DYNAVERSITY

Crop Wild Relatives Genetic Resources (England)

Case study analysis

DYNAmic seed networks for managing European diversity:

conserving diversity *in situ* in agriculture and in the food chain

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PART 1: DESCRIPTION

1.1 Contextualising the case

Currently, *in situ* conservation of CWR (See Annex 1) is advocated by several international bodies and is rising globally into States agenda (Labokas et al., 2018).

In situ conservation approach is complementary to the *ex situ* approach for two reasons: first, it allows plants to evolve dynamically in their natural environment, thus ensuring the expression of their genetic potential. Second, not all genetic resources can be conserved in genetic banks (Maxted et al, 2010; Biodiversity International, 2010). Therefore, *in situ* conservation allows more species to be preserved.

In situ conservation of genetic resources applies to both cultivated species and their wild relatives (Convention on Biological Diversity, 1992; Maxted et al., 2006; Bellon et al., 2017). These wild species are called "crop wild relatives"(CWR). CWR are defined in many ways in scientific literature. The most common definition describes CWR as wild species that are genetically very similar to those currently cultivated in agriculture and horticulture (Maxted and Kell, 2009). More technically, a CWR would be defined as a "plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the crop" (Maxted et al., 2006). This definition refers to categories based on the genetic proximity of a given cultivated species and its wild counterparts. The Millennium Ecosystem Assessment (MEA, 2005) also defines these species as "wild species living and evolving in natural, semi-natural and/or artificial habitats, where their genetic diversity is influenced by a wide variety of factors, including habitat fragmentation and degradation" (Bellon, 2017, p.970).

Many authors agree on the importance of conserving and using CWR (Hajiar and Hodgking, 2007; Maxted and Kell, 2006; Maxted et al., 2010; Iriondo et al, 2016) as a means to strengthen food security and stability in agricultural production(Maxted and Kell, 2009; Maxted et al, 2010; Bellon, 2017; Iriondo et al, 2016). Using traits specific to CWR could improve cultivated species to make them more suitable for various environmental conditions. Improving cultivated species often involves introducing traits of resistance to biotic and abiotic factors (Maxted et al, 2010; Hajjar and Hodgkin, 2007; Zhang et al, 2016; Labokas et al, 2018). According to Maxted and Kell (2010), improving crops through CWR is a strategic approach for both researchers and farmers, who will be able to expect more stable yields through the use of improved varieties.

However, Maxted and Kell (2010) point out that CWR are poorly present in *ex situ* collections, and even under-represented compared to cultivated species, mainly for financial reasons. Thus, *in situ* CWR conservation seems to be a more interesting and cost-efficient approach. Although *in situ* conservation is not an end *per se*, it is a necessary step towards their use in the future.

In order to coordinate national and regional (EU) *in situ* conservation strategies, Maxted et al. (2007), in partnership with the European Forum for the Assessment and Conservation of the Diversity of Related Wild Species (PGR Forum), suggest a protocol and tools to make them more effective. England took their recommendations into account to develop a strategic plan for the preservation of CWR (Maxted et al., 2007; Scholten et al., 2008; Fielder et al., 2015; Labokas et al., 2018). The purpose of such plan is to establish genetic reserves in order to preserve the genetic resources of wild plants on the long term. They could then be a potential source of varietal improvement for breeding programs. The development of genetic reserves is a lengthy process requiring several steps. Throughout these steps, various resources and actors are mobilized to improve knowledge and know-how about CWR on the territory.

1.2 « Doing »

<u>1.2.1 Transformative effects beyond the initiative</u>

The following section describes the process as it occurred in England. The protocol that was followed (Maxted et al, 2007) involves three main steps to identify areas of high genetic diversity, and whose preservation could be helpful for the future of the agriculture and food production (because of the socio-economic interest of the conserved species). These *in situ* conservation strategies are intended to preserve species for a future use, in research and/or breeding programmes.

The policy framework for the development of the initiative included policy makersthe objectives of the Convention for Biological Diversity (CBD, 2011) and the Biodiversity Strategy for 2020 (Defra, 2011) of the Department of Environment, Food and Rural Affairs (Defra).

