efforts can also be deducted from the available data: e.g., Poland, the Czech Republic, and Slovakia do not allow the planting of foreign FRM on their territory (with the exception of non-native tree species); Germany, Bulgaria and Denmark do not allow the use of FRM of the “source identified” category, which could impact the transfer from Southern countries, e.g. Italy, Spain, which primarily produce seeds and plants of that category. Several other countries only use the “source identified” category exclusively for secondary tree species, for which no selected or qualified FRM sources exist in their countries.

Table 5. Synopsis of full country reports of national FRM authorities of 21 European countries showing the high diversity of the FRM market organisation in Europe in selected topics. Abbreviations used for FRM categories: SI = “source identified”, S = “selected”, Q = “qualified”, T = “tested”.

Country	Country region	Nursery ownership public or private or both	Ownership seed stands	Orchard ownership	Categories used	Category Tested available	Transfer to country allowed	Contract production	Container vs bareroot production	FRM Controls executed by
Austria	Central Europe	mostly private	mostly private	mostly public	SI only minor species	no	yes	yes	both	Federal Forest Office
Czechia	Central Europe	mostly private	mostly public	mostly public	all categories	yes	no	yes	both	Czech Forest Institute, CFI
Germany	Central Europe	mostly private	both	mostly public	only S, Q, T	yes	yes	yes	both	Federal Office for Agriculture and Food (BLE)
Netherlands	Central Europe	private	both	mostly public	SI only minor species	yes	yes	yes	mainly bareroot	Naktuinbouw
Slovakia	Central Europe	mainly private	both	mainly public	all categories	yes	no	not known	mainly bareroot	National Forest Centre Zvolen
Switzerland	Central Europe	both	both	both	all categories	yes	yes	yes	both	developing
Bulgaria	Eastern Europe	mostly public	public	public	only S, Q, T	yes	yes	not known	both	FSCS, Executive Forestry Agency
Croatia	Eastern Europe	public	public	public	all categories	no	yes	no	mainly bareroot	Croatian Forest Research Institute
Romania	Eastern Europe	both	both	both	mostly S and Q	yes	yes	not known	mainly bareroot	INCDS, Nat. Forestry Res.-Dev. Institute
Serbia	Eastern Europe	both	public	public	SI, S	no	yes	no	mainly bareroot	Hunting and Forestry Insepection service
Slovenia	Eastern Europe	mainly private	both	public	mostly S, SI	no	yes	developing	mainly bareroot	Slovenian Forestry Institute
Denmark	Northern Europe	private	both	both	only S, Q, T	yes	yes	yes	mainly bareroot	Danish Agriculture Agency
Estonia	Northern Europe	mostly private	both	public	mostly SI, S, few Q	no	yes	yes	both	Estonian Environemental Board
Finland	Northern Europe	private	both	public	all categories	yes	yes	yes	container	Finnish Food Authority
Latvia	Northern Europe	mainly public	both	both, orchards more important than seed stands	all categories	yes	yes	yes	both	State forest service
Lithuania	Northern Europe	mainly public	mostly public	public	all categories, SI only minor species	yes	yes	yes	both	State forest service
Sweden	Northern Europe	private	private	private	mostly Q and T	yes	yes	yes	mostly container	Swedish Forest Agency
Belgium (Flanders)	South-Western Europe	private	public	public	all categories, SI only minor species	no	yes	common		Agency of agriculture and fisheries
Ireland	South-Western Europe	both	both	both	all categories	yes	yes	not known	both	Department of Agriculture, Food and the Marine (D
Italy	South-Western Europe	mainly public	mainly public	mainly public	SI, S	no	yes	developing	both	regional department
Spain	South-Western Europe	both	both	mainly public	mostly SI, S, fewer Q, T	yes	yes	no	both	regional authorities

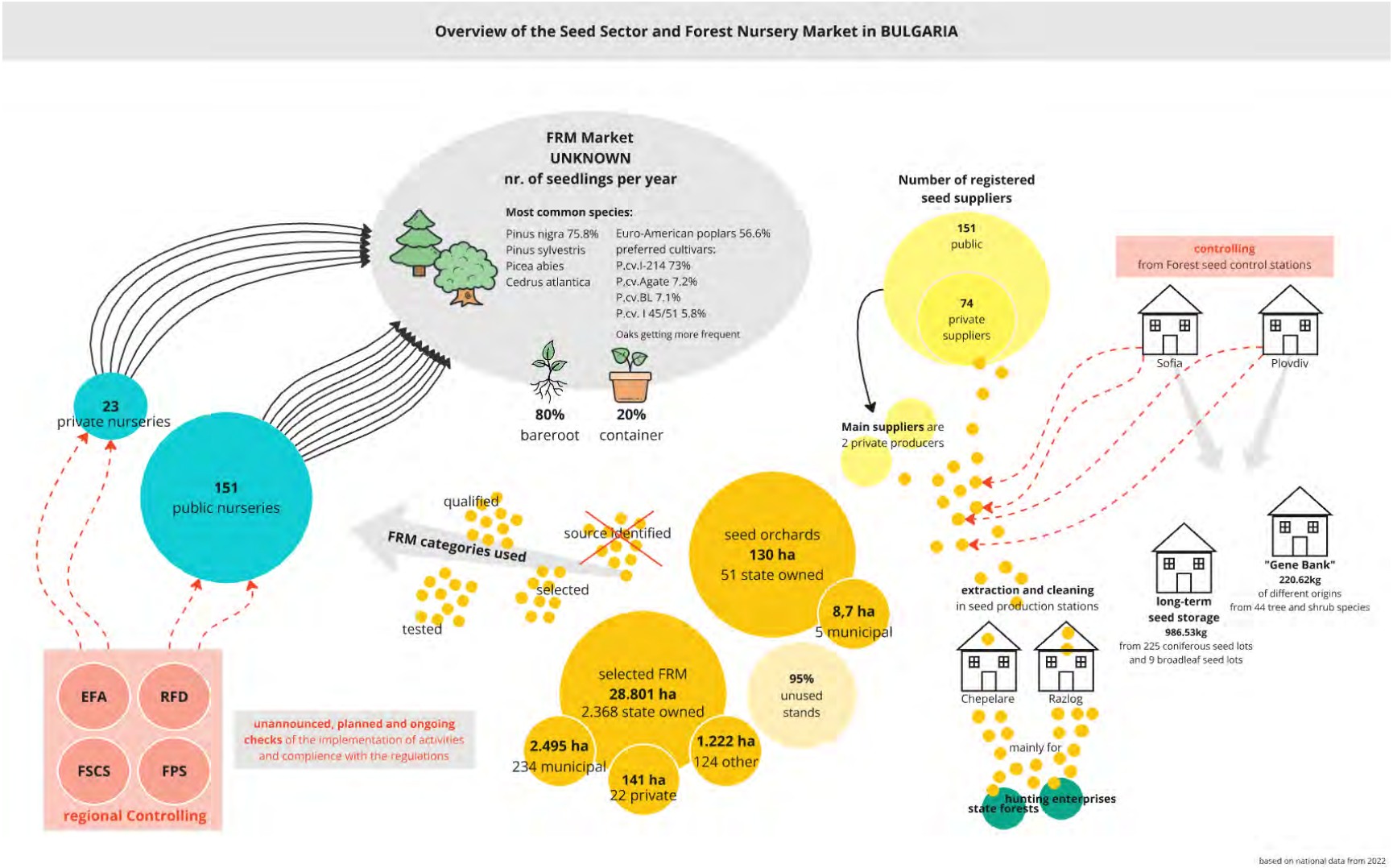

Figure 6. The production capacity and structure of the FRM market in Bulgaria is typical for Eastern Europe; production capacity is relatively low as the proportion of natural regeneration is high; species planted are mostly used to produce construction timber and pulp wood. Most nurseries are publicly owned and the production is closely monitored by the national authority (Executive Forestry Agency of Bulgaria, FSCS).

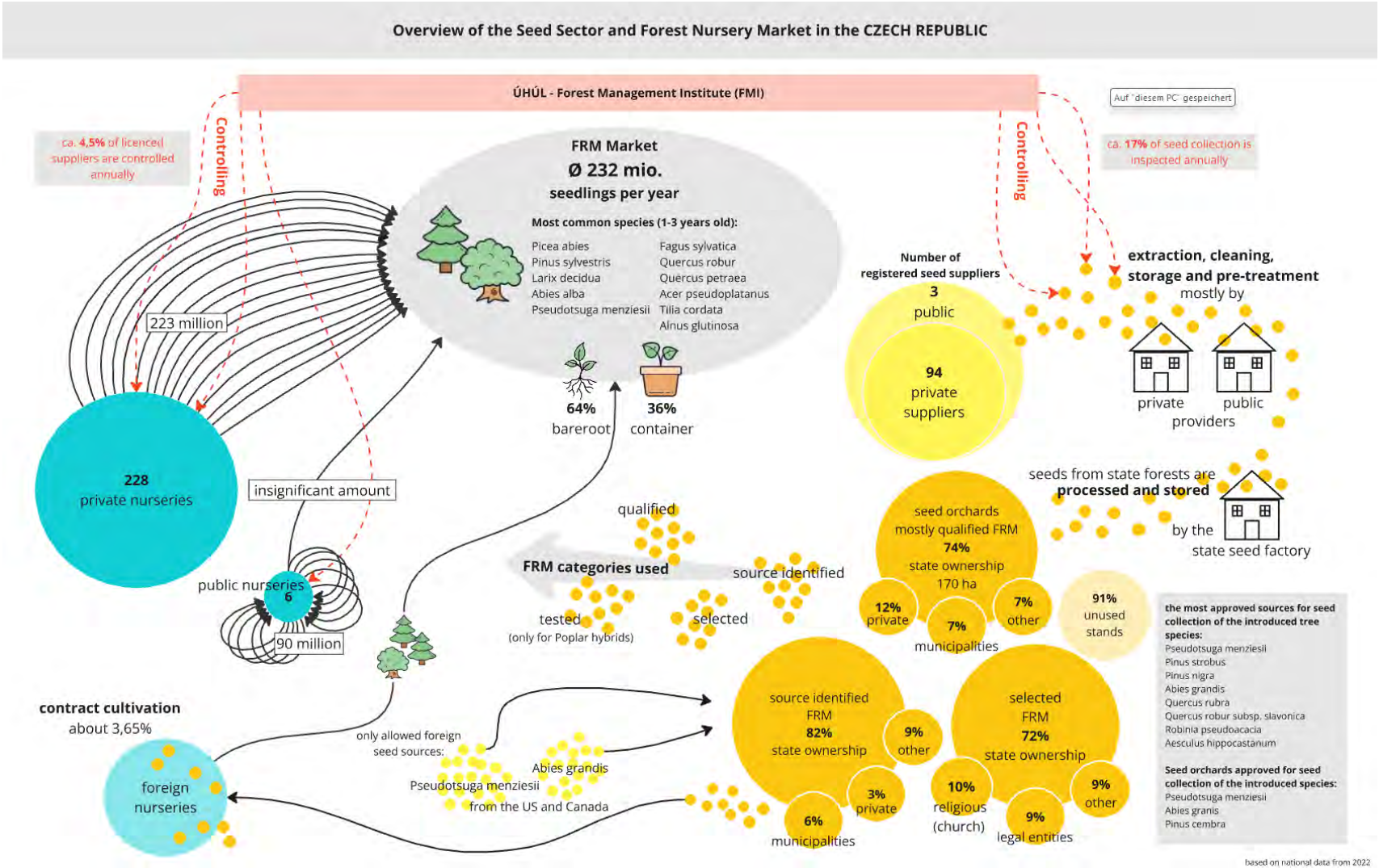

Figure 7. The production capacity and structure of the FRM market in the Czech Republic is typical for a country of Central-Eastern Europe. Most regeneration of forests is done by artificial regeneration, in consequence the production capacity of FRM is very high in comparison to the country size; import of FRM is only allowed for a few non-native species. Private nurseries provide the largest portion of FRM; the few publicly owned nurseries have a high average output in comparison. While most seed sources are owned publicly, seed harvest and trade is dominated by private seed providers.

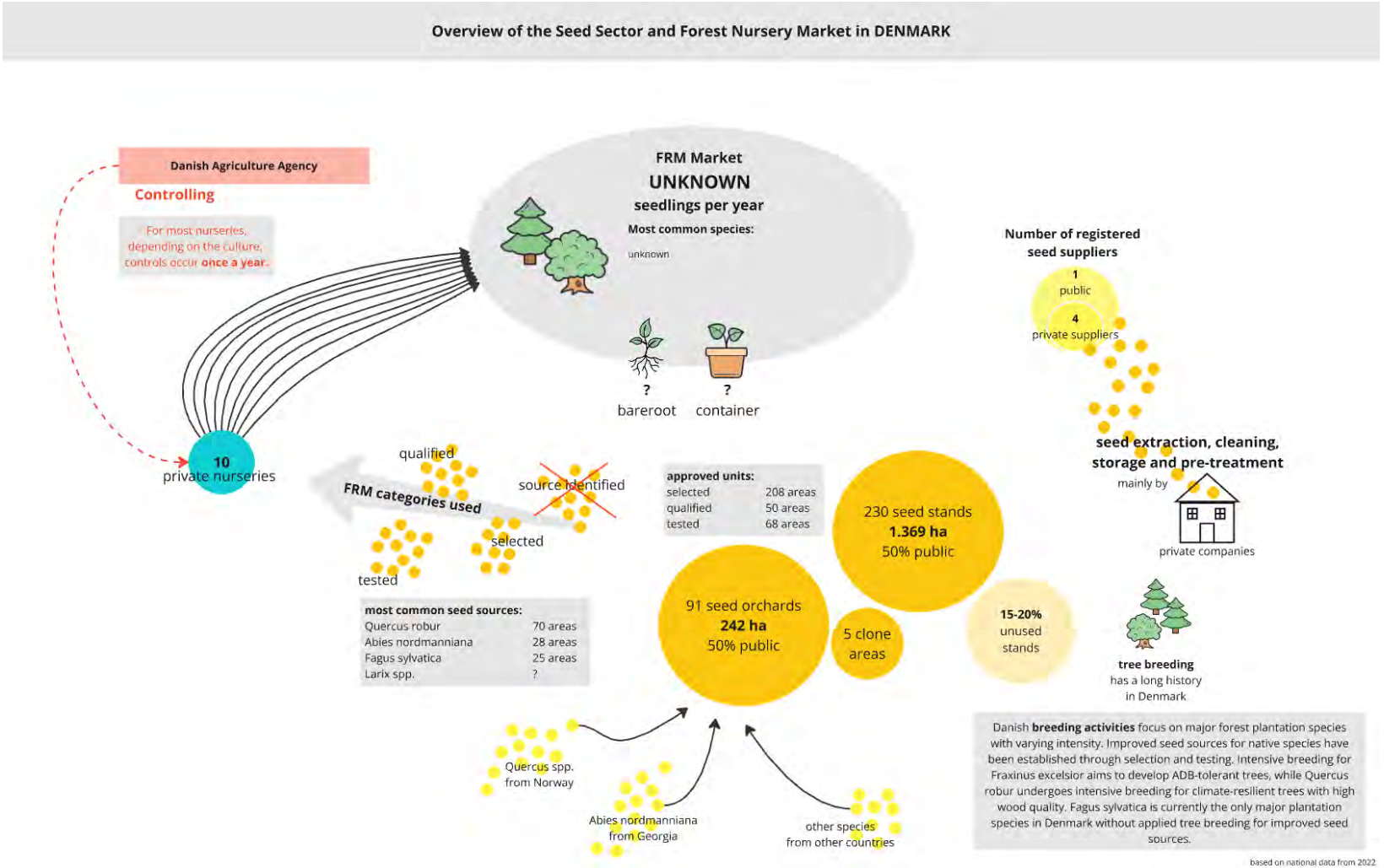

Figure 8. The Danish FRM market is specialized in the production of high quality FRM; artificial regeneration strongly dominates in the country. Though no official statistics are available, based on the feedback from forest nursery to our questionnaire the annual production is estimated to be around 60 mio. plants per year; this also includes *Abies nordmanniana* grown for Christmas tree production. FRM of the category "source identified" is not marketed in Denmark. Breeding is important and most intensive in oak and ash; no breeding activities are currently applied to the most common forest species, *Fagus sylvatica*. Seed supply is concentrated on 1 public and 4 private suppliers; the technological level of seed extraction, cleaning and conditioning is very high.

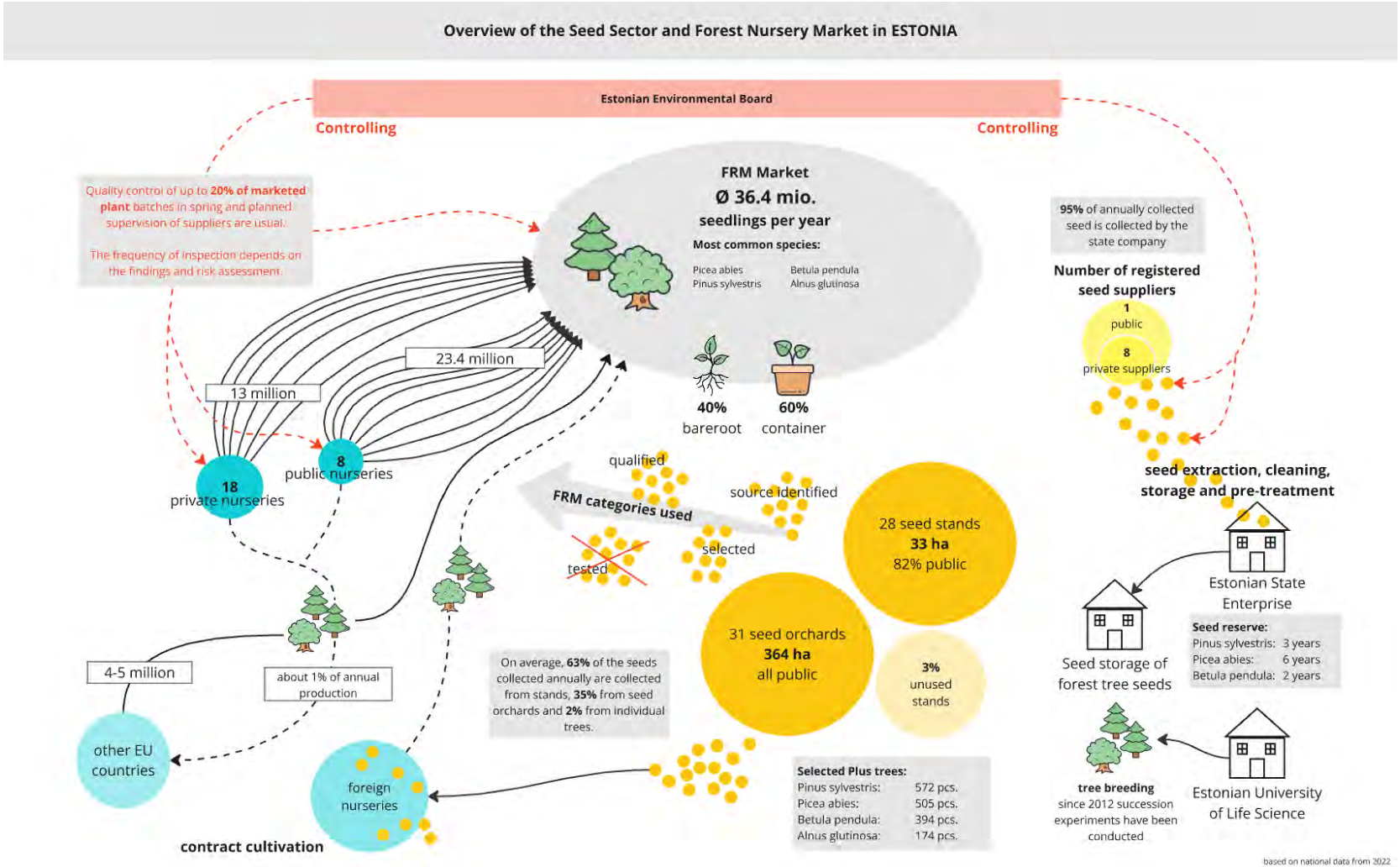

Figure 9. The Estonian FRM market is relatively large compared to country size. Four tree species are dominating the market. Eight public nurseries have the biggest share with 23.4 million plants provided while 18 private nurseries sell 13 million plants annually. FRM of the category “tested” is not available in Estonia. Seed stands account for around two thirds of the harvested seeds, while seed orchards have a share of ca. one third; harvests from the “source identified” category play only a minor role. The number of unused seed stands is very low compared to other European countries. Seed harvest is strongly dominated by the state company.

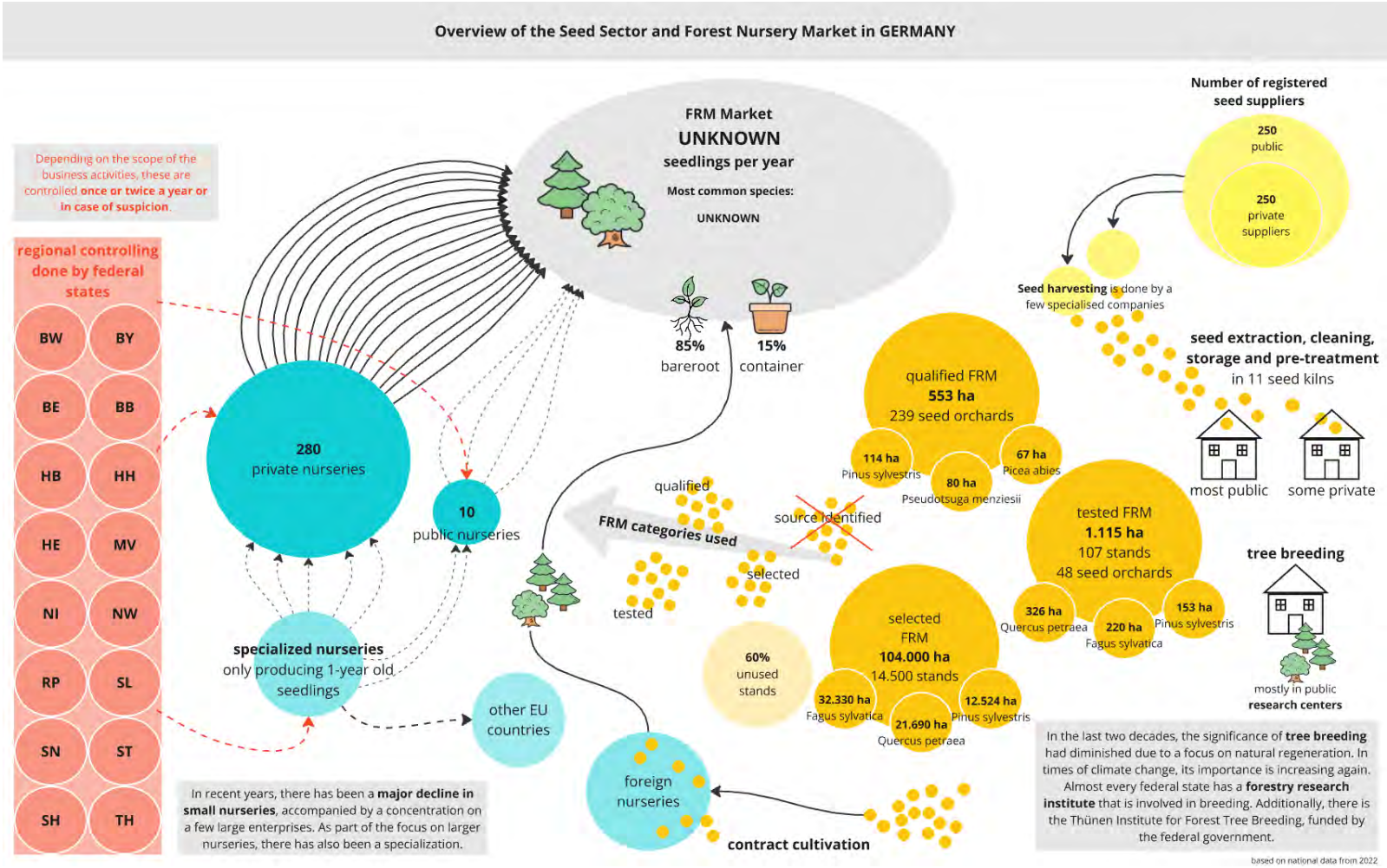

Figure 10. Schematic overview of FRM market in Germany. Germany is one of the bigger producers of FRM in Europe. The control system is highly federalized, i.e. data are collected at the state level and are not fully reported to the national authority. Therefore, no official production figures are available for the whole country, but the production is estimated to be around 250 million plants per year (Wezel & Reis, 2019). The number of small nurseries has been declining over the last decades, leading to bigger nurseries and specialization. FRM of the category “source identified” is not allowed in Germany. Only around 40% of registered seed stands are actually used in seed harvesting. There is a relatively high number of seed sources of the category “tested” available, though breeding activities were reduced in the last two decades.

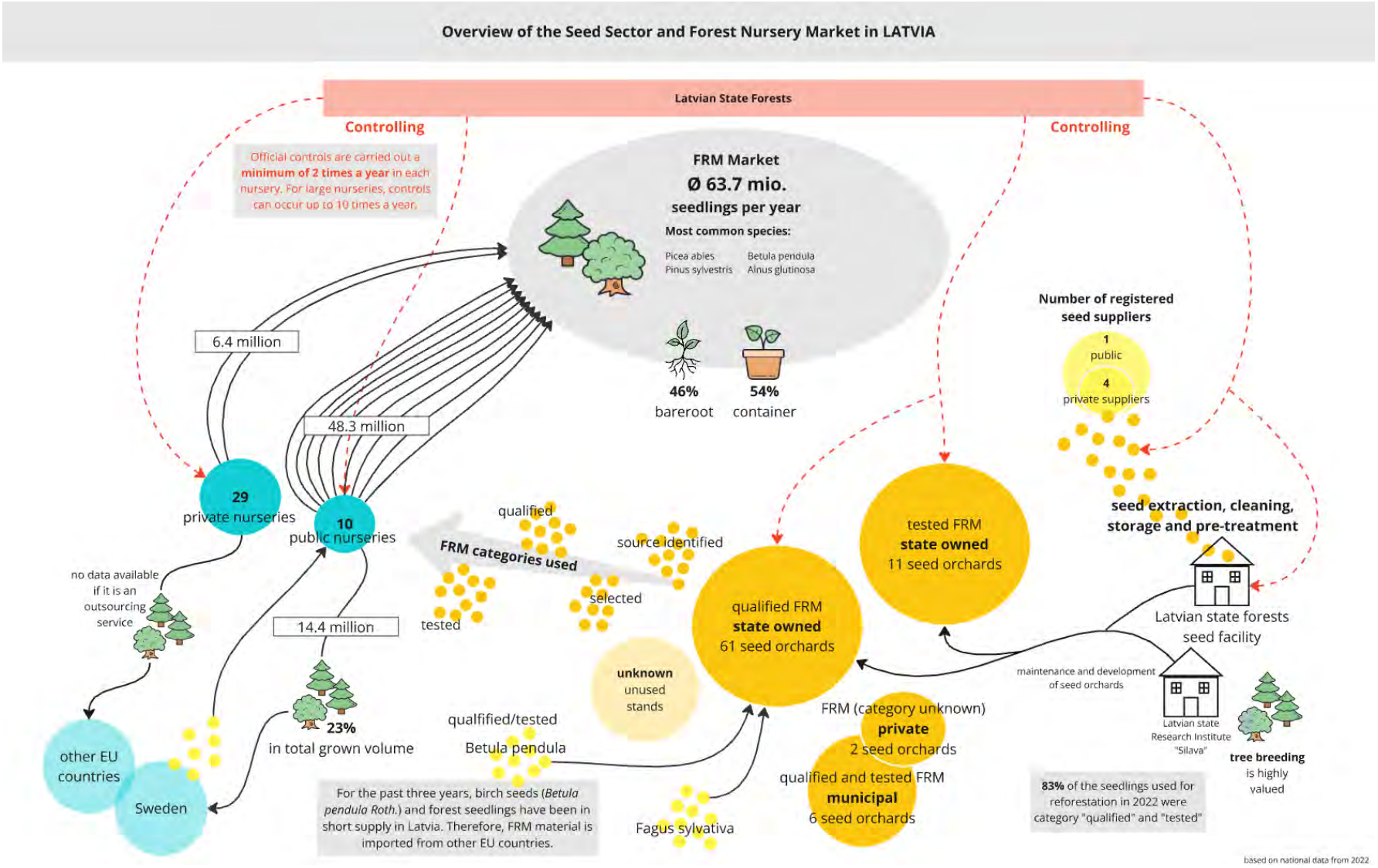

Figure 11. Overview of the FRM market in Latvia. The country has the largest FRM production of all Baltic states with 63.7 mio. plants produced annually. Production is dominated by public nurseries and concentrated on 4 tree species. Seed orchards are particularly important as main seed sources, as 83% of seedlings are derived from seed orchards of the categories “qualified” or “tested”.

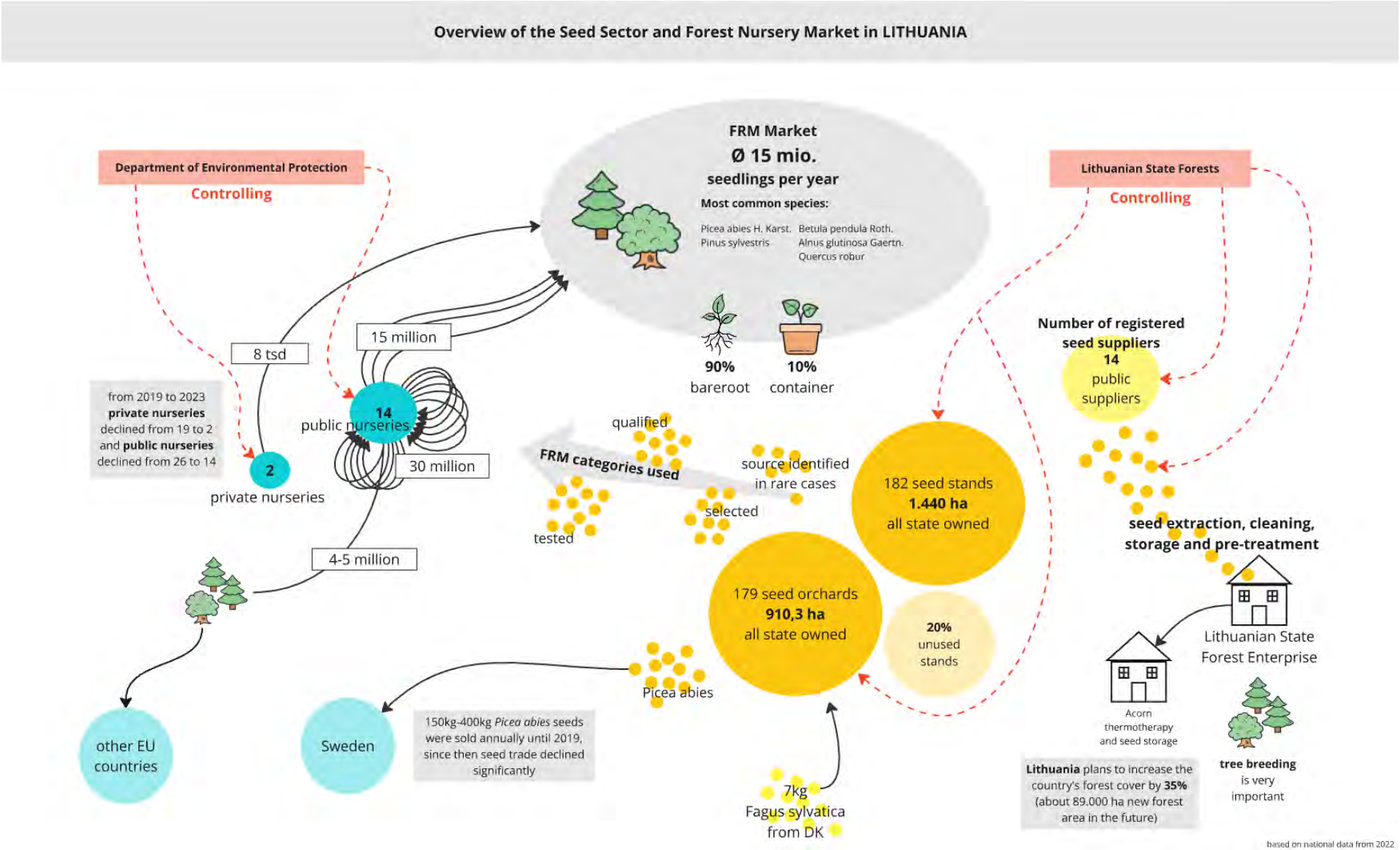

Figure 12. The FRM market in Lithuania is strongly dominated by public nurseries. The number of nurseries has strongly declined, but production is very high compared to the currently forested area. In Lithuania tree breeding is very important - in the forest strategy, it is planned to increase the country's forest cover to 35 % (about additional 89 000 ha of forests are planned).

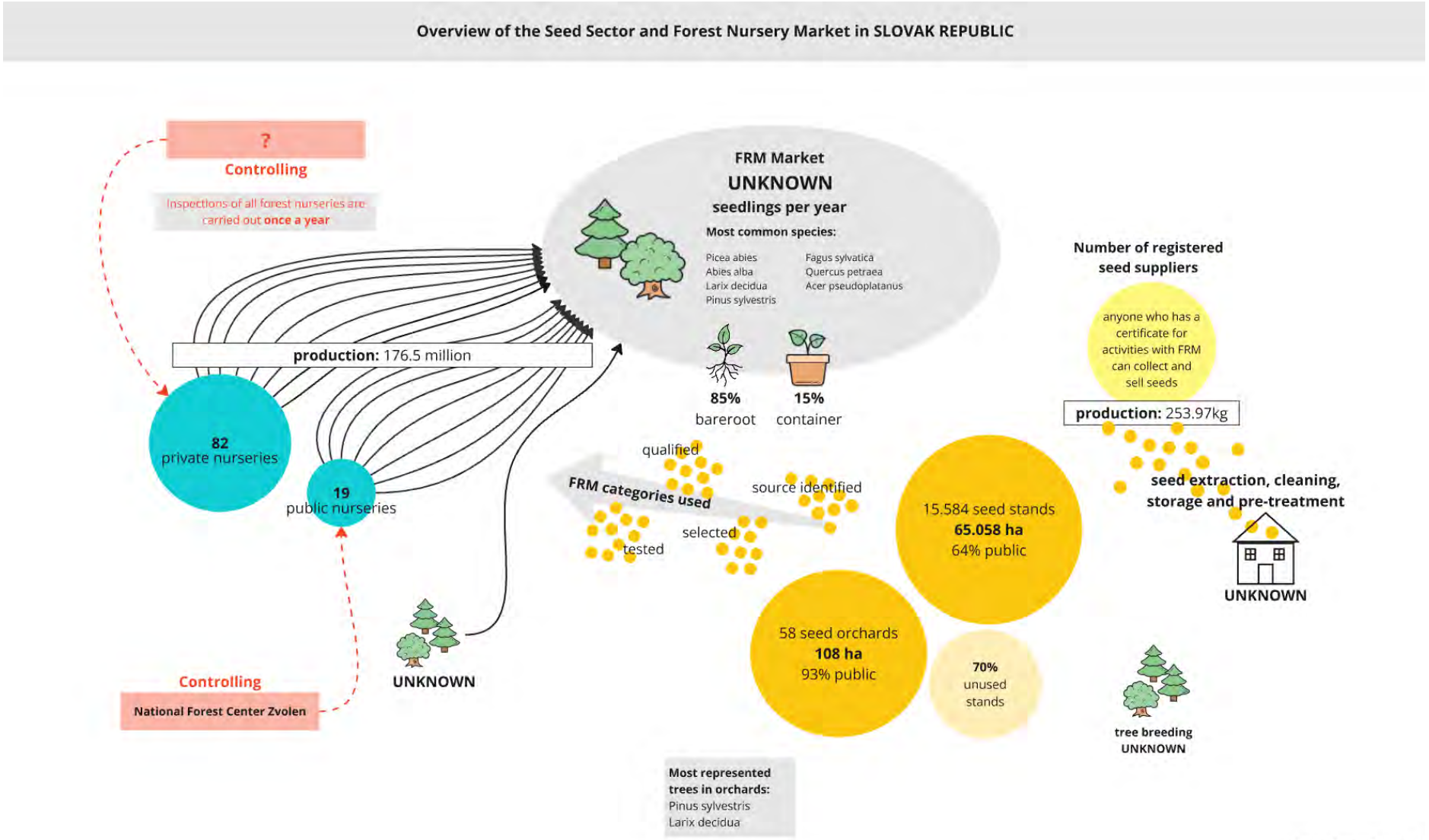

Figure 13. Overview of the FRM market in Slovakia. The market is dominated by private nurseries; annually around 70 million plants are delivered to the forest. A large number of seed stands has been registered, but 70% of these are not used for seed collection.

