Conservation and sustainable use of Forest Genetic Resources for Food and Agriculture

Country report of the Netherlands for the Second State of the World's Forest Genetic Resources for Food and Agriculture

Ministry of Agriculture, Nature and Food Quality, The Hague

WAGENINGEN UNIVERSITY & RESEARCH

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This research was conducted by Centre for Genetic Resources, the Netherlands, commissioned and funded by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV), within the framework of Policy Support Research theme 'Sustainable food supply & production chains & nature' (project number BO-43-023.01-041).

Centre for Genetic Resources, the Netherlands (CGN), Wageningen University & Research
Wageningen, July 2021

CGN Report 54

WAGENINGEN UNIVERSITY & RESEARCH

Ministry of Agriculture, Nature and Food Quality of the Netherlands

LNV, 2021. *Conservation and sustainable use of Forest Genetic Resources for Food and Agriculture; Country report of the Netherlands for the Second State of the World's Forest Genetic Resources for Food and Agriculture.* Centre for Genetic Resources, the Netherlands (CGN), Wageningen University & Research, CGN Report 54. 68 pp.; 9 fig.; 4 tab.; 119 ref.

Dit rapport beschrijft de huidige staat van genetische bronnen van bomen in Nederland en de belangrijkste factoren die van invloed zijn op deze genetische bronnen. Het rapport geeft aanvullende informatie op de eerder ingevulde vragenlijst voor de *First Report on the implementation of the FAO Global plan of action on Forest Genetic Resources.* De Nederlandse informatie in het rapport wordt FAO gebruikt voor de *Second State of the World's Forest Genetic Resources for Food and Agriculture*.

This report describes the current state of the Dutch forest genetic resources and the most important factors influencing them. It gives complementary information to the previously-submitted questionnaire on the *First Report on the implementation of the FAO Global plan of action on Forest Genetic Resources.* The Dutch information in the report will be used by the FAO as input for the *Second State of the World's Forest Genetic Resources for Food and Agriculture*.

This report can be downloaded for free at http://doi.org/10.18174/550632 or at http://www.cgn.wur.nl/cgn under publications.

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CGN is ISO 9001 certified.

Contents

Preface

This national report is the Netherlands' contribution to the second FAO assessment of the State of the World's Forest Genetic Resources for Food and Agriculture. The report has been compiled by a working group coordinated by the Centre for Genetic Resources, the Netherlands (CGN) and guided by an advisory group.

The report consists of a detailed analysis of the state of the Dutch forest genetic resources and provides a factual overview of the challenges and the opportunities we face in improving the management of these resources. The timing of the report is aligned with the Dutch and EU forest strategy, in which the conservation of genetic resources is addressed explicitly. With increasing pressure from climate change, having healthy genetic resources will be key to preserving the forests in the Netherlands to prevent their degradation and to enhance their resistance to pests and diseases, so that they can provide the ecosystem services for which they are so highly valued.

The Dutch forest strategy has the ambition of expanding the Dutch forest area by 10% in 2030. This report addresses the challenge of providing sufficient planting material in terms of quality and quantity necessary to achieve this ambition. Furthermore, the in situ conservation has made limited progress the past ten years. This can be improved by providing formal protective status to the gene conservation units and improving cooperation between different government organisations, so that the in situ conservation can be incorporated better in their nature policies. With regard to the ex situ conservation, the report states that there are still major challenges that should be addressed to improve the Roggebotzand collections' contribution to the availability of autochthonous planting material. The collection should be further expanded, better integrated with in situ conservation and duplicated to prevent the loss of valuable genetic resources. Finally, more emphasis should be placed on communication and awareness should be raised of the forest genetic resources' value and their role in the transition to more future-proof Dutch and European forestry.

I would like to thank the CGN working group for drafting the report and the members of the advisory group for their valuable input.

Donné Slangen
Director of Nature, Ministry of Agriculture, Nature and Food Quality

Executive summary

In 2019, the Food and Agriculture Organization of the United Nations (FAO) invited the Dutch Government to prepare a second national report on forest genetic resources in connection with the preparation of the second report on the State of the World's Forest Genetic Resources. The national report describes the current state of Dutch forest genetic resources and the most important factors that influence the state of conservation and sustainable use of these resources. The report gives complementary information to the previously-submitted questionnaire on the First Report, on the implementation of the FAO Global plan of action on forest genetic resources. The national report is considered a strategic policy document.

In this report, the following definition of forest genetic resources is used, as given in Annex 3 of the Guidelines for the preparation of the country report: the term 'forest genetic resources' (FGR) refers to heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific or societal value.

The first chapter presents a narrative of the role of forests and the forest sector in the Dutch economy and describes the current contribution of forest genetic resources to sustainable development. Chapters 2 and 3 describe the state of diversity in forests and woodlands, the trends that are shaping them and the challenges and opportunities these trends create for the conservation, and the use and development of forest genetic resources. Chapter 4 and 5 provide information on the overall diversity and state of genetic diversity of tree and other woody plant species that are considered as 'forest genetic resources' and managed or utilised in the forestry context. Chapters 6 and 7 describe the current situation of in situ and ex situ conservation of Dutch forest genetic resources and needs, challenges and opportunities for improving. Chapter 8, 9 and 10 provide information on the state of use, tree improvement, breeding programmes and the management of forest genetic resources. Chapter 11 and 12 give updated information on the state of capacities, institutions and policies related to the conservation and use of forest genetic resources, and on involvement in international and regional cooperation. The last chapter summarises the recommendations for further actions to strengthen the conservation, use and development of forest genetic resources in the Netherlands. Additionally, limited information is given in Annex 1 on the forest genetic resources of the Caribbean islands of Bonaire, St. Eustatius and Saba.

The report has been prepared by an advisory group representing the main stakeholders in the sector in the Netherlands and is written in accordance with the guidelines provided by FAO.

Value and importance of forest genetic resources
Forests and the forest sector have a modest position in the Dutch national economy. Nevertheless, forests in the Netherlands are highly appreciated for their social value. Forests and their genetic resources are essential for sustainable development in the Netherlands. Recognised values and ecosystem services include biodiversity, recreation and tourism, wood production, climate regulation (e.g. carbon sequestration), air purification and the production of drinking water. A national Forest Strategy was published by the Ministry of Agriculture, Nature and Food Quality and the provinces in 2020. The Strategy includes ambitions and goals that will be elaborated on in measures that contribute to healthy, climate-smart, future-proof and socially valued forests. For this, a quality impulse is needed in current forests, as well as an expansion of total forest area. In order to implement the ambitions of the new Forest Strategy, the value of forest genetic resources for (e.g.) timber quality, climate adaptation, resistance to pests and diseases, wood production and the use of genetic diversity to support resilience of forests deserve greater attention. Therefore, there is a need to raise further awareness in society and the forest sector about the importance of genetic resources for Dutch forestry. The intended expansion of the Dutch forest area by 10% will lead to an increased demand for planting material. Greater requirements will be placed on the choice of planting materials and tree species, due to effects of climate change on forests, as well as choices on the importance of

autochthonous populations and native species for the conservation of biodiversity. In this regard, the National List of Recommended Varieties and Provenances of Trees (www.rassenlijstbomen.nl) is an important source of information for choice of forest reproductive material.

State of forests

The Netherlands is densely populated and its land is used intensively. This causes great land-use pressures, which also affect the forest area: in the period 2013–2017, an area of approximately 12,145 ha was deforested. In addition to this decrease in forest area, the quality of the Dutch forests is also of great concern, as forests are under pressure from nitrogen deposition, dehydration and fragmentation, which negatively affect all forest functions and biodiversity in particular. Climate change is adding further pressure and enhances other stress factors, such as drought, pests and diseases. The Forest Strategy wants to reverse this negative trend and is therefore mainly focused on the restoration of biodiversity, increasing resilience and counteracting deforestation. A programme called ‘Climate smart Forest and Nature management’ has been started to support forest and nature managers with measures to increase forest resilience, such as with the selection of tree species, revitalising forest stands and postponing harvests. An important action point in the Forest Strategy is the plan to expand forest area by 10% (ca. 37,000 ha). The challenge is finding land area where forests can be planted. A balance of forest functions also has to be made – between timber production and biodiversity – which will be a challenge given current public opinion. To strengthen biodiversity and create more resilient forests, the ‘Climate smart Forest and Nature management’ programme also aims to increase knowledge and to improve communication on climate-smart forest management. It is expected that there will not be an adequate supply of forest reproductive material (FRM) in the coming ten years to realise the planned forest expansion of about 37,000 ha. In addition to quantity, there is a need to pay attention to the genetic quality of FRM for the sake of climate change, biodiversity and high quality timber production.

State of other wooded lands

Woody landscape elements outside forests in the Netherlands include hedges, woodlots, coppices (willow) and urban green spaces. These elements cover about 3.2% of the rural land area in the Netherlands. The new Forest Strategy is aiming to create more wooded landscape elements by 2030. New insights will be gained into how the expansion of forest area may contribute to climate adaptation (carbon storage), regional energy strategies (woody biomass), circular agriculture, decrease nitrogen deposition (air filtering), agroforestry (e.g. forest gardening), urban well-being (temperature regulation and recreation). There is also growing demand for forest reproductive material to extend these rural woody landscape elements. The expansion and protection of woody landscape elements can also bring new opportunities for in situ conservation of the genetic resources of trees and shrubs, particularly if landscape elements are restored or planted with autochthonous source identified (SI) genetic resources. Agroforestry, which is still a rather new system in the Netherlands, will also impose new requirements on the choice of species, the provenance or variety used and the traits the landscape elements need. Woody plants (shrubs and trees) can help to improve the liveability of cities, but tree species and varieties need selected carefully to ensure that they are adapted to the urban climate and site conditions, and that they are less vulnerable to pests and diseases.

State of diversity between species

Over the last decade, more species have been planted in forests, as forest management has been aiming to increase the diversity of tree species, placing more emphasis on native tree species/biodiversity and improving forest resilience. Consequently, the ratio of deciduous to coniferous trees has increased at the expense of Scots pine in favour of native oak and, to a lesser extent, beech and birch. The number of introduced species has increased slightly as, in light of climate change, foresters have been seeking alternative species that are able to cope with more frequent drought spells. Lesser known species that are currently planted experimentally are exotic species that are native to Europe, like *Abies alba*, *Sorbus torminalis* and *Corylus colurna*. As an alternative to ash, the population of which declined due to ash dieback, other exotic species that are being considered include *Liriodendron tulipifera*, *Carya ovata* and *Juglans regia*. In the context of agro-forestry and forest gardening, other introduced species are also being planted. Attention should be paid to the risks of introducing new species, which can be invasive and potentially pose a threat to biodiversity and can affect autochthonous forest genetic resources, especially when forest gardens are being developed in the proximity of forest and other nature areas.

State of diversity within species

Current knowledge of the state of genetic diversity in forest trees and shrubs in the Netherlands is limited as there have only been a few studies conducted that asses the level of genetic diversity in populations of forest species. The state of populations of species based on inventories or expert opinions forms an indication of the existing genetic diversity. Better knowledge of genetic diversity using molecular technology is needed to prioritise conservation efforts and to better utilise genetic diversity. Research is needed to gain insight into the adaptive potential of autochthonous gene resources (or lack thereof) to set priorities in protecting and restoring these local populations and to enable forest managers to include genetic aspects in their adaptive management strategies to enhance the resilience of forests.

In situ conservation of forest genetic resources

Nowadays, about half of native tree and shrub species, in the context of autochthonous genetic resources, are under threat. They persist as fragmented small, often isolated, populations or as single trees. About 70% of the oldest, most valuable landscape elements and ancient woodlands have now been inventoried for autochthonous forest genetic resources. Together, they account for only 3% of the total area of national forests and landscape elements. For species for which in situ conservation is still feasible, existing natural populations are protected in gene conservation units[1] and registered in the European Forest Genetic Resource Inventories (EUFGIS). Progress to extend the number of gene conservation units has been limited in the past ten years. To date, there are a total of 27 gene conservation units for 23 species, comprising a total of 580 hectares. The main constraint for improving in situ conservation is that the established gene conservation units have no formal legal status and this may endanger their conservation in the long-term. Better co-operation is needed between provinces and civil society organisations on how to incorporate genetic conservation of tree species in their nature policies. Although there is increasing awareness of the value of autochthonous populations and woody landscape elements, proper management and regular monitoring of these populations for long term conservation could be improved.

Ex situ conservation of forest genetic resources

Over the past ten years, the number of ex situ collections of autochthonous trees and shrubs (e.g. gene bank Roggebotzand) has increased steadily. The number of accessions has grown from 3,735 accessions in 2011 to 4,790 in 2019, while the number of species conserved in these field collections has increased from 48 to 56 species in this same period. New species that have been added to the collection include *Frangula alnus*, *Genista anglica*, *Ilex aquifolium*, *Lonicera periclymenum*, *Salix repens*, *Sambucus racemosa*, *Taxus baccata* and various *Rosa* species. The collections of *Fraxinus excelsior* have almost been completely lost due to ash dieback. Further development and optimisation of the collections is important, with a focus on species that are most at risk (‘priority species’) and for which no ex situ measures have been taken yet. The number of collections registered as seed source has increased substantially over the period 2012–2020. This registration of collections in the national register has contributed to the increased utilisation of the collections. Further development of these collections will provide opportunities for supporting the use of genetically diverse plant material in afforestation and restoration activities in the near future, as there is increasing demand for forest reproductive material. As threats to autochthonous forest genetic resources are increasing with climate change, the occurrence of new pests and diseases and infrastructure projects, ex situ conservation measures, such as seed banking, may become more important in the future. There is a need to invest in the knowledge development of seed banking and cryopreservation technology in order to implement these ex situ methods for the long-term conservation of trees and shrubs and the establishment safety-duplications in back-up collections.

[1] Forest areas managed for the maintenance of evolutionary processes within tree populations to safeguard their potential for continuous adaptation.

The state of use of forest genetic resources

The Netherlands has a well-functioning seed programme designed to ensure the availability of genetically appropriate seeds in the quantities and of the quality needed for new plantings. Since 2012, the number of species for which seed stands are listed in the National register has increased from 66 to 86, as of 2019. Seed harvest from seed orchards has generally increased throughout this period (with the exception of ash) compared with earlier years (2007–2011). However, the demand for FRM from new species that have hardly used in Dutch forests up until now is increasing due to climate change. It will be a challenge to derive high quality FRM from known seed sources, especially from non-EU directive species. In the past ten years, efforts to promote the appropriate use of FRM have been made, but progress to date has been variable. There is a need to further improve the traceability of FRM, its transparency throughout the chain and end users' increase knowledge on the advantages of using high quality planting material. A voluntary system has been promoted recently, where forest owners can share basic information of and their experiences with species and provenances, but unfortunately, in the past, precise details of provenances were not usually stored.

The state of genetic improvement and breeding programmes

The supply of genetically improved forest reproductive material relies on tree improvement programmes. Despite this, tree improvement activities and the number of seed orchards has declined over the past ten years. A clonal collection of *Fraxinus excelsior* has been set up, to be used for future breeding activities in relation to ash dieback caused by the fungus *Hymenoscyphus fraxineus*. Provenance testing has continued over the past decade with a focus on broad leaved species. Since 2012, several new provenance trials have been established, where climate matched provenances have also been included. There is a need to continue provenance testing, especially because many forest managers have an interest in applying climate assisted migration and introducing new species. There is a need to renew existing seed orchards, which were mostly established between 1960s and the 1990s, and establish new ones, including ones for new species. Development of tree improvement and breeding programmes with a focus on resistance to pests and diseases needs more attention.

Management of forest genetic resources

Climate Smart Forestry has been introduced as way to mitigate climate change and to achieve adaptation goals in forests and the forest sector in the Netherlands. Recently, the 'Climate smart Forest and Nature management' programme began communicating about and researching into this approach. In the context of this approach, there is also a need for more improved FRM and a wide range of species. Forest managers have a responsibility in using a variety of management and silviculture measures to influence the genetic composition of their forests in order to adapt their forests to better cope with climate change. However, forest owners have different views on how to approach this. There is an interest amongst forest managers for using new (non-native) species and foreign provenances, which bring their own risks, while others prefer the use of natural regeneration and using local materials. More research is needed to gain further insight into the role of native species and existing provenance diversity for coping with climate change, and the advantages and disadvantages of introducing species and new provenances.

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

The various actors involved in the conservation and use and development of forest genetic resources have not changed over the past ten years. In the national policy on genetic resources entitled 'Sources of Existence', which includes forest genetic resources (LNV, 2002), the government of the Netherlands outlines how it will approach its international obligations regarding genetic resources. Until now, this policy document has been considered relevant. Over the past ten years, substantial efforts have been put into knowledge transfer and raising public awareness of forest genetic resources. In 2012–2015, the contents of a Green Deal, 'Weet Welk Plantmateriaal Je (Ver)Koopt!', were carried out to improve knowledge and communication about the quality of plant material for forestry purposes, including on genetic aspects. However, it is still necessary to communicate and raise awareness about the value of forest genetic resources, the role they play in the transition to a more sustainable and resilient form of forestry, whether this is production forests, nature forests or trees in suburban landscapes.

