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Preparatory action on EU plant and animal genetic resources

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WORKSHOP REPORT

The impact of climate change on the conservation and utilisation of crop wild relatives in Europe.

15-16 December 2015, Barcelona

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The Workshop took place in the context of the study launched by DG AGRI of the European Commission called ”*Preparatory action on EU plant and animal genetic resources*” which is being conducted by a Consortium of experts and consultants. It started in July 2014 for duration of 2 years to create an overview of actors, networks, activities and issues regarding conservation and sustainable use of GR in Europe.

A total of seven workshops are planned during the period June 2015 – March 2016. Each workshop is dedicated to specific topics/issues linked to a specific regional context and/or covering sectorial or methodological issues in the field of genetic resources. These workshops cover the four different domains under scrutiny: AnGR, PGR, FGR, and MiGR.

The outcomes of the workshops should provide recommendations concerning approaches and solutions applicable for the conservation and sustainable use of GR, reflecting the objectives and themes of the preparatory action.

More information on the objectives of the study can be found on the study website: http://www.geneticresources.eu.

The Workshop is the fourth of the series.

CONTENTS

1 Introduction

The fourth workshop on "*The impact of climate change on the conservation and utilisation of crop wild relatives in Europe"* was organized by the Project Consortium in Barcelona on 15-16 December 2015. It was prepared by:

- **Theo van Hintum** (Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre);
- **Nigel Maxted** (University of Birmingham, UK);
- **Martin Brink** (Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre);
- **Daniel Traon** (Arcadia International, Belgium); and
- **Daniela Biciu** (Cecoforma, Belgium).

The workshop was attended by 30 invited participants from 21 countries, including experts from universities, research institutes, genebanks, botanical gardens, museums, government departments, international organizations and private breeding companies (see Appendix 1 for the list of participants).

The focus of Workshop 4 was to assess the impact of climate change on the conservation and utilisation of crop wild relatives in Europe.

1.1 Background

The growing human population, their increasing demand for food and the likely adverse impacts of climate change on food production is a critical issue for humankind in the 21st century. To adequately meet the food demand will require a suite of carefully targeted actions that sustain and enhance food production and delivery. One of these actions is the more effective utilization of the largely untapped wealth of genetic diversity found in crop wild relative species. Crop wild relatives (CWR) are wild species related to crop plants. Their intrinsic value to humankind is derived from their ability to contribute desired adaptive traits to crop plants, such as resistance to pests and diseases, but also quantitative traits such as tolerance to drought and salt or components of yield potential.

To assure the possibility of utilisation in crop improvement in Europe, conservation of the full breadth of existing CWR is vital, especially given the expected changes that the climate will go through over the coming years. CWR will be one of the primary sources of adaptive traits that plant breeders will have to use to mitigate crops to the new environments they will be confronted with in the 21st century. An essential part of the complementary conservation of CWR is conservation *in situ*, i.e., in their natural habitats. However, CWR in their natural habitats will also suffer from climate change since they themselves will either have to adapt to the new circumstances or migrate to locations where they can survive.

As climate change will have a profound influence on the natural distribution of CWR, and thus on the future availability of *in situ* CWR populations for crop improvement, and given the fact that CWR have thus far been included in *ex situ* germplasm collections to a limited extent only, it was considered highly opportune to organize a workshop to discuss the consequences of climate change for the conservation and utilization crop wild relatives.

1.2 Issues with respect to climate change and crop wild relatives

The issues to be addressed in the workshop included the following:
1. Which diversity is threatened *in situ* and should be conserved *ex situ*?
2. What is the required number of *in situ* populations to safeguard the contained diversity, either *in situ* or *ex situ*?
3. Which diversity do we need where in production systems?
4. What is the extra required capacity of *ex situ* facilities and expertise, to selectively incorporate threatened diversity in *ex situ* collections?

2 Agenda of the Workshop

The objective of the workshop was to bring together a wide range of people working on the effects of climate change on crop wild relatives and/or involved in activities (*in situ* and/or *ex situ*) aimed at the conservation and utilisation of crop wild relatives, and to formulate recommendations on the best approaches to anticipate the consequences of climate change for *in situ* occurring crop wild relatives.

To achieve this objective, the agenda presented below was developed. After introductory presentations by representatives of the organizing committee and the European Commission, two main sessions were held, the first on 'climate change and conservation' and the second on 'climate change and utilisation'. In each of these two sessions, there were two presentations to create a basis for the discussion, after which three working groups were formed to discuss the subject in parallel, aided by a number of questions formulated by the organisers. After each session, the conclusions of the working groups were reported in a plenary session, where there was also some time for additional discussion. At the end of the workshop, a final plenary discussion was held, and conclusions were formulated.

Tuesday 15 December		
13.00	Welcome coffee	
13.30 – 13.45	• Welcome of participants • Reminder of the objectives of the Preparatory Action • Objectives of the workshop	Theo van Hintum
13.45 – 14.00	Introduction by the European Commission (DG AGRI)	Sirpa Karjalainen
14.00 – 14.45	Setting the scene : *climate change and conservation*	
	• The impact of climate change on patterns of CWR diversity: implications for *in situ* and *ex situ* conservation	Speaker: Rob van Treuren
	• Combining *ex situ* and *in situ* conservation strategies for CWR to mitigate climate change effects	Speakers: Nigel Maxted + Anna Palmé
14.45	Coffee/tea break	
15.15 – 16.30	Working groups discussions (part 1) A. What is the required number of *in situ* populations and conservation strategy to safeguard the contained diversity, either *in situ* or *ex situ*? B. How to determine the extra required capacity of *ex situ* facilities and expertise, to selectively incorporate threatened diversity in *ex situ* collections?	Moderators and rapporteurs: WG1: Sabine Zachgo and Filippa Löfström WG2: Sandy Knapp and Matthias Ziegler WG3: Ehsan Dulloo and Shelagh Kell
16.30 – 17.15	Reports Working groups	Rapporteurs
	Workshop dinner	

Wednesday 16 December		
09.00 – 09.45	Setting the scene : *climate change and utilisation*	
	• Shifting goal posts for pre-breeding: tapping 'the wild' to adapt agricultural systems to climate change	Speaker: Jaime Prohens
	• Assuring access to CWR for the development of climate-ready crops in Europe: the role of *in situ* and *ex situ* actors.	Speaker: Hannes Dempewolf
09.45 – 11.15	Working groups discussions (part 2) C. What is needed to create access to CWR *in situ*? D. Which diversity do we need where in production systems?	Moderators and rapporteurs: WG1: Helena Korpelainen and Penelop Bebeli WG2: Ahmed Jahoor and Vojtěch Holubec WG3: Nils Stein and Hannes Dempewolf
in between	Coffee/tea break	
11.15 – 12.00	Reporting of WG discussions focusing on issues and needs	Rapporteurs
12.00 – 12.45	Final Discussion / Conclusions	All
12.45 – 13.00	Conclusions and next steps	All
13.00	Lunch (optional)	

3 Session 1: climate change and conservation

3.1 'Setting the scene'

Two presentations were given, after which questions and remarks could be given in a plenary session. The two individual presentations are included in Annex 2 to this report. Below, a summary of each of the presentations and the questions/remarks is presented.