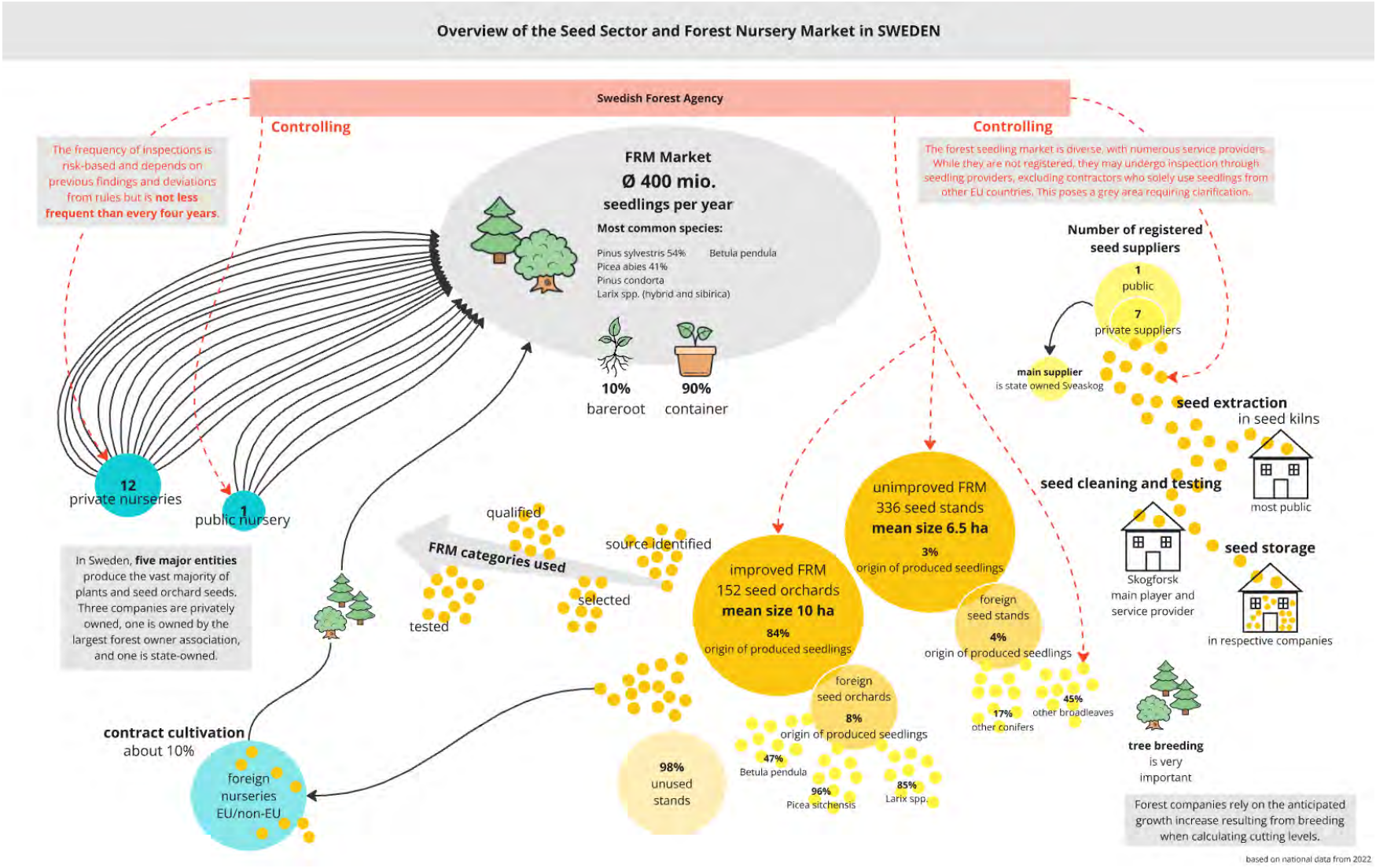

Figure 14. Overview of the Swedish nursery market. Five big nurseries owned by shareholder companies or forest owners associations produce the vast majority of seed (seed orchard seed) and plants; in addition also smaller privately owned companies also produce a significant proportion of plants for the Swedish market. Sweden lacks capacity to grow minor species and a significant proportion of broadleaved plants is imported. *Picea abies* and *Pinus sylvestris* represent more than 95% of the plants. Almost all seeds of these species are derived from improved seed orchards (categories “qualified” or “tested”).

5.1.2. Estimated current annual production capacity of forest nurseries in Europe

An estimate of the national annual FRM production (or marketed plants) volume for European countries was obtained. Different data sources have been used to assess the production of forest nurseries in the European countries, both inside and outside of the European Union. The most important data for most countries came from the respective National Authorities, but when these estimates were not available, also other data sources, e.g. published statistics, published papers and reports and expert estimates (based on the production figures obtained in the online forest nursery survey; see 5.3.2 and Table 6 legend for data source references) were used to get an approximation of the annual national production or sale. Some of the most decisive factors for shaping the forest nursery sector in a given country are the national forest cover, management intensity and the silvicultural system, which determines the main mode of forest regeneration, i.e. countries with intense use of forests (where forest is an important part of the economy) have a higher percentage of artificial regeneration. Therefore, along with the approximate production figures also forest cover and percentage (estimate) of the proportion of artificial forest regeneration and expansion, respectively, are shown in Table 6.

The estimated total production figures show the current annual production of forest nurseries for the 30 countries studied to be around 2.4 billion plants. Given the fact that most nurseries are not running at full capacity (on average production respondents in the online nursery survey stated that they can increase production by at least 50%, see 5.2.2), the estimate for production capacity obtained here is very close or higher than the EFNA estimate of 3 billion plants production capacity per year (technical secretariat of EFNA, personal communication). EFNA is the largest (and a well-known) association of forest nurseries, active in Europe since 1962, and it is the organisation that is closer to the practitioners in the field and in the market. Thus, despite the lack of complete and fully reliable statistics, the EFNA estimate can be considered an acceptable proxy.

A main goal of the European Green Deal is the planting of additional 3 billion trees until 2030. Given the remaining five years to reach the goal, production would have to be scaled up by approximately 20% overall, which theoretically would be feasible, given the available data. In comparison, with the 2.3-fold rate of increase in FRM production to reach reforestation goals in the USA as suggested by Fargione et al. (2021), the increase in production in Europe appears to be feasible (see also Lee et al. 2023). Most of the nursery managers who responded to our survey agree that at least at the national level a moderate increase in production can be handled by forest nurseries – and this has been shown to have been achieved in several instances (see also results of online surveys and semi-structured interviews in 5.2.2 and 5.4.1, respectively). However, it needs to be decided where to plant the trees and which seed material (species, provenances) are to be used. The main barriers to expand production for forest nurseries are explored in the consecutive chapters. The success to achieve the goals of the 3 Billion Trees Pledge not only depends on the nurseries, but also on barriers in the implementation of the needed afforestation and tree plantings, which rely on the availability of land dedicated to the purpose, and national policies and implementation efforts (e.g., Lee et al. 2023).

Table 6. Current average annual plant production of forest nurseries for the 30 European countries studied, based on different data sources.

Country	Forested area (1000 ha)	Naturally regenerated (1000 ha)	Proportion of artificial regeneration	Number of private nurseries	Number of public nurseries	Average annual plant production by private nurseries	Average annual plant production by public nurseries	Totals per country
Austria	3 899,15	2227,50	43%	111	5	16 000 000	5 700 000	21 700 000
Belgium	689,30	251,20	64%	40	-	50 000 000		50 000 000
Bulgaria	3 893,00	3116,00	20%	23	151	n.a.	8 000 000	8 000 000
Croatia	1 939,11	1870,52	4%	0	20	0	10 000 000	10 000 000
Czechia	2 677,09	137,66	95%	228	6	222 455 000	9 000 000	231 455 000
Denmark	628,44	216,44	66%	40	-	40 000 000		40 000 000
Estonia	2 438,40	2222,66	9%	24	18	13 000 000	23 400 000	36 400 000
Finland	22 409,00	15040,92	33%	30	-	165 307 276		165 307 000
France	17 253,00	14819,00	14%	127	6	62 000 000		62 000 000
Germany	11 419,00	5709,50	50%	350	20	250 000 000		250 000 000
Greece	3 901,80	3762,90	4%	n.a.	n.a.	2 000 000		2 000 000
Hungary	2 053,01	1264,23	38%	600	-	200 000 000		200 000 000
Ireland	782,02	107,80	86%	13	1	20 000 000	20 000 000	40 000 000
Italy	9 566,13	8921,09	7%	110	42	4 000 000	2 000 000	6 000 000
Latvia	3 410,79	2945,35	14%	29	10	56 000 000	7 700 000	63 700 000
Lithuania	2 201,00	1590,00	28%	2	14	90 000	50 000 000	50 090 000
Luxembourg	88,70	58,70	34%	0	4	80 000		80 000
Netherlands	369,50	37,92	90%	111	-	20 300 000		20 300 000
Poland	9 483,00	1 706,94	82%	n.a.	1	430 000 000		430 000 000
Portugal	3 312,00	1056,00	68%	277	-	33 000 000	-	33 000 000
Romania	6 929,05	6033,98	13%	450	320	9 000 000		38 000 000
Slovakia	1 925,90	1177,36	39%	92	16	70 000 000		70 000 000
Slovenia	1 237,83	1192,14	4%	4	-	1 265 000	-	1 265 000
Spain	18 572,17	15982,08	14%	1255	19	24 500 000		24 500 000
Sweden	27 980,00	14068,00	50%	12	-	400 000 000		400 000 000
Sum EU								*2 253 797 000*
Norway	12 180,00	12072	1%	-	6	-	44 456 000	44 456 000
UK	3 190,00	344	89%	n.a.	n.a.	90 000 000		90 000 000
Iceland	51,35	11,79	77%	2	-	3 523 000	-	3 523 000
Switzerland	1 269,11	1119,96	12%	3	5	900 000		900 000
Serbia	2 722,65	2606,82	4%	30	55	5 000 000	10 000 000	15 000 000
Sum Non-EU								*153 879 000*
Total Europe								**2 407 676 000**

Note that in Table 6 for most countries the most recent available data or estimates were used, reflecting the current demand situation on the FRM market, which can vary strongly depending on various factors, e.g. storms, bark beetle damage; thus the amounts rather give an estimate of the general production capacity in the various countries. When only one figure is given per country for annual plant production data were not available for private and public nurseries separate. The total forest area and percentage of forest established through artificial regeneration is also presented. Data for forest cover and regeneration mode in 2020 were either obtained from the FAO platform Global Forest Resources Assessment (https://fra-data.fao.org/assessments/fra/2020) or through National Authorities.

[1]Figures provided by National FRM Authority of the respective country; [2]estimate based on figures reported by Flemish FRM Authority; [3]data from Hungarian statistical service: https://agrarstatisztika.kormany.hu/download/0/db/13000/Erd%25C3%25A9szeti%2520csemetetermel%25C3%25A9s_id%25C5%2591sor_2012_2022_publi.xlsx; [4]data from French FRM Authority, available at https://agriculture.gouv.fr/statistiques-annuelles-sur-les-ventes-de-graines-et-plants-forestiers ; [5]estimate based on plant figures provided in Whittet et al. 2016; [6]estimate based on responses to online nursery questionnaire from this report; [7]based on estimate provided in Wezel, G. & Reis, J. (2019) Rückblick und Ausblick zum Forstpflanzenmarkt. Holz-Zentralblatt 38, p.795; number of nurseries obtained from https://www.ble.de/DE/Themen/Wald-Holz/Forstliches-Vermehrungsgut/forstliches-vermehrungsgut_node.html; [8]plant production reported in Mataruga et al. (2023).

With respect to fulfillment of the demands of the 3 Billion Trees Pledge of the EU, the large regional differences in production capacity need to be taken into account. Figure 15 shows the distribution of FRM production capacity per country region. Here, the differences in production capacity among regions become visible. Even when considering that relatively few countries were included in the Eastern European region, still the low production capacity is evident. This low production capacity is driven by the predominance of natural regeneration in the region.

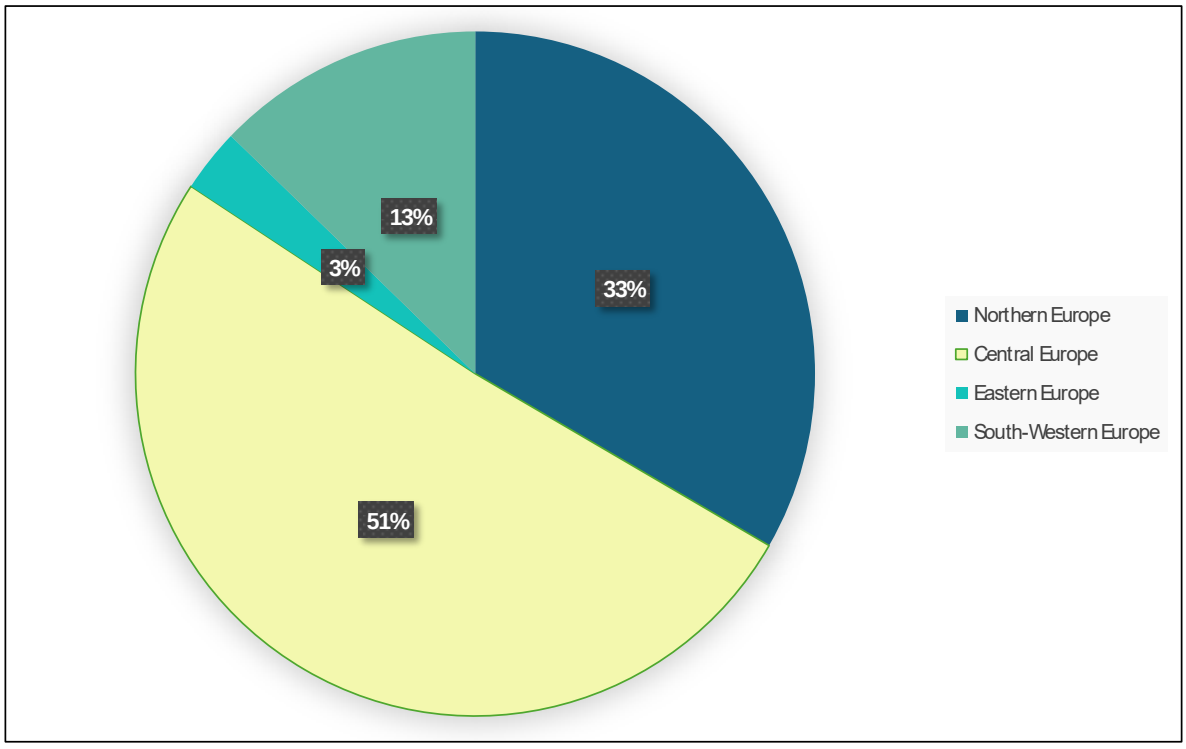

Figure 15. Production capacity of European forest nurseries per country region. Note that the figure is based on the available production data or estimates thereof (see Table 6 for underlying country production figures).

The comparatively very high production capacity for Central Europe is driven by countries with very large producers, i.e. Poland, Germany, the Czech Republic and Hungary. Though for example Poland has relatively low forest cover, reforestation is mainly done by artificial regeneration (82%) and with high planting densities (e.g., 8,000 to 10,000 and 6,000 to 8,000 plants per ha for *Pinus sylvestris* and *Quercus robur*, respectively, as prescribed by the national forest rules; Lasy Panstwowe 2023). In addition, the country has also very ambitious goals in terms of forest restoration on abandoned lands and is set to bring the national forest cover to 33% (Kaliszewski & Jabłoński 2022). A similar situation is present in Hungary, which also tries to increase the forest cover from 21 to 27% (Lee et al. 2022). The same is true for the Netherlands with ambitious goals to plant additional 100 million trees by 2030 (Séveno 2020). At present, in Germany, natural regeneration dominates but the country has relatively

high forest cover; a similar situation exists in Austria. In the Czech Republic, forest cover is lower, but artificial regeneration dominates; the very high plant production observed in 2022 and reported here was caused by extremely high bark beetle damage incidence and currently is resuming to a lower level (see country report by National Authority).

In Northern Europe, the FRM production is comparatively stable with predominant artificial regeneration and a small number of very large nurseries. In the Baltic states, public (state) nurseries dominate, while in Scandinavia large shareholder companies have the ownership of the nurseries. In Denmark, only private nurseries are present, with comparatively high production capacity.

The production capacity in South-Western Europe is very diverse due to the broad geographic scope of this region denomination. Italy, Spain and France have relatively low production capacities compared to their size, as natural regeneration remains dominant, whereas artificial regeneration is prevalent in Portugal. Unfortunately, apart from the figures for production capacity provided in Mataruga et al. (2023), no current information was available on Greek forest nurseries both through National Authorities or the nursery surveys; Greece has very ambitious goals in terms of forest restoration (Wichmann 2020) and it would have been very interesting to get the updated views of the National Authorities and the nurseries on how these targets are to be met. In the UK and Ireland, artificial regeneration has traditionally been predominant, although overall forest cover remains low.

To obtain an estimate of the expected distribution of production capacity, Figure 16 shows the artificially regenerated forest area per denoted country region based on the data available from the FAO Global Forest Resource Assessment database (https://fra-data.fao.org/assessments/fra/2020/EU/sections/forestCharacteristics/). Also, in this representation, the share of Eastern Europe is very low. Differences in the proportion of the other country regions compared to the actual production capacity shown in Figure 16 are probably mostly due to differences in planting density and current efforts to increase afforestation rate; e.g. higher planting density combined with higher FRM production of abandoned lands in Poland may to a large part explain the lower share of the Central European region in this visualization.

According to Lee et al. (2023), a large part of the available lands (abandoned farmland) for reforestation are located in Southwestern and Eastern Europe, but also in Central Europe. Given the available nursery capacity, upscaling of production will be necessary in the two former regions.

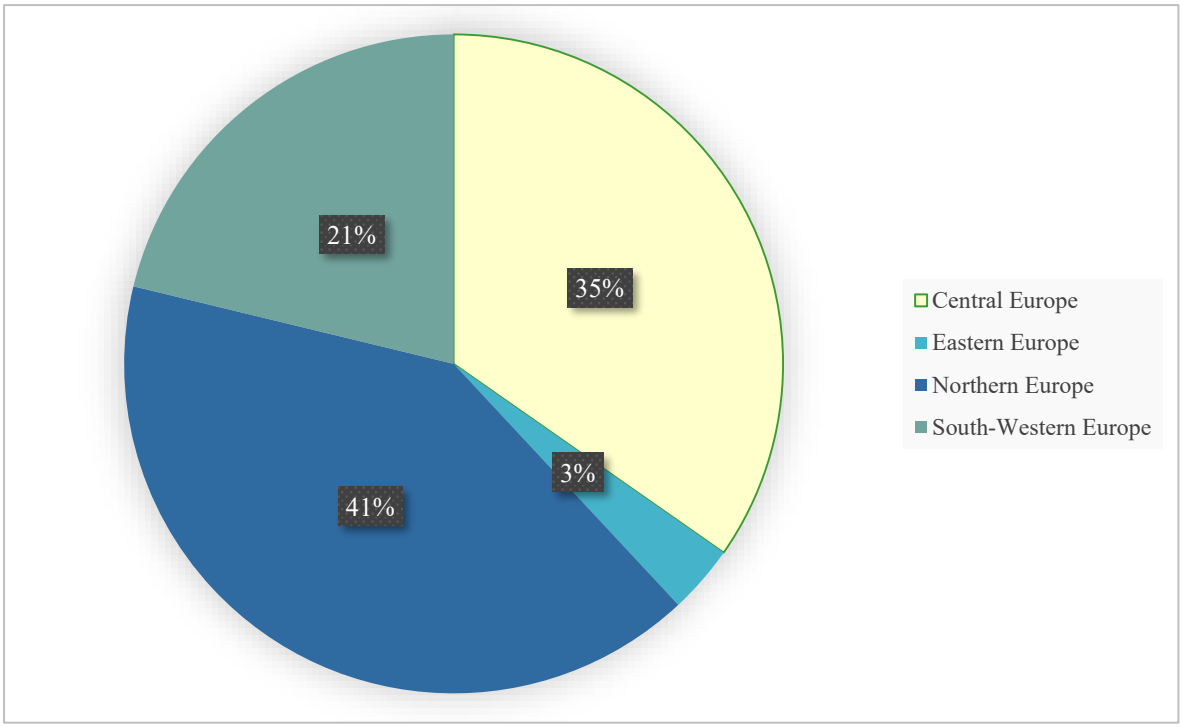

Figure 16. Artificially regenerated forest area per denoted country region based on the data available from the FAO Global Forest Resource Assessment database (https://fra-data.fao.org/assessments/fra/2020/EU/sections/forestCharacteristics/).

5.2. Online forest nursery survey results

As described in the methods section, all producers of FRM need to be registered in their respective country to be able to take part in the marketing of FRM; national authorities keep a register of these providers. However, it is up to the respective entity to decide if they are actively producing or not, so that an unknown proportion of the registered nurseries might not be actively producing plants or may have gone out of service. Therefore, it is almost impossible to obtain an accurate number of active forest nurseries for any country, except for the ones with a very small number of producers. Since the total population of forest tree nurseries in Europe could not be determined, all results are presented descriptively. It is important to note that drawing conclusions about the entire forest tree nursery sector is methodologically not possible. This means that all results are interpreted based on the sample and represent only that sample. However, the insights gained from descriptive statistics are no less significant. The estimated current production capacity of forest nurseries has been presented already in section 5.1.2, therefore in this section we focus on other results important to provide an overview of the structure and in particular the challenges the sector currently faces.

5.2.1. Demographic data and general information

1. Number of Replies

A total of 282 persons participated in the Forest Nursery Survey. Since three respondents (1.06%) did not provide information about their nationality, they were excluded from the analysis, and the number of valid responses was 279. As mentioned in the methodology section, the target area originally included 31 countries. Unfortunately, no cooperation could be established with Greece, which means that ultimately 30 countries participated in the survey. Therefore, if we simply calculate the % of the respondents out of the total potential number of respondents (i.e. 282 out of almost 4800 potential respondents, see Table 6), the response rate is low (less than 6%); however, as stated above the true number of active forest

nurseries is probably much lower (see also part on production capacity of respondents, in 5.2.2).

Figure 17 shows how many respondents participated per country and country region. Looking at participation at the level of country regions, 41.2% came from Central Europe, 25.1% from South-western Europe, 18.6% from Eastern Europe, and 15.1% from Northern Europe. It needs to be noted that the number of forest nurseries is lowest in Northern Europe, which explains the relatively low numbers of responses from that region.

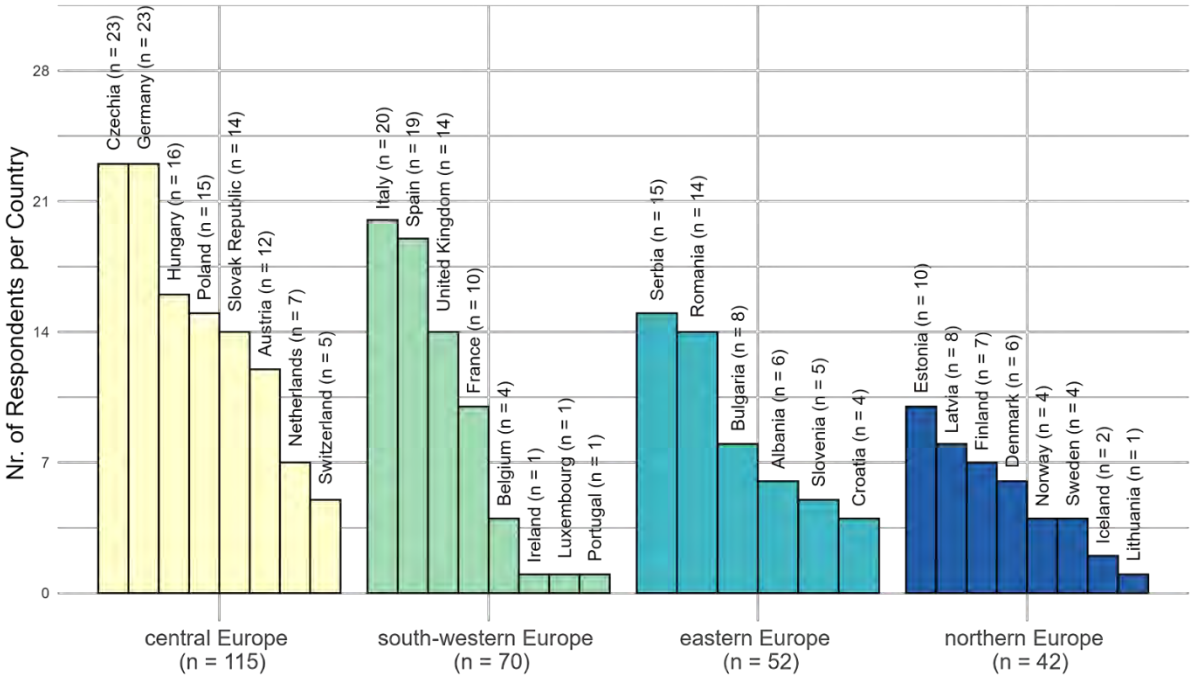

Figure 17. Absolute number of replies per country and country region in online nursery survey.

2. Sex Distribution

Out of the total of 279 responses, one respondent did not provide any information regarding sex (0.36%), and two responses indicated that they prefer not to answer this question (0.72%). The remaining responses were as follows: 225 respondents identified as male, making up 80.94% of the valid sample, and 51 respondents identified as female, making up 18.35% of the total sample. At the regional level, the responses were as shown in Table 7.

Table 7. Gender in Counts and Percent for Country Regions (%)

	Female	%	Male	%	Prefer not to answer	%	No answer	%	Total
Northern Europe	14	33	28	67	0	0	0	0	42
Eastern Europe	11	21	40	77	0	0	1	2	52
Central Europe	15	13	99	86	1	1	0	0	115
South-Western Europe	11	16	58	83	1	1	0	0	70
Totals	51	18	225	81	2	1	1	0	279

The highest percentage of female respondents (forest nursery managers and owners) was observed in Northern Europe (33.3%), followed by Eastern Europe (21.6%), South-Western Europe (15.7%) and Central Europe (13.0%). This is in agreement with the general predominance of males in the forest sector (Böhling et al., 2021; UNECE & FAO, 2020; Andersson & Lidestav 2016; Ludvig et al. 2024).

3. Age Distribution and Age Groups

The mean age of the sample of 273 valid responses (excluding six unavailable responses, 2.15%) was 48.61 years, with a standard deviation of 10.53 years. The age range extends from a minimum of 22 years to a maximum of 79 years.

For better comparability at the country region level, age groups were formed from the age data. These are shown in Figure 18. Each age group contains respondents, with the '46-55 years' age group making up the largest proportion. When comparing the regions, the largest share of this age group comes from Eastern Europe. It is also noteworthy that there is only a very small proportion of respondents below 25 years, and this group is exclusively from the Central Europe region. Additionally, it is striking that the proportion from Eastern Europe in the '56-65 years' age group is only 4%, in contrast to the other three regions, where the proportion is around 28%.

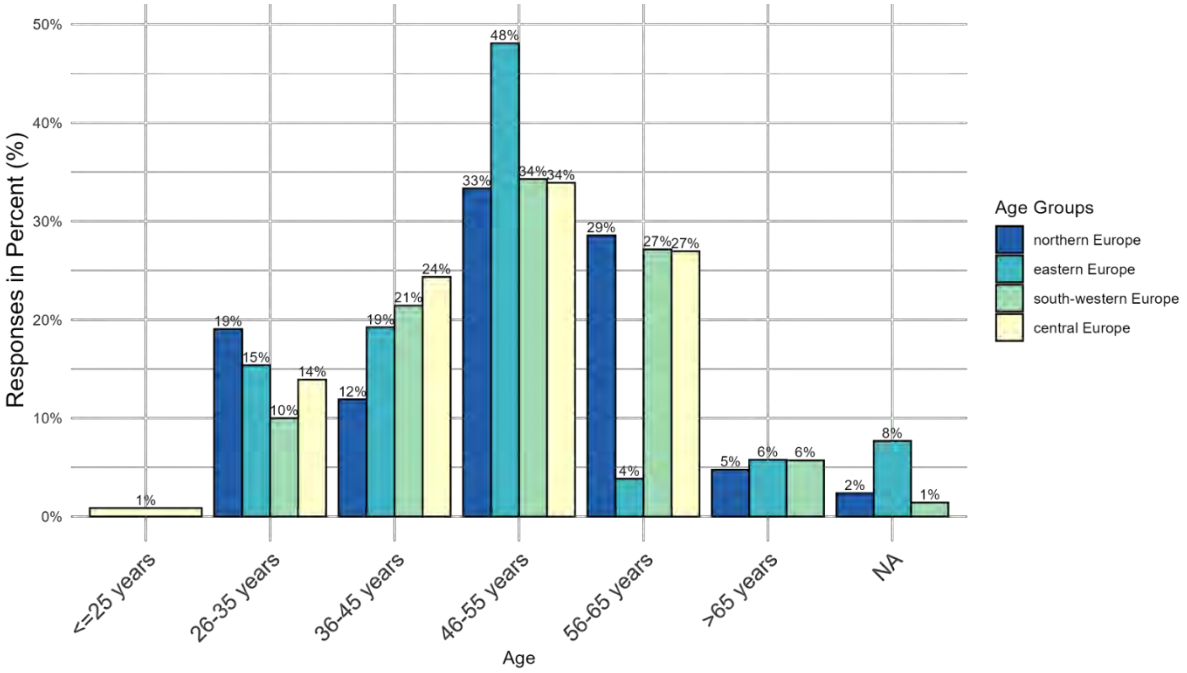

Figure 18. Age group distribution of respondents to online nursery survey across country regions.

4. Role at the Nursery

From the valid 274 responses 50.73% identified as nursery managers, 33.58% stated they are nursery owners, and 15.69% declared that they hold both roles.

At the regional level, it is interesting to note that the Northern Europe sample is the only one, compared to the other three regions, where the percentage of respondents holding both roles is the highest: 30.95%, compared to 14.58% (Eastern Europe), 17.39% (Southwestern Europe), and 9.57% (Central Europe).

5. Ownership Structure

From the 276 valid responses, 60.51% stated that the nursery they work for or own is privately owned. This was followed by "other public ownership" at 11.96%, and state ownership at 11.23%. State-owned forest companies were represented by only 8.33%, while shareholder companies made up 5.80%, and departments of forest enterprises accounted for 2.17%.

Figure 19 shows the ownership structure of forest nurseries across the country regions. Note that the Eastern Europe sample has less private ownership (42.31%) and more state ownership (34.62%) compared to the other three regions. The South-Western Europe sample

has the highest proportion of other public ownership (25.71%), while the Northern Europe sample has the highest proportion of shareholder companies (16.67%).

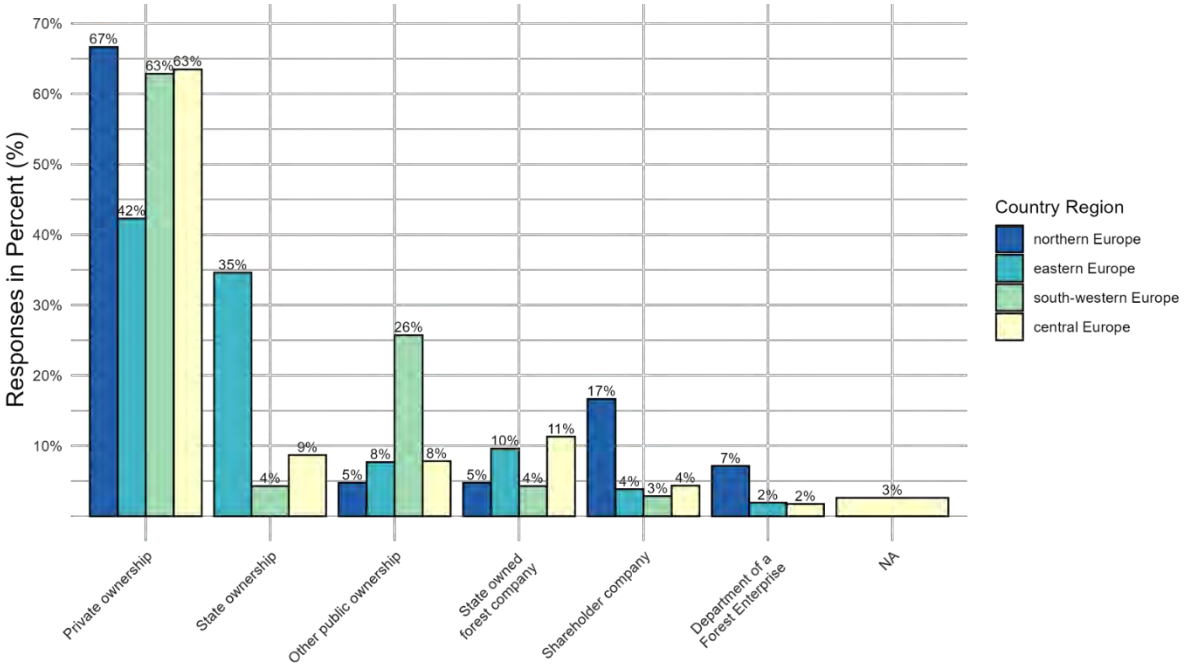

Figure 19. Ownership structure of forest nurseries participating in online nursery survey per country region.

In the online survey towards forest nurseries, a broader range of possible answers to ownership was provided compared to country reports by National Authorities where only public and private was differentiated (see 5.1.1). Nevertheless, in general both distributions in ownership agree; e.g. private ownership dominates in all but Eastern Europe, and “other public ownership” is more frequent in South-Western Europe (e.g. ownership of regional government, autonomous provinces). Private shareholder companies and departments of forest enterprises are more common in Northern Europe, which is also in agreement with the information provided by National Authorities. Ownership structure shown in Figure 19. Ownership structure of forest nurseries participating in online nursery survey per country region.represents the situation of respondents and it was not aimed to infer ownership structure on the national level through the online questionnaire, but rather to show the representation of the sample for the respective country region.

5.2.2. Nursery production and capacity

1. Sales and trades of forest seedlings

Table 8 shows the annual production and trade figures for container and bareroot seedlings from the valid responses of 277 participants, broken down by country region and total numbers. Participants were asked to provide an estimated total number of sold and traded plants. 'Sold' refers to the production of seedlings grown by the nursery itself, while 'traded' refers to plants marketed, but sourced from other nurseries.

Table 8. Annually sold and traded plants broken down by country region and total numbers.

	Annually sold container plants	Annually sold bareroot plants	Annually traded container plants	Annually traded bareroot plants	Total
Northern Europe	517 670 000	48 382 000	8 602 000	6 956 500	581 610 500

Eastern Europe	2 132 500	16 656 099	441 300	3 350 200	22 580 099
South-Western Europe	63 747 400	75 736 500	11 282 500	17 146 800	167 913 200
Central Europe	38 156 500	233 391 500	5 582 500	42 571 000	319 701 500
Total Sum	621 706 400	374 166 099	25 908 300	70 024 500	1 091 805 299

In total, nearly 1.1 billion plants are annually marketed by the respondents; based on the estimate of the total European production capacity and when regarding trade among the nurseries, this is equivalent to about one third of the total estimated production volume derived in 5.1.2. Given the number of registered forest nurseries as provided by the National Authorities and compared to the number of valid responses in the online questionnaire, the obtained value of produced plants reported by respondents appears exaggerated. On the other hand, it is likely that particularly active forest nursery managers with high production were taking part in the survey, while smaller and less active producers may not have been interested to participate in the survey. A comparatively large proportion of large producers from Northern Europe and Central Europe were also participating, explaining the high number of represented plants (see also 5.1.2). Also, it was not taken into account when small seedlings were marketed among nurseries (i.e., contract production), this likely also accounts for a certain proportion of the reported sales figures; contract production is particularly common in Northern and Central Europe. As explained in the methods section (4.6.1), it is likely that also non-active entries are contained in the databases of FRM producers in the various countries, i.e. the number of registered nurseries may be considerably lower than contained in the national register. However, since the true number of active forest nurseries is not known, we can only speculate on this.