International and regional cooperation on forest genetic resources

At the European level, the Netherlands has actively contributed to the European Programme for Forest Genetic Resources (EUFORGEN) network, particularly to developing a European conservation strategy for forest genetic resources. The Netherlands also benefits from scientific knowledge exchange within the EUFORGEN network and collaboration in a variety of EU research projects. However, there is a need to improve the implementation of the European forest genetic resources conservation strategy on a national level through enhanced communication and dissemination of knowledge to policy makers and forest managers.

Recommended actions for the future

In contrast to knowledge on changes in species diversity there is a lack of information and knowledge on changes at the intra-specific and genetic diversity level of Dutch forests. Actions required to better the availability of information on FGR include: 1) the proper identification and mapping of in particular autochthonous populations of the native tree and shrub species, 2) efforts being made into genetic characterisation to support conservation and inform us about the potential use and value of FGR, in particular to better use the (adaptive) genetic diversity that exists within in situ autochthonous populations and in the gene bank collections, 3) to monitor the trends in and risks to autochthonous forest genetic resources using EUFGIS.

Integrating ex situ conservation and in situ strategies will become more important. It is recommended to further develop and optimise the gene bank collections with a focus on species that are most at risk ('priority species') and to take measures for safety duplication. Plant material from the gene bank needs to be used more for restoration and population enrichment projects for rare or endangered species, especially in N2000 areas. In situ gene conservation should be strengthened for species where this is still possible; this includes the designation of more gene conservation units (EUFGIS).

In view of the foreseen expansion of forest area, more variety of FRM will be needed more than before. Promoting awareness of the fact that that planting material should be genetically suited to the sites where it is planted is still necessary. The supply of genetically improved forest reproductive material relies on tree improvement programmes. Establishment of first generation seed orchards of new species and the improvement or rejuvenation of existing ones should be considered. The development of breeding programmes with a focus on resistance to pests and diseases needs more attention. A data information system for keeping records of where FRM is planted should be encouraged.

The Forest Strategy recognises that making use of genetic diversity and genetically appropriate plant material can be an important measure in enhancing resilience in Dutch forests. Therefore, efforts to raise further awareness of the roles and values of these forest genetic resources in diversification in forests and forestry needs to be continued. It is important to raise awareness among provinces and nature conservation organisations on the importance of incorporating genetic conservation of tree species in their nature policies. Opportunities for enhancing the in situ conservation of forest genetic resources in the National Nature Network NNN and Natura 2000 network should be explored, for example, through existing instruments or measures (e.g. subsidy schemes).

1 Value and importance of forest genetic resources

In this report, the following definition of forest genetic resources is used, as given in Annex 3 of the Guidelines for the preparation of the national report: 'forest genetic resources' (FGR) refers to the heritable materials maintained within and among tree and other woody plant species that are of actual or potential economic, environmental, scientific or societal value. Forest genetic resources are embedded in forest reproductive materials and include seeds, seedlings and other propagules.

1.1 The role of forests and the forest sector in the national economy

With a forest area of only 10% and a forest sector with an added value of EUR 6 billion – about 0.9% of national GDP in 2012 (CPB 2020) – forests and the forest sector have a modest position in the national economy. Nevertheless, forests in the Netherlands are highly appreciated for their social value, as shown by media discussions on subjects, such as on the use of woody biomass for energy purposes, the cutting down of forests for the restoration of heathlands and the closure of forests and nature areas during the coronavirus pandemic to avoid issues with crowds.

In general, forests in the Netherlands are multifunctional. Recognised values and ecosystem services include biodiversity, recreation and tourism, wood production, climate regulation (e.g. carbon sequestration), air purification and the production of drinking water (Melman and Van der Heide 2011, Melman and Hendriks 2012, Horlings et al. 2020).

With regard to the economic value of the Dutch forest and wood sector, Silvis et al. (2015) reported that there were 69,000 jobs in the forest and wood complex over the period 2010–2012. In 2019, there were about 39,000 direct jobs in the forestry and wood processing sector of a total 10.8 million jobs in the Netherlands in 2012 (CBS 2020a).

1.2 Economic, environmental, social and cultural values of forest genetic resources

In the Netherlands, domestic wood production covers about 24% of total wood consumption, including energy applications. With regard to solely material applications, the self-sufficiency degree is only 8.5% (Oldenburger 2019). Consequently, up to 90% of the wood used is imported, most of which is European grown. Harvested wood products are processed partly in the Netherlands and partly abroad (mainly in Germany, Belgium and France). All necessary forest industries for processing roundwood are present in the Netherlands, such as paper mills, saw mills, the plate industry, the pole industry and the Dutch clog making industry (Oldenburger 2012). Roughly one third of the total wood use is used for paper and cardboard, one third for saw wood and board materials and one third for energy and other applications (Oldenburger 2019).

The value of the Dutch forest and wood sector is estimated at EUR 6 billion. The wood processing industries are accountable for the largest part of the added value (about 50%). The supply and distribution sector follow with 35% and 13% of added value respectively. The primary wood production sector only accounts for 1.6% (Nabuurs et al. 2016).

Horlings et al. (2020) developed an experimental method for calculating the monetary value of ecosystem services and their assets for Dutch rural areas, which concerns more than only forests areas. In 2015, the value was calculated for ten ecosystem services: crop production, grass production, timber production, water filtration, carbon sequestration, pollination, air filtration, nature recreation, nature tourism and amenity services. The estimated annual flow of the ecosystem services ranged from EUR 6.3 to 12.9 billion, depending on the expenditures that were included in the estimates of tourism and recreation (limited to broad scope). The total asset value was estimated between EUR 208 and 418 billion. The value of forest ecosystem services was not calculated separately, but was estimated at 16% of the total value of the tourism and recreation broad scope estimates. In 2015, the value of timber production (stumpage prices of annual fellings) was estimated at EUR 44 million, which is in the same order of magnitude as the timber value calculated by Nabuurs et al. (2016). Nature related recreation, tourism and amenity services were estimated at EUR 4.2–10.9 billion (Table 1.1). Thus, in these estimations, cultural values represent a much higher value than timber production values. For example, State Forest Service areas receive about 150 million annual visits (www.staatsbosbeheer.nl).

Table 1.1 *Value of ecosystem service flow and associated asset values in 2015 (millions of euros) (Horlings et al. 2020).*

Class	Ecosystem service	Broad scope estimates of tourism and recreation		Medium scope estimates of tourism and recreation		Limited scope estimates of tourism and recreation	
		Flow	Asset	Flow	Asset	Flow	Asset
Provisioning	Crop production	415	13,125	415	13,125	415	13,125
	Fodder/grass production	872	27,569	872	27,569	872	27,569
	Timber production	44	1,381	44	1,381	44	1,381
Regulating	Water filtration	177	7,620	177	7.620	177	7,620
	Carbon sequestration	171	7,391	171	7,391	171	7,391
	Pollination	359	15,470	359	15,470	359	15,470
	Air filtration	86	3,700	86	3,700	86	3,700
Cultural	Nature recreation	3,873	122,394	2,992	94,552	2,012	63,586
	Nature tourism	5,946	187,880	3,392	107,198	1,146	36,218
	Amenity services	1,037	32,402	1,037	32,402	1,037	32,402
	TOTAL	12,981	418,931	9,546	310,407	6,320	208,461

1.3 The contributions of forest genetic resources towards relevant Sustainable Development Goals

Forests and their forest genetic resources are essential to sustainable development in the Netherlands. The contribution of forest genetic resources to towards Sustainable Development Goals are, in particular, to sustainable forest management, biodiversity and the sustainable use of natural resources (SDG15: Life on land), adaptation and mitigation of climate change, carbon sequestration (SDG13: Climate Action), recreation and clean air (SDG3: Good health and well-being), drinking water quality and quantity (SDG6: Clean water and sanitation), renewable energy (SDG7: Affordable and clean energy), bio-economy, efficiency of forest resources use and products from sustainable managed forests (SDG9: Industry, Innovation and Infrastructure). Genetic resources from the Dutch native trees and shrubs have not been used on a large scale in food security up until now (SD2: End Hunger). Recently, interest in agro-forestry and forests gardens has increased, partly because it has been stimulated by a Green Deal, which focuses on developing and sharing knowledge, and removing obstructive regulations when possible (www.greendealvoedselbossen.nl). The contribution of forests and forest genetic resources to SDGs are described in more detail below.

Forest area and sustainable forest management
Most Dutch forests are situated on former heathland with low soil fertility and other first generation forests (Van Goor 1993). On many of these, heather and drift sand reclamation areas pine was sown

or planted at the end of the 19th and beginning of the 20th century (Van Goor 1993, Van de Burg 1996). In the second half of the 20th century, forests were planted in the new Flevo polders, currently cover about 16,000 ha and are largely situated on relatively fertile clay soils and with substantial poplar stands (Schelhaas et al. 2014). Consequently, most forest areas are relatively young forest areas and the forest originally consisted of one species. Nowadays, most of the first generation forest has been replaced by a second or third generation. This is reflected in the mean age of the forest trees, which is 62 years old. Currently, many of the stands are mixed with two or more tree species (Schelhaas et al. 2014). Besides those young forest areas, there are also some older forest bodies, however, these are small and scattered over the country and the forest landscape (Rövekamp and Maes 2002, Copini et al. 2006, Bijlsma et al. 2009). These forest remnants and landscape elements harbour valuable autochthonous populations of trees and shrubs (Maes et al. 2013, Maes, 2016).

In 2018, about 171,000 ha of forest was FSC or PEFC certified meeting criteria for sustainable forest management (Probos 2018). The Dutch Association of Forest and Nature Owners (VBNE) has drafted a Code of Conduct to align forest management with nature regulations aimed at the protection of animal and plant species (VBNE 2014). Requirements for sustainable management are also imposed on forest owners when they apply for subsidies, for example, for maintaining the forest and forest types, opening up for recreation (walking and cycling), the amount of dead wood and the use of species (SVNL 2016 Subsidie Natuurbeheer SVNL | RVO.nl).

Over the past decade, forests have mainly been rejuvenated through natural regeneration and, consequently, demand for planting material has been low. The intended expansion of the Dutch forest area will lead to an increased need for planting material. Additionally, increasing requirements are being placed on the right choice of planting material and tree species, due to the effects of climate change on forests and the importance of autochthonous populations and native species for the conservation of biodiversity. The National List of Recommended Varieties and Provenances of Trees (www.rassenlijstbomen.nl) is an important source of information for choice of forest reproductive material with regard to this.

Sustainable use of wood products
In 2018, about 18.5% (2.7 million m^3) of annual wood consumption in the Netherlands was energy applications, mainly in private heaters and in power plants for electricity production. The amount of wood pellets required for energy production is expected to increase to 12 million m^3 in 2030 (Oldenburger et al. 2020), most of which will be imported. However, the use of woody biomass for energy purposes is part of public debate in the Netherlands. Only 8.5% is used for materials. It is mainly wood from deciduous species that is used as firewood. In general, wood from coniferous species is used more for purposes that require higher quality. Sustainable wood use can be improved by increasing of the percentage used for materials. By using high-quality wood, the products made will remain in circulation longer, so will retain CO_2 for a longer period. Possible high-quality applications could be the use of wood in the construction sector, where it will replace resources with high energy costs in the production phase, such as steel and concrete. High quality applications could also be found in the chemical sector, where wood biomass could replace fossil fuels. If there is a strong increase in high-quality wood in the construction sector in the Netherlands, the demand of sawn wood from coniferous species could increase up to 20 million m^3 and up to 4 million m^3 for plate material. It was calculated that this increase in wood demand could be produced in the European forest area (Oldenburger et al. 2020). Nabuurs et al. (2016) calculated that extra wood production in Dutch forests would account for only 2–3% of this increased demand for wood products.

Biodiversity
The relatively young site age is reflected in the biodiversity of Dutch forests, which is slowly developing towards more mature forest (Siebel 1996). The gradual replacement of pine stands by other species and mixed stands (Schelhaas et al. 2014) is affecting biodiversity. Since the year 2000, typical forest fauna species have shown a positive trend (Figure 1.1). In 2019, the index was, after a period of decrease, slightly higher than in 1990.

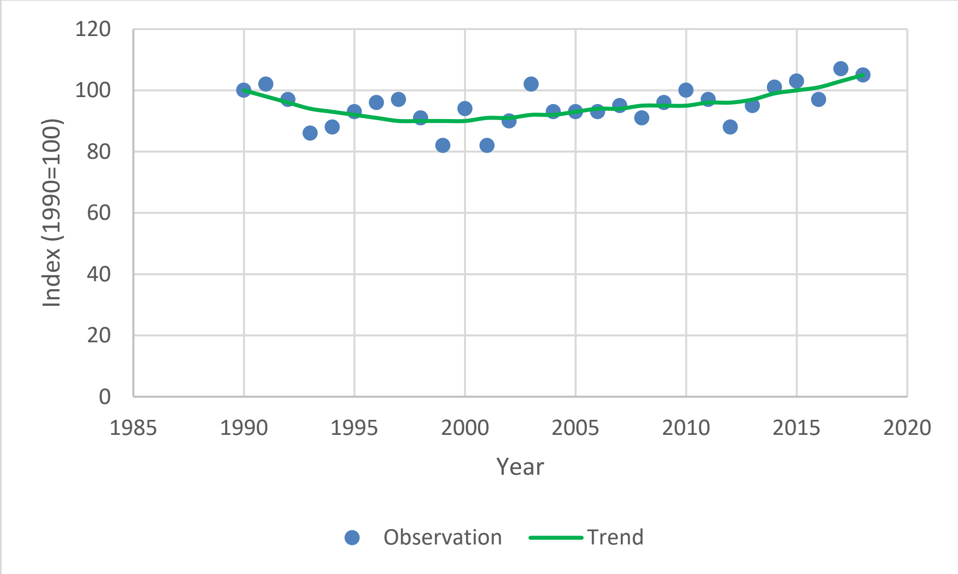

Figure 1.1 *Trend of characteristic forest fauna species (Source: www.clo.nl).*

The trend of forest fauna and flora has a strong correlation with forest nitrogen deposition levels. Forest areas with a nitrogen deposition below 2500 mol N per ha per year show a clear positive trend in the fauna index (+25%), while forest areas where the nitrogen deposition was above 2500 mol N per ha per year show a clear negative trend (-25%). Besides fauna, nitrogen deposition also affects soil acidification and roughening of the undergrowth with grasses, nettles and blackberries, which hampers forest regeneration (Kros et al. 2008).

The proportion protected forest (IUCN codes I–VI) is about 26% of total forest area.

Ecosystem services

The Dutch forest area is very important for key ecosystem services, such as carbon sequestration, drinking water, air filtering and recreation. Lof et al. (2017) estimated the total carbon pool in all Dutch ecosystems at 388 Mton C. The total carbon pool in nature and forest areas was estimated at 88.4 Mton C (Lesschen et al. 2012). Hendriks et al. (2018) estimated that the carbon pool in the nature and forest area of the State Forest Service (Staatsbosbeheer, SBB) was 38.1 Mton C, of which 19.7 Mton C (52%) is stored in the forest area, which only amounts to 35% of the total area owned by the State Forest Service.

Although the exact contribution of forest to the drinking water supply is not known, it is known that forest and nature areas contribute significantly. Forests can increase soil water retention(Veraart et al. 2020). Rainwater can infiltrate deeper soil layers and groundwater through tree root channels that extend to deeper layers than the root channels of agricultural crops. Soil organic matter is also very important due to the water retention characteristics of organic matter. However, many forests in the Netherlands grow on sandy soil, which are low in organic matter content. Forest management experiments are being performed on increasing the water retention of forests (Veraart et al. 2020). Drinking water companies own about 23,000 ha forest and nature areas, which drinking water is extracted from. Hendriks et al. (2018) estimated that about 50 million m^3 or 7% of drinking water comes from forest and nature areas owned by the State Forest Service, which is extracted out of ground water.

Forests also play an important role in air filtering. Hendriks et al. (2018) estimated that the amount of particulate matter captured by forest and nature areas in the Netherlands was 9.3 kton PM10 for the year 2016, which is about 18% of total particulate matter captured by all ecosystems.

Forests are important for recreation and tourism. Fontein et al. (2009) report that both foreign tourists and Dutch recreationists prefer forests above all other landscape types in the Netherlands. The number of visitors to National Parks in the Netherlands is about 6.7 million per year (Nationale Parken

Bureau 2016). Together with the coastal areas, forest areas are the most popular tourist destinations in the Netherlands.

