Plant Genetic Resources: Characterization and Utilization

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Development of a consolidated descriptor list to support *in situ* conservation of plant genetic resources‡

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Abstract

There are increasing calls for greater availability of plant genetic resources (PGR) for use in plant breeding to help counter the adverse impacts of a changing climate and threats from pests and diseases, particularly in a context of reduced agricultural inputs, and the needs of the increasing human population. Managing and promoting *ex situ* and *in situ* conservation of PGR requires an effective data and informatics foundation. However, *in situ* data management is particularly undeveloped, especially when compared to *ex situ* documentation. The work presented here is a consolidated descriptor list to support *in situ* conservation of PGR. The consolidated PGR descriptor list is based on numerous partial lists collated from historic PGR activities, biodiversity conservation and protected area networking activities. New descriptors for *in situ* conservation activities were developed where gaps were identified. The draft consolidated PGR descriptor list was reviewed and revised through a process of consultation with experts in PGR documentation and *in situ* conservation. In total, 171 descriptors were identified, of which seven are defined as mandatory, 47 are defined as core descriptors and 29 are newly developed descriptors for *in situ* conservation of PGR. The descriptors cover all aspects of *in situ* conservation, from gathering passport data (for which there are already well-established descriptors), to monitoring and managing crop wild relative and landrace populations. Recommendations are made for the most effective use and future development of descriptors and how they could be used to further develop and support *in situ* PGR conservation implementation.

Introduction

Plant genetic resources (PGR) are the foundation of our food system as they contain a broad range of genetic diversity potentially useful for plant breeding and crop improvement. To ensure a robust and sustainable food system capable of withstanding climate change, pests, diseases and increasing food demands, the identification, documentation, conservation and utilization of these resources are imperative (Alercia *et al.* 2015; FAO 2025). Lack of access to a greater breadth of genetic diversity is now unnecessarily limiting crop improvement (McCouch *et al.* 2013; IPCC, 2014), with the value of PGR dependent upon the availability of relevant descriptive data to aid germplasm selection and its use (Gotor *et al.* 2008).

PGR are conserved using two main strategies and their associated techniques (CBD 1992). *Ex situ* conservation involves PGR population sampling, transfer to a secure location and potential long-term population maintenance. This is the well-established PGR conservation model whose effectiveness is well recognized and is responsible for over 5.9 million seed accessions in 852 national genebanks across 116 countries, 4 regional genebanks and 13 international genebanks (FAO 2025). *In situ* conservation is the maintenance of the PGR where they occur, either cultivated on-farm and in-garden or as wild populations in wild and semi-natural habitats (Maxted *et al.* 2020). Under *in situ* conservation, PGR populations continue to evolve and respond to environmental changes, within their natural habitats or on-farm systems, while retaining their adaptive diversity. The application of *in situ* conservation techniques focuses on three types of PGR: crop wild relatives (CWR), wild harvested plants (WHP) and landraces (LR; Maxted *et al.* 2020). CWR and WHP conservation takes place within genetic reserves (as defined by Maxted *et al.* 1997), these may be within designated protected areas (albeit often protected by passive conservation measures) or other effective area-based conservation measures (OECM), while LR conservation takes place on-farm or within a home garden. These conservation techniques contrast with *ex situ* conservation, where resources (e.g. CWR, WHP, LR) are collected, moved and stored in another location such as a genebank, field genebank, community seedbank or botanical garden. It is widely accepted that *in situ* and *ex situ* implementation actions should be applied in a complementary manner, where one conservation application enhances and backs-up another (FAO 1996). The application of specific *in situ* PGR conservation techniques has thus far been limited (Maxted *et al.* 2016), but the associated science and its implementation is advancing rapidly, and it is recognized that wider *in situ* implementation has the potential to at least double the PGR diversity available to breeders and other users (Maxted and Magos Brehm 2023). However, a doubling of diversity can only be achieved if methods for conserving PGR *in situ* are applied in a coherent and effective manner across institutions and across countries, and this is dependent on an effective and appropriate PGR data and informatics foundation.

Lack of access to data and the scarcity or absence of exchange of information as well as decision-support tools, which simplify complex tasks, are key factors affecting the effectiveness of conservation and use (Bioversity International 2007; Maxted *et al.* 2020). Due to the complexity of *in situ* PGR systems (as described in Maxted *et al.* 2024), there is a need to progress the development and use of shared data management and analysis tools for *in situ* resources, particularly in data collection and monitoring. Such data management tools and analysis packages can help significantly in ensuring that different countries operate in comparable manners further facilitating ease of data exchange and integration (Stephenson and Stengel 2020).

One method to help facilitate the collection of appropriate PGR conservation data is through the use of descriptor lists. Descriptor lists are used in data management to provide a standardized approach to documenting data and have been extensively developed by Bioversity International and the FAO since 1976 (Gotor *et al.* 2008) to help describe plant germplasm. PGR descriptor lists were initially developed in the 1970s to describe a minimum set of characteristics for a specific crop and then evolved in the 1990s to include comprehensive lists with a minimum set of highly discriminating descriptors (Gotor *et al.* 2008). Due to long-term implementation of *ex situ* conservation techniques over the last 100 years, there are well developed systems for data description, management and exchange of passport data with widely accepted standards and descriptors for the minimum data required for *ex situ* conservation (Gotor *et al.* 2008; Alercia *et al.* 2015). Such data infrastructures help to create a rapid, reliable and efficient means for information exchange, storage and retrieval to facilitate the effective conservation and utilization of germplasm (Gotor *et al.* 2008), the latter being a key reason for PGR conservation. The development of the FAO/IPGRI List of Multi-Crop Passport Descriptors (MCPD) in 2001 provided international standards across crops to facilitate germplasm exchange and is now the standard documentation procedure used in *ex situ* conservation activities (see Alercia *et al.* 2015 for the most recent iteration of these descriptors).

