Networking, partnerships and tools to enhance *in situ* conservation of European plant genetic resources

ISSN 1742-3694 (Online)

www.farmerspride.eu

Crop wild relative

Issue 13 October 2021

Conserving plant genetic resources

for use now and in the future

Farmer's Pride – EU Horizon 2020 Framework Programme – Project 774271

Crop wild relative

Issue 13 September 2021

Contents

Editors:
Nigel Maxted
Jade Phillips

Design:
Shelagh Kell

Layout:
Jade Phillips

Front cover: Farmer's Pride project partners, Advisory Board, Ambassadors and collaborators, without whom the significant achievement of Farmer's Pride would not have been possible.

Correspondence address:
Nigel Maxted, School of Biosciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK Email: n.maxted@bham.ac.uk

 The University of Birmingham edits and publishes Crop wild relative on behalf of Farmer's Pride, a collaborative project funded under the Horizon 2020 Framework Programme of the European Union, project number 774271.

Editorial

Welcome to Issue 13 of Crop Wild Relative, the final issue to be published under the umbrella of the recently concluded EC H2020 Farmer's Pride project (full name - 'Networking, partnerships, and tools to enhance in situ conservation of European plant genetic resources'), as such we sincerely thank the EC for the funding provided.

The Farmer's Pride project is the fourth EC funded project (PGR Forum, AEGRO, PGR Secure, and Farmer's Pride) in a series led by members of the ECPGR Wild Species and On-farm Conservation Working Group and in a real sense Farmer's Pride is a culmination of those projects, in that a lot of concepts and methodologies developed in the earlier projects reach fruition in Farmer's Pride. Particularly among these is the initiative to establish a European Network for *In Situ* Conservation and Sustainable Use of Plant Genetic Resources, but that is not the only product of Farmer's Pride worthy of mention.

However, before we go into the detailed CWR-related products of Farmer's Pride, it is useful to set the scene in the current global and regional European sense. The first article in CWR 13 is an analysis of the seed collecting phase of the 'Adapting Agriculture to Climate Change' project led by the Global Crop Diversity Trust and the Royal Botanic Gardens, Kew (Millennium Seed Bank) that highlights the collection of 3,854 new accessions of 242+ CWR taxa, which is a substantial addition to CWR diversity already available *ex situ*. This is followed by two articles from a sister project to Farmer's Pride, in the Southern African Development Community regions, where the goal is likewise to establish a regional network for *in situ* CWR conservation and here the SADC Council of Ministers has stepped in to provide the necessary governance support. The first article led by Joana Magos Brehm, and colleagues highlights the CWR *in situ* and *ex situ* conservation priorities for the SADC region, specifically identifying 151 *in situ* sites with high CWR concentration that should join the network, as well as areas of Angola, Democratic Republic of the Congo, Eswatini, Madagascar, Malawi, Mauritius, Mozambique, South Africa, Tanzania, and Zimbabwe where further *ex situ* collection is required. The second article led by Ehsan Dulloo reviews how the SADC network team for *in situ* CWR conservation, with the help of the SADC Genetic Resources Centre, were able to move beyond talk to practical network establishment, a global model that all those who follow can learn from. Next follows sub-continental up-date for the Nordic region led by Anna Palmé, an important European region where many CWR are at the extreme edge of their geographic range and so are likely to contain critical unique allelic diversity. Recent regional activities have focused on awareness raising over the value of CWR diversity in breeding, CWR inventories of priority protected areas and associated *ex situ* seed collection in Finland, Iceland, Norway, and Sweden, as well as highlighting the establishment of the first formally recognised Norwegian CWR genetic reserve in the Færder National Park between Vestfold and Telemark. The article also discusses the award of a grant for more systematic research in the Nordic countries and how the funding will further progress Nordic CWR science.

The remaining articles deal with specific aspects of Farmer's Pride research. First, we need to learn from experience, therefore, Maria Luisa Rubio Teso leads a review of previous attempts to establish CWR genetic reserves and reports 29 previous potential exemplars. She then analyses their strength, weaknesses, opportunities, and threats and draws general conclusions that could aid novel network establishment. Luisa also leads the next article which focuses on the relationship between CWR and Natura 2000 network, to see if practically the more formal establishment of *in situ* CWR genetic reserves might be focused in the N2K network. The analysis found a third of the N2K sites (8673 sites) have at least one priority CWR taxa and that 409,642 populations representing 593 CWR taxa occur in these sites. They found 91% of priority CWR analysed were found in N2K sites, clearly indicating a closer CWR and N2K community linkage is fully justified. Another very significant Farmer's Pride practical product is the CWR population management guidelines led by Ada Molina and which are expected to provide a long-lasting impact on CWR *in situ* population management and are likely to prove just as important for non-CWR wild plant population, CWR taxa just being equivalent to any other wild plant species when it comes to management.

Another article describing a significant Farmer's Pride product for PGR Science is the next article focusing on bioinformatic tools, briefly described by Nigel Maxted and Shelagh Kell, and which were produced to resolve practical problems, five tools are associated with CWR *in situ* conservation. The next article describes a welcome application of socio-economics into PGR science, in this case addressing the difficult subject of incentives for public good services, specifically public willingness to pay for support mechanisms for effective conservation. The article led by Adam Drucker finds the social welfare benefits associated with non-market agrobiodiversity-related public good ecosystem services are frequently ignored and that the public's willingness to pay for conservation is more than sufficient to fund critical conservation interventions. One of the fundamentally important issues when establishing an *in situ* CWR network is, not only the practical maintenance of CWR population, but just as importantly how to get the conserved resource out of the *in situ* site and to the end user – if *in situ* is to be sustainable it much be at least equal to the *ex situ* genebank in getting to conserved resource to the end user – but how is this to be achieved? That is an active question of current debate and therefore we include two article one led by Theo van Hintum and the other by Nigel Maxted which look at the issue of linkage between conserved *in situ* population and end user exploitation, from the *ex situ* and *in situ* perspective respectively. Although not fully aligned there are areas of agreement.

The final article prepared by Nigel Maxted and Shelagh Kell discusses the delivery of the European *in situ* conservation network of sites and stakeholders. The combination of stakeholders and sites is required to facilitate *in situ* (including on-farm and on-garden) CWR and LR conservation and use across Europe, which aims to maximize CWR and LR diversity conservation, as well as promoting and facilitating its sustainable utilization in a policy context that encourages user access. It was envisioned that the network would be established by the end of the three-year project lifetime with 30 sites and 4,000 stakeholders included, then post-project grows organically to become more encompassing by adding further stakeholders and sites throughout Europe. Although unfortunately the network has not been formally established within the project lifetime, the Farmer's Pride consortium can feel proud in that we got very close. Almost 100 sites have made a commitment to join the network once established, the first steps in CWR population data collation are currently being taken and we hope this has built sufficient momentum that other steps will inevitably follow.

Finally, although the Farmer's Pride project has come to a successful conclusion, the consortium of partners involved are actively searching further funding to continue the development and implementation of CWR science inside and outside of Europe. In the mean-time we hope you will continue to use the resources available via the Farmer's Pride website—in particular, the networking page (https://more.bham.ac.uk/farmerspride/network/), resources page (https://more.bham.ac.uk/farmerspride/key-documents/), policy documents (https://more.bham.ac.uk/farmerspride/key-documents/policy-documents/) and Networking tools (https://more.bham.ac.uk/farmerspride/key-documents/networking-options/) — and of course we are still available to help wherever we can, so, if you need advice and you think we might be able to help, please contact us.

Treasuring crop wild relative diversity: analysis of success from the seed collecting phase of the 'Adapting Agriculture to Climate Change' project

Maraeva Gianella[1], Filippo Guzzon[2], Jonas V. Müller[3] and Christopher P. Cockel[3]

[1]Department of Biology and Biotechnology "L. Spallanzani", University of Pavia, Pavia, Italy
[2] International Maize and Wheat Improvement Center (CIMMYT), Texcoco, Mexico State, Mexico
[3] Millennium Seed Bank, Royal Botanic Garden, Ardingly, West Sussex, UK.

The exploitation of genetic diversity in crop improvement to produce crop varieties with superior adaptive traits such as increased drought and heat tolerance, and input use efficiency will be key to increase the productivity and sustainability of agricultural systems (Prohens *et al*., 2017). The bulk of genetic diversity in crop gene pools is found in crop wild relatives (CWR), therefore, CWR are important sources of useful alleles for plant breeding and crop improvement (Kishii, 2019). In order to facilitate the use of CWR for plant breeding, they need to be readily accessible in *ex situ* conservation facilities such as germplasm banks (Guzzon and Ardenghi 2018).

Before the 'Adapting Agriculture to Climate Change' project was established, over 95% of all CWR were either absent or insufficiently represented in gene banks, and therefore mostly inaccessible for plant breeding and crop improvement (Castañeda- Álvarez et al. 2016). The seed collecting phase of the 10-year project aimed to address this issue, resulting in the most comprehensive CWR collecting and conservation mission to-date and providing priceless genetic diversity for ongoing and future crop breeding efforts. The seed collecting started in 2013 and concluded in 2019, seed was collected in 22 countries in Africa, Asia, the Americas and Europe and it targeted the CWR of 28 crops of major importance for food security: alfalfa, apple, Asian/African rice, Bambara groundnut, banana/plantain, barley, bean, carrot, chickpea, cowpea, durum/bread wheat, eggplant, faba bean, finger millet, grasspea, lentil, oat, pea, pearl millet, pigeon pea, potato, rye, sorghum, sweet potato and vetch (Müller *et al*., 2021). In total 3,002 target seed accessions of 242 CWR taxa were collected and are currently stored long-term in the countries of collection and, in most of the cases, backed up at the Millennium Seed Bank (UK). While collecting 852 additional non-target populations seed accessions were also collected. For the gene pools of Bambara groundnut, barley, grass pea, sorghum, and wheat, the collecting phase was highly successful in terms of diversity of both species and populations collected (Figure 1).

Overall the Mediterranean and the Caucasus were the areas where the highest median number of seed accessions was collected. Comparing the percentages of target populations successfully collected, the highest percentage of success was achieved in the Caucasus followed by West Africa (Figure 2). Despite the overall positive outcome of the project, in our analysis we discovered several issues that were encountered in the seed collecting. In particular, comparing the initial collecting targets with the seed accessions effectively collected it emerges

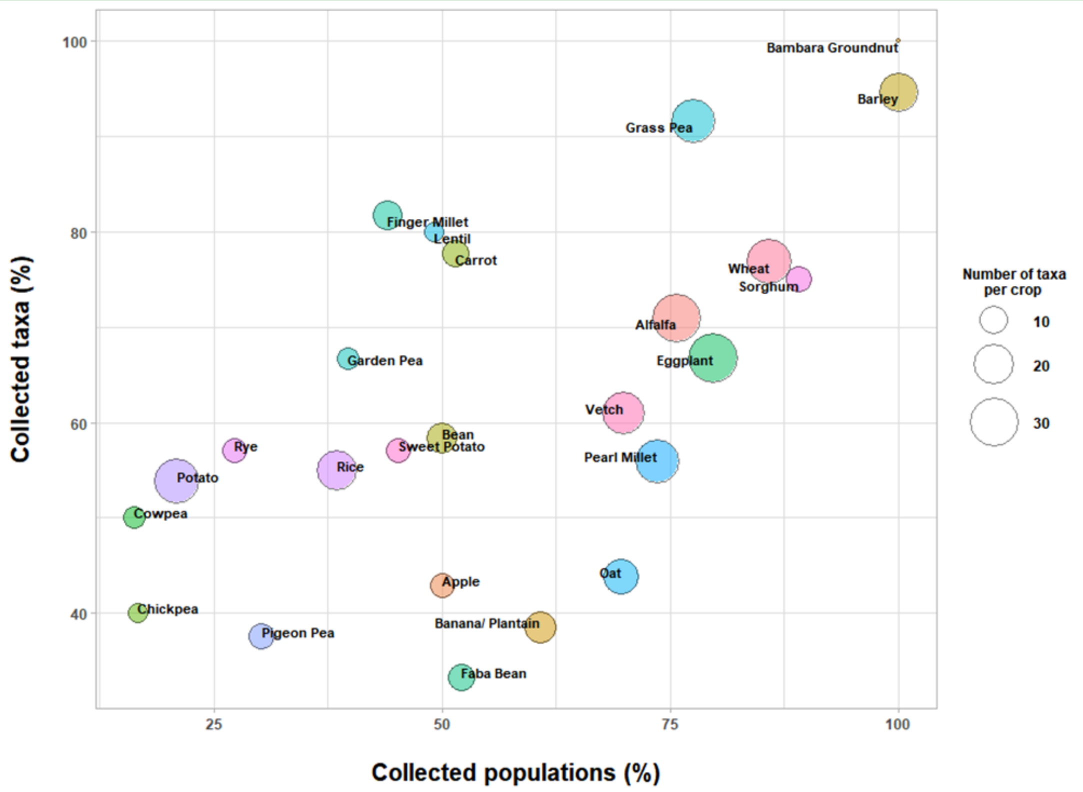

Figure 1. Percentages of collected target taxa (vertical axis) and populations (horizontal axis). The number of target taxonomic units within a crop gene pool (i.e., wild relatives of that crop species) is represented by the diameter of the circle representing the crop gene pool (Müller *et al*., 2021).

that: (1) some crop gene pools important for food security were characterized by a low collecting success (e.g., banana/plantain, potato, rice) (2) some of the crop gene pool 1b (e.g. in eggplant and sorghum) remained under-collected, even though this gene pool comprises the closest relatives to the crop species and therefore are the easiest-to-use genetic material for crop improvement techniques (3) some important geographic centres of plant biodiversity considered in this project (especially the Indian Subcontinent) were underrepresented in the seed collecting. This analysis can help guide further collecting missions in order to fill gaps in the long-term conservation of CWR of great importance for crop improvement. More details and discussion of the seed collection can be found in Müller *et al*. (2021), along with details of how to access the collections.

References

Castañeda- Álvarez N.P., Khoury C.K., Achicanoy H.A. *et al*., (2016). Global conservation priorities for crop wild relatives. *Nature Plants*, 2: 1–6. https://doi.org/10.1038/NPLANTS.2016.22

Guzzon, F. and Ardenghi, N.M.G., (2018). Could taxonomic misnaming threaten the ex situ conservation and the usage of plant genetic resources? *Biodiversity and Conservation*, 27: 1157–1172. https://doi.org/10.1007/s10531-017-1485-7

Kishii, M., (2019,) An update of recent use of *Aegilops* species in wheat breeding. *Frontiers of Plant Science*, https://doi.org/10.3389/fpls.2019.00585

Müller, J.V., Cockel, C.P., Gianella, M. and Guzzon, F. (2021). Treasuring crop wild relative diversity: analysis of success from the seed collecting phase of the 'Adapting Agriculture to Climate Change' project. *Genetic Resources and Crop Evolution*, 68: 2749–2756. https://doi.org/10.1007/s10722-021-01229-x

Prohens, J., Gramazio, P., Plazas, M. *et al*., (2017). Introgressiomics: a new approach for using crop wild relatives in breeding for adaptation to climate change. *Euphytica*, 213: 158. https://doi.org/10.1007/s10681-017-1938-9

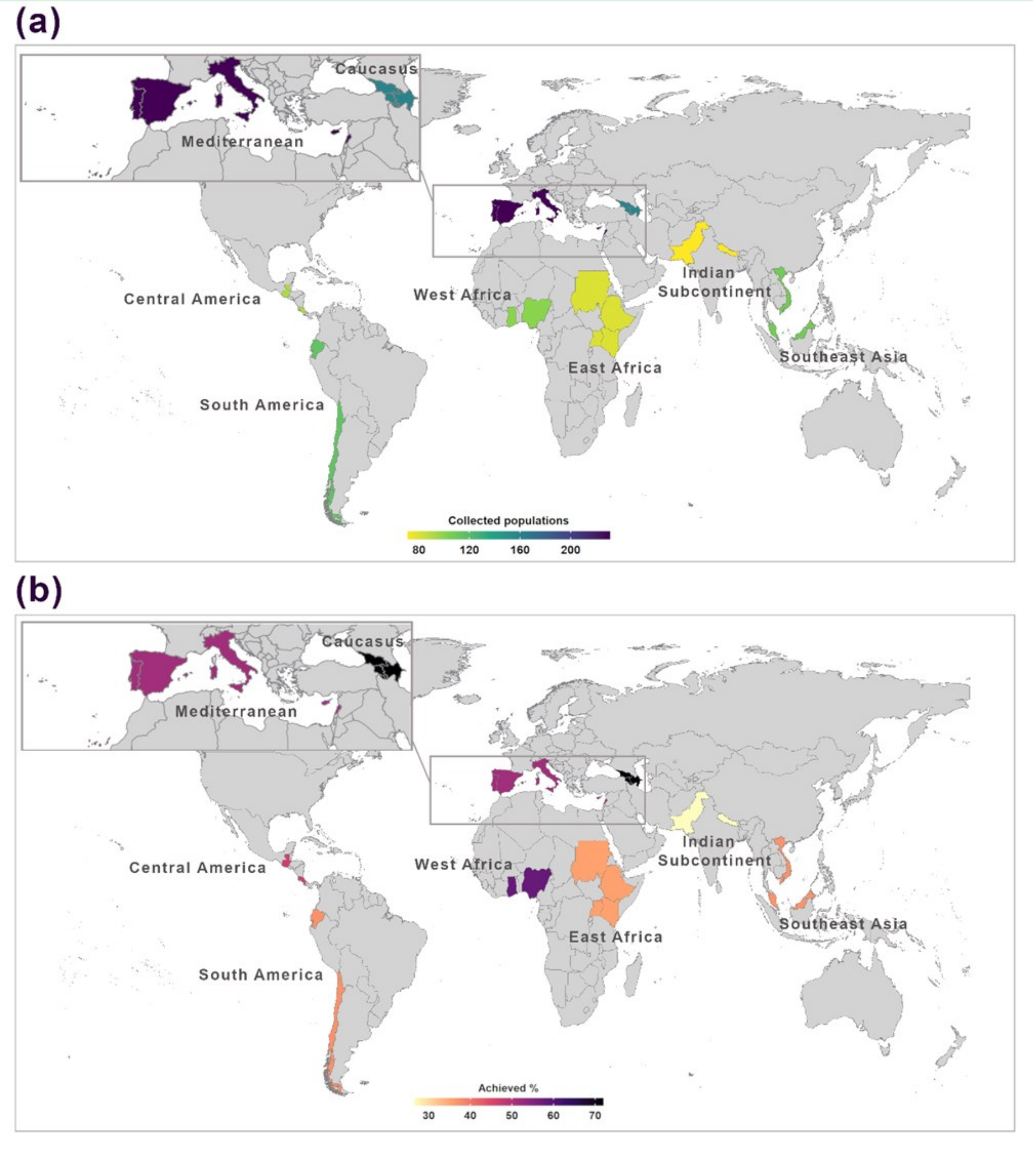

Figure 2. (a) Median number of collected populations by geographical area; (b) Percentage (Median) of target populations collected by geographical area (Müller *et al.*, 2021).

Summary of the *in situ* and *ex situ* conservation priorities for the SADC region

Joana Magos Brehm[1], Hannes Gaisberger[2,3], Shelagh Kell[1], Mauricio Parra-Quijano[4], Imke Thormann[2§], M. Ehsan Dulloo[5] and Nigel Maxted[1]

[1] School of Biosciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK.
[2] The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), Rome, Italy.
[3] Department of Geoinformatics, Paris Lodron University of Salzburg, Austria.
[4] Facultad de Ciencias Agrarias, Universidad Nacional de Colombia, Ciudad Universitaria, Bogotá, Colombia.
[5] The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), Rose-Hill, Mauritius.
[§] Current affiliation: Federal Office for Agriculture and Food, 53179 Bonn, Germany

Crop wild relatives (CWR) are extremely valuable wild plant genetic resources for food security as they are potential sources of important traits that can be used in crop improvement. The Southern African Development Community (SADC) region is important for its diversity of wild relatives of several crops of regional and global importance (Allen *et al.,* 2019). However, not only the CWR of the region are threatened and under-conserved (Magos Brehm *et al.,* submitted), but also the countries in the SADC are facing unprecedented challenges related to climate change (IPCC 2019), food security and poverty reduction. The conservation and sustainable use of CWR, which is worth an estimated US$120 billion globally (PwC 2013), is therefore an urgent priority for the region.

The research here is a summary of and introduction to Magos Brehm *et al.* (submitted) and forms part of the scientific basis of the Regional Action Plan for the Conservation and Use of CWR in the SADC region and will contribute to the establishment of the SADC Network for *In Situ* Conservation of CWR that has been recently approved by the SADC ministers responsible for agriculture, food security, fisheries and aquaculture (see Dulloo and Bissessur 2021 in this Newsletter).

