Nordic Council of Ministers

Nordic Crop Wild Relative conservation

A report from two collaborative projects 2015-2019

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Contents

Summary

The report summarizes results from a cooperation among all the Nordic countries during the period 2015–2019 (two projects). The work has focused on the conservation of Crop Wild Relatives (CWR), i.e. wild plant species closely related to crops. They are of special importance to humanity since traits of potential value for food security and climate change adaptation can be transferred from CWR into crops. The projects represent the first joint action on the Nordic level regarding *in situ* conservation of CWR. Substantial progress has been made regarding CWR conservation planning, including development of a Nordic CWR checklist and identification of suitable sites for CWR conservation. A set of recommended future actions was developed, with the most important one being initiation of active *in situ* conservation of CWR in all Nordic countries.

Chapter summaries

Chapter 1. Introduction

This report summarizes the results from a cooperation among all the Nordic countries during the period 2015–2019 (two projects). The long-term aim of the projects is to promote a well-functioning, climate- and environmentally friendly Nordic agriculture. In particular, the goal is to achieve Nordic synergy in the field of crop wild relative conservation planning and to facilitate Nordic cooperation and knowledge exchange on this topic. Crop Wild Relatives (CWR), are wild plant species that are closely related to crops and of special importance to humanity since traits from CWR can be transferred into crops. CWR are therefore one of the necessary raw materials needed to address future challenges regarding food security, environmentally friendly agriculture, as well as adapting crops to climate change.

Chapter 2. Nordic CWR species

The first step towards a Nordic plan for CWR conservation was to create a checklist including all CWR species in the Nordic region. The checklist covers more than 2,700 wild taxa related to medicinal, ornamental, forestry, food or forage crops. It is freely available online (https://doi.org/10.15468/itkype) and can be used as an input for creating national checklists.

The checklist was prioritized based on the socioeconomic value of the crop the CWR is related to, and on the potential utilization value for plant breeding. From a Nordic perspective, food and forage CWR were deemed the most important for food security and only these categories were included in the final list. The resulting priority list includes 115 priority taxa (https://doi.org/10.6084/m9.figshare.5688130.v1) that are judged to be of highest value and therefore should be the main targets for *in situ* and *ex situ* conservation efforts.

Chapter 3. *In situ* conservation

In situ conservation, i.e. conservation of species in their natural environment, is regarded as the best approach for conservation of CWR. In this way, many species can be conserved within the same conservation area and the CWR have the possibility to continuously adapt to a changing climate and environment. Protected areas specifically designed to conserve within-species diversity in CWR are called "genetic reserves". Until today, no genetic reserves have been established in the Nordic countries. Within the Nordic project, a gap analysis was conducted and conservation areas suitable for genetic reserves were identified in all Nordic countries. It is recommended that each country begin analysing their top three sites (Figure 7, Appendix 1) for potential establishment of genetic reserves.

Chapter 4. Climate change analysis of three example species

Three Nordic priority CWR were selected for a climate change analysis: common hazel, alpine meadow-grass and cloudberry. They were chosen because they represent divergent geographical distributions: southern, northern and general respectively. Simulations under different climate change scenarios show hazel potentially increasing its present distribution by spreading northwards when climatic conditions become favourable. Cloudberry is anticipated to migrate northward, but at the same time lose habitats in the south. Climate change is likely to have the most detrimental effect on alpine meadow grass that has a northern distribution. According to the simulations, it will lose a substantial part of its suitable habitats by 2070. It was concluded that climate change should be considered when planning current conservation actions, especially for the species with a northern distribution.

Chapter 5. *Ex situ* conservation

Ex situ conservation, i.e. conservation of a species outside its natural habitat, is conducted for CWR in the Nordic countries today. The largest seed collection can be found at NordGen, the Nordic regional gene bank for plant genetic resources for food and agriculture. Seeds of CWR are also found in national seed gene banks for threatened species in Finland and Norway, as some CWR are red-listed. For a few of the CWR species on the Nordic priority list, large scale collecting has taken place and seeds have been stored at NordGen, for example for timothy and red fescue. However, most of the species on the priority list only have a few populations conserved *ex situ* or are absent from *ex situ* collections. Within the current Nordic project, a gap analysis was conducted and sites suitable for sampling were identified.

Chapter 6. Integration and cooperation

One of the main aims of the two projects was to facilitate Nordic cooperation and coordination within the field of CWR conservation. Part of this has been realised through the careful Nordic planning work. Another has been the establishment of a Nordic network of CWR stakeholders by arranging workshops, meetings and communicating via websites and e-mails. These have been important channels for knowledge exchange and discussions on the best approach regarding future actions to ensure CWR conservation in the Nordic region, leading to the recommendations from the project. In all the Nordic countries there have been some activities on CWR during the timespan of the Nordic project such as, for example, national projects on CWR that were carried out both in Finland and in Sweden.

Chapter 7. Policy and legislation

The major outcome regarding policy from the two Nordic projects includes a set of policy recommendations based on feedback from a stakeholder workshop held in Vilnius 2016. Eight recommendations summarise the most urgent steps to ensure conservation of CWR in the Nordic region (at https://doi.org/10.6084/m9.figshare.7558658.v1). In addition, a Ministerial Declaration was drafted, aiming to be endorsed by the *Nordic Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry* and the *Nordic Ministers of the Environment* in 2018 as a joint Nordic commitment. Regrettably, the declaration was not endorsed. Several challenges remain regarding policy and legislation for CWR conservation and, while many have a Nordic perspective, several of them need to be addressed on a national level.

Chapter 8. Publication and outreach

Publication and outreach have been important goals within the Nordic CWR projects, and several approaches have been used to reach different stakeholder groups. Communication has taken place via: 1) a Nordic CWR website established under NordGen's main site (will be maintained after the end of the project), 2) monthly plant portraits published at the Nordic CWR pages, 3) a policy brief, 4) social media, 5) scientific publications and presentations at conferences, 6) national publications and 7) project websites. In total, 11 publications are listed as outcomes from the project and 23 CWR plant portraits can be found at the Nordic CWR webpage.

Chapter 9. Toolkit for *in situ* conservation in the Nordic countries

A toolkit for national CWR conservation planning was developed based on Maxted *et al.* (2013) (http://www.cropwildrelatives.org/conservation-toolkit/introduction/). This framework has been used to list tools, publications, analyses etc. that have been developed within the Nordic projects and that can be of use in the individual Nordic countries in national efforts regarding CWR conservation planning.

Chapter 10. Recommendations and conclusions

The most important recommendations from the projects are:

1. Develop national strategies for *in situ* and *ex situ* CWR conservation and sustainable use;
2. At national level, develop policy instruments needed to facilitate conservation and sustainable use of CWRs, involving all relevant stakeholders;
3. Adopt *in situ* conservation as the main approach for safeguarding CWR diversity;
4. Begin implementing *in situ* conservation of priority species, in at least one site in each of the Nordic countries;
5. Form a network of complementary *in situ* conservation sites across the Nordic region, covering different habitats and climates and including top priority CWR;
6. Develop the Nordic approach further based on agreed international guidelines and strategies;
7. Encourage research, infrastructure development and Nordic cooperation to further CWR conservation and sustainable use;
8. Integrate *in situ* and *ex situ* conservation, as appropriate.

1. Introduction

This report describes the results from a cooperation among partners from all the Nordic countries on the topic of Crop Wild Relative (CWR) conservation. The long-term aim of this cooperation is to promote a climate- and environmentally friendly Nordic agriculture, and sustainable use of genetic resources in terrestrial ecosystems. In particular, the goal is to achieve Nordic synergy in the field of crop wild relative conservation and sustainable use, and to facilitate Nordic cooperation and knowledge exchange on this topic.

The cooperation was initiated within the project *Ecosystem services: Genetic resources and crop wild relatives* 2015–2016 and continued within the project *Wild genetic resources – a tool to meet climate chang*e 2016–2019. The projects were funded by the Nordic Council of Ministers, the latter project from two separate calls, and by self-funding from the participating organisations.

1.1 Crop Wild Relatives (CWR)

CWR are wild species that are closely related to crop plants. They are not necessarily different from other wild species, but they are of special importance to mankind since traits that occur in CWR can be transferred into cultivated crops. CWR contain many traits that are not present in contemporary cultivars. Some of these traits have been intentionally selected against to produce the high-yielding modern varieties, while others have been lost as a side effect of the selection process during plant breeding. However, limited diversity decreases the potential for adaptation of a crop, for example to changes in climate, pest and disease pressures, demands for a sustainable climate friendly agriculture and consumer demands.

CWR and other genetic resources are the main sources of genetic diversity when important variation is absent from cultivars and breeding material, and they are therefore central to further development of our crops. For example, a trait yielding resistance against rhizomania in the CWR sea beet collected at the coast of Kalundborg Fjord in Denmark, was successfully introgressed into sugar beet (Frese and Capistrano-Gossmann, 2017). Intraspecific variation that is expected to be central for adaptation to the future climate has been found in many crop species and has already been used in plant breeding (e.g. Dempewolf *et al.*, 2014). Examples include tolerance to drought and waterlogging, pest and disease resistance and tolerance to heat stress.

The global climate has already started to change, and substantial changes are expected during the coming years (International Panel on Climate Change [IPCC], 2007; IPCC, 2013; IPCC, 2018). In the Nordic area, predictions indicate not only an increase in temperature but also more frequent extreme weather events, rise in sea level, changes in precipitation patterns and snow cover (Barua *et al*., 2014). Naturally these changes will substantially affect agriculture and there is an urgent need to start adapting Nordic agriculture to cope with these challenges if we are to continue to produce enough healthy food to assure food security. In addition, there is a need to limit the environmental footprint of agriculture itself and the possibility that agriculture can be used in different ways to mitigate climate change. CWR can play an important role as a source of the variation necessary to adapt crops to these new circumstances. *CWR are therefore one of the necessary raw materials needed to address future challenges regarding food security, environmentally friendly agriculture, and climate change adaptation and mitigation.*

Many wild plant species are under threat in Europe today (IUCN, 2019) and the number of endangered and vulnerable species are expected to increase in the future. In a European study of 1,350 plant species, simulations indicated that more than half could become vulnerable or threatened by 2080 (Thuiller *et al*., 2005). This is a pattern that can also be seen in studies focusing on CWR, and climate change is expected to result in decreased distribution ranges, increased threat levels and extinctions (e.g. Jarvis *et al*., 2008). A Norwegian study on 187 CWR indicates that the threat to CWR species will increase in the future (Phillips *et al*., 2017) and similar patterns are expected for other Nordic regions. *Specific conservation actions are therefore needed to assure the conservation of these vital resources.*

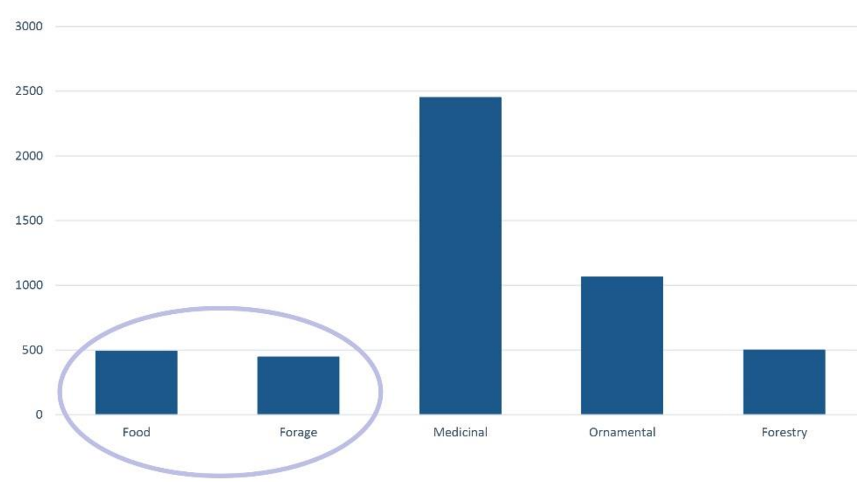
2. Nordic CWR species

2.1 Nordic CWR checklist

A CWR checklist is an inventory of all crop wild relatives, for example in a specific region or for CWR related to a particular crop or crop type. A comprehensive CWR checklist for the Nordic CWR taxa had not been drafted previously. Therefore, it was decided to make such a list in the beginning of the Nordic CWR projects to enable regional conservation planning of crop wild relatives. Additionally, those countries which did not previously have national CWR lists, could draw them from the Nordic list and adapt them to their national needs.

The Nordic regional checklist was based on a broad definition of CWR (Maxted *et al.*, 2006), where all the wild taxa of the region in the same genera as the cultivated crop, were considered crop wild relatives. When drafting the Nordic regional CWR checklist, the Nordic flora list (Dyntaxa, 2016) was matched with global crop genera lists. This resulted in a checklist of 2,753 wild taxa growing in the Nordic region and which are related to medicinal, ornamental, forestry, food or forage crops (Figure 1). The Nordic CWR checklist can be found online (Fitzgerald *et al.*, 2017a).

Figure 1: CWR categories of the Nordic Flora. The Nordic checklist contains species from five different use categories but only two of these, food and forage, were prioritized and included in the Nordic priority list



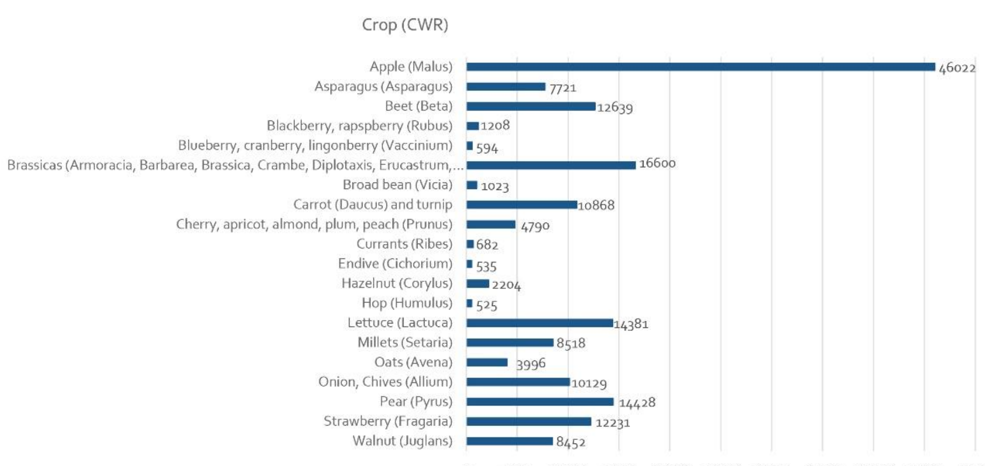
Note: Note that a CWR can be included in more than one use category.

2.2 Nordic CWR prioritisation

A checklist of CWR with ranking of taxa according to their importance to conservation provides a useful tool for conservation planning. To focus on a smaller number of taxa enables more efficient and realistic chances of implementing *in situ* and *ex situ* conservation. The commonly used prioritization criteria (Kell *et al.*, 2017) are socioeconomic value of crops, potential utilization value of CWR for breeding and the threat status of CWR. The first two of these were used when prioritising the Nordic checklist. Detailed description of the criteria is explained in Fitzgerald *et al.* (2019).

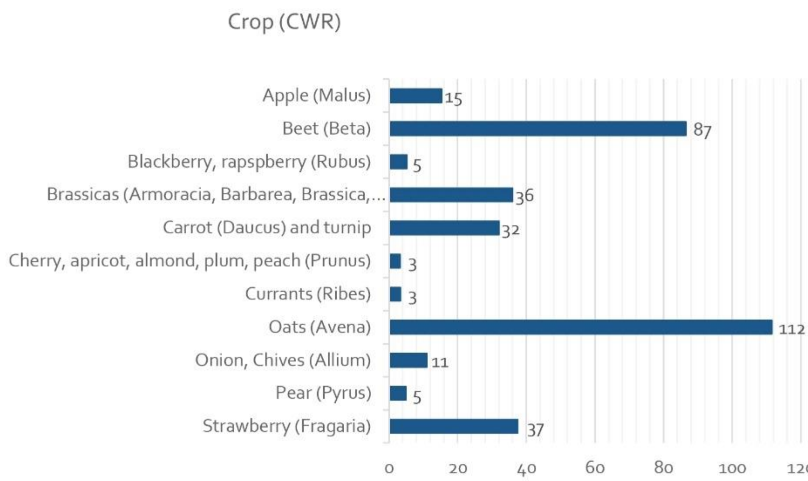
Figure 2 shows the global economic value of crops that have high priority CWR in the Nordic region. The highest monetary value is held by apples, therefore making crab apple (*Malus sylvestris* Mill.) a conservation target. Second highest value was held by *Brassica* group including several crops such as cabbage, mustard seed, rapeseed, swede, kale, broccoli, cauliflower, kohlrabi, turnip, brussels sprouts and horseradish. The third highest are lettuce and pear. The Nordic economic value of crops with wild relatives distributed in the Nordic region was also considered. However, not all crops had a value available. Out of the ones which had, oats, sugar beet and strawberry had the highest value. After that came brassicas, carrot, apples and onions. Figure 3 shows the Nordic economic value of crops with CWR genera in brackets after the crop name. For forage crops, production values for individual genera were not available, and feedback from Nordic plant breeders was instead used to estimate economic value.

Figure 2: The average global production values of food crops to which the Nordic priority CWR species are related, in current million USD in a ten-year period (2004–2013)



Data Source: FAO, 2015.

Figure 3: The average Nordic production values of food crops the Nordic priority CWR are related to, in current million USD in a ten-year period (2004–2013)



Data Source: FAO, 2015.