1.4 Priorities for enhancing the contribution of forests and their forest genetic resources to sustainable development

To meet the challenges forests are facing, a Forest Strategy has been published by the Ministry of Agriculture, Nature and Food Quality and the provinces. Ambitions and goals are formulated that will be elaborated in measures that contribute to a healthy, climate-smart, future-proof and social valued forests. For that, an improvement in quality is needed in current forests as well as an expansion of forest area. An increase in the total number of trees is also needed beyond forests, in rural and urban areas. The sustainable use of forest and trees is important (LNV 2020a).

There are plans to increase forest area by 10% to 407,000 ha by 2030, with the goal being to restore biodiversity and to increase carbon sequestration, wood production and recreation possibilities. There is also an ambition to compensate for the deforestation within the Natura 2000 areas that will take place due to land use change to other nature types (LNV 2020a). With the foreseen extension of the forest area, it is important to use genetically high-quality planting materials so the forests can meet the goals set.

There are plans to increase the lifespan of wood products so the carbon stored in the wood will remain in the wood products for a long period of time. One of the pathways is to increase the use of construction wood in buildings. An outlook study on future wood use expects an 90% increase in demand for construction wood for buildings (Leguijt et al. 2020). To meet the requirements for this high quality wood, it is important to use high quality planting materials with good wood quality characteristics.

Together with water boards, drinking water companies and provinces, the central government is working on plans to adapt the water management of forests to changing climate effects, such as changing precipitation patterns that may result in both periods of severe drought and flooding (LNV 2020a). Demand for drinking and irrigation water is expected to increase in the near future. Strategies are being developed to enlarge the sponge function of forests to protect downstream areas from flooding while also increasing water availability in dry periods.

The central government and provinces are also developing plans to decrease the nitrogen deposition on nature areas and forests.

1.5 Constraints on increasing awareness of the value and importance of forest genetic resources

Until November 2020, the absence of a national forest strategy had hampered the development of a coherent strategy for coping with the challenges Dutch forests were facing. The last National Forest Plan dates from 1993 (Bosbeleidsplan 1993). Since then, forest policy has become more and more integrated into nature policy. Nowadays, forest policy is highly integrated in nature, landscape, water and water policy (Van Duinhoven 2016). In 2011, the implementation of nature policy was decentralised to the provinces, which resulted in its fragmentation over different multiple regional governmental bodies. In general, genetic diversity receives very limited attention in their policies and programmes. Altogether, the absence of a national forest strategy in the past, its combining with other policies and the decentralisation of the implementation of nature policy has not contributed to the communication or the awareness raising of the specific values and importance of forest genetic resources.

2 State of forests

2.1 State of forests and trends in their management

Forest area
Forest areas in the Netherlands have increased gradually from about 167,000 ha in the 19th century to 260,000 ha in the mid-20th century. After the Second World War, an afforestation programme was started (Van Goor 1993, Boosten 2016) and afforestation the new IJsselmeer polders, resulting in a forest area of about 373,480 ha in 2013 (Schelhaas et al. 2014). This was the largest area for the present.

Over the past decade, the forest area has been subject to changes due to spatial developments, such as the cutting of temporary forests, infrastructure and the transformation of forest areas to other nature types (e.g. heathlands) to meet the objectives of European bird and habitat directives, which are part of the Natura 2000 network. As a result, forest area has decreased since 2013, with by net 5,400 ha to 364,830 ha in 2015 (Schelhaas et al. 2017, FAO 2020). Subsequently, the forest area increased again to 369,500 ha in 2020 (FAO 2020) (Figure 2.1).

The current forest area in the Netherlands is about 10% of the total land area (Schelhaas et al. 2017, Oldenburger 2019), which is one of the lowest for Europe and comparable to that of Ireland or the United Kingdom. The EU-27 average is about 44% for both forest and wooded land, and 39% for forest (European Commission 2019).

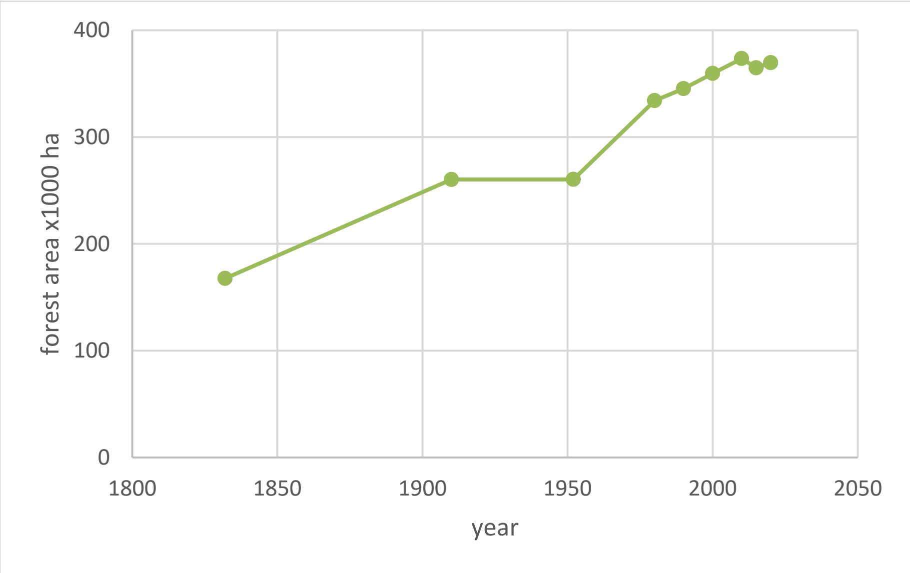

Figure 2.1 *Development of the forest area in the Netherlands (Source: Boosten 2016, FAO 2020).*

About 61% of Dutch forest area is multifunctional, and 39% has nature as its main function (Schelhaas et al. 2018). In multifunctional wood production forests, nature and recreation take place, while in the nature forest area, wood is also harvested, but only as a conservation measure to maintain or develop specific forest ecosystems. About 52% of forests are privately owned; 48% public owned, 26% of which is owned by the State Forest Service (Schelhaas et al. 2014).

Most forest areas are located in the central, eastern and southern provinces. Although the Netherlands has little forest, it has one of the largest, closely-knit forest areas in West-Europe, The Veluwe is located in the Netherlands and is about 1,000 km^2 in size. (Adviescollege Grenzeloze Veluwe 2002).

Besides the Veluwe, there are only a few other large forest areas: 14 areas are larger than 1,000 ha, while most forests (more than 80%) are small (0.5–5.0 ha) and scattered over the country (Dirkse et al. 2003). About 1,900 owners own a forest area of 5 ha or larger (Schelhaas et al. 2014).

Schelhaas et al. (2014) reported the following characteristics of the Dutch forest, resulting from the sixth National Forest Inventory. About 75% of forests were classified as high forest, while 3.5% were classified as special forest, such as coppices, middle forest or park forest. 13.5% was classified as other types of stands, such as landscape forest and recreational forest. The share of uneven-aged forest has increased from 14 to 16%, but at the same time, more clear cuts were observed (1.4% in 2012–2013 vs 0.3% in 2001–2005). Forest stands have become more mixed: stands with one coniferous species are often mixed with deciduous or other coniferous species. Slightly more than half of forests are dominated by conifers, but this share is decreasing. Scots pine is still the most common tree species, dominating about one third of the total area, but its share is decreasing. Oak is the most important broadleaved species (17.2% of the forest area), while the area that birch covers is increasing (from 5.8% to 6.6%) and that of poplar is decreasing (from 4.9% to 3.3%). The Dutch forests continue to grow older. The average age of conifers recorded in 2012–2013 was 67 years old, while for broadleaves it was 58 years old. The average living standing stock increased from 194.6 m^3/ha in 2001–2005 to 216.6 m^3/ha in 2012–2013. The volume of standing dead wood increased from 3.6 to 6.4 m^3/ha and lying dead wood increased from 5.3 to 6.8 m^3/ha. The share of almost all coniferous species in the standing stock has decreased, with the result that conifers accounted for 49% of the standing stock in 2012–2013, versus 54% in 2001–2005. The share of conifers in the mean annual increment has also decreased, from 56% in 2001–2005 to 50% in 2012–2013. The average current annual increment of Dutch forests decreased from 7.5 m^3/ha/yr to 7.3 m^3/ha/yr. The share of poplar decreased both in the stock as well as in the increment. Total annual fellings amount to an estimated 1.3 million m^3 or 3.4 m^3/ha/yr. In 2001–2005, it was estimated at 3.6 m^3/ha/yr. About two thirds of fellings are in coniferous forests and one third in broadleaved forests.

Biodiversity
Although the forest area is decreasing slightly, the quality of Dutch forest is of greater concern and has the highest priority in the recent Forest Strategy. Forests are under great pressure in terms of nitrogen deposition, dehydration and fragmentation, which has its effect on all the forest functions, but especially on biodiversity. Climate change puts extra pressure and enhances other stress factors, such as drought and pests and diseases. Therefore, the focus of the Forest Strategy is mainly on restoring biodiversity, increasing resilience and counteracting deforestation (LNV 2020a).

Climate change
The intended 10% forest expansion will contribute to the targets of the Paris Climate Agreement and contribute to the restoration of biodiversity and other forest functions, such as recreation and wood production. Forest management focus on adaption of forests to effects of climate change, for example by increasing the percentage deciduous trees species, small scale interventions and creating more diverse forest structure and tree species composition (EZK 2019). Pilot studies have been set up to test the climate resilience of tree species that are both common and new to Dutch forests.

Forest management
In the 19th and 20th century, forests were mainly planted as monocultures, with Scots pine as the main tree species, and mainly for wood production and to control drift sand. In the 1980s, nature objectives became more important, and forest management then pursued a larger diversity in tree species. In 2013, the percentage forest stands with deciduous and coniferous tree species was about equal. Forest with unmixed coniferous species were largely replaced with mixed stands and with deciduous species. The area unmixed coniferous species decreased from 47% to 26% (Schelhaas et al. 2014).

Woody biomass
In 2019, the harvested wood volume was about 3.4 million m^3 roundwood equivalents, of which about 2.5 million m^3 was used for energy purposes. The use of woody biomass for energy purposes contributes to achieving the climate goals of the Netherlands and is expected to increase to over

10 million m^3 in 2025 (i.e. 49% and 95% CO_2 emission reduction in 2030 and 2050 respectively, EZK 2019, Oldenburger 2019).

However, the use of woody biomass for energy purposes is part of societal and political discourse (Strengers and Elzenga 2020, SER 2020). Strengers and Elzenga (2020) conclude that the future availability and responsible applications of sustainable produced biomass avery much depend on the prevailing broader view. Putting the interests of biodiversity on top leads to different outcomes than when climate targets (e.g. lowering CO_2 atmospheric concentrations) lead. The Social Economic Council of the Netherlands (which advises the Dutch government and Parliament on social and economic policy) concluded that there is an urgent need to decrease CO_2 emissions and that, in the short term, woody biomass is important for bridging the period needed to achieve low or zero carbon energy production (SER 2020). Biomass is seen also as an indispensable resource for circular economies, like for chemical industries and the construction sector. A third important application of biomass is that of soil improvement. This is reflected in discussions on the use of branch- and top-wood, and whether it is better suited for applications in the bioeconomy or better left in the forest for biodiversity, conservation of important nutrients and for soil improvement (De Jong en Spijker 2014). In order to stimulate the high quality use of woody biomass and to decrease low-grade applications, the Dutch government has adopted a framework for the sustainable use of biomass (IenW 2020).

Besides discussions on the use of woody biomass, there is also a societal debate on biodiversity versus wood production in the Dutch forests (e.g. Bouma 2019a,b). The largest nature conservation organisation, Natuurmonumenten, has decided to adapt their forest management, reduce the cutting of trees and forest and to increase compensation when trees or forests have to be cut down for any reason (Natuurmonumenten 2019). The Forest Strategy responds to this societal aversion to felling forests by promoting small scale, multifunctional and climate smart management interventions, by targeting older forests and by promoting a more diverse forest structure and tree species composition (EZK 2019).

Choice of Forest Reproductive Material
In the early 1980s, most Dutch forest areas were regenerated by clearcutting and planting. Since then, forest management has become more nature oriented, which, in a relative short period of time, resulted in a change from large-scale, surface-wise regeneration by the planting of monocultures with the small-scale, group-wise natural regeneration of mixed stands (Oosterbaan and Van den Berg 2012). The preference for natural regeneration caused a decrease in demand for planting material. Little attention was paid to the genetic quality of the seed-producing mother trees in natural regeneration. The extent of the different regeneration methods in the Dutch forest is unknown. However, natural regeneration dominates in existing forests. In 2018, about 10% of forest areas (38,720 ha) was naturally regenerated (FAOSTAT).

2.2 Drivers of change

The loss of biodiversity, climate change, energy transition, nitrogen deposition, drought, sustainable forest management, land use change and the occurrence of new pests and diseases: all are important issues that influence forests and forest management in the Netherlands. These issues also have strong influences on public opinion, which, in turn, influences forest and nature policy and forest management.

Dutch forests are under pressure from high nitrogen deposition, dehydration and fragmentation (Vos et al. 2007, Kros et al. 2008, Witte et al. 2019, LNV 2020a). Climate change puts extra pressure on the resilience of the forests. Further measures are also needed to reduce the effects of dehydration and drought. This is of even greater urgency since severe droughts have occurred more frequently than over the past decade. Forest and nature managers, together with regional governments, water boards and drinking water companies, are planning measures to increase the sponge function of forests (e.g. Van Duinhoven 2014, Klimaatbuffers 2020).

Dutch forests are suffering from drought (Witte et al. 2019), and in recent years pests (e.g. European spruce bark beetle) (Bosgroep Zuid Nederland 2019) and diseases (e.g. ash dieback, Hiemstra & Copini, 2020) have also been affecting the health of Dutch forests. Ash dieback has spread over the entire country and has infected many of the ash forest stands and road side trees. 80% of the State Forest Service ash stands are infected. Many of the spruce and larch forest stands have suffered from drought in recent years and are now weakened and are being attacked by European spruce bark beetles and the larch bark beetles. On local scale, whole forest stands have died because of these pests and diseases.

Afforestation is also seen as important perspective for climate mitigation due to the carbon storage of forests. In a fossil fuel free world, the use of biomass and timber will increase, for instance for construction, paper and other bio-based applications. This will put extra pressure on forests world-wide and additional and large efforts will be needed to balance timber and biomass production with other forest ecosystem services and biodiversity. The foreseen expansion of the forest area in the Netherlands is, amongst others, meant to ensure that the balance can be managed nationally (LNV 2020a).

Over the past decades, game populations (e.g. roe deer, red deer and wild boar have increased (Dekker et al. 2015, Guldemond et al. 2015). High game populations have a large impact on forest regeneration. In many forest areas, natural regeneration does not succeed because of high game populations (Van Lommel 2018). To make natural regeneration succeed, fences or other measures are needed, which require substantial investments.

The Netherlands is under pressure in terms of land use, which also affects forest areas. Schelhaas et al. (2017) estimated that a total of 12,145 ha was deforested in the 2013–2017 period. Of this area, there was a land use change of 11% to agriculture (land temporarily planted with fast growing tree species without any obligation of replanting returned to agriculture), 38% to nature, 9% to urban areas and 9% was deforested for forest regeneration.

2.3 Challenges and opportunities for forest genetic resources

To face the constraints mentioned in section 2.2, the Ministry of Agriculture, Nature and Food Quality and the Dutch provinces, which are responsible for the elaboration and implementation of the nature policy, published a Forest Strategy (LNV 2020a). One important action point in this plan is the intention to expand the forest area by 10%. With this expansion, the government is targeting the restoration of biodiversity, climate change adaptation and mitigation, improvement of resilience, increase of wood production and the combatting of deforestation. The challenge is to find the land area where these forests can be planted. This will be quite a challenge in the Netherlands, where land use pressures are very high. A balanced choice of forest functions will be also a challenge given current public opinion.

The ‘Climate smart Forest and Nature management’ programme, funded by the Ministry of Agriculture, Nature and Food Quality, has been started to support forest and nature managers with measures to increase the forest resilience, such as the selection of tree species, the revitalisation of forest stands, postponing of harvests, increasing knowledge on climate-smart forest management and improving communication on these topics (VBNE 2020, Lerink et al 2020). New tree species are being tested on their characteristics with regard to changing climate conditions, pests and diseases. A toolbox with measures for climate-adapted forest management is being developed, as are forest management strategies for optimising carbon storage in forests (Boosten et al. 2018, 2020a). Pilots are being carried out with climate-smart forest management and with planting of tree species that are supposed to be more climate resilient (Boosten et al. 2020a). For example, for sites that will likely suffer climate-induced droughts in the future, current advice is to use tree species that are adapted to dry environmental conditions when forests are regenerated, such as Scots pine (*Pinus sylvestris*), Wild service tree (*Sorbus torminalis*) and Chestnut (*Castanea sativa*). Experiments are also being carried out on how to improve forest quality by regenerating forests with small groups of trees, with about 20 to 50 trees (Lerink et al. 2020). When implementing this measure, several tree species are used that are lacking in current tree species composition, such as Hornbeam (*Carpinus betulus*) and Lime (*Tilia* spec.). Through these measures, biodiversity, forest structure and species composition can be improved. The measures can also be combined with the improved production of high quality timber. The challenge is to create a forest tree composition that really contributes to the restoration of biodiversity, resilient forests, and that will fulfil future timber needs.