Several *ex situ* PGR descriptor lists already exist for conservation measures and some of these descriptors have potential for dual application for *ex situ* and *in situ* conservation. In parallel, specific *in situ* conservation descriptors have begun to appear. For CWR these include: a Crop Wild Relative Markup Language (CWRML) (Moore *et al.* 2008); Quality standards for genetic reserve conservation of CWR (Iriondo *et al.* 2012); Core CWR descriptors for *in situ* conservation (Thormann *et al.* 2013); Joining up the dots: a systematic perspective of crop wild relative conservation and use (Maxted *et al.* 2016); Crop wild relative checklist and inventory descriptors v.1 (Bioversity International and University of Birmingham 2017); Occurrence data collation template v.1 (Magos Brehm *et al.* 2017a); CWR checklist and inventory data template v.1 (Thormann *et al.* 2017); FAO Descriptors for CWR conserved *in situ* (Alercia *et al.* 2022); and Descriptors for uploading *in situ* CWR passport data to EURISCO (EURISCO 2025). For LR, existing descriptor lists include: Descriptors for *in situ* LR conservation (Negri *et al.* 2012); Descriptors for farmers' knowledge of plants (Bioversity and The Christensen Fund 2009); and *in situ* LR propagation management and access guidelines (Caproni *et al.* 2020). Descriptors which are relevant for both CWR and LR are discussed in the "Concept for a possible extension of EURISCO for *in situ* CWR and on-farm LR data" (Weise *et al.* 2020). WHP do not currently have any specific existing descriptors for *in situ* conservation, but it is assumed that these will be equivalent to those used for CWR as they are both wild plant species and in many cases they are the same species, for example, according to Ciancaleoni *et al.* (2021) 94% of Italian WHP species are also CWR when the taxon group approach is applied (Maxted *et al.* 2006). The work on integrating *in situ* descriptors into EURISCO (van Hintum and Iriondo 2022; Kotni *et al.* 2023; Maxted *et al.* 2024) is already enabling countries to input and store data on *in situ* populations of PGR to make these data accessible for users of germplasm. However, although there has already been some work done on the development of *in situ* descriptors for PGR, there is no single point to access all descriptors and some descriptors, specifically those related to *in situ* conservation actions, are missing. Such a complete list of descriptors would be applied by those managing *in situ* conserved PGR, with a subset of these being incorporated in the various platforms (such as EURISCO) that aim at enhancing the use of these resources via sharing the data with potential users.

A further critical characteristic of PGR data and information is that CWR, WHP or LR can be described at two different nested levels: the taxon or LR level, and the population level. The taxonomic or LR data are often linked to the creation of the checklist or inventory and includes information such as: taxon or LR names and authorities, threat status, characterization data and legislative protection. On the other hand, population data is linked to a subset of information, such as population distribution, size, and management as well as observational data and experimental or evaluation data related to the population being monitored (Maxted *et al.* 2020). The taxon and population level distinction are not mutually exclusive, with most PGR data sets containing both taxon and population data.

The aims of this study were (a) to compile a consolidated list of all standards and descriptors related to the documentation and management of *in situ* conserved taxa and populations of PGR (CWR, WHP and LR); and (b) to review the consolidated list to identify descriptor gaps and, where gaps exist, propose new descriptors.

Methods

Description of the PGR conservation process

To create a comprehensive descriptor list for PGR conservation, we must first understand how PGR conservation is routinely implemented, describe the process and only then can we locate the data, conduct a gap analysis of current descriptors and fill gaps to generate the consolidated descriptor list. Such a descriptive clarification was recently undertaken by partners within the EU funded PRO GRACE project (https://www.grace-ri.eu/pro-grace), summarized by Maxted *et al.* (2025). They proposed the process is founded on three *Principles of PGR Conservation and Use Congruence*: (a) long-term, sustainable maintenance of PGR diversity, (b) active conservation and characterization of crop, varietal and related wild taxon diversity using complementary techniques, and (c) conserved resource documentation and availability for utilization within the applicable legislative context. PGR conservation and use is a continuum as reviewed in Maxted *et al.* (2020, 2025) and summarized in Figure 1 with three steps:

1. *Plant genetic diversity* – the base resource;
2. *Conservation* – the planning and implementation stages;
3. *Use* – characterization, evaluation and genetic diversity utilization.

Each of these elements can be subdivided and is associated with distinct data types, as listed in Figure 1. Each element will have descriptors associated with it.

Consolidation of available PGR descriptors in relation to in situ *conservation*

To create a comprehensive descriptor list for the PGR *in situ* conservation process, all previously developed descriptors for PGR were collated (see Table 1) into one database. These included the Multi-Crop Passport descriptors (Alercia *et al.* 2015) which are also equally relevant to *in situ* conservation activities. Many of the descriptors were duplicated across the references but with slightly different names or descriptions. The duplicates were consolidated by merging descriptors which were similar in terms of their name and/or descriptions, or by keeping the most commonly applied descriptor name or description. All duplicated descriptors were noted so reference back to the original descriptors can be made.

The categories of descriptors, illustrated in Figure 1 and Table 1, can be applied at different levels related to the individual taxon, the individual LR or the population as a whole. This differentiation has implications for how data are collected in the field and the use of that data for conservation planning. Below, each descriptor category is explained and the level at which data should be collected is identified.