Prioritisation according to the utilisation potential was based on genepool[1] and taxon group concepts (Harlan and de Wet, 1971; Maxted *et al*., 2006). The majority of the prioritised taxa (c. 80%) belonged to the primary genepool (GP1) of crops. Out of the prioritised taxa, 7% belonged to the secondary genepool (GP2), 10% to the tertiary (GP3) gene pool and 4% to taxon group 4 of the crop. Most of the wild relatives are in genepools of several crops, as can be seen in the Nordic priority list (Fitzgerald *et al*., 2017b). In this list, all the crops each CWR is related to are listed together with information about in which Nordic countries it can be found and whether it is indigenous, naturalized or temporary in each country.

By prioritizing only food and forage crops (Figure 1) with socio-economic value and utilization potential, the large number of taxa in the Nordic checklist was reduced to 115 priority taxa, about 4% of the total number of CWR on the checklist. These taxa are seen to be the most important targets for both *in situ* and *ex situ* conservation action. The priority list, along with additional data is available online (Fitzgerald *et al*., 2017b).

The Nordic CWR priority list includes wild species related to several food crop groups such as: vegetables, cereals, fruits, berries, spices, nuts and forages (Figure 4). The priority taxa consist of food and forage wild relatives as they are considered most important for conservation due to their potential role in future food security. The genera with highest number of taxa in the priority list are forages, such as *Trifolium* spp., *Poa* spp. and *Festuca* spp. and berries such as *Vaccinum* spp., *Ribes* spp and *Rubus* spp. (Figure 5).

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[1] *Primary genepool*: crop and all the closely related taxa, able to freely interbreed with the crop and give rise to fully fertile progenies. *Secondary genepool*: taxa more remotely related to the crop, able to cross with the crop and give rise to some fertile progenies. *Tertiary genepool*: taxa remotely related to the crop and naturally incapable of interbreeding with the crop.

Figure 4: The proportion of crop wild relatives in the Nordic priority list that are associated with each crop group

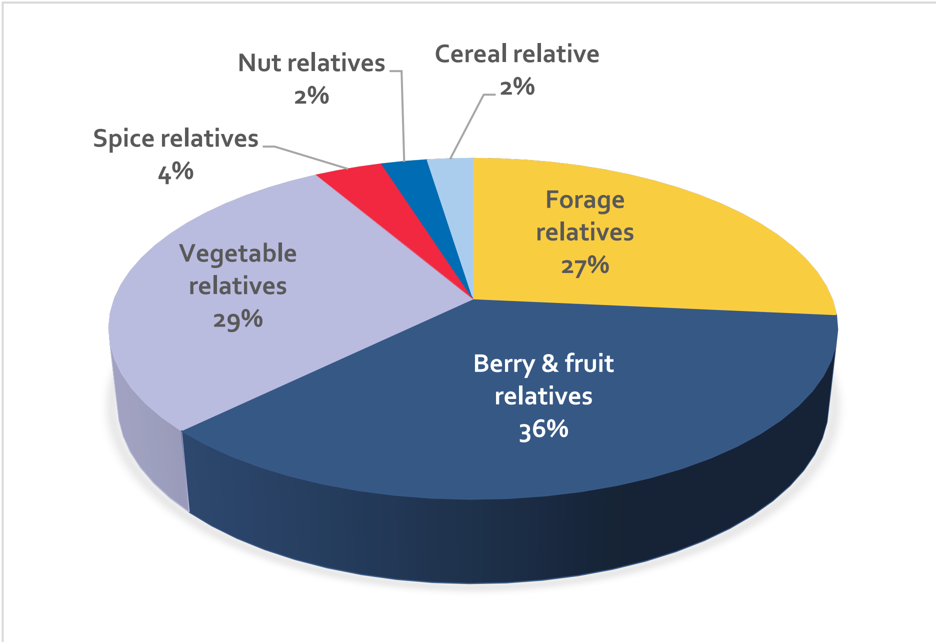
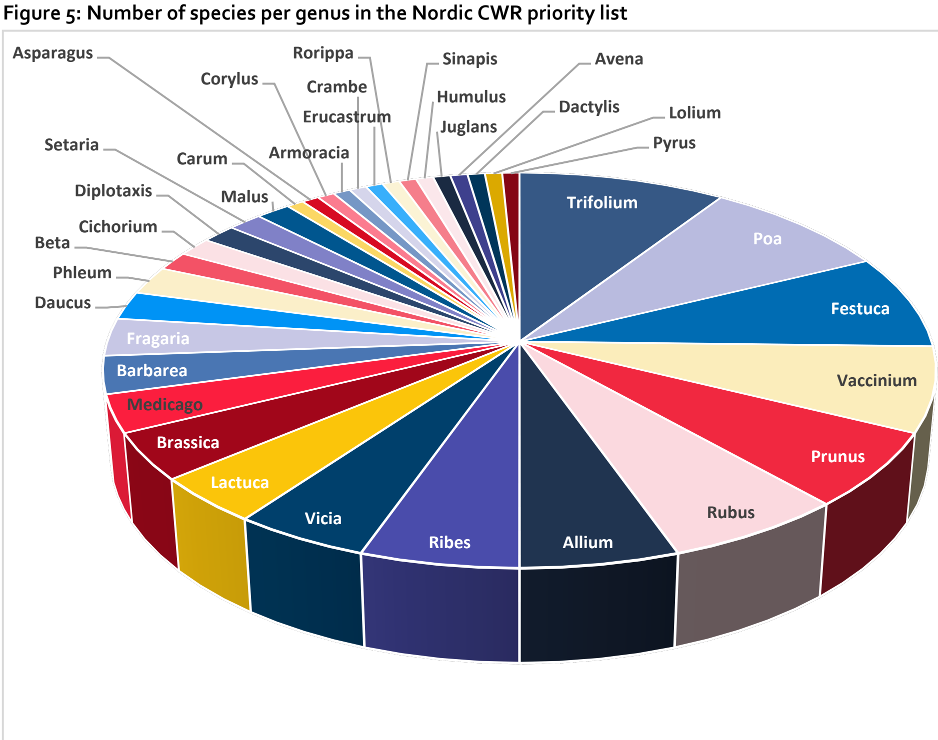


Figure 5: Number of species per genus in the Nordic CWR priority list



3. *In situ* conservation

3.1 Introduction to *in situ* conservation

Like other wild species, crop wild relatives can be threatened by human activities such as habitat destruction and fragmentation, changes and intensification of land management and adverse effects of climate change (Maxted *et al*., 2010; Jarvis *et al*., 2008). Many CWR populations grow in existing conservation areas, but most of them are not presently included in conservation programs (Ford-Lloyd *et al*., 2011) where their populations would be monitored and managed. Therefore, it is possible even for CWR populations in protected areas to decline unnoticed. Due to this, active measures are needed to safeguard CWR genetic resources.

The main approach for conserving CWR species is to maintain them in their natural wild habitats, in so called *in situ* conservation. This way the species can adapt to changing climate conditions, increasing their chances for surviving in the long-term. *In situ* conservation can conserve many species and often populations of substantial size within conservation areas, providing an opportunity to maintain large amounts of genetic diversity.

CWR species are ideally conserved in genetic reserves (Maxted *et al*., 1997), protected areas that are specifically designed for the long-term conservation of genetic diversity within natural populations. They can be established inside existing conservation areas or, if needed, outside existing conservation areas. Establishing genetic reserves within an existing conservation area network would be cost-efficient since there is no need to establish completely new conservation areas and, moreover, in the Nordic countries there is already a large number of established conservation areas. CWR populations would need to be monitored at regular intervals and have suitable management practices to ensure viability and health of the target populations.

So far, no genetic reserves have been established in the Nordic region and there are no active management or monitoring practices for the majority of the CWR species. In Norway, there is an ongoing process with the ambition to establish the first *in situ* conservation site with active conservation and management of CWR. In Finland potential genetic reserve sites have been identified and the work will continue by identifying target populations and their management needs. However, the majority of the CWR in the region remain unprotected or in passive conservation until conservation strategies are implemented.

3.2 *In situ* conservation gap analysis

The aim of the conservation gap analysis was to identify potential genetic reserve sites within existing conservation areas in Nordic countries, which would conserve the genetic diversity of the priority CWR species. We also investigated the most diverse CWR areas in the whole land area of the Nordic region in 10x10 km grid cells (Fitzgerald *et al*., 2019) but decided to continue planning with the existing conservation area sites. The project group, with the help of other stakeholders, drafted a Policy Brief in 2017 (Palmé *et al*., 2019) outlining Nordic CWR conservation goal suggestions. One of the goals was to establish a minimum of one site in each country to start the regional genetic reserve network. These sites would contribute towards national, regional and global food security.

Since data on genetic diversity of the priority species in the region was not available, ecogeographic diversity was used as a proxy for genetic diversity in the conservation gap analysis, a method described in FAO (2018). This was done by using ecogeographical land characterization maps – ELC maps (Parra-Quijano *et al.*, 2012) in assessing the priority CWR species adaptation to their habitats. A priority species ELC map was made using existing environmental data of the sites where the species were observed. These included climatic, ecological and geographical data variables affecting the target species adaptation to their environment, detailed in Fitzgerald *et al.* (2019). The completed ELC map (Figure 6) enabled us to locate complementary conservation areas where the target species ecogeographic diversity would be conserved, if the sites were established as genetic reserves.

The complementarity analysis is used to identify the minimum number of sites where a maximum number of target species occur (Maxted *et al*., 2008). The complementary conservation planning (Rebelo and Siegfried, 1990; Justus and Sarkar, 2002) was carried out for the Nordic priority taxa with *Capfitogen Complementa* (Parra-Quijano, 2016) and resulted in a potential network of 162 complementary sites (Fitzgerald *et al*., 2019). These would conserve the intraspecific diversity of the priority CWR in the region. Figure 7 shows the top three complementary sites in each country and Appendix 1 gives more details of each site. A complete list of all the complementary sites in the *in situ* gap analysis can be found in Fitzgerald *et al.* (2019) supplementary materials, which is freely available online (http://dx.doi.org/10.1017/S147926211800059X).

Figure 6: Ecogeographic land characterization map for the priority species

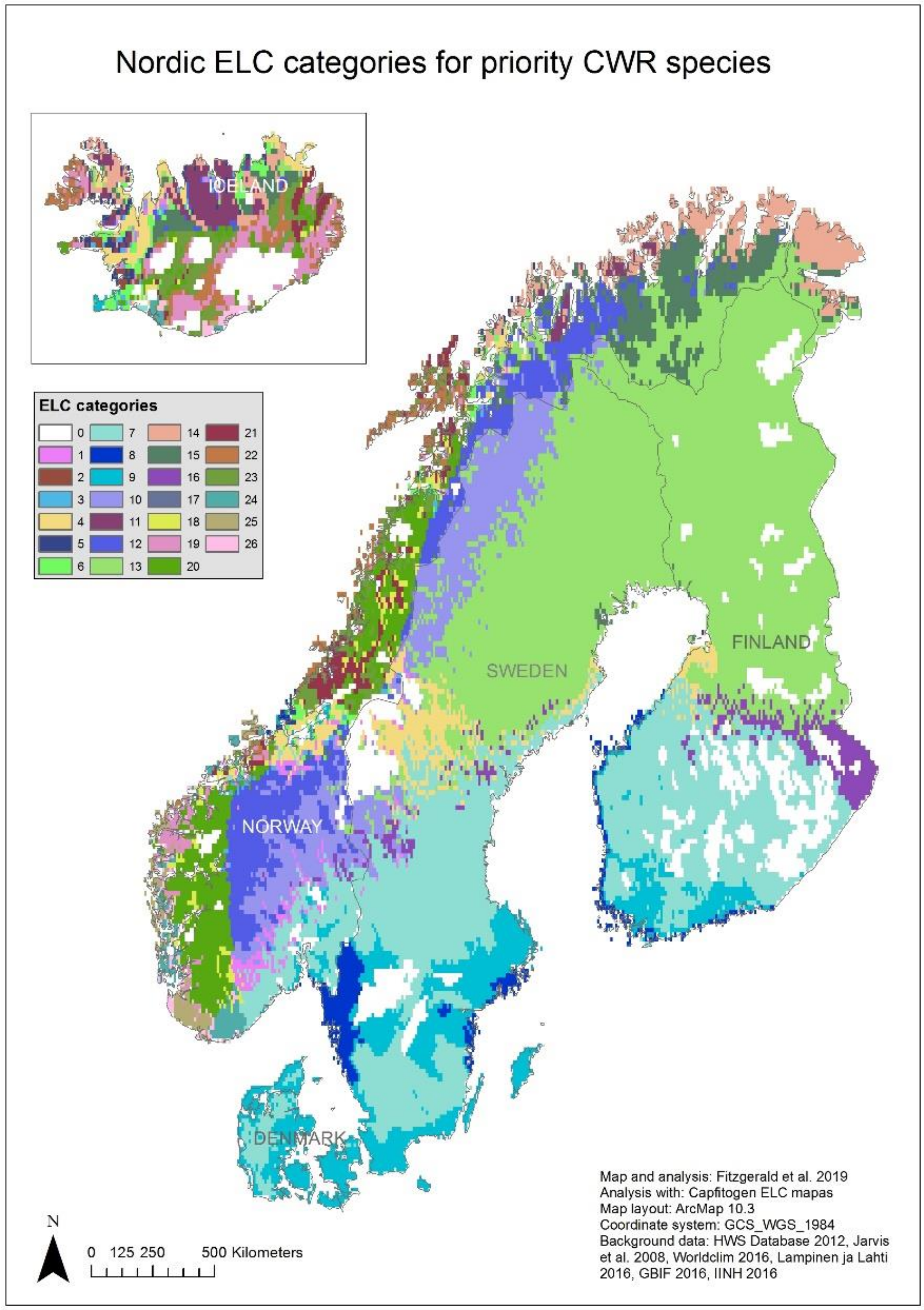
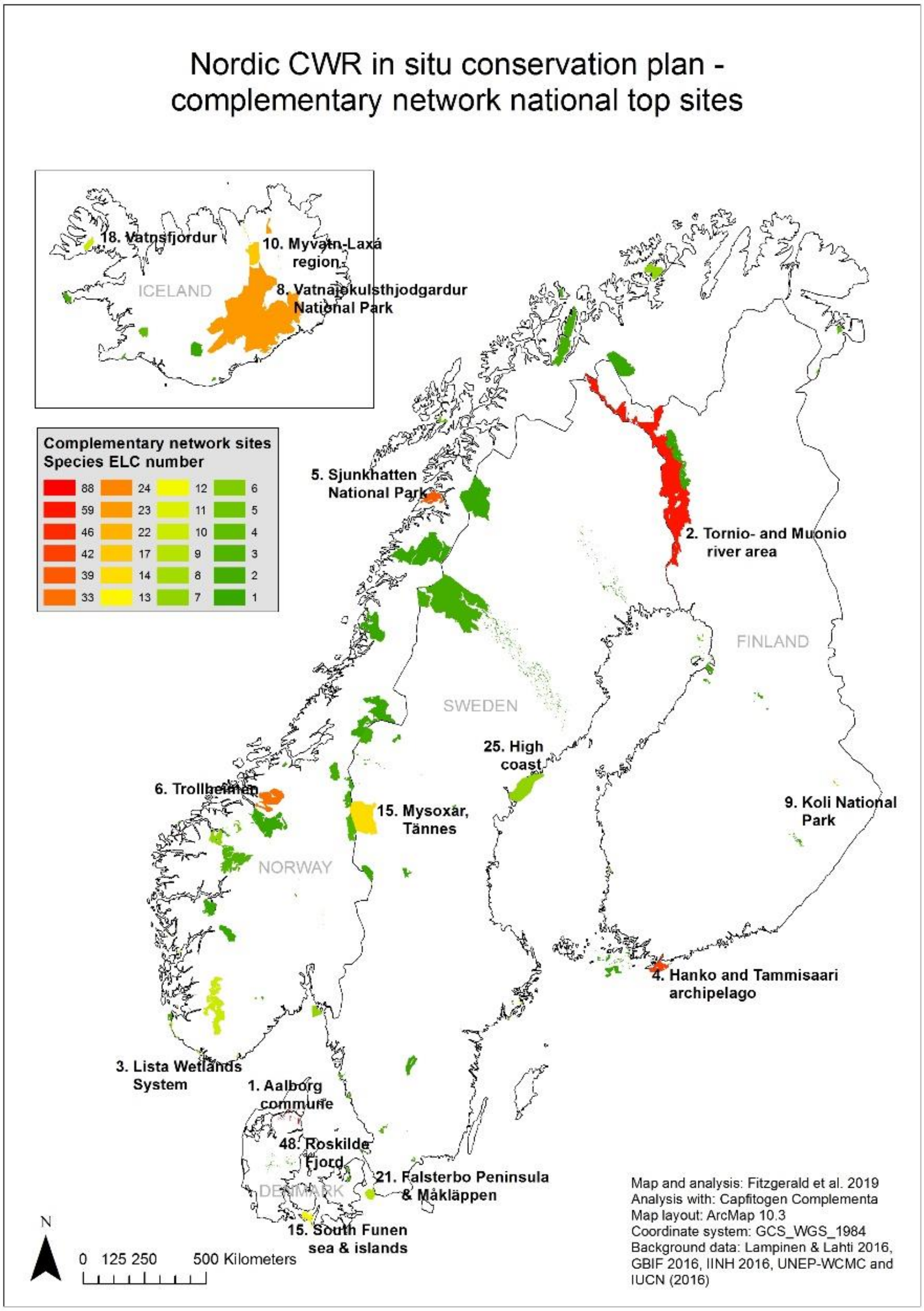


Figure 7: The 162 complementary sites in conservation areas identified as suitable for conservation of the prioritized Nordic CWR



Note: Observe that some sites are small and difficult to observe on the map. The top 3 complementary sites in each country are labelled name and a number indicating the position in the complementary analysis.