We used a combination of species distribution modelling, ecogeographic diversity, complementarity analysis and climate change analyses to identify sites within and outside existing protected areas where active *in situ* conservation of the regional priority 110 CWR taxa could be carried out. We also identified priority areas for the urgent collection of priority CWR diversity that are expected to become extinct due to climate change, as well as for filling gaps in existing *ex situ* collections (Magos Brehm *et al.,* submitted). We identified 120 existing protected areas and 151 sites outside protected areas, located in 13 SADC countries (mainly the Democratic Republic of the Congo, Madagascar, South Africa and Tanzania), that cover regional priority CWR diversity in which no negative climate change impact is predicted and where active *in situ* conservation should be undertaken (Figure 1). We also identified the provinces of Bas-Congo (Democratic Republic of the Congo) and Cabinda (Angola) where urgent *ex situ* collection should be carried out as priority

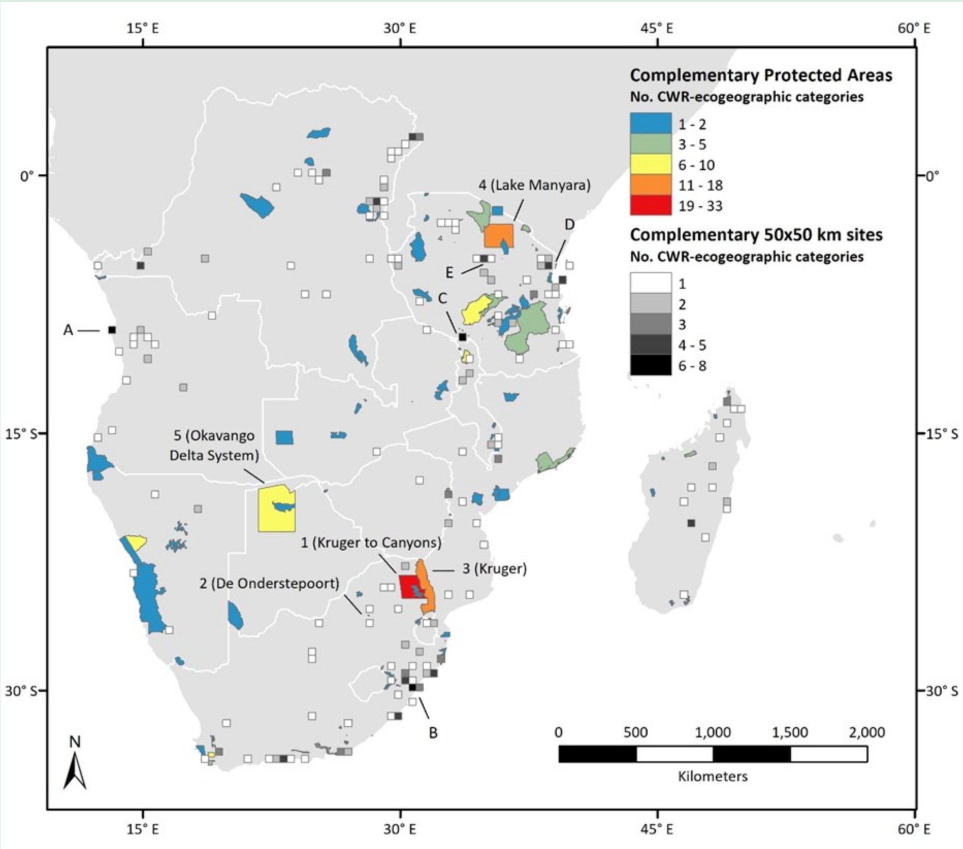

Figure 1. SADC Network for the *In Situ* Conservation of CWR comprising the complementary network of the 120 existing protected areas (PAs) and the complementary 151 sites outside PA where active in situ conservation of the regional priority CWR could take place. The numbers on the map (followed by the PA name) indicate the five highest priority PA (where 1 is the first priority) and the letters indicate the five highest priority 50x50 km sites for conservation (where A is the first priority) (adapted from Magos Brehm *et al.* submitted).

CWR diversity action because of the high level of threat of extinction by climate change (Figure 2). Areas located in Angola, Democratic Republic of the Congo, Eswatini, Madagascar, Malawi, Mauritius, Mozambique, South Africa, Tanzania, and Zimbabwe were also prioritized for the *ex situ* conservation of CWR ecogeographic diversity that is currently not conserved *ex situ* (Figures 3 and 4) (Magos Brehm *et al.* submitted).

The results obtained in this research (Magos Brehm *et al.* submitted) were then used to provide specific recommendations about the active *in situ* conservation of regionally important CWR diversity, to support an *ex situ* conservation programme of target CWR diversity, and on further field surveying to enhance the availability and quality of distribution data of priority CWR but also to confirm CWR populations in the potential sites where genetic reserves could be established.

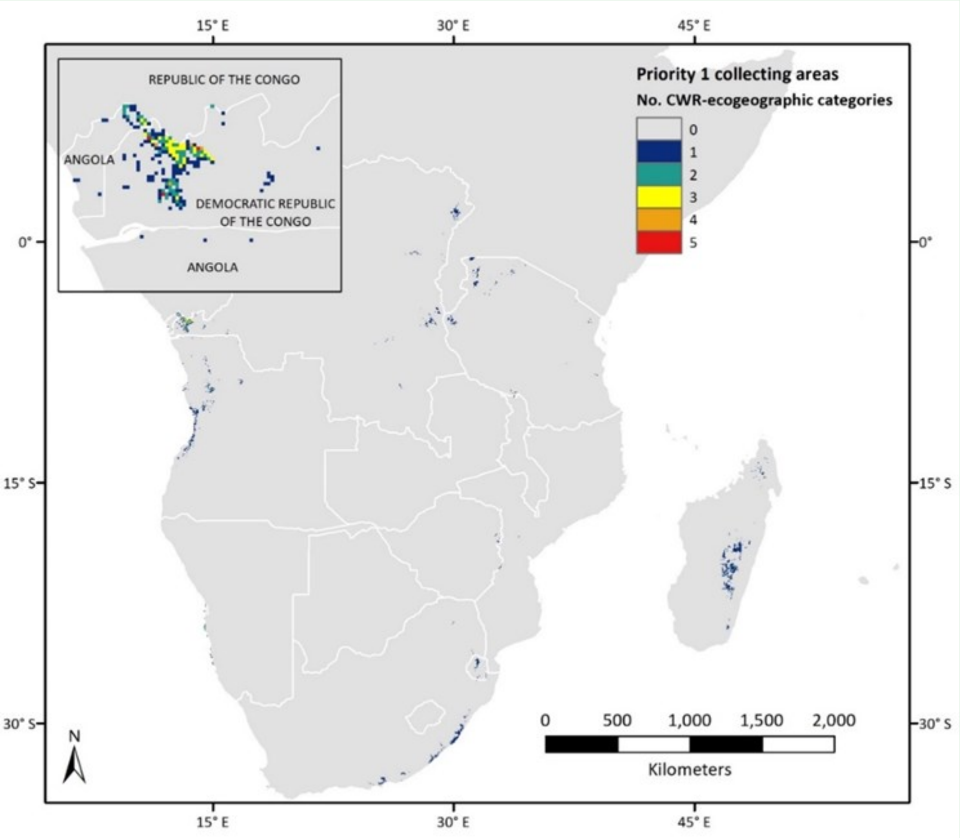

Figure 2. Areas for urgent germplasm collection of regionally important CWR diversity threatened of extinction by climate change. In the box, a close-up of Angola and the Democratic Republic of the Congo (from Magos Brehm *et al.* submitted).

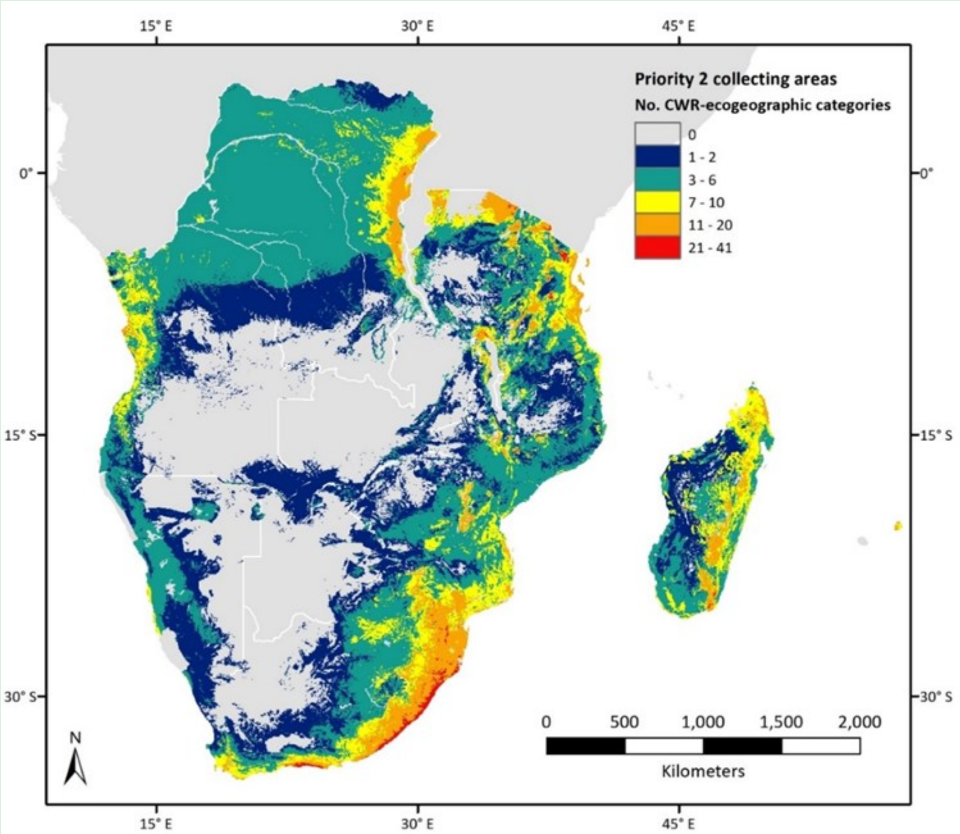

Figure 3. Areas for germplasm collection of CWR diversity (75 taxa) not conserved *ex situ* and that may or may not be negatively impacted by climate change (from Magos Brehm *et al.* submitted).

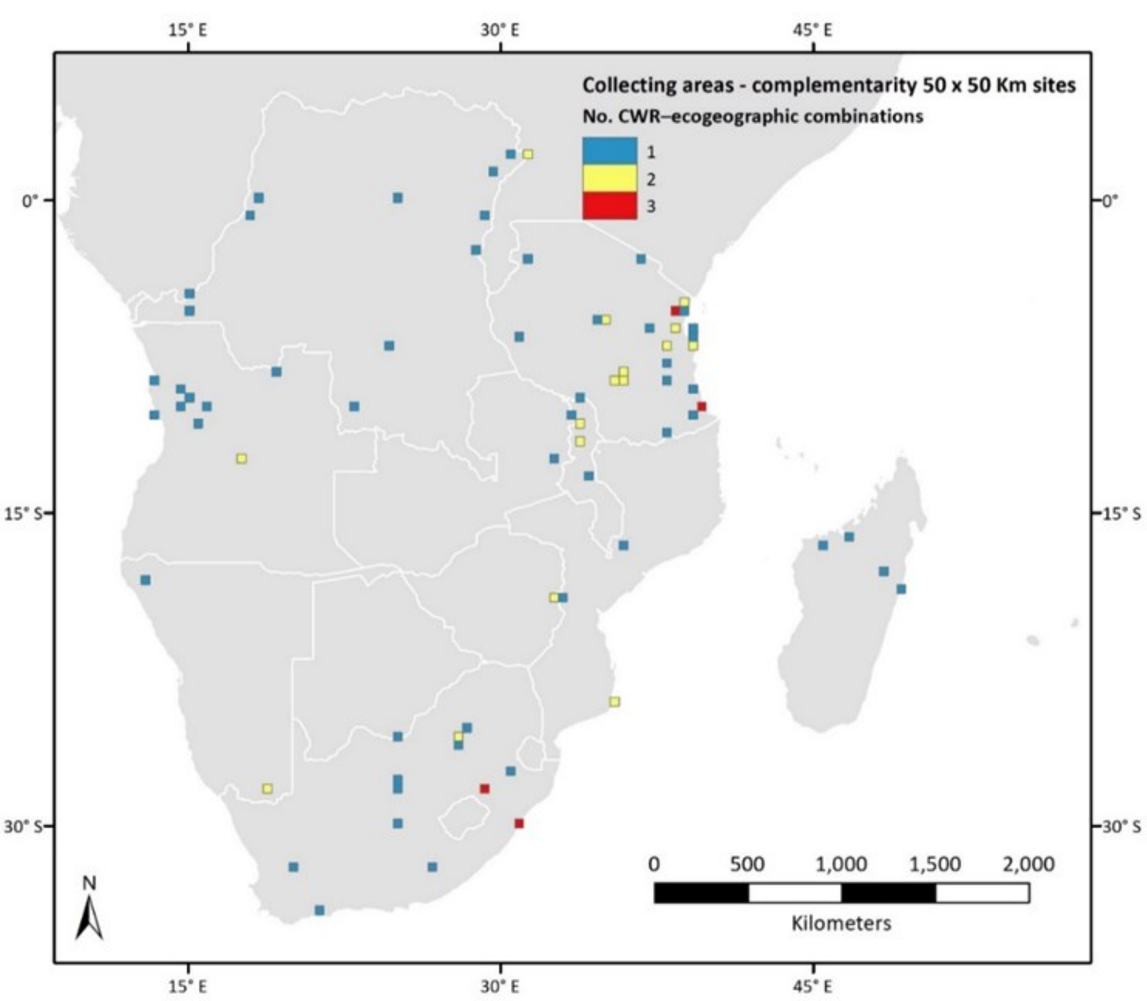

Figure 4. Complementarity collecting areas for *ex situ* conservation of the CWR diversity not conserved *ex situ* for 35 taxa for which species distribution models were not robust enough to be used in the analysis (from Magos Brehm *et al.* submitted).

Acknowledgements

This research was carried out within the framework of two successive projects on crop wild relatives in the SADC region: the project '*In situ* conservation and use of crop wild relatives in three ACP countries of the SADC region' (SADC Crop Wild Relatives for short) (http://www.cropwildrelatives.org/sadc-cwr-project/) co-funded by the European Union and implemented through the ACP-EU Co-operation Programme in Science and Technology (S&T II by the ACP Group of States (grant agreement no. FED/2013/330-210), and the Defra/Darwin Initiative funded project 26-023 entitled 'Bridging agriculture and environment: Southern African crop wild relative regional network' (SADC-CWR Network for short) (http://www.cropwildrelatives.org/sadc-cwr-net/).

References

Allen, E., Gaisberger, H., Magos Brehm, J., Maxted, N., Thormann, I., Lupupa, T., Dulloo, M.E. and Kell, S.P., (2019). A crop wild relative inventory for southern Africa: A first step in linking conservation and use of valuable wild populations for enhancing food security. *Plant Genetic Resources: Characterization and Evaluation* 17(2), 128–139.

Dulloo, M.E. and Bissessur, P., (2021). Establishment of the SADC CWR Regional *In Situ* conservation network. *Crop Wild Relative*, 13: ??-??.

IPCC (Intergovernmental Panel on Climate Change), (2019). Summary for policymakers. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi M. and Malley, J. (eds), Climate change and land: *An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Available from: https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/ [Accessed July 2021].

Magos Brehm, J., Gaisberger, H., Kell, S.P., Parra-Quijano, M., Thormann, I., Dulloo, M.E. and Maxted, N., (submitted). Planning complementary conservation of crop wild relative diversity in southern Africa. *Diversity and Distributions*.

PwC, (2013). *Crop Wild Relatives. A Valuable Resource for Crop Development*. PricewaterhouseCoopers. Available from: https://pwc.blogs.com/files/pwc-seed-bank-analysis-for-msb-0713.pdf [Accessed September 2021].

The establishment of the first regional network globally for crop wild relative conservation and sustainable use : lessons learnt from southern Africa

M. Ehsan Dulloo[1], Justify G. Shava[2] and Prishnee Bissessur[1]

[1]Bioversity International, Rose-Hill, Mauritius; e.dulloo@cgiar.org
[2] SADC Plant Genetic Resources, Lusaka, Zambia

The Southern African Development Community (SADC) groups 16 member states under an inter-governmental organization, established as a development community since 1992, with its secretariat based in Gaborone, Botswana. Some of the SADC countries like Madagascar, South Africa, and Democratic Republic of Congo form part of the top global biodiversity hotspots, endowed with diverse ecosystems and biodiversity (Myers *et al*., 2000), including agrobiodiversity that underpins agricultural production and sustainable livelihoods in the region (Vavilov, 1926). With nearly 1,900 species of wild relatives of several crops of regional and global importance (Allen *et al*., 2019), the Southern African region has prioritized 271 areas in 13 SADC countries for the *in situ* and *ex situ* conservation of crop wild relatives (CWR) (Magos Brehm *et al*., submitted).

Since 2013, Bioversity International (now the Alliance of Bioversity International and CIAT) and University of Birmingham have been working in partnership to establish regional networks globally, in view of expanding the latter into one global network for *in situ* conservation of CWR. In the SADC region, the first step started with an EU/ACP Science and Technology programme funded project that allowed us to carry out the regional assessment of *in situ* conservation of CWR, as well as in three countries, namely Mauritius (Bissessur *et al*., 2019), South Africa (Holness *et al*., 2019) and Zambia (Ng'uni *et al*., 2019). Subsequently, since 2019, another project (Darwin SADC CWR Network project) funded from DEFRA UK under its Darwin Initiative programme, is being implemented with the overall goal of creating an exemplar regional CWR network in SADC region. Furthermore, the Darwin SADC CWR network project also aims at supporting project countries (Malawi, Tanzania and Zambia) to i) to develop National Strategic Action Plans for *in situ* conservation of CWR, ii) identify CWR hotspot areas for establishing genetic reserves, iii) develop links to *ex situ* genebanks and users – farmers and breeders, iii) address the question of Access and Benefit Sharing of *in situ* conserved plant genetic materials, in collaboration with the International Treaty for Plant Genetic Resources and Nagoya Protocol under the Biological Convention and iv) test incentive mechanisms for farmers to conserve CWR on their farm and/or in their adjoining areas (see paper from Drucker *et al*. in this issue).

The SADC Regional CWR Network has as an objective the establishment of priority sites and stakeholders for the conservation of CWR and promote their sustainable use in crop improvement and to foster an effective linkage between this *in situ* network and the existing network of national genebanks. Its establishment was approved in May 2021 by the Joint Meeting of SADC Ministers responsible for agriculture and food security, fisheries and aquaculture, thus making it one of the first established network of the world that is targeting the *in situ* conservation of CWR and its sustainable use.

The successful establishment of the SADC Regional Network was due to several key elements. A first step was to bridge the gap between the environmental and agricultural stakeholders, this was done by providing a platform for a dialogue between the national plant genetic resources centres (NPGRC) and protected area authorities and ensuring their involvement in the decision making process for identifying priority sites and undertaking joint activities. Another important aspect was to figure out who were the key decision makers and what processes the latter follow. This was possible by identifying a boundary partner, under this project the SADC Plant Genetic Resources Centre which helped to build links with the higher-level decision makers at the SADC level, i.e., SADC secretariat, the Summit of Head of States and Council of Ministers which oversee the functions and implementation of activities within the SADC region.

Another key success element was the complementarity between the *in situ* CWR network and the existing *ex situ* network and use of CWR in breeding. This was achieved by working closely with SADC PGR Centre which has the remit of PGR conservation and use in the SADC region and which is already coordinating a network of NPGRCs for *ex situ* conservation. The project's national partners (Malawi, Tanzania and Zambia) also reached out to farmers and breeders to understand their needs and promote the use of CWR in their work.

More importantly, the project produced a draft white paper to explain and justify the necessity and urgency for the creation of a Regional Network and to define the various functions and benefits that network would provide (Dulloo *et al*., 2021). It was important to set the network within the regional policy context to show how the network would contribute to achieve the region's strategic directions for the SADC programmes and activities, such as the Regional Indicative Strategic Development Plan and the Comprehensive Africa Agriculture Development Programme which is Africa's policy framework for agricultural transformation, wealth creation, food security and nutrition, economic growth and prosperity for all. Finally, the white paper clearly articulated the governance structure of the network as well as its funding mechanism. It was agreed that The SADC Regional CWR Network will be managed by a dedicated Network Operation Unit in SPGRC which itself falls under the Directorate Food Agriculture and Natural Resources (FANR), of the SADC Secretariat. The Senior Programme Officer (*in situ*) of SPGRC will serve as the interim network coordinator. Minimum financial resources would be required by SADC Secretariat to sustain the coordination unit of the network (with some extra staff) to allow SPGRC to fulfil this function. In addition, a technical committee, comprising of representatives from the SADC Member States and International Cooperating Partners of SADC Secretariat will be constituted to provide guidance and technical support to the network.

The SADC-CWR network is the first regional network about CWR to have been set up in the world. Another initiative in Europe has been undertaken to establish regional European network for CWR under Horizon 2020 Farmer's Pride project (2017-2021), where key stakeholders across Europe have been brought together to create partnerships for the establishment of a network for the conservation of plant genetic resources, including both CWR and landraces. Once fully established, these two networks will be the precursors for a Global network for the conservation and use of plant genetic resources for food and agriculture.

Figure 1. Newly established crop wild relatives genetic reserve at the Nyika National Park, Malawi (Photo: Nolipher Mponya, MPGRC)

References

Allen, E., Gaisberger, H., Magos Brehm, J., Maxted, N., Thormann, I., Lupupa, T., Dulloo, M. E., & Kell, S. P. (2019). A crop wild relative inventory for Southern Africa: A first step in linking conservation and use of valuable wild populations for enhancing food security. *Plant Genetic Resources*, *17*(2), 128–139.

Bissessur, P., Baider, C., Boodia, N., Badaloo, M. G. H., Bégué, J. A., Jhumka, Z., Meunier, A., Mungroo, Y., Gopal, V., & Kell, S. P., Magos Brehm, J., Thormann, I., & Jaufeerally-Fakim, Y. (2019). Crop wild relative diversity and conservation planning in two isolated oceanic islands of a biodiversity hotspot (Mauritius and Rodrigues). *Plant Genetic Resources*, *17*(2), 174–184.

Castañeda-Álvarez, N. P., Khoury, C. K., Achicanoy, H. A., Bernau, V., Dempewolf, H., Eastwood, R. J., Guarino, L., Harker, R. H., Jarvis, A., & Maxted, N. (2016). Global conservation priorities for crop wild relatives. *Nature Plants*, *2* (4), 1–6.

Dulloo, M. E., Maxted, N., Shava, J. G., Pungulani, L., Hamisy, W., Munkombwe, G., Magos Brehm, J., & Bissessur, P. (2021). *Crop Wild Relatives in the South African Development Community*. Bioversity International.

Holness, S., Hamer, M., Magos Brehm, J., & Raimondo, D. (2019). Priority areas for the in situ conservation of crop wild relatives in South Africa. *Plant Genetic Resources*, *17*(2), 115–127.

Magos Brehm, J., Gaisberger, H., Kell, S. P., Parra-Quijano, M., Thormann, I., Dulloo, M. E., & Maxted, N. (submitted). Integrating diversity and climate change analyses in the conservation planning of crop wild relatives in Southern Africa.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853.

Ng'uni, D., Munkombwe, G., Mwila, G., Gaisberger, H., Magos Brehm, J., Maxted, N., Kell, S. P., & Thormann, I. (2019). Spatial analyses of occurrence data of crop wild relatives (CWR) taxa as tools for selection of sites for conservation of priority CWR in Zambia. *Plant Genetic Resources*, *17*(2), 103–114.