Conservation planning (taxon, LR and population level):

- Passport data (taxon, LR and population level)
  - o Data associated with the inventory, population or accession. These help to keep associated data organized and provide a key reference linking datasets to each other. Information includes: national checklist and inventory code; regional inventory code; managing body information (for both *in situ* and *ex situ*); population/sample origin; population code, and DOI (Digital Object Identifier) (Alercia *et al.* 2018) information (for both *in situ* and *ex situ*).
- Checklist/inventory data (taxon, LR level)
  - o PGR checklist – Initially a checklist of all relevant PGR within a defined area. A checklist could be produced for a particular PGR (e.g. CWR, WHP or LR), at different levels, such as global, regional, national (the most common), local, or based on a particular area (i.e. a protected area). The checklist contains a list of core taxon information for CWR or WHP, or a list of core LR information, including: taxon/LR ID; taxon name or LR name; family, genus, species, authority of the taxon name; rank, synonyms and a photo or image.
  - o Annotated checklist – These data are recorded not for individual accessions or populations but are focused on the taxonomic or LR level and usually relate to national level prioritization. The checklist is annotated with information that aids with prioritization, including: related crop information; gene pool or taxon group concept type; related crop/LR use; breeding use, general distribution, socioeconomic data and threat assessment information.
  - o PGR inventory – The inventory is a subset of the checklist that contains priority taxa/LR identifier and additional data that includes: common name of the taxon or LR; taxon/LR biology details and taxon/LR conservation action information (both *in situ* and *ex situ*).
- Ecogeographic survey and gap analysis (taxon, LR and population level)
  - o Taxonomic, ecological, geographic and genetic information that is gathered as a basis for the ecogeographic survey and the gap analysis. In addition to the data management and passport data descriptors, these data include: detailed location and distribution information of the *in situ* population; presence within a protected area; ecological and habitat information (such as soil type).

Conservation implementation (population level):

- Site/population management information (population level) – A management plan will be put in place for a site that contains the target CWR, WHP or LR populations. Data generated

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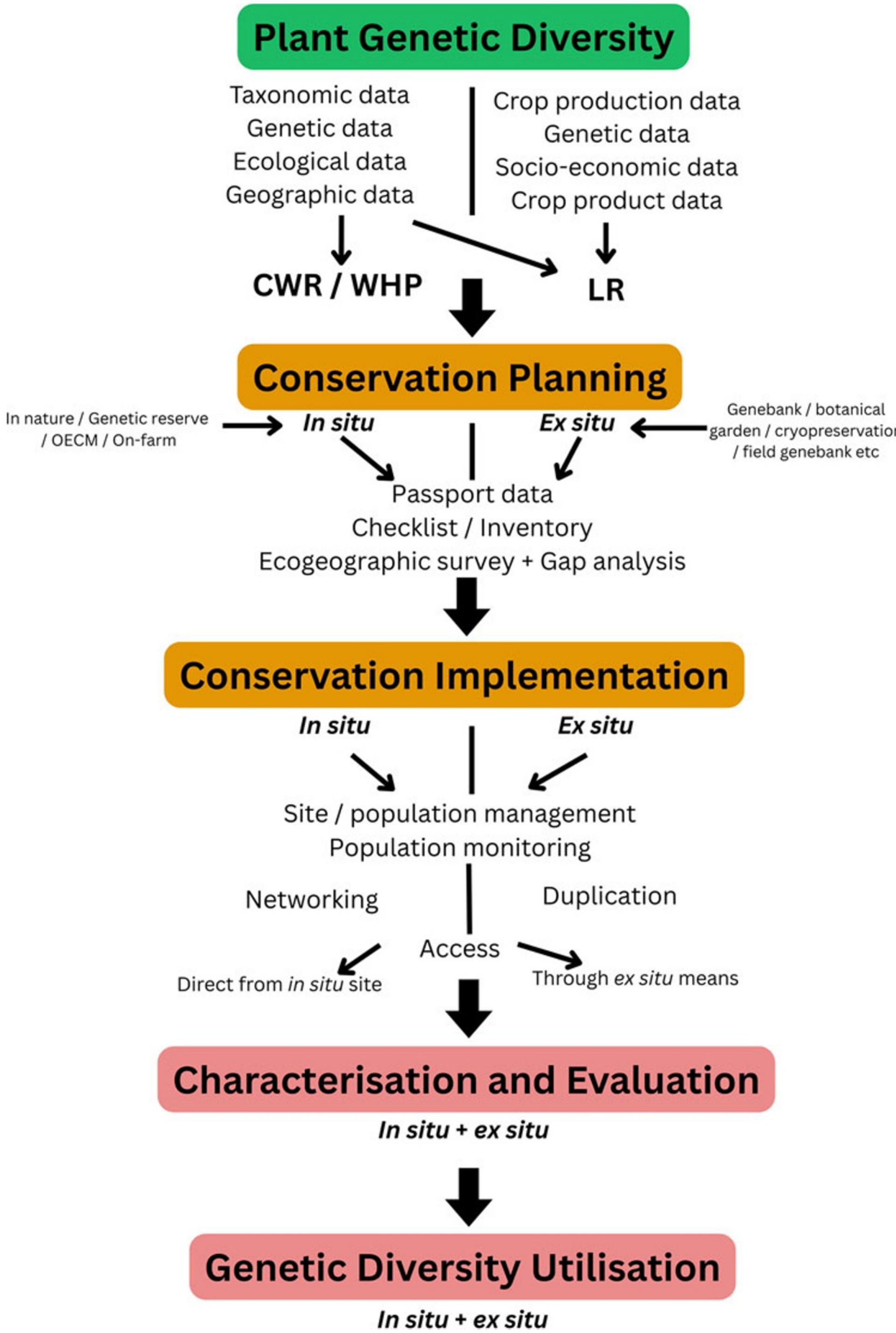

Figure 1. Continuum between PGR conservation and use, showing the links between genetic diversity, conservation actions, and utilisation through associated data types and descriptors.

from this management include: the managing body or maintainer information; management interventions; conservation actions taking place; population sampling and periodic resampling for *ex situ* backup conservation; characterization and user access.

- Population monitoring (population level) – Once sites or populations are being managed for conservation, then monitoring will need to take place. Time series data generated from this process includes: loss risk of LR; continuity of growing LR; cultivation period; status on-farm; regeneration *ex situ*; herbivore impacts; vegetation height; negative habitat features; habitat availability; population information (numbers, frequency); threats to population; monitoring of genetic diversity (including genomic and phenotypic data) and habitat conservation activities.