Notable differences in average plant sales (sold and traded) per nursery are observed across country regions: participants from Northern Europe (n = 42) reported an average of 13.8 million seedlings per nursery, followed by participants from Central Europe (n = 114) with an average of 2.8 million seedlings per nursery. Participants from South-Western Europe (n = 70) reported an average of 2.4 million seedlings per nursery, whereas participants from Eastern Europe (n = 51) reported an average of only 440,000 seedlings per nursery (Table 8 and Figure 20).

Given the fact that proportionally a much higher number of respondents from Northern Europe were represented by survey respondents, the Northern production is overrepresented in the online survey. This is evident when Figure 20 is compared to Figure 15 from the estimated full capacity in 5.1.2. Taking this into account, the relative proportions of the other regions are in good agreement with the values for full FRM production capacity obtained in 5.1.2 (Figure 15).

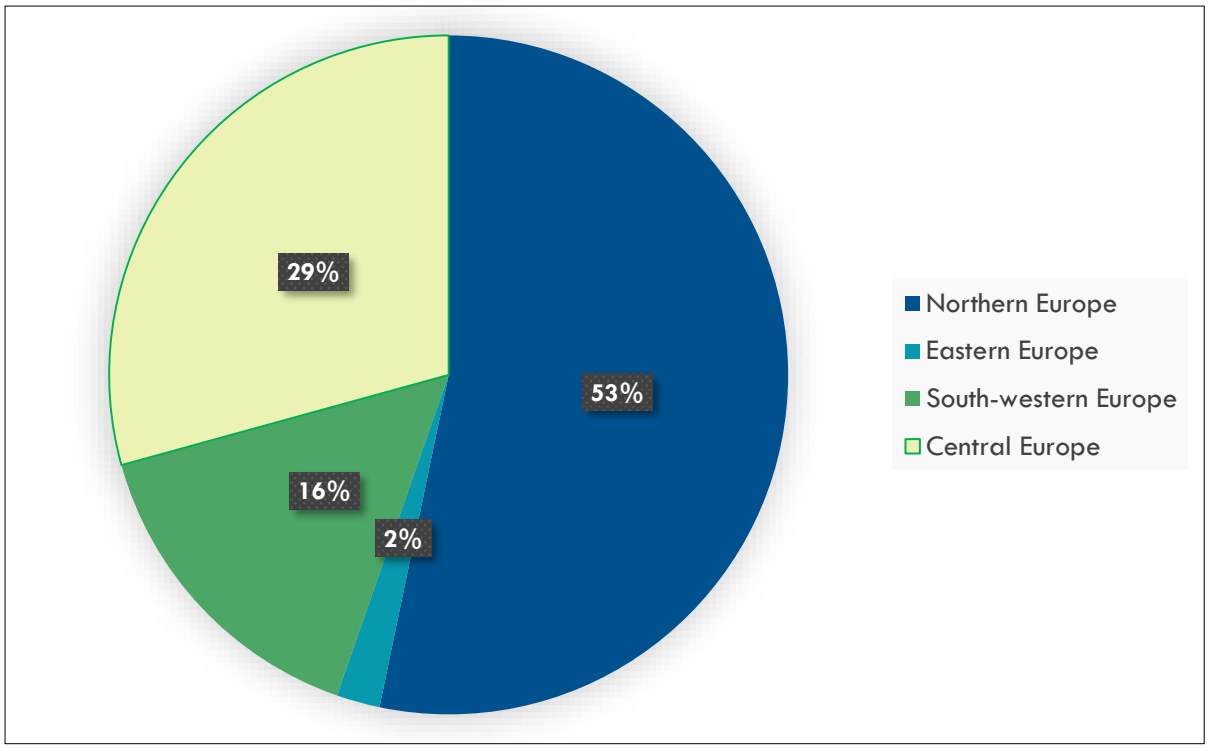

Figure 20. Cumulated overview of sold and traded plants of respondents in online nursery survey per European country region. Nurseries from Northern Europe are overrepresented because a higher proportion of the nursery population relative to the other regions took part in the survey (compare to Figure 15 and Table 6).

When examining annually sold seedlings (Table 9), excluding traded ones, container seedlings accounted for 91.45% of total sales among participants from Northern Europe, highlighting containerized seedlings as the dominant production method. In contrast, participants from Eastern and Central Europe displayed the opposite pattern: 88.65% of the reported total sales in Eastern Europe and 85.95% in Central Europe were bareroot seedlings. Participants from South-Western Europe showed a more balanced distribution, with 45.7% of sales from containerized seedlings and 54.3% from bareroot seedlings. These results are in good agreement with data provided in country reports of National Authorities (5.1.1) and information provided by respondents in the semi-structured interviews (5.4).

Table 9. Percentage of container vs bareroot seedlings sold across country regions as reported by nursery survey respondents (own annual production, excluding traded plants).

	Container seedlings	Bareroot seedlings
Northern Europe	91.45%	8.55%
Eastern Europe	11.35%	88.65%
South-Western Europe	45.70%	54.30%
Central Europe	14.05%	85.95%

2. Loss rate of forest seedlings during production

Participants were asked to provide an estimated percentage of the average annual loss rate in production (i.e., losses of seedlings during production, e.g. diseased or sorted out due to low vigour or quality). A total of 266 respondents provided an answer, leaving 13 unavailable responses to this question (4.66%). The mean annual loss rate for the total valid responses is 18.1% (SD ± 12.67), with a median of 15%.

The boxplots in Figure 21 show the annual loss rate of seedlings per country region in more detail. The box itself indicates the range in which the middle 50% of all values lie. The lower end of the box represents the 1st quartile (Q1), and the upper end represents the 3rd quartile

(Q3). Therefore, below Q1 lie 25% of the data, and above Q3 lies 25% of the data, meaning that 50% of the data falls within the box.

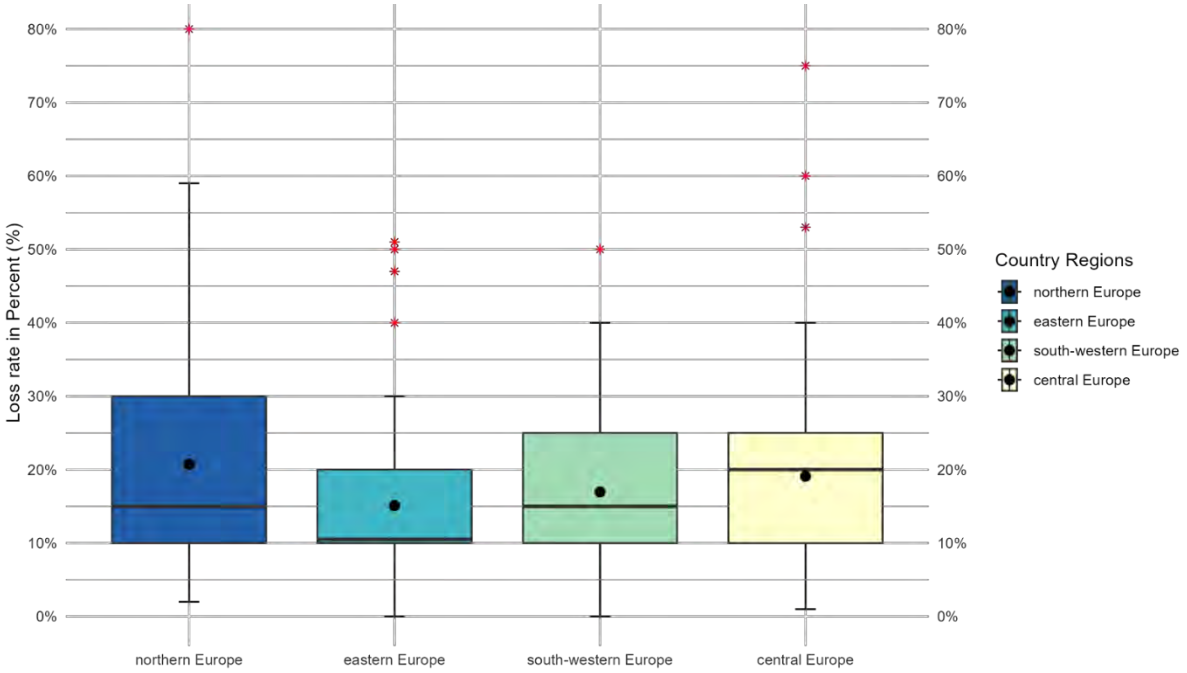

Figure 21. Annual loss rate of seedlings during production per country region as reported by respondents to online nursery survey.

When comparing responses across country regions, the mean annual loss rates are as follows and are represented by dots in Figure 21: participants from Northern Europe (n = 41) and Central Europe (n = 110) reported similar mean loss rates of 20.76% (SD ± 16.43) and 19.1% (SD ± 12.07), respectively. In contrast, participants from Eastern Europe (n = 48) and South-Western Europe (n = 67) reported lower mean loss rates of 15.1% (SD ± 11.92) and 16.97% (SD ± 11.2), respectively.

For example, in the Northern participant group, if Q1 represents a loss rate of 10%, it means that 25% of participants have a loss rate below 10%. If Q3 represents a loss rate of 30%, then 25% of participants have a loss rate above 30%. Thus, 50% of participants in Northern Europe have a loss rate between 10% and 30%. The solid line within the box indicates the median, while the dot represents the mean of the participant group. In the Northern group, the median is 15%, indicating that half of the participants have a loss rate below 15% and the other half have a loss rate above 15%. The median, therefore, divides the participants into two equal groups.

The T-shaped whiskers extend to the last point that is still within 1.5 times the interquartile range. Any observations more than 1.5 interquartile ranges below Q1 or above Q3 are considered outliers, which are represented as red starlets in Figure 21. Each outlier corresponds to one participant. The upper whisker represents either the maximum value or 1.5 times the interquartile range, and the same applies to the lower whisker. In the Northern group, 25% of participants reported a loss rate between 30% and nearly 60%, with one outlier indicating that one participant has a loss rate of 80%.

Examining the overall shapes of the boxplots, the Northern and South-Western participant groups share identical medians. However, the Northern Europe group exhibits greater variability, indicating that discard rates within this group differ more widely. The Eastern Europe group has the lowest median and the least variability, suggesting that overall discard rates in this group are both lower and more consistent. The Central Europe group has the highest median, although its variability is less pronounced compared to the Northern Europe

group. Outliers are present in all regional groups, indicating that participants with very high discard rates exist across all country regions.

The among region differences in loss rate during production might be related to the different quality standards or legal guidelines applying in different countries. As collated by Mataruga et al. (2023) some countries, especially in Northern Europe, e.g. Finland, have laws in place that regulate the morphological and physiological traits and standards of seedling quality. Also, in Spain and Portugal, FRM needs to fulfil specific qualitative and quantitative morphological standards to be marketed. For the Mediterranean climate region also Directive 1999/105/EC foresees morphological and physiological criteria for marketing FRM.

3. Discard rate of forest seedlings (unsold plants)

Participants were further asked to provide the annual average proportion of production that is not sold and needs to be discarded. A total of 150 respondents provided an answer, leaving 29 unavailable responses to this question (10.4%). The mean annual discard rate for the total valid answers is 11.52% (SD ± 10.2), with a median of 10%.

When comparing mean responses across country regions, the annual discard rates are as follows and are represented by dots in Figure 22: participants from South-Western Europe (n = 67) and Central Europe (n = 106) reported similar mean discard rates of 12.46% (SD ± 10.63) and 12.17% (SD ± 8.72), respectively. In contrast, participants from Eastern Europe (n = 39) and Northern Europe (n = 38) reported lower mean discard rates of 10.82% (SD ± 11.05) and 8.76% (SD ± 12.08), respectively.

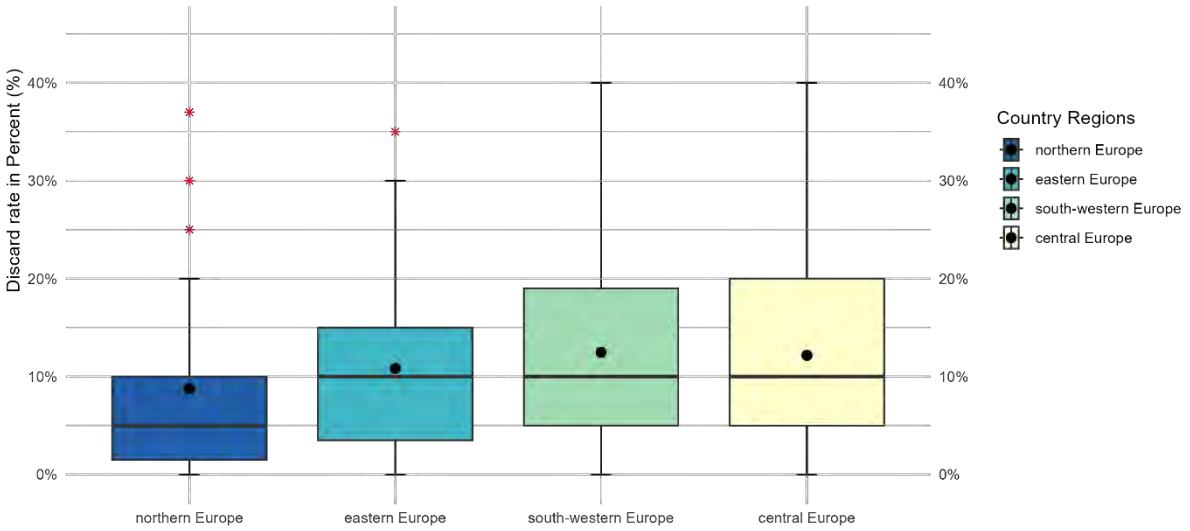

Figure 22. Annual discard rate of seedlings across country regions as reported by respondents to online nursery survey.

Comparing the boxplot groups, participants from Northern Europe have a lower median and less variability than the other three groups, indicating that the reported annual discard rate is generally lower in this group. However, it is notable that this group has the most outliers, indicating some respondents with higher discard rates. The lower general discard rate in Northern Europe may be related to the lower production risk in the region, due to common contract production (see also discussion in 5.4.3). The medians of the other three groups are identical, all at 10%. Participants from Eastern Europe exhibit slightly lower variability within their group compared to those from South-Western and Central Europe, both of which show almost identical distributions of discard rates.

4. Expansion possibility beyond the current maximum capacity

Participants were asked to estimate how much they could expand their annual seedling production capacity over the next five years, beyond their current maximum production capacity, using a slider ranging from 0% to 300%.

With 25 responses missing (8.96%), 254 valid responses were collected for this question. Across the country regions, 90.94% of participants reported that they could expand their production capacity in the next five years.

When comparing mean responses across country regions, participants from Eastern Europe reported the highest mean expansion potential (n = 46, M = 117.9%, SD ± 97.29), followed by participants from South-Western Europe (n = 60, M = 100.23%, SD ± 90.42). Participants from Northern Europe (n = 36) reported a mean expansion possibility of 81.67% (SD ± 76.71), while those from Central Europe (n = 89) reported a mean of 73.98% (SD ± 75.71).

Figure 23 shows the distribution of expansion possibilities in detail. Participants from Eastern Europe not only have the highest median of 100% but also exhibit the greatest variability in their expansion possibilities. This means that 50% of participants who reported being able to expand their production can expand beyond 100%, indicating that they could double their current maximum capacity or more. Participants from South-Western Europe show the same distribution range, but the expansion possibilities for 50% of respondents—and therefore their median (60%)—are lower compared to the Eastern Europe group. Participants from Northern and Central Europe have an identical median of 50%, with the same range and one outlier at 300% in each group. The only difference in the distribution is that the expansion possibilities of the 25% of participants below the median are slightly lower in the Central European group compared to the Northern Europe group.

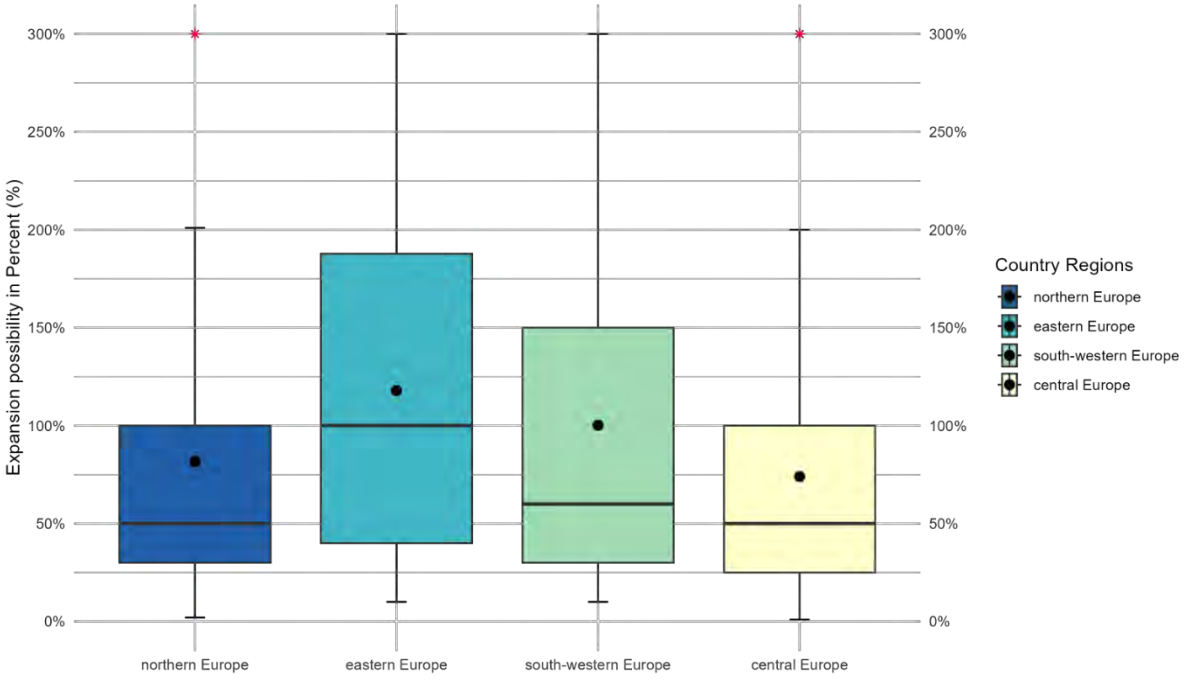

Figure 23. Expansion possibilities beyond current maximum capacity across country regions as reported by respondents to online nursery survey.

The higher expansion possibilities in the Eastern European respondents is probably due to the relatively low demand for artificial regeneration in the region. As demand is expected to increase due to climate change mitigation measures, this is an asset, though the overall production capacity is very low compared to the other regions (see also 5.1.2).

5. Limiting factors to increase production

Participants were asked to rank five factors limiting the increase of nursery production, including the option "There are no limiting factors to increasing production," which they could rank first if they perceived no limiting factors.

The five factors were:

- Technical/Technological (e.g. seed availability, seed quality, availability of production area, soil fertility, etc.)
- Economic/Financial (e.g. high competition with other producers, high labour costs, lack of loans, insufficient fundings, etc.)
- Political/Legal (e.g. too strict regulations, national differences in import regulations, etc.)
- Environmental (e.g. early or late frost, increasing drought incidences, risk of fires, etc.)
- Social (e.g. lack of qualified workers, conflicts with environmental associations, etc.)

When analyzing ranking questions based on average weighting, numerical values are assigned depending on the number of response options. The highest-ranked option receives the highest value, the second-highest receives a slightly lower value, and so on. Therefore, the option with the highest average score is considered the most critical limiting factor. Figure 24 displays the weighted ranks regarding perceived limitations to future production expansion per country regions.

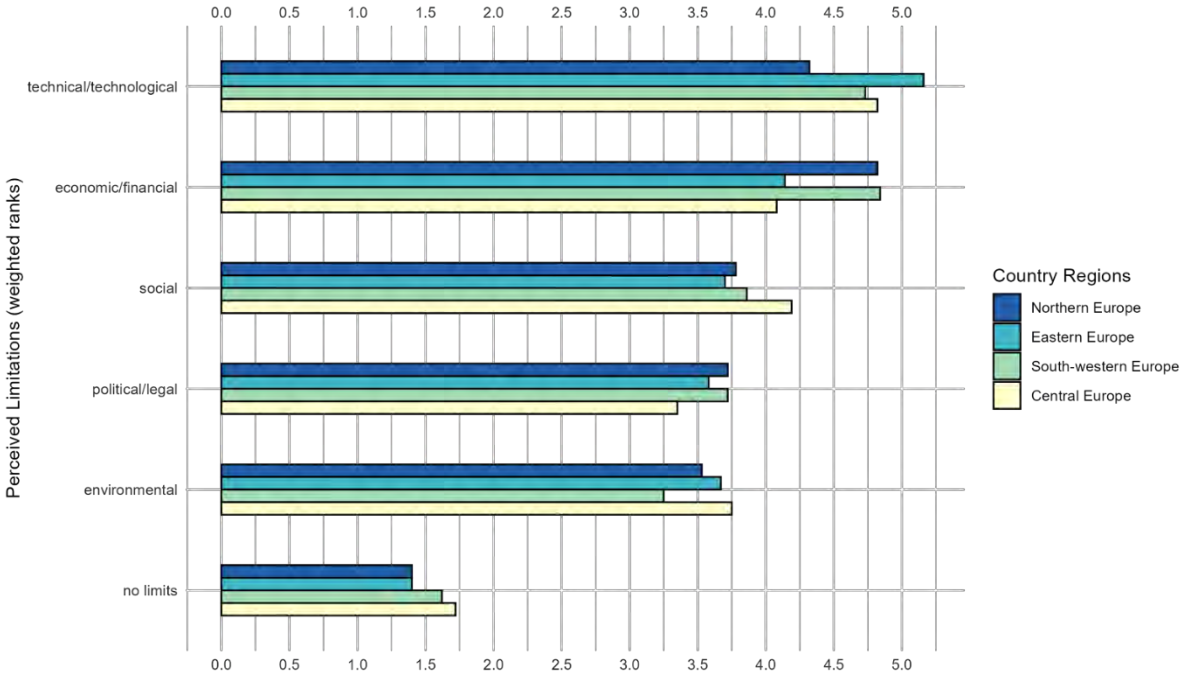

Figure 24. Perceived limitations of respondents to online forest nursery questionnaire to future production expansion per country region depicted as weighted ranks.

The results show that there is not a single dominant limitation, but actually multifactor processes that need deeper analysis to address limitations in the different regions. Nevertheless, technical/technological limitations, regarding issues such as seed availability, seed quality, availability of production areas, and soil fertility, were reported as the most significant factor overall. This result is largely driven by participants from Eastern Europe, followed by those from Central Europe, who ranked this factor as their top concern.

Economic/Financial limitations, regarding issues such as high market competition, high labour costs, lack of loans, and insufficient funding, were reported as the second most significant factor overall. However, it is important to note that participants from Northern and South-Western Europe identified this factor as their primary concern.

Social limitations, including issues such as a lack of qualified workers and conflicts with environmental associations, were reported as the third most significant factor overall. At the group level, this concern was more prominently perceived by participants from Central Europe compared to the other three groups.

Environmental and Political/Legal limitations were ranked similarly overall. Environmental limitations were perceived relatively consistently across participants from three regions, while participants from South-Western Europe ranked this factor lower than the others. A similar pattern emerged for Political/Legal limitations: participants from three regions ranked them comparably, whereas participants from Central Europe assigned this factor a lower rank in comparison.

These results show the main thematic barriers to increase FRM production across the four regions studied. Though regional differences exist, the relative proportions are surprisingly similar given the complexity of the market structure. The main thematic barriers are also in good agreement with the findings of the available literature (e.g., Fargione et al. 2021, Rantasa & Kraigher 2024), while social (staff) related issues were more important in previous research; it was also perceived as a more severe challenge in 5.2.4.1 (investment areas as a reaction to changing demand) and in the semi-structured interviews (SSIs; 5.4.2) in this study.

For a deeper understanding, the following topics (seed supply, market situation and demand) were further explored in the online nursery survey; in addition, semi-structured interviews (SSIs) were performed to get deeper insights into the observed challenges. The full and detailed discussion of the overall findings is presented in section 5.4 along with the results of the SSIs.

5.2.3. Seed supply situation as perceived by respondents to forest nursery survey

1. Seed Sources

Respondents in the forest nursery survey were asked to specify the sources from which they acquire seeds each year over the past five years. They were required to provide an estimate as a percentage of the total amount. Seed source categories were provided. “Own forest” is forest directly owned by the nursery (e.g. a state forest and a state nursery); “private forest” indicates a forest owned by a third private person or entity. Double counting was avoided. One participant was excluded from the analysis due to an incorrect answer format. Therefore, 265 valid responses were analysed, excluding 13 unavailable responses (4.68%).

Additionally, the answers were categorized into percentage groups to facilitate comparison across participants from different country regions. The groups ranged from ‘1-25%’, ‘26-50%’, ‘51-75%’, ‘76-99%’, to ‘100%’. These percentage groups were selected specifically to highlight the nurseries that sourced their seeds from a single category.

Figure 25 illustrates the distribution of different seed sources across country regions, showing the percentage of participants who selected each seed source, divided into percentage groups. To assess the importance of these seed sources, we further weighted the responses, assigning higher values to sources with higher percentages. The text below details the three most important seed sources for each country region.

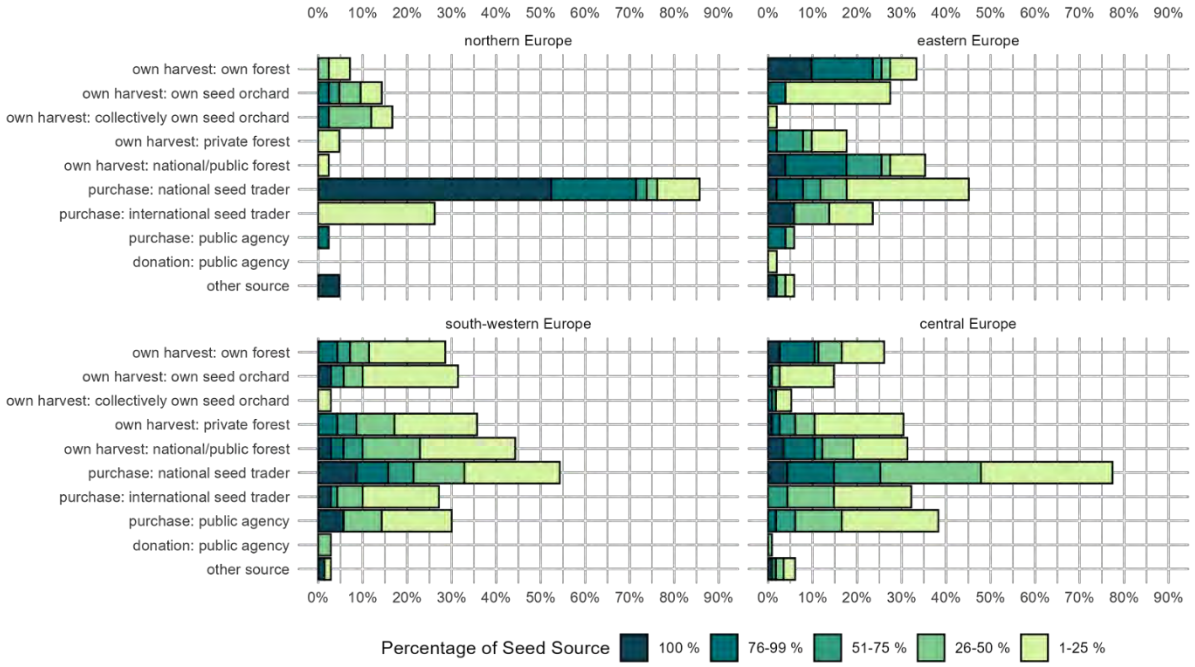

Figure 25. Importance of various seed sources across four European regions, presenting the percentage of respondents selecting each source, categorized into percentage groups.

Notably, 73.17% of participants from Northern Europe report purchasing 76% to 100% of their seeds from national seed traders. This is the highest value compared to the other three regions, though this source is also important in all other regions. Participants from Central and South-Western Europe also cite national seed traders as their primary seed source, but the overall distribution and percentage of purchases are considerably lower than those of Northern Europe participants. Respondents from Eastern Europe reported that their most important seed source comes from their own harvests in own forests, which is related to mostly public (state) forest nurseries in the region.

Participants from Eastern, South-Western, and Central Europe identified their own harvests from national or public forests as their second most important seed source, whereas participants from Northern Europe reported their own harvests from collectively owned seed orchards as their second most important seed source.

The third most important seed source varied across all country regions. Participants from Northern Europe stated that their third most important source is their own harvests from seed orchards. Eastern participants reported purchases from national seed traders as their third most important source. South-western participants mentioned their own harvests from privately owned (third party) forests, while participants from Central Europe reported their own harvests from own forests (again related to public nurseries harvesting in public forests) as their third most important source.

Because of the high importance of seed traders, this sector of the FRM market was analysed in its own online survey (5.3). The findings here are compared to results from the online seed provider survey in 5.3 and further implications and underlying mechanisms are discussed together with the results of the semi-structured interviews in 5.4.4.

2. Challenges faced by nurseries in own seed harvests

Respondents were asked how frequently they encountered challenges related to the quality and quantity of seeds obtained from their own harvests over the past five years. Responses to the provided challenges were given on a scale ranging from “never” to “always,” with an

additional option for participants to indicate if they did not harvest seeds. Provided challenges were as follows:

- Overall lack of seed to meet the demand
- Lack of seeds from preferred species
- Lack of preferred provenance
- Years of intensive fruiting are getting more irregular
- Too low germination rate/ seedlings grow slow or die
- Other, please specify

In addition to the 11 unavailable responses, 73 participants indicated that they do not harvest seeds, leaving 195 valid answers for this question.

Participants from Eastern and Central Europe continue to report slightly higher levels of challenges compared to those from the other two regions; the Northern Europe region is mainly challenged by irregular fruiting. The main challenge, cited as occurring “always” or “often” by over 40% of participants across all regions, is the increasing irregularity of years with intensive fruiting. Additionally, around 40% of participants from Eastern and South-Western Europe reported a frequent or constant lack of seeds from preferred species (Figure 26 , Figure 27).

These findings are compared to results from the online seed provider survey in 5.3.1 and further implications and underlying mechanisms are discussed together with the results of the semi-structured interviews in 5.4.4.

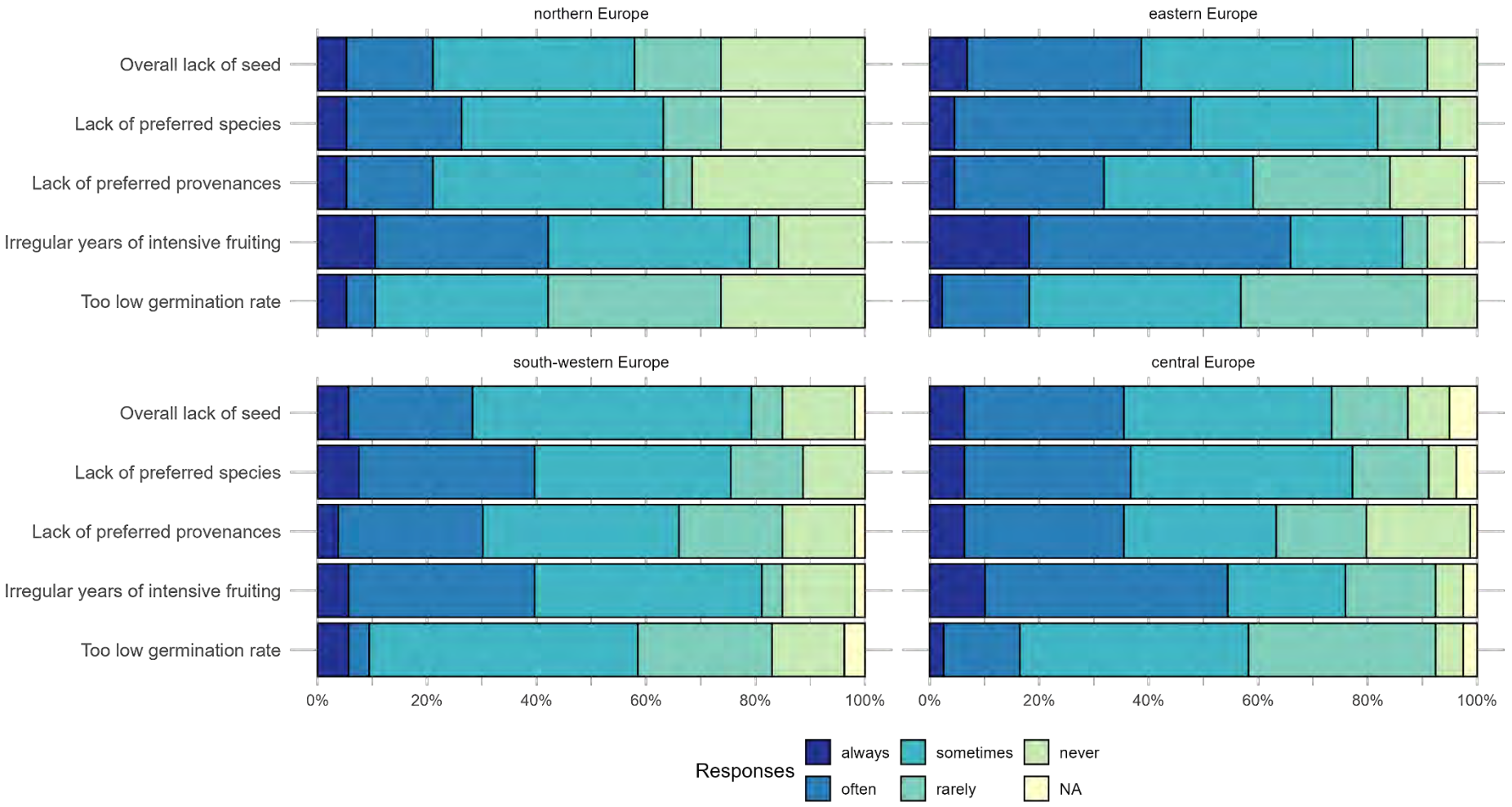

Figure 26. Challenges with seed quantity and quality faced by nurseries in own seed harvests per country region, as reported by respondents to online nursery survey.

3. Challenges regarding purchased seeds

Participants were asked how frequently they encountered challenges related to the quality and quantity of the seeds they purchased over the past five years. Responses to the provided challenges were given on a scale ranging from ‘never’ to ‘always,’ with an additional option for participants to indicate if they did not purchase seeds. Provided challenges were as follows:

- Overall lack of seed to meet the demand
- Lack of seeds from preferred species
- Lack of preferred provenance or origin
- Available material is too expensive
- Origin of available material might be dubious
- Seeds are only available at irregular times
- Seed is not clean, is damaged, affected by pests or diseases
- Too low germination rate/ seedlings grow slow or die
- Other, please specify

In addition to 15 unavailable responses, 24 participants indicated that they do not purchase seeds, resulting in 240 valid answers for this question.

When interpreting Figure 27, particular attention is given to the responses ‘always’ and ‘often,’ as these categories hold significant importance. The description for ‘always’ indicates that “the challenge has occurred consistently and without exception,” while ‘often’ refers to challenges that “happen frequently, regularly, or multiple times.”

At first glance, it appears that participants from Eastern and Central Europe report experiencing more frequent and pressing challenges compared to those from Northern and South-Western Europe. Over 40% of participants from Eastern and Central Europe state that challenges such as an overall lack of seeds to meet demand, a lack of preferred species, and irregular availability of material occur "always" or "often." Additionally, over 40% of participants from Central Europe report that issues such as a lack of preferred provenances or origins and too expensive material also occur "always" or "often". A lack of preferred provenances or origins is the only challenge reported by over 40% of participants from South-Western Europe as occurring “always” or “often”.

These findings are compared to results from the online seed provider survey in 5.3.1 and further implications and underlying mechanisms are discussed together with the results of the semi-structured interviews in 5.4.4.