To kick-start the genetic reserve initiative, Defra called on researchers from the University of Birmingham and Natural England[1] to identify priority species for protection, in order to develop an effective long-term conservation strategy (Fielder et al., 2015).

The first step was to identify the species. Researchers at the University of Birmingham undertook the creation of a national inventory of the national territory's species. This inventory was done in partnership with the PGR Forum. The inventory was based on botanical surveys carried out in 1987 and 2004 (Fielder et al., 2012), which identified the species present in England and their abundance. In order to identify the CWR on the territory, the inventory was compared with various censi previously established for CWR, in particular the European and Mediterranean CWR catalogue (Kell et al., 2005).

The second step was to refine and prioritise the list of species identified in the inventory. Not all species identified can be protected due to limited funding (Maxted et al, 2007a; Fielder et al, 2015; Labokas et al, 2018). Priority criteria were developed by researchers from the University of Birmingham and Exeter andagents from Natural England and English Nature (a government agency for wildlife conservation). The six following criteria were selected: degree and type of use of the related crop, native character, economic value of the related crop, genetic proximity between CWR and the related crop (genepool), threat status and status of the area where it is found (indicator specific to England, which distinguishes between several types of protection and conservation areas) (Kell et al, 2005; Maxted et al, 2007a ; Kell et al, 2017 and Labokas et al, 2018). Most of all, England focused on species that could play a role in food security, for humans and animals (Fielder et al, 2015). A total of 223 species were prioritized. The research related to the construction of this inventory was partly funded by Defra, the PGR Forum, the fifth European framework programme for Energy, Environment and Sustainable Development (Maxted et al., 2007).

The third step of the protocol was to locate priority taxa in order to implement an effective conservation strategy. To do so, geo-referenced floristic data from the British Isles Botanical Society and the National Biodiversity Network were requested to provide a grid of the territory (Maxted et al, 2007; Scholten et al., 2008). The cross-referencing of the data allowed the identification of "hotspots", i.e. geographical areas that host a great diversity of CWR. Then, the location of these "hotspots" was overlaid with the protection and conservation areas already existing in England. This overlap allowed to identify areas that were already protected and those that were not (Maxted et al, 2007). The data were also compared to the accessions present in the *ex situ* collections. This cross-referencing data made it possible to identify the gaps in terms of conservation that are present in the territory, and thus to locate the most suitable place for the establishment of a genetic reserve. Due to limited financial resources, not all the identified "hotspots" were able to benefit from an analysis. Researchers focused on the first 17 identified "hotspots", which include two-thirds of the species on the priority list (Maxted et al, 2007).

Iriondo et al (2007) have observed that it is easier, particularly for economic reasons, to establish genetic reserves in areas that are already protected (Iriondo et al, 2007; Maxted et al., 2007). The 17 sites selected by the University of Birmingham corresponded to existing reserves (Maxted et al., 2007). Most protected areas have CWR, but the protection of these species is not included in their management plan. Therefore, they looked for a way to combine active conservation of CWR with existing reserves to ensure the conservation of CWR habitats in the long term. To this end, local authorities in charge of resource conservation had to set up specific monitoring of related species, particularly for their habitat control (Maxted et al., 2007; Labokas et al., 2018).

Following the identification of these 17 "hotspots", researchers characterised the genetic diversity present at each site. During the characterization of the "hotspots", Maxted et al (2007) highlighted the peculiarity of a site which hosted many CWR species. This site is located in the southwest of England on the Lizard Peninsula. This peninsula conserves 93 species of CWR out of 148 species and subspecies found in England, and many of its areas are already protected: natural sites, natural reserves, site of specific scientific interest (Maxted et al., date). In 2010, researchers from the University of Birmingham undertook a study on this site to assess the genetic diversity of CWR established in the Lizard Natural Nature Reserve (Osborme, 2010). Additional studies were carried out between 2012 and 2013 to analyse the genetic diversity of some of the species present in this territory. Natural England funded the collection and analysed samples of 8 CWR: wild chives (*Allium schoenoprasum*), wild garlic (or ramsons), (*Allium ursinum*); wild asparagus (*Asparagus prostratus*); marine beet, (*Beta vulgaris* subsp. *maritima*); sea carrot, (*Daucus carota* subsp. *gummifer*); marine raddish, (*Raphanus raphanistrum* subsp. *maritimus*); Western trifolium, (*Trifolium repens*) (Natural England, 2016).