Presentation 1: The impact of climate change on patterns of CWR diversity: implications for *in situ* and *ex situ* conservation (Rob van Treuren, Theo van Hintum, Roel Hoekstra & Jesús Aguirre Gutiérrez)

Rob van Treuren presented a co-authored presentation about the expected effects of climate change for *in situ* and *ex situ* conservation of crop wild relatives.

The background of this presentation is a research project of the Centre for Genetic Resources, The Netherlands (CGN) aimed at gaining insight in the CWR in The Netherlands, i.e. providing information to the user community, providing policy support for *in situ* conservation and setting priorities for *ex situ* backing up. An important element of the research was a study, using niche modelling, to predict the effects of climate change on the future distribution of selected CWR in the Netherlands and Europe.

Initially, an inventory was made of the CWR naturally occurring in The Netherlands focussing on the economically most important crops for agriculture and horticulture at national and global level. 214 CWR were identified, of which 53 were Red List species. The Red List species *Bromus secalinus, Erucastrum gallicum, Lathyrus japonicas, Medicago polymorpha, Mentha pulegium, Rubus saxatilis, Scorzonera humilis* and *Valerianella rimosa* were selected for the niche modelling study, based on their ecology, life history, reproduction and dispersal characteristics.

Niche modeling, using occurrence data from GBIF, was performed for present and future environmental conditions. Projections were made for the year 2070 using an ensemble of 14 climatic models and two different climate change scenarios, i.e. an optimistic scenario in which GHG emissions peak in 2020 and then decline (RCP 2.6)) and a pessimistic scenario in which GHG emissions continue to rise (RCP 8.5). The results of the modelling were the averages of the species distribution models MaxEnt, Random Forest and a Generalized Linear Model, using seven selected climatic variables related to temperature and precipitation and two soil-related variables. The study area was the European region.

Two species showed a net gain in distribution area in the European region, while six species showed a loss, ranging from moderate to severe contractions of the distribution area. Shifts in distribution range were observed for all species, mostly towards North and East Europe. Mapping of the predicted distributions on the areas currently included in Natura 2000 showed only a small percentage of occurrence in protected areas.

Notwithstanding the uncertainties related to niche modelling studies, such as the likelihood of climate change scenarios, the quality of the sampling of present occurrences, the absence of possible effects of adaptability, dispersal capacity, competition with other species and non-climatic effects, the following conclusions were drawn from the study: (1) Changing temperatures and precipitation patterns are expected to affect the distribution range of wild plant species (2) Even under the optimistic scenario, most species are expected to show a net loss of distribution area (3) The direction of change of the geographic distribution varies between species (4) The predicted occurrence in protected areas varies between species and between geographic areas (5) Some species can be expected to go extinct in the Netherlands.
In a wider context, the following conclusions regarding the impact of climate change on the conservation of CWR were drawn:

- *In situ* conservation measures, ignoring the effects of climate change, will not be effective for many CWR.
- Large-scale *ex situ* backing up is required, but inclusion in regular gene bank collections is not an option because of capacity constraints of European gene banks.
- New *ex situ* backing up strategies are needed regarding the targets of collecting (priorities and numbers) and the management of the collected material (methodology and access).

Presentation 2: Combining *ex situ* and *in situ* conservation strategies for CWR to mitigate climate change (Nigel Maxted & Anna Palmé)

Nigel Maxted and Anna Palmé co-presented the presentation about combining *ex situ* and *in situ* conservation strategies for CWR to mitigate climate change.

The growing human population, the increasing demand for food, scarcer non-renewable resources for agricultural production, and the likely adverse impacts of climate change on food production present a potential ‘perfect storm’ for the global community in the 21st century. To adequately meet the food demand will require a suite of carefully targeted actions that sustain and enhance food production and delivery. One of these is the more effective utilization of the largely untapped wealth of genetic diversity found in crop wild relative (CWR) species. CWR contain greater breadth of diversity than crops because they have not been subject to the genetic bottleneck of domestication or human directed selection. They are a vital source of novel genetic diversity, particularly that required for climate change mitigation and new technology for incorporating traits from ‘exotic’ germplasm into commercial cultivars is making their use for crop improvement easier than ever before. It has been estimated that the contribution of CWR to improving food production has an annual value of $120 billion; given their significant current and potential value of CWR, it is surprising that many are threatened with extinction or significant genetic erosion. For example, Jarvis *et al.* used distribution modelling for groundnut (*Arachis* spp.), potato (*Solanum* spp.) and cowpea (*Vigna* spp.) gene pools and found a) 16–22% of these CWR species would go extinct by 2055, b) the majority of species are expected to lose greater than 50% distributional range, c) the populations that will remain will be highly fragmented, placing the species under greater threat of genetic erosion or extinction, and d) the impact of climate change varied significantly between species. So how can we ensure CWR diversity is used to mitigate the adverse impact of climate change and ensure future food security? Further what are the most appropriate *ex situ* backing up strategies for CWR populations likely to be lost from the natural environment?

There is a significant intersection between CWR diversity, climate change and food security that involves concrete action to be taken by the various stakeholder communities. In terms of policy there is a critical imperative to feed a 9.6 billion human population in 2050. This will require food supplies to increase by 60% globally and 100% in developing countries where most of the population increase is expected to occur, but at the same time climate change is likely to reduce agricultural production by 2% per decade. This conundrum is recognised in policy edicts such as the Convention on Biological Diversity Strategic Goals and Global Strategy for Plant Conservation, the International Treaty on Plant Genetic Resources for Food and Agriculture, the Food and Agriculture Organisation Global Plan of Action, the United Nations Global Goals for Sustainable Development, the European Parliament’s Feeding 10 Billion people, the European Common Agricultural Policy Reform. But unfortunately policy does not always translate into concrete action. For example there remains no EU agency with responsibility for CWR conservation, ECPGR who might take a lead have a weak funding base, and EC funding streams such as GEN RES and H2020 have insufficient funds, lack the necessary applied focus and could not support such necessary long term ventures.