Forest management that focuses exclusively on biodiversity or on just one of the ecosystem services (e.g. timber production, carbon storage) will have substantial trade-offs with other ecosystem services. In most of the Dutch forests, sustainable forest management is standard practice, which means that a balance is being sought to optimise ecosystem services. In particular, the balance between timber production and biodiversity must be considered carefully because there is a fiercely public debate on this issue. It is expected that the demand for wood will increase in the near future. Dutch forests can only contribute to a small percentage of this increasing demand. Most wood will be imported from other European countries (Nabuurs et al. 2016). It is unclear to what extent such an expansion of the harvest will also lead to more public debate.

The above mentioned ambitions and actions of the Forest Strategy will also have consequences for the conservation, use and development of forest genetic resources (see also section 6.3 (in situ conservation), section 7.4 (ex situ conservation), section 8.3 (use) and section 9.5 (development) of this report). For the planned forest expansion of about 37,000 ha, an estimated 100 million plants will be needed over the next ten years. It is expected that there will not be an adequate supply of planting stock to account for this expected demand (Boosten et al. 2020b). In addition to quantity, there is a need to pay attention to the genetic quality of this FRM both in view of climate change, biodiversity and high quality timber production. It will be a challenge for forest managers to know which FRM to plant where. On the other hand, there are opportunities for forest managers to better manage FGR as a strategy to cope with climate change and making their forests more resilient.

The urgent threat from ash dieback has already stimulated collaborations between organisations and the engagement of citisens in collecting and conserving potential tolerant ash genetic resources (www.essentaksterfte.nu). The conservation of these genetic resources is important for initiating new breeding programmes and the development of more resistant ash trees and the restoration of healthy ash forests.

3 State of other wooded lands

3.1 State of other wooded land

There are three types of other wooded land outside of forests:

- Point shaped: freestanding trees;
- Line shaped: hedges, hedgerows, single tree rows, double tree rows, windbreak tree rows;
- Area shaped: woodlots/small rural forests, willow coppices, standard fruit orchards, park and urban plantations.

The rural landscape elements are widely spread over the country (Figure 3.1) and cover about 3.2% of the rural land area in the Netherlands (De Jong et al. 2009). Urban green infrastructures (park and urban plantations) covers about 9% of built up areas and less than 1% of the total land area in the Netherlands. The areas and lengths of the different landscape elements and urban green areas are presented in Table 3.1.

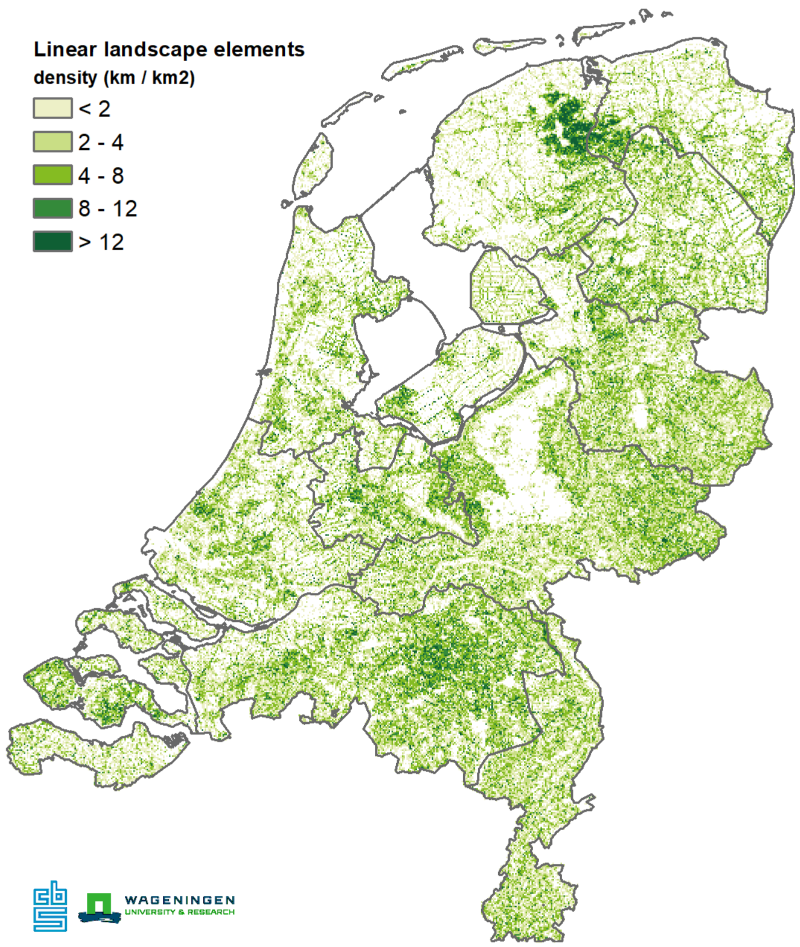

Figure 3.1 *Density of linear landscape elements in the Netherlands (km per km^2) (CBS 2020b).*

Table 3.1 *Overview of woody landscape elements in the Netherlands (De Jong et al. 2009, CBS 2020c).*

Type of landscape element	Length (km)	Area (ha)	Number (x1000)
Freestanding trees			396
Hedge (shrubs)	12,158		
Hedge rows (shrubs and mature trees/coppice)	3,109		
Tree rows	31,336		
Double tree rows	22,013		
Windbreak tree rows	2,292		
Standard orchard of fruit trees		2,787	
Woodlot/small rural forest		35,967	
Coppice (Willow)		142	
Urban green areas (park and plantation)		30,819	
Total	***70,908***	***69,715***	***396***

3.2 Trends affecting other wooded land and their management

The Forest Strategy (LNV 2020a) aims, amongst others, to expand the forest area by 10%. This expansion will contribute to the climate and biodiversity while also contributing to other policy goals, such as the water policy (e.g. flood prevention, drought prevention, drinking water supply) and energy policy (e.g. transition to sustainable energy supply). To elaborate the ambitions and goals of the national Forestry Strategy (LNV 2020b) actions are formulated for the policy goals on 'More forest', 'Vital forest', 'Trees outside forest' and 'Use of forest'. The Forest Strategy is a joint policy intention of the national government and provinces. Together with other governmental organisations and stakeholders the preconditions for realising the actions will be formulated and implemented in the coming years. Actions will contribute to climate adaptation (carbon storage), regional energy strategies (biomass), circular agriculture, decreasing nitrogen deposition (air filtering), agroforestry (e.g. forests gardens) and urban well-being (temperature regulation and recreation) (LNV 2020a).

Tiny forests are small forests the size of a tennis court, consisting of around 600 trees, distributed over 40 species. They are intended to increase biodiversity, improve water storage and air quality, reduce urban heath islands and contribute to nature experience and human well-being. Since 2015, 80 tiny forests have been planted (IVN 2020, WUR 2018).

There are ongoing experiments with agroforestry, specifically with forest gardens. In a green deal, the Dutch government, provinces and others have agreed to stimulate knowledge building and knowledge networks to scale up forest gardens. Forest gardens may contribute to sustainable agriculture, increase biodiversity and climate adaptation. Currently, some 54 forest gardens have been planted, covering about 103 ha (De Groot and Veen 2017).

Furthermore, growing attention is also being paid to climate smart forests and landscape elements. These are forests principally meant for carbon sequestration for climate mitigation, but in which other ecosystem services may also be developed (Penninkhof and Keizer 2020, Delforterie 2020). Valdés et al. (2019) showed that small woodlands in agricultural landscapes have huge potential for multiple ecosystem service delivery, in some cases even more than larger woodlands, for services like carbon storage.

More recently, new initiatives have been begun to plant more trees and shrubs around farm fields and yards (www.meerbomen.nu).

3.3 Drivers of change in other wooded land

In the period 1900–1950, there was a great land use change, through reclamation of natural and semi-natural areas, which were changed into agricultural areas. From 1950 to 1990, agriculture was scaled up; agricultural land was used more intensively, parcel size was increased and many landscape elements were cleared. From 1990 onwards, urbanisation is the most important driver of land use change in the rural area (CBS 2020d). For the period 1900 to 2003, Koomen et al. (2007) showed that the number of cultural-historical woody landscape elements decreased by 55%. This decrease was mainly motivated by changes in agricultural practices like the scaling up and intensification of agriculture, the reclamation of wastelands (between 1900 and 1950), land consolidation schemes (between 1950 and 1990) and, starting in 1990, urbanisation became the main driving force behind changes in the Dutch landscape (Dirkx 2011).

Ash dieback (*Hymenoscyphus fraxineus*) is increasingly causing damage in ash (mainly *Fraxinus* excelsior) in free-standing trees and tree rows. Although substantial areas of ash trees are infected at this moment (about 4,000 ha of the State Forest Service is infected or has died), it is not expected that ash will become extinct in the Netherlands (Siebel et al. 2018).

Since 1990, the oak processionary moth (*Thaumetopoea processionea*) has been a plague in the Netherlands and has spread all over the country in recent years. At first, it mostly afflicted road-side trees, causing a nuisance for pedestrians, cyclists and joggers. In recent years, it has also appeared in forest areas. Infected trees vary annually and it may affect 30–50% of trees, and potentially more. There is talk amongst municipalities and road side managers about replacing oak trees with other species because of the moths (Kenniscentrum 2020).

3.4 Challenges and opportunities for conservation, use and development of forest genetic resources

Woody landscape elements, and particularly the autochthonous genetic resources of trees and shrubs therein, are important for the conservation of biodiversity and forests' adaptation to climate change and are relevant for agriculture. A well-connected green infrastructure of hedge rows, tree rows, small forests are important for the dispersion and genetic exchange of plant and animal species as climate adaptation strategy (Van Teeffelen et al. 2015). The expansion of other wooded land in rural and urban areas also creates opportunities for wild pollinators. When planting new woody elements, the habitat requirements of wild pollinators should be taken into account. Similarly, woody elements should be connected to enable pollinators and other plants and animals to move through the landscape.

The new Forest Strategy is aiming to create more woody landscape elements by 2030. These elements will contribute to climate mitigation (carbon sequestration), biodiversity (creating habitat and green infrastructure), regional energy strategy and circular economy (biomass and timber) and recreation and well-being (attractive landscape). These goals rely on adapted management strategies that have to be developed jointly by regional policymakers, businesses and society in order to maintain support for strategies for funding and implementation generally. The challenge is to combine and optimise these strategies so they can achieve multiple goals.

There will also be a large demand for forest reproductive material to extend rural woody landscape elements. This material will have to be adapted to future climate conditions and have meet biodiversity requirements, requirements for circular sustainable land use in agriculture and forestry, and be pest and diseases resistant. The expansion and protection of woody landscape elements also brings new opportunities for the in situ conservation of genetic resources of trees and shrubs. This will be especially important when landscape elements restoring or planting with autochthonous source identified (SI) genetic resources.

Experiments are being undertaken on forest gardens, agroforestry, the integration of agriculture, livestock and forestry (Boosten et al. 2020a). Agroforestry, still a rather new system in the Netherlands, can help prevent diseases and increase biodiversity, but will also impose new requirements on the choice of species, the provenances and varieties used, and the traits needed. This will have impact on the development of forest genetic resources targeted for these new production systems.

In urban areas, greenery is needed to combat the urban heath island effect and to increase wellbeing. Woody plants can help improve the liveability of cities. The challenge is to select tree species and varieties that are well adapted to the urban climate and site conditions, and that are less vulnerable to pests and diseases (e.g. oak procession moth, elm disease, ash dieback, horse chestnut bleeding canker, fire blight, sooty bark disease, verticillium wilt). Management strategies are also needed so that the woody plants in the cities can contribute optimally to multiple goals. More coherent policy on urban green can contribute to this.

4 State of diversity between species

4.1 Number of species that are considered as 'forest genetic resources' and managed or utilised in the forestry context

In the Netherlands, there are around 100 native tree and shrub species, including 28 trees, 52 shrubs, 16 dwarf shrubs and four climbers (Buiteveld & Copini 2019). In total, three conifer species are native (*Pinus sylvestris*, *Juniperus communis* and *Taxus baccata*). While *Pinus sylvestris* and *Quercus robur* are the most common native species, occupying almost half the forest area (Schelhaas et al. 2014), 21 native shrubs and one tree species are on the Dutch Red List of Vascular Plants, in which *Rosa agrestis* and *Genista germanica* are categorised as 'critically endangered' and *Genista pilosa*, *Genista tinctoria* and *Rosa tomentosa* as 'endangered' (https://minlnv.nederlandsesoorten.nl/content/rode-lijsten-soort-van-rode-lijst-vaatplanten). The most common introduced species are: *Pseudotsuga menziesii, Larix kaempferi*, *Picea abies* & *Pinus nigra*, *Quercus rubra* and *Populus* x *canadensis* (Schelhaas et al. 2014, Mohren en Kramer, 2017). On a smaller scale, the following species are also managed in the forestry context: *Abies grandis*, *Acer platanoides*, *Castanea sativa*, *Juglans regia, Juglans nigra, Larix decidua*, *Larix x eurolepis*, *Thuja plicata*, *Tsuga heterophylla, Pinus strobus, Robinia pseudoacacia*.

4.2 Number of native and introduced species managed or utilised in the forestry context (including agroforestry)

Over the last decade, more species have been planted in forests as forest management has aimed at a greater diversity of tree species and placed more emphasis on native tree species and biodiversity, and improving forest resilience. Consequently, the ratio of deciduous to coniferous trees has increased at the expense of Scots pine, in favour of native oak and, to a lesser extent, beech and birch too. The number of introduced species has increased slightly in light of the climate change foresters experiment, with lesser known species such as *Abies alba*, *Corylus colurna, Juglans* spp & *Sorbus torminalis* being planted.(www.vbne.nl/klimaatslimbosennatuurbeheer/boomsoortenportaal). With regard to the increasing interest in forest gardens and agroforestry, the number of introduced species is also increasing with species like *Actinidia arguta*, *Diospyros sp*., *Lonicera caerulea, Pinus koraiensis* & *Prunus* spp being planted.

4.3 Trends and drivers of change in the number of species

The extreme 2018 summer drought triggered a change in species used in the forestry context towards an increased number of species and the introduction of new species (Pötzelberg et al. 2020, Thomassen et al. 2020). Several exotic conifer tree species were weakened by the drought and were subsequently infested by bark beetles – mostly *Picea abies*, *P. sitchenis* and *P. omorika* and, to a lesser extent, *Larix kaempferi* trees died. *Picea* species are no longer seen as valuable timber species in the Netherlands with regard to climate change. Foresters are seeking alternative species that are better able to cope with more frequent droughts and are therefore considering assisted migration – deliberately selecting planting material and moving it to areas being newly colonised (see www.euforgen.org) – to increase genetic diversity and adaptability. Lesser known species that are currently planted experimentally are exotic species, that are native to Europe, like *Abies alba*, *Sorbus torminalis*, and *Corylus colurna*. American species like *Juglans nigra*, *Quercus palustris*, *Sequoia sempervirens* are also being considered nowadays.

Ash dieback caused by the invasive fungus *Hymenoscyphus fraxineus* induced tree mortality in most of the 13,000 ha of ash forests. As an alternative to ash, other native and also exotic species are being considered, like *Liriodendron tulipifera*, *Carya ovata* and *Juglans regia*.

Agroforestry is only used on a very small scale in the Netherlands. Agroforestry crops are often more complex than 'regular' agriculture or timber production. Agroforestry has great potential to realise the objectives of the Forest Strategy. If only 1% of current agricultural area gets a substantial planting of trees, almost 25,000 ha of 'forest' can be realised (Boosten et al. 2018). There is growing interest among farmers and nature managers in agroforestry systems, for combining trees and arable farming or for combining of trees and animal husbandry for instance (www.kiplekkeronderdewilgen.nl).

Forest gardening is an agroforestry system based on woodland ecosystems. There is a slight trend towards establishing forest gardens (also called 'food forests') in both urban and rural areas in the Netherlands. In 2017, 54 forest gardens, covering 103 ha, were planted (De Groot and Veen, 2017). As the number of forest gardens has increased, more species have been used, like native *Corylus avellana*, *Crataegus* spp., *Prunus avium* and *Hippophae rhamnoides* and introduced species, like *Actinidia arguta*, *Diospyros* spp. *Juglans regia* and *Pinus koraiensis* & *Lonicera caerulea*.

Forest gardens can serve multiple functions: besides food production, much of the interest in forest gardens lies in their environmental benefits, such as diversifying eco systems, their non-reliance on chemicals and fertilisers and their recreational value (De Groot and Veen, 2017). There is also risk in introducing new species. These can be invasive and pose potential risks to biodiversity and could affect autochthonous forest genetic resources, particularly when forest gardens are developed in the proximity of forest- and nature areas. Some (potential) invasive species are *Rosa rugosa*, *Vaccinium macrocarpon*, *Rhus typhina*, *Vaccinium corymbosum* and *Aronia* spp. (Hoppenreijs et al. 2019, NVWA).