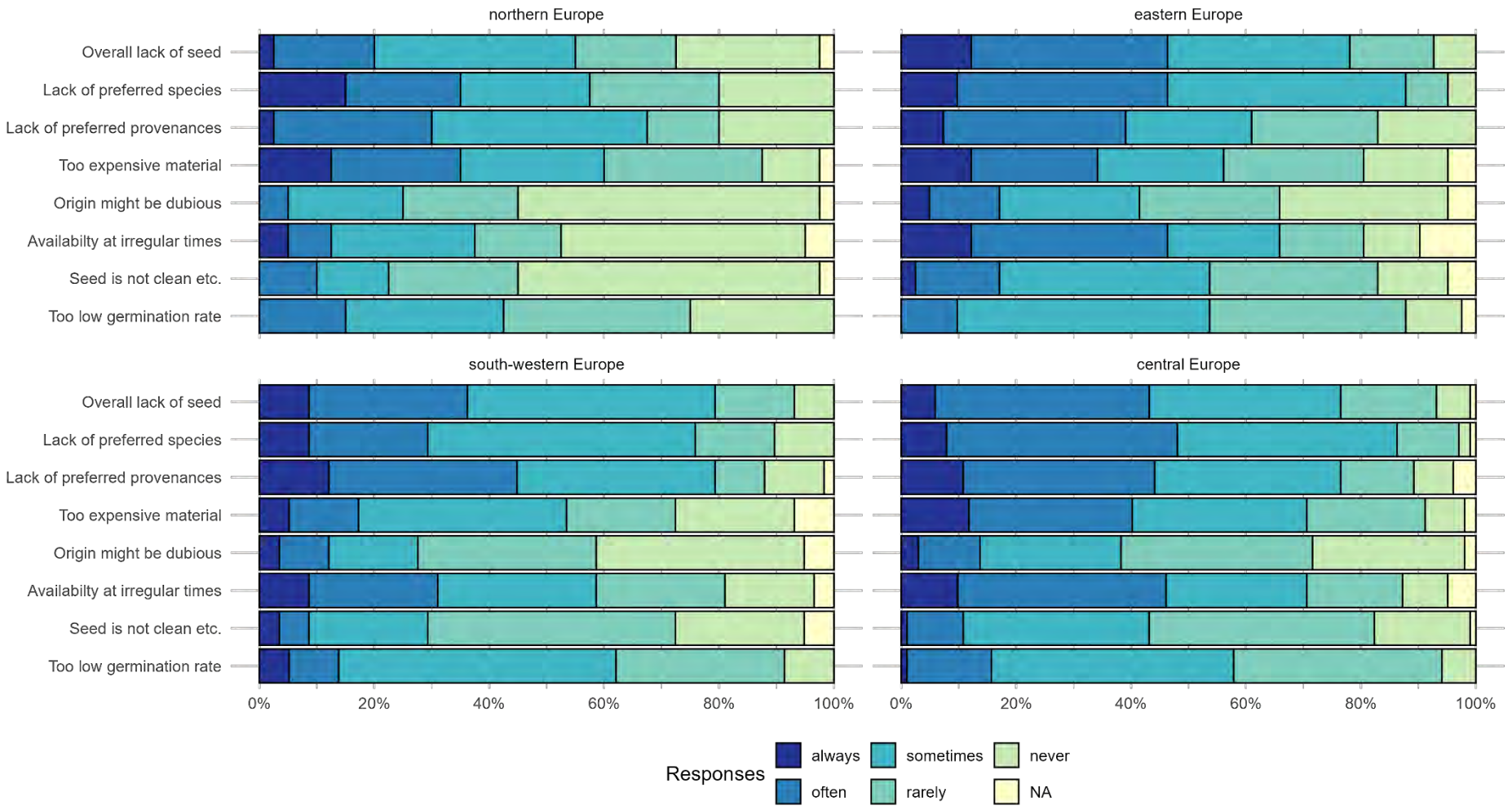

Figure 27. Challenges reported by respondents to online nursery survey with quantity and quality of purchased seeds per country region.

4. Seed pre-treatment

Participants were asked whether they engage in any form of outsourcing for seed pre-treatment, including purchasing pre-treated seeds from suppliers. The multiple-choice question offered three options: “Yes, I send some or all of my seeds away for pre-treatment,” “Yes, I buy some or all of my seeds pre-treated from suppliers,” and “No, I don’t engage in any form of outsourcing for seed pre-treatment.”

A total of 270 valid responses were collected, with a 3.23% rate of 9 unavailable responses. Among the participants, 58.15% stated that they do not engage in any form of outsourcing for seed pre-treatment. Of the 41.85% who do engage in outsourcing, 14.81% send some or all of their seeds away for pre-treatment, 19.63% purchase pre-treated seeds, and 7.41% use both methods. For participants who outsource their seed pre-treatment, a follow-up question (filter question) appeared, asking where this outsourcing takes place. The details are provided in Figure 28.

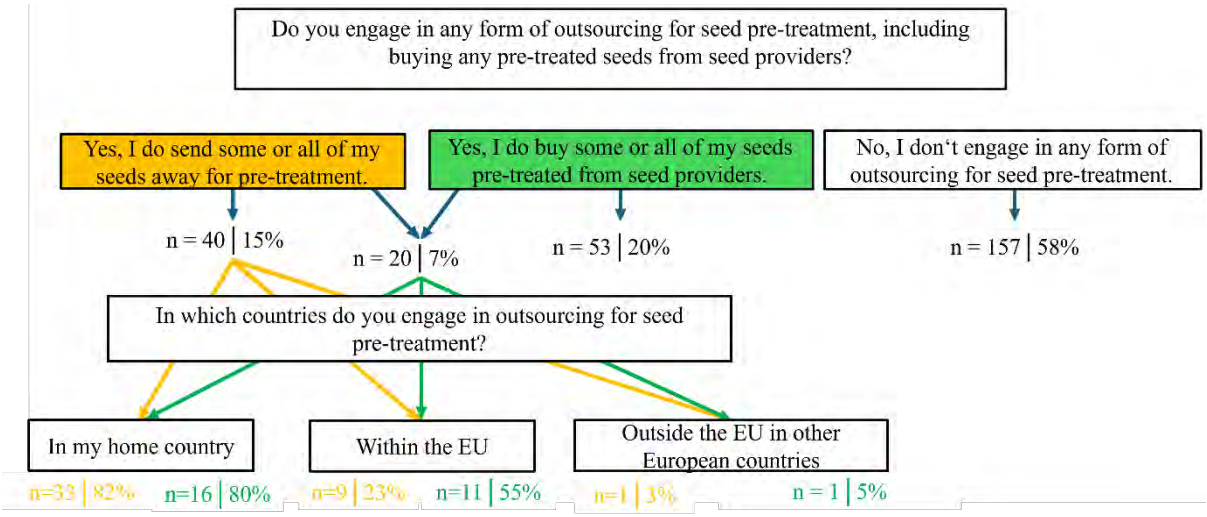

Figure 28. Practice of outsourcing of seed pre-treatment as reported by respondents to online nursery survey.

Table 10 presents the overall participation in outsourcing for seed pre-treatment (expressed as *total n*) and the distribution of this participation across country regions. The share of participation is shown as a percentage of the total responses, highlighting how outsourcing activities are divided among the regions.

Regional comparisons reveal that Central European participants account for 72.5% of those who send their seeds away for pre-treatment, 39.62% of those who purchase pre-treated seeds, and 65% of those who use both methods. In the other regions, purchasing of pre-treated seeds is the common way in which seed treatment is outsourced.

Table 10. Distribution of respondents' practice in outsourcing of seed pre-treatment by country region*

	Northern n	*valid %*	*Eastern n*	*valid %*	*South-Western n*	*valid %*	*Central n*	*valid %*	*Total n*	*Total %*
No outsourcing	21	13.38	40	25.48	46	29.30	50	31.85	157	100
Outsourcing	20	17.70	11	9.73	19	16.81	63	55.75	113	100
NA	1	11.11	1	11.11	5	55.56	2	22.22	9	100
Total n	42		52		70		115		279	
Send seeds	5	12.50	3	7.50	3	7.50	29	72.50	40	100
Purchase seeds	14	26.42	7	13.21	11	20.75	21	39.62	53	100
Both	1	5.00	1	5.00	5	25.00	13	65.00	20	100

*please note that multiple answers were possible

Proper seed pre-treatment is a key component in successful and effective raising of plants from the limited amount of seed available (e.g., Jalonen et al. 2018; and further discussion in 5.4.4).

5. Contract production

In this question, participants were asked in which countries they engage in contract production with specialist nurseries to outsource the initial stages of seedling production, at least to some extent. The multiple-choice question allowed for multiple answers and provided four options: "I don't engage in any form of outsourcing for the initial stages of seedling production," "In my home country," "Within the EU," and "Outside the EU in other European countries."

A total of 274 valid responses were recorded, with five unavailable responses (1.79%). Among all participants, 65.33% stated that they do not engage in outsourcing for the initial stages of seedling production.

Of the remaining 34.76% who reported engaging in outsourcing, 24.45% stated they do so within their home country, 16.42% within the EU, and only 1.46% outside the EU in other European countries. For a graphical presentation of results see Figure 29.

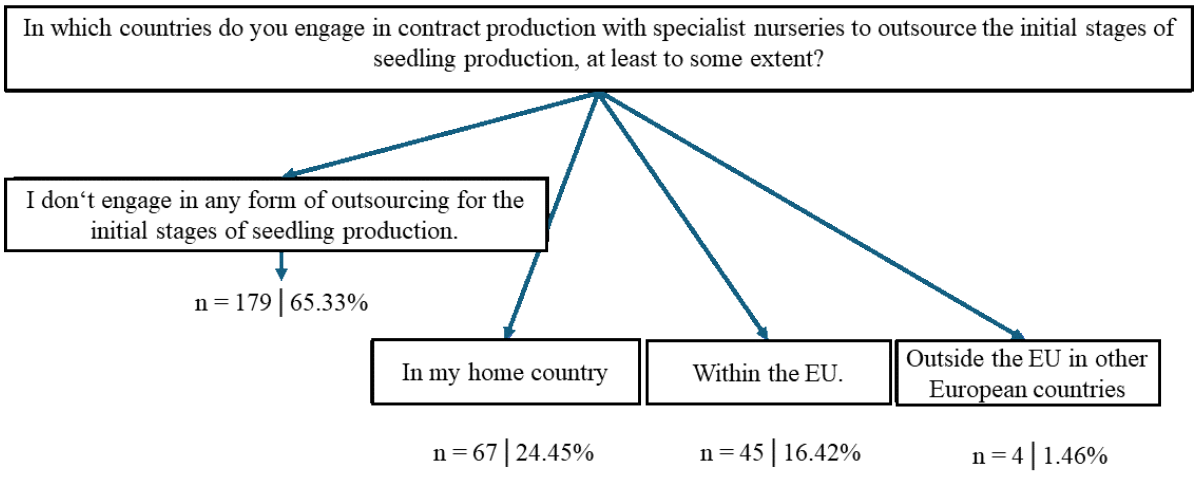

Figure 29. Contract production in European forest nurseries (outsourcing of early stages of seedling production) as reported by respondents to online nursery questionnaire.

Table 11 presents the overall participation in outsourcing for contract production (expressed as *total n*) and the distribution of this participation across country regions. The share of participation is shown as a percentage of the total responses, highlighting how contract production activities are divided among the regions.

Table 11. Distribution of Participation in Contract Production by Country Region*

	Northern n	valid %	Eastern n	valid %	South-Western n	valid %	Central n	valid %	Total n	valid %
No engagement	33	18.44	35	19.55	47	26.26	64	35.75	179	100
Engagement	9	9.47	17	17.89	19	20.00	50	52.63	95	100
NA	0	0.00	0	0.00	4	80.00	1	20.00	5	100
Total n	42		52		70		115		279	
In home country	5	7.46	14	20.90	13	19.40	35	52.24	67	100
Within the EU	6	13.33	6	13.33	9	20.00	24	53.33	45	100
Outside the EU	0	0.00	2	50.00	2	50.00	0	0.00	4	100

*Note that multiple answers were possible.

Contract production can be an important step in effective production of FRM, particularly in species that are difficult to raise (especially broadleaf species) or to obtain a higher number of seedlings per kilo of seed (more efficient use of resources); it can be especially useful in Plug+ production for nurseries producing bareroot seedlings but want to have the benefits of container raised young seedlings. Contract production may also be a tangible solution to reach afforestation goals in regions with low overall production capacity (see also 5.4.7).

5.2.4. Market situation and demand

In this section of the online questionnaire, respondents were asked to provide basic information on the market situation and demand situation they face in their business operations and their potential reaction to changes in the market. These were necessary future areas for investment, as a reaction to the changing demand, and the anticipated magnitude of the investment, their main sales market (i.e. business to consumer or business to business), the extent of international transfer of FRM in their business, and challenges they are facing concerning market conditions and demand.

1. Investment areas as a reaction to changing demand

Participants were asked to rank the three most important areas where their nursery would need to invest in response to changing demand over the next five years. Eight options were provided as drag-and-drop answers, with the instruction that only ranks 1 through 3 would be considered. Provided options for investment areas were as follows:

- Human resources (e.g. staff extension, training, education, etc.)
- Soft infrastructure (e.g. automatization, IT, new technologies, etc.)
- Hard infrastructure (e.g. greenhouses, storage, roads, etc.)
- Increase of production of Forest Reproductive Material
- Market and Promotion

- Diversification of Forest Reproductive Material (e.g. new provenances, new species, etc.)
- Research and development (e.g. pre-treatment of seeds, etc.)
- Certification and sustainable governance practices (e.g. certification, standardization, social and environmental sustainability, etc.)

With 15 unavailable responses (5.4%), a total of 264 valid answers were received. Overall, the top three investment areas focused on four main topics: hard infrastructure, human resources, soft infrastructure, and increasing the production of forest reproductive material (FRM).

As shown in Figure 30, participants from Northern and Eastern Europe ranked "Hard infrastructure" as their top priority, indicating a need to invest in greenhouses, storage facilities, roads, and similar areas. In contrast, participants from South-Western and Central Europe ranked "Hard infrastructure" as their second priority, while both groups identified "Human resources" as their number one priority. This reflects a focus on expanding staff, providing staff training and education, and addressing related needs.

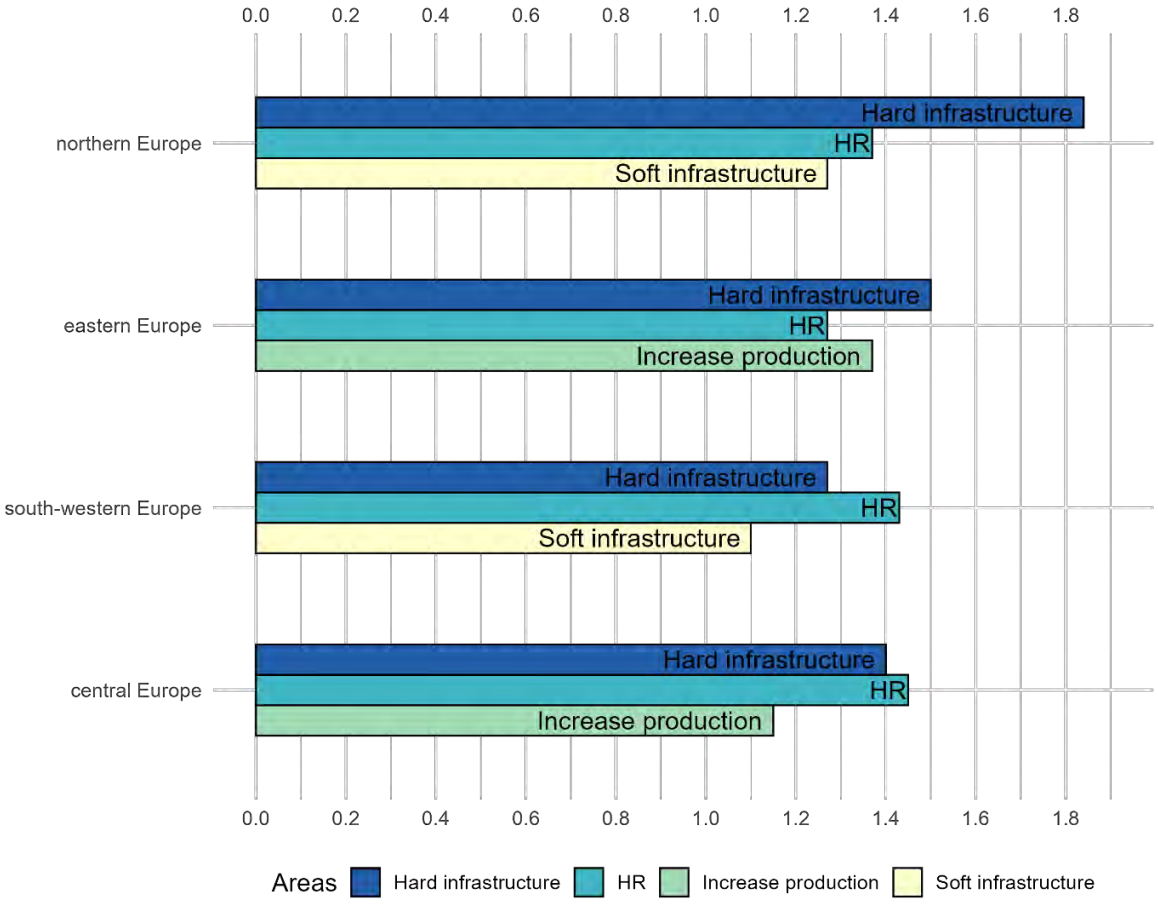

Figure 30. Three most important investment areas as reported by respondents to online nursery survey shown per country region (average weighting scores are shown).

For Northern Europe participants, "Human resources" was ranked as their second priority. Meanwhile, Eastern Europe participants ranked "Increase of production of FRM" as their second priority, with "Human resources" as their third priority.

Participants from Northern and South-Western Europe ranked "Soft infrastructure" third, signifying a need to invest in automation, IT systems, and new technologies. In Central Europe, however, "Increase of production of FRM" was ranked as the third priority.

The results are particularly important because they show which parts of production are essential to increase output. The results from all regions indicate problems with human resources – as either respondents see a need to invest in HR or in hard infrastructure, which is often associated with automatization or mechanization of the production process. Again, this result is in line with previous research in other regions (e.g. Fargione et al. 2021 for the USA). This challenge and its implications are further discussed together with results of the semi-structured interviews in section 5.4.3.

2. Follow-up question on the magnitude of investments

Participants were subsequently asked to estimate the magnitude of total costs associated with these three investment areas, based on their opinion. They were instructed to provide an amount in Euros, with a link to a currency converter included for convenience. A total of 211 valid answers were received, while 68 responses were unavailable (24.37%).

However, upon analyzing the results, it became clear that the question's wording lacked sufficient clarity. Specifically, the scope of the total costs was not defined, leaving participants uncertain whether the costs referred solely to their own nursery or to the investments required across the entire European Union or Europe. Consequently, responses varied widely—from as low as €1 to as high as €1,000,000,000—making it nearly impossible to derive meaningful conclusions. This lack of clarity might also explain the relatively high non-response rate for this question.

3. Main sales markets

The next question focused on participants' main sales markets, estimated as a percentage. A slider was presented, ranging from Business-to-Consumer (B2C) to Business-to-Business (B2B). To provide clarity, the following definitions were included:

- Business-to-Consumer (B2C): B2C sales involve direct transactions between the nursery and the end users of forest tree nursery products and services, such as forest owners, forest enterprises, and others.
- Business-to-Business (B2B): B2B sales involve transactions of forest tree nursery products and services intended for intermediary trade, resale, or refinement by other market participants.

The question was answered by 257 participants, with 21 responses unavailable (8.17%). As shown in Figure 31, the predominant market orientation across participants from all country regions is towards consumers. Participants from Northern, South-Western, and Central Europe showed a median of 80% in their market orientation, while participants from Eastern Europe showed a slightly lower median of 75%.

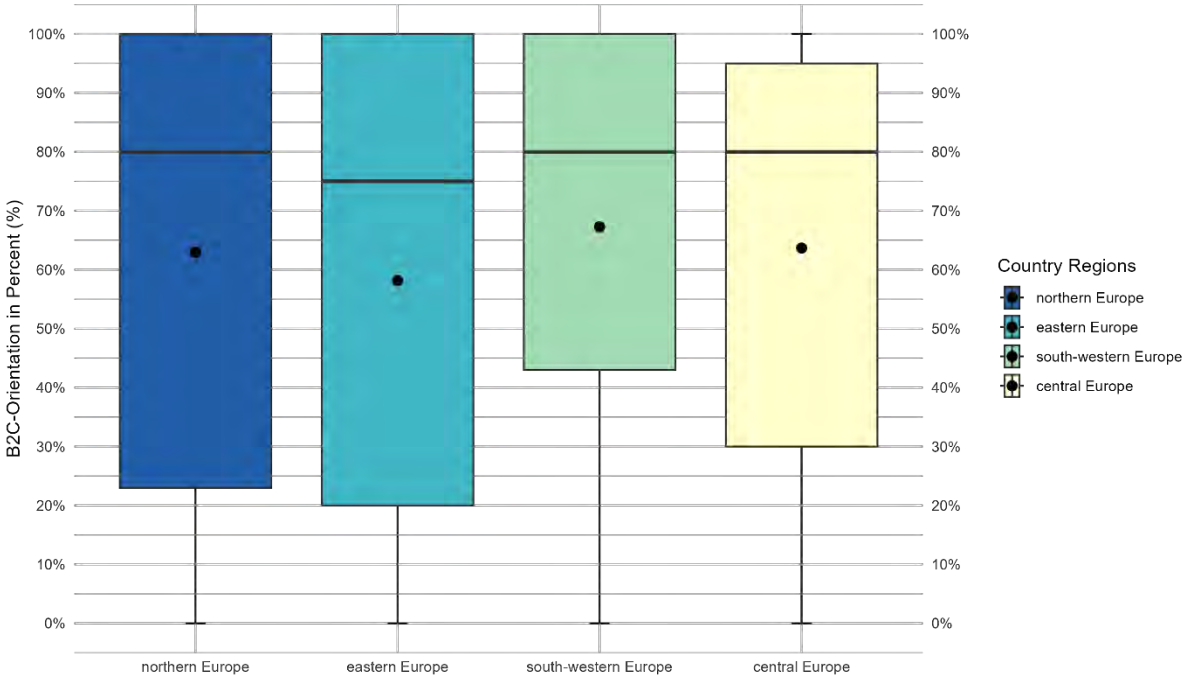

Figure 31. Business-to-Consumer orientation per country region as reported by respondents to online nursery survey.

The mean percentages were lower than the median levels in all regions, indicating significant variation in market orientation among the 50% of participants whose values fall below the 80% threshold. This variation is also reflected in the longer lower sections of the boxes, illustrating a wider spread in market orientation among these participants. Participants from South-Western Europe exhibit a slightly higher orientation towards consumers compared to the other three regions. Conversely, participants from Eastern Europe reported a slightly greater orientation towards businesses. However, these differences are small, so it can be inferred that the largest part of the seedlings produced in all regions are directly delivered to the forest end-users. As discussed further below in 5.4.7, contract production as a B2B way of trade may increase in the future.

4. International transfer of seedlings

Overall, 93 respondents reported that they export seedlings to other European countries (33.35%), while 168 respondents stated that they do not export seedlings (60.43%), leaving 17 unavailable answers (6.12%). Among the 93 respondents who reported exporting, 20.43% were from Northern Europe, 13.97% from Eastern Europe, 27.96% from South-Western Europe, and 37.64% from Central Europe.

When comparing exports across country regions, Figure 32 shows the three most important transfer destinations for each region. Please note that the percentages in the upper row represent the share of participants from each region who report international transfer of seedlings. For example, 45.24% of Northern Europe participants transfer seedlings across country borders. The main receiving countries from Northern Europe are Sweden (reported by 63.16% of participants), Norway (36.84%), Finland and Germany (26.32%).

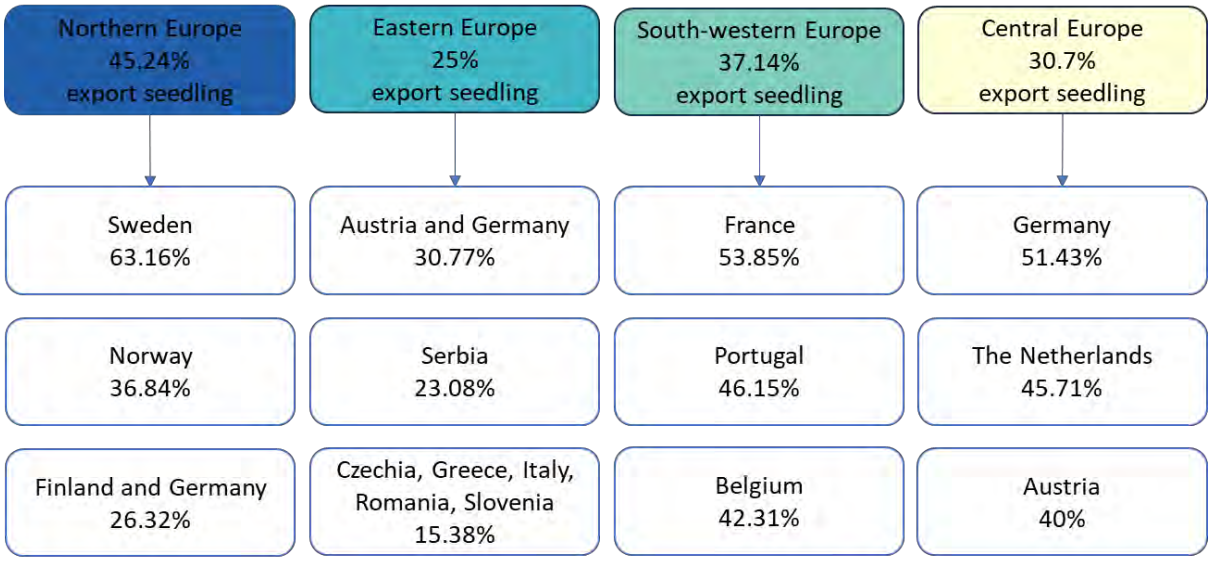

Figure 32. The three most important export destinations per country region as reported by respondents to online nursery survey. Please note that the percentages in the upper row represent the share of participants from each region who report exporting seedlings; percentages in lower rows indicate proportion of region's respondents transferring plants to the respective receiving countries.

The results show that most exporting of seedlings is happening in Central and South-Western Europe, while this is less a market strategy in Northern and particularly in Eastern Europe. Most transfer of FRM is done among neighbouring countries. In Eastern Europe public nurseries dominate which are mostly producing for the respective state forests, with little international transfer; similarly in Northern Europe most plants are produced on contract basis within the country.

Given the increasing internationalization of forestry and the rapid pace of climate change, it is very likely and needed that bilateral trade in FRM will continue to expand (e.g., Loo et al., 2011; Chakraborty et al. 2024). Recent updates to FRM seed zones, which incorporate climatic factors (e.g., Chakraborty et al. 2021), findings from provenance trials on adaptive traits (Leites & Benito Garzón 2023), and insights into the genetic diversity of tree populations (Aitken & Bemmels 2016), support the shift away from strictly geographical (national) approaches and highlight the growing transnational significance of this issue (Frank et al., 2017b). Advancing our understanding of how tree populations adapt, the effects of translocations, and the ecological implications, as well as identifying forest genetic resources suited for future climate conditions, depends on a reliable and consistent data supply. Jansen et al. (2019) therefore suggest that transfer data among countries should be centrally collected at the EU level; this would be an important data source to observe the market and for the development and implementation of climate change adaptation and mitigation measures.

4. Market conditions and demand

Participants were asked how often they faced the following challenges regarding market conditions and demand over the last five years. Responses were given on a scale ranging from "never" to "always", with an additional option to add other challenges. The provided challenges were as follows:

- High competition with other producers
- High labour costs
- Lack of long-term contracts with customers
- Lack of binding contracts (e.g. customers don't accept ordered products)
- Increasing demand in species you do not produce
- Increasing requests for provenances you are not able to provide

- Difficulties to find qualified workers

The mean valid response rate was 263, with an average of 16 unavailable answers (5.75%) depending on the challenge being rated.

Overall, the most pressing challenge reported by participants from all country regions was the 'lack of long-term contracts with customers', with 29.66% indicating this occurred "always" and 27.76% reporting it occurred "often" (in total 57.41%). This was followed by 'high labor costs', which were reported as "always" by 22.81% and "often" by 41.06% of participants (in total 63.88%). The third most significant challenge was 'difficulty in finding qualified workers', with 20.75% indicating this occurred "always" and 36.60% reporting it occurred "often" (in total 57.36%).

When comparing responses across country regions (Figure 33), it is notable that 44.68% of participants from Eastern Europe reported a 'lack of long-term contracts' occurring "always." This was followed by 31.48% of participants from Central Europe, 25.76% from South-Western Europe, and only 14.29% from Northern Europe. Additionally, participants from Eastern Europe reported a 'lack of binding contracts' occurring "always" (21.74%) far more frequently than participants from other country regions.

Regarding 'high labour costs', 69.72% of participants from Central Europe indicate this challenge occurring as "always" and "often". Followed by 68.09% of participants from Eastern, 57.14% of participants from Northern, and 55.38% of participants from South-Western Europe.

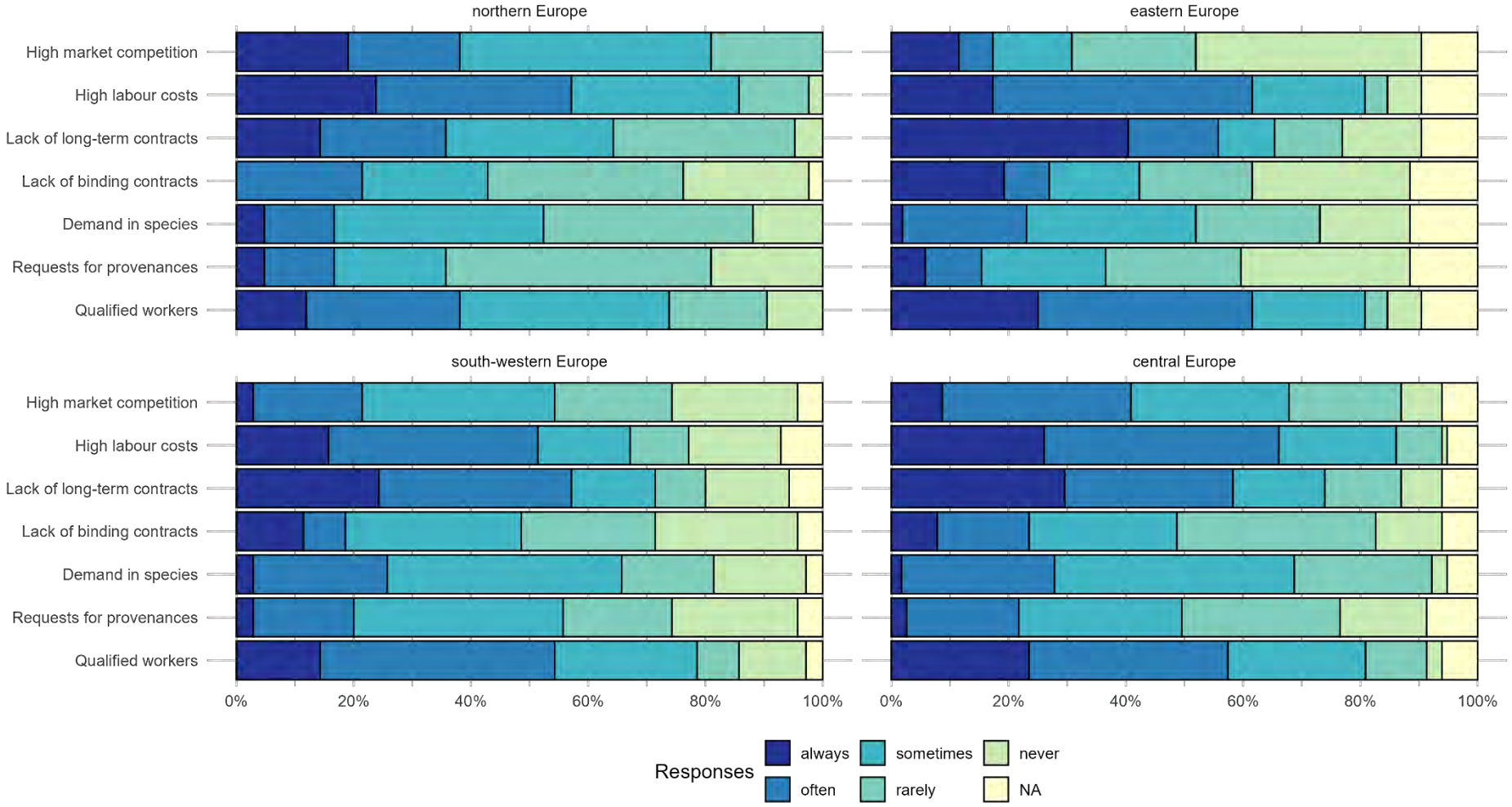

Figure 33. Main challenges regarding market conditions and demand over the last five years per country region as reported by respondents to online nursery survey.

Challenges regarding ‘difficulties to find qualified workers’ were reported as occurring “always” and “often” by 68.09% of participants from Eastern Europe, 61.11% from Central Europe, 55.88% from South-Western Europe, and 38.10% from Northern Europe.

When summarizing these results, they suggest that while these three main challenges occur across all country regions, they are more prominent among participants from Eastern and Central Europe.

The observed problematic challenges are in good agreement with the reports from the available literature, in that production risk (lack of contracts, no assured plant sales) and problems in finding proper staff are the main barriers for forest nurseries – see Fargione et al. (2021), Wezel & Reis (2019), Božič et al. (2021), Friedrich (2022), Rantasa & Kraigher 2024, and Whittet et al. (2016). Notably these social barriers associated with staff issues were not as prominent in 5.2.2. The findings presented here were further corroborated in the subsequent semi-structured interviews together with which these barriers to production are discussed in more detail (see 5.4).

5.2.5. Legal regulations and incentives

1. Satisfaction with public incentives and administrative procedures

In this section of the survey, participants were asked about their satisfaction with the availability of public incentives (e.g., grants, subsidies, or other forms of governmental or public financial support) as well as their satisfaction with the administrative procedures for obtaining these incentives. Responses were presented as single-choice options, ranging from "very satisfied" to "very dissatisfied," with an additional option to indicate if public incentives were not applicable to their nursery. Two follow-up questions were included, asking participants which major changes to public incentives and administrative procedures their government should implement, in their opinion, to ease their operations.

Overall, there were 272 valid responses to the question regarding public incentives, leaving seven unavailable answers (2.51%). For the question regarding administrative procedures, 271 valid responses were recorded, with 8 unavailable answers (2.87%).

To better understand the relationship between the responses to these two questions, a flow diagram is presented in Figure 34.

When comparing responses across different country regions, South-Western Europe stands out for its satisfaction with public incentives: 39.13% of participants reported being very or rather satisfied. This is followed by 21.43% from Northern Europe, 20% from Eastern Europe, and only 12.61% from Central Europe. Interestingly, satisfaction with the associated administrative procedures was not as high and showed much more variation.

It is also worth noting that the highest number of responses concerning the applicability of public incentives comes from Central Europe (around 40%), followed by Eastern Europe (around 30%).