4. Climate change analysis of three example species

Three Nordic priority wild relatives were selected for a climate change analysis; common hazel (*Corylus avellana* L.), alpine meadow-grass (*Poa alpina L.)* and cloudberry (*Rubus chamaemorus* L.). The example species were selected based on their distribution range in the region: hazel having a southern distribution range in the Nordic countries, alpine meadow-grass a northern distribution range and cloudberry a general distribution throughout the region – except Iceland. The main aim of the analysis was to investigate how these CWR species' distribution would change in the future under different climate change scenarios. The knowledge gained could be used in both *in situ* and *ex situ* conservation planning. For example, if a target species is predicted to disappear from one area of the region in the future, *in situ* conservation should not be planned there for that species. This is because genetic reserves are intended to be long-term conservation approaches for populations. However, the populations which are predicted to be adversely affected should be collected to *ex situ* conservation and/or efforts should be made to facilitate migration into suitable areas.

The analysis was undertaken with three climate change scenarios, representative concentration pathways (RCPs), of temperature increase by 2050 and 2070. The selected scenarios were the most optimistic scenario RCP 2.6 which predicts temperatures to increase 0.3–1.7 °C; the more likely scenario RCP 6.0 which predicts 2.5–3.5 °C temperature increase and the worst-case scenario RCP 8.5 predicting a temperature increase of 2.6–4.8 °C by 2100.

When the present and future predicted distributions were compared, it was possible to identify high impact and low impact areas and potential new habitats. The low impact zones include those areas where the species distribution would stay unchanged and the high impact zones include areas where the species would likely disappear. Potential new suitable habitats include areas where the species distribution range can potentially move to in the future according to the climate predictions. The maps of the target species distribution predictions in three RCP scenarios for years 2050 and 2070 can be seen in Figure 8, 9 and 10.

Based on the example species, it is apparent that some of the Nordic species, such as *Poa alpina*, will recede northwards and to higher altitudes, ultimately with nowhere to go. For southern species, such as *Corylus avellana,* their distribution will extend to new suitable habitats towards the central parts of the region. However, when looking at the potential future distribution maps, one must note that each of them are only describing the potentially suitable climatic conditions from the target species point of view. Physical barriers, such as lake districts, seas, mountains and unsuitable habitats or competition with other species are not considered in this example. Many unsuitable habitats are created by humans, such as urban areas or cultivated fields, though some CWR can thrive in such areas.

From these examples, however, some conclusions can be drawn. *Poa alpina* will be most adversely affected out of the three species. A large part of its present distribution range is shown to suffer high impacts of climate change (Figure 8). In the worst-case scenario, the lowland habitats will become mostly unsuitable for the species and only several isolated areas in the mountains remain its refuge. However, the situation in Iceland seems better where the species is predicted to have the majority of its original distribution range intact. The distribution of *Rubus chamaemorus* is predicted to expand in the most northern parts of its range but also disappear in the southern parts such as in Southern Sweden. *Corylus avellana* is shown to increase its Nordic distribution area under all the investigated climate scenarios. Its present distribution range will extend northward, yet still maintaining the southern parts of its range.

The effects of species future distribution ranges on the *in situ* and *ex situ* conservation planning vary. The suggested *in situ* genetic reserve network described in chapter 3 and the *ex situ* collecting strategy outlined in chapter 4 need to be considered with flexibility at the implementation stage as knowledge on climate change effects on the Nordic crop wild relatives grows. It is suggested that populations of *Poa alpina* should be sampled for *ex situ* conservation from the ELC zones within high impact areas. Similarly, the southern populations of *Rubus chamaemorus* should be sampled for *ex situ*. When implementing *in situ* conservation, the potentially adversely affected populations in high impact areas should be conserved in an alternative PA within the same ELC zone if possible. More research is needed to find out the effect of climate change on the rest of the priority CWR species.

Figure 8: Future distribution predictions of *Poa alpina* in the Nordic region according to suitable climate conditions by 2050 and 2070 in different climate scenarios (representative concentration pathways)

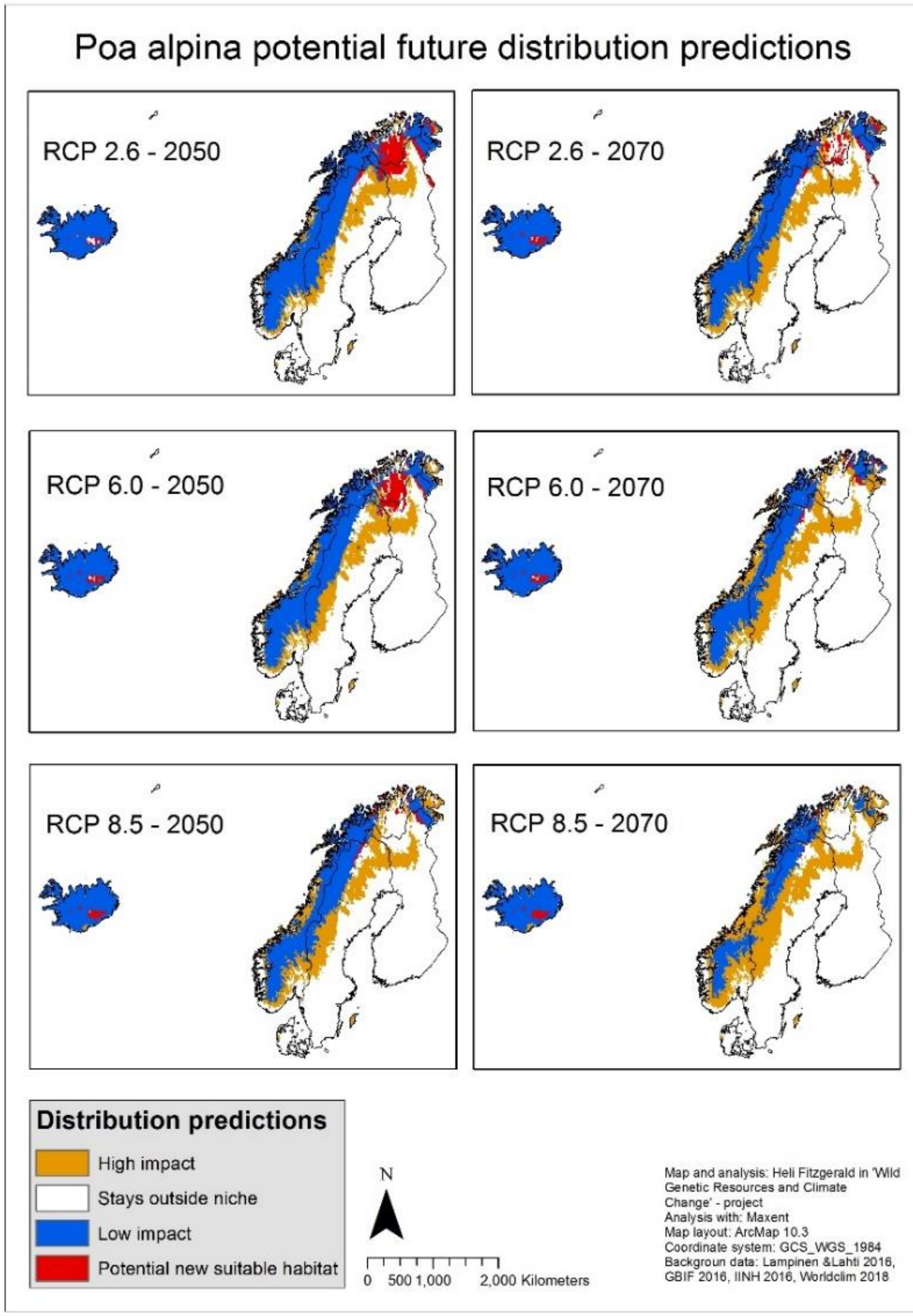


Figure 9: Future distribution predictions of *Rubus chamaemorus* in the Nordic region according to suitable climate conditions by 2050 and 2070 in different climate scenarios (representative concentration pathways)

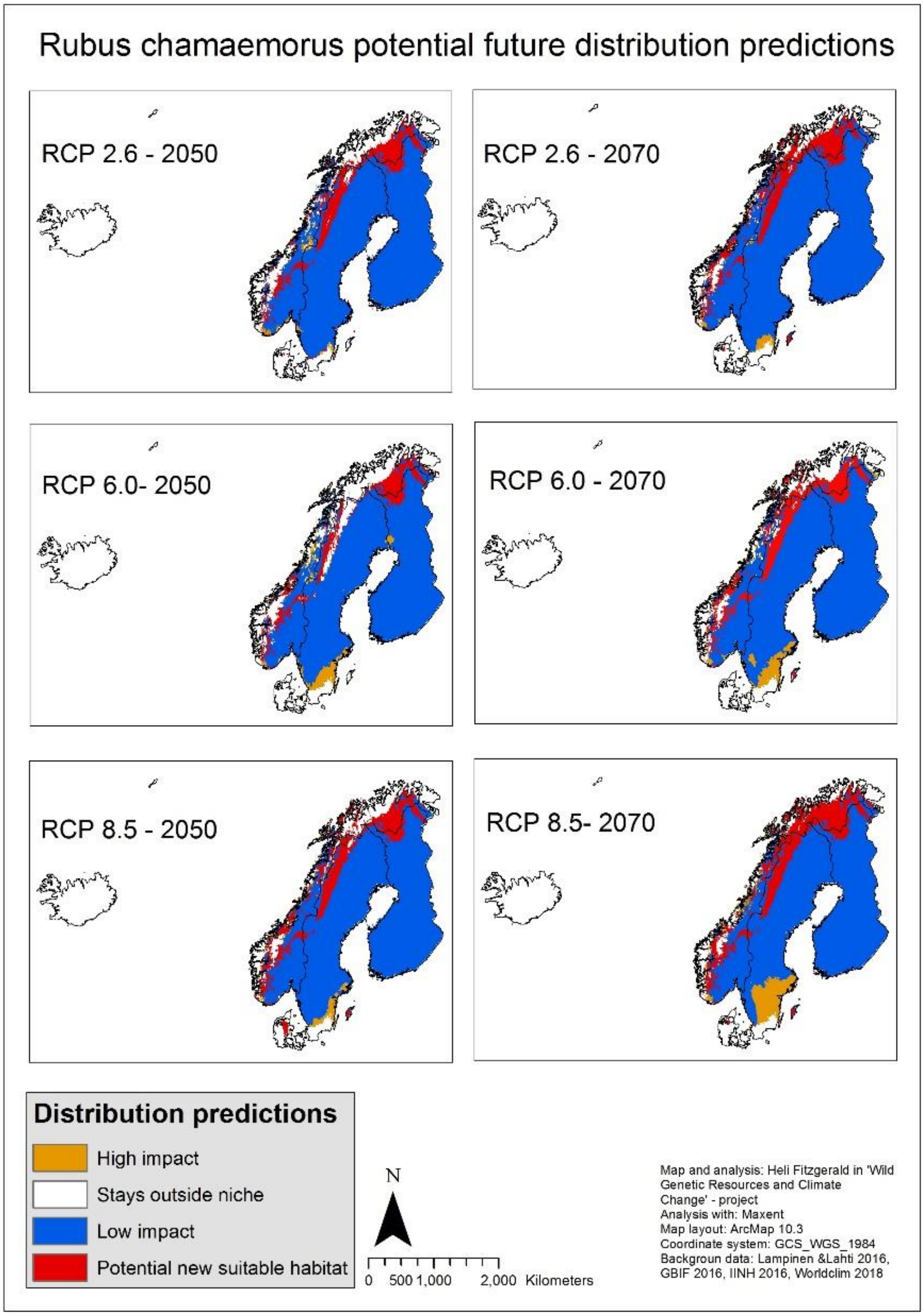
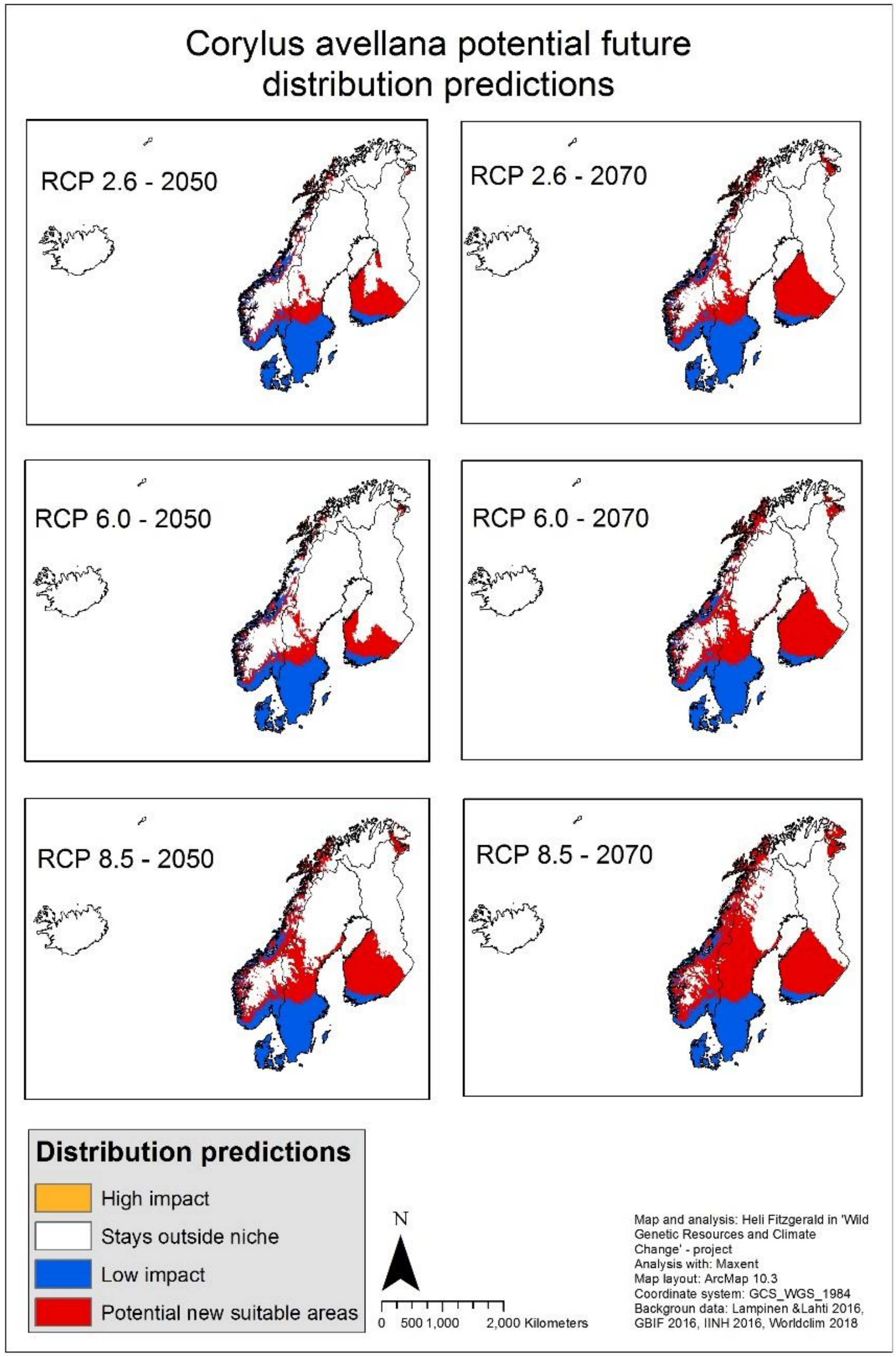


Figure 10: Future distribution predictions of *Corylus avellana* in the Nordic region according to suitable climate conditions by 2050 and 2070 in different climate scenarios (representative concentration pathways)



5. *Ex situ* conservation

5.1 Introduction to *ex situ* conservation

Ex situ conservation means long-term conservation of biological diversity of plants away from their natural habitats (Maxted *et al.*, 1997). It is most frequently done in seed gene banks, but conservation can for example also be done by conservation in the field, *in vitro* or by cryopreservation. CWR *ex situ* conservation has an important role as a back-up and support for the *in situ* approach. *Ex situ* conservation can act as a distribution channel to facilitate the use of CWR genetic resources, for example in breeding or reintroduction programs.

Nordic *ex situ* collections included in this study were the national threatened species seedbanks at Finnish Museum of Natural History in Helsinki and Natural History Museum in Oslo and the regional gene bank at the Nordic Genetic Resource Centre, NordGen in Alnarp. The three major seed collections of the Nordic region were included into the *ex situ* analysis. However, other *ex situ* collections of plants in the Nordic countries, such as national clonal collections or botanic garden and arboretum living collections may include CWR priority species collected from wild habitats. It is believed that the number of wild populations, as opposed to conservation of individual plants or a few individuals, is limited in these latter collections. However, a complete investigation of CWR in these collections would be of interest.