Although there has in recent years been additional use of CWR diversity by commercial breeders in terms of (a) numbers of CWR taxa used, (b) crops using CWR and (c) range of traits derived from CWR, additional actions are needed to help breeders meet their desire to address changing consumer and environmental demands. Although breeders’ goals are still primarily yield stability, in terms of climate change they are searching for traits to enhance water use efficiency, heat tolerance and drought resistance, adaptation to extreme weather (e.g. flooding or heavy rains), and resistance or tolerance to disease and pest. All of which might be met by using a wider portfolio of CWR diversity.

Further it would help improve CWR use if we clearly understood what limits breeders use of CWR diversity, is seems likely to be (a) the availability of CWR taxa / diversity, (b) availability of characterization / evaluation data, (c) access and benefit issues, and (d) the existence of pre-breeding and public / private partnership programmes. Some of these issues are being tackled by current initiatives that could be extended to facilitate CWR use, such as public / private partnership pre-breeding projects, extending use of omics approaches to characterization and evaluation, application of ecogeographic land characterisation maps / predictive characterization to mine for specific traits and development of end user-orientated informatics (e.g. GLIS) to help breeders select material for use in breeding programmes.

In terms of CWR conservation planning the goal is to effectively conserve the broadest possible range of taxonomic and genetic CWR diversity using complementary techniques. It should become routine to assess the relative threat of climate change on CWR distribution (range) and diversity (taxa and genetic diversity) to assist in prioritising taxa and actions for conservation. There needs to be closer dialogue between conservationist and breeders to identify which traits the users requires in the short, medium and long term, so existing conserved or wild population samples are readily available for the user community. Also when establishing *in situ* and *ex situ* goals, they need to be climate smart, to ensure that unique population that are likely to go extinct are conserved *ex situ* and *in situ* and that novel *in situ* conservation sites have maximum climate change resilience. Even assisted migration used to conserve the highest priority CWR populations. Further in terms of conservation implementation, we need *in situ CWR* conservation to understand climate smart adaptive management, how often is genetic monitoring required, how often to back-up to *ex situ* and what might be the role of *in situ* conservation outside of formal protected areas, and for *ex situ* conservation, which *in situ* populations and how many populations of each threatened CWR do we need to backup *ex situ*?

The aim of CWR conservation is to maximise available genetic diversity for the user community. This can most effectively be achieved by complementary *in situ* and *ex situ* activities. In such an approach *ex situ* conservation provides: safety back-up of *in situ* conserved populations, the facilitated use of conserved populations, and conservation of CWR species/populations not suited to *in situ* maintenance; while *in situ* conservation provides: conservation of whole populations, conservation of the whole CWR ecosystem (maintaining CWR along with their pest and diseases) and as such conservation of the adaptive processes in its natural environment. Such an integrated approach to CWR conservation would involve integrated planning, division of responsibilities and coordination of activities. The model proposed for how such an integrated approach to CWR conservation might be achieved would involve a distinction between standard long-term *ex situ* sampling of CWR diversity and populations sampled as *in situ* back-up, to reduce the resource burden on the *ex situ* collection. Populations sampled for *in situ* back-up might be regarded as similar to 'black box' samples, small seed samples held safely but only available to the donor as part of their *in situ* monitoring programme, not routinely monitored, regenerated or made available to the user community. Such an approach would significantly reduce the potential cost of *in situ* back-up where resources were limiting, although where resources were more plentiful the *ex situ* manager may prefer not to distinguish between standard *ex situ* and *in situ* back-up CWR samples.

However, the argument above assumes there are plans afoot to establish a European network of CWR *in situ* genetic reserves or extra-genetic reserve sites, which is currently not the case. Today the only effective CWR conservation in Europe is *ex situ* in genebanks. Yet given their value and the demand from breeders and other users it is becoming apparent that *in situ* CWR conservation can no longer be ignored – action is required now to establish the necessary European network of CWR *in situ* conservation sites.

Short questions/remarks regarding the presentations in the first session

- Characterization and evaluation of currently conserved genetic resources is hardly taking place, due to limited funding. This indicates that it is highly unlikely that there is sufficient capacity to start new activities regarding the conservation of CWR using existing PGRFA funding. Alternative funding options need to be explored.
- To stimulate farmers to protect CWR outside Natura 2000 areas a financial incentive might be necessary, possibly through environmental stewardship funds.
- The issue of focus was raised; should we only consider CWR occurring within Europe, or all CWR of importance to Europe, some of which may occur outside Europe? In this regards, three groups may be distinguished: CWR native to Europe, CWR introduced into Europe, and CWR outside Europe but of potential use for Europe.
- There was agreement that the potential additional financial burden on genebanks of incorporation of *in situ* CWR backup samples would be significant. However, there was disagreement regarding the issue of non-regeneration of *in situ* CWR backup samples; some argue that not regenerating material is dangerous, whereas others argue that re-collecting (provided it still occurs *in situ*) usually is much cheaper than regenerating, and that regeneration changes the genetic diversity of the material. The option should be considered to only store *in situ* CWR backup samples for *in situ* conservation monitoring and reintroduction, and not make it available for distribution to users.
- It was observed that the policy context is critical. Although the *in situ* conservation of CWR necessitates collaboration between the agricultural and environmental sectors, this has proven to be very difficult in part because of the lack of a joint policy framework in Europe.

3.2 Working groups

Three working groups were formed to discuss the subject, aided by pre-formulated questions. Each working groups discussed the same questions. The conclusions of the working groups were reported during a final plenary session, and listed below.