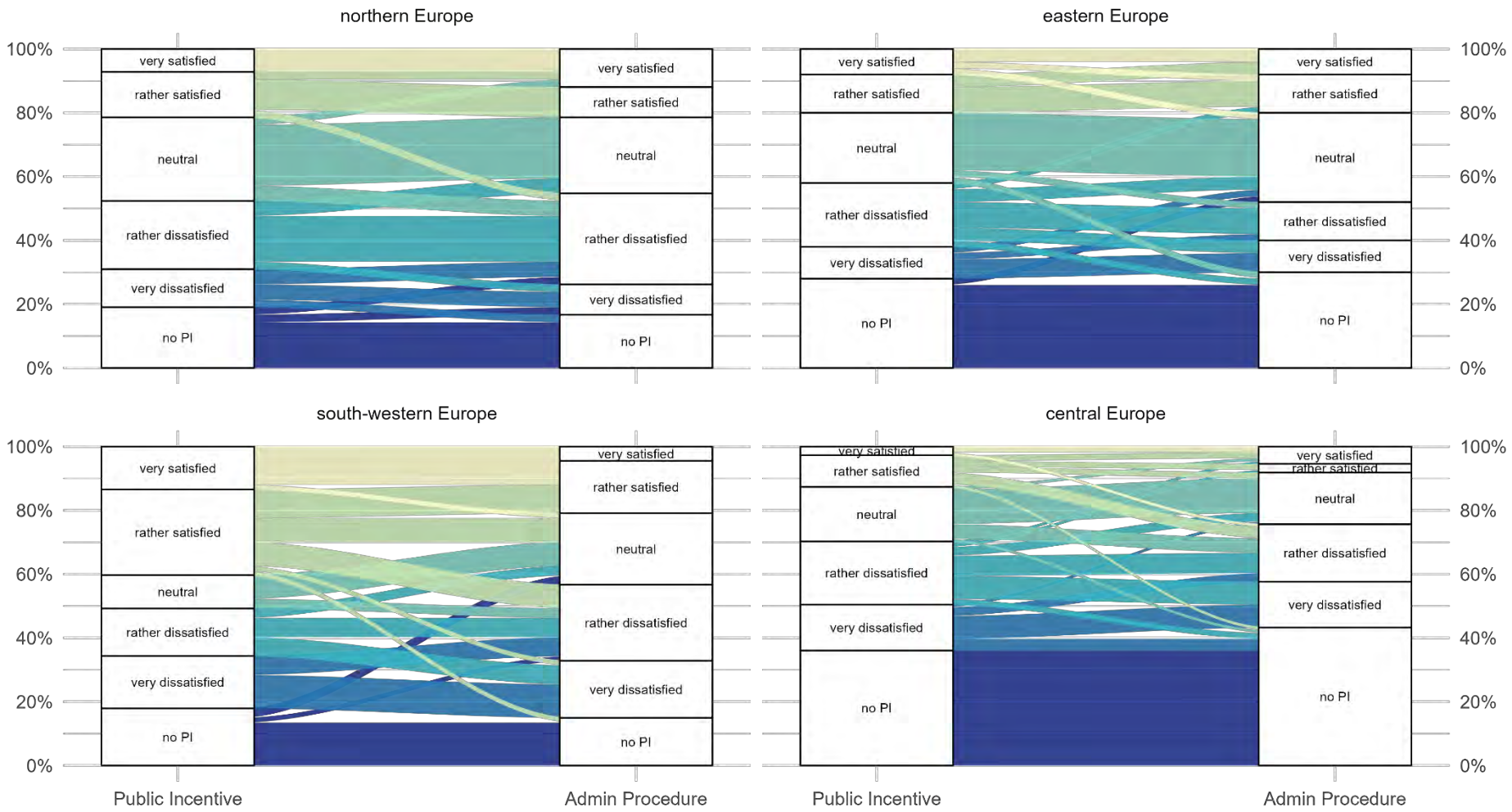

Figure 34. Satisfaction with public incentives and associated administrative procedures per country region as reported by online nursery survey respondents.

The answers to the two follow-up questions were open responses, fully reported in Annex 6. The relationship between the two factors (satisfaction with public incentives and associated administrative procedures) was also maintained to better understand the responses. In the following we present selected suggestions by respondents for the four denoted European country regions to show the range of opinions and common issues towards the availability of subsidies and administrative procedures; respondents are grouped according to their satisfaction with the current availability of subsidies. To allow for anonymity the country of origin of respondents is not provided. The full list of responses can be found in Annex 6.

Common issues brought forward by respondents from all regions were:

- The general lack or low availability of subsidies for forest nurseries.

"The importance of the forestry sector in our country and the amount of subsidies do not match. The situation is improving, but the difference with the agricultural sector, for example, is significant. Investments in nurseries must be made independently. Also, the currently supported amounts for the production of high-quality forest plants are not sufficient."

- If specific subsidies are available the funding rate is perceived as too low.

"The percentage of support [funding rate] could be higher than 50%."

"Public incentives with a higher percentage of co-financing."

"Increase the percentage of assistance in calls for proposals, which is usually around 30%."

- More funds should be set aside for nurseries to increase general funding volume.

"Government assistance for the retooling and modernization of forest nurseries with non-repayable funds."

"Increase how much funding is available so more projects can be funded."

- Funding schemes should be implemented long-term and not in a call system.

"Grants and subsidies should be provided continuously so that the sector can invest."

From the administrative side:

- The administrative burden with the application process (bureaucracy) is seen as a major hurdle to apply to receive subsidies.

"Reduce the bureaucracy required to apply for public incentives."

"Many of the grants are published during vacation months, making it impossible to obtain quotes [from providers]. The grants take too long for processing."

"The level of bureaucracy associated with forestry needs to be reduced. It restricts growth and prevents the multiple benefits of forestry from being realised. This needs to happen at government and EU Commission level […] Unfortunately, due to all the regulation and restrictive conditions now in place, more harm than good is occurring due to all the lost opportunities being missed of not planting more trees."

- Nurseries wish for more information on available funds.

"Facilitating access to information."

"Speed up and simplify the bureaucratic process and inform interested companies about any available tenders."

- Nurseries from Northern, Eastern and South-Western Europe suggested tax breaks for nurseries instead of subsidies.

"Reducing the deductible [tax] to receive support."

"Abolishing all forms of subsidies in favor of tax reductions."

- Eastern Europe nurseries suggested the provision of non-refundable loans to invest in infrastructure and investment in machines:

"Reducing VAT to 5% or its elimination, along with non-repayable financial support for technological upgrades and modernization."

- nurseries in Central and South-Western Europe suggested to have access to funding schemes developed for agriculture and horticulture.

"The state must change the status of forestry nurseries. Currently, forestry nurseries are categorized within the forestry business, and the state provides support for the purchase of forestry machinery, but not for irrigation, cold storage facilities, etc. Our work is similar to that of fruit or ornamental plant nurseries, yet we are unable to access the state's support programs."

Further suggestions and implications on public fundings to nurseries are discussed in the respective section with the results of the semi-structured interviews in this respect (section 5.4.5).

2. Policies and regulations

In two separate questions, the most relevant policies and regulations impacting forest nursery work were listed. Participants were asked to classify how positive or negative each policy/legislation is, in their perception, for their operations both currently and in the next five years, using a scale ranging from "very positive" to "very negative." An additional option, "I am not familiar with this policy," was also provided.

Policies that were provided were as follows:

- EU Forest Strategy 2030
- 3 Billion Tree Initiative and Guidelines on Tree Planting
- Guidelines on Primary and Old-Growth Forests
- EU ABS Regulation
- Forest Genetic Resources (FGR) Strategy
- Regulation of Invasive Alien Species
- Directive on the marketing of Forest Reproductive Material (FRM)
- Council Decision on the Equivalence of FRM produced in third Countries
- European Climate Law
- EU Biodiversity Strategy 2030
- EU strategy on adaption to climate change and “Fit for 55” package
- CAP 2030 and RDP-LEADER
- EU Programme for Employment and Social Innovation

The mean valid response rate for the question focusing on the current situation was 246, with an average of 33 unavailable answers (11.87%), depending on the policy/legislation being rated. A notable observation is the high rate of non-familiarity with these policies across participants from all country regions. It is obvious that a relatively large proportion of forest nurseries lack knowledge on relevant policies. Even when it comes to the EC Directive on FRM production, about 15-20% of respondents declare that they are unaware of it, although they have to follow it in their daily business.

When comparing responses between country regions which are displayed in Figure 35, participants from Eastern Europe not only provide a higher number of responses but also, overall, the most positive perception of policies and legislation compared to the other three regions. Additionally, they show the lowest rate of unfamiliarity with these policies. The overall most positive perception involves the “3 billion trees initiative”, the “Regulation on invasive alien species”, the “Directive on FRM”, and the “EU Biodiversity strategy 2030”.

For the question focusing on the future perception of policies, the mean valid response rate was 229, with an average of 50 unavailable answers (17.92%), which represents the highest nonresponse rate of the entire survey. In Figure 36, the results for the future perception of policies are shown. However, due to the increase in nonresponses, it is challenging to draw any conclusions about changing perceptions. Nevertheless, it can be derived that in general expectations are that not significant changes will occur in the next 5 years, except for few cases (e.g. more positive impacts in the next 5 years within the Northern Europe region on the Regulation of invasive alien species).

Based on these findings, European forest nurseries need better access to information about relevant policies and should develop a greater interest in them. This will enable them to engage more actively in stakeholder discussions with policymakers. Otherwise, they may see policies rather as bureaucratic nuisances and additional barriers in their daily work (see also section 5.4.2 in the results of the semis-structured interviews).

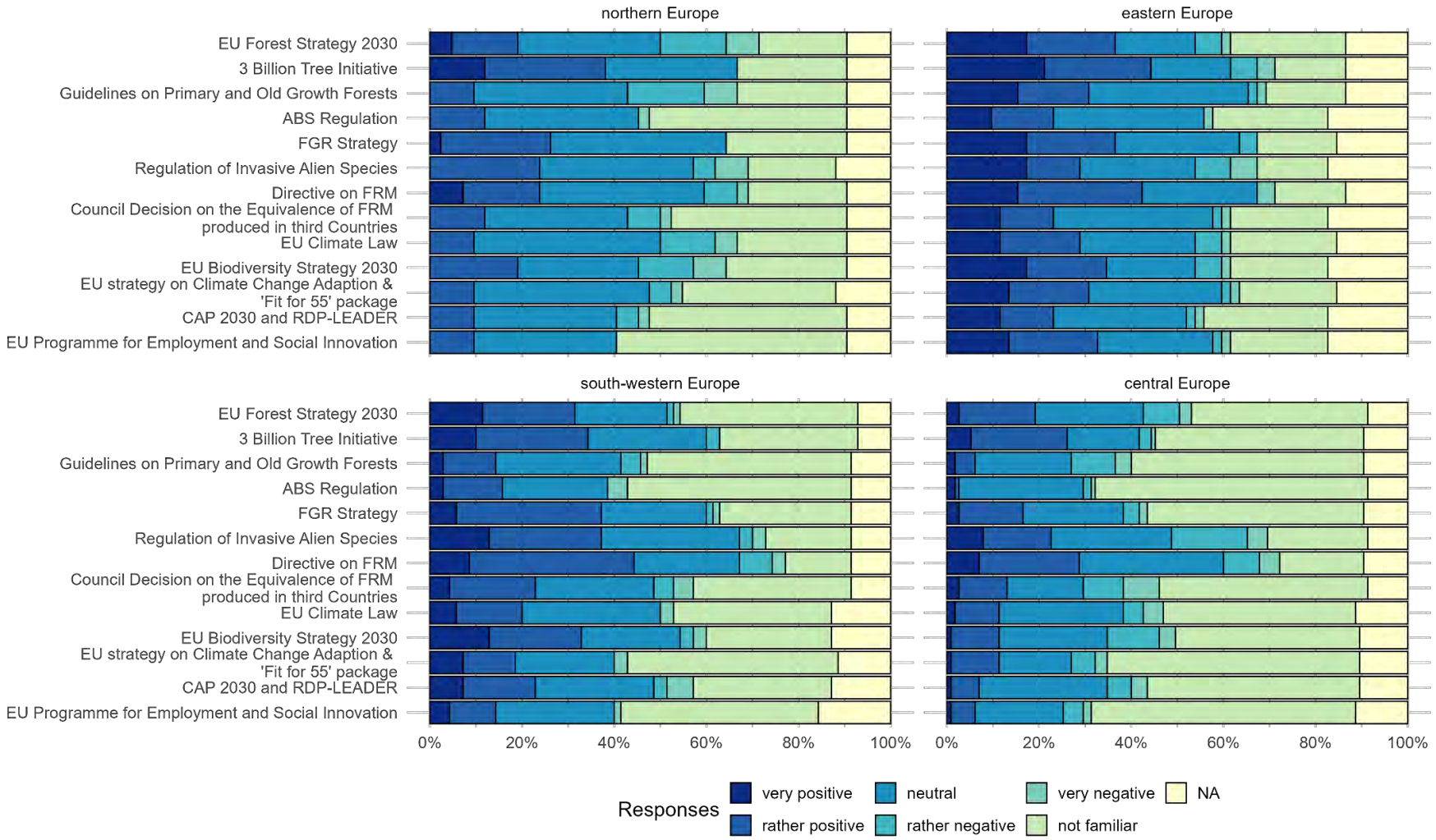

Figure 35. Perception of EU policies and regulations by European forest nurseries per country region as reported by respondents to online nursery questionnaire in 2024.

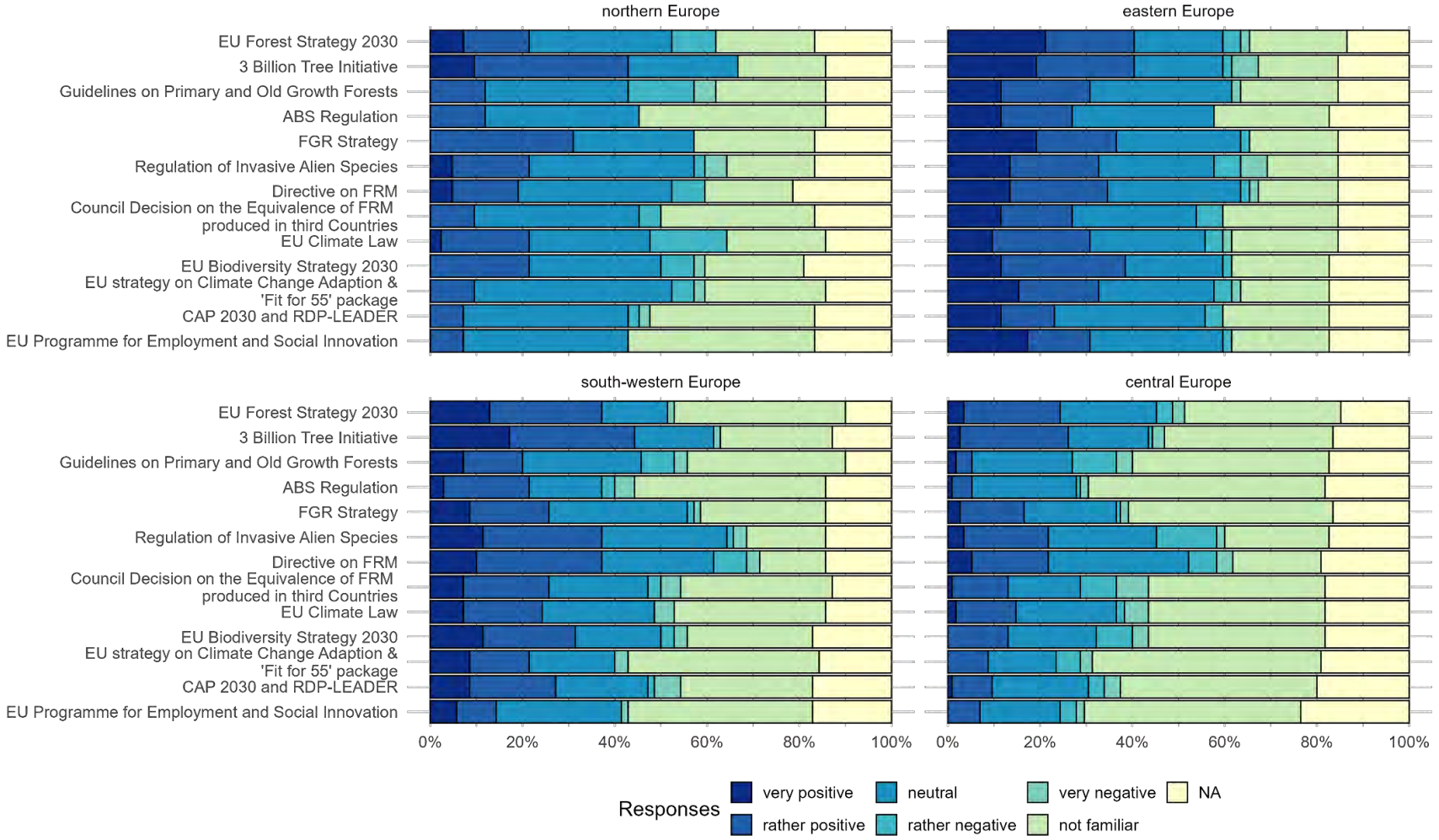

Figure 36. Perception of EU policies and regulations by European forest nurseries per country region as reported by respondents to online nursery questionnaire in 5 years from now.

3. Existing collaborations between nurseries

Participants were asked about the types of areas in which they already collaborate with other nurseries. Multiple-choice answers were provided, including:

- I don't collaborate with other nurseries
- Exchange of FRM (e.g., seeds, seedlings, etc.)
- Knowledge sharing (e.g., on market demands, co-organizing trainings, sharing best practices, etc.)
- Contractual agreements (e.g., supply services, commercial transactions, etc.)
- Sharing of resources (e.g., special equipment, machines, etc.)

30 participants (10.75%) stated that they "don't collaborate with other nurseries," while nine participants (3.23%) did not provide an answer to the statement, leaving 240 participants who do collaborate with other nurseries.

As shown in Figure 37, overall, the most prominent area of collaboration is knowledge sharing, mentioned by 76.67% of the 240 participants. Regionally, this is largely driven by 88.57% of participants from Northern Europe. In the other three regions, approximately 70% also indicated collaboration in this area.

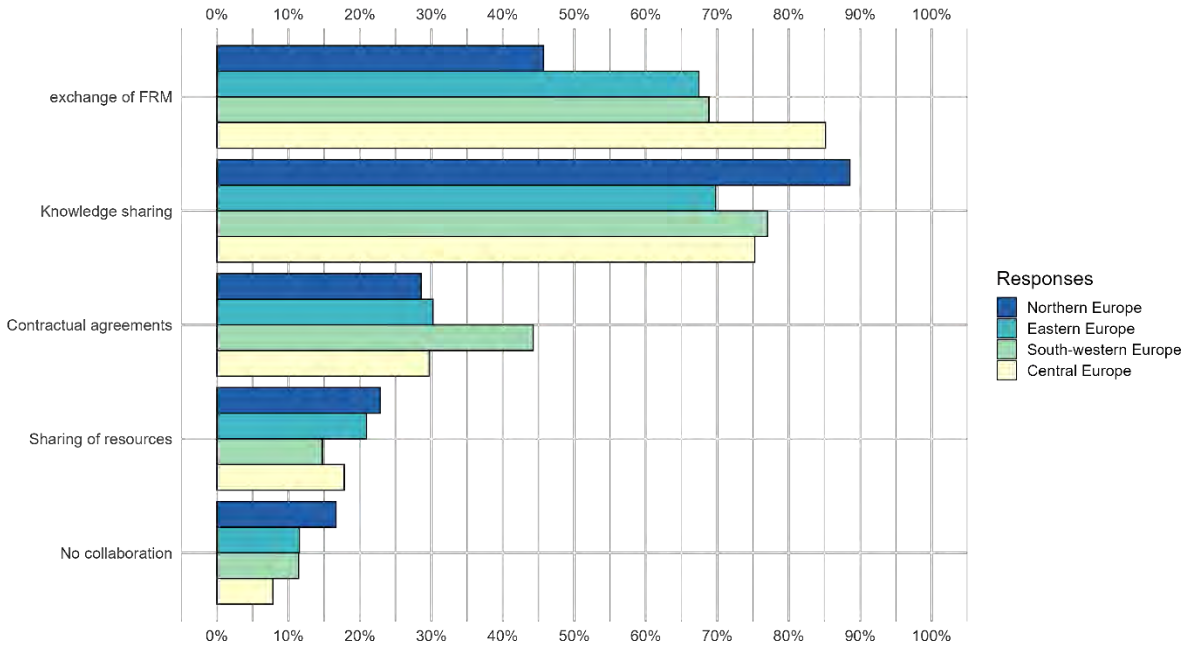

Figure 37. Current areas of collaboration among European forest nurseries as reported by respondents to online nursery questionnaire per country region.

The second most prominent area of collaboration is the exchange of forest reproductive material (FRM), noted by 72.08% of participants overall. This is primarily driven by 85.15% of participants from Central Europe. Approximately 70% of participants from South-Western and Eastern Europe also engaged in collaboration in this area, while only 45.71% of respondents from Northern Europe do so. In Central Europe, forest nurseries probably work under the highest production risk, accordingly they are trading more with other nurseries to fulfil the unpredictable demand; on the other hand in Northern Europe, the demand is relatively well known by the nurseries so the need to trade is relatively low; in the other two regions, the situation appears to be intermediate, probably also due to the many public nurseries, but also due to the high diversity of nursery organisations in South-Western Europe (for which a high number of countries were included in the survey).

Overall, 33.33% of participants highlighted collaborating on contractual agreements, with this figure largely driven by 44.26% of participants from South-Western Europe. By comparison, approximately 30% of participants from the other three regions engaged in this type of collaboration.

Finally, the sharing of resources was the least prominent area, with only 18.33% of participants acknowledging it. Around 20% of participants from Northern and Eastern Europe engaged in this collaboration, while only 17.82% from Central Europe and 14.75% from South-Western Europe did so.

4. Establishment of a European network of nurseries

In this final section, participants were asked how positive or negative the establishment of a European network of nurseries—facilitating collaboration in the following areas—would be for their business operations. Responses were given on a scale ranging from "very positive" to "very negative". The specified areas included:

- Market Intelligence and Market Strategy: collaborating on the exchange of market insights, trends, or consumer preferences.
- Research and Development: collaborating on projects related to plant breeding, genetic improvement, climate of environmental adaption of plants, or other relevant research areas.
- Regulatory Compliance: collaborating on staying updated on relevant laws, regulations, and certifications related to plant health, international trade, or environmental protection.
- Pest and Disease Management: collaborating on sharing knowledge and best practices for preventing and managing pests and diseases.
- Training and Education: collaborating on organized training programs, workshops, and seminars covering various topics including propagation techniques, quality control, or nursery management practices.
- Supply Chain Optimization: collaborating on sharing resources, coordinating logistics, or identifying other synergies.
- Technology and Innovation: collaborating on adopting and implementing advanced technologies such as automation, data analytics, remote sensing, or other innovative solutions.

The mean valid response rate was 258, with an average of 21 unavailable answers (7.53%), depending on the topic being rated. Overall, the rates of “very positive” and “rather positive” responses were notably high. However, Figure 38 reveals that participants from Central Europe generally provided lower “very positive” ratings compared to those from other regions, with the exception of the area of research and development. Participants from Northern Europe displayed greater variability in their ratings. Collaboration in areas such as research and development, training and education, and technology and innovation received high ratings, whereas areas like pest and disease management and supply chain optimization were rated notably lower. In contrast, participants from Eastern Europe showed more consistent ratings across the different collaboration areas. The obtained results are further discussed together with the results from semi-structure interviews on cooperation in section 5.4.1.

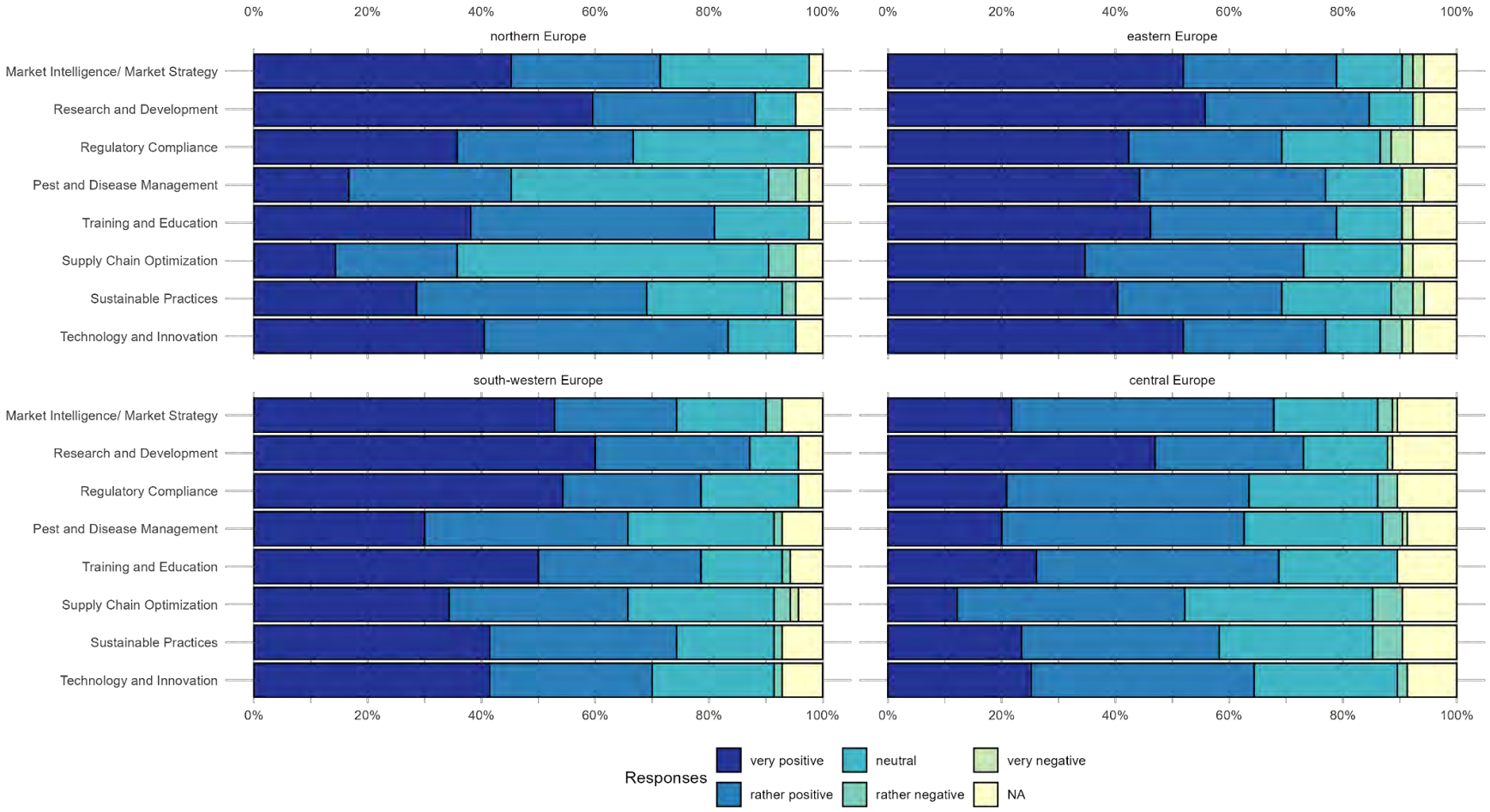

Figure 38. Attitudes of European forest nurseries per country region towards different fields for international cooperation through a network of forest nurseries as reported by respondents to online nursery survey questionnaire.

5.3. Results of online seed sector survey

In total 18 seed providers from nine European countries answered the OptFORESTS seed sector survey; these were comprised of one respondent from Austria, two from Bulgaria, two from the Czech Republic, one from Germany, four from Denmark, one from Spain, one from Finland, two from France and four from Slovenia. As explained in the methods section the sample was chosen based on the knowledge of project partners on the main seed providers in the respective regions or countries. Therefore, it has to be noted, that the resulting data presented below are not derived from a comprehensive sample of the whole market but rather reflect the opinions of the 18 respondents from nine countries.

5.3.1. Seed Procurement and Processing

Challenges with own seed harvests

Sixteen out of eighteen respondents (88.88%) reported that they are organising harvesting operations on their own. A follow-up question investigated challenges related to the quality and quantity of seeds from their own harvests over the past five years. The responses, shown in Figure 39, were as follows: The most prominent challenge identified was the “lack of preferred provenances,” which 18.75% of respondents reported as occurring “always” and 25% as “often.” The second most prominent challenge was the “lack of seeds from preferred species,” noted as occurring “always” by 6.25% of respondents and “often” by 56.25%. Additionally, challenges such as the “overall lack of seed to meet demand” and the “increasing irregularity of years with intensive fruiting” were reported as occurring “often” by approximately 50% of respondents.

Other challenges reported, were “*seed maturity season changed by climate change*”, and “*reporting on seed production*”, the latter indicating problems with locating possible seed harvest opportunities in seed stands or seed orchards.

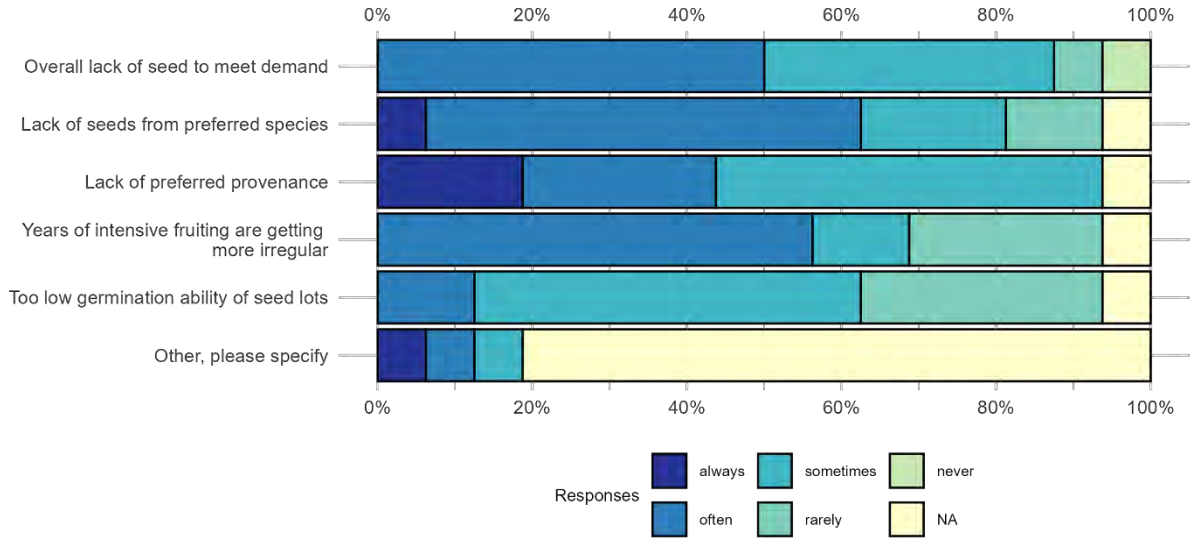

Figure 39. Main challenges regarding own seed harvests as reported by respondents to seed provider online survey.

Challenges during seed harvest operations

Overall, challenges related to seed harvest operations (technical implementation of seed harvests) were reported less frequently than those concerning the quality and quantity of harvested seeds, and the overall response rate for this section was also lower. Results are graphically depicted in Figure 40.

The most prominent challenge identified was “difficulties in accessing seed stands or orchards,” reported as occurring “always” by 6.25% of respondents and “often” by 25%. This was followed by the issue of seed ripening occurring earlier than expected which 37.5% of participants noted as happening “often.” Additionally, 31.25% of participants reported that harvest operations often result in low profitability.

One participant highlighted additional challenges, stating: “*During felling and mechanized removal of remains, pine cones are destroyed. Harvesting in selected lots is very expensive*.”

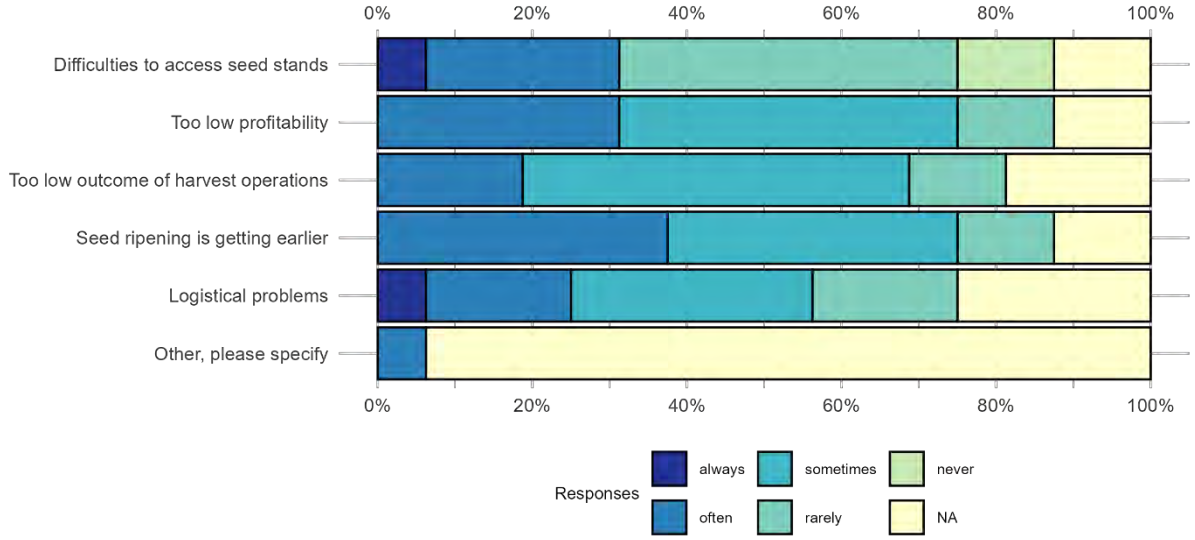

Figure 40. Challenges of seed traders with observed in own seed harvesting operations as reported by respondents to seed provider online survey.

Challenges with purchased seeds

Fourteen participants (77.77%) reported purchasing seeds from other seed suppliers, while three participants (16.66%) indicated that they do not. One respondent did not reply to the question (5.55%).

The three most prominent challenges identified, as shown in Figure 41, where a “lack of preferred provenances or origins”, a “lack of seeds from preferred species”, and an “overall lack of seed to meet demand”.

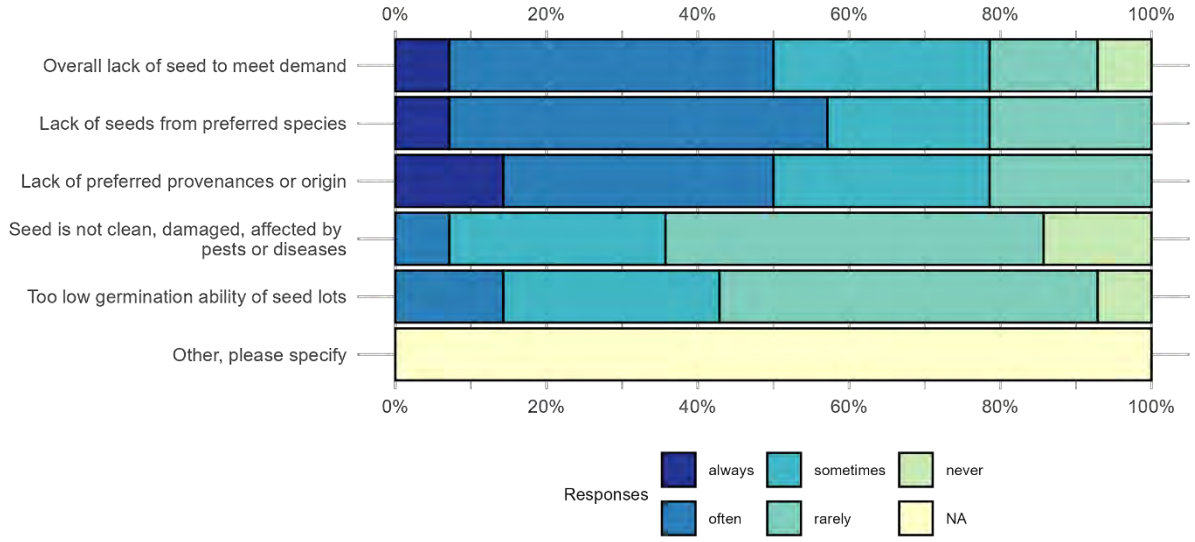

Figure 41. Main challenges of seed traders with purchased seeds as reported by respondents to seed provider online survey.

Utilized seed sources

All eighteen participants responded to this question. Approximately 45% of participants indicated that at least 25-50% of their seeds are harvested from privately owned seed stands. This was followed by harvests from their own seed stands and from publicly owned seed stands, as shown in Figure 42.