The CBD Global Strategy for Plant Conservation (Convention on Biological Diversity [CBD], 2010) goal 8, specifies an agreed intention to conserve 75% of nationally threatened species in *ex situ* seed banks before 2020. NordGen is the largest gene bank in the Nordic region and focuses on safeguarding genetic resources linked to food and agriculture. The Nordic collection managed by NordGen was established in 1979 and now contains nearly 33,000 accessions of Nordic origin and/or relevance, of which about 21% is classified as wild or semi-wild material (SESTO, 2019). Since the focus at NordGen is on food and agriculture, many threatened species fall outside its scope. Gene banks dedicated to threatened species conservation have therefore been established in Finland and Norway. The seedbank in Finnish Museum of Natural History in Helsinki was established in 2012 and now has approximately 60% of the nationally threatened species included in its *ex situ* collections. The Norwegian National Seed Bank is situated at the Natural History Museum, University of Oslo. The *ex situ* conservation work in Norway is a cooperation between all the six botanic gardens in the country. The seed bank was established in 2007 and approximately 43% of the nationally threatened species are now conserved in the seed bank, but when the outdoor collection of living plants is included, nearly 50% of the nationally threatened species are conserved.

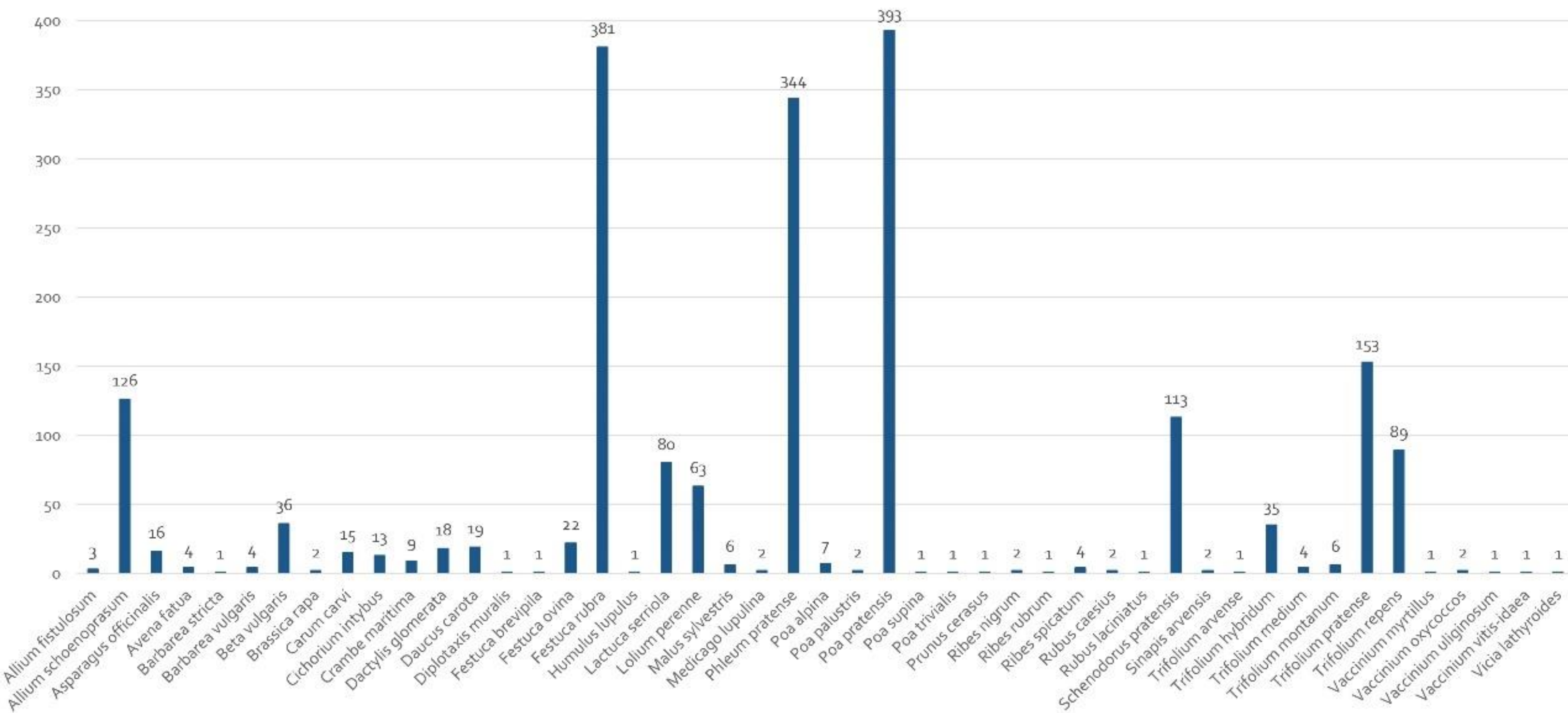
5.2 *Ex situ* gap analysis and collecting priorities

Ideally, CWR material collected for *ex situ* conservation should reflect the species genetic diversity in the wild as much as possible. Crop wild relatives have previously not been collected systematically in the Nordic region, even though they have been taken into account when setting priorities in Finnish *ex situ* collection schemes (Ryttäri *et al*., 2013). However, targeted collections of a few CWR have been made on the Nordic level, for example of timothy and red clover which have been systematically collected across the Nordic region and are now conserved at NordGen. Other CWR have been collected on a smaller scale. These existing *ex situ* accessions were analysed to see how representative they were when compared to the ecogeographic diversity of the priority species in wild populations.

The *ex situ* gap analysis was made on a species level. The 115 priority taxa consist of 83 species and 32 subspecies or varieties. Out of the 83 CWR priority species, 36 species did not have accessions with geographic coordinates in the investigated collections[2] (Appendix 2) and 47 were in collections but only represented by few accessions (Figure 11). Some of the species were in *ex situ* collections but lacked information on longitude and latitude. Large spatial and ecogeographic gaps were evident. Altogether 37 species had meaningful collections to be included in the representativeness analysis which was done in Capfitogen Representa tool (Parra-Quijano, 2016). The principle of ecogeographic representativeness (Parra-Quijano *et al.*, 2008) was used in *ex situ* gap analysis to find those populations in ecogeographic land characterization map categories, which were not represented in regional *ex situ* collections. This was done by comparing the existing *ex situ* collections of the species, the known distribution points and the species specific ELC map categories.

[2] For the data from NordGen, only accessions accepted for long-term conservation were included.

Figure 11: Priority CWR species in Nordic *ex situ* collections. The number of accessions with geographic coordinates per species is given



Finally, a complementarity analysis of the spatial gap populations was undertaken, resulting in suggested collecting sites for species already represented in gene banks, target CWR hotspots (Figure 12). By sampling in these suggested locations, a maximum amount of diversity can be collected from a minimum number of locations. Similarly, a complementary analysis was carried out for those priority species (Appendix 2) which were not present in *ex situ* conservation or which had been collected to *ex situ* conservation but had no location data or were not assigned to long-term conservation in a gene bank. The resulting map provides collecting sites for the species to capture their ecogeographic diversity in *ex situ* conservation (Figure 12). If samples from these hotspot CWR populations would be collected to *ex situ* conservation, they would fill the *ex situ* gaps, make collections more representative and conserve the intraspecific diversity of the species for future use.

Figure 12: Suggested collecting sites to complement ecogeographic gaps of species in already existing *ex situ* collections

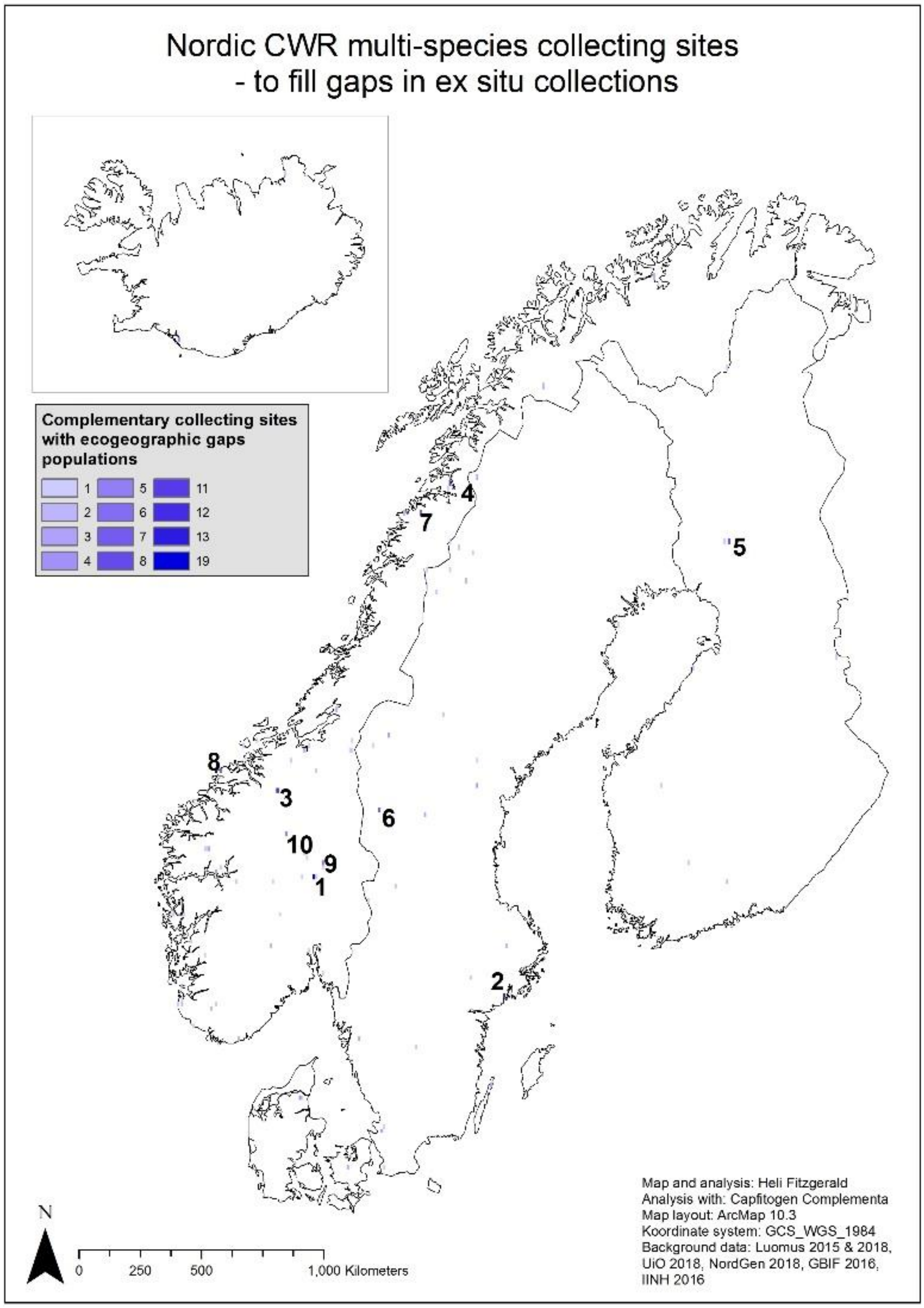
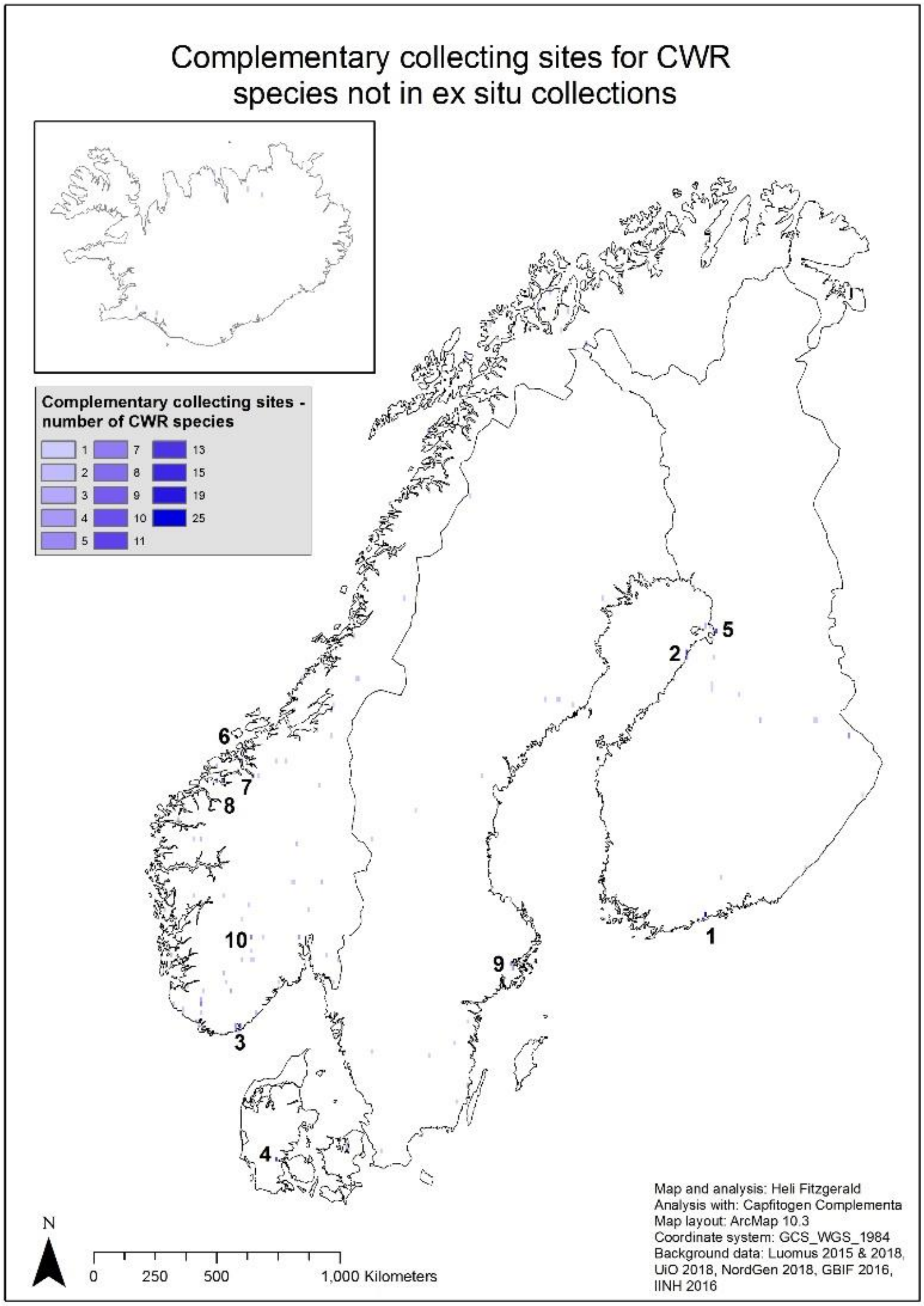


Figure 13: Suggested collecting sites of CWR species that are absent from the investigated Nordic *ex situ* seed collections or only have accessions without geographic coordinates



6. Integration and cooperation

6.1 Integration of National and Nordic conservation

One of the main goals of the projects has been to achieve Nordic synergy concerning CWR conservation. One way to achieve this has been through Nordic level planning (for results, see chapter 2–5). The fact that the same species as well as the similar climate and environment is found across the Nordic region, offers many synergy effects with common planning. In addition, tools and analyses developed in the Nordic project can be further used within national planning (see chapter 8).

Another approach has been the initiation of a Nordic network of CWR stakeholders by arranging workshops, meetings and communicating via websites and e-mail. This has been an important channel for knowledge exchange and discussions on the best approach regarding future actions to assure CWR conservation in the Nordic region, feeding into the recommendations in chapter 10. The project participants, consisting of stakeholders from all Nordic countries, form the core of the network but a larger set of stakeholders has been involved. Several workshops/meetings have been arranged where many additional Nordic stakeholders have attended:

- Start-up meeting, 26 May 2015, Østre Bolærne, Norway;
- Stakeholder workshop "Plant genetic resources for food security and ecosystem services", 18–19 November 2015, the Natural History Museum in Stockholm, Sweden;
- Nordic/ECPGR[3] Joint Workshop "Plant genetic resources for food security and ecosystem services. Planning and implementing national and regional conservation strategies", 19–21 September 2016, Vilnius, Lithuania;
- Nordic Crop Wild Relative meeting, 22 October 2018, Helsingør, Denmark (back-to-back with the workshop "Networking, partnerships and tools to enhance *in situ* conservation of European plant genetic resources" arranged within the "Farmer's Pride" project.

During the Nordic projects, Finland and Sweden initiated national projects on CWR conservation and in both cases participants from the Nordic project took part in the national projects. This has facilitated the exchange of knowledge and ideas among the projects (see below).

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[3] European Cooperative Programme for Plant Genetic Resources (ECPGR), http://www.ecpgr.cgiar.org/

6.1.1 Finland

A project "CWR conservation strategy for Finland" was carried out during years 2017–2018, in order to enhance of CWR-conservation in Finland. The aims of the project were to 1) identify main actors and form a national CWR conservation network; 2) update the priority list, identify ecogeographic diversity and find potential genetic reserve sites from existing conservation areas; 3) investigate the background, practical possibilities and options of CWR *in situ* conservation and 4) find out the potential to utilize existing semi-natural grasslands and conservation areas in CWR *in situ* conservation. The work was not completed during the project, and it will continue in 2019.

Establishment of the potential genetic reserves and their management, monitoring and responsibilities were discussed. A general assessment of the role of protected areas in conservation of CWR-species *in situ* was carried out: how the current management measures of protected areas maintain the populations of CWR-species. It was found that the current restoration and management measures are profitable for several CWR-species whereas several others thrive without any active management measures. It seems that the current network of nature protection areas secure populations of common CWR-species. According to the available data, all the species on the priority list do not have populations in protected areas, so their conservation needs other means.