In the context of knowledge dissemination there are several pilots with agroforestry being carried out in the Netherlands. These pilots are intended to investigate the effects of trees on agricultural crops or livestock, but they also serve as example farms where farmers can see what agroforestry means in practice (https://www.vbne.nl/klimaatslimbosennatuurbeheer/projecten).

Figure 4.1 *Dieback of Picea omorika due to the European spruce bark beetle, Ips typographus, after the 2018 drought.*

5 State of diversity within species

5.1 State of genetic diversity

Knowledge on genetic diversity in forest trees and shrubs present in the Netherlands is scarce as only a few studies have been conducted that asses the genetic diversity of forest species populations. For the majority of forest species, there is no information on the extent of their genetic diversity. Most genetic studies have been carried out on oaks, beech and, more recently, on *Fraxinus excelsior*, *Tilia* spp, *Crataegus* spp, *Ulmus* spp, *Malus sylvestris*, and *Rosa* spp.

5.2 Trends in the genetic diversity of these species and in the state of their populations

As no data on genetic diversity is available for most tree and shrub species, the state of populations of species based on inventories or expert opinions may form an indication for the existing genetic diversity.

The forest inventory, the Sixth Dutch Forest Inventory (NBI6), was completed between 2012 and 2013 (Schelhaas et al. 2014). It gives insight into the percentage of forest area in relation to non-forest area, changes in species share, ownership, age and wood increment, based on sample points. However, no information was gathered on the state of populations of species concerning their number or health.

Since 1991, extensive surveys on the distribution of autochthonous populations of native tree and shrub species have been carried out across the country. The map of green heritage in the Netherlands (www.landschapinnederland.nl/kaart-groen-erfgoed) provides an overview of the state of these inventories of autochthonous genetic resources in the Netherlands and their distribution in valuable cultural-historical forests, landscape elements and hedges (Maes 2016). Nowadays, these old forests and landscape elements with autochthonous genetic resources make up about 3% of the total existing landscape elements and forests in the Netherlands. There has not been a systematic monitoring of the state of these autochthonous populations since then. This map shows the occurrence of autochthonous, mostly relict populations, but does not give any insight into abundance or trends in population decline or increase. The map serves as a base line dataset.

According to the Dutch Red List and following the internationally used criteria of the IUCN, 19 tree and shrub species have declined, based on distribution data or number of individuals in the 1950–2011 period (Sparrius et al. 2014). Examples of shrub species that have declined are: *Andromeda polifolia*, *Calluna vulgaris*, *Erica tetralix*, *Genista anglica*, *Genista germanica*, *Genista pilosa*, *Genista tinctoria*, and *Myrica gale*. However, in this assessment for the Dutch Red List, the autochthonous origin was ignored, so there may therefore be bias concerning the rarity of autochthonous genetic resources, particularly for woody species that were frequently planted in the past. These datasets are highly informative for such species. These species include heather species, *Daphne mezereum*, *Myrica gale*, *Crataegus* x *macrocarpa*, *Malus sylvestris*, *Juniperus communis*, *Populus nigra*, *Pyrus pyraster*, *Rosa* spp., *Tilia cordata* and *Ulmus laevis*. Based on expert opinions, concerning autochthonous genetic resources, which consist about half of all native tree and shrub species in the Netherlands, it is estimated that 46 tree and shrub species have declined since 1950 (Buiteveld & Copini 2019). *Viburnum lantana* is an example of a shrub species that reached the northern border of its distribution range in Southern Limburg and is thought to be almost extinct. Population numbers and sizes of *Fraxinus excelsior* have declined sharply over the past decade due to severe disease pressures (ash dieback). Many species have very small population sizes. Estimations made by experts based on recent inventories indicate that for about 32 tree and shrub species, the number of autochthonous individuals (not planted) still present in the Netherlands is less than 500. In some species like *Genista germanica*, there are very few sites where individuals or populations still occur (Buiteveld & Copini 2019). For several tree and shrub species, the Netherlands is on the edge of their distribution range, mostly the north-western limits. Peripheral populations of these species would be of additional significance, as they may contain unique genetic resources absent elsewhere in their natural distribution range. No data is available on the genetic uniqueness of these peripheral populations based on genetic diversity studies or provenance tests.

5.3 Current and emerging technologies

Molecular technologies (mainly microsatellite markers and SNPs) are being used to analyse and conserve genetic diversity within and between populations, and to provide insight into genetic relationships, the population genetic processes that influence or determine levels and patterns of genetic diversity, particularly gene flow (e.g. in beech and oaks). This information is also used for setting up sampling strategies for establishing gene bank collections (clone archives) and for rationalisation these collections. For instance, the wild apple collection has been analysed to gain insight into redundancies, population structure and genetic relatedness among accessions. This has been done in order to rationalise the collection and to develop the best design for seed harvesting in the collection. More recently, genetic resources from *Fraxinus excelsior* have been screened for genetic variation for ash dieback resistance using an SNP array developed with the EU B4EST project (Adaptive Breeding for Productive, Sustainable and Resilient Forests Under Climate Change).

5.4 Research needs

There is a lack of knowledge about the state and trends of the remaining genetic diversity in the autochthonous populations of tree and shrub species. Genetic diversity is the basis for adaptation of forests to climate change and other environmental changes. The quality of Dutch forests is of great concern, as they suffer from high nitrogen deposition, drought, fragmentation and diseases. Knowledge of the state of genetic diversity in species is needed to prioritise conservation efforts. Insight into the adaptive potential (or lack of) of the autochthonous gene resources is particularly required to set priorities for protecting and restoring local populations. Furthermore, research in genetic diversity is needed to enable forest managers to include genetic aspects in their adaptive management strategies to enhance the resilience of forests – one of the ambitions of the Dutch Forest Strategy (LNV, 2020).

6 In situ conservation of forest genetic resources

6.1 State of in situ conservation efforts

Nowadays, when it concerns autochthonous genetic resources, about half of the native tree and shrub species are under threat (Maes 2016). They persist as fragmented small, often isolated, populations or as single trees. Based on inventories conducted in the past 30 years, it is estimated that the oldest, most valuable landscape elements and ancient woodlands with still-wild, woody flora account for only 3% of the total area of forests and landscape elements in the country (Kemenade & Maes 2019). About 70% of these landscape elements and old forests, which are present on topographic maps from 1850, have now been inventoried for autochthonous forest genetic resources.

6.2 Approaches used for in situ conservation

In the Netherlands, both in situ and ex situ strategies are used to conserve genetic resources of trees and shrubs are used. The two strategies for gene conservation complement each other and are therefore used in tandem. For species for which in situ conservation is still feasible, existing natural populations are protected in gene conservation units and registered in the EUFGIS online information system (www.eufgis.org) for forest genetic resources inventories in Europe. This is done as the Dutch contribution to the European conservation strategy for tree genetic resources, carried out under the EUFORGEN programme (www.euforgen.org). Progress to extend the number of gene conservation units has been limited in the past ten years. Within the period 2011–2020 the number GCUs has increased slightly from ten to 27 and from 11 target species to 23 species. To date, there are a total of 27 gene conservation units, comprising a total of 580 hectares. For many species, no GCUs are established and for 13 species only one GCU is established, which means that the in situ conservation effort is far from sufficient. A gene conservation unit must meet a minimum number of reproducing trees, depending on the purpose of conservation and species' characteristics. In most GCUs in the Netherlands, the populations consist of a low number of remaining individuals (populations sizes of 15–49 and 50–499), so the main purpose of these units is to conserve the remaining populations of rare and endangered species or to conserve adaptive variations in marginal populations. The Centre for Genetic Resources, the Netherlands (CGN) is responsible for designating these gene conservation units and regularly updating the information in the EUFGIS database.

There is no official programme or specific in situ gene conservation activities for woody species, apart from designating gene conservation units for some species. The Netherlands has various types of protected nature areas, such as the Netherlands Nature Network (NNN), Natura 2000 areas and National Parks, all of which contribute to the in situ conservation of wild, woody flora. Different laws and regulations protect these areas. An approximately 309,000 ha Natura 2000 area has been designated on land. Almost all Natura 2000 areas are part of the Netherlands Nature Network (NNN) (Compendium voor de Leefomgeving www.clo.nl). The NNN connects nature areas with each other and with the surrounding agricultural area. The Netherlands has 21 national parks. National parks are designated on the basis of the Nature Conservation Act (2017). Almost all gene conservation units are located in Natura 2000 areas.

6.3 Organisation of in situ conservation efforts

Currently, there is no coordinated plan for in situ gene conservation. Since 2013, parts of the Dutch Nature policy have been transferred to the provinces, as agreed in the 'Pact for Nature' (Natuurpact). The provinces are responsible for policy implementation and realising the ambitions of the Nature Pact, such as expanding the NNN and improving their quality. The national government provides financial and legal frameworks, and remains responsible for achieving international and European targets for biodiversity. For example, the designation of Natura 2000 areas is the responsibility of the Ministry of LNV.

As ownership of forests is scattered in the Netherlands, many stake holders are involved in in situ conservation. The State Forest Service owns most of the forests (98,626 ha of in total 373,480 ha), followed by private owners, municipalities, nature conservation organisations and the Dutch Society for Nature Conservation (Natuurmonumenten), Rijkswaterstaat, Water boards (Schelhaas et al. 2014). Most of them are members of the Dutch association of Forest and Nature reserve owners (VBNE), established in 2013. This association currently unites six groups of members: the Dutch Federation for Private Landownership (FPG), State Forest Service (SBB), Dutch Society for Nature Conservation (Natuurmonumenten), LandschappenNL, the Association of Municipal forest owners (NNG) and the Dutch Central Government Real Estate Agency (RvB). Altogether, they represent 70% of Dutch forests and 90% of Dutch nature reserves.

Within the framework of the decentralisation of nature policy, the provinces are, together with this diverse group of forest owners, the main players in the in situ conservation of forest genetic resources. The effectiveness of in situ gene conservation activities is very much dependent on cooperation between these stakeholders, in particular between those responsible for implementing nature policy, forest managers of valuable old forest areas and Natura 2000 areas and experts in gene conservation.

Figure 6.1 *In situ population of Tilia cordata and Tilia platyphyllos (Savelsbos).*

6.4 Needs, challenges and opportunities

The main constraint on improving in situ conservation is that established gene conservation units registered in EUFGIS have no formal legal status, and this may endanger their conservation in the long-term. For instance, the objective of conserving of Dutch biodiversity of the Nature Conservation Act (2017) does not necessarily coincide with conservation of forest genetic resources. Gene conservation units have some administrative status as all are also registered as seed stands (in the 'Source identified' category according to EU Council Directive 1999/105/EC) and some areas are under general protection by the Nature Conservation Act (Wet Natuurbescherming, 2017) as they are located in Natura 2000 areas.

In 2018, the FSC National Forest Stewardship Standard for the Netherlands was revised (FSC 2019). In this new standard, a link was made between the protection of forest areas and high conservation values, such as forest habitats that are outside designated Natura 2000 areas, but of outstanding quality (HCV3). For example, forest managers are challenged to record and develop strategies for in situ seed stands of autochthonous trees and shrubs (category: Source Identified) within their management units. The better recognition and recording of autochthonous seed stands at local levels may contribute to improving in situ protection of these autochthonous stands.

Societal concerns about the protection of in situ forest genetic resources is growing. Recently, a motion passed the house of representatives to safeguard valuable in situ locations and landscape elements with autochthonous trees and shrubs (www.tweedekamer.nl/kamerstukken/detail?id=2020Z10530&did=2020D22825). Still, forest managers are not sufficiently aware of the existence and the value of these genetic resources. There is a need to extend the network of gene conservation units to more species and to better integrate the dynamic conservation management of these genetic resources in the operational management plans of the forests. This includes e.g. proper registration of the units in local management systems, as well as assessment of natural regeneration, including protection of regeneration from ungulate browsing and monitoring of population sizes at regular intervals, so management can be directed towards the long-term persistence of these populations.

Nature policy in the Netherlands is characterised by the involvement of many parties with their own level of engagement and knowledge on in situ gene conservation of forest genetic resources. Moreover, genetic diversity is not a conservation aim in protected nature areas, neither are there incentives for forest managers to support activities for the conservation of forest genetic resources in their terrains. A better co-operation is needed between provinces and nature conservation organisations on how to incorporate genetic conservation of tree species in their nature policies.

With the recent Nature Programme (Programma Natuur), additional agreements to the Nature Pact of 2013 have been made between the central government and the provinces to further strengthen and improve nature in the coming years (www.rijksoverheid.nl Hoofdlijnen Programma natuur). The Nature Programme will be elaborated on in an implementation programme for the period 2021– 2030, including measures for reforestation, forest revitalisation within the NNN and strengthening of landscape elements. This programme may also provide opportunities for enhancing the sustainable use of these autochthonous forest genetic resources within in the N2000 and NNN areas.

Opportunities for enhancing the sustainable use of these forest genetic resources in protected nature areas (N2000 and NNN) for developing new nature should be exploited, rather than planting non-autochthonous plant materials in important Natura 2000 forests (Kemenade & Maes 2019).

6.5 Priorities for capacity building and research

There is a need to expand the number of gene conservation areas for multiple species. These gene conservation units should preferably be registered in the EUFGIS system, so they fulfil the minimum requirements for long term dynamic conservation. In order to designate new gene conservation units, inventory data of autochthonous species (distribution of native populations, population sizes etc.) should be made available and regular updated, for example through the map of Green Heritage (www.landschapinnederland.nl/kaart-groen-erfgoed). Proper monitoring of the targeted tree populations in these gene conservations units is crucial and will support forest managers to take specific management actions for conserving genetic diversity.

7 Ex situ conservation of forest genetic resources

7.1 State of ex situ conservation

Since 2002, the Netherlands has had a gene bank for native trees and shrubs (*ex situ in vivo*). The primary function of the gene bank is to safeguard the genetic diversity of native tree and shrub species for the long term and secondary, to facilitate the use of this genetic material in forestry and landscaping.

The total size of the gene bank collections has grown from 3,735 accessions in 2011 to 4,790 in 2019 (Buiteveld & Copini, 2019). The number of species conserved in these field collections has steadily increased from 48 to 56 species in this period. New species that have been added to the collection in the past years include *Frangula alnus*, *Genista anglica*, *Ilex aquifolium*, *Lonicera periclymenum*, *Salix repens*, *Sambucus racemosa*, *Taxus baccata* and *Rosa* species. Collections of *Crataegus monogyna*, *Crataegus laevigata* and *Euonymus europaeus* have increased in size considerably. The collections of *Fraxinus excelsior* are almost completely lost due to ash dieback.

For species for which a sufficient number of individuals can be sampled (> 30), the collections are designed as clonal seed orchards or stool beds (poplar and willow varieties) to make seed harvesting and cuttings possible. These collections are included in the national register of approved basic material (category: Source Identified). The number of collections registered as seed sources has increased substantially over the period 2012–2020 (49%) (www.rassenlijstbomen.nl). Nowadays, seeds or cuttings are harvested in the collections of 33 species (of a total of 45 species). In the other seven species, seed production is low because the plant material is still too young or growing conditions are suboptimal (e.g. *Genista anglica*, *Juniperus communis*). This registration of the collections in the national register contributed to increased utilisation of the collections.

7.2 Approaches used for ex situ conservation

Ex situ conservation of forest trees and shrub species in the Netherlands is mainly focused on native tree and shrub species that are endangered and rare. Genetic material is maintained as living tree collections (field collections). Material is collected from several relict populations, propagated vegetatively and maintained in clonal archives or clonal seed orchards. Apart from these field collections for rare tree and shrub species, genetic resources of the main forest tree species are conserved in seed orchards and long-term tests (clones, families and provenances) as part of provenance and improvement programmes (see chapter 9).

7.3 Organisation of ex situ conservation efforts

The long term conservation of native tree and shrub genetic resources is a public responsibility. The LNV has given this public task to the State Forest Service (SBB) and the Centre for Genetic Resources, the Netherlands (CGN) of Wageningen University & Research as a shared responsibility. The State Forest Service is responsible for the management and the maintenance of the field collections. Since 2004, CGN has been mandated to contribute to the conservation of forest genetic resources and has advised the SBB on the acquisition of new materials, development, management and documentation of the collections.

In addition to the gene bank for native trees and shrubs, botanical gardens, arboretums, private owners and NGOs manage several field collections of native and non-native tree species (see www.botanischetuinen.nl and www.plantencollecties.nl). These include collections of 21 native tree and shrub species. However, their role in conserving local, autochthonous genetic diversity of native species is limited.