[1] Government's adviser for the nature environment in England

 

Wild carrot from The Lizard (Natural England, 2016)

The University of Birmingham undertook genetic analyses: some species from this sampling had a unique genetic structure, specific to this site and not found in any other part of England (Maxted et al., 2015; Natural England, 2016). Various factors can explain the genetic specificity of CWR present on the Lizard: the geology of the area and the associated soils, the geographical location and the meteorological conditions (making this site one of the warmest in England), and finally a diversity of land use. The latter factors have created a singular habitat, influencing the genetic diversity of CWR. That diversity and the genetic distinctiveness of the CWR present on Lizard made it a prime candidate to set up an active conservation plan to preserve this genetic richness.

Consequently, further studies were carried out to localise CWR on the peninsula. The work carried out at the scale of the United Kingdom and on that of England was thus undertaken on the Lizard peninsula: identification of priority taxa, geographical distribution, superposition of this distribution on already protected areas.

Geographic analyses showed that CWR were mostly distributed between three conservation actors: Natural England, Natural Trust (already protected sites) and private landowners (mainly farmers). The largest proportion of CWR is located on Natural England and Natural Trust properties, within the Lizard Natural Nature Reserve or in areas of specific scientific interest (SSSI). As for farmers, the ten most important properties were identified. Those farmers received specific advice for the management of CWR present on their land.

Natural England, which is the manager of the Lizard Natural Nature Reserve, included the active conservation of CWR in its management plan. This modification of the management guidelines for the nature reserve enabled the implementation of an active preservation strategy for future use. The transition from conservation to use still needs to be made in order to achieve the initial objective of this initiative.

Thus, genetic resources are conserved in their habitats so they can continue to evolve in their natural environment. For now, their use is limited to analyses carried out by researchers of the University of Birmingham to identify the genetic diversity of the CWR on the Lizard peninsula. Samples from these analyses are kept at the Millennium Seed Bank, Kew (United Kingdom), but have not yet been used in breeding programs. For now, there has been no record of their use for plant breeding. Therefore, no seeds are multiplied or disseminated. In the future, it is possible that interested breeders can access information on the identified CWR by contacting the actors involved in multiplication and dissemination across and beyond the network. Seed distribution would take the form of a commercial exchange between the private owner who keeps the CWR on his land and the company/organization interested in the resources (Natural England, 2016).

1.3 « Organizing »

1.3.1 Properties WITHIN the initiative (closure)

Each member of the network is independent in his/her work, which contributes with that of all others to developing the conservation strategy.

Defra has placed the conservation of CWR on the British political agenda and encourages local stakeholders to implement active conservation plans (Biodiversity Strategy 2020). It provides financial support to Natural England and English Nature to implement policy guidelines for the conservation of CWR. Defra has also developed other programmes to safeguard genetic resources, including the UK Plant Genetic Resources program, chaired by Nigel Maxted of the University of Birmingham. Defra and this University are in fact collaborating to establish a coordinated management of national genetic resources.

The University of Birmingham supported this genetic reserve project by providing its technical and scientific expertise. The institution participated in the mapping and genetic characterization of CWR in the Lizard Peninsula, notably through Hannah Fielder's doctoral research work. What is more, University researchers were involved in the establishment of the reserve by making recommendations for the management of protected lands and CWR. The University of Birmingham (and more specifically Nigel Maxted) brings together the multiple actors involved in this conservation strategy.

Natural England and English Nature are two conservation organizations that operate in the field at national level. They develop and implement management plans for various natural areas. In collaboration with researchers from the University of Birmingham, they participated in the creation of the national inventory and the list of priority species.