Co-operation was done on Nordic (projects: *Ecosystem services: genetic resources and crop wild relatives* and *Wild genetic resources – a tool to meet climate change*) and European (European Cooperation Programme for Plant Genetic Resources, ECPGR) levels. Awareness was increased by participating in the development of the NordGen CWR-pages, publishing a brochure in Finnish, and by presentations in seminars and conferences. The project was funded by the Ministry of Agriculture and Forestry, and it was carried out by the Natural Resources Institute Finland (Luke); the Finnish Museum of Natural History, University of Helsinki; and the Metsähallitus, Parks and Wildlife Finland.

6.1.2 Sweden

Given the results from the ELC (Ecogeographic Land Characterisation) analysis involving all five Nordic countries, where the southern half of Sweden was being characterised by very few ELC zones, it was considered worthwhile to carry out an extended analysis. The three main aims of the study included the following:

- How are prioritized taxa distributed across the country?
- Can an extended ELC-analysis give more information about the distribution of genetic diversity?
- How well does the observed distribution correspond to existing protected areas (PA)?

The analysis was carried out by Dr. Jade Phillips, University of Birmingham. Data included close to 558,000 presence points obtained from GBIF Sweden for the 118 priority taxa, and available PA information. The ecogeographic map for Sweden was created with the CAPFITOGEN software using the environmental variables isothermality (average temperature range/annual temperature range), elevation, aspect of slope, direction towards North or East, topsoil organic carbon content, topsoil pH, and topsoil depth. As outlined by Fitzgerald *et al.* (2018), the ELC zones obtained can be used as a proxy to represent genetic diversity.

Following a complementary analysis of taxon distribution and the existing PA network, nine sites were identified that conserve 115 of the 118 priority taxa, i.e. approximately 97.5%. The number one site was found to be the UNESCO-MAB Biosphere Reserve *Kristianstad Vattenrike*, located in southern Sweden and listed for 92 of the taxa. The joint analysis of ELC categories and PAs revealed that 13 of the 21 identified categories were present within the existing network. A complementary analysis with priority taxa further showed that altogether 212 PA sites across the country would be needed to conserve all combinations of taxon x ELC category.

Finally, the study also included an analysis of taxon diversity within grid cells of 5 km^2 size. Many of the cells with the highest diversity were found along the coast of East and South Sweden. Altogether 12 grid cells were observed to conserve all 118 priority taxa, and eight of them were located close to a PA. The fact that the top grid cell, containing all priority taxa, is located outside Stockholm points to the obvious risk of observation bias close to larger cities.

Several conclusions can be drawn from the results of this project. *First*, looking closer at the GBIF data it became obvious that they need to be validated properly. While some occurrences were clearly erroneous, white "deserts" in some parts of the map led to the suspicion that other data, such as those of some regional flora inventories, were missing. *Second*, a proper selection of protected areas needs to be made. Of the 18,121 land-based PAs, only 12,607 (69.6%) represent sites of stricter protective value (i.e. national parks, nature reserves, habitat protection areas, etc.). In this study, the richest site was found to be *Kristianstad Vattenrike*, a UNESCO-MAB Biosphere Reserve. The second richest site was *Southern Öland*, a UNESCO World Heritage site.[4] Neither of these comprise the stricter form of legislation to protect species. This does not exclude, however, the possibility of bringing the attention of conservation of crop wild relatives into focus since, after all, such sites must be properly managed to maintain their status. And, *third*, complementary analyses of the likely effects of climate change on both priority taxa and existing suitable PAs, as well as the need for *ex situ* back-up storage, should follow.

[4] Full name: The Agricultural Landscape of Southern Öland.

6.1.3 Norway

A Norwegian strategy for *in situ* protection of Crop Wild Relatives in Protected Areas was initiated through a joint project with Birmingham University, Dr. Nigel Maxted and carried out by Dr. Jade Phillips from 2013–2017. The project was further extended in 2016–2018, when it became possible to further enrich the studies, particularly at the protected area (PA) site of Faerder, a genetic diversity hot spot in the Oslo Fjord region chosen as an example of a practical *in situ* conservation site, as well as looking further into climate change scenarios for the selected species and proposed PA areas. The project is since the autumn of 2018 in the final stages, and final reporting will be done during 2019. The Norwegian strategy proposed through Dr. Phillips PhD thesis was published in April 2017 (Philips, 2017). The remaining work concerns further promoting *in situ* conservation of CWR amongst funding structures and competent authorities in Norway.

The PA site of Faerder was chosen to develop an example of good practice, 108 of 204 prioritized CWR were present in the area, and populations of 52 species were included in the management plans for the PA (Forvaltningsplan Færder nasjonalpark, 2017). However, since 2015, it has not been possible to sort out clear responsibilities regarding funding of monitoring and possible active conservation measures, or how access to PGRFA should be secured. The process has become entangled in discussions on national implementation of the Nagoya protocol, particularly the Norwegian bioprospecting regulation where a first attempt to issue regulations was made in 2012, however despite subsequent hearings and attempts to revise the national implementation, the issue remains unsolved. There is a strong wish to attach the collaboration on general access to CWRFA[5] to the bioprospecting regulation, so the process stranded despite good intentions from all sectors involved. Still, Faerder could serve as inspiration, and the aim is being able to apply Faerder as a model for implementing *in situ* conservation measures for other PA in Norway as well as in other Nordic countries.

Integration of Nordic regional priorities to the proposed Norwegian strategy as an outcome of this project would be a next step for the Norwegian CWR work. Creating bridges between involved sectors and creating an understanding for the important contribution that genetic diversity of CWR will have on crop development to adapt to climate change is still an issue.

6.1.4 Denmark

Before the cooperation among all the Nordic countries on conservation of CWR was initiated, a Danish project by Aarhus University back in 2007 resulted in a national inventory on crop wild relatives. Ten different criteria for prioritising mandate CWR were set up, such as: present or earlier breeding; present, earlier, or potential growth in Denmark; a crop wild relative; direct use of the wild plant species collected from nature; distribution and occurrence; native or introduced; conserved under other programs; in

[5] CWRFA = Crop Wild Relatives for Food and Agriculture.

Annex I of the ITPGRFA; common in Denmark but uncommon in other countries; used elsewhere than in Denmark.

A total of 449 of wild growing mandate species had been identified with priority as follows: 139 low priority, 142 middle; 168 high. Of the total number, 68 species were common and not threatened whereas for 101 species the state of conservation was unclear. In 2011, Bjørn *et al.* (2011) published their report "Bevaring af plantegenetiske ressourcer i de vilde slægtninge til jordbrugets afgrøder" (Conservation of plant genetic resources of wild relatives to agricultural crops).

Based on these recommendations for conservation of CWR, Aarhus University, in close collaboration with relevant stakeholders, continued the project based on the identified 101 prioritised wild growing mandate species. These species have been further inventoried at ten different localities and recommendations for their *in situ* conservation, including complementary conservation of seed *ex situ*, have been provided. The *in situ* conservation is still being discussed in Denmark in relation to other national efforts, whereas the plan for collection of seeds for *ex situ* conservation has been initiated during two national projects during 2013–2015. For each of the species, attempts have been made to collect seeds from at least three localities, which succeeded for most. The seeds, of variable quality, have been transferred to NordGen for long-term storage. Furthermore, reference material (plant and seed) for the national herbarium (Jutlandicum Herbarium) has been collected.

However, with the joint Nordic collaboration on CWR, the next step as described in the Danish strategy on plant genetic resources 2017–2020 will be to seek accordance between the Danish conservation efforts and the efforts in the other Nordic countries to obtain effective CWR conservation *in situ* and *ex situ*. Furthermore, the right authorities in Denmark must also be involved to create the foundation for collaboration and securing CWR conservation.

6.1.5 Iceland

Representatives from the Icelandic Genetic Resource Council and the Environment Agency of Iceland attended the workshops in Stockholm and Vilnius of the Nordic network of CWR stakeholders. The Nordic projects and workshops have thus contributed to an increased awareness and discussion within and between the agricultural and environmental sector in Iceland.

The policy document of the Icelandic Genetic Resource Council 2014–2018 lists as one of its goals to evaluate, in cooperation with NordGen, the need to conserve CWR *in situ* and also to discusses the feasibility of conserving old meadows and forage grasses *in situ*. The regional work on CWRs the past few years is therefore in line with the policy document of the Icelandic Genetic Resource Council.

6.2 European cooperation and integration

In addition to Nordic cooperation and synergy, cooperation on the European level has been a goal within the project. Many of the project members are also members in the "ECPGR Wild Species Conservation in Genetic Reserves Working Group" and have been/are engaged in European level projects on CWR.

When arranging workshops and meetings, care has always been taken to link to the European cooperation on CWR and European experts have taken part in all the meetings listed above (under 5.1). Some of the meetings have been arranged jointly or back-to back with European initiatives/projects on CWR conservation: the Nordic/ECPGR Joint Workshop in 2015 and the Nordic Crop Wild Relative meeting in 2018. In the latter, the members of the Nordic project were also invited to attend the 2-day workshop arranged by the Farmers Pride project and many attended this workshop dedicated to CWR and landrace conservation. These joint meetings/workshops have given much opportunity for knowledge exchange and joint discussions of common issues.

7. Policy and legislation

7.1 On policy

The two recent joint Nordic projects – *Ecosystem services: genetic resources and crop wild relatives* and *Wild genetic resources: a tool to meet climate change* – were the first ever where the five Nordic countries collaborated actively to get aspects of *in situ* conservation in place. Whereas it has been much easier to join forces on proper *ex situ* conservation and management of seeds, *in situ* conservation means entering an area that poses new challenges, some of which cannot be solved by the gene bank community alone. *In situ* conservation implies collaboration with a range of stakeholders, of which the nature conservation community plays a key role. But it has, for reasons yet to be understood, been surprisingly difficult to bring the two communities together, despite conservation and sustainable use of biodiversity being central to both.

In this respect, Norway has led the way. Floristic inventories have earlier shown that the most botanically rich areas are found in the calcareous areas around the so-called Oslofeltet and south-east Norway. The study published by Phillips *et al.* (2016) paved further ground for concrete actions. The new management plan for Færder National Park 2017–2027 (Forvaltningsplan Færder nasjonalpark, 2017) explicitly mentions the conservation of genetic resources as one of the central aims, thus taking the first steps towards establishing the national park as Norway's first genetic reserve for crop wild relatives (CWR). The close and active collaboration between the Norwegian Genetic Resource Centre, the protected area authorities and the regional administration of Vestfold has been pivotal in the success.

Similarly, in Finland a CWR conservation project, funded by the Finnish Ministry of Agriculture and Forestry, was launched in 2017. In this project, a national expert network was established for CWR-conservation issues, including the key stakeholders for guiding and developing CWR-conservation, based on the National CWR strategy report of Finland (Fitzgerald, 2013). The main partners of the project were the Natural Resources Institute Finland, Metsähallitus / Parks & Wildlife Finland and Finnish Museum of Natural History. The Finnish Environment Institute and the Ministry of the Environment were also represented in the project advisory board. The priority list for the Finnish CWR-species was updated (Fitzgerald and Kiviharju, 2018) and harmonized with the Nordic CWR priority list (Fitzgerald *et al.*, 2017b). Potential key CWR genetic reserve sites and target species in ecogeographic land characterization zones within existing conservation areas were identified. The project produced background knowledge and practical suggestions on the future conservation actions of Finnish CWR diversity. The work will continue in 2019.

From a policy perspective, the joint Nordic project has had as one of its main objectives to bring the two conservation communities together. To make this happen also in those countries where a concrete process has been lacking, such as e.g. Sweden, several tools were applied. *Firstly*, in March 2017, a policy brief (Appendix 3) was published summarising eight concrete actions. The brief was based on recommendations developed within the first project, *Ecosystem services: genetic resources and crop wild relatives*, with feedback from the participants in the workshop *Plant genetic resources for food security and ecosystem services; Planning and implementing national and regional conservation strategies*, held in September 2016 in Vilnius, Lithuania. *Secondly*, a Declaration (Appendix 4) concerning crop wild relatives was prepared for the joint meeting in June 2018 of the Nordic Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry and the Nordic Ministers of the Environment. The Declaration, accompanied with explanatory notes (Appendix 5) was aimed at being endorsed as a joint Nordic commitment to implement and fulfil Target 2.5[6] of the UN Sustainable Development Goals (SDGs). The initiative was deemed highly appropriate since during the period 2017–2020 the Nordic Council of Ministers implements the programme *Generation 2030* (NMR, 2017) to promote the SDGs.

The declaration, however, was not endorsed. This is unfortunate for several reasons, but mainly because our countries are in fact already carrying out most of the proposed actions. The question is less about funding and more about increasing efficiency. What needs to be done in order to achieve higher output is to coordinate work better, primarily at the national level. One way of improving the situation could be to task relevant sectoral authorities from both production and conservation sectors with a common assignment to implement conservation and sustainable use of CWR, with joint reporting obligations and a system for monitoring success. Such an arrangement could help foster new, innovative and collaborative approaches that are "outside the box". Today, work is perpetuated in a downpipe fashion that is regrettably detrimental to the necessary management of our genetic resources.

7.2 On legislation

Conservation of genetic diversity poses specific challenges, which we shall see in the following section. All five Nordic countries are parties to the Convention on Biological Diversity (the "CBD"), a legally binding treatise regulating the conservation and sustainable use of biodiversity including the fair and equitable sharing of benefits arising from its use. The Convention entered into force in December 1993.

The CBD defines biodiversity at three levels: genetic diversity, species diversity and ecosystem diversity. In other words, diversity is defined as the frequency and diversity of different genes and/or genomes, species and ecosystems, respectively. A closer look at Nordic domestic legislation[7] adopted or active since 1993, and relating to the

[6] "[…] by 2020 maintain genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at national, regional and international levels, and ensure access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge as internationally agreed."

[7] DK: Bekendtgørelse af lov om naturbeskyttelse 1).

conservation of nature, reveals interesting differences. *Two* countries only – Norway and Iceland – have included a definition of biological diversity, or biodiversity (Article 3c,[8] *Natur-mangfoldloven; Article 5,*[9] *Lög um náttúruvernd)*. Furthermore, Articles 33b and 37c of the Norwegian law specifies that protected areas "shall contribute to the conservation of [...] species and genetic diversity, [...]" and "Areas can be protected as nature reserves [...] [if they are] of particular importance to biological diversity[10]", respectively.

No other Nordic country has introduced and implemented nature protection legislation as explicit as Norway when it comes to conservation of genetic diversity. It is true that, as Parties to the CBD, all five countries have adopted the Convention and the elaborated definitions. Since the Convention is a legally binding document, parties must adhere to the text. It would also seem true, however, that any domestic implementation of the CBD would benefit from incorporating definitions of key concepts – such as biological diversity – into relevant national legislation. While the *Swedish Environmental Code* targets the concept in its section on Protection of areas (Article 7.4), the definition – as outlined above – is lacking. From our interpretation of the mentioned article,[11] however, it would seem possible for authorities in Sweden either to assign new protected areas based on conserving genetic diversity (populations), or widening the scope for already existing ones.

We should recognise that the conservation of CWR, independent of the model chosen, may be hampered either by associated costs[12] or simply by the fact that the target taxa grow elsewhere,[13] in sites not currently under a protective regime. This should not hinder us from finding the most cost-effective and appropriate means to conserve those CWR identified within the joint Nordic projects as priority species. Being small countries, we should preferably see this as a common undertaking for the future, in preparation for needs yet unknown.

FI: Naturvårdslag/Luonnonsuojelulaki/Nature Conservation Act 2).

IS: Lög um náttúruvernd/The Nature Conservation Act 3).

NO: Naturmangfoldloven 4) - § 3c: definition av biologisk mångfald; § 33b: bevarande av genetisk mångfald; § 37c: "Som naturreservat kan vernes områder som [...] c) på annen måte har særlig betydning for biologisk mangfold, [...]";

SE: Miljöbalk (1998:808) 5).

[8] "Biologisk mangfold: mangfoldet av økosystemer, arter og genetiske variasjoner innenfor artene, og de økologiske sammenhengene mellom disse komponentene";

[9] «Líffræðileg fjölbreytni: Breytileiki meðal lifandi vera á öllum skipulagsstigum lífs, þar á meðal í vistkerfum á landi, í sjó og í ferskvatni. Hugtakið tekur til vistfræðilegra tengsla milli vistkerfa og nær til fjölbreytni innan tegunda og milli tegunda og vistkerfa».

[10] Free translation.

[11] "A land or water area may be declared by the county administrative board or municipality as a nature reserve in order to preserve biodiversity, conserve and preserve valuable natural environments or meet the needs of outdoor recreation areas. [...]."

[12] "5. *Legislative protection*. Experience from ecosystem and wild species conservation has repeatedly shown that the establishment or expansion of protected areas, or even less formal sites where *in situ* conservation occurs, requires significant investment of resources and that legislative protection is required to ensure the long-term sustainability of the sites. When promoting *in situ* conservation of CWR there might be a need to encourage and facilitate local and national legislative protection of sites, e.g. genetic reserves designated for active conservation." (CGRFA-15/15/Inf. 24, p. 12).

[13] "9. *Create a national network of conservation sites.* The establishment of CWR genetic reserves within existing Protected Areas (PA) is likely to be a widely adopted option for *in situ* CWR conservation, given the additional costs associated with the creation of new PAs for CWR conservation. However, this is not always practical or possible, especially in countries with a limited existing PA network and where priority CWR do not occur in any formal PAs. In addition, many close relatives of crops grow in disturbed or semi-disturbed habitats more commonly found outside PA. Therefore, a national network of conservation sites is likely to include a mix of CWR genetic reserves and informal CWR management sites. [...]" (CGRFA-15/15/Inf. 24, p. 34).