Vavilov, N. I. (1926). Centers of origin of cultivated plants, in N.I. Vavilov ed. Origin and geography of cultivated plants, pp.536.

Recent progress on crop wild relative conservation in the Nordic region

Anna Palmé[1], Birgitte Lund[2], Elina Kiviharju[3], Heli Fitzgerald[4], Hjörtur Thorbjörnsson[5], Jenny Hagenblad[6], Jens Weibull[7], Kjersti Bakkebø Fjellstad[8], Kristina Bjureke[9], Linn Borgen Nilsen[8], Magnus Göransson[10], Maija Häggblom[11], Marko Hyvärinen[4], Mora Aronsson[12], and Virva Lyytikäinen[4]

[1] Nordic Genetic Resource Centre (NordGen), Box 41, 234 56 Alnarp, Sweden
[2] Danish Agricultural Agency, Ministry of Environment and Food, Copenhagen, Denmark
[3] Natural Resources institute Finland (LUKE), Jokioinen, Finland
[4] Finnish Museum of Natural History, LUOMUS, University of Helsinki, Helsinki, Finland
[5] Reykjavik Botanic Garden, Reykjavík, Iceland
[6] Department of Physics, Chemistry and Biology, Linköping University, Linköping, Sweden
[7] Swedish Board of Agriculture, Alnarp, Sweden
[8] Norwegian Genetic Resource Centre, Norwegian Institute for Bioeconomy Research (NIBIO), Ås, Norway
[9] Natural History Museum, University of Oslo, Oslo, Norway
[10] Agricultural University of Iceland, Reykjavik, Iceland
[11] Ålands landskapsregering, Miljöbyrån, Mariehamn, Åland, Finland
[12] Swedish Species Information Centre, Swedish University of Agricultural Sciences, Uppsala , Sweden

The Nordic countries include the northern edge of the distribution of many European species. The region has a unique combination of photoperiod and climate, which in turn leads to unique adaptations in the wild plants. A wealth of Crop Wild Relatives (CWR) have been identified in the region with over 2 700 taxa related to food, forage, medicinal, ornamental and forestry plants (Fitzgerald *et al*., 2017). Over time, these taxa have adapted to local conditions evolving traits that are not only important for their survival but can also have a potential use in breeding and pre-breeding efforts when creating tomorrow's crops adapted to climate change and new demands.

While the Nordic countries have collaborated for more than 40 years on *ex situ* conservation of plant genetic resources, joint efforts on *in situ* conservation of CWR are still in their infancy. During the last couple of years there has been a dramatically increased effort to conserve the Nordic CWR. Since 2015 there has been an active Nordic cooperation on *in situ* conservation of CWR funded by several consecutive projects, creating an informal network dedicated to CWR (Palmé *et al*., 2019; Fitzgerald *et al.,* 2020). During the last two years, additional project funding has been received and it has been possible to expand the work with, for example ,communication activities, inventories of CWR in protected areas, collection of seed for *ex situ* conservation and genetic studies. Below we describe some of the work conducted during 2020 and 2021.

A travelling exhibition in five Nordic languages

An important step towards enhancing the conservation of CWR is to increase the understanding of the value of genetic resources. To increase the awareness, a travelling exhibition was developed in the form of outdoor posters and an accompanying information folder. The focus is on the basics of CWR: what they are, why they are important, how they can be conserved and examples of CWR from the Nordic region. Texts with similar content were written in English and the main Nordic languages, Danish, Finnish, Icelandic, Norwegian and Swedish. Five separate sets were printed on metal posters, each with a Nordic language and English (Figure 1). The posters are mounted in sturdy metal frames in order to withstand outdoor conditions during large parts of the year. A folder that had been developed in a previous Finnish project was translated and adapted to national conditions during the project. Six different versions were printed, one for each Nordic language and one in English.

The Norwegian posters were the first ones to be ready and the exhibition was launched in the Botanical Garden of the Natural History Museum in Oslo on the 20th of April 2021. A press release was made and accompanied by information on the homepage, which garnered some attention in the press ("De ville slektningene", 2021). The exhibition was displayed in Oslo until 25th of June and was then moved to Bergen botanical Garden in Milde, and is now on display in the Museum Garden in the centre of Bergen. As it was spring when the exhibition was presented in Oslo, only small plants of *Carum* and *Angelica* were on display. In the summer period in Bergen, more CWR plant species were on display by the posters. In the light of the COVID-19 pandemic, we were lucky to have planned for an outdoor exhibition. Many museums and greenhouses were (and are still) closed to the public due to the risk of infection but an outdoor exhibition was approved, and visitors could stand at appropriate distance from each other and read the posters.

In Finland the CWR exhibition was first displayed in Kumpula Botanic Gardens, Luomus, in Helsinki, and after that in Elonkierto Agriculture Exhibition Park in Jokioinen. The exhibition was in Kumpula Botanic Garden from 14th of June to 15th of August. It was located near the entrance by the Medicinal and Herb Garden (Figure 1a). Kumpula Botanic Garden already has a number of CWR species in the living collections and 30 of these were included in a plant trail to support the exhibition. In addition to these, seeds of 19 CWR priority species, collected originally in Finland or other Nordic countries, were ordered from NordGen's seed collection. They were sown in Kumpula Botanic Garden nursery and a majority of them were planted this summer in permanent displays in the Medicinal Garden. The remaining species will be planted outside next year. Altogether 102 free guided tours were arranged in the garden and CWR exhibition during the summer. The public found the exhibition very interesting and the CWR topic raised many questions and discussions with the tour guides. The exhibition was advertised on Instagram, Twitter and Facebook Luomus channels and on the Luomus webpage.

The exhibition came to Elonkierto Park, Finland, in late August. It was placed close to a barn café and will stay there until winter. The Park is open for visitors without entrance fee. The first primary school pupil groups have been exploring park and the CWR exhibition there (Figure 1b). The CWR exhibition will be announced for a larger public and media as a part of the Children's Science Days and following harvest market day in September. Many cultivated and CWR species can be found in the park and can be presented as a part of tours. Next year, 2022, the exhibition moves to Oulu Botanic Garden and the Åland Islands.

The first stop for the Swedish version of the exhibition was Station Linné on the island of Öland. The station is a knowledge and information centre, neighbouring the Unesco World Heritage Site Stora Alvaret, and a popular visiting site at the end of the school spring semester. With an increased interest in domestic vacationing as an effect of the pandemic, estimates indicate that at least 1 600 people saw the posters here. After Öland, the exhibition travelled to Helsingborg and Fredriksdal's open-air museum, located in southern Sweden. Here the posters were nicely fitted in the museum's botanical garden, specializing in rare and threatened plant taxa, including crop wild relatives. To complement the exhibition, poles with pennants were placed here and there in the garden to exemplify CWRs (Figure 1c). At the end of August, the road trip continued up to Gothenburg and the city's botanical garden. Founded in 1923, the garden welcomes 600 000 visitors annually. Here the exhibition will remain during the autumn months, and possibly even during the winter.
For 2022, three new sites have been identified in Sweden: Tyresta National Park south of Stockholm, Jamtli open-air museum close to Östersund, and Naturum at High Coast World Heritage Site. Although the two latter ones are situated in tougher climatic zones with severe winters, this part of the country harbours important CWRs, notably of forage grasses and legumes.

The Green Museum (Grønne Museum), located close to Randers in Denmark, has displayed the Danish exhibition during 2021 (Figure 1d). The exhibition is an ornament to the historical garden, has been a success with the visitors and the CWR information folder has been handed out to many visitors. The museum would therefore like to incorporate it as a permanent part of their exhibition.

The Icelandic version of the exhibition was opened in the end of August in Reykjavík Botanic Garden and will be open until winter. The exhibition was placed in the centre of the garden (Figure 1d), close to the collection of Icelandic plants. A press release was made, and on social media a special focus was put on the importance of crop wild relatives and the exhibition. An offer has been made to other Icelandic Botanic Gardens, open air museums


Figure 1. The outdoor travelling exhibition displayed at different locations across the Nordic region. A) Kumpula Botanic Garden, Helsinki, Finland, 2021. Photo Pertti Pehkonen. B) Elonkierto Park, Jokioinen, Finland 2021. Pupils from Urjala primary school viewing the exhibition. Photo Elina Kiviharju. C) redriksdal's open-air museum and botanical garden, Sweden. Poles with pennants were placed in the garden to indicate where local CWR were cultivated in the garden. Photo Lena Ansebo.D) Det Grønne Museum (the green museum), Denmark 2021. Photo Kenneth Sletten Christensen. E) Reykjavík Botanical Garden, Iceland, 2021. Photo Hjörtur Þorbjörnsson.

and national parks to receive the exhibition during the summer 2022 and possibly 2023.

Inventories and seed collection 2021

Within one of the current Nordic CWR projects, funding has been received for inventories on CWR in protected areas and for collection of seeds of prioritised CWR taxa. This work was initiated during the summer of 2021 and will continue during 2022 and 2023. At the end of this period inventories and seed collections will have been made in Denmark, Finland, Iceland, Norway, Sweden, and Åland.

Finland

Seed collection planning in Mainland Finland started with selecting target species from the Nordic CWR priority collection list based on the possibility to find required quantity of seeds from long-established populations in Finland. Collecting permissions were applied for the conservation areas. Collecting trips during the summer were focused mainly in southern coastal areas, such as Hanko Peninsula (Figure 2), Vuosaari, and Nuuksio National Park which is one of the Finnish CWR hotspot sites. The drought this summer affected seed maturation in some populations. So far, seeds of the following species have been collected: *Crambe maritima*, *Leymus arenarius, Mentha arvensis, Schedonorus arundinaceus, Trifolium arvense, and Trifolium medium*. Collection in Oulanka National Park and other areas will continue during autumn 2021 and the following year. Additionally, leaf samples of *Corylus avellana* and *Vaccinium vitis-idaea* have been collected for genetic studies.

Figure 2. Seed collection in Finland focused on southern coastal areas in 2021. In the picture several individuals of the green-blue seakale, *Crambe maritima*, can be seen growing on the sandy beach in Tullinie-mi, Hanko Peninsula. Photo by Virva Lyytikäinen.

Iceland

In Iceland, inventory activities were focused on Vatnajökull National Park, which is Europe's second largest national park covering 141.41 km^2. The site was chosen based on the previously published ranking of Nordic protected areas (Fitzgerald *et al.*, 2019) where Vatnajökull National Park ranked as the most CWR rich protected area in Iceland. A research permit was obtained from the national park, and export permits for seeds and leaf samples were obtained from the Icelandic Institute of Natural History. Activities were focused in three areas of the national park: Skaftafell in the south, and Jökulsárgljúfur and Ásbyrgi in the north. Along with the inventories, leaf samples for genetic diversity studies were collected from *Carum carvi, Vaccinium vitis-idaea, Fragaria vesca, Vaccinium myrtillus,* and *Vaccinium uliginosum* (Figure 3). Seed collection will continue in the autumn of 2021 in Vatnajökull National Park, as well as throughout the country. Up to date, accessions of *Poa alpina, Carum carvi,* and *Phleum alpinum* have been collected.

Figure 3. Hjörtur Thorbjörnsson sampling tissue of *Carum carvi* for genetic studies in Skaftafell in the southern part of Vatnajökull National Park, Iceland. Photo Magnus Göransson.

Norway

The Norwegian inventory work for CWR is carried out in Færder National Park, an archipelago approximately in the middle of the Oslo Fjord. In the management plan for the national park, it is mentioned that, in addition to all its other qualities, the management aims to preserve the CWR *in situ*. Oddvar Pedersen, Natural History Museum in Oslo, has botanized in the archipelago for several years and is now carrying out the inventory on selected islands. Seed collection of CWR plant species were mainly done at Færder National Park (Figure 4), Vestfold, and in an area of national cultural landscape of cultural heritage in Nordmarka, Oslo.

Figure 4. Inventory and seed collection of sand cat's-tail (*Phleum arenarium*) in Færder National Park, islands south of Oslo. Within the Nordic project, Kristina Bjureke (on the left) is responsible for the seed collection and Oddvar Pedersen (on the right) for the CWR inventory in Norway. Both work at the Natural History Museum, University of Oslo. Photo by Vigdis Røren.

Sweden

In Sweden three main areas were selected for conducting as inventory, one in southern Sweden, one in central Sweden and one area further north. This selection was made to include as many as possible of the prioritized CWR species. In 2021, focus has been on the southern area, Kristianstad Vattenrike, which is a UNESCO Biosphere Reserve and has been identified as a hotspot for CWR diversity in Sweden (Weibull and Phillips 2020). It covers an area of about 35 x 35 km^2 and includes a wide range of habitats and 30 nature reserves, five of which was selected for inventory in 2021. Part of the work carried out in 2021 was to test methods and protocols. One important lesson from the inventory was the possibility to set up plans for each reserve on how it best could serve the long-term conservation of crop wild relatives, including what species should be prioritized in each reserve.

National activities

Færder national park – a pioneer for in situ *conservation of crop wild relatives*

Færder national park (Figure 5) in the Norwegian county of Vestfold and Telemark is about to become the first genetic reserve for crop wild relatives (CWR) in Norway. Since the establishment of the national park in 2013, there has been close collaboration between the management of the park and the Norwegian Genetic Resource Centre, with the aim to include CWR as part of the overall conservation efforts. In the park's management plan, the rich genetic diversity that exists in the area is mentioned, with particular reference to the 110 CWR species that have been identified. This was the first management plan in any of the Nordic countries where conservation of CWR diversity was mentioned.

Recent Nordic and national developments in 2020 and 2021 have accelerated the process of ensuring appropriate *in situ* conservation of CWR. With ongoing field inventories as part of the Nordic project and direct collaboration with the national park management, we are now laying the ground for concrete measures related to conservation of CWR in Færder national park. As proposed in attachment 12 to Færder national park management plan, the suggestion is to focus on 51 CWR species and 7 of the islands.

An agreement of cooperation for CWR conservation is currently being drafted by the Norwegian Genetic Resources Centre and the environmental authorities responsible for the national park. With this step, Færder national park is on the way of becoming a pioneer for CWR conservation in the Nordic region.

Figure 5. Færder National Park was established in 2013 to protect the landscape, habitats, species, geology and coastal ecosystems in a large section of outer Oslofjord. The park has some of the greatest biodiversity in Norway, covering mainland, islands, skerries and seabed in the municipality of Færder, and is a hot spot for CWR diversity. Kristina Bjureke, Natural History Museum (left), Kjersti Bakkebø Fjellstad, Norwegian Genetic Resource Centre/NIBIO (middle) and Anne Sjømæling from Færder National Park discussing conservation at the island of Østre Bolærne. Photo by Linn Borgen Nilsen/NIBIO.

Finland

In Finland, a final report of the national three-year project for CWR conservation strategy development was published (Fitzgerald *et al.,* 2020, in Finnish). It included a prioritized CWR -species list and presented ways and options for organizing the conservation of CWR species in Finland *in situ* and *ex situ*. In addition, the report estimated resulting costs. The report forms the base knowledge for implementation of CWR conservation in Finland. To increase media visibility, Luke News was published in Finnish and in Swedish.

Future plans

As part of the Nordic project initiative "Nature-based solutions", 8 million DKK has been set aside by the Nordic Council of Ministers for work on CWR during the period 2021 - 2024. The aim is to improve the conservation and facilitate use of CWR, as well as strengthening cooperation in the Nordic countries. The work on CWR inventories and seed collection described above is part of this project. The inventories will result in reports from each of the locations describing the status of CWR populations in the protected areas and suggestions regarding future conservation actions. The collected seeds will be donated to NordGen where they will be processed, conserved under long-term conditions, and made available for ordering by for example researchers, plant breeders and museums.

Communication will continue to be an important part of the work and not only will the outdoor exhibitions continue to be displayed in the Nordic countries, but short films will be prepared on the topic of CWR, plant portraits will continue to be written for the common Nordic CWR webpage, and communicated on social media. Stakeholder workshops will be arranged with the aim to facilitate knowledge exchange and networking and support national work on for example management plans and the policy and legal aspects of *in situ* conservation of CWR.

Studies on within-species genetic diversity will be conducted in at least four CWR species. During 2021 sampling of leaf and/or seed material was initiated for four focal species: *Vaccinium vitis-idaea, Carum carvi, Corylus avellana*, and *Poa trivialis*. The aim is to genotype 30 individuals in at least 2-3 populations of each species in each of the Nordic countries and in this way develop a large-scale overview of the diversity of these species on the Nordic level as well as within-population diversity. A postdoc will be recruited for this part of the project, and we also hope to attract undergraduate students with an interest in conservation. Should funding permit, additional species will also be studied.

Climate change modelling will be conducted for those species on the CWR priority list that have adequate data. The aim is to model potential future distributions of these species with different future climate scenarios. The results will feed into recommendations regarding CWR *in situ* and *ex situ* conservation in the Nordic region.

The Nordic CWR priority list will be updated during the project. So far, a preliminary list for the use in project tasks has been agreed on. It includes all the taxa in the original priority list (Fitzgerald *et. al*., 2018) and several new taxa for both food and forage categories.

Acknowledgements

The work has been carried out with financial support from the Nordic Council of Ministers and the Nordic Joint Committee for Agricultural and Food Research.

References

De ville slektningene sikrer matforsyningen. (2020, April 19) Gartneryrket. https://gartneryrket.no/tema/blomster/de-ville-slektningene-sikrer-matforsyningen/

Fitzgerald, H., Aronsson, M., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Palmé, A., Rasmussen, M., Weibull, J., and Þorbjörnsson H. (2017). Nordic crop wild relative checklist dataset. Version 1.10. Nordic Genetic Resource Center, NordGen. Available at: https://doi.org/10.15468/itkype

Fitzgerald, H., Eisto, K. and Kiviharju, E. 2020. Viljelykasvien luonnonvaraisten sukulaislajien suojelu Suomessa. Luonnonvara- ja biotalouden tutkimus 38/2020. LUKE. Helsinki. 82 s. Available at: http://urn.fi/URN:ISBN:978-952-326-981-1

Fitzgerald, H., Palmé, A., Asdal, Å., Endresen, D., Kiviharju, E., Lund, B., Rasmussen, M., Thorbjörnsson, H., and Weibull, J. (2019) A regional approach to Nordic crop wild relative *in situ* conservation planning. *Plant Genetic Resources* 17: 1-12. doi:10.1017/S147926211800059X.

Fitzgerald, H., Aronsson, M., Asdal, Å., Endresen, D., Kiviharju, E., Palmé, A., *et al.* (2018): The Nordic priority crop wild relative gene pool and distribution dataset. Figshare. Dataset. https://doi.org/10.6084m9.figshare.5688130.v1

Fitzgerald H, Palmé A, Hagenblad J and Weibull J. (2020) A Nordic network for Crop Wild Relative conservation. *Crop wild relative 12*: 10-13. (http://www.farmerspride.eu/, http://www.cropwildrelatives.org/resources/publications/newsletters/)

Palmé. A., Fitzgerald. H., Weibull. J., Bjureke. K., Eisto. K., Endresen. D., Hagenblad. J., Hyvärinen. M., Kiviharju. E., Lund. B., Rasmussen. M. and Þorbjörnsson, H. (2019) Nordic Crop Wild Relative conservation: A report from two collaborative projects 2015–2019. Copenhagen: Nordisk Ministerråd (TemaNord). https://doi.org/10.6027/TN2019-533

Weibull, J., and Phillips, J., (2020) Swedish Crop Wild Relatives: towards a national strategy for *in situ* conservation of CWR. *Genetic Resources*. 1. 17-24. 10.46265/genresj.2020.1.17-24.

Crop wild relative network showcases

Clara Álvarez-Muñiz[1],Maria Luisa Rubio Teso[1], Joana Magos Brehm[2], Parthenopi Ralli[3], Anna Palmé[4], Eshan Dulloo[5], Nigel Maxted[6], Valeria Negri[7], Hannah Löwenhardt[8], Lerzan Aykas[9], Shelagh Kell[6], and José M. Iriondo[1]

[1] Departamento de Biología y Geología, Física y Química Inorgánica, Área de Biodiversidad y Conservación, Universidad Rey Juan Carlos, Móstoles, Spain.
[2] National Institute for Agricultural and Veterinary Research, I.P., Braga, Portugal.
[3] Institute of Plant Breeding and Genetic Resources. Hellenic Agricultural Organization-DIMITRA, Thessaloniki, Greece.
[4] Nordic Genetic Resource Centre (NordGen), Alnarp, Sweden.
[5] Bioversity International, Rose-Hill, Mauritius.
[6] School of Biosciences, University of Birmingham, Edgbaston, Birmingham, UK.
[7] Dipartimento di Scienze Agrarie Alimentari e Ambientali (DSA3), Università degli Studi di Perugia, Perugia, Italy.
[8] Eurosite, Tilburg, The Netherlands
[9] Aegean Agricultural Research Institute, Menemen, Izmir, Turkey

The establishment of Crop Wild Relative (CWR) *in situ* conservation practices is still very limited and these experiences are frequently isolated and unconnected to each other. One of the objectives of the Farmer's Pride Project was to gather all available information on current and past examples of *in situ* conservation of CWR to identify good examples of design and implementation of CWR networks operating at different scales from all around the world. This was the reason behind gathering a global collection of *in situ* maintained CWR network experiences that were documented and analysed (Crop Wild Relative Network Showcases –Analysis and Best Practices, Álvarez-Muñiz *et al.*, 2021). Diverse approaches to *in situ* conservation and population management of CWR were examined to determine the peculiar characteristics that mainly contributed to their success, to establish standards and showcase options for best practices.

To standardize the information gathering process, the description of the showcases was organized into four separate sections covering the i) creation, ii) development, iii) objectives, and iv) social components of the network. A broad range of features were gathered and jointly analysed thanks to this systematization of the information. However, in certain cases, it was not possible to find all required and current information or details. For most of the non-European showcases, information was particularly scarce and hard to access.