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Table 1. The different categories of descriptors with a list of corresponding references. The references refer to literature where particular descriptors have previously been published and have been included in the consolidated descriptor list. Some descriptors fit into more than one category

Category of descriptor	Key references
Conservation Planning – Includes passport data, checklist and inventory information, ecogeographic survey and gap analysis data.	**LR**: Bioversity and The Christensen Fund 2009; Negri *et al.* 2012; Caproni *et al.* 2020; Weise *et al.* 2020 **CWR/WHP**: JNCC 2004; Bioversity International 2007; Moore *et al.* 2008; Wieczorek *et al.* 2012; Thormann *et al.* 2013; Alercia *et al.* 2015; Bioversity International and University of Birmingham 2017; Thormann *et al.* 2017; Magos Brehm *et al.* 2017a, 2017b; IUCN Red List Technical Working Group 2018; Weise *et al.* 2020; Darwin Core Maintenance Group, 2025; Alercia *et al.* 2022; Armstrong *et al.* 2023; Almeida *et al.* 2024; EURISCO 2025
Conservation implementation – Includes management, monitoring, *in situ* networking information, duplication and access	**LR**: Negri *et al.* 2012; Weise *et al.* 2020 **CWR/WHP**: Moore *et al.* 2008; Thormann *et al.* 2013; Alercia *et al.* 2015; Maxted *et al.* 2016; Maxted *et al.* 2016; IUCN Red List Technical Working Group 2018; Weise *et al.* 2020; Alercia *et al.* 2022; Almeida *et al.* 2024; EURISCO 2025
Characterization and Evaluation – Descriptors which are often specific to crops and used in *ex situ* activities. These are outside the scope of this paper.	See Bioversity International (2007) and Alercia (2011) for information on detailed crop specific descriptors
Utilization – Includes information on how the taxa may be used	**LR**: Negri *et al.* 2012; Caproni *et al.* 2020; Weise *et al.* 2020 **CWR/WHP**: Wieczorek *et al.* 2012; Thormann *et al.* 2013; Alercia *et al.* 2015; Weise *et al.* 2020; EURISCO 2025

- *In situ* networking (population level) – *In situ* conservation networks of sites and populations should be established where possible to ensure the range of diversity of a taxon (as recorded in previous data collection) is efficiently and effectively conserved within a meta-population context. The network can be at a local, national, regional and global scales. Data associated with the creation of a network include: the number of sites in a network; the scale of the network; if samples of the *in situ* network populations are backed-up and/or conserved *ex situ* (this information should be harmonized with *ex situ* information); *ex situ* backup samples (see below).
- *Ex situ* conservation and *in situ* backup (population level) – *In situ* population collection and safety *ex situ* duplication are essential for complementary conservation, characterization and to promote utilization. This is distinct from *senso stricto ex situ* conservation, where a wild or cultivated population is sampled, collected and placed in an *ex situ* facility, but the original sampled population is not being actively conserved *in situ* or on-farm. Whether the sampled population is an *in situ* backup or a normal *ex situ* sample, existing *ex situ* descriptors can be used to describe the accession. *Ex situ* descriptors have been widely developed and utilized (Alercia *et al.* 2015) with a recent project producing descriptors that bridge the gap between *in situ* conservation and *ex situ* back up (Weise *et al.* 2020; van Hintum and Iriondo 2022; EURISCO 2025). Both the *in situ* and *ex situ* conserved resource can be backed up *in situ.* when a sample is taken from an actively conserved *in situ* population, and *ex situ* when the sample is duplicated across multiple genebanks. These descriptors incorporate *ex situ* data which includes information on: *ex situ* institute; *ex situ* accession number; and provides information on the *in situ* population DOI from which the *in situ* backup sample was collected.
- Access to *in situ* conserved populations (population level) – Whether the population is conserved *in situ* or *ex situ*, it is essential that potential users can access the conserved resource. For *in situ* resources this could most effectively be provided from the *ex situ* backup, or less easily from the *in situ* population. Descriptors for *in situ* access include the Multilateral System status of the *in situ* material (Alercia *et al.* 2022) and *in situ* population access. The record needs to clearly show that national or international ABS legislation has been adhered to in relation to the provision of user's samples from the *ex situ* backup.

Characterization and evaluation (LR and taxon level):

- Specific characterization and evaluation descriptors have traditionally been developed separately to *ex situ* conservation descriptors. They have been directly associated with *ex situ* conservation activities and have been developed for over 115 crops (see the Bioversity Descriptors at https://hdl.handle.net/10568/56589; Alercia 2011). Characterization and evaluation descriptors are crop specific and must be defined for each new crop being utilized (Bioversity International 2007). It is assumed that practical characterization and evaluation is independent of the mode of conservation being used, and descriptors developed in the *ex situ* context will be equally applicable for *in situ* conserved CWR, WHP and LR germplasm. Also, practically it seems unlikely that characterization and evaluation will be conducted on *in situ* populations due the lack of expertise in these assessments of the *in situ* population maintainers (individual farmers or protected area managers) and therefore it is much more likely that the necessary characterization and evaluation will be carried out on the backup sample of the *in situ* resource which is held in the genetic resource centre.

Utilization (taxon, LR and population level):

- Sustainable utilization of PGR is a fundamental reason for the conservation of PGR. These resources can be used by plant breeders and farmers (for LR material) and may also have a direct market use as food or medicine. The following data may be collected: any geographical designation or registration (for both LR and WHP); variety registration (for LR); DOI registration; use by breeders; market demands; product use; part of plant used; reasons for growing or harvesting the taxon from the wild and socioeconomic value.