8. Publication and outreach

Communication has been one of the important goals in the Nordic projects. The aim has been to use different approaches to reach different kinds of audiences: 1) Nordic stakeholders and policy makers, 2) the scientific community and 3) the interested general public. Availability has been an important part of this goal and publications have been made publicly available via the Nordic CWR website, open access data repositories and open access publication.

8.1 A Nordic CWR website

A website dedicated to Nordic CWR was established during the first phase of the project and has continued to be updated during the second phase. The website is placed at NordGen's site with the address www.nordgen.org/CWR and can be reached directly from NordGen's main page. The purpose is to provide information both to the interested general public and to stakeholders and policymakers in the Nordic region. This website will be maintained by NordGen after the end of the project.

Some of the subpages give basic information on what a CWR is, why they are of interest and how they are conserved. One subpage is called "conservation tools" and the target audience is people involved in national CWR conservation planning. The page makes it easy to access the tools developed within the project but there are also links to national and international literature, tools and websites that can support national conservation planning. Another subpage is dedicated to Nordic and national activities. Here, readers can find links to the Nordic project websites and to associated publications as well as to websites and publications related to national activities in the Nordic countries. Of the last two subpages, one links to iNaturalist described below and one is dedicated to plant portraits.

8.1.1 Plant portraits

At the moment there are 23 plant portraits published under the Nordic CWR website. With the portraits we aim to increase the public interest in the CWR site and at the same time spread knowledge about CWR species. New portraits were published every month during 2017 and 2018 (with some exceptions) and announced both at the main Nordic CWR page and via NordGen's Facebook.

The portraits include: rocket (*Eruca sativa* Mill.), angelica (*Angelica archangelica* L.), hazel (*Corylus avellana* L.), lingonberry (*Vaccinium vitis-idaea* L.), turnip (*Brassica rapa* L.), chicory (*Cichorium intybus* L.), cloudberry (*Rubus chamaemorus* L.), beets (*Beta vulgaris* L.), sea kale (*Crambe maritima* L.), crab apple (*Malus sylvestris* Mill.), common vetch (*Vicia* *sativa* L.), caraway (*Carum carvi* L.), common corn salad (*Valerianella locusta* (L.) Laterr.), red clover (*Trifolium pratense* L.), plum (*Prunus* sp.), blackberries (*Rubus* sp.), parsnip (*Pastinaca sativa* L.), chives (*Allium schoenoprasum* L.), alsike clover (*Trifolium hybridum* L.), strawberry (*Fragaria* sp.), awnless brome (*Bromus inermis* Leyss.), prickly lettuce (*Lactuca serriola* L.), and timothy (*Phleum pratense* L.).

8.2 Policy brief

As described in chapter 7 above, a policy brief was developed (Appendix 3) with the aim of informing policy makers about CWR and their importance and at the same time about eight concrete actions needed to conserve CWR in the Nordic region. Most of the recommendations focus on national actions, but Nordic level actions are also included. The document was distributed to the CWR stakeholder network established during the first part of the project, delivered to the Nordic Council of Ministers and discussed by NordGen's Board and the Nordic Committee of Senior Officials for Fisheries, Aquaculture, Agriculture, Food and Forestry. It was also made publicly available via NordGen's website and the open access repository Figshare (Palmé *et al.*, 2019).

Figure 14: Sea kale on Tromøya in Norway reported within the iNaturalist Crop Wild Relative citizen science project

Source: Available at: https://www.inaturalist.org/observations/7135229

8.3 iNaturalist

The choice of iNaturalist (2019a) for citizen science CWR data collection in the Nordic countries (iNaturalist, 2019b) was part of an overall project strategy decision of reusing existing biodiversity research data solutions and infrastructures. Most of the biological resources designated as crop wild relative species are already fully integrated in existing networks and mechanisms for conservation of biological diversity and ecosystems. This again leads to an even stronger rationale for reusing and contributing to further development of existing mechanisms rather than proposing new mechanisms for crop wild relative inventory and monitoring.

Almost all crop wild relative species occurrence data used in the data analysis routines for this project originated from existing data sources made available from the Global Biodiversity Facility (GBIF) research data infrastructure (Telenius, 2011) and new datasets generated by the project were in turn published in GBIF (Fitzgerald *et al*., 2017a). This strategy provided efficient access to a much larger, and in addition regularly updated, volume of relevant data than would be available only from data sources within the Nordic genetic resources network.

iNaturalist provides an existing citizen science platform with a regular and stable dataflow into the GBIF data infrastructure. Public citizen science contribution (Figure 14) of crop wild relative species occurrences by using the iNaturalist platform would thus directly contribute to the data analysis tools and mechanisms developed in this project. The configuration of a dedicated Nordic crop wild relative community inside the iNaturalist platform furthermore allowed us to mobilize a large existing iNaturalist user base while new users joining the Nordic crop wild relative citizen science group in iNaturalist benefit from several relevant iNaturalist-services including smartphone CWR species reporting tools and expert data validation. Experts from all over the world efficiently contribute to the validation of species identification in addition to the more recently added advanced machine-learning routines in iNaturalist for data validation.

8.4 Social media

Social media was used to distribute information on the plant portraits described above. When a portrait was published, about once a month, a short text, picture and link was published on NordGen's Facebook page (Figure 15). In addition, a few postings were made to promote the site and inform about meetings and iNaturalist.

Figure 15: Promotion of the plant portrait on sea kale published on NordGen's Facebook in June 2018

8.5 International scientific publications and presentations at meetings

Scientific publications were made with two main types of audiences in mind: stakeholders in the Nordic countries working nationally on CWR conservation and scientists/researchers interested in CWR, plant genetic resources and conservation. The first scientific result to come out of the projects was the CWR checklist with CWR species from all the Nordic countries. It was published in GBIF (Fitzgerald *et al*., 2017a) and followed by the priority CWR list published in figshare (Fitzgerald *et al*., 2017b), making them publicly available and easy to find using the Digital Object Identifier, or DOI. The main scientific paper to come out of the project so far, Fitzgerald *et al*. 2019, is published with open access in a special issue of the international journal *Plant Genetic Resources: Characterization and Utilization*. It describes the Nordic cooperation on CWR and includes information on approaches used to develop the Nordic CWR lists and identifies suitable conservation sites for CWR in the Nordic region. The results from the project have so far been presented at two scientific conferences: the EUCARPIA genetic resource meeting in 2017 (Palmé *et al*., 2017) and Eurogard VIII in 2018 (Fitzgerald *et al*., 2018).

8.6 National publications

The first publication to come out of the projects was published in English in the Journal of the Swedish Seed Association (Weibull *et al*., 2016). It is available via the Nordic CWR website as well as from the magazine's public journal archive and focuses on Nordic cooperation, project goals and progress and on CWR in general. The next year a paper describing the project was published in Finnish in the Finnish magazine GeeniVarat (Fitzgerald *et al*., 2017c), which is publicly available via Luke's publication archive and linked from the Nordic CWR website. Also, a brochure in Finnish was published (Kiviharju *et al*., 2018).

8.7 Project websites

Project websites were established both for the first and second project. They can be found among NordGen's project pages with the headings: "Ecosystem services: Genetic resources and crop wild relatives"[14] and "Wild genetic resources – a tool to meet climate change"[15]. The purpose of these websites is to explain the aims of the projects and present some of the activities and results. However, the results were also presented at the Nordic CWR website, which will be visible for a longer time period.

8.8 Publications from the project

Fitzgerald, H., Aronsson, M., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Palmé, A., Rasmussen, M., Weibull J, & Þorbjörnsson, H. (2017a). *Nordic Crop Wild Relative Checklist Dataset, Version 1.10*. Nordic Genetic Resource Centre, NordGen. Available at https://doi.org/10.15468/itkype

Fitzgerald, H., Aronsson, M., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Palmé, A., Rasmussen, M., Weibull, J., & Þorbjörnsson, H. (2017b). *The Nordic priority crop wild relative gene pool and distribution dataset*. Available at: https://doi.org/10.6084/m9.figshare.5688130.v1

Fitzgerald, H., Asdal, Å., Kiviharju, E., Palmé, A., Þorbjörnsson, H., & Weibull, J. (2018). *Nordic countries join forces in crop wild relative conservation*. Eurogard VIII, Lisbon, Portugal, 7–11 May 2018. Available at: https://figshare.com/s/49d564fcf3bcd9d7bc2d

Fitzgerald, H., Palmé, A., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Rasmussen, M., Þorbjörnsson, H., & Weibull, J. (2019). *A regional approach to Nordic crop wild relative in situ conservation planning. Plant Genetic Resources: Characterization and Utilization*., 1–12. Available at: https://doi.org/10.1017/S147926211800059X

Fitzgerald, H., Palmé, A., Weibull, J., & Kiviharju, E. (2017c). Viljelykasvien sukulaislajien suojelusuunnittelu. *GeeniVarat* 14. Available at: https://jukuri.luke.fi/handle/10024/539195

iNaturalist (2019b). *Nordic Crop Wild Relatives*. Available at: https://www.inaturalist.org/projects/nordic-crop-wild-relatives

[14] https://www.nordgen.org/en/plants/projects/genetic-resources-and-crop-wild-relatives-in-the-nordic-countries/

[15] https://www.nordgen.org/en/plants/%20projects/wild-genetic-resources/

Kiviharju, E., Fitzgerald, H., & Eisto, K. (2018). *VILJELYKASVIEN LUONNONVARAISET SUKULAISLAJIT (CWR) ja niiden monimuotoisuuden suojelu*. Available at: https://www.luke.fi/wp-content/uploads/2019/01/viljelykasvien-luonnonvaraiset-sukulaislajit-CWR-esite.pdf

NordGen (2018). *Nordic CWR plant portraits*. Available at: https://www.nordgen.org/en/plants/crop-wild-relatives/species-information/plant-portraits/

Palmé, A., Fitzgerald, H., Weibull, J., Asdal, Å., Lund, B., Endresen, D., Kiviharju, E., Þorbjörnsson, H., Rasmussen, M., & Carlson-Nilsson, U. (2017). *A Nordic regional approach for crop wild relative (CWR) conservation*. EUCARPIA genetic resource meeting, Montpellier, France, 8–11 May 2017. Available at: http://www.nordgen.org/ngdoc/NordicCWR_2016/Poster_EUCARPIA_2017_final.pdf

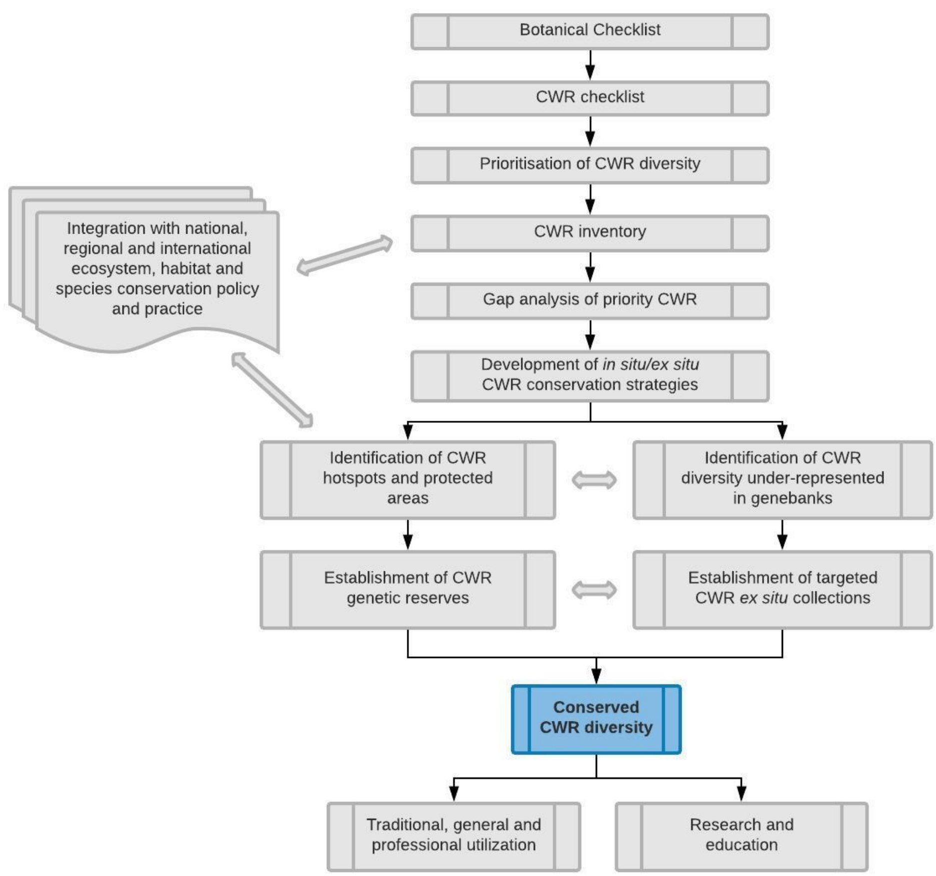
Palmé, A., Asdal, Å., Endresen, D., Fitzgerald, H., Kiviharju, E., Lund, B., Rasmussen, M., Thorbjörnsson, H. & Weibull, J. (2019). *Policy Brief - crop wild relatives: actions needed to assure conservation of an important genetic resource*. Figshare. Available at: https://doi.org/10.6084/m9.figshare.7558658

Weibull, J., Fitzgerald, H., Lund, B., Palmé, A., & Þorbjörnsson H (2016). Conservation and sustainable use of crop wild relatives: a Nordic initiative. *Sveriges Utsädesförenings Tidskrift* 2:2016. Available at: http://www.sverigesutsadesforening.se/SUFs-aldre-argangar-p107.html

9. Toolkit for *in situ* conservation in the Nordic countries

In 2017, the FAO Commission on Genetic Resources for Food and Agriculture adopted voluntary guidelines (FAO, 2017) to assist countries in their work for better conservation planning and implementation. Much of the background work that led to the development of the guidelines rested in several consecutive EU-funded projects (PGR Forum, PGR Secure and others), including specific reports commissioned by FAO (Maxted *et al*., 2013).

Figure 16: A generalized model for the development of CWR and wild food plants conservation and use strategies



Source: Adapted from FAO 2017.

There is no such thing as a single model or process for planning and implementing national *in situ* conservation. To that extent, countries are different regarding legislation, funding, capacity, infrastructure, and other aspects. The toolkit, however, can serve as a roadmap to guide countries in their desire and ambition to embark upon the important mission to conserve and sustainably use wild crop genetic resources. The table below includes a list of consecutive steps developed by Maxted *et al*. (2013) and is available as an interactive toolkit.[16] An overview of the steps can be seen in Figure 16. Here we have chosen to present the various measures taken within the two joint Nordic projects (second column, Table 1).

[16] http://www.cropwildrelatives.org/conservation-toolkit/introduction/

Table 1: The toolkit steps developed by Maxted *et al*. (2013) (column 1) and measures taken/suggested within the Nordic projects (column 2)

Essential toolkit steps[2]	Measures taken within the Nordic project(s) or suggestions for future work
National systematic crop wild relative (CWR) conservation planning This process involves planning systematic *in situ* and *ex situ* conservation of CWR diversity at the national level. The implementation of which results in the systematic representation of the nation's CWR diversity in an *in situ* network of genetic reserves (within existing protected areas or by establishing novel conservation areas) with back-up *ex situ* collections of genetically representative population samples in national gene banks (i.e. seeds, tissue, DNA, living plants). The conservation recommendations that result from this national CWR conservation planning process can, and should, feed into the National Strategic Action Plan for the conservation and utilization of CWR.	While systematic CWR planning has taken place in all five Nordic countries, the joint Nordic projects have specifically taken a regional perspective. So far, focus has been on existing *ex situ* collections including only orthodox seeds and live plants in field gene banks. In the Nordic countries there is a need for both national conservation planning, especially regarding *in situ* conservation, as well as Nordic coordination and planning.
Generation of a CWR checklist A CWR checklist is a list of all CWR taxa found in a defined geographic unit (region, country etc.), comprising a list of taxon names and authorities.	A common Nordic CWR checklist has been generated and published (https://doi.org/10.15468/itkype). Based on this checklist, national checklists can easily be made and used for further national planning.
Prioritizing the CWR checklist Establishing priorities for CWR conservation is an obvious and essential step in the development of the NSAP (National Strategic Action Plan). It involves reducing the number of CWR in the checklist to a more manageable and realistic number for active conservation.	A Nordic list of priority CWR has been developed and published (Fitzgerald, 2017b), based on average Global Gross Production Value (million USD) breeders' estimate of forage value and use gene pool and taxon group concepts.[1] The Nordic priority list can be used as a point of departure for making national lists. It can be used directly by simply filtering for species from a country. However, if a country does not agree with the prioritisation that has been made on the Nordic level, species can be added, or a new prioritisation can be made on the Nordic checklist.
Compilation of the CWR inventory An inventory of CWR is a list of CWR taxa present in a defined geographic unit (region, country etc.) with ancillary information, such as: the applied Gene Pool or Taxon Group concepts, biology, eco-geography, populations, uses, threats and conservation. An inventory is usually created after prioritization of the CWR checklist, for the priority taxa only.	The following CWR inventory data is provided with the Nordic checklist and priority list datasets: • The checklist includes distribution category of the CWR taxa in each country (native, introduced, temporary, not present), taxon names, authors and vernacular names in all the Nordic languages. • The priority list additionally includes the Gene Pool and Taxon Group concept data.
Diversity analyses: distribution and ecogeographic analyses of priority CWR This is the process of collating ecogeographic and occurrence data for the priority CWR, followed by the analysis of these data to understand the patterns of diversity within and among priority CWR taxa (hotspot analysis, ecogeographic diversity etc.). The results obtained from these analyses then help in formulating, establishing and implementing conservation priorities.	Ecogeographic and occurrence data for the Nordic priority CWR was collected. Regional diversity analyses were carried out for the priority CWR species with the result of potential regional genetic reserve network sites. The results are explained in detail in Fitzgerald *et al*. (2019) and as a summary in chapter 3 of the report.
Diversity analyses: genetic data analysis of priority CWR Genetic diversity studies are important (a) to understand the richness and evenness of diversity across the geographic breadth of the species, (b) to obtain genetic baseline information against which future genetic data can be compared to detect changes in diversity and to identify genetic erosion, (c) to establish population priorities for conservation within each taxon, and (d) to identify traits of interest for crop improvement.	Not carried out within the Nordic project(s) but recommended for future studies.
Novel threat assessment of priority CWR Threat assessment is a process used to evaluate the risk of extinction of a particular taxon. When there is no existing threat assessment information for priority CWR (e.g. national red lists, IUCN Red List of Threatened Species), a novel threat assessment can be undertaken in parallel to conservation planning as the information collated for the diversity analyses can be also used to undertake these assessments. Threat assessments can then be used to further prioritize/enhance CWR conservation.	Not carried out within the Nordic project(s) but recommended for future studies.