Locally, Natural England is in charge of the management of the Lizard National Nature Reserve. In 2018, when drafting the new management plans for the site, Natural England formally included the active conservation of CWR in its conservation strategy (Nigel Maxted interview, 2019; Natural England, 2016). Natural England also works in collaboration with local conservation actors, such as the National Trust and Cornwall Wildlife Trust, who manage other protected areas on the peninsula. Together they are trying to develop a concerted and well-coordinated vision for the conservation of CWR. As mentioned above, Natural England and National Trust are the two largest landowners on the peninsula. Thus, if these two actors develop a concerted conservation action for habitats and species present on their lands, there is a fair chance that a population maintenance strategy could be implemented in the long term.

In order to achieve this objective, Natural England also works with private landowners on the peninsula to raise awareness and advise them on their practices and the impact they can have on CWR populations. For example, a presentation day for CWR was held by Nigel Maxted in the presence of stakeholders interested in the matter in order to highlight the importance of CWR. Natural England agents also advise on appropriate farming practices and visit farms to provide personalised advice to any stakeholder who wishes to be involved.

In the future, local conservation organizations may be able to facilitate access to *in situ* genetic resources for the users, due to their positive and close relationships with landowners. Following the owner's' authorization of access, those in charge of the selection and/or research programs will be allowed to come and take samples. Commercial negotiations for the use of the resources will be undertaken between the stakeholders concerned (Natural England, 2016).

While conservation actors are adapting their practices and sensitizing landowners to do the same, Defra has not officially recognized the genetic reserve on the peninsula, because Defra fears it would have to bear the financial costs of managing a new reserve. According to Nigel Maxted (interview 2019), this essentially financial concern is unfounded with regard to the future benefits and uses of CWR.

<u>1.3.2 Properties BEYOND the initiative (outreach)</u>

In order to make the work carried out on the Lizard Peninsula visible, local conservation organizations have been contemplating ways to promote CWR. Nothing has been started yet, although some ideas have been formulated, such as using media and/or social networks, which are communication devices that could give visibility to the CWR and their conservation strategies (Natural England, 2016).

In order to move from conservation to utilization, genetic resources must be accessible to future users. The Kew gene bank (Millenium Seed Bank) has some samples from Lizard but lacks funds to conserve all the species present on the peninsula. Therefore, in order to make CWR visible, information about them must be transmitted. The national inventory fulfils this function and conveys the particularities of the sites where CWR are located (e. g. soil and climate). What is more, the various national catalogues are recorded in the European EURISCO Catalogue (Maxted and Kell, 2009) which provides information on the different accessions in genebanks, but also on the species that are found *in situ*. Thus, with the help the European coordination for the preservation of genetic resources, the CWR of the Lizard peninsula have a greater visibility. The specific soil and climate conditions on the Lizard are also described in the inventories and contribute to providing relevant information about the CWR of the peninsula. The drylands in this area are particularly interesting to future breeding programs, allowing to focus their breeding work on drought-tolerant species, for example. Thus, inventories are also important to raise the interest of potential users. Research programmes and/or breeders who consult the inventories can then know where they need to go to access the genetic material they want.

H. Fielder with *Beta Vulgaris* subsp. *maritima* on the Lizard peninsula (Fielder et al., 2015)

PART 2: ANALYSIS

2.1 Knowing

2.1.3 Transformative effects beyond the initiative

Knowledge about the importance of CWR and about the importance of their conservation is created by academic actors: researchers from the University of Birmingham and mostly by Nigel Maxted. Hehas been working with his team for several years on CWR. The research results of his team are communicated in numerous scientific articles that serve as a knowledge base for the network (see Annex 1 and bibliography). These scientific articles allow knowledge to be recognized and discussed beyond the network, notably in scientific arenas and contribute to raising awareness among new actors about the utility of CWR.