Selection of the descriptors

Using the methodology outlined above, the existing descriptors relevant to *in situ* conservation (Table 1), were evaluated against the descriptor categories associated with the *in situ* conservation process (Figure 1). Gaps were identified where there were no existing descriptors covering a particular descriptor category. These new descriptors were generated through a process of consultation and review with experts. New descriptors were given a definition and description to ensure ease of use. Consistent with previous PGR descriptor lists (Alercia *et al.* 2022; EURISCO 2025) a 'Mandatory' set of descriptors was identified as the minimum amount of data required for the *in situ* material. Furthermore, a more extensive prioritized subset of descriptors, known as the 'Core' descriptor set, was identified to enhance data collection efficiency, as suggested by Thormann *et al.* (2013), Magos Brehm *et al.* (2017b), Alercia *et al.* (2022). Finally, a 'Recommended' set of descriptors were identified to incorporate the breadth of data that may be possible to collect for the *in situ* material. This strategy enables recorders to prioritize essential information for each *in situ* conservation activity, while remaining flexible to include additional relevant data where appropriate. The descriptor lists were then reviewed by a panel of 22 experts from the PRO-GRACE project consortium, and the ECPGR CWR, On-farm Conservation, and Documentation and Information Working Groups representing leading European research and conservation institutions to generate the final recommended set of descriptors.

Results

The consolidated descriptor list titled 'Plant Genetic Resource consolidated *in situ* descriptors v1' is available from Harvard Dataverse (Phillips *et al.* 2025). The list comprises 171 descriptors, of which seven are designated as 'Mandatory descriptors' (Table 2) and 47 are designated as the 'Core descriptors' for *in situ* conservation of PGR. 'Mandatory descriptors' are those which are required to be filled in when collecting and recording PGR. 'Core descriptors' are additional highly recommended descriptors which will greatly improve the information available for conservation and use of the PGR. 91 descriptors are designated as 'Recommended' to help enable a more thorough assessment of *in situ* populations. Of the total number of descriptors, 145 relate to CWR, 169 relate to LR and 159 relate to WHP (Table 3). There are 12 descriptors which are unique to LR and one descriptor is unique to WHP. In terms of the different levels of data for each descriptor, 95 descriptors relate to population level data, 82 descriptors relate to taxon level data and 79 relate to LR level data. There are eight descriptors which relate to all three levels of data, primarily descriptors related to conservation planning. The 'Other' category includes two options for the user to enter 'REMARKS' and 'COMMENTS' on other descriptor values. These are excluded from the counts of different descriptors as they are not considered true descriptors because they do not define an attribute, characteristic or measurable trait that is observed.

The 'Plant Genetic Resource consolidated *in situ* descriptors v1.2' is composed of the following Excel sheets: 'Explanatory notes' – a title page displaying information about the descriptor tables and 'All_descriptors', showing the full set of 171 descriptors plus information on references related to each descriptor. Table 3 gives an overview of the total number of descriptors identified.

The consolidated list of *in situ* descriptors (Phillips *et al.* 2025) is extensive and it is not expected that all descriptors will be used by any one PGR institution, project or application. This is why the 'Mandatory descriptors' (Table 2) and 'Core descriptors' have also been developed (see Table 3 for an overview). It is expected that the user will collect the 'Mandatory descriptors' information for either CWR, WHP or LR. The user can select these subsets using the filters provided. The 'Core descriptors' provide an opportunity for the user to input more information useful for conservation but are not mandatory (see Phillips *et al.* 2025).

The full descriptor list (Phillips *et al.* 2025) also contains information on which descriptors are useful for the following assessments: Red listing (IUCN Red List Technical Working Group 2018) = 13 descriptors; LR threat assessment (Almeida *et al.* 2024) = 11 descriptors; inclusion of populations or sites in *in situ* networks (Maxted *et al.* 2016) = 16 descriptors; and for the establishment of *in situ* genetic reserves (Iriondo *et al.* 2012) = 13 descriptors. The consolidated list of *in situ* descriptors does not cover the full range of information required for each of these assessment methods.

There were 29 new descriptors generated, with a further 16 descriptors for which either the description or descriptor code was altered from the original to provide more clarity (for a full list of new descriptors see Table S1), therefore resulting in a total of 45 new or modified descriptors (Table 3). Of these new or modified descriptors, one descriptor is a 'Mandatory descriptor', eight descriptors are included in the 'Core descriptor' list and an additional 26 are included as 'Recommended descriptors' (Table S1). Proportionally the number of new descriptors was highest for the conservation planning category, with the utilization category having the lowest number of new descriptors (Table 3). The main type of data required for each descriptor is text, however, some descriptors require numeric data relating to coordinates, a code number (which then relates back to text), or a specific measurement or estimation such as 'slope angle in degrees'. For each descriptor in the PGR consolidated *in situ* descriptor list (Phillips *et al.* 2025) there is a clear description for which type of data to input.

Discussion

The PGR consolidated *in situ* descriptor list presented is built on existing diverse descriptor lists and where gaps were identified further descriptors were added. The number of available descriptor lists in the *in situ* domain implies that the adoption of these lists has been low as no list has become the standard. We hope that consolidating these lists will create a timely resource to enhance future, practical implementation of PGR *in situ* conservation at national, regional and global levels, providing a basis for improved information and data management. It is widely accepted that using standardized descriptors avoids unnecessary repetitive data input and input errors, facilitates data exchange, allows multiple uses of the same dataset, reduces any problem of text synonyms, provides greater consistency and automatic checks for data integrity, allows easier comparison of results, and quicker data searching (Gotor *et al.* 2008). Therefore, having a consolidated list of appropriate descriptors will help ensure improved *in situ* resource conservation and access to PGR materials that are currently not accessible for users.

Of the 171 descriptors, there are seven designated at 'Mandatory descriptors' required as the minimum information for *in situ* conservation of PGR. There are 47 designated as 'Core descriptors' which are highly recommended for *in situ* conservation of PGR, but they are not mandatory. Eight of the 'Core descriptors' are newly developed (Phillips *et al.* 2025), with the other descriptors being common across multiple other descriptor lists. Thormann *et al.* (2013) developed 65 core descriptors for *in situ* CWR conservation, therefore the number identified here seems realistic.