In 2018, a new consortium of parties started working together to collect seeds of Dutch wild plants and to set up a National Seed Collection (www.hetlevendarchief.nl). The consortium consists of Botanical gardens, nurseries, research organisations, nature conservation organisations and volunteers at Floron (an organisation in the Netherlands for monitoring flora with volunteers). The consortium also aims to bring the importance of biodiversity and necessity to conserve wild flora to the attention of a wider audience.

Figure 7.1 *Salix ex situ collection.*

7.4 Needs, challenges and opportunities for improving ex situ conservation

There is a need to improve the ex situ conservation of species for which no ex situ measures are taken yet (e.g. *Genista* spp, *Myrica gale*, *Ulex europaeus*, *Arctostaphylos uva-ursi*, *Erica cinerea*, *Vaccinium uliginosum*, *Viburnum lantana*, *Rosa* spp.). For a number of species already included in the genebank (e.g. *Rosa* spp, *Tilia platyphyllos*, *Rosa* spp), it is advisable to optimise the collection composition by filling gaps and removing redundancies (Buiteveld & Copini, 2019). It is noted that the safety of field collections is relatively low, as only a small part of accessions (5%) has been safety duplicated in other locations (outside Roggebotzand area). With an ex-situ-in-vivo collection, the danger of loss of material due to diseases, pests or accidents is a serious risk. It is necessary to duplicate the collections, preferably by using other ex situ conservation methods (seed banking) and starting with duplication of material that is most at risk or is lost in the original in situ places since acquired in the genebank (e.g. wild apple accessions) (Buiteveld et al. 2021).

The field collections are an important source of genetic variation. This provides opportunities for the genebank to support the use of genetically diverse plant material in afforestation and restoration activities in the near future as there is an increased demand for forest reproductive material (Boosten et al. 2020b).

7.5 Priorities for capacity building and research

As threats to autochthonous forest genetic resources increase due to climate change, the occurrence of new pests, diseases and infrastructure projects, ex situ conservation measures, such as seed banking, may become more important. There is a need to invest in knowledge development for seed banking and cryopreservation technology in order to implement ex situ methods for the long term conservation of trees and shrubs, and to establish safety-duplications in back-up collections.

Characterisation of field collections is needed to better understand how they may be conserved. The role of genetic diversity and the significance local genetic resources in establishing resilient forests with high adaptive capacity is not well understood. Molecular markers and genomic technologies could be used, where appropriate, to fill this gap of knowledge.

8 The state of use

8.1 State of forest genetic resources use

FRM in the Netherlands is traded under the Seeds and Plant Material Act 2005 (Zpw, 2005). This law implements Council Directive 1999/105/EC from 22 December 1999 on the marketing of forest reproductive material within the EU. This directive ensures the supply of high quality FRM from the species concerned within the EU by demanding that FRM is not marketed unless the basic material from which it originates falls into one of four categories ('Source-identified', 'Selected', 'Qualified' and 'Tested') specified by the directive and that only approved basic materials can be used in its production. All information on units of approved basic material in the Netherlands is held in the national register. This national 'List of recommended varieties and provenances of trees' includes the national list of basic species material species that are subject to Directive 1999/105/EC and the recommended list of basic materials of 'non-directive species'. The list is available on www.rassenlijstbomen.nl. Its main aim is to inform users about the characteristics of the different varieties and provenances of trees that can be marketed. As a rule, reproductive material derived from basic materials not listed in this register cannot be certified and therefore cannot be marketed for forestry purposes. Naktuinbouw is the designated authority responsible for issues concerning the control and certification of marketed seeds/plants.

Since 2012, the number of species listed in the National register has increased from 66 species to 86 in 2019, and includes rare, native species like *Populus nigra* and *Rosa tomentosa*. Most seed stands are listed in the 'Source Identified' (autochthonous) category, followed by the 'Selected' category and four species seed stands are listed in the 'Tested' category. Improved material is available, mostly from 21 seed orchards of 12 species. For *Larix x eurolepsis* (syn. *Larix* × marschlinsii), there is a seed orchard in the 'Tested' category. There are also qualified and tested clones of *Populus spp* and hybrids, *Prunus avium* and *Salix* spp. FRM for shrub species is only sourced from autochthonous populations and gene bank collections (cat. SI) (Table 8.1). The number of seed orchards has decreased compared to a decade ago. The last seed orchard was established in the 1990s. Recently, the State Forest Service has started rejuvenating seed orchards and is establishing new orchards for some species.

In 2016, Naktuinbouw implemented a voluntary chain certification scheme to further improve transparency throughout the chain, under the name 'Select Plant Forest Reproductive Material from the Approved List of Basic Material'. It was to supplement the EU-based certification scheme. The aim of this new scheme was to promote and specifically identify seeds and planting material from seed sources/origins that are included in the Dutch register ('Rassenlijst Bomen'), and to ensure that the plant material was traceable throughout the whole chain, including database registration. Nevertheless, it did not provide sufficient added value in relation to the current EU-based certification scheme, so it was decided to discontinue the 'Select Plant' chain certification system as of 1 January 2021. Currently, the State Forest Service, together with LTO (the Netherlands Agricultural and Horticultural Association), the trade group BoHeZa and Naktuinbouw are discussing other options for improving the transparency and availability of planting material.

8.2 Trends in production of and demand for forest reproductive material

The mean seed production (in kg) of 39 species, consisting of 34 native and 5 introduced species between 2013–2016, is listed in Table 8.1. Mean total net seed production was 60,374.8 kg/a of which 91% is sourced from only two species (*Quercus robur* and *Quercus rubra*). Pedunculate oak and beech are the only species for which a substantial amount of seeds is sourced from tested stands (Table 8.1). Douglas was entirely sourced from seed orchards. In the 2007–2011 period, the total seed harvest (in kg) for the main forest tree species was higher. This was mainly due to higher quantities of seed harvest of *Quercus robur* (twice as high) and *Quercus rubra*. Compared to the 2007–2011 period, the seed harvest of *Castanea sativa*, *Fagus sylvatica*, *Pinus sylvestris*, *Prunus avium* and *Quercus petraea* increased. In the 2007–2011 period, no seed harvest was documented for *Pseudotsuga menziesii*, but is being harvested again nowadays. Seed harvests from seed orchards have generally increased over time. In particular, seed harvests from seed orchards of *Prunus avium*, *Quercus robur* and the conifers *Pinus sylvestris*, *Pseudotsuga menziesii* have increased. On the other hand, seed production from seed orchards of *Fraxinus excelsior* has decreased, most likely due to ash dieback. About 50% of harvested seeds are exported to other EU-countries, particularly seeds of *Quercus robur* (cat. Tested) and *Quercus rubra* (cat. Selected) (Source Naktuinbouw).

Table 8.1 *Mean annual quantity (kg) of seed harvested in the Netherlands in the 2013– 2016 period (Data source: Naktuinbouw OECD reports). Note that the Netherlands reserves the category SI for forestry purposes for autochthonous seed stands.*

Scientific name	Native (N) introduced (I)	Total (kg)	Source Identified (SI)	Selected (S)	Qualified (Q)	Tested (T)
Acer campestre	N	10.8	10.8	0.0	0.0	0.0
Acer platanoides	I	127.4	0.0	0.0	127.4	0.0
Acer pseudoplatanus	N	160.8	0.0	0.0	160.8	0.0
Alnus glutinosa	N	9.2	9.1	0.0	0.1	0.0
Berberis	N	1.2	1.2	0.0	0.0	0.0
Betula pendula	N	8.2	1.5	0.2	6.5	0.0
Betula pubescens	N	1.6	1.6	0.0	0.0	0.0
Carpinus betulus	N	20.9	20.9	0.0	0.0	0.0
Castanea sativa	I	730.5	0.0	730.5	0.0	0.0
Cornus sanguinea	N	31.0	31.0	0.0	0.0	0.0
Corylus avellana	N	119.0	119.0	0.0	0.0	0.0
Crataegus laevigata	N	5.7	5.7	0.0	0.0	0.0
Crataegus monogyna	N	147.9	147.9	0.0	0.0	0.0
Euonymus europaeus	N	16.2	16.2	0.0	0.0	0.0
Fagus sylvatica	N	3359.3	114.3	1018.5	0.0	2226.5
Fraxinus excelsior	N	152.3	16.0	102.5	33.8	0.0
Ilex aquifolium	N	0.5	0.5	0.0	0.0	0.0
Juniperus communis	N	0.6	0.6	0.0	0.0	0.0
Ligustrum vulgare	N	5.6	5.6	0.0	0.0	0.0
Malus sylvestris	N	1.5	1.5	0.0	0.0	0.0
Pinus sylvestris	N	9.7	1.6	0.0	8.1	0.0
Prunus avium	N	132.8	62.3	0.0	70.5	0.0
Prunus padus	N	1.7	1.7	0.0	0.0	0.0
Prunus spinosa	N	18.8	18.8	0.0	0.0	0.0
Pseudotsuga menziesii	I	14.8	0.0	0.0	14.8	0.0
Quercus petraea	N	335.9	335.9	0.0	0.0	0.0
Quercus robur	N	47161.9	664.9	29894.3	1002.5	15600.3
Quercus rubra	I	7741.5	0.0	7741.5	0.0	0.0
Rhamnus catharticus	N	6.1	6.1	0.0	0.0	0.0
Rhamnus frangula	N	5.1	5.1	0.0	0.0	0.0
Rosa arvensis	N	0.1	0.1	0.0	0.0	0.0
Rosa canina	N	8.0	8.0	0.0	0.0	0.0
Rosa corymbifera	N	1.0	1.0	0.0	0.0	0.0
Sorbus aucuparia	N	9.8	9.8	0.0	0.0	0.0
Thuja plicata	I	0.7	0.7	0.0	0.0	0.0
Tilia cordata	N	1.0	1.0	0.0	0.0	0.0
Ulex europaeus	N	0.0	0.0	0.0	0.0	0.0
Ulmus laevis	N	6.8	6.8	0.0	0.0	0.0
Viburnum opulus	N	9.5	9.5	0.0	0.0	0.0
Grand Total (kg)		60374.8	1636.4	39487.4	1424.3	17826.8

Mean annual plant production for all species in the 2013–2016 period was 11.4 million plants (Table 8.2). When compared for the main forest tree species, this output is substantial lower than that of the 2007–2011 period (approximately 29.5 million plants). Seedling production decreased almost for all species, except for the conifers. The production of seedlings of *Larix* spp, *Picea abies*, *Pinus sylvestris* and *Pseudotsuga menziesii* show an increase in the 2013–2016 period (Table 8.2). Almost 50% of the produced FRM belongs to the Selected category, followed by Qualified (21%), Source Identified (15%) and Tested (14%).

More than 90% of the plants of species under the EU directive produced for forestry purposes are exported to other EU countries; the rest is used for domestic forestry plantings. More than 50% of plant species like *Fagus sylvatica* and *Carpinus betulus* are traded for non-forestry purposes (Source Naktuinbouw).

Table 8.2 *Mean annual quantity of plants produced in the Netherlands in 2013–2016 period (Data source: Naktuinbouw OECD reports). Note that not only FRM from the National register was produced, so non-autochthonous material or autochthonous material imported from other countries may also be included.*

Scientific name	Native (N) introduced (I)	Source Identified (SI) Produced	Selected (S) Produced	Qualified (Q) Produced	Tested (T) Produced
Abies alba	I	0	311782	0	0
Abies grandis	I	14608	196779	33230	0
Abies nordmanniana	I	8033	0	0	0
Abies procera	I	0	0	0	64480
Acer campestre	N	17061	0	0	0
Acer platanoides	I	10175	36162	84910	0
Acer pseudoplatanus	N	55788	56150	91473	0
Alnus glutinosa	N	285293	109284	7718	0
Alnus incana	I	12175	169	0	0
Berberis vulgaris	N	1262	0	0	0
Betula pendula	N	101070	43400	69111	30428
Betula pubescens	N	138217	313	5639	0
Carpinus betulus	N	76058	78451	49514	0
Castanea sativa	I	4534	23748	0	0
Cornus sanguinea	N	17060	0	0	0
Corylus avellana	N	33828	0	0	0
Crataegus laevigata	N	1933	0	0	0
Crataegus monogyna	N	404650	0	0	0
Euonymus europaeus	N	20258	0	0	0
Fagus sylvatica	N	32710	140304	0	321118
Fraxinus excelsior	N	4140	5649	26568	0
Ilex aquifolium	N	540	0	0	0
Larix decidua	I	0	190875	149868	0
Larix eurolepis	I	0	71338	2019	0
Larix kaempferi	N	0	0	267195	31189
Ligustrum vulgare	N	238	0	0	0
Malus sylvestris	N	140	0	0	0
Picea abies	I	2800	1324694	398614	16289
Picea omorika	I	0	11600	0	0
Picea sitchensis	I	14050	8644	57393	637713
Pinus cembra	I	0	19698	0	0
Pinus contorta	I	0	125	0	0
Pinus nigra	I	694	104179	20735	0
Pinus nigra Arnold var. austriaca	I	0	3713	0	0
Pinus sylvestris	N	1313	11181	253401	1000
Populus nigra	N	8278	0	0	0

Scientific name	Native (N) introduced (I)	Source Identified (SI) Produced	Selected (S) Produced	Qualified (Q) Produced	Tested (T) Produced
Populus spp.		0	0	0	0
Populus tremula	N	4750	0	0	0
Prunus avium	N	24338	32375	87905	0
Prunus padus	N	252	0	0	0
Prunus spinosa	N	1065	0	0	0
Pseudotsuga menziesii	I	234135	1464999	715035	147857
Quercus cerris	I	0	194	0	0
Quercus ilex	I	2775	0	0	0
Quercus petraea	N	71431	82125	0	0
Quercus robur	N	54104	1118121	27315	390202
Quercus rubra	I	0	45170	0	0
Rhamnus catharticus	N	2616	0	0	0
Rhamnus frangula	N	5089	0	0	0
Robinia pseudoacacia	I	0	9076	0	0
Rosa canina	N	17001	0	0	0
Rosa corymbifera	N	388	0	0	0
Salix alba	N	4212	0	0	0
Sorbus aucuparia	N	4200	0	0	0
Thuja plicata	I	0	19909	0	0
Tilia cordata	N	35200	113120	28674	3613
Tilia platyphyllos	N	7055	27742	2013	0
Ulex europaeus	N	48	0	0	0
Ulmus laevis	N	15759	0	0	0
Viburnum opulus	N	6064	0	0	0
Grand Total		**1757380**	**5661066**	**2378326**	**1643887**

8.3 Needs, challenges and opportunities

Dutch forests need to cope with adverse climate conditions – including more severe drought spells and increased risk of late frost damage and pests and diseases –to ensure forest stability and productivity. Given the usually long rotation period of forests, forest managers need to select appropriate species (i.e. productive and climate-change resilient tree species and/or provenances) to lower expected tree-mortality risks and sustain current wood production rates at the end of the 21st century. Additionally, the planned forest expansion will lead to an increased demand for forest reproductive material. There is uncertainty whether a sufficient number of plants can be produced. Based on the seedling production statistics, it is clear if there are only limited plants available for the domestic market, it will be a challenge to match the demand of high quality planting material with supply.

There is a need for registration of more seed stands and establishment of high quality seed orchards to meet the future demand of FRM.

In light of climatic uncertainties and new pest and diseases, there is a tendency towards planting a broader range of species, not necessarily subject to the EU Directive 1999/105/EC to reduce risks of dieback in forests. In the forestry community, these species are frequently described as 'climate smart species' (e.g. *Corylus colurna*, *Populus tremula, Sorbus torminalis* and *Tilia cordata*). However, the demand for planting species is not yet reflected in the data on seedling production. It will be a challenge to derive high quality FRM, especially for the non-directive species as *Corylus colurna* and *Sorbus torminalis*.

With the predicted increase in heat and drought spells, there is also uncertainty about where FRM should be sourced from. The perceptions and views of Dutch forest managers differ on introducing new species or whether or not it is desirable to plant more species with southern provenances. Currently some forest managers have particular interest in provenances originating from southern locations because of assumed drought tolerance. Using plant material sourced from more southern European provenances (climate matched) could have advantages, such as higher production and they are better adapted to longer growing seasons. The drawback is that these trees may be poorly adapted to the current climate in the Netherlands, including late frosts. Especially more southern provenances may be more prone to frost damage as they are generally early flushing (e.g. Robsen et al. 2018) compared to local provenances and late frost damage increased in Europe (Zohner et al. 2020). Besides risks of maladaptation, there are also risks of genetic pollution, disturbing the native flora and fauna and introducing new pathogens. Some Dutch forest managers prefer using local materials.

8.4 Priorities for capacity building and research

There is a need to improve the traceability of FRM and transparency throughout the chain and increase end users' knowledge on the advantages of using high quality planting materials. As a broader range of species and provenances are expected to be planted, it is vital to monitor the health of planted trees. Keeping records of the species and their provenances planted in Dutch forests in accordance with the FRM regulation is extremely important. In the Netherlands, this fact is also acknowledged by the Royal Dutch Forestry association, which promotes the development of a voluntary system, where basic information on success rates of species and provenances can be stored (https://www.vbne.nl/klimaatslimbosennatuurbeheer/boomsoortenportaal). This system has been used since 2020, but unfortunately, precise details of provenances are scarce, owing to provenances not being widely recorded previously.