What is more, within the network, researchers from the University of Birmingham worked in collaboration with Natural England actors to identify the territory's "hotspots". A first study (2007) was carried out solely by researchers from the University of Birmingham. In 2016, Natural England repeated the geographical analyses of these "hotspots", to take part in the process and to confirm the results. Thus, most of the knowledge that builds and animates the network comes from scientific skills and knowledge which are built upstream of the network but applied to the establishment of the reserve. The academic actors have passed on their knowledge and know-how to the field actors so they can be mobilized and put it into practice. Nigel Maxted made a presentation, followed by a discussion with stakeholders on the Lizard Peninsula, to share with them the challenges and interests of CWR conservation. He also made recommendations to Natural England on land management and conservation to ensure the preservation of CWR habitats.

Natural England used these recommendations to modify the management plan for the Lizard Natural Reserve, which caused CWR to be actively conserved on the Lizard Peninsula. The implementation of this active conservation was enabled through the advice and awareness-raising work of Natural England. As field actors and manager of the Lizard, Natural England also participated in the dissemination of knowledge within the network, transmitting the recommendations made by researchers to the farmers.

2.2 Framing

2.2.1 Properties WITHIN the initiative (closure)

Beyond the example of the Lizard peninsula, two elements emerge from CWR conservation strategies.

First, there is a general desire to preserve and conserve CWR for the maintenance of agriculture in the future. Due to climate change (IPCC Report, 2007), the agricultural sector will face many challenges. Limited water resources, soil salinity and the development of diseases are all issues that will affect it, with a significant impact on yields. The stakeholders in the CWR conservation argue that the use of CWR could provide solutions to these challenges, particularly through the use of resistance traits. Conservation strategies are important for supporting the agricultural and food sector, and our food security.

Second, conservation strategies are aimed at research centres and breeding programmes. These actors have the financial resources and adequate technical equipment to carry out analyses, isolate resistance characteristics and create new varieties. It appears that these conservation strategies are better intended for the private sector, which has the financial resources and the time to carry out this type of research. However, nothing prevents researchers and/or public institutions from using these genetic resources. Thus, research and/or breeding programs are in direct need of the genetic resources preserved in these reserves. However, they are intended for farmers in a second stage. Among the varieties that are most useful to farmers are those whose resistance or tolerance to different stresses has been improved. (See Annex 1).

2.2.2 Properties BEYOND the initiative (outreach)

This point was partly discussed in section 2.1, in particular with regard to the scientific articles written by researchers at the University of Birmingham. Many scientific articles link CWR conservation and the incoming food security issues. Both are linked, as the use of these genetic resources could be one of the ways to develop a more resilient agriculture in the face of climate change. With increasing concerns about the impacts of climate change on the agricultural and food sectors, the conservation and use of CWR seem to be increasingly explored. The establishment of genetic reserves is a way of discussing the conservation and use of CWR.

What is more, the diversity of actors (researchers, public administration, park managers, preservation associations) in the network also seems to be an effective way to make CWR conservation public. Indeed, these actors reach different audiences because their objectives diverge, and their roles in establishing the reserve are not identical.

The political sphere, represented by Defra, has placed the conservation of CWR on its political agenda. This politicization allowed to show that some regions are taking up the recommendations made by researchers regarding the conservation of genetic resources.

Academic actors acknowledge the relevance on questions related to the importance of CWR conservation, namely for future plant breeding programs in a context of a changing climate. Data and results are discussed among peers and could serve as a basis for further studies. These publications contribute to the interest in CWR and legitimize their inscription on political agendas.

Also, the tools developed to facilitate the implementation of conservation strategies, including inventories, are relevant and effective means for transcending network boundaries. These national inventories are listed in a European catalogue (EURISCO).

2.3 Networking

The University of Birmingham can be considered the central actor of the network. However, the importance of Nigel Maxted needs to be emphasised. Through his incredible experience and the credibility of his functions (researcher; president and/or actor of programmes for the conservation of genetic resources, etc.), he was able to get other actors on board. These actors generally act on the recommendations made by Nigel and his team. Maxted was able to raise the potential of each actor and bring them together around the common objective of conserving the UK's CWR and particularly those of the Lizard Peninsula. What is more, the tools developed, allow the actors who gravitate around the genetic reserve network to collaborate (the inventory is a good example). Potential users are informed of the existence of the different genetic resources and their specificity through these tools. Other networks of conservation experts and/or botanists can take advantage of these tools and of the information they provide.