Working Group 1 (chair: Sabine Zachgo; rapporteur: Filippa Löfström)
Question 1 **What is the required number of *in situ* populations and conservation strategy to safeguard the contained diversity, either *in situ* or *ex situ*?** • Depends on different factors. Sometimes a few populations are sufficient, while in other areas you need more populations. • Step 1: you need a map (biotic and abiotic factors). • The more you search, the more you find (30000 genomes of rice – the more they sequence, the more they found). Never enough. • Dangerous to trust neutral genetic diversity. • It is not as expensive and difficult as before to run a genetic analysis. Focus on those of high importance. • Widely and broadly. *Ex situ* conservation is not that cost intensive (200 euros per sample). • Analysis of a European scale – make available to the European conservation community. • Duty / responsibility for each country. • Prioritisation – danger of being extinct. • If no threat, no conservation action needed. • Currently each country has its own priority list. • PGR secure project: European priority list? Or only a summary of national priority lists? • Prioritisation, concentration on the protected areas. • Clear prioritisation in Europe of species that need conservation, then strategy per species. • *In situ* cannot be lost, back up by *ex situ*. • *Ex situ* for back up, not for use? What is the first priority? Act quickly not to lose species. • Germany – 4000 species, strategy for conservation. • Need to integrate into a European wide strategy. • Estimate needs and costs. • Problem of maturity of the seeds, or bad condition of seeds in *ex situ*. • For collecting – need for a list. PGR secure mad a list – good information source, surveying the species. • Not too difficult on national level, should therefore be possible at European level too. • The scope must be defined. What should be included? Broad scope, but prioritisation. We never know. • Priority area – inclusion of several species, different priorities. If you prioritise too hard, you might lose some things. • Not only richness but also diversity when we select these – important to look at both. • Identify CWR and the genepool. • Level of threat – prioritisation, importance for food security. • Ecogeographical regions – to map different regions/species. Clustering of the sites. • A certain number per site. Starting with hotspots where most species are. • Recollection every 5 year? Monitor the changes.

Question 2
How to determine the extra required capacity of *ex situ* facilities and expertise, to selectively incorporate threatened diversity in *ex situ* collections?

- Funds to safeguard CWR – priority to collect them.
- Genebanks are underfunded, no European strategy.
- Limited time of projects.
- Determine areas, how they move, get them together.
- Even just taking and freezing is still costly (energy, maintenance and documentation).
- Botanical gardens ideal for this.
- Lack of integration between genebanks.
- Making use of specific knowledge.
- GIS work, make it more attractive.
- ENV/AGRI working together – right time for joint activity.
- Connect the two areas Europe wide.
- Only frozen does not mean conserved: important to think about the long term perspective. Funding is needed for regeneration.
- Funding for transnational activities. Need for specific calls matching these needs.
- Basic, important actions.
- PPP in Nordic countries.
- Conservation as the end product – funding earmarked for this specific work.
- Not all species have the same importance – focus on the most important ones for breeding seen that funding is limited. Taking into account climate change

Summary

It became very clear that we need to act to conserve CWR diversity in Europe, because otherwise the full range of CWR adaptive traits will remain unavailable for exploitation and, as we know the resource is threatened, we will lose valuable genetic diversity.

To target conservation activities, we need to establish a priority list of CWR species based on work that has already been done, amongst others in previous EU-funded projects. In these projects methodologies and lists of species were developed. In the priority setting and methodology development ECPGR could play a role as platform. ECPGR recently commissioned the concept note 'Preserving diversity: a concept for *in situ* conservation of crop wild relatives in Europe', which is endorsed by the ECPGR Steering Committee and could act as a blueprint for action.

The impact of climate change will vary throughout Europe, as will its relative effects on the naturally occurring CWR; this will need to be taken into account in the development of strategies. Hotspots and dispersal corridors or stepping stones should be identified, with the aid of niche modelling techniques, depending on the different species and associated geography. Collecting should start in these hotspots (also outside of Europe for priority CWR of importance to European agriculture). As a second step, sites for collecting outside of the hotspots should be identified.

There is a need for an EU wide documentation system of CWR to facilitate conservation planning and implementation, aid breeders' selection of material, and enable statistical analysis and informed policy making.

Collecting and *ex situ* storing at -20°C is clearly the first step in safeguarding the European CWR diversity. For this, seed quality is an important factor. However the knowledge and techniques to determination this quality is still a weak where it concerns CWR. Of equal long-term importance is the research and establishment of the necessary climate-smart European network of CWR *in situ* conservation sites, incorporating both formal protected area (genetic reserve) and less formal *in situ* site CWR conservation, to ensure that the full range of taxonomic and genetic diversity is actively conserved.

It was evident that EU wide collaborative action is needed to safeguard CWR. However, the governance structure was less clear: who should be involved (genebanks, botanical gardens, nature conservationists), how should national and regional activities be coordinated, and how should it be financed. There is a critical need for an EC agency to take up the challenge.

Questions/remarks in plenary session

- The first priority is to deep-freeze CWR material.
- Could the documentation system mentioned be aligned with EURISCO?
- Knowledge is available, but should be applied Europe-wide. This would make priority setting more complicated, however. Also, funding from other than national sources will become more important. Some participants argue that national and European approaches should be combined.
- Why has CWR *in situ* conservation been ignored in Europe when there is such a well-established network of protected areas (Natura 2000) and why won't they engage with the agricultural community?
- We should build on the already existing CWR priority list and conservation concept for Europe.
- Correct identification of specimens is essential (e.g. GBIF is not always dependable). Basic knowledge is therefore important. Identification skills should be taught at universities.
- Skills to maintain material in genebanks are also essential.
- It is not clear to everybody what is meant with 'hotspots'. It is explained that hotspots are determined by mapping species distribution and seeing which localities have higher CWR concentrations.

Working Group 2 (chair: Sandy Knapp; rapporteur: Matthias Ziegler)

Question 1
What is the required number of *in situ* populations and conservation strategy to safeguard the contained diversity, either *in situ* or *ex situ*?

The conservation strategy depends on a range of factors:
- scale (ecogeographical distribution);
- kind of diversity (epigenetic expression in phenotype but what about if taken *ex situ*);
- habitat (hot spot area);
- rareness;
- traits for use and in breeding;
- species (biological characteristics);
- breeding activities in the country (breeding context – adaptive traits);
- population genetics.
- The required number of populations depends on:
- phenotypic and genetic variation (heritability);
- mating system (inbreeding plants or open-pollinating);
- generation time (trees or annual plants).

In determining the minimum required number of plants per sample, the Marshal and Brown criteria can be used. The resources needed for a crop depend on the economic value of that crop, and the distribution over the CWR of this crop depends on the relatedness to the crop (the genepool) and the number of species. Finally, CWR need pre-breeding to open the possibility of practical use in agriculture.

For adaptation to climate change, sampling of CWR after extreme years may be useful.

Question 2
How to determine the extra required capacity of *ex situ* facilities and expertise, to selectively incorporate threatened diversity in *ex situ* collections?