Empirical proof of the advantages and disadvantages of introducing southern provenances is lacking, but urgently needed. Research is particularly needed for evaluating different seed sourcing strategies (e.g. comparing seed-sourcing based on climate matching, a combination of seed sources and local sources).

9 The state of genetic improvement and breeding programmes

9.1 Approaches used for tree improvement and/or breeding

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.

9.2 Prioritisation of uses and traits

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.

9.3 Organisation of tree improvement and/or breeding programmes

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.).

Figure 9.1 *Selection and propagation of Fraxinus excelsior clones with field tolerance to ash dieback.*

9.4 Use of current and emerging technologies in tree improvement and/or breeding

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.

9.5 Needs, challenges, and opportunities for tree improvement and/or breeding

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.

10 Management of forest genetic resources

10.1 Management of forest genetic resources in natural and planted forests, and in other wooded lands

In the past, forest regeneration was mostly done by natural regeneration, even when stands were inferior. Over the last decade, there has been increasing focus put on artificial regeneration and more interest in choosing FRM in times of climate change, although natural regeneration still dominates in existing forests. Artificial regeneration is not only done in afforestation, but it is also used to revitalise low productive forest stands and forests stands affected by pests and diseases by enhancing tree species mixture to increasing tree species diversity (Lerink et al. 2020). Species mixing is applied as a silvicultural tool to counteract the adverse impacts of droughts, pests and diseases on tree growth and vitality, thereby stabilising forest ecosystems (Bauhus, 2017; Bouwman et al. 2020). In addition, mixed forest may also be more productive compared to monocultures, as shown in a case study in the Netherlands (Lu et al. 2018). No data is available on the share of natural regeneration versus artificial regeneration (planting or sowing). In 2018, around 10% of forest areas (38,720 ha) were naturally regenerated (FAOSTAT).

To support the choice of appropriate FRM, at a forest practice level, in 2015 a practical guide was developed with recommendations on how to order high quality trees and how to use the National List of Recommended Varieties and Provenances of trees (Jansen and Boosten, 2015). This guide helped forest owners improve their knowledge on provenance choice and ordering high quality plant material. There is a common consensus that it is important to maintain a high level of genetic diversity to select appropriate FRM in times of climate change, for instance by planting a diverse range of suitable provenances and species (Konnert, 2015).

Management of rare, autochthonous populations in semi natural forests is gaining more attention. The Cultural Heritage Agency published a management advise for conserving these autochthonous populations (Kemenade and Maes, 2019, Kemenade et al. 2021). For example, light demanding species like *Malus sylvestris* and *Crataegus* decline because historic forest management was discontinued (Kemenade and Maes, 2019). While some organisations pay attention to the management of these populations in order to conserve them, others do not include these populations in their management plans. The new national standard for FSC certification includes autochthonous in situ populations registered on the List of Recommended Varieties and Provenances of trees (www.rassenlijstbomen.nl) as objects with high conservation values. Consequently managers need to develop strategies how to conserve or improve these areas (FSC 2019).

Natural regeneration is seen as the preferred method for conserving these semi natural forest (i.e. rare autochthonous populations). However, high ungulate levels in the Netherlands may prevent natural regeneration (e.g. Ramirez et. al., 2020). Browsing is of particular concern, as it may reduce seedling and sapling density and lead to the loss of genetic variation in the new generation, thereby disturbing the selection process. This may have consequences for the rate of adaptation of autochthonous forest genetic resources.

10.2 Consequences of the changes in the forest sector for forest genetic resources and their management

The Paris Agreement and the IPCC Assessment Report (2018) emphasise the need for urgent and efficient actions for climate change mitigation and adaptation. The Climate Smart Forestry has been named as one approach to help in achieving these goals in forests and the forest sector. The Climate

Smart Forestry approach builds upon three main objectives: (i) reducing emissions of greenhouse gases into the atmosphere, (ii) increasing forest resilience to climate change and (iii) sustainably increasing forest productivity (Kauppi et al. 2018; Nabuurs et al. 2017, 2018). For these purposes, several pilots with climate smart forestry have already been funded by the Dutch government, with the aim of capturing an additional 1.5 million tons CO_2 per year by 2030 in forest management and the wood chain (VBNE 2020, Lerink et al. 2020). A climate management toolbox has been developed for the realisation, testing and monitoring of these pilot experiments. The pilots focus on a variety of things. For example, on forest regeneration with lesser known tree species, small scale afforestation, agroforestry, the creation of forest reserves, novel combinations of new forests with water storage, building using wood, biomass from hedges and small forests (Lerink et al. 2020). There is also an emphasis on rich litter species like *Tilia cordata, Acer pseudoplatanus* and *Prunus species* that may counteract soil acidification caused by nitrogen and sulfur deposition (Desie et al. 2020). Stand improvement underplanting is also being used to diversify species composition (Figure 10.1). This toolbox and the pilots should create a basis for larger scale measure in subsequent years (Lerink et al. 2020). In the context of this climate smart forestry approach, there is a need for more genetically improved FRM and a wider range of species, including new species with high drought tolerance and high litter quality to reduce soil acidification. Needs, challenges and opportunities

The use of appropriate FRM and integration of genetic conservation activities in forest management practises are key to sustainable management of forest genetic resources. There is an urgent need to further implement the above mentioned Climate Smart Forestry approach. Genetic aspects in forest management (e.g. Matyas & Kramer 2016) should gain more attention in the Climate Smart Forestry approach.

Figure 10.1 *Stand improvement underplanting in a Picea abies monoculture.*

10.3 Priorities for capacity building and research

Forest managers are responsible for using a variety of management and silviculture measures to influence the genetic composition of their forests. Special attention could be given to the role of natural regeneration for the conservation of semi-natural forests/autochthonous populations. More insight is needed into the role of native species and existing provenance diversity in order to cope with climate change. Further knowledge transfer on provenance choice is important, particularly with regard to climate change (drought tolerance). Provenance trials in combination with tree-ring research can play an important role to understanding drought tolerance (Buras et al. 2020).

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

11.1 National coordination mechanisms and other institutions dealing with forest genetic resources

There is no formal national coordination mechanism for the conservation, use and development of forest genetic resources. The various actors that are involved in the conservation, use and development of forest genetic resources have not changed over the past ten years. The Centre for Genetic Resources, the Netherlands together with the State Forest Service are the main institutions actively engaged in the conservation of forest genetic resources. The Naktuinbouw is responsible for issues concerning control and certification of marketed seeds/plants. The Board for Plant Varieties is the Official Body responsible for the National Register of approved Basic material of species subject to the EU Directive 1999/105/EC. The advisory committee Rassenlijst Bomen, which consists of experts within the forestry and nursery sector, advises the Board for Plant Varieties on approving basic material of the controlled species. It can also make recommendations on approving basic material of species that are not controlled by the EU Directive.

An important policy instrument for promoting cooperation between governments and other actors is the 'Green Deal' (www.greendeals.nl). It is a mutual agreement or covenant under private law between a coalition of companies, civil society organisations and local and regional government. This Green Deal instrument is used to supplement existing instruments, such as legislation and regulation, market and financial incentives, and measures to stimulate innovation around nine themes: energy, the bio-based economy, mobility, water, food, biodiversity, resources, construction and the climate. The Green Deal approach forms part of the green growth policy and is a joint initiative by the Dutch Ministries of Economic Affairs and Climate Policy (EZK), Infrastructure and Water management (I&W) and the Interior and Kingdom Relations (BZK). In the period 2012–2015, the 'Weet Welk Plantmateriaal Je (Ver)Koopt!' Green Deal was carried out to improve knowledge and communication on the quality of plant material for forestry purposes, including on genetic aspects. The parties involved were actors from all along the forest reproductive material production chain (from seed harvest, processing, storage, nursery production to the end user).

11.2 Policies and strategies relevant to forest genetic resources

In the Netherlands, conserving forest genetic resources for the long term is considered a public responsibility. The conservation and sustainable use of genetic resources for forestry is based on a number of voluntary and legally binding international agreements. The most important international commitment for forest genetic resources conservation is the Convention on Biological Diversity (CBD). In addition to the CBD, an important commitment is the Resolution S2 adopted by the Forest Europe Ministerial process (www.foresteurope.org) in which Member States committed themselves to implement a policy for the conservation of forest genetic resources. Another significant commitment affecting conservation and sustainable use of forest genetic resources for the Netherlands is The Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources of FAO Commission on Genetic Resources for Food and Agriculture (CGRFA). The Netherlands has directly implemented these agreements nationally without needing new legislation. In the national policy on genetic resources entitled 'Sources of Existence', which includes forest genetic resources (LNV, 2002), the Dutch government outlined how it will approach its international obligations regarding genetic resources. Until now, this policy document has remained considered topical. Forest gene conservation actions undertaken so far (e.g. ex situ conservation measures and designating in situ gene conservation units), including Statutory Research Tasks of CGN have arisen (directly) from the national implementation of these international policy commitments.

A change is needed in agriculture and forestry to respond to various challenges, such as climate change, and to halt the loss of biodiversity and circularity. There have been a number of national policy frameworks developed in the past years that address these challenges and that impact the conservation and sustainable use of forest genetic resources. Recently, the Ministry of Agriculture, Nature and Food Quality and the provinces published a joint Forest Strategy (LNV, 2020a). The Forest Strategy is about increasing cohesion between nature, climate and forest policy and is intended to improve the quality of the forests and to increase the total amount of forest. The Forest Strategy gives substance to the National Climate Agreement (Ministerie van Economische Zaken en Klimaat (2019) Klimaatakkoord), but can also be seen as an update of the former 1994–2020 Forest Policy Plan. The National Climate Agreement, which was concluded in June 2019, contains an agreements from the sectors that the Netherlands will reduce its emission by 0.4, to 0.8 megatonnes of CO_2 by 2030, by using trees, forests and nature to help achieve these goals. The planting of new forests and trees plays an important role in this.

In the policy document 'Agriculture, nature and food: valuable and connected' (Visie Landbouw, Natuur en Voedsel: Waardevol en Verbonden, 2018), the LNV Ministry gives a vision of a transition towards circular agriculture. The government's goal is for cycles of raw materials and resources to be closed at the lowest possible level, either nationally or internationally, by 2030. Attention to the relationship between nature and agriculture is of crucial importance to the goal of circular agriculture and in line with the government's aim of making agriculture more nature-inclusive. The utilisation of forest genetic resources is an important element especially in relation to nature-inclusive agriculture, for example in forms of agriculture that seek to combine trees and multi-annual crops (agroforestry) or in the role of landscape elements. The LNV Ministry is a partner in the Delta Plan for Restoring Biodiversity (www.samenvoorbiodiversiteit.nl Deltaplan), an initiative of several stakeholders from agriculture, agro-industry, nature and environmental protection and science. The Delta Plan outlines an area level approach, based on cooperation between farmers, the private sector, researchers and governments to turn the loss of biodiversity around.

The government-wide circular economy programme (https://www.rijksoverheid.nl/documenten/rapporten/2016/09/14/bijlage-1-nederland-circulair-in-2050) focuses on the development and realisation of a circular economy before 2050. The government's ambition is to achieve a 50% reduction in the use of primary raw materials (mineral, fossil and metals) together with social partners by 2030.

11.3 Legislation and/or regulations related to forest genetic resources

In 2014, the European Union adopted a regulation (EU Regulation 511/2014) to implement the Nagoya Protocol in the EU. The regulation applies to all genetic resource use in the EU, and includes obligations on genetic resource users in the EU. The national law to implement EU Regulation 511/2014 in the Netherlands came into force on 23 April 2016. The explanatory memorandum accompanying the law stated that no specific rules governing the access to genetic resources occurring in situ in the Netherlands would apply (www.absfocalpoint.nl).

In January 2017, the Nature Conservation Act (Wet Natuurbescherming) came into force and replaced the Nature Conservation Act 1998, the Forest Act and the Flora and Fauna Act. Forest stands are legally protected under the Nature Conservation Act. The Dutch government has two instruments for this purpose: 1) notification of felling and 2) the obligation to replant. Every felling must be reported to the provincial authorities. Provinces also have the option of imposing logging bans. A forest's location also determines whether provinces or municipalities are authorised to set rules. The forest sector uses a code of conduct for forest management (VBNE, 2014) in relation to the Nature

Conservation Act. This code of conduct helps forest managers, owners and forest contractors to carry out regular work without exemption for species protection under the Nature Conservation Act.

Relevant legislation affecting the use and marketing of forest reproductive material are the EU directive 1999/105/EC, and the UPOV Act1991. Both were implemented in the National Seeds and Planting Material Act (2005).

The EU Plant Health regulation (2016/2031/EU) came into effect in December 2019 and regulates various harmful organisms as EU quarantine organisms.

11.4 State of education, research and training related to forest genetic resources

Wageningen University offers a BSc course in Forest and Nature management and MSc courses on Forest and Nature Conservation and Plant Breeding. The Van Hall University of Applied Science offers a BSc course in Forestry and Nature Management. These programmes address provenance issues, however, there are no specific modules dedicated to this topic or to the conservation of genetic resources.

Efforts to promote the appropriate use of FGR are made, but not on a regular basis. In the framework of the 'Weet Welk Plantmateriaal Je (Ver)Koopt!' Green Deal, training sessions and workshops were held for nurserymen, forest managers and end users, practical guidelines on how to order quality plant materials. Informative movies and articles were also produced on the sustainable use of forest reproductive material. The CGN actively participated in these activities, together with Probos and the Green Deal partners.

Field workshops (www.veldwerkplaatsen.nl) are meetings where new and specific knowledge about particular management-related topics is shared and discussed by NGOs, forest managers and researchers. Some of these workshops are dedicated to the autochthonous genetic resources of trees and shrubs.

Besides, the Statutory Research Tasks of CGN on forest genetic resources, Value for Cultivation and Use (VCU) research is carried out by CGN related to the National List of Recommended Varieties and Provenances of trees (www.rassenlijstbomen.nl) and is based on provenance tests in tree species. Wageningen University & Research is the main organisation directly involved in research on the sustainable use of forest genetic resources. Research activities are carried out in areas related to climate-smart forestry and the resilience of forests and partly related to forest genetic resources.

11.5 Needs, challenges and opportunities

Although substantial effort has been put on knowledge transfer and public awareness of forest genetic resources over the past ten years, these factors still deserve greater attention. Several Dutch policy documents foresee a role for existing and new forests in CO_2 sequestration, and a role for their products in achieving a more circular economy and improving biodiversity. There is a need to communicate and raise awareness about the value of forest genetic resources and the role they can play in the transition toward more sustainable and resilient forestry, whether this is production forests, nature forests or trees in the urban landscape.

11.6 Priorities for capacity building

One major outcome of the 'Weet Welk Plantmateriaal Je (Ver)Koopt' Green Deal is that communication and trust between different actors in the production chain of forest reproductive material has increased. Despite this, the need to strengthen collaboration between stakeholders in the sector, and between government and other actors remains. Recommendations were made that need implementation in a follow up of this Green Deal. These include the creation of transparency in the availability of seeds (particularly for seeds derived from seed orchards and the gene bank for autochthonous trees and shrubs), investments in FRM certification systems with track and trace options and a further increase of the level of knowledge via training and better education of all actors throughout the production chain, from producer to end user, on the necessity and value of using of high quality FRM.

12 International and regional cooperation on forest genetic resources

12.1 International and regional cooperation

The Netherlands is participating in Phase VI (2020-2024) of the European Programme for Forest Genetic Resources. The country has been a member of EUFORGEN since its start in 1994. The programme aims at promoting conservation and the appropriate use of forest genetic resources as an integral part of sustainable forest management, by preparing science-based guidelines and recommendations. EUFORGEN is an instrument of international cooperation for the implementation of Forest Europe Strasbourg Resolution 2 (Conservation of Forest Genetic Resources) on forest genetic resources, relevant CBD decisions and the implementation and monitoring of regional-level strategic priorities of the Global Plan of Action for the Conservation, Sustainable Use and Development of Forest Genetic Resources (GPA-FGR). The Netherlands has actively contributed to the network and several working groups, particularly to developing a European conservation strategy for forest genetic resources (De Vries et al. 2015).

Over the past ten years, Wageningen University and Wageningen Research, which are both part of Wageningen University and Research centre (WUR), have participated in following EU-funded research projects related to forest genetic resources FORGER (FP7, 2012-2016) and Trees4Future (FP7, 2012-2016). Currently, there is an ongoing EU-funded H2020 project (B4est) on adaptive breeding for productive, sustainable and resilient forests facing climate change, which Wageningen Research participates in. Additionally, the Netherlands has participated in several EU-COST networks on forest genetic resources: MaP-FGR (2012–2016), Fraxback FP 1103 (2012–2016), STReESS (2012–2016) and Biosafety of forest transgenic trees (2010–2014).