Natural England fulfils several roles: it provides a link between the political level, the academic level and the local level, working both on the creation of the inventory and on implementing the management plan and/or raising awareness among landowners. Natural England also acts as an interface between the academic world and the agricultural world.

PART 3SUMMARY

Three lessons can be drawn from this case study. They are hypothetical because the objective of using CWR has not been yet achieved.

First, the heterogeneity of the actors of the network seems to be a determining factor in implementing an effective and relevant conservation strategy. Thanks to a heterogeneous collective, the resources that can be mobilized are greater, the different stakes of each part of the collective can be brought together around a common objective, and a greater diversity of actors can thus be affected by the initiative. The CRW purpose is based on a scientific framework concerning the production of knowledge and the capacity to interest political and administrative actors.

The second learning concerns the economic value of the conservation strategy. The involvement of stakeholders, apart from conservation organizations, requires highlighting the economic interest in safeguarding CWR. That is why the priority protected species are those with a socio-economic interest, and why it is important to remember that the final use of CWR is through commercial exchange.

Thirdly, there seems to be a gap between strategies that are intended to be long-term and others that act in the medium and/or short term. The conservation of plant genetic resources is a long-term strategy that requires immediate funding for its implementation. The breeding programs are medium term, requiring about fifteen years to create a new variety. Political strategies are on a much shorter time scale since policy makers are regularly renewed. Thus, several time scales come under tension, which can weaken the implementation process.

Annex

Since the early 1990s, several events have followed one another and highlighted the importance of *in situ* genetic resource conservation at the global level, such as the Convention on Biological Diversity in 1992, the FAO International Treaty on Plant Genetic Resources for Food and Agriculture in 2001 (FAO, 2001). *In situ* conservation of genetic resources applies to both domesticated species, that are multiplied on farms and to wild species related to them (Convention on Biological Diversity, 1992; Maxted et al., 2006; Bellon et al., 2017). Since the 2010's, the conservation of Crop Wild Relatives (CWR) is included in many international and regional treaties (CBD, 2010; FAO 2011; EP2012; CBD, 2015).

CWR conservation is recommended for a potential future use. Due to their genetic proximity to crop, CWR can be used in breeding programs. Resistance traits are used to improve the genetic potential of our cultivated plants. Some resistance traits can become evident because some CWR are evolving in environments where they are forced to adapt in order to survive. Currently, new functional characteristics are being studied, including tolerance to biotic and abiotic stress. Indeed, tolerance to the various environmental factors such as drought, extreme temperatures and soil salinity are genetic criteria sought after in related species.

Thus, the use of genes from wild plants is now recognized by several authors (Hajjar and Hodgking, 2007; Maxted and Kell, 2009; Maxted et al, 2012) as one of the way to ensure food security and stability in the agricultural world due to a socio-economic potential that may emerge from these species (Maxted and Kell, 2009; Bellon, 2017).

In the 1970s, new actors began to develop an interest in the genetic potential of CWR. Crop improvement programs carried out by research centers have testify to this interest. The development of knowledge in the field of genetics and biotechnology has contributed too. Scientific progress in DNA sequencing and molecular technologies allowed crossing more distant species (in terms of genepool) and to select specific genes for crop improvement (Biodiversity International, 2007; Hajjar and Hodgkin, 2007, Monteiro, 2013).

Today, improving crops through their wild relatives is a strategic approach for both research centres and farmers, as the use of resistant varieties allows them to stabilize and/or increase yields (Hajjar and Hodgkin, 2007; Maxted et al, 2008; Dempewolf et al, 2014).

However, according to Biodiversity International (2007), CWR are threatened. The destruction of their habitats reduces their geographic distribution and affect the size of their populations and their genetic diversity. The destruction of their habitats can be explained by several factors: intensive agriculture, tourism and urban development. Maxted et al. 2009 points out that habitat degradation can affect the intraspecific genetic variations of a population, which affects their ability to respond to environmental pressures.