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Table 2. The seven 'Mandatory descriptors' for *in situ* conservation of PGR

Descriptor category	Descriptor level (taxon/population)	Descriptor field name	Description
Conservation planning	Taxon/Landrace/ Population	NICODE	National Inventory code: Code identifying the National Inventory; the Three-letter ISO 3166-1 code of the country preparing the National Inventory. Exceptions are possible if agreed with EURISCO. Example: NLD
Conservation planning	Population	PUID	Population Unique Identifier. A unique DOI assigned to the *in situ* population so it can be unambiguously referenced at the global level and the information associated with it harvested through automated means. Report one PUID for each CWR *in situ* population that the National Focal Point considers as long-term available source of germplasm (e.g. the population is being monitored and potentially available under the terms of the MLS). Note: for *ex situ* accessions the ACCEDOI and/or ACCENUMB is used as a unique identifier.
Conservation planning	Taxon	GENUS	Genus. Genus name for taxon, in Latin. Initial uppercase letter required. Example 1: Vigna. Example 2: Vicia.
Conservation planning	Taxon	SPECIES	Species. Specific epithet portion of the scientific name, in Latin, in lower case letters. Example 1: unguiculata. Example 2: faba.
Conservation planning	Population	ORIGCTY	Country of Occurrence. Country where the CWR population was observed or inventoried. Use the Three-letter ISO 3166-1 code of the country where the site is located.
Conservation planning	Population	MAINTAINERNAME	Maintainer name: Name of the institute, organization or individual that holds rights or is responsible for the *in situ* population. IMPORTANT: GDPR may apply to this information if confidential information is likely to be made public. Release of this information should follow the regulations in place at the institute/organization who is collecting this information. Or if in doubt, this information should not be publicly available if not approved by the population maintainer of the material/site/population. The FAO WIEWS code (http://www.fao.org/wiews) or the research organization code (https://ror.org/) maybe be appropriate to use here.
Conservation planning	Population	OBSDATE	Observation date [YYYYMMDD]: The most recent date the *in situ* population was observed, where YYYY is the year, MM is the month and DD is the day. Missing data (MM or DD) should be indicated with hyphens or '00' [double zero]. (e.g. 2024-06-10)

Table 3. The number of descriptors in each category for: CWR, LR, WHP, core descriptors, recommended descriptors and new and modified descriptors. Counts do not include the 'Other' category which allows the user to enter 'REMARKS' and 'COMMENTS' on other descriptors

Category of descriptor	CWR	LR	WHP	Consolidated descriptor list	Mandatory descriptors	Core descriptors	Recommended descriptors	New and modified descriptors
Conservation planning	93	94	94	94	7	28	51	24
Conservation implementation	37	42	40	44	0	19	37	16
Utilization	15	33	25	33	0	0	3	5
Total	145	169	159	171	7	47	91	45

However, Thormann *et al.* (2013) further reduced the number to 13 for the minimum mandatory descriptors required when exchanging data. In other work on descriptor development for *in situ* conservation activities of PGR, EURISCO (2025) identified 28 minimum descriptors; Alercia *et al.* (2022) identified 24, including seven mandatory descriptors, and Magos Brehm *et al.* (2017a) identified 35. The list of seven 'Mandatory descriptors' is aligned to both Alercia *et al.* (2022) and EURISCO (2025), and thus it is expected that this will be the minimum information required for *in situ* PGR. The likelihood of acquiring the data required for the 'Mandatory descriptors' is high as there are only seven descriptors required. If it was not possible to collect this data, the material should still be collected and a clear pathway should be put in place to ensure the 'Mandatory descriptors' are completed in a timely manner. Without this information it would not be possible to follow the conservation continuum (Figure 1), thus limiting the effectiveness of *in situ* conservation and the usefulness of the material for the user. It should therefore be a priority to ensure the information for the 'Mandatory descriptors' are collected.

The consolidated descriptor list presented here is expected to be applied across three categories of PGR (CWR, LR and WHP), therefore there will be higher numbers of the 'Core' descriptors required than previous descriptor lists which have covered one type of PGR. The descriptor list also includes a 'Recommended' descriptor category to enable more thorough data collection to take place. It is expected that this list of descriptors will change over time as they are used in-the-field, so refinement in the number of 'Mandatory', 'Core' and 'Recommended' descriptors may occur at a later point. The mechanism for such a process of descriptor development would need to be identified. At a European level the ECPGR Documentation and Information Working Group, could take on responsibility for coordinating development and use of the descriptors. The list could also be ratified by the Biodiversity Information Standards (TDWG) association, which would also help to ensure the descriptors adhere to the FAIR principles of data sharing (Wilkinson *et al.* 2016, 2022).

The descriptors cover three types of PGR, namely CWR, WHP and LR with many of the descriptors being common

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across these groups. For example, all the descriptors relating to 'Conservation Planning' are applicable to all three components of PGR. This is because 'Conservation Planning' data are composed of foundational data around plant breeding systems, taxonomy, common names, etc. and is also why this category has the highest number of descriptors. The 12 descriptors which are unique to LR are composed of a subset of 'Conservation Implementation' and 'Utilization' descriptors, which were developed by Negri *et al.* (2012) and Caproni *et al.* (2020). These descriptors represent the unique way in which LRs are maintained by continued farming practices and how they are used not only for their genetic resource potential (like CWR and WHP), but also for their direct market value (also like WHP). The one descriptor which is unique to WHP is the 'Wild Harvested Plant Continuity' descriptor which is a new descriptor (Phillips *et al.* 2025). This descriptor was based on a LR descriptor and gathers information on whether the people harvesting the WHP plan to continue doing so. This information will help to determine the conservation needs of the taxa and relative threat, which may change as the wild collection and use of the WHP changes. There are no unique CWR descriptors as they are all shared with WHP, with many of these also shared with LR. This is because both CWR and WHP are components of the natural flora and do not require management by humans. Unlike CWR and WHP, LR populations require management interventions and utilization to continue to exist, this being a key component of their conservation management. This is reflected in the number of 'Utilization' descriptors for LR which is twice as many as for CWR. The 'Utilization' category has the lowest number of total descriptors which may be because they are generally less developed for *in situ* conservation, although they are highly relevant for use of PGR. Further development and application of 'Utilization' descriptors is required, as data on utilization of resources is not necessarily available when the material is first collected and this study was only focused on the active *in situ* conservation aspect of PGR.