Different types of networks conserving CWR

Showcases were classified into four categories: i) Genetic Reserves network initiatives ii) Potential Genetic Reserve Networks iii) People and Institution Networks and iv) Networks associated to projects. The information gathering process resulted in 29 CWR genetic reserve network initiatives (areas inside or outside protected areas that conserve the genetic diversity of CWR); nine showcases classified as potential genetic reserve networks (areas where interesting CWR are known to occur as well as initiatives for their conservation); three people and institution networks (networks of scientific groups, administrations or managers that contribute to the conservation of CWR in different

Figure 1. Worldwide location of the collected experiences grouped by the type of network (Álvarez-Muñiz *et al.*, 2021).

ways); and 17 networks associated with projects (networks of sites that hold CWR and/or people and institutions dealing with CWR conservation projects, but conservation activities are linked to the project's life period) (Figure 1).

Genetic reserve networks

The analysis of the key factors affecting genetic reserve networks showed that the typical genetic reserve network was designed following a monographic approach, and that genetic reserves were established at a local conservation scale over the last decade and were placed in an existing protected area managed by a national agency. Overall, these networks protect between one to ten non-threatened CWR species and are usually set up as a series of small reserves on both private and public properties with a total area of less than 200 ha. Genetic reserve networks have typically been established over a 15-year period and have limited financial and personnel resources, which are usually provided by national administrative agencies. However, in most cases, the network was not operated as part of an institutional framework built for CWR conservation.

The genetic reserve conservation initiatives involve different partners, most of which are national governments and research institutions. Furthermore, the typical genetic reserve network is a member of an external supporting network, such as indigenous conservation programs, citizen scientific organizations, and national flora conservation networks. Although numerous conservation actions are conducted within these networks, the implementation of a CWR management plan is often lacking. Aside from conservation, the typical genetic reserves are also used for agriculture and cattle rearing. Local communities are involved and receive public recognition, but they do not receive economic rewards for membership. Genetic reserve networks are usually managed by a multidisciplinary group of agrobiodiversity technicians and conservationists. While no special educational activities connected to CWR are conducted, reserves generally participate in other conservation and environmental programs.

A SWOT analysis (compilation of each networks' Strengths, Weaknesses, Opportunities, and Threats) was carried out (Figure 2). The main strengths are related to the years of prior experience gained, consistent financial support, commitment to long-term conservation, continuous engagement in scientific projects, and participation in other external networks. The weaknesses are frequently linked to a lack of human and financial resources, as well as impediments related to the implementation of CWR management strategies. The identified opportunities involve the location of reserves in CWR biodiversity hotspots, as well as the high social participation. Furthermore, the strong will and motivation of the local community appears as one of the most important factors responsible for the long-term persistence of CWR genetic reserve conservation networks. On the other hand, the greatest threat is the unpredictability of obtaining regular funding, while other significant risks are the possibility of physical damage to the natural populations (*e.g.* wildfires, flooding, human disturbance), land ownership ambiguity, and the fact that the value of CWR conservation is not properly acknowledged.

To address an action plan to respond to the conclusions derived from the SWOT analysis, a CAME analysis (strategic planning tool to 'Correct the weaknesses', 'Adapt to the threats', 'Maintain the strengths' and 'Explore the opportunities') was performed. Specific showcases and particular features discovered were chosen to illustrate exemplary *in situ* management approaches. Some examples of these practices are displayed in Table 1.

Main conclusions

A record of evidence-based best *in situ* management practices has been generated through selected good examples of design and implementation of CWR networks. The knowledge gained as a result of this study provides relevant considerations to take into account in the development and establishment of a European network of CWR genetic reserves and could serve as a model for the CWR stakeholder community in general. A more detailed review of the analysis and associated discussion can be found in the full paper Álvarez-Muñiz *et al.* (2021).

Acknowledgements

The authors gratefully acknowledge the support provided for this research by the EC Horizon 2020 project Farmer's Pride (Networking, Partnerships and Tools to Enhance *in situ* Conservation of European Plant Genetic Resources - Project Number: [774271]). The authors also express gratitude to J. Akopian, Y. Anikster, R. Araya Villalobos, A. Avagyan, N. Bernhardt, M. Bönisch, V. Cecco, A. Contreras Toledo, D. Debouck, A. Esipov, H. Fielder, H. Fitzgerald, J. Hopkins, N. Hovhannisyan, C. Kägi, E. Kiviharju, K. Krommydas, E. Laguna, A. Manzi, L. Martino, A. Molina, M. Â. Pinheiro de Carvalho, M. Santo, A. Shehadeh, A. Singer, I. Thormann and J. Weibull for their valuable contributions to the showcases compiled.

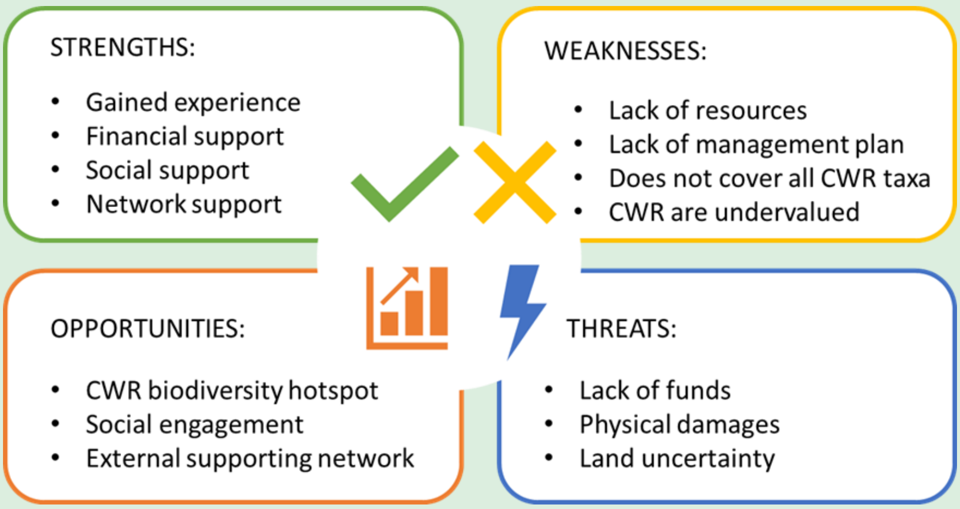

Figure 2. General features that were most frequently found in the SWOT analysis of genetic reserve networks (Álvarez-Muñiz *et al.*, 2021).

Table 1. Design, implementation, and social practices that have been shown to succeed at different CWR genetic reserve networks (Álvarez-Muñiz *et al.*, 2021).

DESIGN PRACTICES	IMPLEMENTATION PRACTICES	LINKING SOCIAL INICIATIVES
• Bottom-up approaches • Involvement of national agencies • Location at public and private lands • Location inside Protected Areas • Structured as numerous small reserves (Laguna *et al.*, 2010) • Existence of a coordination unit (Frese, 2019) • Officially designated by public administration • Based on scientific research (Jarvis *et al.*, 2015; Community of Madrid, 2019)	• Partial self-control of the budget by the managers (Martino, L., Cecco, V., Santo, M. and Manzi, A., pers. comm., 2019) • Involvement of several partners and national governments • Updated site management plan with active CWR management interventions • Area also used for other purposes	• Non-intrusive planning and deep respect for local stakeholders (Al -Atawneh *et al.*, 2007) • Involvement of scientific and agro-biodiversity communities • Budget allocated to stakeholders (Office fédéral de l'agriculture, 2019)

References

Al-Atawneh, N., Amri, A., Assi, R., and Maxted, N., (2007). Management plans for promoting *in situ* conservation of local agrobiodiversity in the West Asia centre of plant diversity. In N. Maxted, B. V. Ford-Lloyd, S. P. Kell, M. E. Dulloo, & J. Turok (Eds.), *Crop wild relative conservation and use* (pp. 340–363). CAB International. Wallingford, UK. https://doi.org/10.1079/9781845930998.0340

Álvarez-Muñiz, C., Magos Brehm, J., Ralli, P., Palmé, A., Dulloo, M.E., Maxted, N., Negri, V., Löwenhardt, H., Aykas, L., Kell, S., Rubio Teso, M.L. and Iriondo, J.M., (2021). *Crop Wild Relative Network Showcases: Analysis and Best Practices. Farmer's Pride: Networking, partnerships and tools to enhance* in situ *conservation of European plant genetic resources*. https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2021/04/D1.5_CWR_network_showcases.pdf

Community of Madrid, (2019). *La Comunidad identifica 173 especies silvestres de cultivo en la Reserva de la Biosfera Sierra del Rincón*. Press Release. https://www.comunidad.madrid/notas-prensa/2019/12/05/comunidad-identifica-173-especies-silvestres-cultivo-reserva-biosfera-sierra-rincon

Frese, L., (2019). *Designation of the first five crop wild relative genetic reserves in Germany and Europe*. www.ecpgr.cgiar.org/fileadmin/templates/ecpgr.org/upload/PHASE_X/WORKING_GROUPS/Wild_species/Designation_genetic_reserves_Germany_final_with_photo_v2.pdf

Jarvis, S., Fielder, H., Hopkins, J., Maxted, N., and Smart, S., (2015). Distribution of crop wild relatives of conservation priority in the UK landscape. *Biological Conservation*, 191, 444–451. https://doi.org/10.1016/j.biocon.2015.07.039

Laguna, E., Ballester, G., Francesc, H., Gandia, D. B. De, and Deltoro, V., (2010). La red valenciana de microrreservas de flora: Síntesis de 20 años de experiencia. In: A. S. P. Giménez, J.A. Marco, E. Matarredona, A. Padilla (Ed.), *Biogeografía. Una Ciencia para la Conservación del Medio* (pp.265-272). Universidad de Alicante, Alicante, Spain.

Office fédéral de l'agriculture (OFAG), (2019). *Plan d'action national pour la conservation et l'utilisation durable des ressources phytogénétiques pour l'alimentation et l'agriculture (PAN-RPGAA), BLW.* https://www.blw.admin.ch/blw/fr/home/nachhaltige-produktion/pflanzliche-produktion/pflanzengenetische-ressourcen/nap-pgrel.html

Figure 3. *Daucus carota* subsp. *gummifera* (sea carrot) on the Lizard Peninsular in Cornwall, UK, the first formally recognized genetic reserve in the UK.

Crop wild relative conservation in the Natura 2000 network

Maria Luisa Rubio Teso[1], Clara Álvarez-Muñiz[1], Hannes Gaisberger[2,3], Shelagh Kell[4], Carlos Lara-Romero[1], Joana Magos Brehm[5], Nigel Maxted[4], and José M. Iriondo[1]

[1] Rey Juan Carlos University. Biodiversity and Conservation Area. C/ Tulipán s/n. 28933 Móstoles (Madrid) Spain.
[2] Bioversity International, Via di San Domenico 1, 00153 Rome, Italy
[3] Department of Geoinformatics, Paris Lodron University of Salzburg, Hellbrunner Str. 34, 5020 Salzburg, Austria.
[4] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.
[5] Instituto Nacional de Investigação Agrária e Veterinária, I.P., Portugal

The context

In the pathway for the safe-guarding of global food security and the sustainable use of plant genetic resources, crop wild relatives (CWR) are a valuable source of genetic diversity for pre-breeding and breeding programs (Hajjar and Hodgkin, 2007; Brozynska *et al.*, 2016; Prohens *et al.*, 2017; Zhang and Batley, 2020). Under the climate change context their value as gene donors for adaptive traits is undeniable (Warschefsky *et al.*, 2014). Despite their obvious value, there are presently few examples of *in situ* conservation of CWR in Europe and there are significant gaps in their *ex situ* conservation.

One of the objectives of the EU funded Farmer's Pride project was to approach CWR conservation planning in a complementary way, considering a combination of *in situ* and *ex situ* techniques. Such an approach at the regional level was needed to enhance their use and facilitate accessibility to final users.

Following the endorsement of the European Cooperative Programme for Plant Genetic Resources (ECPGR) for the concept for *in situ* conservation of CWR (Maxted *et al.*, 2015), the establishment of a CWR conservation network should rely on the identification of the Most Appropriate Wild Populations (MAWP), selected at the national and regional level. These MAWPs should ideally be integrated with other biodiversity conservation initiatives in Europe and additionally, should be followed by the establishment of a policy context for CWR diversity conservation in Europe.

Within this framework, one of the tasks of the Farmer's Pride project aimed at assessing the potential of the Natura 2000 network as an infrastructure to host CWR genetic reserves for active *in situ* conservation.

The analyses

Distribution data of the European crop wild relative priority list

The first step was the generation of a European CWR Priority Inventory that would be used as the reference basis for the analyses. The implementation of selection criteria based on the socio-economic relevance of the related crops, the crossability of the wild species with the crops and the threat status of the wild relatives provided a list of 863 taxa (485 species and 378 sub-specific taxa) (Kell in prep.) (see Rubio Teso *et al.*, 2020b for further details).

The second step involved the acquisition of distribution data of the targeted taxa. For this purpose, a data search was conducted in the Global Biodiversity Information Facility (GBIF – www.gbif.org) and Genesys (www.genesys-pgr.org/) databases. To obtain trustable information about CWR occurrence in Europe, raw distribution data underwent a cleaning and filtering process using a script developed in the R environment (R Core Team, 2020). Filters applied included the exclusion of cultivated records, non-accurate entries, elimination of invasive species and unreliable occurrences (see Rubio Teso *et al.*, 2020a, b; Rubio Teso *et al.*, 2021, for further details on the filtering process). The downloaded information was then filtered for the European countries that participate in the Natura 2000 network. The process resulted in a database of CWR with 2,933,820 occurrences that represented 652 priority taxa (75.5% of the total priority taxa).

Natura 2000 and gap analysis

The geographic information system (GIS) layers of the protected areas of the Natura 2000 network (N2000) were downloaded from the European Environment Agency website (https://www.eea.europa.eu/data-and-maps/data/natura-11/natura-2000-spatial-data/natura-2000-shapefile-1), with the updated N2000 GIS layers version at the moment of the study (Natura 2000, 2019 version) which included more than 27,000 protected areas.

The assessment of the coverage of CWR by N2000 was performed through a gap analysis between N2000 layer and the CWR distribution data. Then, CWR taxa richness was calculated per each site in N2000. The top 50 hotspots areas (areas with higher richness of CWR taxa) were identified and results were visualized and mapped in ArcGIS v.10.5 (ESRI, 2016).

The gap analysis revealed that around one third of the N2000 sites (8673 sites) have at least one priority CWR and that 409,642 populations belonging to 593 CWR taxa occur in these sites (Figure 1). This represents 68% of the CWR priority taxa (863 taxa) or close to 91% if we consider only the taxa for which there were available data (652 taxa).

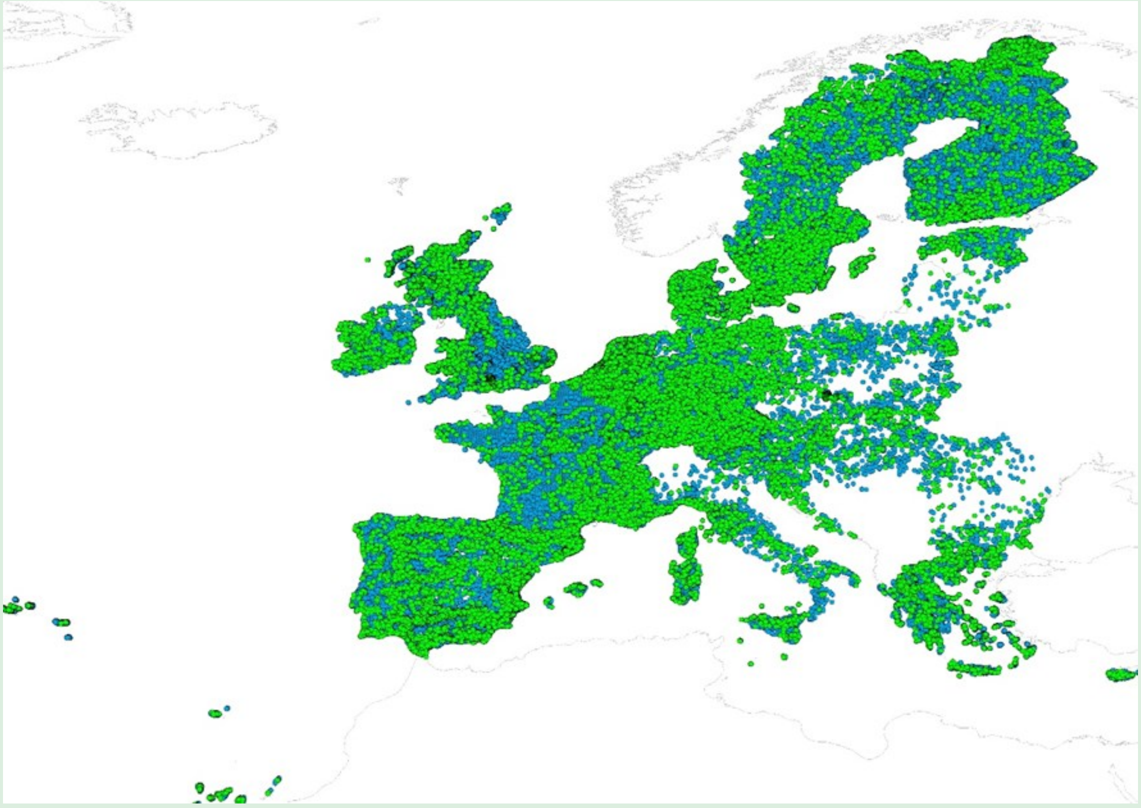

Figure 1. Crop wild relative (CWR) population locations in the European Union and the United Kingdom. Green dots are CWR populations found within the limits of the Natura 2000 network. Blue dots are CWR populations outside the Natura 2000 network (Rubio Teso *et al*., 2021).

The estimation of CWR ***richness*** per N2000 site showed that the mean number of CWR taxa is 15, ranging from one to 118 (Figure 2).

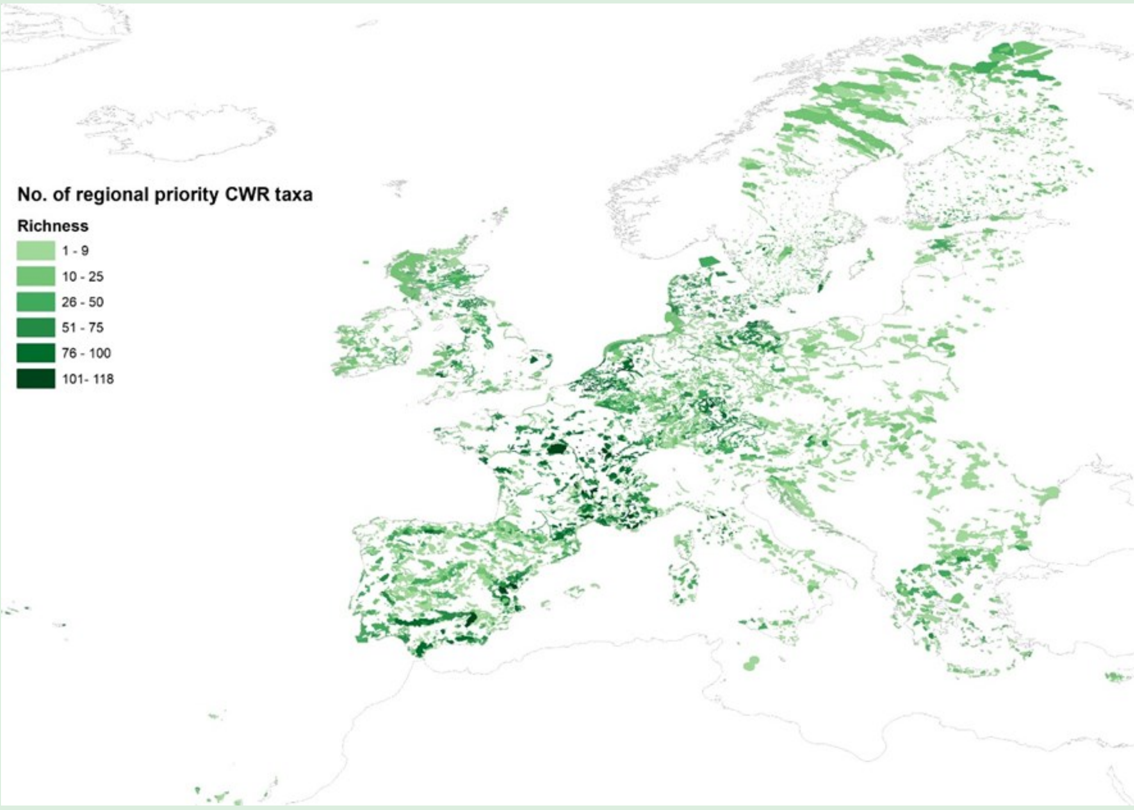

Figure 2. Crop wild relative taxon richness in the Natura 2000 network (Rubio Teso *et al*., 2021).

The top 50 hotspots in the N2000 network, in terms of CWR richness is shown in Figure 3 and are found in France (22 sites), Germany (9 sites), Spain (8 sites) Belgium (5 sites), Italy (3 sites) and The Netherlands (3 sites) (Figure 3).