- This is difficult to determine.
- Literature survey is necessary.
- Lot of basic biology to do at species level (germination biology, storage, viability, cultivation, etc.).
- For genebanks it is difficult to handle CWR (mostly open-pollinating).
- Avoid oversampling of *in situ* populations: sampling 100 species or 10000 samples of a grass is too much.

Other remarks

Different groups have to work jointly to tackle climate change. Potential user (breeders, end users), genebank and *in situ* communities should work together. It is necessary to build bridges between nature protection authorities and agriculture (scientists, value chain, pharmaceutical users, farmers, land owners, NGOs and breeders). Stakeholder platforms might have to be established to accomplish this.

Evaluation and pre-breeding of CWR are essential. Also, experimental crosses can be necessary to find out the practical use for breeders regarding linkage between undesirable and desirable traits as backcrosses are costly.

Questions/remarks in plenary session

Oversampling should not only be avoided to prevent swamping of genebanks, but also because it can lead to overexploitation of *in situ* populations.

Working Group 3 (chair: Ehsan Dulloo; rapporteur: Shelagh Kell)

Question 1
What is the required number of *in situ* populations and conservation strategy to safeguard the contained diversity, either *in situ* or *ex situ*?

What criteria are important to consider and how will CC impact on those criteria?

- Biology of the species.
- Distribution of species.
- Target traits.
- Intraspecific diversity.
- Diversity within populations – using genetic diversity studies and proxy methods.

- Depends on crop pool – no. of species, level of hybridization, range.

Practical issues:

- If populations are not protected, it is imperative to collect samples for *ex situ* conservation.
- Give priority to collecting samples from vulnerable populations.
- Policy to support complementary conservation is essential.

General issues:

- Research needed (e.g. on climate change vulnerability - Wendy Foden method).
- Do we need to consider how many taxa?
- Reference to populations, not sites?

Question 2
How to determine the extra required capacity of *ex situ* facilities and expertise, to selectively incorporate threatened diversity in *ex situ* collections?

2a. When should conserved in situ *populations be backed-up into* ex situ *conservation?*

- Ideally, collect complementary samples from all populations. However, need to prioritize to tailor actions to available resources.

2b. What technical issues might arise as a result of ex situ *conservation acting as a backup for conserved* in situ *populations?*

- Quality control issues (e.g. adhering to standards for sampling, data management, seed handling, regeneration).
- When and how to regenerate.
- Knowledge on germination requirements.
- One solution could be to streamline efforts and share responsibilities between gene banks.

2c. What role is appropriate for ex situ *conservation staff in planning and implementing* in situ *conservation?*

- Gene banks are to play a greater role in promoting the importance of CWR amongst the environmental sector and policy-makers.
- In particular, gene banks need to be involved in the beginning of strategy planning.
- Could be involved in active *in situ* conservation (e.g. population monitoring, site suitability).

2d. How might genetic resource centre staff better meet users' requirements for germplasm conserved in situ *and* ex situ*?*

- Increase availability of characterization data.
- Clarity on ABS requirements.
- Improve information availability.
- Size of seed samples.
- Quality of germplasm samples.

Questions/remarks in plenary session

With respect to the first question: this depends on factors such as the susceptibility to climate change and the Red List status of the species.

With respect to the second question: instead of tailoring actions to available resources, you could also look the other way round: what do we really need to do, and what resources do we need for that.

The question was asked if we are really addressing a new situation (climate change) or if we are addressing the existing situation of CWR protection? The agreed answer was that the aspect of moving adaptation zones is really new. It was agreed that some of the issues addressed are not directly connected to climate change, but others are. Important CC-related issues are the urgency to collect, to commence *in situ* conservation and to be ready for the changes in existing practices that are necessary.

Can genetic barcoding play a role? Taxonomy should be seen as an assessment of the genetic variation, it is not fixed. It is important to define what a CWR is. In Brassicas, for instance, it is difficult to distinguish between CWR and escaped plants because there are wild and cultivated forms of the same species, which is also the case for many forages.

It is logistically easier to protect areas than to protect populations. Others argue that this is true, but that, with climate change, plants ‘start to climb over of the fences’. It is added that you could apply assisted migration to move individuals to protected sites.

4 Session 2: climate change and utilisation

4.1 ‘Setting the scene’

Two presentations were given, followed by questions and remarks, in a plenary session. The two individual presentations are included in Annex 3 to this report. Below, a summary of each of the presentations and the questions/remarks is presented.

Presentation 1: Shifting goal posts for pre-breeding: tapping ‘the wild’ to adapt agricultural systems to climate change (Jaime Prohens, Universitat Politècnica de València, Spain)

Agriculture will be one of the sectors most affected by climate change, with increased occurring of abiotic and biotic stresses in many areas. Many wild species are tolerant to stress. In view of the impact of climate change, a new paradigm is necessary: tapping ‘the wild’ for adapting crops to climate change. Up to now, the use of wild relatives in crop breeding has been mostly restricted to the introgression of specific traits (such as disease resistance) from single wild relatives, but now the breeding objectives have to be broadened (“the goal posts shifted”): climate change adaptation instead of only introgression of specific traits.

The new approach uses ‘introgressiomics’: mass scale development of multiple plant materials carrying introgressions of genomes from (mostly wild) related species into the genetic background of crops, that may allow developing new cultivars adapted to climate change (and other breeding goals). Two possible strategies can be distinguished, *focused*: aimed at one specific target (drought, high temperatures, climate change adaptation), and *non-focused*: aimed at the massive generation of introgression materials for present and future (unforeseen) needs (climate change adaptation, quality, new challenges).

Tapping 'the wild' is not easy, because CWR also contain many undesirable traits and are difficult to manage under "domesticated" conditions, crossing barriers may exist between crops and wild relatives, it takes a long time to develop pre-bred materials that are usable by breeders, and protocols are needed for screening for climate change traits. Furthermore, CWR accessions are much less represented in collections than crops, access to germplasm collections is perceived as increasingly difficult by breeders, information on already existing pre-bred materials is often missing or unavailable, often only limited evaluation data are available for crop wild relatives, and the taxonomy of crop wild relatives is too often confusing.

Introgressiomics would comprise the following steps:

1. identifying the target wild species (based on genetics, phenotype, evaluation, environment, origins, and the genepool position);
2. interspecific hybridization;
3. ensuring the fertility of the hybrids (use hybrid as maternal parent; genome duplication to restore fertility);
4. backcrossing;
5. the development of introgression materials (collection of introgression lines, chromosome substitution lines);
6. the combination of genes from different wild species (intercrossing of introgression lines from different wild species; Multiparent Advanced Generation Inter-Cross (MAGIC) populations.