Regarding the decline of CWR habitats, and in order to respect the objectives of international treaties for the conservation of plant genetic resources (FAO 2001, 2011; CBD 2010, 2015; EP2012), conservation programs have emerged. They are implemented to preserve the CWR diversity both *in situ* and *ex situ*. There are different types of conservation programs: some are carried out internationally by international research organizations such as Biodiversity International and with the support of the United Nations Environment Program, in collaboration with other actors and funded by entities such as the Global Environment Fund; while others depend on the interest and finances of each country (Labokas et al, 2018).

Although there are various ways to implement conservation strategies for CWR, a protocol and tools have been developed by researchers in partnership with the European Forum for the Assessment and Conservation of Relative Diversity of Related Wildlife Species (PGR Forum) (Maxted et al., 2007) to coordinate *in situ* conservation planning at national and regional (EU) levels. Maxted et al (2007) propose key steps to make the implementation of a conservation strategy for future potential use more effective.

The first step aims to produce a national inventory of CWR taxa present in the territory. This inventory will enrich the European database and create a catalogue for Europe and the Mediterranean region (PGR Forum, 2005; Kell et al., 2007).

The second step aims at establishing a priority list of taxa to be protected according to their threat status or economic interest. The priority list results from the interest and direction that countries decide to take in terms of conservation.

The third and final step is to combine previously collected data with existing biogeographic and chorology data in order to highlight the distribution and location of the species to protect. Cross-referencing the data from this third step helps to identify threats and gaps in the conservation of CWR diversity in a territory. The identification of these threats and gaps will serve as a basis for the implementation of an *in situ*, but also *ex situ* conservation plan.

The aim of these conservation strategies is to cover as much diversity as possible and that is why Maxted et al (2013) advocate for a dual approach, *in situ* and *ex situ*. The combination of these two approaches allows for a compensation of the under-representation of certain taxa in gene banks. For *in situ* conservation, the use of biogeographic data results in the possibility to identify hotspots and complementary areas. The identification of hotspots and complementary areas should then be cross-referenced with existing natural protection areas in order to identify gaps and establish national reserves specifically dedicated to the protection of CWR in areas of high diversity (Maxted et al., 2007).

Labokas et al (2018) reported that some States (Germany, Portugal, Finland, United Kingdom) have taken up these recommendations and have begun to develop their conservation strategies and plans. While these strategies are being developed at the national level, the European Program for Plant Genetic Resources (ECPRG) supports the combination of *in situ* and *ex situ* conservation. The ECPPRG aims at ensuring the long-term conservation and use of plant genetic resources in Europe and has recently highlighted the importance of *in situ* conservation of related wild species (ECPRG, 2015). In order to meet its objectives, the ECPRG operates as a species-specific working group, where a range of actors collaborates to identify, protect and use wild genetic resources.

In summary, knowledge of CWR has increased significantly in recent years, particularly because awareness was raised concerning their value for climate change, in order to ensure long-term production and food security (Kell and Maxted, 2009; Maxted et al., 2012, 2015, 2018). In addition, knowledge in terms of planning and implementation of *in situ* conservation strategies has been developed with the aim of establishing coordinated approaches across Europe (Maxted, 2007).

However, according to Maxted et al (2015, 2018), despite the interest in CWR, the lack of collaboration between the actors involved seems to be an issue. State agencies and/or agencies responsible for wild genetic resources are separate from those responsible for agriculture and food resources. While sharing conservation approaches with both may be a key element to foster collaboration, it is not enough to put in place effective conservation strategies. Another element necessary for adequate coordination seems to be the establishment of a harmonized legislation and a responsible agency at European level (Maxted et al., 2015, 2018). These two elements would increase public support and therefore funds to implement these conservation plans, as their success appears to be determined by policy interest. (Maxted et al., 2018). Indeed, very few countries have really implemented conservation plans or reserves specific for the preservation of related species. Many countries are still in the process of establishing their inventories and the use of CWR in breeding programs is not yet relevant. Thus, many challenges hinder the implementation of conservation strategies, but examples such as the United Kingdom can highlight collaboration between different political organizations that promote coordinated strategies.

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