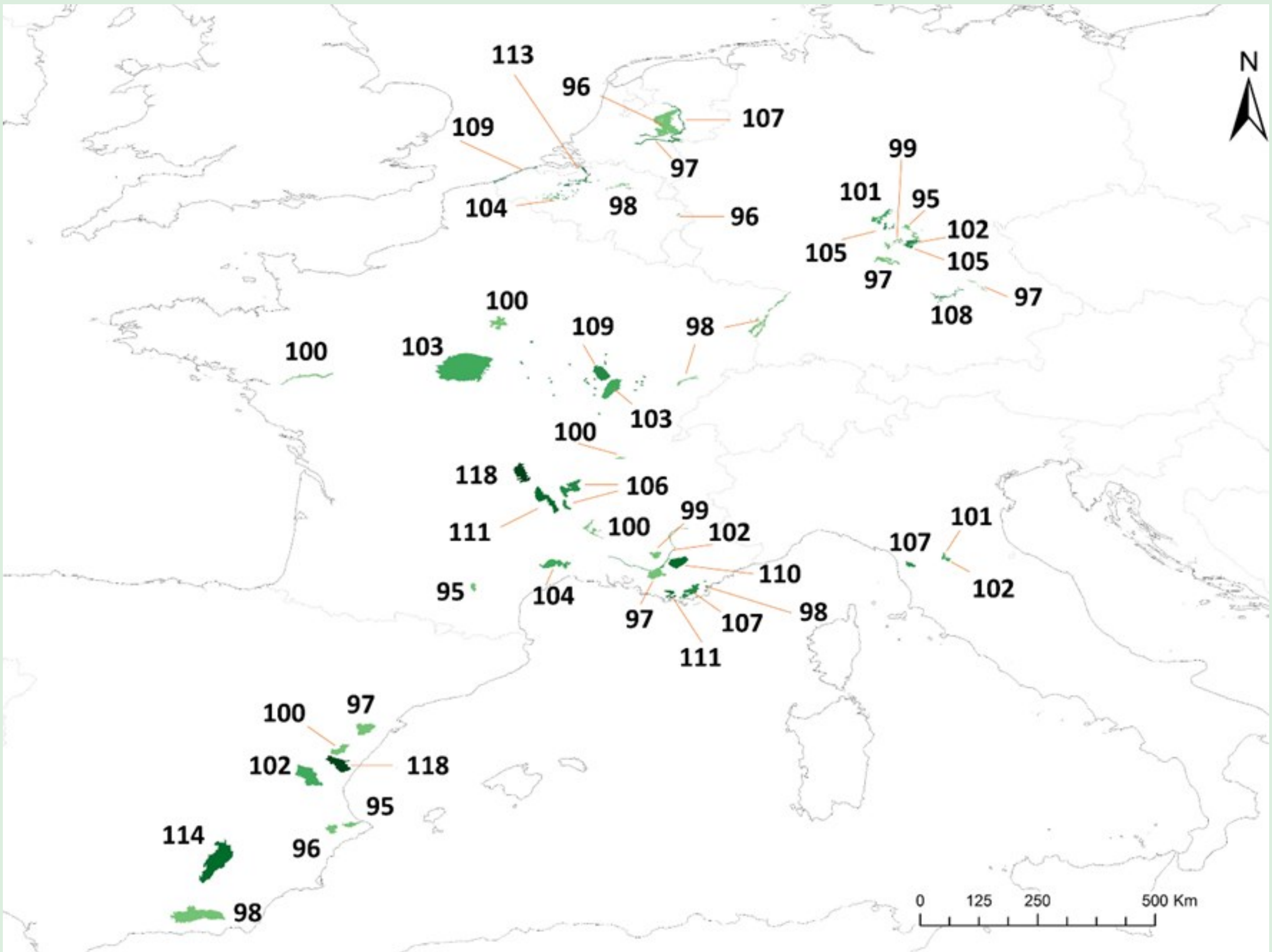

Figure 3. Top 50 hotspots Natura 2000 areas for priority crop wild relatives. Number of CWR taxa indicated (Rubio Teso *et al*., 2021).

Discussion

The search for distribution data of priority CWR in the consulted databases returned an elevated number of records. However, most of the records lacked the needed distributional accuracy to be included in the analyses (Rubio Teso *et al*., 2020b) and therefore, only a small part of them were analyzed. Additionally, distribution data were spatially biased, with some countries having a lower representation than expected, based on their known floristic diversity. This may be explained by the different participation of European countries in contributing data to the global databases used in this study. The bias can be further explained by additional differences between countries in the gathering of chorological information and digitalization of botanical inventories. Admitting that not all CWR populations are recorded and that not all recorded populations are transferred to global databases, then CWR diversity in these countries particularly should be further explored by other means (contacting botanical gardens, research institutions, groups and experts dealing with plant diversity, searching other national datasets, etc.). Despite these limitations, this is the largest and most accurate CWR distribution database generated for Europe to date.

The N2000 network is the largest coordinated network of protected areas in the world, covering around 18% of the land territory in the European Union (with the UK) (https://ec.europa.eu/environment/nature/natura2000/faq_en.htm) and was built upon the commitment of the European Union to preserve the European natural heritage across its territory. Its focus is especially on rare and threatened species and habitats designated under the Habitat Directive (European Commission and DG Environment, 2013). The N2000 network does not only include natural areas but also farming areas (European Commission, 2018), managed by both public and private stakeholders. This combination of natural and managed environments provides an excellent range of habitats for CWR conservation, considering that these wild species are not only linked to natural areas but also to agroecosystems. The high coverage of priority CWR (91% of species with available data represented) and the high richness found in some sites (over 10% of priority taxa found in each of the top 50 hotspot sites) show that N2000 network is already playing an important role in the passive conservation of CWR and renders the network an excellent infrastructure for the establishment of CWR genetic reserves for active *in situ* conservation. A final point to consider is that the results presented here are conservative and that the real number of priority CWR covered by the network is likely to be considerably higher if we were able to have a better representation of CWR distributional data. Complete information about the results of these analyses as well as more comprehensive analyses performed for all European countries plus Turkey taking into account the complete network of protected areas of these countries is available in Rubio Teso *et al*. (2020a, 2021).

Conclusion

Despite the detected bias in the available distribution data and its potential impact on the results, this study provides a first proposal of the sites where genetic reserves for CWR conservation could be established at the European level. This work also highlights the value of the existing N2000 network as a suitable network of sites to structure and support the establishment of a network of CWR genetic reserves in Europe.

Acknowledgments

This work was carried out in the Farmer's Pride project (Networking, Partnerships and Tools to Enhance *In Situ* Conservation of European Plant Genetic Resources) (2017-2021), funded by the EC Horizon 2020 programme of the European Union, grant agreement: 774271.

References

Brozynska, M., Furtado, A., and Henry, R. J. (2016). Genomics of crop wild relatives: Expanding the gene pool for crop improvement. *Plant Biotechnology Journal,* 14: 1070–1085.

ESRI (2016). *ArcGIS Desktop v.10.5.* Environmental Systems Research Institute, Redlands, CA.

European Commission (2018). Farming for Natura 2000. *Guidance on how to support Natura 2000 farming systems to achieve conservation objectives, based on Member States good practice experiences.* 145 pp. European Commission, Brussels, Belgium.

European Commission, and DG Environment (2013). Interpretation Manual of European Union Habitats. European Commission, Brussels, Belgium.

Hajjar, R. and Hodgkin, T. (2007). The use of wild relatives in crop improvement: A survey of developments over the last 20 years. *Euphytica* 156: 1–13.

Maxted, N., Avagyan, A., Frese, L., Iriondo, J. Magos Brehm, J. Singer, A. and Kell, S. (2015). ECPGR Concept for *in situ* conservation of crop wild relatives in Europe. Wild Species Conservation in Genetic Reserves Working Group. European Cooperative Programme for Plant Genetic Resources. Rome, Italy.

Prohens, J., Gramazio, P., Plazas, M., Dempewolf, H., Kilian, B., Díez, M. J., Fita, A., Herráiz, F. J., Rodríguez-Burruezo, A., Soler, S., Knapp, S. and Vilanova, S. (2017). Introgressiomics: a new approach for using crop wild relatives in breeding for adaptation to climate change. *Euphytica,* 213, 158. https://doi.org/10.1007/s10681-017-1938-9

R Core Team. 2020. R: A language and environment for statistical computing.

Rubio Teso, M. L., Álvarez-Muñiz, C., Gaisberger, H., Kell, S., Lara-Romero, C., Magos Brehm, J., Maxted, N. and Iriondo, J. M. (2020a). Crop wild relatives in the Natura 2000 network. *Deliverable report of the Farmer's Pride Project: MS19. Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources. Project funded by the Horizon 2020 Framework Programme of the European Union (GA 774271)*. Available at: https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/10/MS19_Crop_Wild_Relatives_in_the_Natura_2000_Network.pdf

Rubio Teso, M. L., Álvarez-Muñiz, C., Gaisberger, H., Kell, S., Lara-Romero, C., Magos Brehm, J., Maxted, N. and Iriondo J. M. (2020b). *In situ* plant genetic resources in Europe: crop wild relatives. *Deliverable of the Farmer's Pride Project: D1.2, 'Knowledge of in situ resources/sites'. Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources. Project funded by the Horizon 2020 Framework Programme of the European Union (GA 774271)*. Available at: https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/10/D1.2_In_situ_PGR_in_Europe_crop_wild_relatives.pdf

Rubio Teso, M. L., Álvarez-Muñiz, C., Gaisberger, H., Kell, S., Lara-Romero, C., Magos-Brehm, J., Maxted, N. and Iriondo J. M. (2021). European crop wild relative diversity: towards the development of a complementary conservation strategy. *Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources. Project funded by the Horizon 2020 Framework Programme of the European Union (GA 774271).*

Warschefsky, E., Penmetsa, R. V., Cook, D. R., and von Wettberg, E. J. B. (2014). Back to the wilds: tapping evolutionary adaptations for resilient crops through systematic hybridization with crop wild relatives. *American Journal of Botany,* 101: 1791–1800.

Zhang, F. and Batley, J. (2020). Exploring the application of wild species for crop improvement in a changing climate. *Current Opinion in Plant Biology,* 56: 218–222.

Crop wild relative population management guidelines

Ada Molina[1], Clara Álvarez-Muñiz[1], José M. Iriondo[1], Joana Magos Brehm[2], Ehsan Dulloo[3] and Nigel Maxted[4]

[1] Departamento de Biología y Geología, Física y Química Inorgánica, Área de Biodiversidad y Conservación, Universidad Rey Juan Carlos, Móstoles, Madrid, Spain.
[2] National Institute for Agricultural and Veterinary Research, I.P., Braga, Portugal.
[3] Bioversity International, Mauritius.
[4] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.

One of the key objectives of the Farmer's Pride project was to enhance population management and best practices for CWR *in situ* conservation. In pursuing this objective, the CWR Population Management Guidelines were developed by 20 researchers from different institutions across Europe to provide genetic reserve managers (site managers, onwards) with a clear understanding of how CWR species should be most effectively managed, documented, secured, and made available to diverse users. That is, "how to do" CWR *in situ* population management. Furthermore, the Guidelines are meant to provide guidance on how to manage CWR target populations in a dynamic and participatory way by promoting close collaboration and effective communication amongst the whole stakeholder community involved in their conservation and utilization.

A tour through the Guidelines

The Guidelines aim to give all the necessary knowledge and resources for protected area managers, farmers, policy makers, and anyone else who is responsible for conserving CWR to effectively manage CWR populations *in situ*, adapt to climate change, and make these valuable resources available to research and breeding communities.

The first chapter briefly outlines the purpose, objectives, and scope of the Guidelines, followed by some background information on the intrinsic value of CWR as plant genetic resources and the importance of conserving them *in situ*. It also emphasises the fact that in order to succeed CWR conservation and management requires an interdisciplinary cooperation based on trust. The entire stakeholder community, from the actual site managers to local people, small entrepreneurs, organizations, policy and decision makers, scientists, researchers, and breeders should all participate and get actively involved in the different stages of both the conservation and management processes (Figure 1) .

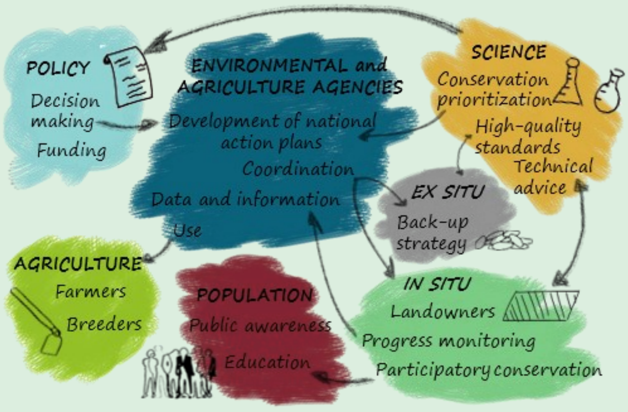

Figure 1. Potential stakeholders that interact in CWR conservation

Chapter 2 works as a know-how guide to design and implement a management plan for a genetic reserve. Site managers are presented here with the main elements that the management plan should include, which range from describing the site and target taxon/taxa, characterising the habitat, and assessing threats, to the actual management of targets, interventions, resources needed and monitoring plan. The chapter gives an insight into the key management goals to achieve and what to consider when deciding on the interventions needed for mitigating threats to the target populations. Moreover, it provides specific tips when designing a work plan to efficiently coordinate the implementation process. Last but not least, other complementary aspects of great relevance to the management of a genetic reserve are also highlighted and discussed. These refer to the importance of getting institutional support, developing a communication strategy, managing information, implementing national, regional, and international policies, and ensuring and regulating access and use of CWR by following existing regulated procedures.

Most CWR are passively conserved inside protected areas and where active conservation happens it is often because taxa are considered charismatic or threatened (Maxted *et al*., 1997). Furthermore, even when CWR are actively conserved management practices fail to maximize genetic diversity conservation. Chapter 3 sets the context for active CWR conservation to succeed within protected areas, identifying key management aspects and stressing the need for including genetic reserve management plans into the general management framework of the protected areas. On the other hand, since many CWR are often found growing in anthropogenic, disturbed habitats, such as weedy roadsides, field margins, orchards, and even fields managed using traditional agro-silvicultural practices (Jarvis *et al.,* 2015), *in situ* conservation sites may need to be established outside protected areas. Chapter 4 deals with CWR management on farmlands or any other type of private land, highlighting community support and incentives as essential factors to consider for sustaining CWR conservation. In both cases, inside or outside protected areas, team responsibilities, budget, and economic considerations as well as specific risks and problems are also discussed.

On a different matter, it is acknowledged that CWR diversity is under threat from climate change (Phillips *et al*., 2017), therefore it is essential to consider it in conservation planning and ensure that management is climate-smart (Maxted *et al*., 2013; Stein and Moser 2014). Chapter 5 sets the framework to tackle the climate change challenge based on an adaptive management approach. It also provides site managers with some management techniques to mitigate the climate change effects, such as conservation translocation, habitat management or enhancement of evolutionary resilience.

Since the current *ex situ* sample of diversity alone is unable to supply breeders with the breath of CWR diversity they require (Maxted *et al.* 2017), chapter 6 goes into detail on how to link *in situ* conservation to utilization through *ex situ* conservation and how to promote use. Maxted and Palmé's (2015) potential model for how *in situ* and *ex situ* conservation might be effectively linked, which was later enhanced by further discussion with stakeholders, is presented here to help site managers decide on the most appropriate approach for them. This chapter also describes the challenges associated with CWR *ex situ* conservation, in terms of both seed processing (i.e., drying protocols, dormancy) and access to information that can limit their use.

Finally, chapter 7 provides a simplified view of this undertaking by listing the minimum quality standards for design, implementation and management of genetic reserves and some concluding remarks. The Guidelines also include a set of resources, such as sample sheets for data collection in the field and a further section with a list of references for the user to find more information on the different topics.

Web Tool for CWR population management

Based on these Guidelines we have developed a user-friendly web tool (Figure 2) where users can easily access all this information online. From the basic elements of CWR population management to the more complex matters presented, the web tool allows the user to easily choose how far they need or want to learn to achieve their target.

References

Jarvis, S., Fielder, H., Hopkins, J., Maxted, N., and Smart, S. (2015). Distribution of crop wild relatives of conservation priority in the UK landscape. *Biological Conservation*, 191, 444–451.

Maxted, N, Hawkes, J., Ford-Lloyd, B.V, and Williams, J.T. (1997). A practical model for *in situ* genetic conservation. In N. Maxted, B. Ford-Lloyd, and J. Hawkes (Eds.), *Plant Genetic Conservation: The In Situ Approach* pp. 339–367. Chapman & Hall, London.

Maxted, N., Kell, S., Magos Brehm, J., and Kell, S. (2013). Crop Wild Relatives and Climate Change. In Jackson, M., Ford-Lloyd, B. and Parry, M. (Eds.). *Plant Genetic Resources and Climate Change,* pp. 114-134. CAB International. Wallingford.

Maxted, N. and Palmé, A., (2016) Combining *ex situ* and *in situ* conservation strategies for CWR to mitigate climate change. In: The impact of climate change on the conservation and utilization of crop wild relatives in Europe (Eds. Valdani Vicari & Associati *et al.*), Barcelona, Spain, 15th December 2015. Preparatory action on EU plant and animal genetic resources (AGRI-2013-EVAL-7) Workshop Report, Directorate General for Agriculture and Rural Development, European Commission, Brussels, Belgium.

Maxted, N, Labokas, J., and Palmé, A. (2017). Crop wild relative conservation strategies. Planning and implementing national and regional conservation strategies. *Proceedings of a Joint Nordic/ECPGR Workshop.*

Phillips, J., Magos Brehm, J., van Oort, B., Asdal, Å., Rasmussen, M., and Maxted, N. (2017). Climate change and national crop wild relative conservation planning. *Ambio*, 46(6), 630–643.

Stein, A., and Moser, C. (2014). Asset planning for climate change adaptation: Lessons from Cartagena, Colombia. *Environment and Urbanization*, 26(1), 166–183.

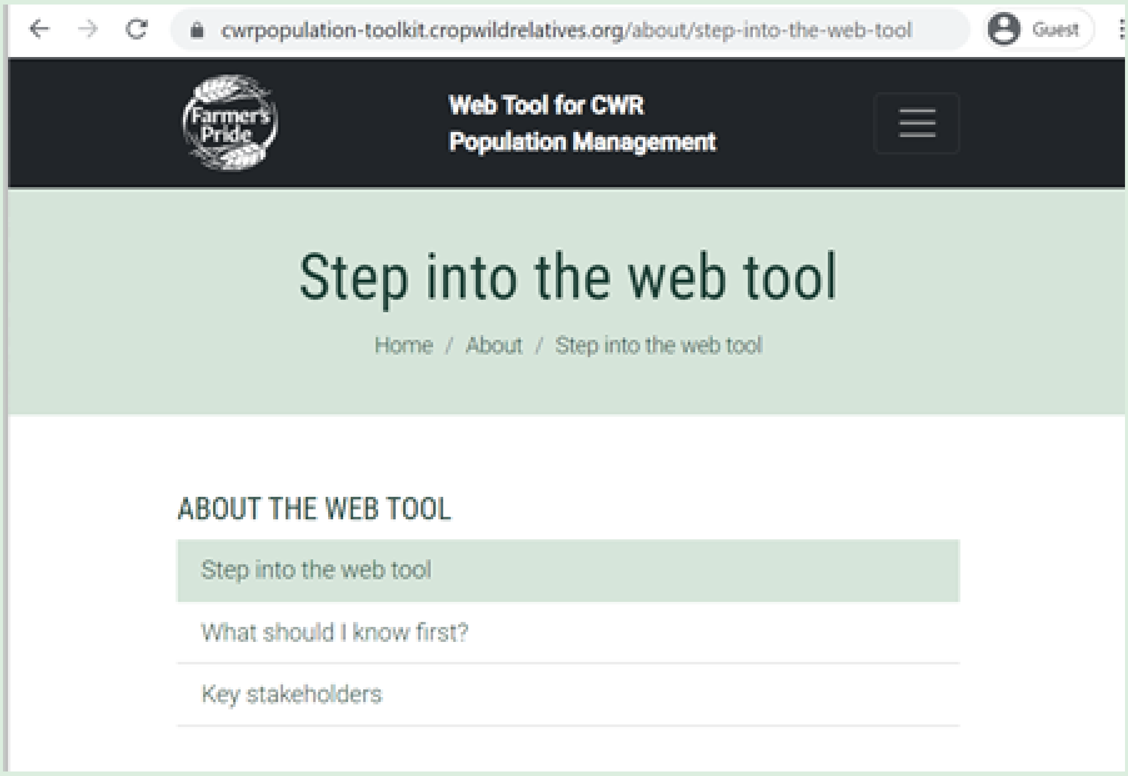

Figure 2. Web tool for CWR Population Management.

In situ plant genetic resources conservation information management tools

Nigel Maxted[1] and Shelagh Kell[1]

[1] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK. Email: n.maxted@bham.ac.uk

To support and promote *in situ* conservation and sustainable use of plant genetic resources (PGR), the Farmer's Pride project collaborators have developed and published several tools and standards for the management of data associated with *in situ* PGR conservation and sustainable use. These practical tools and associated standards are freely available to all stakeholders, including farmers, protected area managers, plant breeders, and researchers. The tools and standards are summarized here with links to the resources.

The *In situ* PGR conservation information management tools are:

1. CAPFITOGEN tools for crop wild relative and landrace conservation planning

CAPFITOGEN3 is the new iteration of the CAPFITOGEN toolbox, developed to provide support to the global PGR conservation and sustainable use community by providing software tools designed to perform spatial and ecogeographic diversity analyses to facilitate more efficient and effective PGR conservation and sustainable use planning. The new version is composed of 15 tools usable either directly on a server via an online portal, or downloadable and used in local mode on a computer hard drive. In addition to deploying the CAPFITOGEN tools on a server, a new tool for undertaking predictive characterization has been developed, and several other tools in the suite were completed, tested and optimized for use on the server. CAPFITOGEN3 is currently available on the server until June 30 2022, and in the meantime, opportunities for a permanent host for the server application are being explored.
See: www.capfitogen.net/

2. Concept for an extension of EURISCO for in situ *crop wild relative and on-farm landrace data*

The European Search Catalogue for Plant Genetic Resources (EURISCO) is currently limited to germplasm accessions maintained *ex situ*—primarily in genebanks. However, to allow access to a greater breadth of genetic diversity and meet users' requirements, it is critical that germplasm is equally accessible whether it is held *ex situ* in a genebank or *in situ*—either on-farm or in nature. This document constitutes a first proposal for an extension of the EURISCO descriptors to allow *in situ* crop wild relative (CWR) and on-farm landrace data to be included in EURISCO in the future. The decision as to when this extension will be practically implemented lies with the EURISCO Advisory Committee.
See: farmerspride/wp-content/uploads/sites/19/2020/10 D2.5_EURISCO_in_situ_extension_concept.pdf

3. In situ *crop wild relative population look-up tool*

Based on extensive data collated of *in situ* population occurrences of priority CWR taxa in Europe (In_situ_PGR_in_Europe_crop_wild_relatives.pdf) and subsequent analysis of their occurrence in the Natura 2000 network (Crop_Wild_Relatives_in_the_Natura_2000_Network.pdf), a tool was developed to promote the active *in situ* conservation of CWR within existing protected areas throughout the EU and UK. This searchable database facilitates the identification of which CWR are present in which protected areas, and allows users to search by a species name, a country, a protected area, or habitat type, as well as allowing searches on multiple fields. The tool is available via the website of the European Cooperative Programme for Plant Genetic Resources (ECPGR) to ensure its long-term maintenance and availability, and to facilitate future updates.
See: https://www.ecpgr.cgiar.org/crop-wild-relatives-in-natura-2000

4. Crop wild relative in situ *population management guidelines: online toolkit*

These web-enabled guidelines provide protected area managers, conservation practitioners, farmers and any other professionals or volunteers responsible for the conservation of CWR populations with access to a user-friendly platform giving practical step-by-step guidance for the management of CWR populations and the genetic reserves where they are being conserved (see Iriondo *et al.*, 2021). The guidelines provide a quick and accessible tour to all the elements that one should consider for the design and implementation of a management plan, including habitat characterization, population threat assessment, management interventions, monitoring schemes, management of information and legislative requirements, among other issues.
The guidelines contemplate the different situations in which a CWR genetic reserve can be established and provide specific management tips to consider when reviewing their placement either within or outside protected areas, in farmlands and other types of publicly or private owned property. Furthermore, considerations are also provided concerning the management needs to address climate change. Finally, the essential coordination needs that link *in situ* with *ex situ* CWR conservation activities and connecting with the stakeholders that can be the end users of these plant genetic resources. The toolkit is available in the CWR Global Portal to ensure its long-term maintenance and availability, and to facilitate future updates.
See: cwrpopulation-toolkit.cropwildrelatives.org/

5. Descriptors for crop wild relative diversity management

Awareness of the value of CWR for adapting crops to the environmental impacts of climate change, and knowledge of the diversity that exists in the wild and in genebanks, has increased substantially since the beginning of the 21st century. At the same time, there has been a growing number of national, regional and global strategies and initiatives for the conservation and sustainable use of CWR diversity. This increasing focus on the identification and management of important CWR resources has called for improved management of information associated with their conservation and sustainable use.