Programmes need to be stablished for the simultaneous introgression from many wild species. The objective of the project 'Adapting agriculture to climate change' is to collect many of the most important species of crop wild relatives, ensure their long-term conservation, and facilitate their use in breeding new, improved crops. This will facilitate having materials readily usable by breeders against climatic change challenges and unforeseen future needs, and will allow combining genes from different wild species to get crops adapted not only to disease resistance but to the broader objective of adapting to climate change.

In conclusion, the new motto, coined during this workshop, is: "Introgress, baby, introgress".

Presentation 2: Assuring access to CWR for the development of climate-ready crops in Europe (Hannes Dempewolf, Global Crop Diversity Trust, Bonn, Germany)

In the period 1980-2008 considerable changes in the growing season temperature for crop growing regions have been observed, which have resulted, for instance, in global wheat yield reductions of more than 5%. The suitability of regions for specific crops is expected to change dramatically, and breeding priorities (e.g. for responses to water availability and temperature) will change as well.

During domestication and subsequent breeding, the genetic diversity of crops has decreased strongly, resulting in less climate resilient agricultural systems. Furthermore climate change will have profound effects on the distribution of CWR, which are also threatened by habitat loss and degradation, pollution, and alien species. In Europe we are dependent on many crops and their CWR from outside of Europe.

The word ‘availability’ has several components:
- Biological ‘availability’ of germplasm: world germplasm holdings amount to 7.4 million accessions, of which 2 million unique ones. The number of unique, threatened accessions, needing regeneration is estimated at 168,000. In the framework of the Crop Trust’s Global System Project (2006-2011) 74,705 accessions were regenerated and are now available through the MLS, 3,675 were put *in vitro*, while 12,255 accessions (±13%) were not viable.
- Long-term availability vs short-term availability: long-term storage in Svalbard seed vault.
- ‘Legal’ availability of germplasm: clarity on access requirements and legal availability of germplasm is key for users of any PGRFA. Which international framework is applicable to the transfer of genetic resources depends on the material (what it is, when it was obtained or created, who provided or created it, under what conditions it was provided or created) and the transfer (purpose of the transfer, status/jurisdiction of the provider, status/jurisdiction of the recipient).

So, there are lots of complexities in a continuously shifting policy landscape.

According to EURISCO, genebanks in Europe hold 137,534 CWR accessions, but how many of these are actually available (both biologically and legally)? According to EURISCO, 29,223 CWR accessions are part of the MLS. The status of the other 108,311 accessions is unknown, since availability information is not (yet) included in EURISCO. Anecdotal evidence suggests that many are not available for distribution. An important question is also how it can be assured that material reported as available is in actually available for distribution. For CGIAR genebanks, availability is one of the ‘key performance targets’: the target is that 90% of the collection is clean, viable, in sufficient seed number to be made immediately available for international distribution. All too often, passport data and all other data associated with germplasm are placed in ‘data morgues’ and forgotten. The key challenge is to link up passport, genomic and phenotypic information on genebank accessions.

In the conservation and use of CWR, partnerships are key; not only public / private partnerships, but also conservation / utilization / research, *ex situ* / *in situ,* and basic / applied.

With respect to public/private partnerships:
- Breeders often don't know where to start looking. Poorly characterized genebank holdings are a major obstacle for PPP.
- Focus is key: bringing in necessary diversity for specific traits of importance to specific breeding programs.
- Businesses have to respond to market-demands, they need material for short-term needs. This is only achievable through long-term partnerships with the public sector to build up a pool of suitable resources.
- Clarity on IP conditions is essential. PPPs for Pre-breeding are typically in the pre-competitive domain.

An example of a PPP is the project 'Adapting Agriculture to Climate Change' project, aiming at collecting, protecting and preparing CWR ($50 million over 10 years pledged by the Norwegian government). The project outputs include newly collected CWR seeds conserved and made available from genebanks; pre-bred lines made available to farmers and breeders through genebanks; capacity on 'collecting, conserving and using CWR' built in developing countries; data on collected seeds and pre-bred lines made available publicly online.

Some key issues, in this regards, for the genetic resource community to address include:
- How 'available' are CWR from European genebanks? Do we need to strive for more ambitious targets? Do we need better quality management frameworks for genebanks in Europe?
- Conservation and distribution of pre-bred lines and other types of genetic stocks: Who, where, when how, for how long, who pays for it? Under which terms should it be made available?
- What do genebank users want us to conserve and make available to them? Maximum allelic diversity sets? Sets of haplotypes? Core collections?
- Where is the 'data' generated from accessions over the last few decades? How can we improve our information management and sharing systems?
- Maintenance and sharing of data: who, where, when how, for how long, who pays for it? Under which terms should it be made available?
- How best to engage users?

In conclusion, there are no 'single gene' solutions for climate change. However, CWR utilization and conservation will be important if we want to adapt agriculture to climate change in Europe (and elsewhere). Whole 'crop delivery pipelines' need to be redesigned. Institutions, such as genebanks, need to re-think the way they are operating. A dual role of long-term conservation and a service function will be important. New trusted partnerships need to be built and maintained. However, all of this takes time: funders need to support a more long-term vision and new funding models need to be explored. Project funders need to get used to the idea of providing funding for genebanks to conserve and make available materials for use.

Questions/remarks

It would be desirable if it were possible to check the availability of PGR in genebanks through EURISCO.

Gene editing is an issue to consider. It will not make PGR irrelevant, because edits will be based on functions determined on the basis of PGR. Furthermore, editing is now based on down-regulation, whereas breeding needs up-regulation. Legislation will determine whether gene editing can be used in breeding in Europe.

Massive introgression is needed, but this is not straightforward as the crossability varies between and within species. Currently introgression from CWR is usually based on one or a few plants from the CWR; other strategies might be needed such as 'evolutionary breeding'.

4.2 Working groups

Three working groups were formed to discuss the subject, aided by pre-formulated questions. Each working groups discussed the same questions. The conclusions of the working groups were reported during a final plenary session.