The descriptors cover data at the levels of the population and taxon or LR. This ensures that the data recorder gathers the appropriate information for the survey they are conducting. In many instances, data at both population and taxon or LR level will be required for a complete assessment of the effective conservation of a particular taxon or LR. Population level data helps to assess the size of a population, and taxon level data helps to determine the bigger picture in terms of conservation actions or its wider distribution (Bevilacqua *et al.* 2021) for that taxon or LR. The descriptors which represent either taxon or LR and population level data, are those related to conservation planning information, such as, the National Inventory Code. This commonality is necessary as either taxon or LR and population level data need to be interlinked and findable across different levels of assessment.

The work in this project was focused on the consolidation and development of conservation descriptors, not on the development of Characterization and Evaluation descriptors. These have traditionally been developed separately to conservation descriptors as they are taxon or variety specific. However, it is worth considering how they might be applied to *in situ* PGR taxa and LR in the future. *In situ* characterization of traits of interest for each taxa or LR would help to inform on how the genotype is expressed under the environmental conditions of origin. The benefit of defining taxa specific *in situ* descriptors is that the connection between conservation and use could be more closely aligned, through the enabling of more targeted *in situ* conservation efforts of those traits which are relevant for the user community. Clearly, generating such data poses a significant challenge, as the *in situ* populations must be surveyed precisely when the trait of interest is expressed. In addition, genotype-by-environment interactions complicate comparisons across different populations. Nevertheless, it would be valuable to develop some pilot characterization and evaluation descriptors for the CWR of a few specific crops or for some LR varieties, and to test them in the field.

Currently, the data and information included in EURISCO (Kotni *et al.* 2023) which previously related to *ex situ* accessions only, is being expanded to include the passport data for *in situ* CWR populations' data. Should consideration be given to expanding EURISCO beyond its current 28 *in situ* descriptors proposed by van Hintum and Iriondo (2022), to include the additional descriptors generated here? The remit of EURISCO is clearly stated, 'to provide a European Search Catalogue for Plant Genetic Resources' (EURISCO 2025), in other words, it is a germplasm search engine to enable potential users to locate and access actively conserved *ex situ* or *in situ* PGR resources. It is not a generalized PGR information system and so it is not recommended that the additional descriptors generated here be added to an extended EURISCO. Just as genebank curatorial information is not added to EURISCO, so the equivalent *in situ* curation (= management and monitoring data) should not be included. However, one of the several distinctions between *ex situ* and *in situ* applications is the level of conservation site integration. Genebanks have historically worked well semi-independently, with van Hintum and Wijker (2024) calling for the wider application of quality management standards in the genebank environment, resulting in the Genebank Managers Network being recently formed with the aim of improving the function and strengthening the cooperation among genebank managers in Europe (ECPGR 2023). The more recent implementation of systematic and formal *in situ* and on-farm conservation has highlighted the benefit of a more integrated structure that encourages the building of a curatorial (i.e. management related) evidence-based approach; however for such an approach to be implemented effectively, individual *in situ*/on-farm sites need to be networked, not working in isolation (FAO 2014; Maxted *et al.* 2015, 2016, 2024). Elements of such an integrated structure have begun to be established, including the *in situ* LR best practice evidence-based database (ECPGR 2025a) and the interactive tool for identifying the CWR taxa in European Natura 2000 protected areas (ECPGR 2025b). Such resources are enhancing the value of the ECPGR website and offer a complementary resource to EURISCO that helps maximize conservation efforts of PGR.

All active *in situ* or on-farm conservation sites will require a site management plan that sets out the prescription for target population management and inevitably this will require and generate significant data as a routine part of population management and monitoring. A question to be addressed is should these data be held entirely within the national PGR network or is there advantage in aggregating these data at the European or global level. There are pros and cons of both approaches, but it is obvious whichever approach is followed, that (a) it would be helpful to debate now the best way forward rather than allow it to evolve *ad hoc*, and (b) it would be beneficial to have a coherent informatics infrastructure, including tools to aid analysis, at the national, European or global level or all three, to collate population management data over repeated monitoring cycles.

To increase interoperability and ensure that the descriptors contribute to broader biodiversity conservation efforts, alignment with international data standards such as the Biodiversity Information Standards (TDWG) and integration with platforms like GBIF (https://www.gbif.org/) and Genesys PGR

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(https://www.genesys-pgr.org/) should also be explored. This would enhance visibility, avoid data silos, and facilitate cross-sectoral applications of PGR data. It will still be important to differentiate between purposes of information systems at different levels (e.g. regional, national and conservation network focused) and the different details of information required at each of these levels. These issues, and those relating to which data should be held at what level, require further discussion in the ECPGR Documentation and Information WG, the EURISCO Advisory Committee, and with the CWR and On-farm WGs.

Integration of the consolidated list could be further developed as the basis of a proper ontology, linking terms used in various contexts and allowing automatic analysis of data about *in situ* PGR conservation activities (Arnaud *et al.* 2020). The basis of an ontology for PGR descriptors has already been developed (Škofič and Dias 2014) and addition of the PGR consolidated *in situ* descriptor list would help to expand this ontology. The Crop Ontology (Arnaud *et al.* 2020), which is primarily focused on characterization and evaluation data of crops and has been developed based on the FAIR principles (Wilkinson *et al.* 2016, 2022), should also be used to help refine the PGR consolidated *in situ* descriptor list and develop it towards a functional ontology. Furthermore, we recommend that the development of a PGR ontology be based on the Open Biological and Biomedical Ontology Foundry (OBO Foundry) principles, to help increase accessibility to conservation communities.