In the context of several past collaborative projects—notably those funded by the EU Framework Programmes, the Global Environment Facility and the UK government—descriptors for the management, monitoring and exchange of information related to CWR conservation and sustainable use have been developed and published. However, gaps remain in these descriptor sets (mainly related to monitoring CWR populations *in situ*) and the publication of the various descriptor sets and associated data recording templates are somewhat dispersed.

In the context of the Farmer's Pride project, previously drafted descriptors for CWR population monitoring, as well as for strategies and action plans, have been reviewed and updated, and published in combination with existing descriptor sets and data recording templates for CWR checklists and inventories. Thus, practitioners dealing with all aspects of CWR conservation planning, the development and implementation of national and regional strategies and action plans, including ongoing population monitoring, have access to a one-stop shop for the management and exchange of the associated data at all levels. The descriptors will be made available via the CWR Global Portal to ensure easy access and long-term availability to user community. Draft descriptors have been prepared and are under review (to be published in the CWR Global Portal – cropwildrelatives.org/).

6. Landrace repatriation tool

The landrace repatriation tool allows users (e.g., farmers and gardeners) who would like to cultivate crop landraces with a biocultural connection to the area in which they are growing their crops, to search for these varieties by entering the crop species and their location, and retrieving a list of qualifying varieties, where they are conserved and how to obtain reproductive material from commercial producers or conservation collections. As a proof of concept, a stand-alone Excel-based interactive tool was constructed that allows searches for old Dutch apple varieties based on a location. The landrace repatriation tool extends this proof of concept to a range of crops and countries in Europe. With an increasing range from very local to regional, varieties are listed with a description, information of where to obtain them, and when available, a story elaborating why this variety is connected to the location. The landrace repatriation tool will be available in the ECPGR website to ensure its long-term maintenance and availability, and to facilitate future updates. The prototype is being prepared and web-enabled (to be published on the web page of the ECPGR On-Farm Conservation and Management Working Group – ecpgr.cgiar.org/working-groups/on-farm-conservation).

7. Best practice evidence-based database: a tool for promoting landrace conservation in situ

This tool is for landrace maintainers or those considering the cultivation of landraces to diversify their crop production system. It provides access to evidence-based information on the benefits, opportunities and best practices of landrace cultivation to help in decision-making and to promote their *in situ* maintenance as a means of conserving and diversifying PGR for food, nutrition and livelihood security. It includes 105 examples of *in situ* management practices and of adding value to landraces of a range of different crops and in different socio-cultural, environmental and economic contexts from 14 European countries. This information can help to enhance landrace cultivation and make it sustainable and profitable at the same time, while conserving biodiversity for future generations. The tool is published in the ECPGR website to ensure its long-term maintenance, and to facilitate future updates.
See: ecpgr.cgiar.org/in-situ-landraces-best-practice-evidence-based-database

8. Exemplar National CWR Information Tool for England

This guide prepared by Natural England and the University of Birmingham provides an introduction to the 148 priority English CWR taxa and is meant to promote CWR conservation and awareness raising among a broad range of stakeholders. For each taxon profile the user will find a brief description of the key features of the species. The description is purposefully short and succinct, though some species may require greater descriptive information to permit identification. In the latter case it is best to use more thorough identification guides. The maps are based on current data available through the Botanical Society of the British Isles and it is possible that distributions of species may have changed or that data is incomplete. It is also advised that if the user is struggling to identify a species, the habitat in which the plant is found may help distinguish species. The phenology is also a good identification tool, where the flowering time of a plant can differentiate species, though note that fluctuations in flowering times can be found due to seasonal changes in climate. Therefore, to successfully identify species it is advised that all information provided in the taxon profiles is used. The initial tool is a printed guide but soon will be complemented by a mobile phone app that can add to and used from a smart phone.
See:https://www.ecpgr.cgiar.org/working-groups/wild-species-conservation

References

Iriondo, J., Magos Brehm, J., Dulloo, M.E. and Maxted, N. (eds), (2021). Crop Wild Relative Population Management Guidelines. *Farmer's Pride:* Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources Available at: https://cwrpopulation-toolkit.cropwildrelatives.org/fileadmin/Websites/CWRWebTool/Uploads/Documents/Crop_Wild_Relative_Population_Management_Guidelines.pdf

Getting incentives right? Public willingness to pay for support mechanisms for effective conservation and use of landraces in Europe

Adam G. Drucker[1], Nicholas Tyack[2], Béla Bartha[3], Judit Fehér[4], Konstantinos Krommydas[5], Nigel Maxted[6], Helene Maierhofer[7] and Irene Tzouramani[5]

[1] Alliance Bioversity International – CIAT, Via di San Domenico, 1, 00153 Rome, Italy
[2] The Graduate Institute of International and Development Studies, Chemin Eugène-Rigot 2A, 1202 Geneva, Switzerland
[3] ProSpeciesRara, Unter Brüglingen 6, 4052 Basel, Switzerland
[4] Research Institute of Organic Agriculture (ÖMKi), Miklós tér 1, 1033 Budapest, Hungary
[5] Hellenic Agricultural Organization DIMITRA, Nirvana 68, Athens 111 45, Greece
[6] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.
[7] Arche Noah, Obere Strasse 40, A-3553 Schiltern, Austria

Agrobiodiversity is associated with a range of important but poorly quantified public good ecosystem services, the conservation of which requires public support. Here we report the results of a survey designed to determine the general public's willingness-to-pay (WTP) for wheat landrace conservation in Europe.

Public WTP for wheat landrace conservation

With the objective of determining the general public's WTP for landrace conservation and to inform decision-making regarding the allocation of public funds to crop diversity conservation, 801 adult resident respondents across five[1] EU countries were interviewed in person using a stated preference choice experiment to elicit the value that the general public places on crop genetic resources conservation, using traditional wheat landraces as a case study. The data were analysed using random parameter logit (RPL) models, which permit the robust analysis of preference heterogeneity across individuals and countries.

Four conservation programme attributes plus programme cost were applied: (i) insuring against the risk of agricultural production loss, (ii) the maintenance of landscape and ecological values, (iii) protection of wheat landrace diversity, and (iv) the maintenance of traditional knowledge and cultural practices (including aspects of food culture). A description of the attributes and their levels (selected in consultation with genetic resources and agricultural experts) can be found in Figure 1. The survey was designed so that each of the four different attributes represents a component of the total economic value (TEV) of the

	Attribute	Options	Description
	Landscape Conservation	Increase / Decrease / Stable	The cultivation of landraces / traditional varieties of wheat can be important for the maintenance of the landscape. The loss of genetic diversity can negatively impact ecological processes and the appearance of the landscape, for example leading to different types of vegetation growing, affecting water flow, reducing soil quality and potentially having negative impacts on wildlife.
	Risk of loss of agricultural production	Low / Moderate / High	The lack of genetic diversity in agricultural systems can increase the vulnerability of crops to extreme events such as hail, wildlife, diseases, etc, resulting in lost agricultural production and negatively impacting regional food security. Conservation of traditional wheat varieties will make sure that plant breeders and farmers have the option to use these varieties in the future to increase the resilience of wheat production in your country.
	Wheat diversity for future generations	10% / 50% / 90% (Percentage of currently existing numbers of landraces / traditional varieties in 50 years)	Market pressures for certain types of wheat have increased the risk of extinction for other varieties with lower market values. Your donation to a conservation program will help to ensure that a given proportion of traditional wheat varieties will still be in existence in the future (regardless of their use) and also that they will remain available for the benefit of future generations.
	Maintaining traditional knowledge, cultural practices and special food products	Yes /No	Biodiversity is an important cultural asset. Different varieties of wheat are often associated with local cultural events and special food products. For example (specify example relevant for country context)
	Cost of Program	0 / 5 / 10/ 20 / 35 / 75 (Euro)	Each program is associated with a payment level that reflects the cost of implementing the conservation option under consideration. These payments represent your single individual contribution.

Figure 1. Description of Choice Experiment Attributes and Levels. Source Drucker *et al.* (2021a), Annex 1.

genetic resource, such that the sum of the separate attribute values may be used as an estimate of the TEV of the public good ecosystem services associated with the maintenance of wheat landrace diversity in farmers' fields.

Results

Results reveal strong support for the conservation of wheat landrace diversity, with average WTP amounting to just over €95 (one-off donation) per respondent (see Table 1). In particular, strong preferences were revealed for the landscape and ecological values of wheat conservation, which are associated with the presence of landraces *in situ* through on-farm conservation .
We find, however, quite a high degree of heterogeneity between countries (see Table 2), particularly in terms of preferences for avoiding risk and for the number of varieties maintained.

With an average one-time only total WTP per respondent of €95 and a total population of slightly over 100 million across the five countries, we estimate that the general public of these five countries would be willing to pay €10 billion for the conservation of wheat landrace diversity alone. Even assuming that only 10% of those individuals would actually be willing to pay in practice (to counteract any hypothetical bias experienced in our survey), we would still obtain a one-time WTP of €1 billion, which is equivalent to approximately Euro 80.2m /per annum over a 20-year time horizon at a 5% discount rate.

Conclusions and policy recommendations

These findings demonstrate the significant and frequently ignored social welfare benefits associated with non-market agrobiodiversity-related public good ecosystem services. Furthermore, given the public's levels of WTP for wheat landrace conservation, which—even at the relatively low levels found in the Alpine countries and the UK—is sufficient to fund critical conservation interventions (see Drucker et al., 2021b p.12 who estimated that conservation costs range from €1.8m–€33m p.a, resulting in a high benefit-cost ratio [2.4–44.6]), there is potential to better align agrobiodiversity conservation funding with EU citizens' preferences for the conservation of agricultural diversity.

Given that formal support schemes (€200/livestock unit under the new CAP) exist for animal genetic resources, while at best only ad hoc support schemes exist for landraces, national policymakers, urgently need to explore mechanisms through the CAP (and for non-EU countries, their national legal instruments[4]) to systematically support the on-farm conservation of Europe's agricultural heritage of landrace/ traditional varieties of wheat and other crops.

Table 1. Mean individual and aggregate WTP for conservation programme attributes

	Pooled sample (household estimates)	Aggregate esti-	Conservative (10%) estimate
Avoid high production risk	€30.94	€3.2 billion	€323 million
Maintain/Improve landscape & ecological values	€34.09	€3.6 billion	€356 million
Support cultural aspects	€3.04	€320 million	€32 million
Maintain 100% of current extant diversity for the future/future generations	€27.30	€2.9 billion	€290 million
Total Economic Value	€95.37	€10 billion	€1 billion

Table 2. Mean individual WTP for landrace conservation programme attributes

	Greece	Hungary	UK	Alpine[3]
Avoid high production risk	€ 67.28	€ 44.82	€ 12.95	€ 2.15
Maintain/Improve landscape & ecological values	€ 48.02	€ 59.52	€ 15.11	€ 3.10
Support cultural aspects	€ 17.12	€ 22.58	-	€ 2.17
Maintain 100% of current extant diversity for the future/future generations	€ 10.70	€ 7.20	€ 0.90	€ 0.40
Total WTP/ « Total Economic Value »	€ 143.12	€ 134.12	€ 28.96	€ 7.82

References

Drucker, A.G., Tyack, N., Bartha, B., Fehér, J., Krommydas, K., Maierhofer, H., Maxted, N. and Tzouramani, I., (2021a). Public willingness to pay for agrobiodiverse-related goods and services in Europe. *Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources*. Available here

Drucker, A.G., Tyack, N., Bartha, B., Fehér, J., Koutis, K., Maierhofer, H., Maxted, N. and Ralli, P., (2021b). Effectiveness of existing levels of *in situ* support for conservation and use in Europe. *Farmer's Pride: Networking, partnerships and tools to enhance in situ conservation of European plant genetic resources*. Available here

[1]Austria [n=100], Greece [n=200], Hungary [n=200], Switzerland [n=101] and the U.K. [n=200]. [2] Based on an aggregate five-country population estimate for 2019 of approximately 105 million, data from EUROSTAT. [3] Austria and Switzerland were merged into a single "Alpine" sample as the number of respondents for each country was not large enough to support country-level analysis. [4] Such as the 2020 UK Agriculture Bill [Chapter 21, Part 1 (Financial Assistance), Chapter 1 (New Financial Assistance Powers), Article 1 (Secretary of State's powers to give financial assistance), Item 1.i]

The conservation and use of CWR: the case for the establishment of PGR-Centres

Theo van Hintum[1], Rob van Treuren[1] and Rik Lievers[1]

[1] Centre for Genetic Resources, The Netherlands (CGN), Wageningen University & Research, Email: theo.vanhintum@wur.nl

Crop Wild Relatives (CWR) constitute an important source of genes for use in plant breeding and crop research and an important component of the Plant Genetic Resources (PGR), necessary to allow continuous improvement of the crops available for food production. Therefore, CWR need to be conserved and made available for interested users.

Despite the large potential value of these *in situ* PGR, they are generally hardly accessible due to various reasons (Hintum *et al.,* 2021a). PGR users often do not know about the existence and potential value of the CWR populations, and if they know it is usually not clear if and how they can access them. On the other hand, the owners of the land where the CWR occur *in situ*, often are not aware of the concept of CWR and the fact that they occur on their land, and when confronted with a request for material don't know how to handle this in terms of physical sampling or legal, phytosanitary and logistic aspects. As a result of the lack of awareness of the landowner the danger of accidentally losing the CWR population is high and access to these populations is lacking.

Maxted & Palmé (2016) first proposed a potential model for how *in situ* and *ex situ* CWR conservation might be effectively linked. The complex model focused on the distinction between standard *ex situ* sampling of CWR populations for inclusion in the collection and subsequent conservation and distribution to users, and

"it is usually not clear if and how PGR users can access CWR populations"

populations sampled for *in situ* back-up. In the years that followed, the discussions that were held in, for example, the EU Horizon 2020 funded project Farmer' s Pride resulted in new insights. Some of the options presented in Maxted & Palmé (2016) appeared not feasible (too labor-intensive and expensive) or hindered by legal obstacles (ownership of the material). The model became much simpler, distinguishing between the conservation component: preventing populations from disappearing, and the access component: making sure that users can get hold of the material for use in research, breeding or other purposes.

In this simplified model, the conservation aspect is tackled by safety backing-up the CWR populations in secure *ex situ* facilities. The access component is covered by creating a liaison between the landowner and the potential user. Since these activities will not happen by themselves, the establishment of Plant Genetic Resources Centers is proposed.

Conservation

After making an inventory of the CWR occurring in a certain area (e.g. Treuren *et al.,* 2017), the first step towards CWR conservation and access is raising awareness of the existence of the CWR populations amongst landowners. This can be done in various ways and will involve publications in journals, presentations during meetings, bilateral visits, etc. Experiences regarding approaching landowners, amongst others in the aforementioned Farmer's Pride project, showed that landowners such as nature management organisations are generally positively surprised to learn that they are not only conserving nature but also resources that could help feed the world.

Once the landowners are aware of the potential use value of populations occurring on their land, the first issue to address is conservation. Accidental loss should be avoided. For this purpose, safety back-up seed samples of the populations should be stored in an *ex situ* genebank. Not all CWR populations are in high need of being backed up; the potentially threatened populations should obviously be given priority.

Making a safety back-up comprises the sampling of seed from the natural population, drying it, verifying the seed quality, and storing it at -20˚C at a safe location, with backup power supply, proper fire extinguishers, etc. *Ex situ* genebanks generally have the procedures and appropriate facilities to do so (FAO 2014). Under the standard *ex situ* genebank storage conditions seed can generally be stored for many decades. In case the CWR population is lost *in situ*, it can be recovered from the genebank.

Obviously this seed back-up can only be applied to CWR with orthodox seeds, i.e., seeds that can be stored in a dried and frozen condition. Fortunately, most CWR have orthodox seeds. For the other species, other solutions for safety back-up have to be sought, such as duplication of the population in the form of living plants (in field genebanks), or tissue (*in vitro* or *cryo*). These solutions will often be much more expensive and prioritisation will be even more important.

An important aspect to consider when organising safety back-up is the legal component. Issues such as, 'who can access the backed-up material', 'how long will it be stored', and 'who will cover the costs', need to be arranged in a so-called Material Transfer Agreement (MTA) to avoid distrust and misunderstandings. Models for these MTA's for safety back-up were created in the Farmer's Pride project (Hintum *et al.*, 2021s). Generally, to promote the safety backing up of vulnerable populations, these MTAs are kept very simple: only the donor (the landowner) has access to the material, the (very limited) costs for storage are covered by the genebank, and every 5 or 10 years the agreement can be reviewed.

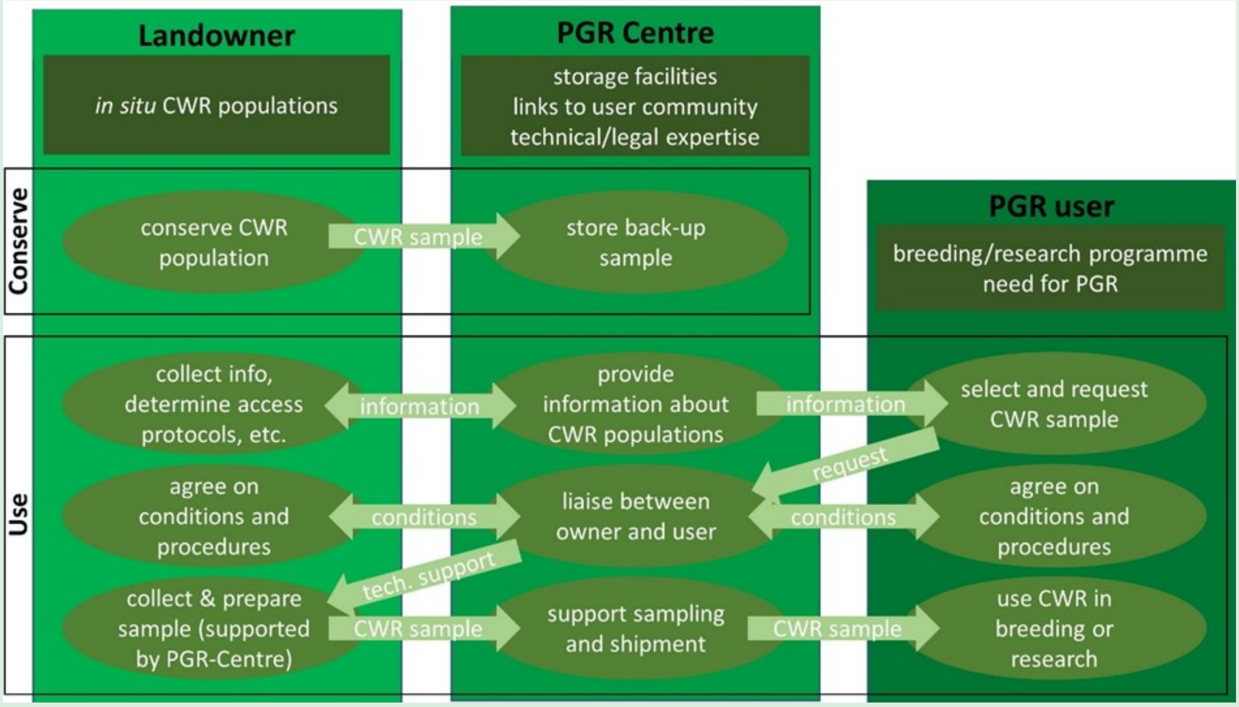

Figure 1. Roles of the PGR Centre in conservation and providing access to CWR occurring *in situ*.

The big issues in this safety back-up approach are, apart from the incentives for actually making them, the technical difficulties and associated costs of sampling the CWR populations. This needs to be done at the right moment when the seeds are ripe but not yet dispersed. Usually, this requires good preparation, a lot of goodwill, and a source of funding.

Access

Once the danger of loss is prevented, one should start thinking about making the CWR accessible to potential users. The simplest way is to include the CWR in the collection of an *ex situ* genebank (this makes the safety back-up step redundant, as it becomes part of the regular genebank protocol (FAO 2014)). Obviously, this requires the consent of the landowner. However, since CWR are generally very difficult to manage in a genebank due to their wild behaviour, genebanks will not be too eager to include too many CWR in their collections. The seeds of CWR often do not germinate well due to dormancy or other mechanisms that prevent them from germinating all at the same time, the plants do not grow or flower simultaneously, and the seeds tend to shatter. These, and other factors can make regeneration and viability testing a very difficult and expensive task. As a result, genebanks only include the most important populations in their regular *ex situ* collection, as they try to spend their limited funds most effectively.