Working Group 1 (chair: Helena Korpelainen; rapporteur: Penelop Bebeli)
Question 1 **What is needed to create access to CWR *in situ*?** *1a. What tools (including informatics systems) are available or need to be developed to identify germplasm that meets user's requirements?* • We don't have a single tool to meet all needs. • There is a need to define what type of information we need for collecting. • Access to a complete on-line flora (GSPC Target 1 – Plant List and WCSPF), including distribution. • Establish genetic reserves technical tools e.g. DNA barcoding, trait genomic markers. • Sorting out access and benefit regimes. Who owns genetic resources, including landowners, contracts, difficult to exchange material? Regulation under Nagoya. Ability to access is a tool. An SMTA could be signed to gain access. Working with CBD and national authorities. • Characterization, evaluation of *in situ* material? Easier in *ex situ*: same environmental

conditions. Limited to identify genetic variation. But problem of backlog of uncharacterised material.

- For *in situ*: predictive characterization, ecogeographical land characterisation maps, GIS techniques and genomic approaches
- Use different sites for characterization.
- Prioritise characterization and evaluation of rare species (quick characterization to understand the value). Meeting requirements from the users.
- Collection of CWR-germination-dormancy problems- there are websites such as SID (seed information database) at Kew. Difficulties with material to be sent and has no good quality.
- There is a need to improve seed germination protocols.

1b. Who should be responsible for obtaining fresh collection from in situ *populations to meet user's requirements?*

- Let genetic reserves staff collect material as genebanks may need payment or be too busy.
- It is better to have a one page A4 training guide that could help to choose the seeds to collect etc. Protocols. It would be cheapest for people that are in the protected areas to collect.
- Education of the people that are in the protected areas how to collect; ENSCONET guide to collection is available.
- Developed information system to collate and disseminate all related data and make available on-line for users.
- Access permit for collecting will help to avoid over-collecting, e.g. ENSCONET guide.

1c. How to obtain sufficient sized samples to meet user's requirements?

- Seed quality / sampling issues: 50 population of 50 seeds (Marshal and Brown, 1975).

1d. What are the implications of providing user access to in situ *conserved populations?*

- Genetic reserves with a network of different stakeholder groups involved with management, monitoring and use. Appropriate information system at national level for genetic reserves and with genebank data (Germany example), Very good developed information system to collate and disseminate all related data and make available on-line for user.
- Trying to establish a best practice protocol. Reporting obligation about the growing species.

1e. How will climate change impact stakeholders' selection of in *situ populations for utilisation?*

- Decided by user community. But then prioritization on which populations are more impacted by CC or diseases.
- Prioritized areas of Mediterranean where there is highest diversity and largest impact, this could form a alive experiment as populations try to adapt.

Question 2
Which diversity do we need where in production systems?

2a. How will climate change over the next 25 years affect the need to duplicate diversity existing in nature or on-farm ex situ *and what can be maintained* in situ*?*

- Conserve the more threatened, conservation issues, monitoring activity, how is impacting in terms of diversity, how is dynamically evolved, to understand the process of the evolution, exploit the moment in time.
- A set of criteria, i.e. material that grow in a narrow habitat has priority, link of CWR and associated flora. Distinction man-induced changes and climatic change, reappearance of species in abandoned field areas.

- CWR in forest areas are largely already conserved. Actively focus on grasslands or CWR rich habitats Funding will provide a limitation.

2b. Given that ex situ *techniques require by definition a sampling of the diversity that exists in nature or on-farm, what factors will define the diversity that needs to be duplicated* ex situ *and what can be maintained* in situ*?*

- The ones that are most threatened and more impacted by CC, populations that are in high risk.

Questions/remarks in plenary session

With respect to the sample size sufficient to meet user's requirements: it is commented that "50 population of 50 seeds" for each CWR sounds rather arbitrary, but this figures from the standard genetic thinking (Marshal and Brown, 1975). In the context of CWR, we should have geneticists look at it in more detail. Work is being done on this at the moment. It is also argued that the numbers depend on the species (breeding system), its distribution etc., and that you should not have a general rule. Perhaps it is better to establish 'best practices'.

With respect to the question of who should be responsible for collecting from *in situ* populations, botanical specialists can also be involved in collection. In general, different kinds of people can be involved. Let people decide from situation to situation.

Let's not focus too much on the Mediterranean area alone. There is a risk that northern countries will doubt the necessity of collecting in their country.

Working Group 2 (chair: Ahmed Jahoor; rapporteur: Vojtěch Holubec)

Question 1
What is needed to create access to CWR *in situ*?

General

- Who are users? Public research, company research, hobby users, breeders, SME breeders, NGO, local farmers, commercial seed sellers, multipliers.

1a. What tools (including informatics systems) are available or need to be developed to identify germplasm that meets user's requirements?

- Information system (easy searchable, filled with detail data including ecological descriptors such as coordinates, landscape, soil, vegetation).
- Genetic data (citable, publishable data).
- Link to national databases with data sets on phenotyping and evaluation.
- Characterisation, to make more characterisation data available.
- A problem is that breeders do not want to be open on what they need.

1b. Who should be responsible for obtaining fresh collection from in situ *populations to meet user's requirements?*

- Partnerships of botanical gardens, genebanks, nature protectors (incl. all protected landscape regions) and universities.

1c. How to obtain sufficient sized samples to meet user's requirements?

- Depends on species.
- Sample enough, without affecting the population.

- Outcrossers: more than 30 plants sampled.
- Regenerate.

1d. What are the implications of providing user access to in situ *conserved populations?*

- We do not recommend providing localities and/or coordinates for protected species and small populations.
- It would be better to provide access to regenerated *ex situ* material.

1e. How will climate change impact stakeholders' selection of in situ *populations for utilization?*

- Necessity to speed up collecting, and to get high *ex situ* diversity for use.
- New diversity will be needed for breeding, new genes that may be present in marginal populations.

Question 2
Which diversity do we need where in production systems?

2a. How will climate change over the next 25 years affect the need to duplicate diversity existing in nature or on-farm ex situ *and what can be maintained* in situ*?*

- Evolving of populations in the wild, coevolution with pathogens in reaction to climatic changes: any resampling of material after some time may result in more or less different material
- Therefore earlier collection is desirable: conserved status quo in longer perspective.

2b. Given that ex situ *techniques require by definition a sampling of the diversity that exists in nature or on-farm, what factors will define the diversity that needs to be duplicated* ex situ *and what can be maintained* in situ*?*

- Define species and populations that are more vulnerable to climatic changes and that need to be collected (more susceptible, on the borders of distribution areas that are expected to move N/S, along existing or new corridors).

Questions/remarks in plenary session

The presentation of the rapporteur was clear, so there were no questions nor remarks.