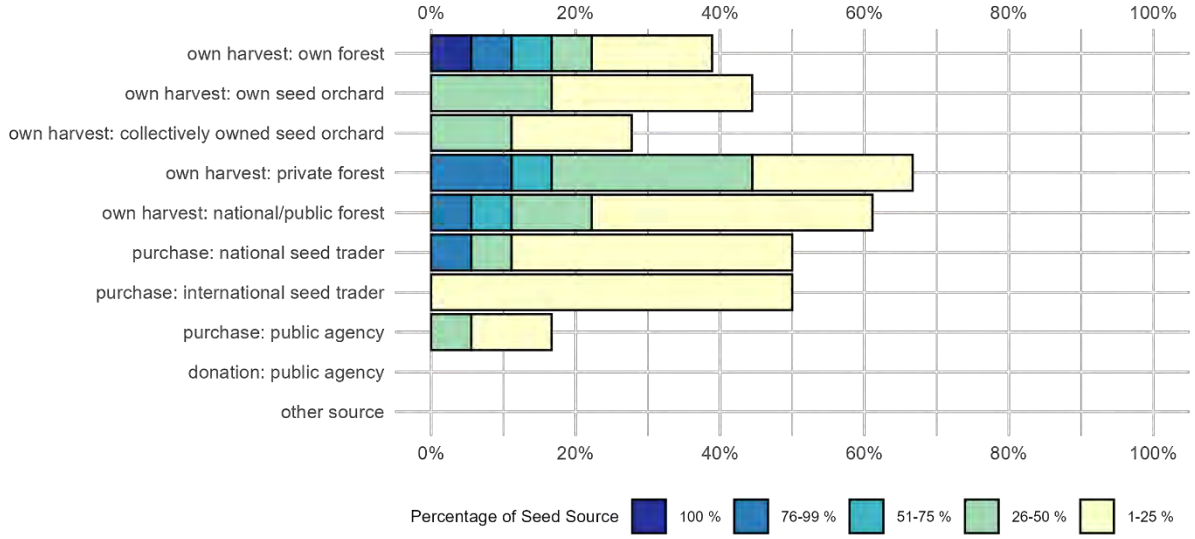

Figure 42. Seed sources utilized by European seed providers as reported by respondents to seed provider online survey.

Some providers harvest their seed exclusively in their own forest; on average seed harvest from privately or publicly owned seed stands dominate as seed sources; seed orchards and purchased seed from international trade have a relatively small share.

Expansion possibility of harvesting capacity

Participants were asked to estimate their potential to expand annual seed harvesting capacity over the next five years. Using a slider ranging from 0 to 300%, they provided estimates of expansion beyond their current maximum capacity. An expansion possibility of 100% means that the current harvesting capacity could be doubled, while an expansion possibility of 200% indicates that the current capacity could be tripled.

A total of 72.22% of participants indicated they could expand their harvesting capacity, while 11.11% stated they could not. Additionally, 16.66% did not respond to this question. The reported expansion possibilities ranged from a minimum of 20% to a maximum of 200%, with a median value of 70% and a mean value of 100.08% (Figure 43).

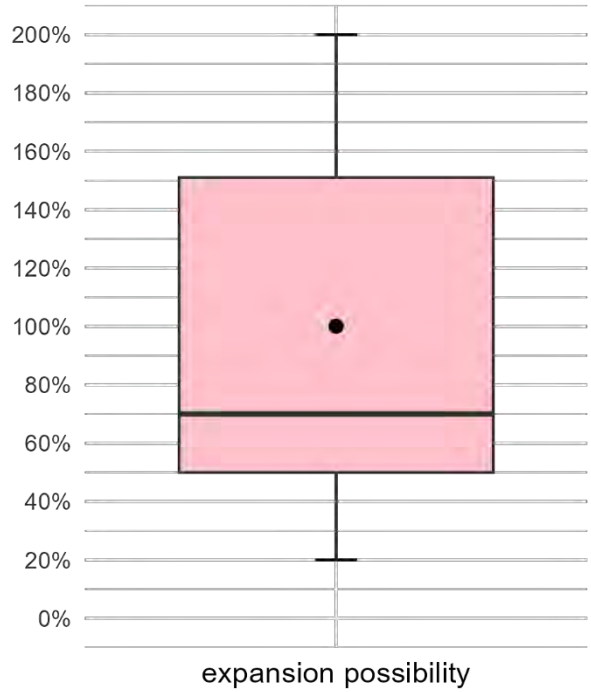

Figure 43. Amount of expansion possibility as reported by respondents to seed provider online survey.

Perceived limitations to expanding seed harvest operations

As a follow-up question, participants were asked if they foresee specific factors as potential barriers to expansion. Nine participants (50%) identified specific limiting factors, while two participants (11.11%) stated there were none. Two participants (11.11%) indicated that they had no interest in expanding harvesting capacity, and five responses (33.33%) were unavailable.

Additionally, respondents were asked to rank the potential barriers, with '1' representing the most prominent barrier. The barriers provided were as follows:

- Political/Legal (e.g. too strict regulations, national differences in import regulations, etc.)
- Environmental (e.g. seed availability, seed quality, increasing drought incidences, etc.)
- Social (e.g. lack of qualified workers, etc.)
- Technical/Technological (e.g. seed harvest logistics and timing, lack of cleaning capacity, lack of storage possibilities, etc.)
- Economic/Financial (e.g. high competition with other seed suppliers, high labour costs, lack of loans, insufficient subsidies, etc.)

All nine participants who identified expansion barriers answered the ranking question. As shown in Figure 44, the most prominent barrier to expansion was environmental, concerning the impact of environmental changes on seed availability and seed quality, e.g. changes in the masting behaviour or the increasing drought incidences. The next most significant barriers were social limitations (i.e. relating to staff availability), followed by technical/technological and economic/financial challenges. Political/legal barriers were perceived as less pressing by the respondents from the forest seed sector.

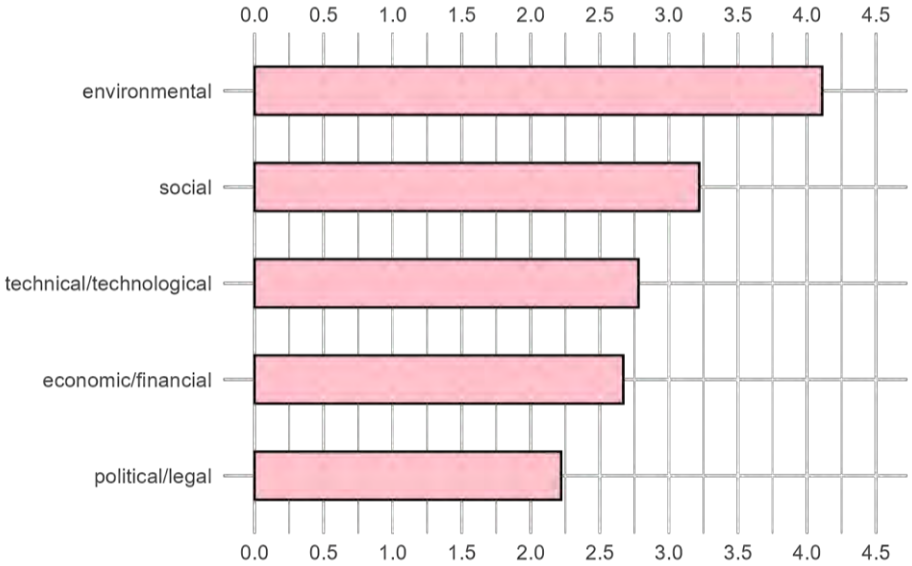

Figure 44. Perceived limitations of European seed providers to expanding seed harvest operations. Environmental factors clearly dominate, indicating the effect of climate change on seed production; social (sourcing of staff) factors are in second place.

The three identified main barriers are in good agreement with the challenges also reported previously (Jalonen et al. 2018; Fargione et al. 2021; Whittet et al. 2016b). The further implication are discussed in more detail in the following section together with the results of the semi-structured interviews.

Seed cleaning, testing, pre-treatment and storage

The following five questions address topics related to seed cleaning, seed testing, seed pre-treatment, and storage. Both the questions and the responses are presented in Table 12. Questions and answers regarding seed cleaning, testing, pre-treatment and storage

Table 12. Questions and answers regarding seed cleaning, testing, pre-treatment and storage

	n	*%*
Do you clean seeds at your company? (multiple-choice)		
No, I outsource the cleaning to a professional company.	0	0
No, I collaborate with other seed suppliers to clean seeds.	2	11.1
Yes, I clean seeds fully with my own seed cleaning facility.	10	55.5
Yes, I clean seeds partially at our own seed cleaning facility.	6	33.3
Other, please specify:	0	0
Do you have your own certified seed laboratory?		
Yes, I have my own certified laboratory.	6	33.3
No, I send my seeds to a certified seed laboratory.	10	55.5
NA	2	11.11
What additional seed testing do you perform?		
I do not perform any additional seed testing.	5	27.7
X-ray certificates	0	0
Germination tests	11	61.1
NIRS	0	0
Different types of vigour tests	2	11.1
Other, please specify:	3	16.6
Weight of 1000 seeds		
Pathology analysis		
TTZ		
Do you do pre-treatment yourself?		
No, I don't sell pre-treated seeds at all	5	27.8
Yes, I do the pre-treatment of some or all seeds inhouse	12	66.7
Yes, I do obtain some or all of my seeds pre-treated	1	5.6
Do you have a seed storage facility?		
Yes	6	33.3
No	12	66.7

Results show that most seed providers at least partially have their own cleaning facilities. One third of respondents have their own seed laboratory. In addition to seed testing most respondents also perform additional tests for germination capacity, like full germination tests, vigour test, and others, though these were not specified. Two thirds of respondents (n=18) do all pre-treatment of seeds in their own facilities. These results show that the contributing seed suppliers from all regions have a high level of sophistication and technical infrastructure to provide high quality seeds. High level infrastructure is needed to provide seeds of high quality to forest nurseries (Oldfield and Olwell, 2015; Broadhurst et al., 2016; Gömöry et al. 2021).

Discard rate of seeds (unsold seeds)

Participants were asked to provide the annual average proportion of seeds that remain unsold and need to be discarded. Fifteen participants (83.33%) responded to this question, while three participants (16.67%) did not provide a response. As shown in Figure 45, the average annual discard rate ranges from 0% to a maximum of 25%, with the maximum representing an outlier. The median discard rate is 5%, and the mean is 7.53%, indicating that the majority of seeds are successfully sold.

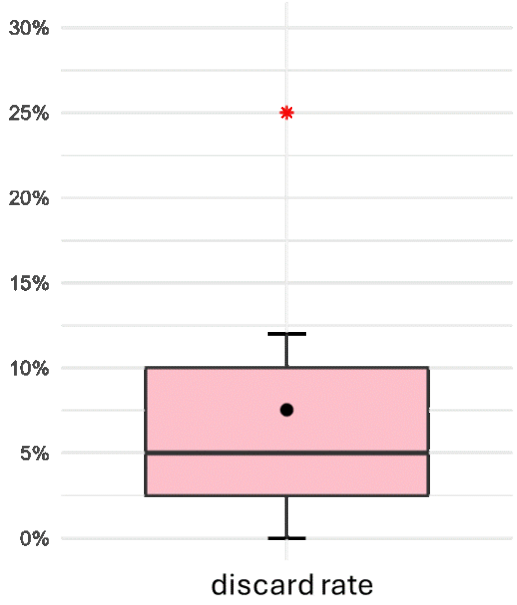

Figure 45. Average annual discard rate, i.e. seeds that cannot be sold and have to be discarded, as reported by respondents of seed sector survey.

The results indicate that demand is higher than supply, very little seed cannot be sold. This corresponds to the responses in the online nursery survey (5.2.3) on general seed shortage for most species. Some species can be stored for very long periods (e.g., conifers like spruce and pine for several decades) therefore unsold seeds may be rare. High demand for species with less storage capability probably prevents disposal of unsold seeds also in those. Lack of seeds has also been reported by e.g., Friedrich (2022), Rantasa & Kraigher (2024).

5.3.2. Investment needs

Investment areas as a reaction to changing demand

Participants were asked to rank the three most important areas their company would need to invest in to adapt to changing demand over the next five years. Nine areas were presented in a drag-and-drop question, with instructions specifying that only rankings from 1 to 3 would be considered. The areas provided were as follows:

- Improvement of seed quality (e.g. seed viability and germinability, control of pathogens, etc.)
- Diversification of seed species array (e.g. new provenances, new species, etc.)
- Research and development (e.g. pre-treatment of seeds, etc.)
- Increase in the overall production of seeds (e.g. amount of kilograms harvested, etc.)
- Human resources (e.g. staff extension, training, education, etc.)
- Hard infrastructure (e.g. cleaning facilities, storage, etc.)
- Certification and sustainable government practices (e.g. certification, standardization, social and environmental sustainability, etc.)
- Marketing and Promotion
- Soft infrastructure (e.g. automatization, IT, new technologies, etc.)

As shown in Figure 46, participants ranked “diversification of seed species array” as the most critical area for future investments, followed by “research and development” and “improvement of seed quality.”

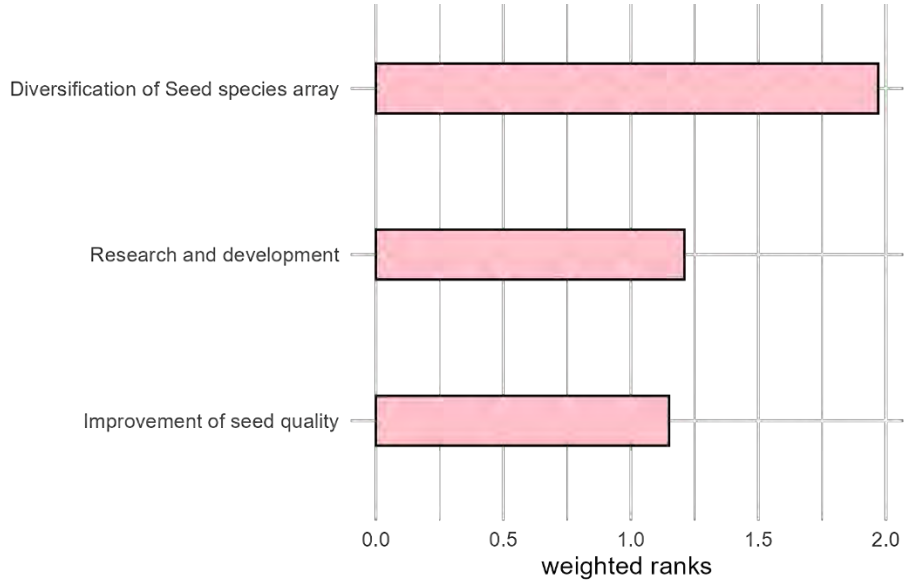

Figure 46. Most critical investment areas as a reaction to changing demand in the next five years for European forest tree seed providers. Investments in diversification of seed species array (e.g., new provenances, new species) clearly have the top priority.

Follow-up question on the magnitude of investments

Participants were subsequently asked to estimate the magnitude of total costs associated with these three investment areas, based on their opinion. They were instructed to provide an amount in Euros, with a link to a currency converter included for convenience. A total of 10 valid answers (55.55%) were received, while 8 responses were unavailable (44.45%).

However, upon analyzing the results, it became clear that the question's wording lacked sufficient clarity. Specifically, the scope of the total costs was not defined, leaving participants uncertain whether the costs referred solely to their own business or to the investments required across the entire European Union or Europe. Consequently, responses varied widely—from as low as €150 to as high as €8,000,000—making it nearly impossible to derive meaningful conclusions. This lack of clarity might also explain the relatively high non-response rate for this question.

5.4. Results of semi-structured interviews with a selected set of forest nurseries

In total 25 semi-structured interviews (SSIs) were conducted for the development of this deliverable. The SSIs were particularly important to get an in-depth understanding of barriers and challenges observed by a selected number of forest nurseries in different European countries for efficient and sustainable plant production in their operations. Many factors are intertwined and interconnected and would have been very difficult to understand and properly report without these interviews. Although the number of interviews is comparatively low and public nurseries are underrepresented, the obtained insights are very important to understand barriers to FRM production but also a wide range of solutions was suggested.

5.4.1. Most voted barriers to production expansion

In the SSIs, respondents were asked for the main two barriers for production expansion. The most voted barriers to production expansion identified in the SSIs are shown in Figure 47.

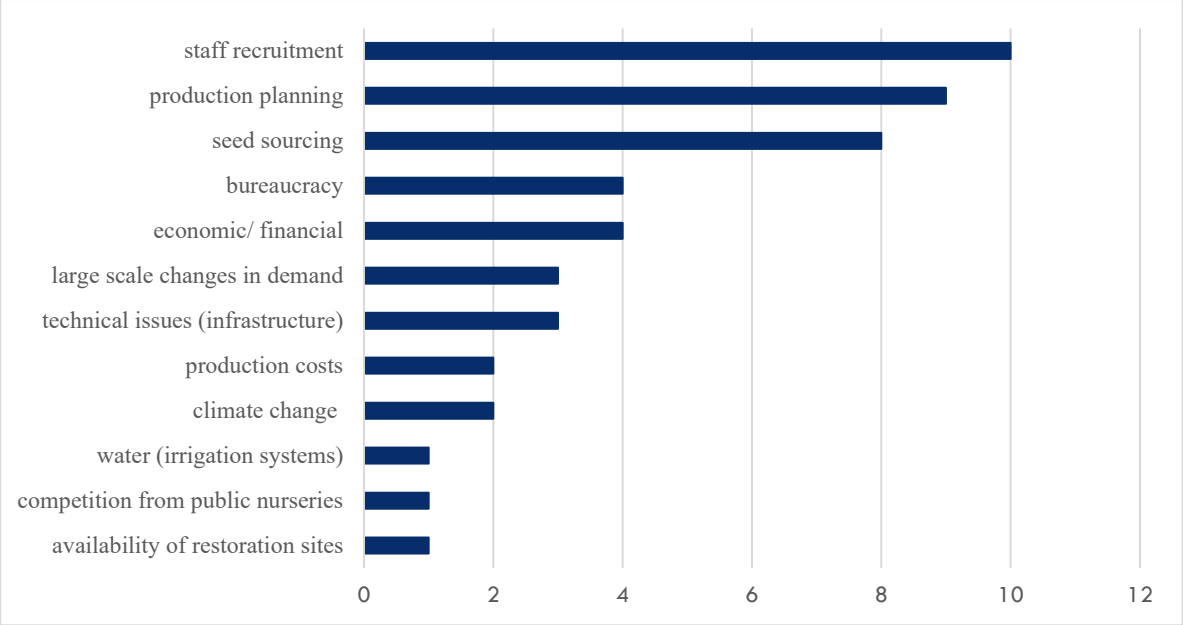

Figure 47. Number of nominations as main and second most important barriers to increase production in 25 semi-structured interviews done with European forest nurseries from the four denominated regions in Europe (two respondents only identified one main barrier each).

A similar set of main barriers was identified for the USA in the study of Fargione et al. (2021); there, labour was the most frequently identified limitation to expanded production, followed by financial needs and market risks (associated to production planning); seed supply was also identified as an important limiting factor by US nurseries in that study, but with lower urgency compared to our results; still, Fargione et al. (2021) point out urgent needs for improved seed supply. The main barriers identified in this report are further in good agreement with the relatively few studies dealing with the European forest nurseries (e.g., Wezel & Reis, 2019; Whittet et al., 2016b; Božič et al. 2021; Friedrich, 2022; Rantasa & Kraigher 2024).

Due to the uneven representation of country regions, as well as public and private nurseries in our sample, identifying the most significant barrier is challenging. Therefore, the barriers are not ranked but instead are dealt with based on the number of regions they impact. All barriers perceived as most significant by respondents, along with their interactions, are described and discussed in detail in the following subchapters. This detailed analysis provides very interesting insights into the business operations of forest nurseries across Europe. It also shows that often the different factors are intertwined, e.g. the spot market system is exacerbated by funding schemes as well as lack of seeds of proper species and provenances.

5.4.2. Challenges in recruiting and training staff

Plant production in forest nurseries is a specialized branch of plant production that needs qualified staff with specific knowledge in all parts of the production process, e.g. from seed conditioning (stratification), to sowing, replanting and plant protection. In the SSIs, 14 out of 25 respondents reported problems in staff recruitment (SSIs 3-5, 7-9, 11, 12, 15-18, 22, 24, 25; of which 10 name it as one of the main barriers). Investment in staff was also seen as a top priority in our online nursery survey (section 5.2.4). We deduct from this that a large part of forest nurseries in Europe have problems in finding qualified staff (see also Friedrich 2022). Also, they often struggle to find seasonal workers to help out at peak time in production, during plant excavation, sorting and packaging of plants. In general, investment in novel staff is a pressing topic in a large part of the European forest nurseries. Similar problems with staff sourcing have also been identified in the USA (Fargione et al. 2021).

In the following we provided some quotes to illustrate the problems of nurseries with the availability of staff:

SSI17: "*There are not too many people with knowledge anymore, and all the people they all are too old. And they are out of business. And this knowledge is not given to the younger ones*."

SSI3: "*We are [located in] one of the strongest economic regions [of our country]. We have full employment in [our] districts. There are practically no employees on the market. None. And I'm not just talking about skilled workers, but even unskilled laborers are not available*."

SSI12: "I would also highlight [the] training issue, meaning that the supervisors responsible for the nursery activities need specific training, which is not always easy to obtain."

SSI11: "For example, the average age of in one of our teams of unskilled workers is seventy-four years."

Because of the economic uncertainties laid out above, in many cases forest nurseries are not able to pay wages similar to the level of ornamental nurseries or gardening enterprises (also SSI24).

SSI15: "*But as soon as I get into gardening, landscaping, those have much more money, there are many more companies that pay into a fund and they have many more opportunities for certain training aids on one side and automatically can also pay more, and that's our big competitor in this sector*."

SSI8: "*We don't need to be financially padded wildly and excessively. We need a reasonable return that is proportional to the risk. And we need to be a good workplace where we're not forced to exploit our employees to keep things together. […] Yes, but that also requires that we […] earn more money.*"

One respondent also stresses the importance of social costs included in the wages, which vary among countries, and affect staff costs heavily: SSI3: "*That's actually an EU problem. We don't have harmonized wage structures, no harmonized social structures in terms of payment. And especially in border areas, that's the biggest problem.*"

A respondent from a public nursery in South-Western Europe (SSI22) reports problems in hiring new staff, because European Contracting Regulations (quota of public personnel per country) and his country is already above the average on staff employment in the public sector. Similarly, a public nursery from the same region reports "*bureaucratic hurdles in hiring new or temporary staff quickly because we have to follow certain selection procedures*" (SSI13).

Problems start with the training of expert staff. Because the job market is small there is no specific education for "forest nursery expert" apprentices; in most cases graduates with a horticultural background are hired and specific knowledge is acquired "on the job"; this seems to be a problem particularly in Central Europe (SSIs 3, 12, 16). Because of this lack of a specific education, it is also difficult for forest nurseries to train their own staff in the available education system (for gardeners, horticulturists) "from young age" because certain skills (e.g. grafting, plant identification) need to be taught in those education schemes, and these skills are not part of the work in forest nurseries. Therefore, training directly in the forest nurseries is difficult and very few graduates with a horticultural background are willing to work in forest nurseries – they rather stay in the horticultural sector. Some quotes for illustration:

SSI16: "*Then there's the problem that a [ornamental] nursery gardener ['s apprentice] must also be able to ball plants, graft, and know all ornamental plants. The exam mostly covers ornamental plants. There are 20 ornamental plants, and you have to know at least half of them, and we can't provide [that knowledge to our apprentices].[So this part of the education] only works in cooperation with another company that also produces these ornamental plants*."

SSI3: "*In the past, the forestry nurseries were mostly in large forestry estates or forestry companies. At some point, they detached themselves, it stopped, and that's how the forestry nurseries came about as they are now […] and because of that, you don't really know who belongs where. And that goes so far that you don't even know where to fit in the collective*

payment scheme, because there is a forest gardener and a forest gardening specialist, there is training, yes, [but] it is almost never offered. […] On the other hand, the forest gardening specialist is included in the "forestry" payment scheme, and not in the horticulture payment scheme. But those are totally different things. Almost no one uses the former, because actually, the other is more [attractive]."

SSI12: "*Because obviously nursery activities require specialized, trained staff with experience. This is because it involves using techniques that are not trivial, so a deep technical understanding of nursery operations is necessary. It's essential to have people who possess not only theoretical knowledge from educational training but also practical experience. Therefore, I believe it's important to also include specific training courses with internships in settings where individuals dedicated to nursery activities can be adequately trained and gain some experience. From what I've seen, theoretical knowledge alone is not enough*."

One respondent tries to find skilled employees by motivating them through the sustainable work the nurseries are doing – both environmentally and economically – but so far with limited success.

SSI8: "*Well, we do what we can to be visible on social media. But many times we use an external recruitment agency to reach out and tap some people on the shoulder, asking if they might be interested in working in nature and in different seasons. It works to some extent, but we can't really find anyone for production who has the skills we are actually looking for. We can't find them, at least not at the moment*. […] *We need to start much earlier with young people. We participate in job project programs at schools*."

A nursery manager in the SSIs was optimistic to be able to find young specialist personnel through the use of new technologies, e.g. using drones, GIS guided machinery and automatization procedures:

SSI17: "*We need technical guys, not especially nursery men, we need completely different employees to work in nursing to get it grown. Because of the lack of knowledge from real nursery men. So we have to look to other techniques to get to get this knowledge for the plans. It will be completely different."*

Temporary (unskilled) staff are comprised often by e.g., seasonal workers from Eastern Europe or third countries; but also here nurseries observe increasingly problems to find workers, or workers are not returning after one season (after they had their training) (SSIs 17, 5, 18, …).

SSI7: "*The people who come now are not as qualified as they were before, and this is an expression of the fact that the countries in Europe, and especially the northern parts of Eastern Europe, where we recruit them from, have become more prosperous and economically better run, and therefore can now offer better conditions and work-wise for these people in their home country*."

To overcome this, some nurseries try to employ all year round to keep trained staff on the job, e.g. by using them in other branches of their business for horticulture or tending of outplants (SSI8, 20). In this respect, nurseries would be very interested in employing more people from third countries, but often regulations are prohibitive to this.

Some quotes for illustration:

SSI5: "*If we could just employ those people [from third countries] directly. Everybody would make money off it. […] I'd be covered from customs from everything, these people make money, they pay the social insurance, the state gets money out of it, for me the ideal option. Not that it's completely impossible these days, but it's considerably complicated*.

One SSI respondent reported that his company has installed a sorting facility in a Central-East European country to outsource this production step, instead of bringing additional workers to their main facility (SSI18).

Another reaction of forest nurseries to difficulties in staff recruitment is to invest in mechanization and automatization, e.g. for weeding, sorting and packaging (SSIs 11, 7, 5, 18, 24). Also a switch to plug (young seedlings in containers, i.e. Plug+) systems is considered by respondents to save on manual labour:

SSI7: "*In other words, a robotic solution to some of our tasks, especially in the indoor production with sorting […] and then packing […] the next thing to come is probably self-driving equipment.[…] if we switch more to starting our production in a plug system. Then you can use machines primarily from the vegetable industry, which has a much larger capacity and development funds.*"

SSI5: "*Like without the human labour it's irreplaceable in our country, although there is some automation and robots and such, but that's it, that's the music of the future as in operation it's not very functional […]. It's just all going to be in those human hands. And [our citizens] won't do that, they'll never do that again.*"

5.4.3. Seed sourcing, provenance selection and FRM transfer

In the SSIs, seed sourcing was named as one of the top 3 most frequent challenges for nurseries to increase production (14 out of 25 interviews: SSIs 1, 4, 6, 7, 11, 12, 15-18, 20, 21, 23) with 8 respondents considering it one of the two most important barriers. Seeds of forest trees are the basic material for the production of most kinds of FRM (except for vegetatively propagated material, which only plays a minor role in European forestry). Yet, the provision of a sufficient amount of seeds for production from the desired species/provenance is a major problem for the majority of nurseries in Europe, especially in Southern and Western, Central and South-Eastern Europe (see results from online questionnaire towards forest nurseries, 5.2.3). Chronic under-investment in skilled labor, infrastructure, and staff training has, not only in Europe, led to a limited capacity for seed collection, testing, and storage, all which contributes to higher seed costs and limited availability (Oldfield and Olwell, 2015; Broadhurst et al., 2016).

Nurseries either can buy seeds from registered forest seed dealers or seeds are harvested directly by the nurseries. The different sources have different importance in the different countries, but in most cases national seed traders are the most important source (see results of nursery survey, Figure 22).

As laid out in the introduction, the sourcing and marketing of FRM is highly regulated in the European Union (and through the OECD Forest Seed and Plant Scheme in most European non-EU countries). The sourcing of proper seed (or FRM in general) is at the base of any production in forest nurseries. Growing proper species and provenances is also decisive for the final product to be sold. While forest owners are generally free in the choice of the FRM they want to plant, if they want to receive subsidies for planting, they have to follow the recommendation of the subsidy scheme. In most countries subsidy schemes give priority to regional provenances of species, as the general principle is that locally adapted FRM will give the highest quality timber and guarantee sustainable forest management. Regional provenances are located in specific seed zones, that have been defined in most countries. Seed zones (or regions of provenance) have been delimitated by similar site conditions and elevation under the assumption that within these zones FRM can be transferred with minimal risk of maladaptation and loss of productivity (Konnert et al. 2015). Most countries have published such seed or provenance zones (as asked for in Directive 1999/105/EC), and these serve as guidelines for subsidy schemes for sourcing of proper FRM for the specific afforestation site.

Though transfer of FRM between countries is in principle suggested by scientific recommendations to allow for assisted migration/gene flow to facilitate adaptation of European forests to climate change (especially transfer from south to north, and from lower to higher elevations; Chakraborty et al. 2024), funding schemes or also national regulations are rigid and make the international transfer impossible in many cases (see also below).

Since a large part of the production is sold to forest managers who apply for afforestation subsidies, the species and provenance (provenance region) used need to comply to the suggested afforestation subsidy scheme. In many cases, this creates problems if the suggested species/provenance cannot be delivered by forest nurseries. To make forests more resilient to climate change, subsidy schemes usually have changed to fund the establishment of diverse forests with 3-5 species instead of 1 or 2. This creates further bottlenecks for seed sourcing, especially since the suggested mixed species are mostly broadleaves, of which the seeds cannot be stored as long as in most conifer species (Himanen et al. 2021); the demand has basically exploded for oak species, which are recalcitrant species in terms of seed storage, i.e. acorns can be stored for two years at the maximum.

Quote from SSI6 for illustration: "*For conifers it's not usually a problem. They […] can be stored for a long time, but with broadleaves it is a problem to respond to market demand because even though the demand for oaks may be growing now, we have a problem because there were simply no acorns and we are not able to offer them to those customers so the second big obstacle is simply the resource. Seed source, you can't do it without that.*"

A possible way to deal with seed shortage of recalcitrant species is suggested in SSI6: "*Storing seed for a longer period of time if possible, which is not really possible with acorns for example, and dividing that production into bare rooted, container, when there is a harvest, so that you have something as an annual, something as a biennial. […] It has been possible to shorten the growing time by using container planting material*."

In addition, seed production has been negatively affected by climate change (due to drought and high temperatures in summer, or frost or rain during the flowering period; also through the destruction of seed stands by storms and bark beetle damage), so that in some species the amount of seed produced and the seed quality have deteriorated over the last decades (Konrad et al. 2023; and see results of online-surveys for nurseries and seed sector). In some cases, novel pests and pathogens also have had a negative impact on seed production on certain species; e.g. oak masting has been negatively affected by the widespread occurrence of the oak lace bug in many regions of South-Eastern Europe from ca. 2018 (Paulin et al. 2020).

SSI6: "*So the whole economics of growing depends on the quality of the seed and generally the yield, how much of that acreage we're then able to sell.*"

SSI17: "*I think [seed supply] will be worse and worse in the in the future with the climate change. And beside this there are not too many harvesters anymore as in the 90s and 80s; there were harvested enough, you could find seeds everywhere and now nowadays it's not so easy to get the good seeds*."

SSI12: "*Seed availability is increasingly becoming a problem because it is necessary to have seeds from local ecotypes with certified origins [and in some regions] many of the seed-producing forests have been compromised [by storm damage]*.

SSI11: "*So basically it's a problem with the [broadleaf species], but the conifer species are basically becoming poorer and poorer in quality as well. […] Practically speaking, what I threw away 5 years ago, I'm happy with now*."

Optimal pre-treatment of seeds is necessary to get the most possible plants out per weight unit. This can be a very limiting factor in seed supply but also for genetic diversity of plant lots (Gömöry et al. 2021). Thus, nurseries and seed traders who have expert knowledge about how to properly store and pre-treat their seeds, have an advantage. Respondents in the SSIs (SSI8, SSI17) also note that specific knowledge has been partially lost in the last decades, because seed pre-treatment also needs a lot of personal experience:

SSI8: "*Many have gathered that knowledge over many years, and there has been a generational shift also in the companies that deal with seeds, which means that knowledge*

has been partially lost because it's almost impossible to describe with words. It's a craft where you have to go out and see, feel, touch, and sense."

A way to overcome the lack of knowledge in seed pre-treatment is the outsourcing of early production stages to specialized nurseries to avoid losses during the germination stage.

Seed collecting is logistically and administratively demanding; collection managers have to identify, secure access and monitor seed ripening, and special staff has to be organized when the trees have to be climbed to collect seeds (or cones) (Kelly, 1994; Hay and Probert, 2013; Whittet et al., 2016b; Pike et al., 2020). Seasonal workers for collecting seeds from the ground or cones from felled trees are difficult to organize, especially for short periods of time. Seed harvesting also takes place in a relatively short period of time and thus always is logistically demanding, e.g. fir cones need to be harvested in a very narrow time window before they dissolve, oak acorns may be consumed by animals or maple seeds will be blown away by the wind. Therefore, seed collectors harvest only what they have a market for and where the amount of seed allows for a cost-efficient harvest:

SSI8: "*They harvest what they, like us, have a market for. So if they have to go out and harvest something where, for some reason, there is a shortage, and where it might not be economically beneficial, and where they are not sure of a sale, they don't harvest it. So they think the same way we do. If there's no market for it, it doesn't get harvested.*"

In addition, it is most effective for seed collectors to collect many seeds in single stands and which are easy to access. Often seed harvesters bemoan the lack of access to registered seed sources, e.g., publicly owned seed stands in which only public forest nurseries are allowed to harvest or the harvesting concession has been awarded to another seed collector.

SSI17: "And there are a lot of provenances which are not harvested. You cannot collect seeds in a lot of provenances, because there are the owners, who do not issue permits to collect the seeds."

Eventually also the number of seed traders has dropped in the recent past, making collection efforts even more logistically demanding (SSIs 4, 16, 18; see also Wezel & Reis 2019):

SSI18: "The seed companies they had capacity in the past, they were numbers of seed collectors, and they get less numbered now."

SSI4: "When I tell [to forest owners], I need seeds, no one cares. Customers only care when they don't get the plants. Then they say, why don't you have it? I say, did you ever harvest?"

In the SSIs, several respondents (SSIs 15, 3, 16, 20, 21) did not perceive a general lack of seed production (an exemption being the situation with *Quercus* species in South-Eastern Europe and parts of Central Europe) as the main problem in seed provision, but rather in access to seed sources (seed stands, seed orchards) or the lack of information on stands or regions where sufficient fructification can be observed in the respective country; i.e. that seed collection was not done efficiently. While some nurseries undertake their own seed harvesting, several respondents in the SSIs (SSIs 3, 16, 20, 21,…) believe that this should be done or at least assisted by the public administration, since the latter is also responsible for the subsidy guidelines and FRM (transfer) regulations.

SSI3: "*The seed supply- here we also agree with representatives from agricultural and forestry operations - should be in state hands or at least partly state-owned. […] The best approach would be in a private-public-partnership (PPP) model, where the nurseries also contribute."*

SSI20: "[We hope] that the state will pre-finance the costs of seed collection, so that in the future we will have a stock of seeds of those species that we will need for forest renewal. Of course, we nursery owners will then buy this seed, not get it for free.[…] If we had enough seeds of those species available, it would be a great solution to this problem, so that this part of the obligation wouldn't fall on us."

SSI17: [Our government] owns most of the provenances and they don't allow to have private people making the harvest.

Problems of European forest nurseries to access to high quality seeds have also been reported in the EC report on data gathering and analysis to support a Commission study on the Union's options to update the existing legislation on the production and marketing of plant reproductive material (EC 2021) were 80% of respondents report having problems in seed procurement; problems mentioned there were the increasing consolidation of the seed market (fewer providers), difficulties in obtaining sufficient amounts of seeds of Norway spruce, Douglas fir, larch and sessile oak; problems in obtaining seeds from abroad including phytosanitary issues; also the inaccessibility of sites for seed collections (seed stands) was mentioned in that survey.