So, the challenge is to conserve the CWR *in situ*, preferably with a safety back-up in an *ex situ* facility, and to make these resources accessible to the user in an alternative way. This involves several steps that are not trivial (Figure 1). A well-organised *ex situ* genebank will have a good website and other means to communicate to the potential user about the available material in its collection and ways to obtain material from it. For *in situ* material, scattered all over the country in various protected areas and other locations, managed by many actors often unaware of these resources, this reference point does not exist. Therefore information about *in situ* PGR needs to be brought together: collected and presented on the web and via other means. This information should include at least lists with the CWR populations, possibly with information about their potential use value and the conditions for access.

Secondly, as mentioned before, the owners of the land with the *in situ* populations need to be convinced of the importance of, and opportunities connected to, making the PGR available and the possibilities to define the terms of use. These terms should, at least from the users' perspective, preferably be as simple and as standard as possible; the Standard Material Transfer Agreement (SMTA) as defined by the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA (FAO 2001)) is the preferred option. However, a landowner can also decide on other terms that can include financial compensation, restrictions on further distribution, or distinction between the conditions for different categories of users. Landowners should also be stimulated to think about procedures in case seed requests are made, most importantly a contact person who knows about the issue and can arrange the necessary further steps.

National laws concerning 'access and benefit-sharing' of PGR might complicate matters and have to be taken into consideration. For countries that joined the Convention on Biological Diversity (CBD) and have signed the Nagoya Protocol, very strict rules regarding the international transfer of PGR might apply depending on the national implementation of these agreements (Brink & Hintum 2020).

Once this is organised, i.e., the potential user can find out about the CWR population of potential value, and the landowner is aware of the potential requests for the material, the material is, in principle, available for use. However actual transfer of material still requires rather complicated steps, such as agreeing about the terms of use in case these were not pre-defined, sampling the population, meeting phytosanitary and other import requirements, and shipping the material. This can best be supported by an organisation with all the necessary knowledge and experience, that can act as a liaison between the potential user and the landowner.

Plant Genetic Resources Centres

Since the majority of potential users of *in situ* CWR will be the same as the users of *ex situ* genebank collections, it makes sense to have genebanks also accept the liaison task between potential user and landowner, and let *ex situ* genebanks transform into Plant Genetic Resources Centres (Maxted *et al.* 2016).

These PGR-Centres would manage their own *ex situ* collections, support other PGR conservation actors, both *in situ* and *ex situ* with technical support (scientific, phytosanitary, legal), and act as an entry point for potential users for identifying and obtaining the material (Figure 1). For the most important CWR populations, where frequent use can be anticipated, the PGR-Centre could already sample material and prepare it for use, possibly even including it in its own *ex situ* collection (provided that the owner agrees). For other CWR populations, the PGR-Centre only supplies information on the web and assists in reaching an agreement between an interested potential user and the owner of the land where the population grows. Once this agreement has been reached, it can support or organise the sampling of the population, legal and phytosanitary issues, and the shipment.

Some genebanks, such as the Centre for Genetic Resources, The Netherlands (CGN), have already made this transition. They expanded their mandate from managing their *ex situ* collections, to performing, supporting, and promoting activities that contribute to better conservation of, and access to PGR. This includes managing their own *ex situ* collections, but also providing support to *in situ* activities (both on-farm and in-nature), act as expertise centre for legal and phytosanitary matters, and contribute to the development of international policies regarding conservation, access and benefit-sharing (ABS), digital sequence information and other issues related to PGR conservation / use.

“...let *ex situ* genebanks transform into Plant Genetic Resources Centres”

This transformation needs to be funded, and *ex situ* genebanks are generally short on funds (as the costs of maintaining large genebank collections have always been underestimated). Underfunded genebanks will not be eager to accept additional tasks, especially if these are somewhat outside their area of expertise. Obviously, the user of the *in situ* CWR can be charged with handling fees as part of the agreement, thus covering the costs of making the CWR available for use. However, it is not likely that these fees can cover all costs associated with scaling the genebank up to a PGR-Centre. Therefore, additional funding is conditional to offering these additional services.
PGR-Centres can be national, regional or crop-based (similar to current *ex situ* genebanks). In any case, they can serve as focal point for collecting information about *in situ* CWR, which can serve as input for aggregated databases. Based on this information, these databases could provide overviews of all available PGR both *in situ* and *ex situ*. In Europe, EURISCO (Weise *et al.* 2017) could play the role of aggregating information about available *in situ* CWR populations, similar as it does for *ex situ* PGR.

The standard descriptors for documenting the CWR populations have already been defined (Alercia *et al.* 2021).

Conclusions

Currently *in situ* CWR populations are not always securely conserved and often very difficult to access for interested users. To improve this situation awareness of these CWR needs to be raised, safety back-up protocols need to be implemented for threatened populations, and various steps need to be taken to facilitate access. All these elements are doable but require, apart from the landowners to cooperate, specialised PGR-Centres that have the expertise and facilities. Since this expertise and facilities are very similar to what current *ex situ* genebanks already have, these are the likely actors to develop into such PGR-Centres.

References

Alercia, A., López, F., Marsella, M. and Cerutti, A.L., (2021) Descriptors for Crop Wild Relatives conserved *in situ* (CWRI v.1) FAO, Rome, Italy. Available online: http://www.fao.org/documents/card/en/c/cb3256en/

Brink, M. and Hintum, T.J.L. van., (2020) Genebank Operation in the Arena of Access and Benefit-Sharing Policies. *Frontiers of Plant Science*, https://doi.org/10.3389/fpls.2019.01712

FAO, (2001) International Treaty on Plant Genetic Resources for Food and Agriculture. FAO, Rome, Italy. Available online: http://www.fao.org/plant-treaty/en/ (Accessed 14.09.2021).

FAO, (2014) Gene Bank Standards for Plant Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: http://www.fao.org/3/a-i3704e.pdf (Accessed 06.08.2021).

Hintum, T. van, Csörgõ, S., Veteläinen, M., Bartha, B. and Heinonen, M., (2021a) Improving access to *in situ* plant genetic resources. Farmer’s Pride: Networking, partnerships and tools to enhance *in situ* conservation of European plant genetic resources. Available online: https://more.bham.ac.uk/farmerspride/wp-content/ uploads/sites/19/2021/07/D3.4_Improving_access_to_in_situ_plant_genetic_resources.pdf (accessed 14 09 2021)

Hintum, T. van, Iriondo, J., Treuren, R. van, Rubio Teso, M.L. and Álvarez, C. (2021b) Templates of Material Transfer Agreements for black-box safety backup in an *ex situ* genebank. Appendix 2 in: Guidelines for integrated *in situ* and *ex situ* PGR conservation. Available online: https://more.bham.ac.uk/ farmerspride/wp-content/uploads/sites/19/2021 /07/D2.6_Guidelines_for_integrated_in_situ_and_ex_situ_conservation.pdf (accessed 16.09.2021)

Maxted. N., Amri. A., Castañeda-Álvarez, N.P., Dias, S., Dulloo, M.E., Fielder, H., Ford-Lloyd, B.V., Iriondo, J.M., Magos Brehm, J., Nilsen, L-B., Thormann, I., Vincent, H., Kell, S.P., (2016) Joining up the dots: a systematic perspective of crop wild relative conservation and use. In: *Maxted, N., Ehsan Dulloo, M. & Ford-Lloyd, B.V. (eds.), Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement.* Pp. 87-124. CAB International, Wallingford, UK.

Maxted, N., Palmé, A., (2016) Combining *ex situ* and *in situ* conservation strategies for CWR to mitigate climate change. In: The impact of climate change on the conservation and utilization of crop wild relatives in Europe (Eds. Valdani Vicari & Associati *et al.*), Barcelona, Spain, 15th December 2015. Preparatory action on EU plant and animal genetic resources (AGRI-2013-EVAL-7) Workshop Report, Directorate General for Agriculture and Rural Development, European Commission, Brussels, Belgium.

Treuren, R. van, Hoekstra, R, Hintum, T.J.L. Van. (2017) Inventory and prioritization for the conservation of crop wild relatives in The Netherlands under climate change. *Biological Conservation* 216: 123-139. https://doi.org/10.1016/j.biocon.2017.10.003

Weise, S., Oppermann, M., Maggioni, L., Hintum, T.J.L. van, Knüpffer H. (2017) EURISCO: The European search catalogue for plant genetic resources. *Nucleic Acids Research* 45(D1): D103-D1008 https://doi.org/10.1093/nar/gkw755

The conservation and use of CWR: the *in situ* perspective

Nigel Maxted[1]

[1] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK. Email: n.maxted@bham.ac.uk

Establishing an efficient and effective way to link *in situ* crop wild relative (CWR) conservation and use is critical to the sustainability of *in situ* CWR conservation itself, *in situ* must be as viable a conservation technique to complement *ex situ*. If the germplasm access linkage works as well as the standard *ex situ* to the breeder, researcher and other users, then the proposed European CWR Regional *in situ* CWR conservation Network is likely to be established, if not it is unlikely the network will be implemented. Another complexity from the *in situ* resource provision perspective is that the *in situ* conserved resource (or un-conserved resource) is found in an array of distinct environments - the farmers field, the garden, the orchard, edges of habitation, the protected area or all of these environments within a protected area network, such as the Natura 2000 network in Europe. Whilst the *ex situ* conserved resource is found in the seed genebank, field genebank, tissue culture (*in vitro* or cryopreservation) collection, living collection, but in each case the resource is maintained by professional conservationists, rather than the often amateur maintainer with another prime goal of land management, producing food and feeding their family. Therefore, getting the CWR *in situ* or for that matter the LR on-farm conservation to user linkage practically resolved does have very significant potential impact and is at the core *in situ* or on-farm conservation.

Fundamentally there are two possible approaches to *in situ* conservation for user linkage (Figure 1): (a) direct links between the conserved resource and the user, whether held *in situ* or *ex situ* with a back-up sample deposited *ex situ*, or (b) indirect linkage between the *in situ* resource and the user via the *ex situ* plant genetic resource centre, as argued by Maxted *et al.* (2016). The early consensus when considering the *in situ* conservation to user linkage was to take approach (a) as discussed by Maxted *et al.* (1997). The user would need to approach directly the resource maintainer for resource access, *i.e.*, either the breeder or the protected area manager, farmer or landowner and negotiate 'fair and equitable' access to the *in situ* conserved resource, applying a Standard Material Transfer Agreement (SMTA) defined by the International Treaty on Plant genetic Resources for Food and Agriculture (FAO, 2001). This would be a new interface and there would be a need for extensive training in what constitutes 'fair and equitable' access and how to apply SMTAs for both the resource supplier and resource user. Over years of experience working with protected area managers, farmers or landowners managing *in situ* CWR and on-farm LR resources it became obvious that the direct access model was untenable because the majority of protected area managers, farmers or landowners have no precise *a priori* concept of the value of the resource they maintain. They do not know how to implement the access and benefit sharing articles of the ITPGRFA, or how to negotiate mutually beneficial access with commercial resource users. Further, practical experience has found protected area managers, farmers and others managing *in situ* populations do not see provision of the conserved resource as part of their conservation role and are generally unwilling to engage in these additional responsibilities beyond the simple conservation of the populations themselves. So, trying to persuade them to fulfil this role may be counter-productive and unnecessarily block user access to potentially useful *in situ* conserved germplasm. The commercial resource users would also be at a disadvantage,

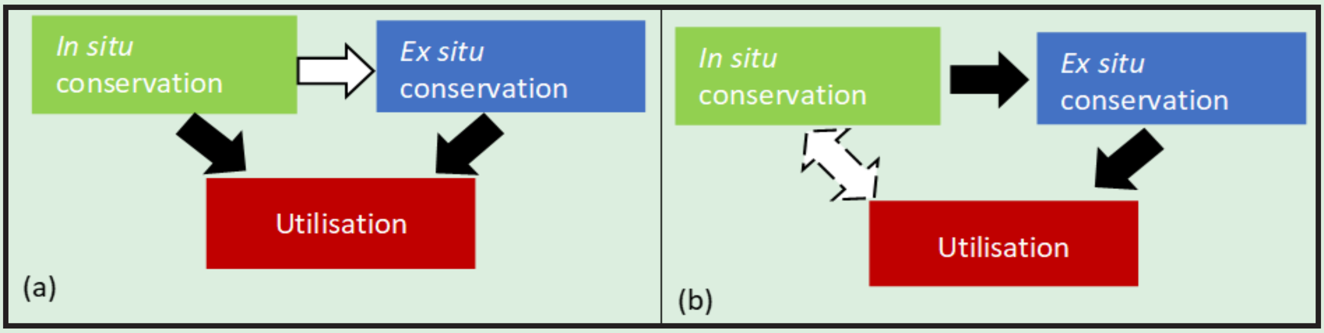

Figure 1. Two possible approaches to *in situ* conservation to user linkage (a) direct links between the conserved resource and the user, whether held *in situ* or *ex situ,* with a back-up sample deposited *ex situ*, or (b) indirect linkage between the *in situ* resource and the user mediated by the *ex situ* plant genetic resource centre.

when dealing with a uninformed resource maintainer and be open to suggestions of exploitation. Therefore, over time the *modus operandi* has moved to approach (b), where the *ex situ* gene bank acts as an intermediary between the *in situ* resource maintainer and the user, applying their years of successful experience at the *ex situ* resource/user interface. To acknowledge this additional role for the gene bank, Maxted *et al.* (2016) proposed gene banks that are also actively involved in *in situ* resource provision should be renamed Genetic Resource Centres (GRC) to make it clear their role is to provide access to both *ex situ* and *in situ* conserved resources.

Finally, it should be recognised that if approach (b) is followed there still may be occasions when the user may wish to gather additional information from the *in situ* resource maintainer, farmer, protected area manager, or other form of population manager and so approach (b) should not preclude contact between the maintainer and the user who may wish to obtain more information on the cultivation practice applied, detailed environmental data or adaptive traits recognized by the maintainer for example.

.A second critical question, if the expediency of approach (b) is acknowledged, is how exactly will the *in situ* to *ex situ* to user linkage work? Maxted and Palmé (2016) first proposed a potential model for how *in situ* and *ex situ* CWR conservation might be effectively linked. The model focused on the distinction between standard *ex situ* sampling of CWR population for conservation and user distribution and populations sampled for *in situ* back-up (Figure 2). Option 1 outlines the normal route that germplasm enters the Genetic Resource Centre (GRC): population samples are either collected from the wild or on-farm location, on entering the genebank the samples are registered and documented, the collection samples are cleaned and dried to 15 ±3 % relative humidity, the germination rate is tested and if over 85% the sample is packaged and banked at 18 ±3°C and upon user request a viable seed sample of 40-50 seeds is made available. The sample is tested periodically for the germination level, if the seed viability is less than 85%, then the sample must be grown out and regenerated to ensure the seed viability is maintained above 85% (FAO, 2014). So, the approach would be the same as any accession added to the gene bank, but the source would be an *in situ* conserved population.

Alternatively for option 2, Maxted and Palmé (2016) proposed the *in situ* back-up sample would be treated similarly to an *ex situ* 'black box' sample: the samples are registered and documented, cleaned and dried, the germination tested, then packaged and banked, with the banked sample tested periodically for the germination level. But the difference to option 1 is that the sample is not made available to users and is only available to the donor as part of their *in situ* monitoring programme or population reinforcement. However, given the imperative of seed accessibility for actively conserved population samples, the black box option does not meet this requirement, so is ineffec-

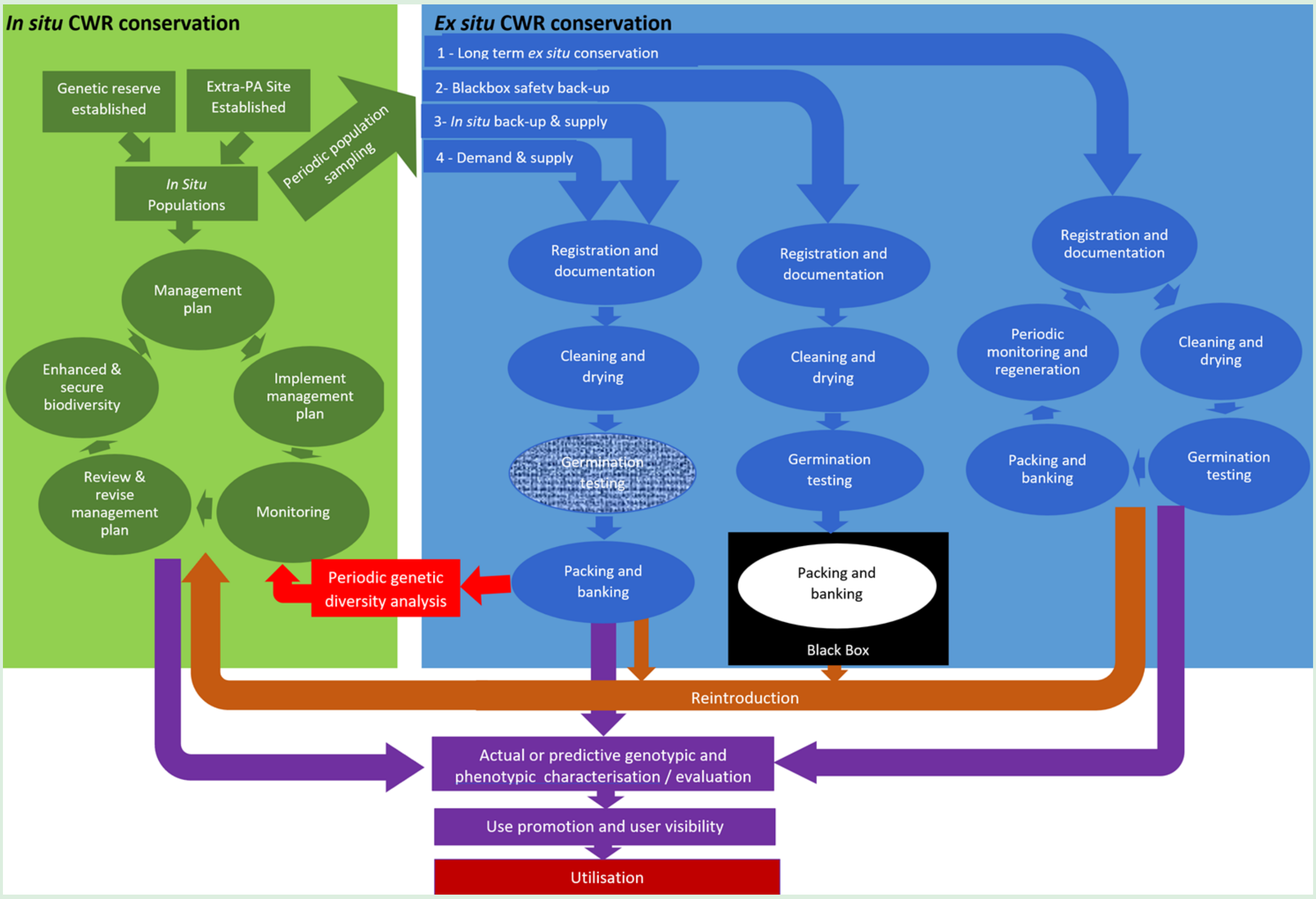

Figure 2. Integration of *in situ* and *ex situ* CWR conservation with utilization – four options . Note PA=protected area and the hatching of germination testing suggests it may or may not be necessary in the *in situ* context.

tive as a plant genetic resources (PGR) conservation measure. The *in situ* black box sample would be treated purely as a back-up sample and accessibility for actively conserved *in situ* population samples would remain only possible directly from the conserved *in situ* populations.

To help resolve this issue, Maxted (2019) proposed a more dynamic option 3 which would facilitate access to the *in situ* conserved resource (Figure 2). By far the most expensive element of *ex situ* gene bank storage is the periodic population regeneration to maintain germination levels, option 3 involves all the standard germplasm banking steps but here the *in situ* back-up samples are not regenerated. When seed viability of the *in situ* sample stored *ex situ* falls below 85% a further sample is taken from the host population. Ideally, in option 3 the *in situ* population samples would be made accessible alongside the *ex situ* conserved material, no distinction being visible to potential users between *in situ* and *ex situ* conserved samples. This would significantly reduce the potential cost and staff work load of *in situ* back-up and means the sample would better reflect the current genetic diversity content of the *in situ* populations that are continually evolving. The provision of accessibility to *in situ* population samples via the genebank would acknowledge the fact that they have the appropriate expertise in user seed supply and might see this as a natural extension of their existing role. A further advantage of option 3 is that *in situ* population samples could be included in the routine characterization and evaluation activities that *ex situ* conserved accessions were subject to, so providing characterization and evaluation data for *in situ* populations and thereby significantly improving their use value.

Option 3, *in situ* back-up and supply, is the favoured option from the *in situ* perspective, but it does involve additional work for the GRC staff. Therefore, a fourth option was proposed by the GRC community of 'demand and supply' that minimised the GRCs additional workload. Option 4 involves the user identifying the *in situ* population they wish sampled, expressing their wish to their national GRC and then the GRC collectors collect and supply the population samples to the user on demand (Figure 2). This may involve direct delivery of the fresh sample to the user or via the steps outlined in option 3 (i.e., registration and documentation, cleaning and drying, germination testing, and packaging and distribution). This option would undoubtedly require least intervention by the GRC apart from the collection and this direct cost could be passed onto the users. However, from the *in situ* perspective this would unnecessarily restrict access to the *in situ* resource and would not make the *in situ* population samples equally accessible compared to *ex situ* conserve material. The user would need to know a particular *in situ* population had adaptive traits, possibly from past experience of the *in situ* population or by applying some form of predictive characterisation (Thormann *et al.*, 2014), which might deter some users from requesting *in situ* population samples and would limit the accessibility of *in situ* conserved populations. Further seasonality and regularity of supply would also be a limitation on option 4 supply efficiency (Maxted, 2019). *Ex situ* conserved accessions in genetic resource centres are available for user distribution year-round as seed samples, but *in situ* conserved germplasm which would also normally be supplied in the form of seed samples would only be available *in situ* or on-farm for few weeks of the year following fruit ripening, so *in situ* users may be forced to waiting twelve plus months for the samples they require – another negative feature of option 4. Therefore, Option 3 remains the favoured option from the perspective of the *in situ* conservationist.