Essential toolkit steps	Measures taken within the Nordic project(s) or suggestions for future work
Gap analysis of priority CWR A gap analysis of priority CWR is a conservation evaluation technique that identifies "gaps" in the conservation of these taxa. In practice, gap analysis involves a comparison between the range of natural diversity found in the wild, and the range of diversity already effectively represented by current *in situ* conservation actions (*in situ* gap analysis) and all accessions of the target CWR represented in gene bank collections (*ex situ* gap analysis). Gap analysis can be undertaken at both species and infra-specific level (e.g. ecogeographic diversity).	Regional gap analysis for *in situ* and *ex situ* conservation were undertaken during the projects. The results are shown in chapters 3 and 4. Gaps in existing *ex situ* collections were identified both on spatial, ecogeographic and species level. Complementary collecting sites were identified which would enable filling the gaps in *ex situ* collections and to create a backup for the genetic diversity of priority CWR species in the wild.
Climate change analysis Climate change analysis allows (a) the identification of the CWR that are most affected by climate change, (b) the prediction of the impact of climate change on taxon distribution, and (c) the development of recommendations for the *in situ* and *ex situ* conservation of CWR.	A climate data analysis was carried out for three example CWR priority species with southern, northern and general distribution within the Nordic region. Predictions on the effects of climate change on species distribution are explained in chapter 4 and recommendation for conservation action in chapter 10. More research on the effects of climate change on priority taxa is needed to draw overall conclusions and recommendation for *in situ* and *ex situ* conservation of CWR taxa in the Nordic region.
Establishment and implementation of *in situ* conservation priorities A NSAP for the conservation of CWR aims, in part, to recommend a national network of *in situ* conservation sites where long-term active conservation (in order to safeguard their genetic diversity) and sustainable use of CWR are implemented as a contribution to national, regional and global food security. Once appropriate sites for active *in situ* conservation have been identified, the establishment of the network of sites can begin. These sites may be established (a) within existing protected areas, (b) as new conservation areas specific for CWR conservation, or (c) as informal CWR management sites.	Steps towards national implementation of CWR conservation are taken in Norway and Finland, as explained in chapter 6 of this report. The implementation of *in situ* conservation is a national task that cannot be undertaken on the regional level, even though regional analysis can suggest national actions.
Establishment and implementation of *ex situ* conservation priorities Periodic sampling of CWR populations for *ex situ* conservation should provide, whenever possible, a back-up of populations actively conserved *in situ*. Diversity conserved *ex situ* primarily facilitates the access to these materials for crop improvement and research.	Since 1979 a Nordic cooperation exists regarding *ex situ* conservation of genetic resources and today nearly 33,000 accessions are stored at the gene bank at NordGen. About 21% of these accessions are classified as either wild or semi-wild. However, none of these accessions are formal back-ups of *in situ* conservation since the latter has so far not been established in the region. When *in situ* conservation sites are established, arrangements need to be made regarding *ex situ* back-ups.
Monitoring CWR diversity Monitoring of plant populations ensures the systematic collection of data over time to detect changes, to determine the direction of those changes and to measure their magnitude. The monitoring of CWR populations, and the habitats in which they occur, aims (a) to provide data for modelling populations trends, (b) to enable assessment of trends in population size and structure, (c) to provide information on trends in population genetic diversity, and (d) to determine the outcomes of management actions on populations and to guide management decisions.	Not carried out within the Nordic project(s). Some of the threatened Nordic priority CWR species might however be included in national monitoring plans, but a majority of the CWR species in existing conservation areas are now in passive conservation.
Promoting the use of conserved CWR diversity CWR are defined by their potential utilization as gene donors for crop improvement. Conservation of CWR is thus explicitly linked to utilization. This link forms the basis of enduring human food security, highlighting that the promotion of the sustainable use of conserved CWR diversity is as relevant as its effective conservation.	Not carried out specifically within the Nordic project(s), although aspects of use have been discussed during stakeholder workshops, where users have also participated. Enabling use of CWR should be an integral part of future *in situ* and *ex situ* conservation.
A note on CWR data management in conservation planning CWR conservation planning (along with the development of National Strategic Action Plans for the conservation and utilization of CWR) involves significant data collation, analysis and management.	This aspect was not targeted in the current Nordic project(s). The issue of data collection, storage and management is something that needs to be addressed for *in situ* conservation. There is already a common Nordic data system available for storing information regarding *ex situ* conservation. To incorporate *in situ* data, this system needs to be expanded or supplemented by another system.

Note: [1] Maxted N, Ford-Lloyd B V, Jury S, Kell S and Scholten M (2006) Towards a definition of a crop wild relative. *Biodiversity & Conservation 15*, 2673–2685; Harlan J and de Wet J (1971) Towards a rational classification of cultivated plants. *Taxon 20*: 509–517.

[2] The different steps are available at www.cropwildrelatives.org, phrased in the same way.

10. Recommendations and conclusions

10.1 Recommendations

The recommendations below have been developed by the project group with feedback from the participants in the stakeholder workshops and meetings held within the projects. The recommendations that were deemed most important were summarised and distributed in the form of a policy brief that was made publicly available via NordGen's website and later via an open access repository (Appendix 3; Palmé *et al.*, 2019).

10.1.1 Policy and conservation planning

Recommendations regarding policy and conservation planning:

- Develop a national strategy in each Nordic country for *in situ* and *ex situ* CWR conservation and sustainable use, in line with relevant international agreements and guidelines but adapted to national priorities and needs. The work done at the Nordic level can be used as a framework or supporting information. The Nordic and national work should be complementary to each other and to European and global strategies. Stakeholders both from the agricultural and environmental sectors should be involved in the development of the strategy;
- At the national level, develop the policy instruments needed to facilitate conservation and sustainable use of CWR involving all relevant sectors in this process. Suggested measures include evaluating the policy actions necessary for effectively implementing conservation and use of CWR, and/or analysing obstacles that hinder such effective conservation and use;
- Adopt *in situ* conservation as the main approach for safeguarding CWR diversity. Traditional *ex situ* conservation (e.g. seed banks, in vitro collections, field collections) should act as back-up and complementary measure to *in situ* conservation, and only in rare cases be the main approach. New *ex situ* conservation methods such as assisted migration and ecosystem hotels should be carefully considered when dealing with taxa threatened by climate change and habitat loss;
- Further develop a common Nordic approach on CWR conservation based on international guidelines and strategies. This approach should address future challenges of climate change and food security. The aim would be to facilitate the national processes and identify areas where joint planning and/or cooperation would be more effective and efficient than independent national efforts;

- Develop Nordic networking and integration of *in situ* and *ex situ* conservation. Establish a framework for cooperation between stakeholders working with *in situ* and *ex situ* conservation of CWR. The cooperative network created during the current project should be used as a basis, it should be linked to European networks and NordGen should have a coordinating role when dealing with CWR;
- Encourage research, infrastructure development and Nordic cooperation to further CWR conservation and sustainable use, aiming at ensuring high efficiency and quality in conservation planning and implementation. More information on important research topics can be found under 9.1.4;
- The regional Nordic planning needs to be updated on a regular basis, for example every 5 years, and its targets should be in synchrony with those of the Global Strategy for Plant Conservation (GSPS). National efforts implemented during this time period (such as establishment of genetic reserves) should be integrated into the Nordic level planning and recommended action updated accordingly. Other issues that can affect the plan include improved information on current plant distribution, geographic distribution of genetic diversity and effect of climate change.

10.1.2 Practical recommendations regarding in situ conservation of CWR

We recommend that the following steps are taken to initiate *in situ* conservation in each Nordic country:

- Assess the suitability of the top three conservation areas in each country (see Figure 7, Appendix 1) and determine if they are suitable for establishing genetic reserves for CWR. The assessment should include inventory of the CWR species in the protected area, evaluation of population size and threat, evaluation of the effect of climate change on CWR in the area, assessment of best management approaches for the CWR and determination of whether this management can be accommodated within the protected area. If the top conservation areas are not suitable, other sites should be investigated;
- As a first step, implement *in situ* conservation of prioritised species, in accordance with relevant international guidelines, in at least one site in each of the Nordic countries. The aim would be to gain practical experience with this process in each country. International documents such as Iriondo *et al*. (2012) and Maxted *et al*. (2015) can give background information. Suggested steps include:
  - Adjust the management plan of the protected area to include monitoring of CWR from the Nordic priority list (e.g. every 5 years);
  - Evaluate which CWR are promoted by the current management practices and, if possible, adjust practices to favour those CWR that are not;
  - Make sure that the status of the genetic reserve and CWR conservation is recognised by the appropriate authorities;

  - Clarify the conditions of access to seeds or other genetic material (c.f. national ABS-legislation);
  - Register data about the CWR populations and the genetic reserve in an open access data sharing platform (some data on threatened species might have to be restricted).
- In the long-term, establish complementary *in situ* conservation sites across the Nordic region. The sites should represent different types of habitats and climate and should include the most important CWR species in the region. The analysis presented in chapter 3 can be used for prioritisation and selection of locations for *in situ* conservation. For species not thriving in currently protected areas, alternative sites might be needed;
- Establish a formal Nordic network for CWR *in situ* conservation (genetic reserves). This network should be integrated with the Nordic *ex situ* conservation network and linked to nature conservation network(s) (e.g. Natura 2000) and upcoming European CWR network(s) (e.g. being developed within the EU project Farmers pride, http://www.farmerspride.eu/). The purpose of the network would be to achieve Nordic synergy within this field, for example including:
  - Exchange of knowledge and information;
  - Sharing of data infrastructure;
  - Establishment of minimum criteria for Nordic genetic reserves.
- Establish a data handling system for collecting and managing data of *in situ* conservation sites and CWR populations and making this data publicly available. This could either be achieved by using GBIF and its national data providers such as FinBIF (Finland) and ArtDatabanken (Sweden) or by establishing a new system at the Nordic level, which should be linked/integrated into current *ex situ* management systems. The system should be adapted for easy upload of information into the European data system (being developed in EURISCO).

10.1.3 Practical recommendations regarding ex situ conservation of CWR

Ex situ conservation has been implemented for quite some time in the Nordic countries. The Nordic gene bank was established in 1979 (now NordGen) and seeds from all the Nordic countries are conserved here. In addition, there is *ex situ* conservation of clonally propagated crops in each of the Nordic countries and NordGen coordinates networking among the *ex situ* stakeholders. Moreover, endangered wild plants are conserved *ex situ* in seed banks run by the Botany Unit of the Finnish Museum of Natural History in Helsinki and the Natural History Museum in Oslo. Currently, these both contain c. 60% of the endangered plant taxa in these countries. This means that the framework for *ex situ* conservation is in place for the Nordic region. However, CWR have not been the main focus and we recommend the following future actions:

- Make sure that *ex situ* conservation efforts are coordinated with *in situ* conservation (Figure 17);
- For most CWR populations, *ex situ* conservation should be used as a back-up to *in situ* conservation and to facilitate use. Such back-up conservation should include:
  - Sampling according to international guidelines and paying special attention to sampling size to capture as much of the variation in the natural population as possible;
  - Conserving the seeds according the guidelines for long-term conservation with the exception that no regeneration is performed;
  - Resampling of seeds in the natural population will replace regeneration when seed quality decreases, unless the *in situ* population has gone extinct or seriously decreased in size;
  - Seeds from the back-up can be used to reintroduce extinct populations into the wild.
- When *in situ* conservation is not possible for a certain species or population, long-term *ex situ* conservation should be used following international guidelines. One example is populations expected to disappear within the coming 50 years due to climate change (see chapter 4);
- To efficiently sample a high proportion of the diversity in the Nordic CWR species, the sampling strategy described in chapter 5 should be applied. This is also a way to make these CWR populations are easily available to users.

10.1.4 Research needs

The establishment of *in situ* conservation for CWR (genetic reserves) is still in its infancy and therefore there are large gaps in knowledge on this topic and there are also research needs connected to the use of CWR. We recommend the following:

- Increased efforts to collect, and make available, occurrence data for the prioritised CWR to determine detailed geographic distribution and to serve as a baseline for future monitoring. This should include both enabling access to historic data sets and collecting new data;
- Analysis of genetic diversity in priority CWR (using molecular markers):
  - At the Nordic level, or across the distribution range of the focus species, to understand the geographic distribution of diversity. This can be used as a basis to prioritize conservation actions among *in situ* sites;
  - In individual *in situ* sites, to first establish a baseline and then monitor diversity to detect changes/loss of diversity over time.

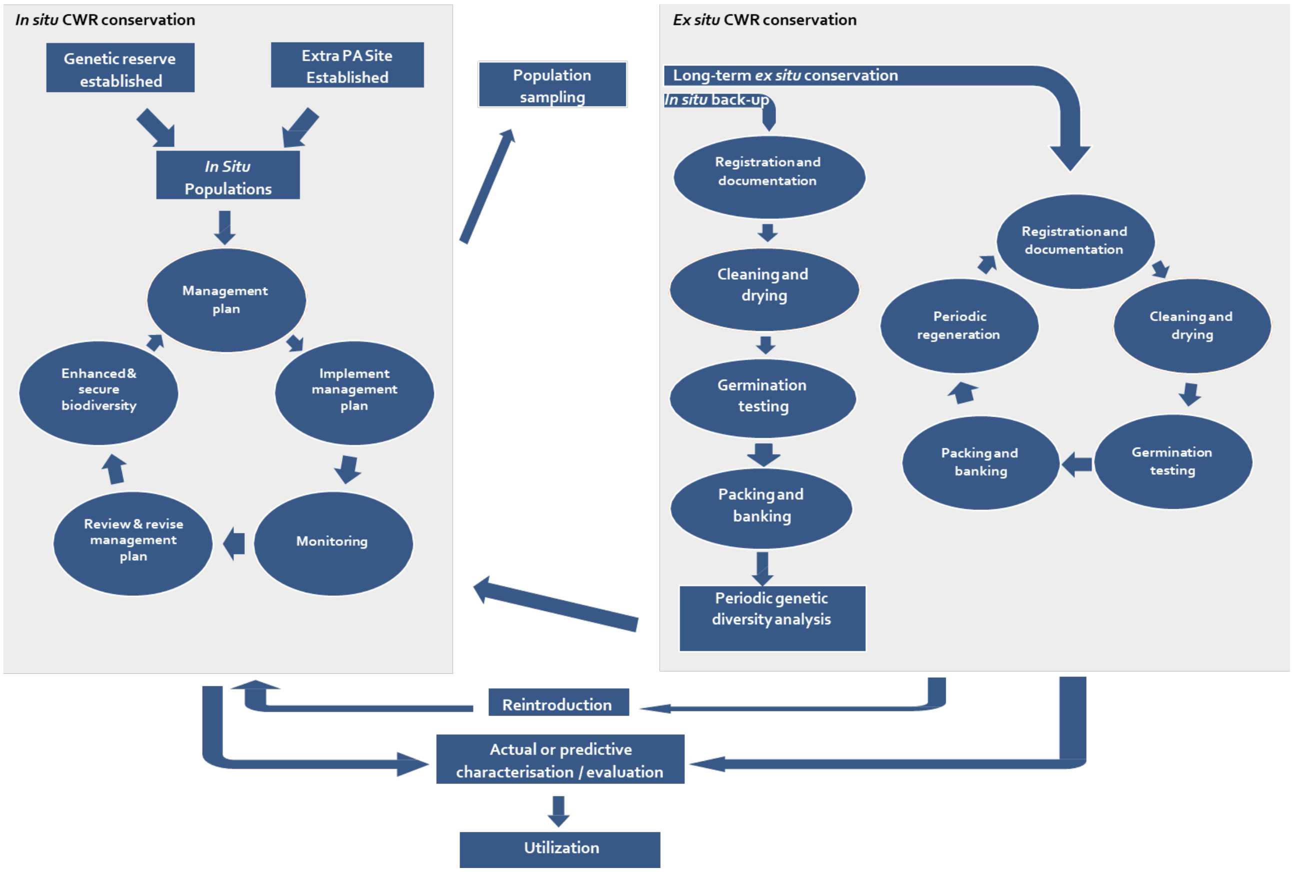
- Analysis of morphological and phenological variation in priority CWR, focusing on traits deemed to be of importance for humans (e.g. important in agriculture under climate change scenarios). This can be done at the Nordic level, or across the distributing range of the focus species:
  - Such data can be used as a basis to prioritize conservation actions among *in situ* sites and to identify CWR populations/individuals of interest to use in plant breeding.
- Pre-breeding projects designed to use CWR to improve food security and adaptation to climate change;
- Conduct an extended climate change analysis on prioritised CWR and protected areas in the Nordic region;
- Promote cooperation on common standards on taxonomy, habitat classification, inventory protocols and common Nordic presentation tools. The results should be presented on a common Nordic portal;
- Make cost evaluations of CWR conservation under different scenarios (for example different levels of management intensity, number of focus species, *ex situ* back-up approach). The goal will be to gain a better understanding of conservation costs and to communicate this to policy stakeholders in order to support decision making.