In most countries, subsidies are granted for seed collection in registered stands. Still, to organize their own seed collections is a large logistic and financial burden for forest nurseries. Public support in monitoring and access to seed stands would naturally also support the work of the seed providers. This is indeed implemented in the French public forests and e.g., also prescribed in Slovenia, although in the latter case an SSI respondent (SSI20) criticizes the lack of implementation of this regulation.

All in all, this situation has resulted in the fact that often only a small number of the available seeds stands are indeed harvested in relatively high frequency, while many stands in the national register are rarely or ever harvested (e.g., percentage of registered seeds stands from which seeds have been harvested in the last 5 years in Bulgaria: 5%; similar in many other countries). This may also have negative effects on genetic diversity of resulting forests in the long-term (Gömöry et al. 2021), i.e. genetic diversity in these forests will decline in the long-term due to the narrow genetic base of the founding population.

Seed collections in seed orchards are logistically less demanding, but in most parts of Europe (with the exception of Northern Europe) seed orchards are often relatively small, over-aged and lack management, i.e. are not producing enough seeds to meet the demand (SSI17). This has been recognized and some countries invest in novel (federally owned or private) seed orchards (e.g. Germany; Paul et al. 2010). In this respect it might be sensible to follow the example of Nordic countries to install large (private) seed orchards that are owned and operated by a group of forest nurseries; in either case the installation of new seed orchards is suggested by several respondents in the SSIs (17, 11, 18, …):

SSI14: "What is the problem with financing larger seed orchards within the EU? That's what you would need to do. The more access there is to seed, the less fraud will arise. No one will be interested in cheating if there is a lot of seed available."

SSI11: "It would be [very] worthwhile to install a regional seed base [seed orchard centre} So this would be a […] cardinal question."

The lack of seeds may indeed lead to problems with proper declaration of FRM, one of the reasons for installing systems for genetic certification of FRM (e.g., Konnert & Hosius 2010) to make sure that FRM true to identity is sold:

SSI3: "' [The whole nursery sector is accused of] that everyone cheats and everyone delivers something other than what is stated [on the invoice]' but] that is not true. There are control mechanisms. But they also need to be applied.[…] As long as I save on the control agencies to the point of death, and don't let them check, or don't staff them, I can make as many regulations and laws as I want, it won't work. And if someone wants to cheat, they will cheat. No matter how. But they make life difficult for those who don't cheat."

Transfer of seed sources (and plants) beyond country borders could be a solution to FRM shortages and is recommended as a measure of assisted migration, yet is also often problematic:

(i) The country of origin/ seed provider may not be willing to share seeds because these are needed to fulfill the demand of the national market (supported by national nurseries who want to produce the plants for their own country); also further trade of seeds (e.g. from Eastern Central Europe to other regions, for a higher price) is seen critically in the source countries: SSI11: "If [foreign nurseries] take it out of the country, so if they take even more than [what is already being sold], then they will basically kill us in the long run."

(ii) Regulations may actually prohibit the use of foreign FRM, this is the case for native species e.g., in Poland, Slovakia, Czechia.

(iii) Subsidy schemes may require an exempt permit to allow the use of foreign FRM (e.g. Germany, Austria, Slovenia).

(iv) Regulations may allow the use only of FRM of the categories "selected", "qualified" and "tested" to be used in the country, but not of the category "source identified" (e.g. Germany, Bulgaria).

(v) Since countries can add species to the list of regulated species in EC Directive 105/1999 some species regulated in one country, may not be regulated in the source country, which also impedes seed transfer between countries (e.g. Spain has 76 species instead of 47 from the list of the Directive regulated). Some respondents in the SSIs would be in favor of relaxing these barriers to allow for free flow of FRM.

Some quotes from the SSIs for illustration:

SSI7: "In other words, if we want to be able to move plants across the EU get rid of [those barriers to FRM transfer] or have them uniform and harmonized within the EU." This is also supported in SSI22 (public nursery in SW Europe).

The respondent in SSI7 also suggests to increase the number of purposes for FRM use (currently there is only "forest" and "non-forest" foreseen in the EU Directive):

SSI7: "There are very strict provenance requirements. […] And we are largely in favour of that. And our production is also based on the best genetics. But if you want to achieve the goal of so much more [additional] forest, then I think you have to soften those very strict limits. And simply expand the areas from which it may be allowed to harvest seeds without spoiling the main purpose of planting. Because some of the forest we plant for different purposes. After all, not all forest is 100% targeted for production forest."

In most countries (as pre-scribed by the respective EU Directive) national registers exist, where nurseries can search for suitable registered seed sources (seed orchards, seed stands). However, these are outdated in some countries (e.g. Romania), or are not available at the national level (e.g. Germany).

A respondent on data collection of seed sources and plant production in Central Europe (SSI15): "*That would [be a solution], merging data on demand quantity and merging data on harvesting opportunities [on a federal level] because the registers don't converge. There is indeed the merger of production sites, but there the data are not merged at that moment by the registers and […] through the federal system each federal state does it differently.*"

The central database at the EU level was created to give an overview of the FRM sources available in the EU, which is publicly accessible (FOREMATIS database; https://ec.europa.eu/forematis/); however, not all member countries – for reasons listed above - have input their national lists (e.g. Germany, Romania). Online tools already exist, where all involved stakeholders can search for seed sources adapted to the future climate, e.g. www.seed4forest.org. These tools are linked to the FOREMATIS data, so they also suffer from the incomplete data contained there at the moment.

SSI23: "*The National Catalog for the basic materials should be updated (the last edition was 2012) because the fructification is increasingly weak for some species, some seed stands no longer correspond to the purpose for which they were selected. These aspects make it very*

difficult to ensure the production of the forest reproductive material, i.e. we cannot think about developing the seedling production capacities in nurseries if we don't have a basis for obtaining necessary seeds."

SSI3: "*And there are other countries that don't report [into FOREMATIS] either. So the problem isn't in production, and it won't fail because of production to have more output. It fails due to bureaucracy.*"

5.4.4. Production risk and subsidy system

One of the most significant barrier (most often named in the SSIs as a main barrier; see Figure 47– nine out of 24 SSIs: five from Central Europe [SSIs 4, 5, 11, 15, 16], three from Eastern Europe [SSIs 20, 23, 24], one from Northern Europe [SSI 8]) for plant production in the SSIs is connected to production planning and the associated economic risks. In addition to the nine respondents naming "production planning" as a main barrier, the issue also came up in SSIs 3, 6, 7, and 18 (all from Central Europe). The challenges with production planning (resulting in production risk) are based on the lack of understanding of customers and policy makers, that growing plants for afforestation takes one to several years, depending on the tree species produced and the European region. Especially bareroot seedling of conifers (spruce, fir) have long production times of 3 to 5 years. Previous research in Europe has come to similar conclusions (Wezel & Reis, 2019; Božič et al. 2021; Rantasa & Kraigher 2024). Forest nurseries need to plan long time ahead to make sure that they will be able to sell their products and create revenue for sustainable development of their business. This would need close collaboration and dialogue with customers (see Dumroese et al. 2016) but also policy makers involved in the development and implementation of subsidy for afforestation and restoration schemes. Unfortunately, according to the SSI respondents listed above the situation on the market is far from this, especially in the private forest nurseries of Central Europe. In the following we try explore the details of the phenomenon.

Currently in most countries the market is structured as a spot market, where customers are asking for tenders for specific products and the cheapest provider makes the deal (codes used: "production planning", "spot market", "unsafe sales", "unsafe production").

SSI15: "It is absolutely incomprehensible that we are active in the green sector, green is more in demand than ever, and the businesses are all going bankrupt. (…) This does not exist in almost any other sector over such a long period and most people are not aware of what problems and risks we are burdened with."

SSI6: "….] nurseries in general have no specification of what they should grow and in what quantity. […} So nurseries are predicting out of a crystal ball. […] I don't know but just our effort is to get some input from those customers in advance I don't know if there would be any motivation in some planning [..] but again we are at those subsidies which then bind that market. […] we just lack the assignment to know what to grow and who to grow it for. […] However, it usually comes down to price because nobody looks at the price of [the final wood product], but [forest] owners look at the price of that seedling and they don't care what quality they're getting if it's going to grow […] of course mostly they go for the cheapest one."

SSI8: "It's […] the economic uncertainty in starting to produce plants for a spot market, meaning expanding production for a market where we don't know what will be needed on the other end and when. So we end up producing some things blindly."

SSI18: "[…] we are buying our seeds with the idea that probably because of those plans, there will be a market in the next five years. Because the seeds bought now will be plants not before next year or the years after. So what we are buying now is our own risk and we are depending on the market situation in five years, so we are gambling a little bit and with those ideas and those challenges we have here in Europe, it should not be a gamble for our industry."

SSI3: "Of course, guaranteed purchases would be good. I must also say, the forestry operations are [required] to improve their planning. […] I know other large forestry operations

that have no idea what will be planted next year. Let alone what will be in 2 or 3 years. And I need to plan 3 to 4 years ahead. If I have coniferous trees."

SSI20: "[Even in our contract production] there is no 100% guarantee that the grown seedlings will also be planted in the forests or will be purchased. […] This should be the customer's problem, not the suppliers. […] The financial risk is completely on the side of our nursery."

According to several respondents in the SSIs, this barrier is at the base of the decline of numbers of forest nurseries in many parts of Europe, especially in Central Europe. Constant revenue is needed for stable businesses that can adapt to future needs and are able to invest in new technologies. The smaller the production volume, the higher the costs per unit of product:

SSI19: "*When production increases, our per-unit production cost decreases slightly, but our overall sales increase significantly. The operational aspects, like growth periods, remain almost the same, even if we produce millions more plants. Thus, our revenues increase with additional units produced.*" (see also 5.4.2).

Nurseries often struggle to cope with this situation and/or as a result have problems finding a successor when owners retire.

SSI15: "*The youth, if there are children, they usually don't want to go into the profession because when they see how hard their parents have worked and the risks they take, you can also understand when they say, 'No, I don't want to endure that.'*"

As a result the concentration in the market continues, especially in Central Europe.

SSI15: "The old large nurseries have all died out in Germany. And when I look abroad in Europe, […] when I look at France, we also had over 30 forest nurseries, I think only 4 are left that play a role. In Denmark there were also once 20, I think only 3 still play a role. In Belgium there are only 2 left, in Holland there are only 2 left that are involved in the markets. You can see what is happening."

SSI7: "But also because there is not as much nursery area disappearing as nurseries disappear, but nursery area is not the same as it was 10 to 15 years ago in area. […] I think that the development with fewer and much larger units, then the alternative is to actually reduce your own production and let others make it."

SSI18: "Before 10 years, we had a decade, 10 years of [economic] crisis and crisis production and often prices were set out on production cost or lower. So for that reason, many of the forest nurseries, they quit it. They […] got bankrupt and there is only a small number of forestry nurseries still existing in Europe."

According to several respondents [SSIs 7, 15, 3, 4], a large part of these problems is associated with the award procedures for subsidies for afforestation provided by the EU to forest managers (but not directly to forest nurseries; see 5.4.9 for specific subsidies to nurseries). A special case exists in Slovenia where plants are provided by the administration to forest owners, i.e. subsidies are used by the administration directly. For implementation of subsidy projects, in most cases the administrative scheme does not foresee that plants are ordered in advance (before granting of subsidies); often this is also not possible due to the relatively short funding periods to order plants two or three years in advance (Whittet et al. 2016). Because of the relatively short funding periods, forest managers also might be reluctant to order plants in advance, if they cannot be sure of receiving subsidies. In addition, private forest owners are bound to demand profiles by advisory bodies for subsidies and cannot plan (e.g., when applying for a reforestation project a certain species mix has to be used, which is suggested by the subsidy advisory body, but can change over time). In consequence, at the end of the production process forest nurseries are left with a finished product with the risk of uncertain sales prospects:

SSI15: "*A big problem is communication and coordination with the various customer segments. Because all forest ownership corporations are bound to demand profiles [given by the subsidy scheme] and cannot plan in advance. So, we have enough capacities and we can easily produce 500,000 plants per year, 500 million plants per year more. […] It just needs to have secured purchase because we cannot take on more risk, we are already the worst stock market speculators because we buy seeds, take them into production for 3 years and have the uncertainty whether our customers really need the plants or can take them.*"

SSI11: "*It should not happen that, as this year, [that first the customer tells us) I will definitely take the seedlings, [but at delivery informs us] sorry, we did not expect that the timber market would collapse (and they would not take the goods). I understand everything, but I have been given the job to produce and you have been given the job to then solve that problem. You are leaving us with a lot of problems*."

On the other hand, there are instances where large-scale consumers (large forest enterprises) inform forest nurseries of their seedling needs very late, demanding species or provenances the nursery has not produced.

SSI20: "*Large buyers inform us of their seedling needs very late. If the planning of seedling needs were stable, it would be much easier for us to grow suitable seedlings. Now the situation is such that large buyers come to the nursery for seedlings of forest tree species that we don't even have in the nursery that year.*"

For these reasons it is very difficult for forest nurseries to commit customers to order plants for three and four years in advance (e.g., SSI8).

Subsidies for replanting are especially important in Central European forestry sector, because forest ownership is mostly small or medium forests, and these rely heavily on subsidies to make management profitable.

SSI5: "*The legislation, well the ordinances, […] one is for the marketing of planting material and the other is for subsidies and they don't really work together, […] And everybody wants subsidies for that nowadays, all the private people.*"

Problems also arise when funding schemes are too rigid, so that the forest owners get frustrated with the application process. This results in less orders for plants or ordered plants cannot be planted because funding applications have not been granted (and available funds remain unspent); this seems to be a problem particularly in Denmark with public funding through the EU:

SSI7: "*The worst thing is that our customers are starting to opt out of the state support scheme because it is far too rigid. […] This means that the money that is available is not being used, and it means that we have raised less forest. […] We would like to see a lot more forest, but it is being killed by case processing and authority limitations. […] So a plant season is a plant season, and before all those things are dealt with, we are well into the planting season in the spring and then it becomes tricky. […] In the end, people also experience problems regarding the payment of money around the entire case processing. It can take up to 2 years to get the grant money. As a result many [customers] have to get hold of an intermediate financing.*"

SSI8: "*For several reasons, only 25% of the money allocated for forest subsidies is used. This results in significant waste in nurseries. […] It has been that way because suddenly there's a sense that there will be a shortage of plants. And then when we reach March, suddenly there are just some things that cannot and should not be planted, and so on. And then the market is flooded with plants again. And it drives prices down. And we have experienced that so many times.*" […] *Planning should align with the intended planting times. If we can produce plants according to this schedule, avoiding waste, there would be room within our price structure to further develop. But if we have to discard millions of plants each year, it impacts the bottom line."*

The opposite problem occurs when all funds are spent in a subsidy scheme, and less projects are actually funded than planned. So, nurseries produce more plants in the expectation that they will be able to sell them, but if funds are spent, forest managers react strategically and wait with afforestation measures until new funds are available (reported particularly from respondents from Eastern Central Europe). This is also true in the public forest sector, which is also dependent on other budgets and/or has to implement similar award rules and procedures like requested by the EU.

SSI4: "*I almost need three years [to produce oaks], and then if […] the state says, the money is out, there are no more subsidies for reforestation, then we can dispose of the half-million oaks we produce.*"

Severe problems have occurred with unstable funding schemes, this seems to be a problem particularly in Germany (SSIs 15, 16):

SSI15: "*It started in '92, '93, [that] was when it began. And then again in 2004. […] Both times, economic crisis. Both times, the public sector ran out of money. And the subsidies stopped flowing. […] It happened last year […] in North Rhine-Westphalia, they did it in spring with a subsidy stop, the entire market in the state collapses from one moment to the next. Orders are canceled, and the plans are ruined with it, and we face a huge problem because we have these consequences - most people are not even aware of it."*

SSI16: "*When savings have to be made everywhere, it's of course easiest to say, okay, let's save on forestry. Yes. That old saying: 'the forestry party has it good; the forest grows even without them'. Yes, that's sometimes a bitter reality*."

SSI4 on the interaction of wood prices and FRM sales: "*If prices are low, more wood has to be harvested, but less money is available, so nurseries cannot raise prices; if wood prices are high, less wood is harvested, less plants are sold.*"

So continuous funding schemes with sufficient funds are needed and highly demanded by forest nurseries (SSIs 8, 3, 10, …). It is not possible for nurseries to react fast, when the demand of some species/provenance goes up and then drops within a short timespan (one to three years). This should be taken into account by policy makers when developing subsidy schemes. Forest nurseries need a reasonable return that is proportional to the risk. They also strive to be a good workplace without needing to exploit employees to fulfill the demand. Without proper planning and a guarantee that plants can be sold, nurseries are not willing to take the risk of producing plants to fulfill the 3-billion-tree goal of the European Green Deal:

Quote from SSI8: "*As long as we don't have a reasonable assurance of selling what we start, we shouldn't expand any further - no*."

SSI4: "*We are not even asked [during subsidy development], which is also interesting, they issue subsidy guidelines with tree species, [for which seed sources] maybe don't even exist. Or with provenances that are not available. Yes, so I have to say, […], 'are you serious?', because then the customers come and say, yes, the authorities said we have to plant these. Then they don't exist. That is one of the big problems*."

Additional problems affecting final delivery of the product occur in planting logistics putatively associated with climate change. For instance, planting operations at forest sites might get postponed due to the necessity to clear up wind-throws or bark beetle infestations, or by the narrow time window to plant out (planting is mostly done in the fall or early spring to make use of the generally more moist soil conditions during winter, allowing for better rooting of plants); this time window has shrunk considerably during the last decades, mostly due to fast warming in the spring. So, for these reasons, when it comes to delivery for planting, ordered plants that are held in cold storage may end up being wasted, because the time window for planting has closed. The nurseries are taking the risk that ordered plants cannot be delivered (lack of binding contracts). This has especially been reported by respondents from Central Europe (SSIs 15, 18, 8,…).

SSI18: "So in our business we are too much used to everything is an open business. So 95 to 98% of our production is at our own risk. We buy the seeds, we grow them and then as soon as they are ready, we try to find a customer for that. On the spot market, exactly. So and then there are customers and they engage to all those things. But if you, for example because of the weather or other issues, the planting cannot be executed they cancel those orders easily and then we get in a fight. Who is responsible for that and who is getting, who's gonna pay the invoice for that? So that is an issue, because there are many ideas on what we have to do, but there is not enough commitment [taking of responsibility from customers]."

SSI8: "If we have the plants ready after a given growth period, we can't just leave the plants and take them up after the next growth period because they will become too large. It becomes too expensive for our customers to plant. So if they aren't sold by that time, they are waste products."

A related problem occurs related to subsidy schemes: even when subsidy schemes are available, forest managers may not have the time to plan and implement afforestation due to work-overload with clearing of disaster sites or lack of staff. Again, plants produced in advance have to be destroyed or the surplus of plants on the market has to be sold at lower prices and thus creates a revenue problem for the forest nurseries.

For these reasons forest nurseries on average have to destroy between 10 to 25% of their production (see 5.2.2 in results of nursery survey; SSI 15), which, in sum, for 5 years, is close to the extra demand asked to be created in the European Green Deal to reach the 3 billion trees pledge by 2030.

In Northern Europe the market is mostly structured in a different way, in many cases the forest nurseries have a very high production capacity and are actually owned by forest companies, so that long-term planning can be implemented. Here also the production cycle is in general one to two years, which also makes production planning easier. This can be seen in the discard rate obtained in the nursery questionnaire which is half of the discard rate in the other European regions (see under 5.2.2).

SSI14: "*A large part of what we actually grow is already ordered plants. It is not that we grow all our plants without having a customer before we grow them. It is on order. There is a huge difference in how you do those businesses in the north compared to how you do those businesses in the [more] southern part of Europe. There are no long-ordered plants, but there the growers are at a chance and then hopefully they get rid of all the plants*."

The situation is somewhat different again for public nurseries which often produce plants for specific afforestation or restoration projects or specific forest entities.

SSI13: "*Typically, these are EU-funded projects. In this way, over the past few years, we have stabilized the number of plants we produce because by participating as partners and planning our production according to the objectives of these specific projects, we can confidently plan our production based on what is needed*."

Also here, in many cases it is expected that the surplus is sold on the open market. If plants cannot be sold, the nursery has to cover the production cost from other business areas, which hampers investment in other areas (e.g. mechanization, infrastructure; SSI23). In other cases (e.g., according to respondent from South-Western Europe) public nurseries do not have the need to be profitable:

SSI13: "*Therefore, the obstacle is essentially that, even if the nursery has a certain capacity, the bottleneck is the amount which is requested [for reforestation] by the territory.[…] When the importance of local seed origin and traceability is included in the project specifications, the demand for plants and the relevant land we manage increases*."

SSI13: "[…] *there needs to be an increased awareness among all structures involved in reforestation. This means more education, more culture, and a better understanding of planning. Planning is crucial for forest nurseries—it's in our DNA. […] I would invest heavily in*

educating those involved in reforestation, especially the entities receiving […] funds, about the need to plan interventions clearly and in advance. (...) It's essential to plan with a good amount of time ahead what needs to be done with plants, when, how, and where. This involves setting objectives and monitoring the final impacts of what is done. It should not be a single, improvised intervention done out of necessity within a defined deadline. As nursery managers, we suffer this weak planning. This is the biggest reform: increasing the culture and awareness of those working in this field."

In their analysis of the UK forest nursery sector, Whittet et al. (2016b) come to a similar conclusion, in that the lack of long-term market predictability brought about by the current configuration of forestry grants and regulations, and the administrative systems for processing grant applications create major impediments to sustainable business operations for domestic forest nurseries in the UK. The authors also conclude that the time frame and effort production (the work of forest nurseries) takes to supply vigorous FRM to the forest deserves much wider recognition throughout the sector and will be crucial if planting objectives are to be met sustainably. Optimally, there should be sufficient resources for common detailed planning of reforestation and restoration of both forest managers and forest nurseries, as suggested by Dumroese et al. (2016) under the "Target Plant Concept", but under current conditions this will be very difficult to implement.

Solutions and suggestions of nurseries to react to unsafe production conditions:

As outlined above, better coordination among market participants and stakeholders in many European countries is urgently needed for sustainable operations of both private and public forest nurseries; this includes mainly forest managers (forest services), funding agencies, advisors on subsidies, scientists and nurseries. A major problem for the private nurseries is communication and coordination with the various customer segments. Raising awareness of the problems of forest nurseries at policy makers, forest managers, and other stakeholders is a major request of the nurseries participating in the semi-structured interviews. In the following, we summarize some of the most important suggestions that respondents have made in the SSIs to make their business operations more sustainable:

SSI16: "*A subsidy policy that is fixed for several years [is needed].*"

SSI10: "*We've had these subsidies for afforestation, so I'm sure they have some impact, as long as they are like long term things, that there are no big changes between years. Or that they would not be sort of short term, like projects. That those more just mess up the market, when the demand of some articles goes up and the drops, and so forth.*"

SSI20: "*Politics and forestry science should come together and advocate for the profession, so that then, regardless of the current governments, they could act in the direction of the development of forest nurseries. The [government] gives too much emphasis to agriculture, so that minimal funds remain for forestry*. […] *We have no obstacles. We have enough land for growing seedlings, we are technically equipped, we have the knowledge, we have the will. We only need the state to allocate enough funds for seedlings. Climate change and with it also the disasters that are happening and will unfortunately happen even more often, and the need for seedlings will only be greater. Only the funds will need to be provided."*

SSI23: "The integration of the specialists in the field of FRM into decision-making structures at the political level is highly suggested."

Some nurseries have tried and managed to form partnerships or close relationships with (large) customers (forest enterprises), who do not so much rely on subsidies or are willing to commit to long-term contracts (SSI8) or get involved more in contract production of certain FRM lots for clients (SSI11). The ability for long term planning through contracts with forest managers would be much appreciated by forest nurseries (see also Wezel & Reis 2019; Rantasa & Krajgher 2024); at the moment the spot market system is working for the customers because there are still enough plants around, but that could change if the economic situation further worsens for the FRM producers.

SSI16: "*You can make pre-contracts and so on. That's also a cost saving. If we know we have a certain sales volume in 4 years, then I'm actually already setting a price for 4 years from now. And that is of course much cheaper than if 3% is added every year. But that's done very little*."

Many nurseries have started to diversify their products into the production of ornamental plants or provide also services like planting, fencing and tending of outplants (e.g., SSI 3, 5, 20).

Another approach that respondents from Central Europe have implemented is cooperation and specialization among a group of forest nurseries, i.e. try to complement each other, instead of competing with each other. They specialize in certain species to improve cooperation, where one partner produces part of the species and the other produces the remaining ones. In this way also efficiency of production due to specialization to certain species can be improved (SSIs 4, 8, 11, 24):

SSI7: "*When we are at the end of a season, there are not very many superfluous plants […] left in our cold storage. And we can achieve that much better by the fact that we actually enter into […] partnerships*."

SSI4: "*The crucial thing would be, of course, improved cooperation to reduce production risk.*"

SSI8: "*We can't do everything individually. We become too broad. We end up with too many species. Yes, and we don't become skilled enough with the species we need. Remember, because all the small species take up too much space [in our nursery]. Even though they are important somewhere in the market, they need to be consolidated somewhere and then produce a certain quantity. And then there are [other nurseries] who produce different quantities.*"

SSI11: "*We have managed to build a small producers' cooperative, […] we have managed to practically triple the production of those who are in this circle. What this means is that we are all working together, both in terms of seed purchases and sales, and we are trying to produce practically the same, to produce the same quality. We divide up and in many cases among ourselves who produces what, so that we do not cross-produce each other.*"

In technical terms, nurseries are also trying to minimize the risk of waste products, by marketing plants at different ages and sizes, e.g., part of the production is already sold as annual plants, another part is marketed as a biennial, and some can even be grown into a triennial; in this way the risk is lowered by spreading production over a longer time period.

SSI6: "*Our endeavour is always to get along with the customer. The first is to offer a different height category of the same planting material. If it's not possible to offer a different technology instead of bare root, container; if that's not possible to offer a different species, but a lot of times this is not possible. Like, because we compete public contracts as well, so sometimes it clashes with the specification that […] has to be adhered to*."

Forest nurseries are also active in lobbying, especially through EFNA, at the EU level to make nurseries be heard and raise awareness of their problems at the EU/political level. Forest nurseries feel that too much support is given to agriculture and too little to forestry and forest nurseries considering the role forests play for European ecosystems (almost 40% of Europe is covered in forests) and the Green Deal (nature restoration). They wish for specific nursery-targeting subsidies with minimal bureaucracy.

Quote from SSI19: "*In addition to advice from highly educated biologists and natural scientists, policy makers also should be listening to highly educated forestry professionals on what is the right way to operate sustainably. [….] It is crucial that the forestry industry is heard. What we are doing is very green and sustainable; but I miss a comprehensive approach from the government to significantly increase production by planting more. We need to invest heavily in this*."

5.4.5. Changes in general market demand

In addition to the difficult planning of production, forest nurseries have also been affected by changes in general demand particularly in Central Europe, e.g. when the demand suddenly increases very fast in the wake of natural disasters (e.g., in Czech Republic following large-scale bark beetle damage). Such large scale changes in demand have an effect on the sector, e.g., in the Czech Republic, production was scaled up by the creation of additional nurseries, although demand is returning to lower levels now again (see country report by National Authorities for Czech Republic). This results in nurseries going out of the FRM business again according to SSI respondents SSI5 and SSI6:

SSI6: "*And if we look at the years just mentioned, for example 2011 to 2015, 117, 120, 113 million seedlings were planted in the Czech Republic, so on average somewhere between say 110 and 120 million seedlings, whereas in those years it went up to some say 250 million seedlings maximum.*"

SSI5: "*There's just been a huge boom with the bark beetle calamity. Millions and millions of planting stock have been produced. Those clearings are forested and there's nothing to harvest. There's not going to be new clearings created, right, at least in our region here there's already no trees in forest and within two years and the demand for seedlings is just going to go down rapidly already, actually last fall there was already a one-third drop.*"

Moreover, in some countries such an increase in production has not been observed or was less pronounced following storm or bark beetle damage; e.g., in Germany with changes in forest policy giving preference to natural regeneration, which resulted in a lasting development in decreasing the number of (small) forest nurseries. Based on national statistics, Wezel & Reis (2019) report that the number of producers of FRM (forest nurseries) in Germany has declined dramatically from 2004 with *c.* 550 active forest nurseries to *c.* 280 nurseries in 2017; this corresponds to a drop by more than 50%! A similar trend has been observed in Austria, with a drop in the number of private forest nurseries from 180 in 1991 to 106 in 2024 (data provided by the Federal Forest Office and Ministry of Agriculture); in the same timeframe, the number of produced plants dropped from 66 million to around 30 million plants.

*S*SI6: "*Germany has really been fighting bark beetle quite extensively, but there hasn't been a huge increase in demand for planting material, and on the contrary, perhaps [owners] will still get some allowance for [natural regeneration]. So, if this trend is across Europe, then the demand for planting material is going to fall, which again does not correspond to the fact that we should be reforesting more areas in a meaningful way*."

A similar development has also been observed in Slovenia, where natural regeneration is the main mode of reforestation:

SSI20: "*After 2008, the need for seedlings started to decline again. The increase was evident only during the period [2019 and 2020]. This was followed by another steep decline in the purchase of seedlings. If we look at and compare the spring planting of 2023 and 2024, this decline was 70 percent.*"

Of course, forest nurseries are in favor of planting instead of natural regeneration: they argue that if additional planting and the restoration of those major damage events that occur in the forest are desired, forest policy in general should give preference to artificial regeneration to strengthen the forest nursery sector. Some nurseries suggested in the SSIs that international cooperation should help to cover exceptional peak demand (SSIs 8,17), while others were not willing to cooperate internationally because they fear competition with foreign nurseries (especially in Central-Eastern Europe; SSIs 5, 6, 11; see also 5.4.12).

General demand is directly affected by the afforestation planting density (i.e. plants per ha) that is also prescribed in subsidy schemes. A respondent from Central Europe (SSI15) reports that the planting density for Norway spruce in 1990 was 12,000 per ha and that currently 1,500 trees per ha are planted (compare current guidelines in silviculture, e.g.

https://www.fnr.de/fileadmin/Projekte/2022/Mediathek/Brosch_Begruendung_Waldbestaende_RZ_bf_final.pdf). In terms of sales, it is in the interest of forest nurseries that plant spacing should be decreased; this is also in agreement with climate change mitigation efforts as more plants per ha take up more CO_2 at an early growth stage, allow for more selection of the best growing trees and create a better microclimate for forest establishment (SSI 19; Chakraborty et al. 2024). On the other hand, densely spaced afforestation sites are more difficult to tend (keep free of weeds etc.). Dense planting has also been criticized for having a negative influence of water availability in catchments although this depends on the local site conditions (Teuling et al. 2019; van Meerveld & Seibert 2025); quote from an SSI respondent from South-Western Europe:

SSI22: "Reducing the density of forest plantations is proposed to reduce water consumption, to increase the arrival of rainwater to reservoirs. This trend may reduce the number of repopulations and restoration plantations. The tendency of these studies is that there are too many trees, when the reality is that forest management is lacking (i.e., lack of thinning), but this is the discourse that is now permeating society. What to do to resolve this trend? Disseminate, raise awareness and explain ideas well."

In recent years, the demand also has changed for many nurseries in the number of tree species to grow (more species should be planted to mitigate risks of climate change effects on the forest), further increasing production costs and the risks. For this reason, nurseries suggest that rare (secondary) tree species should receive higher subsidies (for planting), because they are also sold at a higher price (SSI8); this is already implemented in some countries, e.g., Germany and Austria (e.g., https://www.waldwissen.net/de/waldwirtschaft/waldbau/erstaufforstung-wenn-acker-zu-wald-wird). As already suggested in 5.4.2, funding schemes should be designed in the long term, with no quick changes in the species and species mixes subsidized.

The analysis of future demand for tree species was also recommended to reduce production risks by Friedrich (2022) for the German nursery market, while potential new market entrants were not seen as a significant threat by respondents of that study. Moreover, established nurseries do not see a need to invest in the creation of new nurseries in some regions, but rather suggest subsidized investments in the established ones.

SSI20: "*The fact is that we have old nurseries that are only utilizing 40% of their capacity, which means that we should invest more in existing nurseries, not in establishing new ones*."

5.4.6. Scale of operations and production costs

Production costs were identified as main challenges in their nursery business only by a minor number of respondents in the SSIs (1, 19, 23). Nevertheless, they are an important factor in all business operations. In businesses in general, when production increases, but prices stay stable, the per-unit production cost decreases slightly (economies of scale; Stigler 1958). Some operational aspects, like growth periods, remain almost the same for forest nurseries, even if production is heavily increased. Thus, revenues increase with additional units produced, resulting in increasing profits and operations reaching a size where businesses are not too small to survive. In consequence, at a larger production scale, nurseries can also negotiate better with customers about prices and conditions. The scale of business operations in private businesses is decisive to be more resilient to fluctuations in the market (see also Friedrich 2022).

SSI19: "*Being bigger allows us to have more influence and ensure sustainable operations. This isn't just about keeping up; it's about developing further. One thing I see as incredibly important is that by increasing our production, we can hire more skilled people. If we're a small unit producing a limited quantity, we can't retain highly skilled employees. […] By increasing our internal expertise, we enhance our company's environment. This is crucial because we can have professional discussions, dialogues about challenges and experiences. I believe larger units are better because they provide more strength also in human resources*."

SSI5: *"[Production expansion would bring] some stabilization in the market, economic stabilization. Because, when you have more facilities, even though now we had frost in both facilities, if it is somehow diversified, that at least one facility can survive such weather, then we can somehow function economically there. You might not make any profit, but we'll survive it."*

SSI19: *"Customers have accepted price increases because we deliver quality plants consistently. They know our prices are higher than in other nurseries, but they also know we always deliver, which is crucial. Being able to deliver means not just quality but also reliability, which is something they find difficult to get elsewhere."*

Public nurseries are less affected by business parameters, but rather by a lack of funds to finance their operations, if the administration budgets are small. Nevertheless, they are also affected by rise of production costs. For example, SSI1 mentions "*implementing better financial planning and cost saving measures, optimizing the production process, ensuring incomes by sale of seedlings to third parties, and developing new EU funded projects"* as countermeasures to rising production costs and budget cuts."

In the wake of the general cost increase in Europe also production costs for forest nurseries have significantly increased during the last years. Many respondents in the SSIs (SSIs 1, 2, 5, 6, 11, 18, 19, 20, 21, 22, 23, 24, 25) quote that costs for salaries, energy, fertilizer and consumable have significantly increased, also the interest rate for loans:

SSI5: "*Actually, everything has gone up, but energy costs have gone up the most. Whether electricity, diesel, right, chemicals, fertilizers. The energy is the most significant.*"

SSI19: "*Our input costs have increased [considerably]. Some factors have risen by hundreds of percent, like electricity and fertilizer.*"

SSI11: "*Fertilizer prices have gone up double, chemicals have gone up double*."

SSI15: "*Fertilizer. Fertilizer is a factor and it's becoming more significant."*

SSI6. "*The increase in energy in general of those inputs in terms of electricity, fuel and fertiliser. This was the biggest burden. And the biggest increase with the fact that the nitrogen shortage caused a huge increase in the price of fertilizers*."

SSI5: "*Well, lately it's been mostly inflation and the price of money, I mean, financing, interest rate increases and just expensive money. […] We take out loans on a regular basis. […] So it all goes through financing because it just works out best accounting-wise, right. Buying with cash is nonsense. So operating financing is common."*

The cost for renting land (e.g., SSI16) has also increased in the same range, which makes land availability in general (SSI3) more complicated. In some cases also the cost for seeds have increased dramatically, when there was no seed crop for several years (SSIs 11,13,21, …):

SSI11:"The price of oak has gone through the roof in the last 5 years. 5 years ago it was possible to get one kilo for one Euro […], now they are practically out of the question for us for less than 3€."

SSI3: "[Though] the quality has deteriorated, the seed has become more expensive."

Many nurseries were not able to fully pass the full raise in costs on in plant prices, i.e. their revenue has decreased in the last years.