Also, if option 3 were implemented and the *in situ* source regularly provided fresh samples for the *ex situ* backup and user provision, it might also reduce the necessity for germination testing. As van Hintum *et al.* (2021) noted a disadvantage of taking CWR sample into *ex situ* collections is their dormancy and germination requirements may be unknown, but also their preferred storage or cultivation conditions may also be unknown. If both germination testing and regeneration were excluded, the additional cost to the genebank of addressing *in situ* would be reduced significantly, though presumably some users would still need to understand the preferred storage or cultivation conditions, and dormancy and germination requirements, so the cost could potentially be past to the user. However, the plant genetic resource centre staff would need to liaise potential discussion between the *in situ* maintainer and the user, a further additional cost for the genetic resource centre.

It can also be argued that if option 3 were implemented, only the more 'important' *in situ* populations should be conserved (van Hintum *et al.,* 2021), this would reduce the additional costs for the gene bank, but it would not serve the *in situ* conservation requirement. Again, it would limit the availability of *in situ* conserved resources and not make them truly comparable with *ex situ* resource availability. Further how would 'important' *in situ* populations be recognized? Such characteristics can be identified by presence of adaptive traits in populations at the edges of their CWR distributional range, samples selected using ELC mapping or hotspots of CWR taxonomic diversity, even CWR population genomic analysis, but given there are approximately 50-60,000 CWR (Maxted and Kell, 2009) and even 1,667 priority CWR taxa (Vincent *et al.*, 2013) the data is just not adequately available to select 'important' *in situ* populations – we need to aim to produce true parity in availability of *in situ* and *ex situ* samples.

As mentioned above, Maxted *et al.* (2016) argued for a change in the role of existing genebanks, from essentially '*ex situ* conservation and user supply' to the broader 'conservation and user supply', conservation in the latter case being both *ex situ* and *in situ*. The change in role would necessarily involve additional workload and therefore needs to be accompanied by an upgrade in resourcing to reflect the additional responsibilities of the GRC. The regular re-sampling of the *in situ* population for *in situ* backup would obviate the need for germination monitoring or regeneration and the lack of the latter would significantly reduce the financial burden of *in situ* germplasm supply on the GRC. It would also facilitate access to the *in situ* conserved resource and avoid unnecessary direct contact between germplasm users and the protected area managers, farmers or landowners. The protected area manager's, farmer's or landowner's interests under option 3 would be protected by the ABS agreement signed between the resource manager and the GRC. However, practically the choice over which option 1 to 4 was applied would depend on discussion between the national PGR coordinator, GRC staff and those involved in national *in situ* plant conservation. If option 3 were applied and equally beneficial complementary PGR conservation was applied, then the additional responsibilities placed on GRCs would need to be recognised and adequately resourced.

All four options require the transfer of conserved *in situ* or wild collected population samples to the GRC for either conservation, or conservation and access to users. The transfer of *in situ* conserved materials to the other conservers or users is covered by the ITPGRFA (2001) Art. 12.3(h) which states:

"*Without prejudice to the other provisions under this Article, the Contracting Parties agree that access to plant genetic resources for food and agriculture found in* in situ *conditions will be provided according to national legislation or, in the absence of such legislation, in accordance with such standards as may be set by the Governing Body.*"

But the ITPGRFA has yet to set a standard for *in situ* access which is also the case for most national governments. However, Art. 15.1(b) (ii) states:

"*The Contracting Parties in whose territory the plant genetic resources for food and agriculture were collected from* in situ *conditions shall be provided with samples of such plant genetic resources for food and agriculture on demand, without any MTA.*"

van Hintum *et al.* (2021) also concluded that a material transfer agreement (MTA) was not required when transferring seed samples from the *in situ* site to *ex situ* GRC as follows:

"… it was decided not to define strict protocols for collecting or regarding the Material Transfer Agreement (MTA) to be used, as the anticipated frequency of use was low."

This appears to assume linking option 4 is applied and usage would be limited, but as is argued above were option 3 preferred by national stakeholder then van Hintum *et al.* (2021) concludes the lack of using an MTA should be reconsidered (or preferably an SMTA[1]) to reassure the *in situ* donor that their rights were being protected and notes, that any donor wishes related to user exploitation could be enforced.

Throughout this brief review the focus has been on linking CWR conserved *in situ* to the *ex situ* GRC and through onto potential users, but in principle there is no reason why on-farm conserved landrace material could not be linked equally from the farmer to the GRC and onto potential users.

[1]Standard Material Transfer Agreement, where all conditions are predefined. See: http://www.fao.org/plant-treaty/areasof-work/the-multilateral-system/the-smta/en/

References

FAO, (2001). International Treaty on Plant Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Available online: http://www.fao.org/ag/cgrfa/itpgr.htm (Accessed 06.08.2021).

FAO, (2014). *Gene bank Standards for Plant Genetic Resources for Food and Agriculture*. Rev. Ed. Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: http://www.fao.org/3/a-i3704e.pdf (Accessed 06.08.2021).

Maxted, N. and Kell, S.P., (2009). Establishment of a network for the *in situ* conservation of crop wild relatives: status and needs. Commission on Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. 211 pp. http://www.fao.org/docrep/013/i1500e/i1500e18a.pdf

Maxted N., Amri. A., Castañeda-Álvarez, N.P., Dias, S., Dulloo, M.E., Fielder, H., Ford-Lloyd, B.V., Iriondo, J.M., Magos Brehm, J., Nilsen, L-B., Thormann, I., Vincent, H. and Kell, S.P., (2016). Joining up the dots: a systematic perspective of crop wild relative conservation and use. In: Maxted, N., Ehsan Dulloo, M. & Ford-Lloyd, B.V. (eds.), Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement. Pp. 87-124. CAB International, Wallingford, UK.

Maxted, N., Hawkes, J.G., Ford-Lloyd, B.V. and Williams, J.T., (1997). A practical model for *in situ* genetic conservation. In: Plant genetic conservation: the *in situ* approach (eds. Maxted, N., Ford-Lloyd, B.V. & Hawkes, J.G.), pp. 545-592. Chapman & Hall, London.

Maxted, N. and Palmé, A., (2016). *Combining ex situ and in situ conservation strategies for CWR to mitigate climate change*. In: *The impact of climate change on the conservation and utilization of crop wild relatives in Europe* (Eds. Valdani Vicari & Associati *et al.*), Barcelona, Spain, 15th December 2015. Preparatory action on EU plant and animal genetic resources (AGRI-2013-EVAL-7) Workshop Report, Directorate General for Agriculture and Rural Development, European Commission, Brussels, Belgium.

Maxted, N., (2019). Another look at *in situ* / *ex situ* CWR conservation linkage. *Crop Wild Relative*, 11: 22–25.

Thormann, I., Parra-Quijano, M., Endresen, D.T.F., Rubio-Teso, M.L., Iriondo, M.J. and Maxted, N. (2014). Predictive characterization of crop wild relatives and landraces. Technical guidelines version 1. Bioversity International, Rome, Italy. Available online at: http://www.bioversityinternational.org/index.php?id=244&tx_news_pi1%5Bnews%5D=4967&cHash=7cd3c6c2b8360927b83fa6ef7cc28d99 (Accessed 06.08.2021).

Van Hintum, T., Iriondo, J., Van Treuren, R., Rubio Teso, M.L. and Álvarez, C., (2021). Guidelines for integrated *in situ* and *ex situ* PGR conservation. Farmer's Pride, University of Birmingham, Birmingham, UK. Available at: https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2021/07/D2.6_Guidelines_for_integrated_in_situ_and_ex_situ_conservation.pdf (Accessed 06.08.2021).

Vincent, H., Wiersema, J., Kell, S.P., Dobbie, S., Fielder, H., Castañeda Alvarez, N.P., Guarino, L., Eastwood, R., León, B. and Maxted, N., (2013). A prioritised crop wild relative inventory as a first step to help underpin global food security. *Biological Conservation*, 167: 265-275.

Establishing a European *in situ* conservation network of sites and stakeholders

Nigel Maxted[1] and Shelagh Kell[1]

[1] School of Biosciences, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK. Email: n.maxted@bham.ac.uk

Crop wild relatives (CWR) and crop landraces (LR) are widely acknowledged as the basis of crop varietal improvement, as well as current and future food and nutritional security (FAO, 1998). Yet the ineffectiveness of current conservation measures and high levels of threat facing PGR is known to be resulting in substantial and increasing genetic erosion and even extinction of CWR and LR genetic diversity (FAO, 2010). It has been argued that more effective CWR conservation, including *in situ* to complement existing *ex situ* techniques, could double the available PGR available to breeders and farmers (Maxted, 2019). Therefore, the Farmer's Pride project (http://www.farmerspride.eu/) brought together key actors to lay the foundations for the lasting *in situ* conservation and sustainable use of PGR in Europe by planting the seed and nurturing the growth of a new regional network of sites, populations, and conservation and use stakeholders, which builds on existing regional, national, and local networks, and relevant initiatives and policies. The project deliberately included a deliverable 4.4 which was the establishment of a *European network for in situ conservation and sustainable use of plant genetic resources*. Perhaps in retrospect it was naïve to expect the Network could be established by a three year research project but we are proud to report Farmer's Pride got very close to achieving this target and the momentum is there for its establishment in the near future.

In summary, Network establishment was the main goal of the project, discussions about the concept of the network began at the kick-off consortium meeting in December 2017 and were the major focus of the project's stakeholder workshops. Following Workshop 1, the white paper '*Proposal for the establishment of a European network for in situ conservation and sustainable use of plant genetic resources*' was prepared, and this was further developed to produce the document, 'European network for *in situ* conservation and sustainable use of plant genetic resources—in cultivation and in the wild: A proposal' after discussions held at Workshop 2, which was published in eight languages.

A vital part of the process of establishing the European *in situ* PGR network is to ensure full stakeholder representation throughout the region and to build a coalition of support for its establishment. The Farmer's Pride project consortium, along with the Farmer's Pride Ambassadors and members of the External Advisory Board, was designed to be representative of the full range of stakeholder groups in PGR conservation and sustainable use: farmers and growers, seed networks, genebanks, plant breeders, the private seed sector, protected area managers, and the research community, including representation at national, regional, and global levels. This strong collaborative approach enabled not only the right voices in the process of designing the network concept, but also the advantage of attracting engagement and support via the actors in each collaborator's professional network. However, to extend the reach of the project even further, two stakeholder surveys were launched to 1) gain a full understanding of and document the range of stakeholders involved or with an interest in *in situ* (including on-farm) conservation and sustainable use of PGR; and 2) to help ensure full stakeholder representation in the European network throughout the region.

The results of stakeholder survey 1 exceeded our expectations in terms of the overall number of responses (1022), the geographic coverage, the breadth of stakeholder organizations represented, and the interests of respondents in the *in situ* conservation and sustainable use of PGR. Fundamentally, more than 56% of respondents are interested in becoming a member of a new European network for *in situ* conservation and sustainable use of PGR. Notably, all countries in the target area were represented in the sample, and critically, representatives of all the anticipated main broadly defined stakeholder groups responded to the survey, including independent farmers, protected area managers, seed companies and policymakers.

Stakeholder survey 2 was launched on 16 June 2020 to gather expressions of interest in joining the European network from farmers, protected area managers, gardeners, seed producers and other land managers—the custodians of crop LR and CWR populations *in situ*. By the 20th of October 2021, there were 86 expressions of interest, and these are plotted on an interactive map (Figure 1) The survey will remain open and monitored at minimum until 31 July 2022.

For the network to be successful, support for its full establishment and permanent operation is vital at the national level, since network activities will be channelled through the national PGR programmes. Therefore, in addition to the above activities, letters of support were solicited from the National Coordinators of the ECPGR, as well as from other organizations. The institutes and organizations that have submitted letters of support for the establishment of the network are also recorded in the afore-mentioned interactive map embedded in the web page dedicated to the European network. This currently includes eight letters of support from ECPGR National Coordinators and eleven from other organizations. The Chairs of the ECPGR *In situ* Conservation of Wild Species in Genetic Reserves and On-Farm Conservation and Management Working Groups—also the Farmer's Pride Project Coordinator and Work Package 1 Leader, respectively—are continuing to solicit support and to promote the establishment of the network in the context of ECPGR (as the proposed main governing body of the network) beyond the lifetime of the Farmer's Pride project.

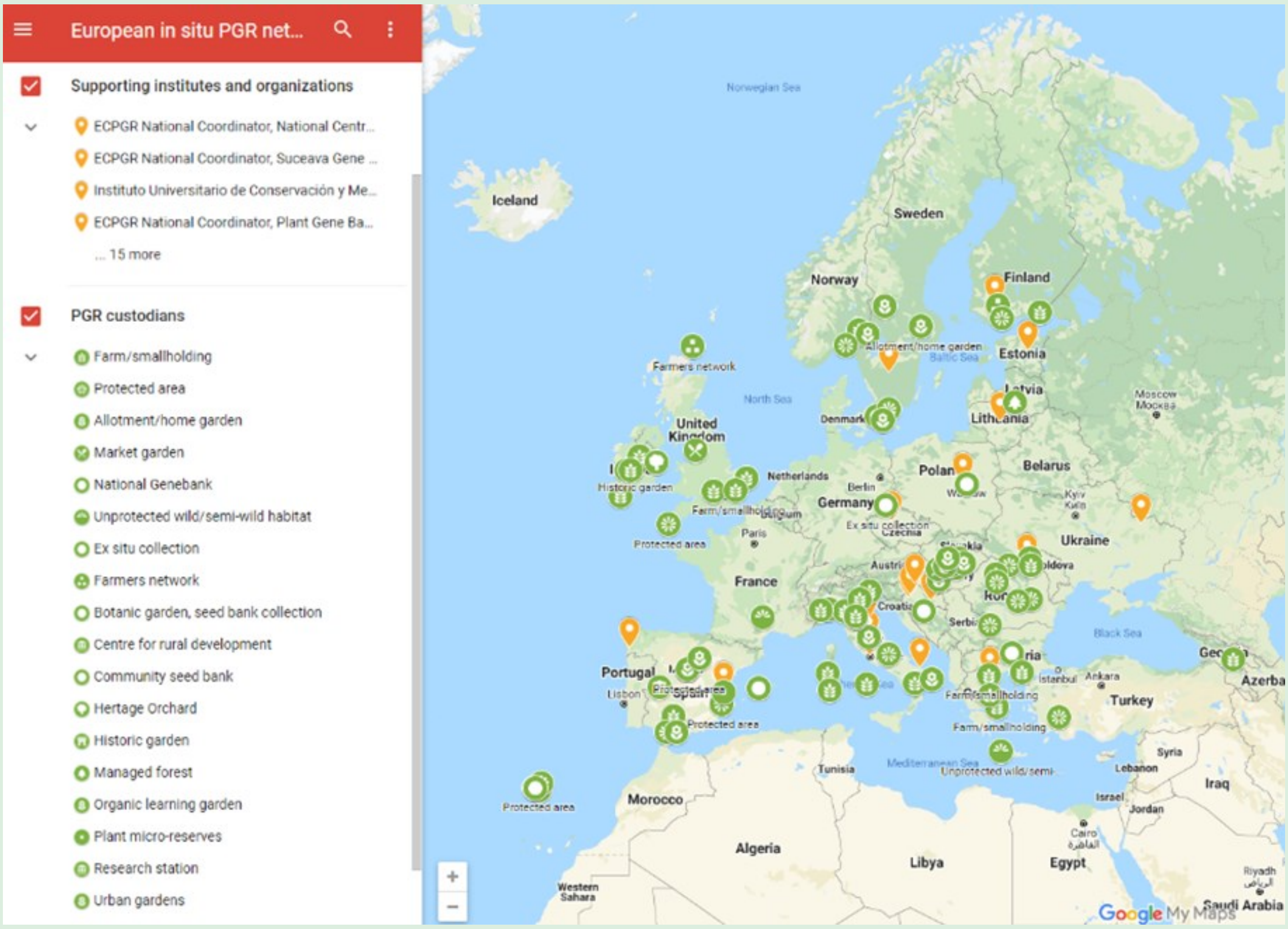

Figure 1. expressions of interest in PGR *in situ* / on-farm sites joining the European network for *in situ* conservation and sustainable use of PGR.

A major milestone in the establishment of the European *in situ* PGR network was the convening of Session 4 of the Farmer's Pride online final dissemination conference, organized in association with the Genetic Resources section of EUCARPIA (the European Association for Research on Plant Breeding) and ECPGR. In this final conference session, the establishment of the network was promoted and debated, including aspects of governance, operation, benefits to stakeholders, and the policy framework within which the network can be rooted and sustained.

The session began with a presentation by Professor Nigel Maxted (UOB)—Coordinator of the Farmer's Pride project and Chair of the ECPGR Wild Species Conservation in Genetic Reserves Working Group—in which he explained the concept of the *in situ* PGR network, the context and rationale for its establishment, and a proposal for network governance. Next there was an audience Q&A session. This was followed by a policy roundtable on the establishment of the European *in situ* PGR network, chaired by Geoffrey Hawtin OBE, Former Director General of Bioversity International and CIAT, and involving panellists from: the Food and Agriculture Organization of the United Nations; Euroseeds; Eurosite – the European Land Conservation Network; the European Environment Agency; the Ministry of Agriculture of the Czech Republic; the Secretariat of the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA); and the European Commission, DG Agriculture and Rural Development. The panellists' statements and audience Q&A were centred around four key questions:

- What next steps are needed to ensure the network is established and provided with a viable log-term governance structure?
- How do you see the network being integrated into relevant biodiversity, agricultural, environmental and genetic resources policy and legislative frameworks (at European and global levels)?
- How best could the network be designed to support the European Green Deal, the Second Global Plan of Action on PGRFA, the International Treaty on PGRFA, and the post-2020 global biodiversity framework?
- What new policies/legislative instruments are needed to support the network and broader PGR conservation and sustainable use in Europe?

There was resounding support for the establishment of the network from all the panellists, but two key interventions came from Chikelu Mba, FAO and Annette Schneegans, EC, DG AGR:

Chikelu Mba, FAO – Noted that critical steps towards the eventual establishment of a global network for PGRFA that are best maintained outside of genebanks. He stated FAO is keenly interested in the establishment of a European *in situ* PGR network as the lessons learned will be critical assets in fostering the development of the envisaged global network.

Annette Schneegans, EC, DG AGR – Stressed that the idea of using the Natura 2000 network for the conservation of both CWR and LR is very interesting and should follow up post-Farmer's

Pride. She also stressed the importance of maintaining the momentum for the European *in situ* Network created under the auspices of the Farmer's Pride project.

The key conclusion was that this initiative is so critical to future more effective PGR conservation and use and European food security, the 'community at large' (involving all involved stakeholders) are so invested in its success that the formal establishment of the Network must follow very soon.

Following the policy roundtable, the final stakeholder workshop was convened in which the conference participants split into breakout rooms to further discuss questions 1 and 2 of the policy roundtable, and a final plenary reporting and discussion session took place. Key conclusions of the stakeholder workshop are summarized in Box 1.

The Farmer's pride consortium are justifiably proud of the impact generated by the project, the extent of impact was obvious in the discussion generated at the final dissemination conference, in the Policy Roundtable and the enthusiasm of the project partners, ambassadors and Advisory Board. So, although the actual formal establishment of the European network for *in situ* conservation and sustainable use of plant genetic resources has yet to achieved, the groundwork has been completed and formal establishment is expected to follow. Finally, under the list of most important/critical next steps for establishing the European *in situ* PGR network in Box 1 is the advice to obtain seed funding to kick-start the network and start small and we do intend to take this route. Post-dissemination conference a key further step in European network establishment has already been taken with the announcement of funding for the inclusion of *in situ* conserved CWR diversity in EURISCO with generous funding from the German government - possibly using the *in situ* population descriptors developed in Farmer's Pride (Weise *et al.*, 2021) – from such 'acorns' do mighty 'Networks' grow.

Box 1. What are the most important/critical next steps for establishing the European *in situ* PGR network?

Keeping up the momentum generated by the Farmer's Pride project

- Keep talking and maintain contact
- Establish an ongoing partnership to prepare a new project proposal to complete Network establishment

Continuing collaboration with existing structures

- Continue working with DG Environment, Eurosite– the European Land Conservation Network, and with Natura 2000 site managers at national level to promote the importance of Natura 2000 for PGR conservation (both CWR and landraces)

Securing funding

- Obtain seed funding to kick-start the network
- Seek funding at national level and from the EC for the establishment and permanent operation of the network

Seeking the buy-in of policymakers

- Identify the specific policy areas and aspects of legislative instruments that the network will address
- Continue to engage national governmental/ parliamentary policymakers, including ECPGR National Coordinators
- Continue to engage DG Environment and DG Agriculture and Rural Development

Developing and promoting the network

- Clarify the mandate, structure and scope, including the integration at national and European levels
- Identify short-term goals and milestones
- Include all stakeholders and countries in the process
- Link the network to good examples of ongoing local/national/regional initiatives
- Formulate strong incentives for network membership
- Identify a 'network champion'
- Present some 'good' genetic reserve examples
- Start small

Identifying network governance

- Continue discussions within ECPGR, especially the Executive Committee, concerning Network governance
- Develop coordination between existing networks, such as ECPGR, Euroseeds and NGO/community

References

FAO, (1998). *State of the World's Plant Genetic Resources for Food and Agriculture*. Food and Agriculture Organization of the United Nations, Rome, Italy. Available online: www.fao.org/agriculture/crops/thematic-sitemap/theme/seeds-pgr/sow/en/ (Accessed 20.10.2021).

FAO, (2010). *Second report on the State of the World's Plant Genetic Resources for Food and Agriculture*. Food and Agriculture Organization of the United Nations, Rome, Italy. Available online: http://www.fao.org/agriculture/seed/sow2/en/ (Accessed 20.10.2021).

Maxted, N., (2019). Another look at *in situ* / *ex situ* CWR conservation linkage. *Crop Wild Relative*, 11: 22–25. Available online: https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/05/CWR_Newsletter_Issue_11.pdf (Accessed 20.10.2021).

Weise, S., Kreide, S. and Maxted, N., (2020). *Concept for a possible extension of EURISCO for in situ crop wild relative and on-farm landrace data*. Available online: https://more.bham.ac.uk/farmerspride/wpcontent/uploads/sites/19/2020/10/D2.5_EURISCO_in_situ_extension_concept.pdf (Accessed 20.10.2021).