Working Group 3 (chair: Nils Stein; rapporteur: Hannes Dempewolf)

Question 1
What is needed to create access to CWR *in situ*?

1a. What tools (including informatics systems) are available or need to be developed to identify germplasm that meets user's requirements?

- We need genebanks to prepare better information (passport, evaluation and characterization info if available) about their resources for breeders;
- Research & Development of some tools is still needed, e.g. tools for *de novo* domestication; tools to show specific haplotypes; tools that better integrate taxonomic information, information about duplicates etc.
- The outputs of prediction and modelling exercises to help guide the selection of accessions by users could be useful.
- Discussion around whether it would be useful for genebanks to do specific evaluation of

CWR on climate –change related traits.

1b. Who should be responsible for obtaining fresh collection from in situ *populations to meet user's requirements?*

- National genebanks (though some specialized collections can also play a role).
- Crop committees are a good mechanism to provide user perspectives.
- Global crop conservation strategies could play a role.
- ECPGR crop specific working groups could be an important mechanism.
- Better involvement of local experts.

1c. How to obtain sufficient sized samples to meet user's requirements?

- Genebanks need greater clarity from use community about what user's requirements actually are, and in which form they would like to see material be provided.
- Key is to capture the available diversity under consideration of population genetic parameters.

1d. What are the implications of providing user access to in situ *conserved populations?*

- Risks are bigger than opportunities in our view.
- Some breeders prefer going directly into *in situ*, however the serious risks associated with this are overexploitation, restricted access for others, and lack of long-term conservation. Furthermore, legal uncertainties exist around the conditions for access of *in situ* populations; it may be illegal without prior informed consent and signing of an SMTA.

1e. How will climate change impact stakeholders' selection of in situ *populations for utilization?*

- It is not clear to what extent climate change actually matters on how to sample and more research is needed on this.
- Urgency to collect before diversity is gone *in situ*.
- Some breeders may be more interested in populations that are experiencing abiotic stresses in their regular habitats.
- Needed is to have the best possible information about what we have in *ex situ* to better understand what to prioritize collection from *in situ*.

Question 2
Which diversity do we need where in production systems?

2a. How will climate change over the next 25 years affect the need to duplicate diversity existing in nature or on-farm ex situ *and what can be maintained* in situ*?*

- Important to consider ways to influence decision making on *in situ* conservation in areas outside of Europe.
- On-farm landraces will not be able to move – so collection from on-farm needs to be also a priority.
- Better monitoring systems are needed for CWR diversity *in situ* to highlight conservation concerns and communicate this to key decision makers (early warning system that could include crowd sourcing; also consider asking nature conservation networks to extend their monitoring specifically to also include CWR).

2b. Given that ex situ *techniques require by definition a sampling of the diversity that exists in nature or on-farm, what factors will define the diversity that needs to be duplicated* ex situ *and what can be maintained* in situ*?*

- Diversity that is most threatened needs to be prioritized: Wild and weedy types are of less concern from a conservation standpoint, but those with limited ranges and small populations need to be prioritized.

Questions/remarks in plenary session

With respect to collecting *in situ* populations, there is a risk of overburdening the already busy genetic reserves staff, if they also get the task of collecting material. Others argue that these people are best able to prioritize species.

The questions was raised if breeders themselves really collect CWR *in situ*. This happens indeed; some participants gave examples such as tomato breeders collecting, but nobody knows exactly what they do.

Genebanks do not always have enough expertise to collect CWR; additional training is advisable to enhance their capacity.

5 Recommendations

In the final plenary session, recommendations were formulated on the best approaches to anticipate the consequences of climate change for naturally occurring crop wild relatives:

1. Stakeholder collaboration platforms for planning and implementation of *in situ* and *ex situ* conservation, and use activities should be set up with participation from the PGR community, environmental sector and the policy arena, from within and outside Europe where critical CWR diversity of European interest is located.
2. National, regional and pan-European approaches should be integrated in a common European strategy.
3. Inter-operable national and regional networks of formal *in situ* protected areas and less formal *in situ* conservation sites, (including sentinel sites and stepping stones) should be climate change assessed, designated and established.
4. Based on a common European strategy, the activities of *in situ* and *ex situ* actors should be integrated, assuring optimal interaction and synergy.
5. An inventory of CWR in Europe should be completed, giving an overview of potential use, current occurrence and expected shifts due to climate change.
6. Mechanisms for prioritization of CWR species should be completed on the basis of use potential, threat level and climate change modelling.
7. CWR Diversity and gap analyses need to be made, including CWR niche modelling.
8. The conservation tools available for producing ecogeographical land characterisation maps, climate change mitigation, and gap analysis via GIS techniques and genomic approaches need to be enhanced and made more widely available to conservationists.
9. Samples of *in situ* conserved CWR diversity should be routinely collected and backed up at -20°C, though not necessarily forming part of active collection and so not subject to regeneration protocols.

10. The developments in CWR in Europe should be monitored, with reporting to the FAO Global Plan of action and the next State of the World's Plant Genetic Resources report.
11. Access to the breadth of CWR diversity should be facilitated for the user community from *ex situ* collections, *in situ* conservation sites and from nature itself, once the appropriate access and benefit arrangements are in place.
12. Germplasm selection tools, such as those for predictive and genomic characterization, and associated datasets need to be enhanced and made more widely available to germplasm users to help aid germplasm selection.
13. Some priority species should be evaluated for user-defined traits, pre-bred (including the use of various omics techniques) and data and material should be made publically accessible in collaborative projects, thus developing mechanisms that could be scaled up towards massive introgression efforts.
14. European CWR conservation and use should be put in a global context and linked to technology transfer activities.
15. A governance structure needs to be put in place for European CWR conservation, and associated long-term resources should be made available (provision of financial resources, supporting european networks,.....) to adequately conserve this resource and make it available to germplasm users to underpin European food security and commercial development.

ANNEX 1: List of participants

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ANNEX 2: Presentations

On the CGN website dedicated to the workshop, pdf-files will be made available from all four presentations (after approval from the European Commission): http://www.wageningenur.nl/en/Expertise-Services/Statutory-research-tasks/Centre-for-Genetic-Resources-the-Netherlands-1/Centre-for-Genetic-Resources-the-Netherlands-1/Education-and-Information/Education-and-Information/Show-education-and-information/Workshop-The-impact-of-climate-change-on-the-conservation-and-utilisation-of-crop-wild-relatives-in-Europe..htm