SSI6: "*That final price of seedlings is determined by the market, not determined by cost. It's not like we're saying, we had a frost this year. It is clear that next year it will be 10 cents more expensive. No. The price, unfortunately, is coming from the other side. […] That means our profit is shrinking and there is not as much room for further development."*

SSI14: "It is much more difficult to increase plant prices than to pay for what you need for growing."

SSI7: "*If there was stronger demand, we would also be able to raise prices to cover these costs for [the production] to be profitable*."

SSI8: "*Costs have significantly increased over the past many years. And you could say plant prices have been stagnant for 20 years. Only in the last couple of years have prices started to rise again. A little bit, but not as much as our costs*."

SSI10: "*There are some raises that we have been able to make in the prices, but not in the same magnitude. The price has not risen as much as the costs*."

On the other hand, another SSI respondent SSI4 acknowledges: "*We have massively increased plant prices. So economically we are doing well. That is no problem. We had massive price increases* […] *The price is not crucial, but how much quantity I sell.*"

SSI24: "*Both production costs and seedling prices have increased.*"

This development speeds up the market consolidation in that especially smaller nurseries suffer more from this increase in production costs than larger nurseries. Similar results were also obtained e.g. in the study of Friedrich (2022) on the German forest nursery sector. In the latter study, the competitiveness of forest nurseries on the German market was investigated. Based on her results, it was concluded that forestry plant businesses with 49 or more employees and 15 hectares of cultivation area had market advantages.

5.4.7. Lack of specific subsidies for forest nurseries

There are no specific continuous subsidies for private forest nurseries in the EU (apart for general area related subsidies for agricultural land). However, forest nurseries should, benefit indirectly from subsidies for planting that go to forest managers for reforestation and afforestation. But, as laid out under 5.4.2, this does not benefit the nurseries in many cases. However, improved specific support to forest nurseries is needed, if production capacity should be increased at the regional level in Europe. Fargione et al. (2021) came to the same conclusion to increase nursery production in the USA. Opinions of forest nurseries towards specific subsidies from the online nursery survey already have been described in 5.2.1; in the following, we provide some quotes from SSIs:

SSI11 (eastern Central Europe): "*[In our country] the producers are characterised by this simplistic and simplified production, which has two reasons: one is the lack of know-how, and the other is the fact that a lot of people have simplified machinery.[…] Support [through subsidies] would be good, both in terms of mechanisation and infrastructure, this would be very much needed*. [But] *we are really not supported by anyone. So as far as what we've done here or what you're going to see is all completely self- financed. […] The machines that are designed for us are, with these seedling prices, generally what they are, what they move, they're out of reach*. […} *Applications are so specific that I do not fit into horticulture because we are not horticulture, and we do not fit into agriculture because we are not agriculture. We are basically such a small segment of the crop production that nobody thinks about us."*

Another respondent does not want to depend on subsidies (also SSI17):

SSI15 (Western Central Europe): "*I'm not a fan of subsidies. We have to earn that ourselves. I believe in our own economic strength. What must be secured […] is the market demand."*

We can deduct from the answers both from the SSIs as well as from the online nursery survey that subsidies are differently structured among the different regions and countries (see also e.g., Haeler et al. 2023); it goes beyond the scope of this report to review all the funding schemes available, but some general remarks and suggestions of the SSI respondents are discussed here. Interestingly, suggestions are still rather similar across the different regions despite differences in the national fundings schemes and procedures (see 5.2.1).

The available subsidies to nurseries are mostly provided directly to forest nurseries through specific calls related to infrastructure or machinery. However, several SSIs (SSI3, 11, 16,…)

and respondents to the online questionnaire report that the funding rate is too low for the nurseries, the application procedure too long or the duration from submission to granting of the subsidies are too long. In the EU subsidy scheme, forest nurseries have to prefinance the costs for any measure and this burden is also too high for many nurseries, especially when re-funds are provided late due to slow administrative procedures at the national subsidy organization (SSIs 20, 3, ..). Similar problems were also reported by Whittet et al. (2016) for forest nurseries in the UK.

The results of our EU-wide nursery survey (online questionnaire, 5.2.1) shows that there is strong criticism about the available subsidies for forest nurseries, especially on the administrative procedures associated to obtain subsidies – even from respondents which have replied that they are satisfied with the available funding opportunities (see comments section there and respective Annex 6). This critique continues in the SSIs:

SSI5: "*There are some subsidies, right, but for me it's unnecessarily complicated. We try to avoid them, because the administration of it, like it's quite difficult, uncertain, but nevertheless, when we use it, we are just expensive again compared to the competition. […] There are financial aids… I'm not saying they're not, but it's all unnecessarily overcomplicated for me.*"

SSI20: "*And because these are basically almost unique products, the prices are also higher, and a higher percentage of co-financing would significantly facilitate our investments. The other thing is that when we, for example, purchase a machine, we would also get a refund of the invested funds as soon as possible, and not that we get the co-financing funds returned only after a year or at the end of the call period.*"

SSI11: "Things were going so slowly that by the time everything was sorted out and put in order, the application had been closed due to lack of interest.[…] *Many people fall into the mistake of applying, getting it […], maybe even taking out a loan, they can't afford*."

A general suggestion and the most common one is to make subsidy applications much easier and less bureaucratic for the nurseries (faster processing speed of grant applications, deadlines at appropriate time [not during peak or holiday season]).

SSI23: "*In the case of funding granted from the state budget or from European funds, the period of evaluation of funding applications should be much shorter to be a sufficient period for the implementation of projects.*"

Also difficulties in the number of quotes that can be provided for specific machines/infrastructure needs to be respected by funding authorities, since often there is only one provider for a specific machine.

SSI3: *"[If I want to invest in] a specialized machine that's just for forest nursery production, not something you can generally use in agriculture, […] then I'm supposed to bring three offers. But there is usually only one manufacturer because it's so specialized. […] How is that supposed to work? So, that's nonsense."*

Several respondents report that due to the complicated administrative procedures to obtain funds they themselves or their customers are losing interest to apply for funds at all; that the EU would need to re-think or reorganize the procedures to rebuild trust in EU subsidies. Some respondents indeed suggested abandoning the subsidy approach and instead propose lower taxes for nurseries (e.g., SSI4).

Bureaucracy in general is also seen as a main obstacle:

SSI4: "*EU statistics, statistics, statistics. We have to report every delivery within the EU! Every single one! Every delivery note!* […] *I mean that is complete nonsense. Such things, which are of course against all reason and against common sense, that I say the same climatic conditions, the soil conditions, but the bureaucracy says: Stop!*"

One respondent from a public nursery in South-Western Europe suggests:

SSI22: "*Reduce bureaucracy and procedures. The private sector cannot survive the amount of paperwork that has to be done [by public nurseries]. The regulations required for ornamental plants and those required for forestry are not equitable. Private companies could not afford the effort to make the amount of plants that they do because they would not be able to do the paperwork that entails. There must be traceability and security for the user, of course, but there must be a more agile way of working: working with seeds and plants and not with papers. Many nurseries evolve into ornamental plants for this reason."*

Respondents also often ask for better and regular information about funding possibilities (see also quotes in 5.2.1). In general, respondents also suggest that the governments should provide an afforestation strategy and to actively promote this strategy, also by providing public lands for afforestation. Several respondents in the online survey towards forest nurseries (see 5.2.1) also suggest continuous subsidy budgets (not bound to six years common to the EU's common agricultural policy) and more funds allocated to forest nurseries and reforestation in general (also in SSI 20). Some online respondents also believe that the sector is too small for specifically dedicated funds; others suggest that forest nurseries should be treated in funding schemes like fruit tree/ornamental nurseries, since more funds are available in the agricultural sector compared to the forestry sector (this might be problematic since FRM is treated differently compared to plant reproductive material [PRM] in agriculture and horticulture).

Especially in South-Western and Eastern Europe respondents believe that start-up grants would be needed to increase production/install new nurseries (SSI20, and online survey in 5.2.1), because start-up costs are very high. They suggest that the respective government (or the EU) should provide low interest loans or non-refundable loans to create more nurseries to fill the rising demand for FRM especially in those regions (see also responses in online survey, 5.2.1).

Several SSI respondents (SSIs 3, 20) and online respondents suggest higher funding rates for infrastructure; currently the funding rate is between 10 and 30% of the investment needed, but respondents suggest that this number should be 50% or up to 90%; one respondent suggested a 90% funding rate with a cap at 50,000 EUR annually per nursery.

SSI3: "*The [forest] nurseries, we're scraping around at 30% [funding rate for machines]. In agriculture, there are sometimes 40-50%. If I look at industrial operations, they sometimes get 70-80% funded.*"

5.4.8. Climate change effects on forest nursery production

Problems in seed production due to climate change have already been discussed under "seed sourcing". In terms of plant production, the warming climate has sometimes resulted in plants growing too fast (SSI8), especially in business-to-business operations this can cause problems with customers. Moreover, forest growth increases due to climate change especially in Northern Europe, which allows for shorter rotation periods, which in turn results in higher plant demand.

As are result of climate change, some respondents (from Central Europe) have moved seed sowing to spring (SSI11), moved production steps to glass houses or outsourced to other regions because of danger from late frosts in Central Europe. There is also a general trend to increase production in containers to increase the duration of the planting season:

SSI11: "*With the high temperatures in January or February, the seedlings started to germinate, [but then we had] a number of frosts, so [they] did not escape the frost damage. That's why I've moved my seed sowings to spring, […] there's wind and rain, the weather conditions are bad, they have never been so bad before.*"

SSI3: "*The problem is, I don't know if another frost will come. Then I have the personnel there and then I can't do anything for 3 weeks because we have the soil frozen. What do I do with that? And those are the cost factors."*

SSI3: "*I have production done in Belgium, I have production done in Holland, and I already have production done in Germany. Because I simply have to spread the risk. In the young plant productions*. […] *So I have it produced for two years and that costs 30 or 40% of what it costs here. And I have double the output. Because the soil conditions are simply better there.*"

SSI4: "*We are located with the customers. Where my young plants come from doesn't matter to the customer anyway, so I have them produced where the best conditions are. And, risk diversification, logically*."

SSI5: "*If we were expanding, I guess we would specialize purely in container seedlings. Yeah, because the demand for that one has grown tremendously […]. I guess the way it is too, given the weather fluctuations, the container production seems like probably a good option. […] So if we were to change anything strategically, we'd probably go more with the container seedlings*."

However, such a change is not yet seen as necessary or feasible by the majority of bare-root producers in the SSIs (DK, DE). The change from bare-root plants to container plants would entail extremely high investment costs in the whole production process, therefore nurseries try to avoid this or do investments in novel infrastructure step-by-step.

Drought periods have increased in Central Europe due to climate change and this also affects the production of nurseries in some regions. Respondents from South-Western but also from Central Europe reported that water shortages especially in summer are increasingly becoming a problem (SSI3, SSI6, SSI22).

SSI3: "We are one of the driest communities in [our country] here, and we struggle immensely with drought and too little rainfall. And that has been massive in the last five to eight years. It has really become significant, yes."

One respondent (SSI3) report that they have problems due to administrative procedures to use water for their production (competition with agriculture and drinking water supplies). Additionally, a lack of subsidies to invest into irrigation systems creates additional problems for successful plant production, as respective calls are linked to large agricultural irrigation systems, and there are no calls for small irrigation systems so that individual nurseries could apply. So, there is a lack of subsidies for small irrigation systems intended for forest nurseries (SSI3, SSI20; respondents from Central Europe and Eastern Europe, respectively).

The creation of a productions insurance system against environmental factors for forest nurseries has been suggested by several respondents in the SSIs (SSIs 8, 24, …).

5.4.9. Problems related to funding in public nurseries

Economic/financial barriers are mostly related to the subsidies available as described under 5.4.2. Here we describe the problems in capacity enlargement directly associated with a lack of funds that occurs particularly in the expansion and the development of public nurseries in South-Western and Eastern Europe, associated with generally lack of funds for public forestry as reported by SSI respondents.

Some statements of SSI respondents from Eastern Europe:

SSI2 (public nursery): "*[Our expansion] is slowed down through administrative procedures regulated by legislation (i.e. Public Tenders Act) and related normative documents. [We run into these problems] every time we try to purchase goods/materials or develop new infrastructure requiring permissions by authorities. [This is] mainly slowing down the implementation of any development plan."*

SSI23 (public nursery): *"The situation of limited possibilities for selling surplus of forest seedlings has determined us, in the last 4-5 years, to reduce the quantity of the produced seedlings, in order to limit possible financial losses. […] The bureaucracy is high in [our country]. We still must obtain a lot of approvals and authorizations for investments. We are*

obliged by the public legislation regarding procurements to comply with very long waiting periods. Basically, there are no real chances to make investments."

In Southern Europe, forest nurseries have played a minor role for afforestation in the past due to preference for natural regeneration, but are becoming more important due to forest restoration efforts and major calamities in the wake of climate change (e.g., storm damage, bark beetle outbreaks, forest fires). In this region especially public nurseries are demanded to provide sufficient FRM to keep devastated areas forested. Respondents from these public nurseries report lack of support from policy makers and/or rigid bureaucratic schemes at the national level for obtaining funds as a major barrier to their expansion of production capacity.

SSI12: "*In [our country] nursery activities have been somewhat neglected because, […] Alpine forestry relied on natural forest regeneration principles, focusing almost exclusively on the natural evolution of forest ecosystems. Nursery activities were essentially abandoned or very much neglected, and to this day, there are no specific tools at either the local or national level to support and finance this activity, because forestry was headed in the opposite direction until a few years ago. […] In 2018, following [a heavy] storm, it became clear that we needed to prioritize/ increase our seedling production. […] [As a solution] we've taken the initiative by gradually hiring dedicated staff. […] We have been aided by the fact that both the production costs and especially the planting costs are funded by private sponsors. […] This provides significant help in financing our nursery activities. […] [Future] collaboration with [the regional administration] and the Forestry Service definitely needs to be implemented and strengthened, as we've all realized that nursery activities are crucial, especially to cope with climate change and its consequences.*"

The same respondent (SSI12) from Southern Europe: "*Bringing together all entities with nursery experience is strategically very important to create well-defined nurseries where species with certified origins are produced, thereby supporting the needs of small forest owners. Experiences in nursery management in [other regions] need to define strategic guidelines and concretely determine the real needs of various communities and integrate them into well-organized nurseries capable of producing different species and ecotypes to meet all owners' needs. A substantial public involvement in nursery activities is needed. While private entities can fund nursery operations, perhaps indirectly, the goal is inherently environmental and forest-based. I do not see, nor do we contemplate—given our current deliberations—a nursery operation aimed merely at business within the forestry sector. From our perspective, expansion means optimizing available resources. Our nursery has a greater capacity than we currently utilize. Expanding allows us to better fulfill our institutional mission of biodiversity conservation, and potentially collaborate with private nurseries that aim for profit."*

As shown under 5.1.2, FRM production capacity is particularly low in Eastern and South-Western Europe. Therefore it would be critical to invest in forest nurseries and plant production in the region. Possible solutions in cooperation between public and private nurseries are being developed and this topic is continued in section 5.4.7.

5.4.10. Private and public nurseries: competition and cooperation

In this report, the term public nursery is used in a relatively broad context. The different kinds of public nurseries will deserve further attention in future analysis. In some cases, public forest nurseries have the primary objective to produce diversified, high-quality, certified material in quantities sufficient to meet demand and aims of the regional administration.

SSI13: "*For us, it's not about profit since we are a public agency*."

In other cases, public nurseries need to provide the plant demand for state forest enterprises (especially in Eastern Central Europe; see also 5.4.4). In both cases, to obtain additional funds, public nurseries also try to sell plants on the free market and by participating in national and international projects. This can create competition with private nurseries.

One respondent (private nursery) from South-Western Europe (SSI21) bemoaned the competition from public nurseries, especially in that seed sources are not made available (see also under 5.4.3) and the way restoration projects are generally awarded to public nurseries. Due to these conditions, the respondent stated that he does not have the ability to expand his production.

Given the current challenges for forest restoration in Europe, it appears that competition between private and public nurseries should be avoided. Both kinds of nurseries should work together, and each should have their place on the market, e.g. public nurseries may provide plants of rare species, which cannot be produced profitably by private nurseries; cooperation between public and private nurseries appears essential to be effective in plant production.

SSI12: *"The bulk of nursery activities in forest environments [in our country] is handled by public entities, which also have the most experience in this field. However, there should also be a place for private entities with relevant experience or those looking to gain such experience, as many private parties are also considering establishing their own nurseries. And for the reasons mentioned earlier, the presence of research institutes and experimental centers, including universities, can provide adequate scientific support.*"

A very interesting approach is currently being developed in Italy, where it has been recognized that the current FRM producers (mostly public forest nurseries) do not have the capacity to produce the plants needed to reach the goals of forest restoration (Martini et al. 2022). Instead, it has been proposed that public and private nurseries work together to provide sufficient FRM both in terms of quality (genetic diversity, selected seed sources) and quantity. This means that the public institutions provide seeds and guidance to the private nurseries (who are new in the market) to provide a sufficient amount of plants to cover the rising demand. In this way, a fruitful cooperation for both sides can develop; this system could be a model for other regions of Europe with low FRM production capacity and avoiding competition (Mariotti et al. 2022).

5.4.11. Other technological issues

Seed availability was considered a technological issue in the online nursery survey and has been identified as one the top three production barrier for nurseries (see 5.4.2). Other technical issues, e.g. availability of land for raising plants, other production means, etc., are seen as challenges by a relatively small fraction of respondents. The availability of land is named as a main barrier for production expansion in SSI 25 (public nursery from Eastern Europe), this was also mentioned as additional but low impact barrier in SSI 22 (public nursery form South-Western Europe) and SSI 16 (private nursery from Central Europe).

SSI25: *"[We would need land that] is located near [our] existing nurseries and that it is not forest land. Also, the problem is the price of the land that would then be sold to the state. Mainly, legal-property relations are a big factor for us."*

SSI respondents (SSI8, 11, 20, 18, 3) report that chemicals for plant protection and weed control are increasingly difficult to obtain for forest nurseries as admission procedures are costly, and many producers of chemicals do not find it profitable to invest in product development, or registration for this relatively small market segment. One respondent in the SSIs also stated that there are too few pesticides available, and another that phytosanitary health plans are needed per species (SSI18).

SSI8: "There are definitely legal challenges [in relation to pesticides], because our plants don't fall under regular approvals. And then there are only off-label approvals for the few pesticides we still have. […] It's becoming so narrow and specific that it's hard to find something suitable for use in a forest nursery. Even though the areas we treat are relatively small […] But there are some substances we no longer have, and we'll have to learn to live without them. This will likely mean that we need to produce plants differently."

SSI11: "*The problems we have with the way we're set up to use chemicals in our culture and we're basically stepchildren again. In this atmosphere, no one really thinks about us, so there is no such thing as actually allowing chemicals in [forest] nurseries*."

SSI18: "*The three billion plants we see as a challenge; without chemicals we cannot produce them. It's not about the cost. […] The issue is that we can not grow any plants anymore without chemicals*."

As a reaction to this lack of official permits/registration of specific pesticides/herbicides/insecticides/fungicides, as well as due to shortage of staff, some nurseries are investing in changes of production technologies, i.e. the mechanization of weed control and alternative growing technologies, e.g. Plug+ system or switching from bareroot to container production. In the Plug+ system, young seedlings are raised in containers to facilitate their establishment and are then planted out. In this way, nurseries have lower loss rates in seedling numbers compared to seed beds (damping off disease), can achieve the rapid growth of container seedlings in the spring (by using glass houses for germination) and then by planting out realize the advantages of bareroot seedling culture, especially better root collar diameter and better developed root systems. In addition, mechanized weed control can be applied when seedlings are planted in exact rows. Some nurseries are also very interested in minimizing the application of chemicals to their soils, so they are also using e.g. mycorrhizae to support production and protect their soils (SSI 17).

5.4.12. Views on international cooperation and policies

In general, most nurseries are open to cooperation in certain aspects of their business. Almost 90% of respondents in the online nursery survey and all respondents in the SSIs reported that they are already actively cooperating with other (mostly) regional nurseries; several also reported that they already have exchanged knowledge and visited nurseries in other countries. Therefore, in general, forest nursery managers are very interested in cooperation with market participants, visits to other nurseries, internationally, workshops, discussions, etc. Exchange of experience is generally seen not as a problem but very important to keep up with innovations, and also interesting for future partnerships.

SSI13: "*These relationships are invaluable for exchanging knowledge, practices, advice, and perspectives.*"

SSI17: "*I always say, I'm an open book. Everyone can ask me something and I will tell them, but not everybody is like me. […] That's a pity, I think it is important to have a network, and if I go to Germany or I go to Denmark or go to Belgium or wherever and I tell what I do and I get the information back*."

On the opposite end, one respondent had negative views on cooperation.

SSI4: "[*Cooperation], you can forget about it; because there's mistrust. I know the colleagues. There is mistrust. It's unfortunately like that."*

Some nurseries (mostly from the public sector) are also very interested to participate in research on FRM related topics, e.g. provenance trials (SSI 20), silvicultural experiments and mycorrhization (SSI 12), and research into plant breeding (SSI 21), but also in the expansion of production towards agroforestry and other fields (urban forestry, etc.).

To diversify the range of species/provenances they offer, nurseries are already doing trade with foreign nurseries (especially in Central Europe this is very common, see also 5.2.4. For (international) cooperation of plants(trade), nurseries need to have the logistic resources and infrastructure to produce and deliver plants to a foreign partner to a certain date and in a certain condition. Respondents report on problems in cooperation with small nurseries:

SSI7: "*Then they need to have the capacity that allows us to get the plants in 3 days or 4 days. Large nurseries have respective storage capacity which makes operation easier, smaller don't have these. (…) You have to be able to deliver large quantities in the open time windows for*

planting. But they must also recognize that they must hit the goals of quality and delivery and precision that are important for our system. That needs to be clear from the beginning."

SSI8: "*There's a threshold where it can be feasible. If production is too small, it simply won't work. And then it's better to let it go economically*."

Exchange on business and (confidential) production practices is also seen critically, in that forest nursery managers do not want to discuss these issues openly for fear of competition (e.g. SSI10), which is of course a valid concern.

SSI10: *"[On] economical issues and such […] I'm not sure how much people want to share, that would be business secrets and other things that involve the business, that is not something people want to openly discuss. Or when does it become like a competition.*"

In some countries, especially in Eastern Central Europe (where actually imports from foreign sources are not allowed for native species), nurseries are in opposition to international cooperation in plant production:

SSI6: "*The concern is that [plants from foreign nurseries] actually flood that other market. (…) So the fear is that those countries that have better climatic conditions will put pressure on us here.*[…] *So there is a problem in terms of the transfer of planting material between those countries, but it is also to protect the market and actually those producers.*"

SSI5: "*The biggest challenge of international trade is whether or not they break the borders and allow imports, but that's not good for us because they will just overwhelm us.*"

Also further trade of seeds (e.g. from Eastern Central Europe to other regions, for a higher price) is seen critically in the source countries:

SSI11: "*If [foreign nurseries] take [seeds] out of the country, so if they take even more than [what is already being sold], then they will basically kill us in the long run*."

SSI24 suggests "*Facilitating international cooperation could be achieved through the allocation of [EU] funds for this purpose.*"

One respondent had very clear ideas on how a collaboration platform could be organized:

SSI11: "[*To] make a website where we can track what [seed] is available: I need 10 kilos of pear seeds, if I can click on it, they can send me 10 kilos of pear seeds. […] But if there was a secure source of this, where I could buy seeds, I would certainly choose it, because the basis for a secure production is to be able to buy a good quality basic propagating material. That would be the first [step], the second one is to really bring these customer and producer sites closer together. The needs should be open and timely, rather than this ad hoc production that we're involved in [now], so one of those options would be the contract production.*"

The role of EFNA in influencing policy makers, has been especially important to create a dialogue among European forest nurseries and to unify the complex sector in Europe. It has become an important platform for the forest nursery sector for exchange on policies and legislation, plant diseases and technical issues. EFNA has also been regularly invited to policy events organized by the EU (Directorate-General for Environment [DG ENV] and others; e.g., https://data.consilium.europa.eu/doc/document/ST-12232-2023-INIT/en/pdf), the OECD, and other organizations dealing with FRM (e.g. national forest nursery associations). It is the main contact for policy makers who want to interact with the forest nursery sector and also has been involved in the recent exchanges with the EC on the novel regulation towards FRM which is currently being developed. (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:415:FIN). At present, EFNA has members from 14 countries, i.e. Austria, Belgium, Czech Republic, Denmark, France, Germany, Hungary, Iceland, Ireland, the Netherlands, Norway, Portugal, Sweden and the UK.

6. Conclusions and recommendations

In Deliverable D6.1, we provide a first status report on the forest nursery sector in Europe. It provides an overview of the production capacity of European forest nurseries, market organisation in different countries by input from National FRM Authorities, and identifies barriers and suggests steps (tools and methods) to be taken to expand production capacity and FRM diversity. The obstacles to efficient production and the potential for up-scaling have been determined through online questionnaires towards forest nurseries and seed providers and through semi-structured interviews with selected nurseries from all European regions. In this way, difficulties in the terms of the market (production lag, planning uncertainties), seed provision, problems concerning workforce retention and development, among other issues, have been identified as main barriers for efficient FRM production and expansion of production at least by some of the explored nurseries. While this is not representative of the full situation, it provides important data of the positions and visions of a large number of the actors directly involved in the management of forest nurseries.

The estimated production capacity of European forest nurseries is currently around 3 billion plants. Given the EU target of planting additional 3 billion trees by 2030, our data show that this goal can potentially be reached, as most forest nurseries currently are not producing at full capacity. However, production capacity is strongly concentrated in Northern and Central Europe, with very low capacity in Eastern Europe. Data gaps were also identified in that comprehensive data were not available for all European countries, so that our result is only an estimate of the true number of seedlings produced annually in European forest nurseries.

The highest FRM production capacity among all defined regions is found in Central Europe. During the last decades the number of forest nurseries has declined considerably in the region due to changes in general demand (priorization of natural regeneration, lower planting densities), but also the risks associated with a spot market system. Long production times and unsecure sales, along with lack of specific or volatile subsidies, problems in seed availability, and problems in recruiting staff, along with rising production costs (staff, energy, consumables) are the main problems observed by the majority of forest nurseries there, particularly in the private sector.

In Northern Europe the market is differently structured with few but very large nurseries. Here, production is mainly done on pre-order; this results in higher stability of forest nurseries. Strong changes of general demand (mainly due to changes in recommended planting density) are also impacting nurseries in this region.

In South-Western (excluding Portugal, the UK and Ireland) and Eastern Europe, forest nurseries have played a minor role for afforestation in the past due to predominant reliance on natural regeneration, but are becoming more important due to forest restoration efforts and major calamities in the wake of climate change (e.g., storm damage, bark beetle outbreaks, forest fires). The market in South-Western Europe (due to the broad geographic scale chosen in our report) is quite heterogeneous. Spain, France, Italy, and Greece have low production capacities relative to the country size associated to dominant natural regeneration, while in Portugal artificial regeneration dominates. In Italy innovative approaches are being developed to increase production capacity through the cooperation between public and private nurseries to provide sufficient FRM to keep devastated areas forested and to mitigate climate change effects. In the UK and Ireland, the rate of artificial regeneration is traditionally high, but forest cover overall is low.

In Eastern Europe, public nurseries dominate, mostly organized in a high number of small nurseries with respective low production capacity. Rigid bureaucratic schemes and lack of funds at the national level can make the expansion of production capacity difficult for these nurseries.

European forest nurseries work in a highly regulated workspace, producing a niche product, often under high economic risks. To improve the sustainable development of forest nurseries

in Europe market participants, policymakers and stakeholders need to be aware of the production environment in the different regions. The most common barriers for forest nurseries to expand production and have sustainable business operations in all European regions were identified through an online survey with 278 respondents and 25 semi-structured interviews with selected nurseries. The most common barrier was related to production planning. The production of saleable plants (FRM) usually takes several years, and in many cases at the end of the production process, sales are not guaranteed; overall due to this phenomenon around 10% (often more) of the total annual production have to be destroyed because it cannot be sold.

Increasing challenges in seed sourcing significantly complicate production planning for a large proportion of forest nurseries in Europe. The difficulty in obtaining high-quality seeds, driven by logistical issues in seed collection, is further exacerbated by the impacts of climate change on seed production. This is particularly evident in Eastern and Central Europe but is increasingly becoming an issue in the other regions as well. Additionally, subsidy schemes often recommend changes in species or provenances to be used, but seeds for these may not be readily available, placing additional strain on nurseries to procure them. These factors collectively add substantial complexity to the planning decisions forest nurseries must make.

Problems in recruiting skilled staff has been reported by a large proportion of respondents and has also been described in the available literature (e.g. Whittet et al. 2016b; Friedrich 2022; Rantasa & Kraigher 2024). While unskilled workers are increasingly difficult to find for re-planting and packaging, but also for seed harvests, this can be compensated to a certain degree by investing into automatization and mechanization. However, the lack of specialist staff is a severe problem on the long-term, since the FRM market is too small for a specific line of education in several countries. Also, competition with horticulture (higher salaries) is a significant factor in this respect.

Our results show that cooperation (also international) among nurseries is generally seen in a positive way by most nurseries, especially when it comes to knowledge sharing and lobbying for interests at the EU level. Concerns of some nurseries about sharing of market access are obvious.

The lack of a general strategy for species and provenance choice in relation to climate change mitigation efforts (i.e., assisted gene flow or migration) is an important factor that adds to the complex interaction between FRM production and deployment and market demands. In this respect OptFORESTS is set to develop suggestions for a strategy for FRM deployment (Task 6.3); the status report presented here is a very important part to develop this strategy. Due to the diversity in forestation rate, importance of wood production, mode of regeneration, ownership structure and not least the structure of the respective forest nursery sector, each country needs to invest in its own forest strategy for the future. The increase of forest area (the goals of the 3 Billion Trees Pledge) can only be done through national/international strategies; ensuring the need for FRM must be part of this strategy. In a consecutive task, OptFORESTS is set to develop regional pathways for expanding the production capacity of nurseries (Task 6.4).

For exact information and development of policies at the EU level, it would be very much needed that data on FRM production is recorded every year in every member country and respective statistics are made available to the EC and the public. The current FRM Directive asks only for National Authorities "*to assist each other administratively in order to obtain appropriate information necessary to ensure the proper functioning of [the] Directive, particularly where forest reproductive material moves from one Member State to another.*" Also, this data transfer is not analysed or published on a regular basis, so the motivation of member countries to report the data is low. As already asked for by Jansen et al. (2019) the implementation of a centralized European FRM database would provide a reliable dataset.

In conclusion to our findings, we make the following recommendations to increase sustainable FRM production to cope with the current challenges:

1. Improve planning for nurseries through development and implementation of pan-European and national forest strategies considering FRM production, the implementation of long-term commitment for stable subsidies, and increased direct support to forest nurseries thorough specific subsidies.
2. Install regular stakeholder dialogue when developing policies and funding schemes associated to FRM production. Consensus approaches for effective implementation of national and Pan-European strategies are needed for sustainable business operation of forest nurseries; this dialogue should include policy makers, funding agencies, scientists, seed providers, forest nurseries, and forest owners.
3. To counteract shortage in staff, investments should be done to provide specialized education for expert and skilled staff. Also in this respect, international cooperation should be implemented. Further development of and investments in automatization and mechanization should also be supported to reduce the demand for manual labour which will continue to be difficult to be found.
4. Seed sourcing logistics (information on harvest opportunities, access to seed stands and orchards) should be supported from general forest administration whenever possible and needed. More seed orchards, and seed processing and storage facilities need to be installed for proper provision of high quality and quantity of seeds to cover the increased need for FRM. This could be achieved through the public or public private partnerships where needed (all regions except Northern Europe where demand currently appears to be stable); also improved guidelines for long-term management of seed stands for optimum seed production should be developed. Respective subsidies should be provided to accelerate the process.
5. The instalment of a network of forest nurseries supporting each other is seen positive in most regions, except in Eastern-Central Europe. Such a network needs to be formed gradually, as common business operations strongly depend on mutual trust. The network could build on the existing EFNA, this association already has increased dialogue and knowledge exchange among European forest nurseries in several European countries. In this way, a larger community of forest nurseries can be created. Regular knowledge exchanges (webinars, meetings, excursions…) may eventually make FRM production in Europe more effective.
6. In regions with low production capacity but rising demand (particularly in Eastern and South-Western Europe), the model currently being developed in Italy through the cooperation of established (public) nurseries with horticultural nurseries or new market participants could be very effective in rapidly increasing production numbers and should be implemented more broadly: the established nurseries could take over the production of small seedlings, which after establishment could be transferred to the less experienced market participants for further cultivation. International cooperation should also be intensified in this respect. Specific grants could provide support to improve capacity of established nurseries and - given long-term market demand - to establish additional nurseries in regions with low production capacity.

Forest nurseries are an integral and essential part of sustainable forest management, climate change mitigation and nature restoration in Europe. Based on the available data, this report has collated a status report on European forest nurseries in terms of production capacity, barriers to sustainable production and ways to improve cooperation among nurseries. Our results show that the inclusion of all stakeholders (forest managers, policy makers, forest nurseries, scientists, etc.) is necessary when developing further support and solutions. This report only deals with the situation of the forest nurseries in Europe. It does not consider the additional steps in the reforestation pipeline, e.g. out-planting and post-planting operations that would be needed to fulfil the ambitious targets of the European policies including the 3 Billion Trees Pledge of the EU. We hope that our results lay the foundation for future informed

decision-making processes, in which the decisive role of forest nurseries to reach the ambitious goals for the future development of European forests are adequately recognized.

7. Project outputs achieved

In Deliverable 6.1 of the EU Horizon Europe project OptFORESTS, we provide the first comprehensive status report on European forest nurseries. We provide an overview of the structure of the sector in Europe, as well as an estimate of the current production capacity. Impediments for efficient FRM production of forest nurseries were identified and discussed in detail; recommendations to overcome these challenges are presented, including views on improved of cooperation among forest nurseries. This constitutes one main key result of the project and provided valuable information for following tasks in WP6 and associated workpackages.

8. Planned publications

Based on the results of this report, we are planning for several publications related to the complexity of the European forest nursery sector and the challenges it currently faces.

First, we are planning for a high-impact publication on production capacity and the chances and challenges to fulfil the needs of the European "3 billion trees pledge" (e.g., to be published in *PNAS* or other general scope scientific journal). In addition, we are considering a publication on the impediments for implementation of assisted migration in relation to forest policies in Europe related to nursery production (to be published in, e.g., *Forest Policies and Economics* or *Forest Ecology and Management*). Finally, a publication on the possibilities for cooperation in the FRM producing sector will be prepared (e.g., for Land Use Policy).

In addition, the results of this deliverable will be published also especially for stakeholders in professional magazines in the respective country languages (e.g., AFZ – Der Wald).

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11. List of figures

12. List of tables

13. List of abbreviations

ADB	ash dieback disease
B4EST	EU H2020 project B4EST (https://b4est.eu/)
BFW	Austrian Research Centre for Forests
CZU	Česká zemědělská univerzita v Praze (Czech University of Life Sciences Prague)
EC	European Commission
ETIFOR	Etifor Srl Società Benefit, Padova
EU	European Union
FRG	Forest genetic resources
FRM	Forest reproductive material
FSCS	Executive Forestry Agency, Bulgaria
GIS	Gozdarski Institut Slovenije (Slovenian Forest Institute)
INCDS	National Forestry Research-Development Institute „Marin Drăcea”, Romania
Luke	Luonnonvarakeskus (Natural Resources Institute Finland)
NA	national authorities (responsible for FRM)
NIBIO	Norsk Institutt for biookonomi (Norwegian Institute of Bioeconomy Research)
NNTS	non-native tree species
OECD	Organisation for Economic Co-operation and Development
ONF	Office national des forêts (French National Forests)
TRAGSA	Empresa Transformación Agraria, S.A.
UCPH	Københavns Universitet (University of Copenhagen)
UNIPD	Università di Padova (University of Padova)

14. Annexes

Annex 1 – Nursery production essentials

Annex 2 - National Authority Questionnaire

Annex 3 – Online Forest Nursery Survey (English version)

Annex 4 – Online Seed Provider Survey

Annex 5 – Interview Guidelines for Semi-Structured Interviews (SSIs)

Annex 6 – Full list of replies of respondents to views on available incentives (section 5.2.5)