12.2 Benefits from international cooperation on forest genetic resources

The Netherlands benefits from knowledge exchange within the EUFORGEN network and collaboration in various EU research projects. It has helped improve scientific knowledge on conservation and the sustainable use of forest genetic diversity. The European gene conservation strategy helped the Netherlands to develop a national forest genetic resources conservation strategy, in line with other European countries. There is a need to improve the implementation of European strategy on a national level through enhanced communication and the dissemination of knowledge to policy makers and forest managers.

12.3 Needs, challenges and opportunities

In the past, the Netherlands has benefited from international cooperation in the establishment of international provenance trials, for example those initiated by the International Union of Forest Research Organisations (IUFRO), and within EU-wide research projects. Further cooperation at the European level is needed to establish new provenance trials that involve the exchange of provenances between countries and the joint analyses of data. These are particularly important for strategizing a response to climate change.

13 Recommended actions for the future

Recommendations for future actions to strengthen the conservation, use and development of forest genetic resources in the Netherlands are given below and clustered following the four priority areas of the FAO Global Plan of Action for Forest Genetic Resources.

13.1 Availability of information on forest genetic resources

Until recently, Dutch forestry was focused on conifers, but climate challenges, the restoration of biodiversity, increasing the resilience of forests, triggered a change in species shares and species diversity. There is a trend in species diversification in forest systems and agroforestry, which involves planting (although experimentally) more exotic non-native species. In contrast to knowledge on changes in species diversity, there is a lack of information and knowledge on changes at the intra-specific and genetic diversity level of Dutch forests. The proper identification and mapping of autochthonous populations of the native tree and shrub species in particular is a prerequisite for this. There is a base line of inventory data that has been gathered over the past decades, but future monitoring is not foreseen. Autochthonous populations should preferably be mapped in the management systems of local forest managers.

Specific autochthonous populations that fulfil the minimum requirements for establishing in situ gene conservation units should be included in a national documentation system, which will allow the better monitoring of the status of these genetic resources. We recommend using the European information system of forest genetic resources as national documentation system. A better monitoring system of trends in and risks to autochthonous forest genetic resources would improve access to information on in situ forest genetic resources for all main players and stakeholders. It would also improve the identification of gaps in conservation of these in situ genetic resources.

Genetic characterisation data is only available for a few species. More effort in genetic characterisation is needed to support conservation and inform about the potential uses and values of FGR, particularly on how to better use the (adaptive) genetic diversity that exists within in situ autochthonous populations and in the gene bank collections.

13.2 Conservation of forest genetic resources

Over the past ten years, ex situ collections of autochthonous trees and shrubs (gene bank Roggebotzand) have grown steadily. Many of these collections are designed for seed harvest as well, and their utilisation is facilitated by being registered as seed sources. Further development and optimisation of the collections with a focus on species that are most at risk (priority species) is important. Therefore, the State Forest Service and CGN are implementing measures to develop the collections further in the coming years. These ex situ collections already contribute to the supply of FRM, but could be further exploited in the coming years. In particular, autochthonous planting material derived from these ex situ collections could be used for increasing woody landscape elements, estates, forest expansion within the NNN and Nature 2000 network. Additionally, it is recommended that gene bank material is used more for restoration and population enrichment projects, especially for rare or endangered species in N2000 areas. Integrating ex situ conservation and in situ strategies will become more important.

Almost none of the ex situ collections have been safety duplicated. It is recommended to consider other ex situ measures, beyond living tree collections, such as seed banking or cryopreservation as a backup strategies or alternatives, particularly for genetic resources that are most at risk or almost lost in situ (e.g. *Malus sylvestris* and *Fraxinus excelsior*).

In situ gene conservation should be strengthened for species where possible, and gene conservation units should be designated as such (EUFGIS). Gene conservation units do not have a formal status in the Netherlands and this is still a major drawback for their long term protection. Incentives and resources for forest managers to support activities for the conservation of forest genetic resources in their terrains are generally limited. Moreover, genetic diversity is not a conservation aim in protected nature areas (e.g. N2000) per se. Although there is growing awareness about the value of autochthonous populations and woody landscape elements, proper management and regular monitoring of these populations could be improved for long term conservation.

13.3 Use, development and management of forest genetic resources

The restoration of biodiversity, increasing forest resilience and counteracting deforestation are major challenges for Dutch forest managers. Beyond these issues, we predict that forests will play a role in CO_2 sequestration and contribute to a more circular economy. The proper management and sustainable use of forest genetic resources are part a way to address these challenges in the long run. Over the past ten years, efforts promoting appropriate use of FRM have been made (e.g. the 'Weet Welk Plantmateriaal Je (Ver)Koopt' Green Deal), but progress to date has not been steady. Accordingly, promoting awareness that planting material should be genetically suited to the sites where it is planted is still timely. In view of the intended expansion in forest area, a new variety of FRM will be needed to meet the future challenges more than before. This includes (i) genetically improved material with good growth characteristics, high timber quality and resistance to pests and diseases, adapted and genetically diverse material to cope with climate change, (ii) autochthonous plant material (e.g. for the restoration and establishment of woody landscape elements), and (iii) new planting material for urban green areas and agroforestry.

The Netherlands has a well-functioning seed programme that ensures the availability of genetically appropriate seeds in the quantities and of the quality needed for these new plantings. However, owing to climate change, the demand for forest reproductive material from new species that have hardly been used in Dutch forests until now is increasing. The supply of genetically improved forest reproductive material relies on tree improvement programmes. However, the number of tree improvement activities and of seed orchards has declined over the past ten years. Therefore, the establishment of first generation seed orchards of new species and improvement or rejuvenation of existing ones should be considered. The development of tree improvement and breeding programmes with a focus on resistance to pests and diseases needs more attention.

A data information system for keeping records of where FRM is planted is currently lacking. That said, a voluntary system was promoted recently, in which forest owners could share basic information about and their experiences with species and provenances. The further development of such a documentation system should be encouraged and expanded, and this system should record what is planted and where.

13.4 Policies, institutions and capacity building

In 2002, the government policy document 'Sources of Existence: Conservation and the sustainable use of genetic resources' was adopted. Until now, no new updates to this policy have been deemed necessary. The Forest Strategy is an important policy document of the Ministry and Provinces, in which ambitions for the development of forests over the next ten years are outlined. The Strategy recognises that making use of genetic diversity and genetically appropriate plant material can be an important measure in enhancing the resilience of Dutch forests. However, there is uncertainty about whether sufficient FRM can be produced. Therefore, a working group called 'Genetic resources and plant material' has been commissioned by the Ministry recently as an important first action. A working group consisting of representatives of the Board for Plant Varieties, the Netherlands Agricultural and Horticultural Association (LTO) and nature and landscape conservation organisations will develop a plan on how to guarantee the availability of suitable FRM in the short and long term. The working group will also investigate options for applying autochthonous plant material for restoring and establishing forests and landscape elements. However, efforts to raise further awareness of the roles and values of these forest genetic resources in diversification in forests and forestry need to be continued.

European collaboration (e.g. EUFORGEN) remains of the utmost importance to understanding and conserving the existing genetic diversity of forest species for the Netherlands. This includes also setting up provenance trials to assess the impact of climate change on the genetic diversity of tree populations, and to recommend choices of FRM and appropriate seed sourcing strategies.

The National Nature Network and Natura 2000 areas (most N2000 areas are part of the NNN), which are aimed at biodiversity conservation, are the back bone of Dutch biodiversity policy. The management goals in these areas may conflict sometimes with the conservation of forest genetic resources. Provinces are responsible for the nature policy and the further development of the NNN and N2000 areas. It is recommended that the provinces, in close cooperation with nature and landscape management organisations and other actors, explore opportunities for enhancing the in situ conservation of forest genetic resources in these areas, through subsidy schemes, for example (e.g. SNL the subsidy system for Nature and Landscape management or SKNL, the Subsidy system for improving nature and landscape quality).

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Annex 1 Bonaire, St Eustatius and Saba

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The Caribbean islands of Bonaire, St. Eustatius and Saba (BES islands) are special municipalities of the Netherlands. The total population is of Bonaire is 20,915, St. Eustatius has a population of 3,139 and Saba, 1,993 as of 2020. The islands are covered by various land use types, ranging from grassland, thorny shrubland and forests, to agricultural and urban areas. The total land area of the islands is 328 km^2 (Bonaire: 294 km^2, St. Eustatius: 21 km^2, Saba: 13 km^2). Despite their small size, the islands of Saba and St. Eustatius have a relatively large surface area, due to the height of their volcanic mountains. The top of Mount Scenery on Saba is 887 m, the highest point in the Dutch Kingdom, while the summit of the volcano Quill on St. Eustatius reaches 601 m. The three islands are situated in one of the world's biodiversity hotspots: the Caribbean Hotspot (Myers et al. 2000). Species richness is high, especially compared to the area, with about 370 known wild vascular plants in Bonaire, about 620 in St. Eustatius and more than 800 in Saba.

Bonaire's climate is very dry, representing a semi-desert climate, while the windward islands Saba and St. Eustatius have a wet, tropical climate, with much higher amounts of rainfall. On the latter islands, however, temperature and rainfall vary greatly from site to site, depending on altitude and exposure to prevailing trade winds. The large difference in climate between the leeward and windward Antilles is reflected in the vegetation of the islands, which is dry tropical forest on large parts of Bonaire, and wet tropical forest on most of Saba and St. Eustatius. On the latter two islands, the belts at low altitude have a type of dry tropical forest as climax, except for the very steep slopes, where nearly no trees are able to survive.

Bonaire

It is likely that Bonaire largely consisted of dry forests when the European colonists first arrived on the island in the 17th century. Since then, the trees have been exploited for building, firewood and charcoal production, resulting in the nearly complete deforestation of the island (de Freitas and Nijhof, 2005). On Bonaire, the best examples of forests (or rather woodlands) are found on the highest limestone terraces between Kralendijk and Rincon, an area that is difficult to reach and therefore has been relatively well preserved (Janssen et al. 2020). Several rare and endangered tree species are found here, like *Guaiacum officinale*, *Guettarda roupalifolia*, *Maytenus tetragona*, *Maytenus versluysii*, *Zanthoxylum monophyllum* and different species of *Bursera*, some of which have a limited world distribution range. The well-developed forest is also home to some species of epiphytic bromeliads and orchids, which can only grow when air moisture is relatively high. On the limestone terrace of Lima, there are also some relatively well developed woodlands that harbour the endemic palm species *Sabal lougheediana* (see Figure A1), which is critically endangered. A survey conducted in 2018, identified only 25 reproductively mature individuals on the island and urgent conservation actions are needed, including both in situ and ex situ conservation (Griffith et al. 2019). The limestone has a better water capacity in the dry season, and therefore a greater number of evergreen trees and shrubs are found, while on the volcanic soils, deciduous species prevail. On volcanic soils, there are only a few patches of well-developed forests due to the intensive grazing, with some exceptions in the Washington-Slagbaai National Park. On the south side of Bonaire on the shores of Lac Bay, there is an extensive, protected mangrove forest. These mangroves occasionally suffer from the deposition of high amounts of Sargassum-algae, which causes anoxic conditions and the die-off of mangrove trees.

Over-grazing by goats and donkeys is a severe threat to forest genetic resources and rare tree species, as it prevents their juvenilisation. For this reason, threatened species are being grown in a nursery by Echo Conservation Centre and ca 15,000 trees have been planted in 32 ha of exclosures, where grazing is prevented (http://www.echobonaire.org). In the national park, a project was recently started to remove herbivores from larger areas, to enable recovery of the vegetation. Herbivores were also removed from the islet Klein Bonaire (Dutch for 'Little Bonaire') and reforestation has been started.

Figure A1 *Sabal lougheediana a critically endangered island endemic, native solely to Bonaire.*

St. Eustatius

Large areas of tropical forests must have existed on Saba and St. Eustatius in the past, but the flatter parts of the islands have been clear-cut and nowadays are used for building and agriculture. However, large parts of abandoned urban and agricultural areas are now overgrown by Coralita (*Antigonon leptopus*), an alien invasive plant that is extremely difficult to get rid of. In the past, the crater floor of the Quill volcano has been used for growing fruit trees, but tropical rain forest has recovered here. In fact, some of the largest rain forest trees in the Dutch islands are found here, including species like *Spondias mombin*, *Ficus nymphaeifolia* and *Quararibea turbinata* (Van Andel & van der Hoorn, 2016). The crater slopes are covered by wet forests, with species like *Coccoloba swartzii*, *Guettarda scabra*, *Myrcia citrifolia*, *Ardisia obovata*, *Clusia major*, *Inga laurina* and *Byrsonima spicata (*de Freitas et al. 2012). Forest genetic resources here are threatened by goats and chickens, which hamper rejuvenilisation of trees. As far as known, no actions have been taken on St. Eustatius to study or limit the negative impact of grazing by these animals on forest genetic resources. Some dry tropical forests are found in the protected area on the north part of the island, with characteristic species like *Pisonia subcordata*, *Eugenia ligustrina* and *Bursera simaruba*, while degraded patches are dominated by the shrub *Leucaena leucocephala*.

Saba

Flat ground is rare on Saba, so agricultural plots have been established on the slopes. Over the last 50 years, most of these agricultural fields have been abandoned, and the forests have recovered. However, as goats and chickens roam everywhere, the understorey of the forest is sparsely vegetated. The forests of Saba show a nice arrangement based on the altitudinal zone, from dry tropical forests at low altitude, towards transitional forests and tropical rain forest on the higher slopes, and elfin woodland (= cloud forest) on the summit of Mount Scenery. The dry tropical forest is similar to that on St. Eustatius and has several tree species in common with the better-developed forests of Bonaire. However, well-developed stands are rare on Saba. They have been replaced by low shrubland and grassland due to grazing and cutting, while the steepest low slopes are sparsely vegetated due to erosion. The transitional forest is characterised by wet forest species (*Inga laurina*, *Clusia major*, *Coccoloba swartzii* and *Guettarda scabra*) and is found above 450 m. It is less degraded than the dry forests, as it occurs on slopes that are not very well suited for agriculture. Many fruit trees are found as remnants of former agricultural fields. The higher belt, roughly above 500 m, is occupied by tropical rain forest, but mainly in a degraded, secondary stage. This is partly a result of the steepness of the slopes, but these forests may have also been cut in the past. Nowadays, trees do not grow high on these slopes because of erosion and occasional felling by hurricanes. Tree ferns (*Cyathea species*) and the palm *Prestoea montana* form a low tree layer, while the Araceae *Philadendron giganteum* dominates the low shrub layer (de Freitas et al. 2016). In some deep gullies and on sheltered sites, taller trees are found, including *Cordia sulcata* and *Myrcia splendens*. The rim of Mount Scenery is covered by a cloud forest, dominated by the tree *Freziera undulata* and an endemic variety of the shrub *Charianthus purpurea*. The summit is covered in clouds for a large part of the year. This creates a high air moisture content, which is reflected by a wide variety of epiphytic mosses, ferns and vascular plants. Among these are many rare species, including the epiphytic *Notopleura guadalupensis*, *Utricularia alpina*, *Huperzia taxifolia* and the 'ghost plant' *Voyria aphylla*. The cloud forest was severely damaged at the end of the 20th century by two sequential hurricanes, but most of the felled Freziera's are now slowly recovering and becoming taller, although they are not yet at original, pre-hurricane sizes. The sound of chickens can be heard from the highest point of the mountain, but it is unknown to what extent these birds affect the forest understorey and the regeneration of trees and shrubs.

Annex 2 Abbreviations

FAO	Food and Agriculture Organization of the United Nations
FGR	Forest Genetic Resources
FSC	Forest Stewardship Council
PEFC	Programme for the Endorsement of Forest Certification
ABS	Access and Benefit-Sharing
BES	Bonaire, St. Eustatius and Saba
CBD	Convention on Biological Diversity
CGN	Centre for Genetic Resources, the Netherlands
EHS	National Ecological Network
EU	European Union
EUFGIS	European information System on Forest Genetic Resources
EUFORGEN	European Forest Genetic Resources Programme
FRM	Forest Reproductive Material
IUCN	International Union for the Conservation of Nature
IUFRO	International Union of Forest Research Organisations
LTO	The Netherlands Agricultural and Horticultural Association
LNV	Ministry of Agriculture, Nature and Food Quality
MCPFE	Conference on the Protection of Forests in Europe
NGO	Non-Governmental Organization
NNN	National Nature Network
NVWA	Netherlands Food and Consumer Product Safety Authority
OECD	Organisation for Economic Co-operation and Development
SBB	State Forest Service
VCU	Value for Cultivation and Use

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Published by:
Centre for Genetic Resources the Netherlands & Ministry of Agriculture, Nature and Food Quality

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Photography
Centre for Genetic Resources, the Netherlands (CGN), M. Pasteels, J.A.M. Janssen, L. Kragt and Shutterstock

Design and printing
MediaCenter Rotterdam

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