10.1.5 Communication

The knowledge about CWR and their value is limited among many stakeholder groups and efficient communication is therefore central. We recommend the following:

- Continued maintenance and updating of the Nordic CWR website (www.nordgen.org/CWR) as well as national sites on genetic resources and CWR;
- Develop case studies on concrete use of CWR in plant breeding. Communicate these via several channels such as CWR websites, social media, workshops etc.;
- Develop information material on CWR, for example small exhibitions, posters and information folders that can be presented at local protected areas that already communicate to the public about nature conservation;
- Develop information material that can be presented at botanical gardens, for example plant material that can be cultivated to communicate information on CWR, folders and posters;
- Arrange stakeholder workshops/meetings on CWR conservation within the frame of the network suggested under 10.1.1.

Figure 17: Integration of *in situ* and *ex situ* CWR conservation



Note: PA = protected area.

Source: Figure adapted from presentation at by Nigel Maxted and Anna Palmé at the workshop "The impact of climate change on the conservation and utilisation of crop wild relatives in Europe", Barcelona, December 2015.

10.2 Conclusions

CWR are one of several tools that are needed to address humankind's challenges regarding food security and adaptation to climate change. Making sure that these genetic resources are adequately conserved and available for utilisation, should therefore have high priority on the Nordic policy agenda. Today no active *in situ* conservation of CWR is taking place in the Nordic region, and only a small subset of the CWR species are adequately conserved in gene banks.

The most central action needed today to safeguard our CWR for the future, is the establishment of *in situ* conservation of CWR (genetic reserves) in the Nordic countries. We recommend starting with one genetic reserve per country within an already established protected area to develop routines and protocols in each country. The second stage would be to establish several such sites and then a Nordic network of sites and stakeholders. Cooperation between the environmental and agricultural sectors will be important for success, and cooperation among the Nordic countries will also facilitate the process.

In this project we have identified the CWR in the Nordic region, pinpointed the most important CWR, suggested *in situ* conservation sites across the region that would optimise the amount of diversity conserved in a minimum number of sites, and studied the effect of climate change on example species. Other activities have initiated a Nordic network on CWR conservation, increased the knowledge on CWR and evaluated the status of *ex situ* conservation of CWR. This information can facilitate the national processes for planning and establishing *in situ* conservation.

11. Glossary

Some concepts and abbreviations used in the report are defined below:

- *Crop Wild Relative (CWR)*: "A wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to genepools 1 or 2, or taxon groups 1 to 4 of the crop. CWR include crop progenitors and can broadly be described as any taxon in the same genus (or closely related genera) as a crop" (ECPGR Concept for *in situ* conservation of crop wild relatives in Europe, Maxted *et al*., 2015).
- *CWRFA*: Crop Wild Relatives for Food and Agriculture.
- *Ex situ conservation*: "[…] means the conservation of components of biological diversity outside their natural habitats". Convention on Biological Diversity, Article 2 (1992).
- *Genetic reserve*: "an area of land and/or sea where the protection and maintenance of genetic diversity in natural populations is an agreed conservation objective and where there are good prospects for active, long-term conservation" (Maxted *et al*., 1997). The group at the stakeholder workshop in Stockholm 2015 suggested the following modification of this definition: "the location, designation, management and monitoring of genetic diversity in wild or semi-wild populations within defined areas designated for long-term conservation and controlled access for potential use."
- *Genetic resources*: "[…] means genetic material of actual or potential value." Convention on Biological Diversity, Article 2 (1992) ("Genetic material" means any material of plant, animal, microbial or other origin containing functional units of heredity).
- *In situ conservation*: "[…] the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties." Convention on Biological Diversity, Article 2 (1992).
- *PGR*: Plant Genetic resources (see definition of genetic resources above).
- *PGRFA*: Plant Genetic Resources for Food and Agriculture.

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Sammanfattning

Rapporten sammanfattar resultat från ett samarbete mellan alla de nordiska länderna under perioden 2015–2019 (två projekt). Samarbetet har inriktats på bevarande av vilda kulturväxtsläktingar, d.v.s. vilda växter som är nära släkt med odlade grödor. Dessa är betydelsefulla för oss människor eftersom de har egenskaper som kan vara av värde för framtida livsmedelssäkerhet och anpassning till klimatförändringar. Projekten representerar det första aktiva samarbetet på nordisk nivå om *in situ* bevarande av vilda kulturväxtsläktingar. Betydande framsteg inom planering av bevarandeåtgärder har gjorts i projektet, t.ex. en nordisk checklista för vilda kulturväxtsläktingar och identifiering av områden lämpliga för bevarande av dessa arter. En rad rekommendationer har utarbetats inom projekten och viktigast är att initiera *in situ* bevarande av vilda kulturväxtsläktingar i samtliga nordiska länder.

13. Appendices

13.1 Appendix 1: Top *in situ* conservation sites

Table 2: Top 3 sites in each Nordic country from *in situ* complementarity analysis

Country	Nordic network complementary site number	Protected area name	Designation	Designation type	No. of priority taxa in ELC zones	Total no. of priority taxa in ELC zones	ELC zones covered in site
Denmark	1	Aalborg Kommune	§3 protected habitats (all lakes, bogs, streams, heaths and meadows etc.)	National	88	88	7, 9
Denmark	15	South Funen sea with islands, South Funen Archipelago	Baltic Sea Protected Area (HELCOM); Ramsar Site, Wetland of International Importance	Regional	12	47	9
Denmark	48	Roskilde Fjord and Jaegerspris Nordskov	Baltic Sea Protected Area (HELCOM), Special Protection Area (SPA)	Regional	3	76	9, 7
Finland	2	Tornio- and Muonio river area	Site of Community Importance (SCI)	Regional	59	59	13, 10, 15
Finland	4	Tammisaari and Hanko Archipelago and Pojo Bay marine protection area	Baltic Sea Protected Area (HELCOM), Sites of Community Importance (SCI), Special Protection Area (SPA)	Regional	42	86	7, 8, 9
Finland	9	Koli National Park	National Park	National	22	22	16
Iceland	8	Vatnajokulsthjodgardur National Park	National Park	National	23	38	6, 15, 19, 22, 23
Iceland	10	Myvatn-Laxá region	Ramsar Site, Wetland of International Importance	International	17	30	6, 11, 14, 15
Iceland	18	Vatnsfjordur	Nature Reserve	National	10	14	2, 5, 19
Norway	3	Lista Wetlands System	Ramsar Site, Wetland of International Importance	International	46	46	25, 26
Norway	5	Sjunkhatten National Park	National Park	National	39	39	4, 6, 18, 21, 23
Norway	6	Trollheimen	Protected Landscape	National	33	43	3, 10, 12, 20
Sweden	12	Tännäs	Wildlife and Plant Sanctuary	National	14	45	10, 12, 13
Sweden	21	Falsterbo Peninsula with Måkläppen	Baltic Sea Protected Area (HELCOM)	Regional	9	29	9
Sweden	25	High Coast	Baltic Sea Protected Area (HELCOM)	Regional	7	31	4, 7

13.2 Appendix 2: CWR species with no or limited *ex situ* conservation

Table 3: CWR species not in Nordic seedbank collections, or in collections but with no location data (longitude and latitude), or with no accessions assigned to long-term conservation in a gene bank

Taxon and author	Danish name	Finnish name	Norwegian name	Swedish name
Armoracia rusticana P. Gaertn., B. Mey. & Scherb.	Peberrod	Piparjuuri	Peparrot	Pepparrot
Brassica elongata Ehrh.		Hoikkalitukaali	Stautkål	
Brassica nigra (L.) W. D. J. Koch	Sort sennep	Mustasinappi	Svartsennep	Svartsenap
Corylus avellana L.	Hassel	Pähkinäpensas	Hassel	Hassel
Dactylis glomerata L.	Hundegræs	Koiranheinä	Hundegras	Hundäxing
Diplotaxis tenuifolia (L.) DC.	Sandsennep	Isohietasinappi	Steinsennep	Sandsenap
Erucastrum gallicum (Willd.) O. E. Schulz	Svinesennep	Kaalisinappi	Svinesennep	Kålsenap
Festuca brevipila Tracey	Bakke-svingel	Jäykkänata	Stivsvingel	Hårdsvingel
Fragaria × ananassa (Weston) Decne. & Naudin	Have-jordbær	Puutarhamansikka	Hagejordbær	Jordgubbar
Fragaria moschata Weston	Spansk jordbær	Ukkomansikka	Moskusjordbær	Parksmultron
Fragaria vesca L.	Skov-jordbær	Ahomansikka	Markjordbær	Smultron
Fragaria viridis Weston	Bakke-jordbær	Karvamansikka	Nakkebær	Backsmultron
Humulus lupulus L.	Humle	Humala	Humle	Humle
Juglans regia L.	Valnød		Valnøtt	Valnöt
Lactuca quercina L.				Karlsösallat
Lactuca sibirica (L.) Benth. ex Maxim.		Siperiansinivalvatti	Sibirturt	Älvsallat
Lactuca tatarica (L.) C. A. Mey.	Strand-salat	Sinivalvatti	Tatarturt	Sandsallat
Lolium multiflorum Lam.	Italiensk rajgræs	Italianraiheinä	Italiaraigras	Italienskt rajgräs
Malus domestica Borkh.	Sød-æble	Tarhaomenapuu	Eple	Apel
Malus sylvestris Mill.	Skov-æble	Metsäomenapuu	Villeple	Vildapel
Medicago sativa L.	Foder-lucerne	Sinimailanen	Lusern	Foderlusern
Poa trivialis L.	Almindelig rapgræs	Karheanurmikka	Markrapp	Kärrgröe
Prunus avium (L.) L.	Fugle-kirsebær	Imeläkirsikka	Morell	Sötkörsbär
Prunus cerasifera Ehrh.	Mirabel		Kirsebærplomme	Körsbärsplommon
Prunus domestica L.		Luumu	Plomme	Krikon/plommon
Prunus mahaleb L.	Weichsel		Mahaleb	Vejksel
Prunus spinosa L.	Slåen	Oratuomi	Slåpetorn	Slån
Pyrus communis L.	Pære	Päärynä	Pære	Päron
Ribes rubrum L.	Have-ribs	Lännenpunaherukka	Hagerips	Trädgårdsvinbär
Ribes uva-crispa L.	Stikkelsbær	Karviainen	Stikkelsbær	Krusbär
Rorippa islandica (Oeder & Murray) Borbás			Islandskarse	Islandsfräne
Rubus allegheniensis Porter ex L. H. Bailey	Allegheny-brombær	Mustavatukka	Alleghenybjørnebær	Sammetsbjörnbär
Rubus arcticus L.		Mesimarja	Åkerbær	Åkerbär
Rubus armeniacus Focke	Armensk brombær		Arménbjørnebær	Armeniskt björnbär
Rubus chamaemorus L.	Multebær	Muurain, hilla, lakka	Molte	Hjortron
Rubus idaeus L.	Hindbær	Vadelma	Bringebær	Hallon
Rubus spectabilis Pursh	Laksebær		Prydbringebær	Prunkhallon
Setaria viridis (L.) P. Beauv.	Grøn skærmaks	Viherpantaheinä	Grøn busthirse	Kavelhirs
Trifolium alpestre L.	Skov-kløver			Alpklöver
Trifolium arvense L.	Hare-kløver	Jänönapila	Harekløver	Harklöver
Trifolium montanum L.	Bjerg-kløver	Mäkiapila	Bakkekløver	Backklöver
Trifolium striatum L.	Stribet kløver	Juova-apila	Stripekløver	Strimklöver
Vaccinium microcarpum (Turcz. ex Rupr.) Schmalh.	Dværg-tranebær	Pikkukarpalo	Småtranebær	Dvärgtranbär
Vicia sativa L.		Rehuvirna	Bondevikke	Åkervicker

13.3 Appendix 3: Policy brief

Policy brief: Crop Wild Relatives - actions needed to assure conservation of an important genetic resource from the project *Wild genetic resources – a tool to meet climate change*. Can be accessed by the following link:

- https://doi.org/10.6084/m9.figshare.7558658.v1

13.4 Appendix 4: Draft ministerial declaration

Below is a text drafted for a ministerial declaration intended for both the Nordic Council of Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry (MR-FJLS) and Nordic Council of Ministers for the Environment and Climate (MR-MK). The draft has so far not been approved by either council.

13.4.1 Ministerial declaration: Crop Wild Relatives in the Nordic Countries

Crop wild Relatives (CWR) are an essential source for providing solutions to the future demand for genetic material when adapting new plant varieties to climate changes, aiming at sustainable food production.

Today the majority of CWR species are either missing or insufficiently represented in gene banks. This means that important genetic traits of CWR are currently unavailable for use at a time when new plant varieties need to be developed even faster to meet even greater needs. Further, the CWR species risk a decline as their habitats are under pressure from urbanization, pollution, (de-) forestation, fragmentation and climate change.

We, the Nordic Ministers for Fisheries, Aquaculture, Agriculture, Food and Forestry and the Nordic Ministers of the Environment: *recognize* the importance of Crop Wild Relatives (CWR) for solving future challenges regarding food security, adaptation to climate change, sustainable ecosystems and a sustainable agriculture; *note with concern* that many Nordic CWR species are threatened and their populations are becoming increasingly rare and fragmented; *emphasise* the need for active *in situ* conservation of the most important CWR populations, with *ex situ* conservation in gene banks serving as a complementary measure, as appropriate.

We, therefore:

1. endorse the development of a CWR strategy in each Nordic country for *in situ* and *ex situ* CWR conservation and sustainable use, in line with relevant international agreements and guidelines;
2. call for an evaluation of international policy actions for effectively implementing conservation and use of CWR;
3. recommend implementing *in situ* conservation of prioritised CWR species, in accordance with relevant national and international guidelines;

4. call for further development of a Nordic approach on CWR conservation, addressing common challenges regarding climate change, ecosystem services and food security;
5. encourage research, infrastructure development and Nordic cooperation for further conservation and sustainable use of CWR.

13.5 Appendix 5: Comments on the declaration

13.5.1 Comments on the declaration "Crop Wild Relatives in the Nordic Countries"

1: Develop a CWR strategy

A national strategy for safeguarding important national plant genetic resources should include:

- National CWR checklist (can be extracted from the regional checklist prepared within the Nordic CWR project);
- Prioritization and inventory (can use the one already prepared within the Nordic CWR project or chose to prioritize differently);
- *In situ* and *ex situ* gap analysis (such an analysis is already done/will be done on the regional level within the CWR Nordic project. Generally, a national strategy also includes gap analysis on the national level);
- Recommendations of *in situ* and *ex situ* conservation measures on the national level. While recommendations from the Nordic report[17] can be considered, scope and implementation are to be decided at the national level.

2: Evaluate agreed policy measures

Evaluate the need for implementing internationally agreed policy actions, and their extent, preferably by establishing a joint Nordic taskforce of experts.

3: Implement *in situ* conservation of prioritised CWR species

Important Nordic CWR are already present in areas of various protective regimes. It is central that their populations are recognised in the management plans of these areas and that their survival and development are monitored. This should be the first step for implementing *in situ* conservation of CWR. Later, CWR should also be considered when establishing new conservation areas, as appropriate.

4: Develop a joint Nordic approach

The development of a Nordic approach on CWR conservation began in 2015 based on funding from the Nordic Council of Ministers and is still ongoing.

[17] To be finalised in the beginning of 2019.

This includes the tailoring of tools and approaches to facilitate national processes on CWR conservation planning (cf. 1, above). Since the Nordic countries largely share the same species and types of habitat, joint planning can also make the conservation actions more efficient (cf. 5).

5: Encourage research, infrastructure development and Nordic cooperation for further conservation and sustainable use of CWR

Nordic research on CWR of importance for food and agriculture is limited. Important topics to explore include, among others:

- scope and geographic distribution of genetic diversity of key CWR;
- changes in genetic diversity over time;
- evaluation of traits important for future plant breeding;[18]
- complementarity of *ex situ* – *in situ* cooperation.

Aspects of infrastructure development includes e.g. *ex situ/in situ* database integration, and other methodologies/datasets (FIGS – Focused Identification of Germplasm Strategy, GIS, LifeWatch data, etc.).

[18] Climate change, plant resistance, development/domestication of new crops, nutrient uptake, biofuel, etc.

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Nordic Crop Wild Relative conservation
The report summarizes results from a cooperation among all the Nordic countries during the period 2015 – 2019 (two projects). The work has focused on the conservation of Crop Wild Relatives (CWR), i.e. wild plant species closely related to crops. They are of special importance to humanity since traits of potential value for food security and climate change adaptation can be transferred from CWR into crops. The projects represent the first joint action on the Nordic level regarding in situ conservation of CWR. Substantial progress has been made regarding CWR conservation planning, including development of a Nordic CWR checklist and identification of suitable sites for CWR conservation. A set of recommended future actions was developed, with the most important one being initiation of active in situ conservation of CWR in all Nordic countries.

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