Practical application, specifically of the *in situ* descriptors (Phillips *et al.* 2025), is also needed to help with the testing, continuous development and updating of the consolidated descriptor list presented here. Although the list is comprehensive, it should be viewed as an initial version to be replaced by improved future iterations. To ensure the widest possible adoption, especially in countries with limited resources or technical infrastructure, a phased or tiered implementation model could be beneficial. Starting with the 'Mandatory descriptors' then the 'Core descriptors' and allowing for progressive integration of additional data fields, such as the 'Recommended descriptors'. This would enable flexibility while maintaining core data integrity. With the funding of the 'Extension of EURISCO for CWR *in situ* data and preparation of pilot countries' data sets' in several countries (Albania, Bulgaria, Cyprus, Czech Republic, Georgia, Germany, Italy, Lithuania, The Netherlands, Poland, Portugal, Romania, Slovenia, Spain and the United Kingdom; https://www.ecpgr.org/working-groups/crop-wild-relatives/cwr-in-eurisco) and the production of the initial iteration of the consolidated descriptor list (Phillips *et al.* 2025), there is a need for further capacity building for users (both *in situ* and *ex situ* practitioners) on how to use and apply these descriptors and their value and importance for conservation of PGR. Such training might be offered jointly by the regional ECPGR Documentation and Information, CWR and On-farm WGs and national nodes for PGR conservation.

The descriptor list should continue to be developed in line with the FAIR principles (Wilkinson *et al.* 2016, 2022) and could also be integrated into a network of FAIR germplasm bank databases, in line with the work of Cámara Ballesteros *et al.* (2024), that would allow greater sharing of data and thus more effective conservation strategies for PGR. Although the Cámara Ballesteros *et al.* (2024) study focuses on *ex situ* material, the principles should be explored in their application to *in situ* conservation methods. Descriptors could also be added into information systems which are being developed for the management of PGR such as GRIN Global Community Edition (GRIN-Global Community Edition | GGCE). In parallel with capacity building, user-friendly digital tools, such as mobile data collection templates, automated validation systems and decision-support dashboards, would help streamline field implementation. These tools are critical to lowering barriers for adoption, ensuring data consistency and reducing the workload for practitioners managing multiple taxa or sites.

Timely resolution is essential, as the practical implementation of *in situ* CWR population conservation at a broader national and regional level is currently occurring. This urgency is underscored by EC funding for three Horizon Europe research projects: COUSIN – CWR utilization and conservation for sustainable agriculture (https://cousinproject.eu/); PRO-WILD – Protect and promote CWR (https://www.pro-wild.eu); and FRUITDIV – Sustainable agriculture to preserve nature's treasures (https://fruitdiv.eu). Although each of these three projects focus on a narrow subset of European crops, they all incorporate *in situ* conservation and recognize the need for accessible CWR information for stakeholders and users. The consolidated *in situ* descriptor list will help them achieve their aims effectively and efficiently.

Development of the consolidated *in situ* PGR descriptor list presented here has highlighted the value that the PGR community sees in effective PGR and *in situ* data management for PGR conservation. The descriptors can be applied at all levels from local and national to regional and global. The process has increased discussion around the appropriate descriptors to use, as well as the process of *in situ* conservation and how practical it is to conduct this level of data collection. The robustness of the *ex situ* conservation process and community has helped to enable the development of the *in situ* descriptors in a pre-emptive rather than reactionary manner. Much work remains to develop robust *in situ* PGR descriptors. Primarily the descriptors need to be used and adapted by the PGR community to allow further refinement, including the addition of descriptors from other sources. Critically this process of refinement should ensure the descriptors adhere to the 'FAIR principles' of Findable, Accessible, Interoperable and Reusable, regarded as the cornerstone of contemporary informatics (Wilkinson *et al.* 2016, 2022) and essential for the effective use of PGR. These processes to improve the consolidated *in situ* PGR descriptor list will be essential to ensure the continued effective conservation of our most valuable resources.

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References

Alercia A (2011) *Key Characterization and Evaluation Descriptors: Methodologies for the Assessment of 22 Crops*. Rome, Italy: Bioversity International. ISBN: 978-92-9043-874-8. Available at https://alliancebioversityciat.org/publications-data/key-characterization-and-evaluation-descriptors-methodologies-assessment-22-crops (accessed 09 February 2026).

Alercia A, Diulgheroff S and Mackay M (2015) *FAO/Bioversity Multi-Crop Passport Descriptors V.2.1 [MCPD V.2.1]*. Rome, Italy: FAO/Bioversity

International. Available at https://alliancebioversityciat.org/publications-data/faobioversity-multi-crop-passport-descriptors-v21-mcpd-v21-december-2015 (accessed 30 September 2025).

Alercia A, López F, Marsella M and Cerutti AL (2022) *Descriptors for Crop Wild Relatives conserved in situ (CWRI v.1.1) Revised version*. Rome: FAO on behalf of the International Treaty on Plant Genetic Resources for Food and Agriculture. https://doi.org/10.4060/cb3256en.

Alercia A, López FM, Sackville Hamilton NR and Marsella M (2018) *Digital Object Identifiers for food crops - Descriptors and guidelines of the Global Information System*. Rome: FAO. Available at https://openknowledge.fao.org/server/api/core/bitstreams/52a8b5bc-0a5f-47e2-a6c3-3e93434057ae/content (accessed 09 February 2026).

Almeida MJ, Barata AM, De Haan S, Joshi BK, Magos Brehm J, Yazbek M and Maxted N (2024) Towards a practical threat assessment methodology for crop landraces. *Frontiers in Plant Science* **15**, 1336876. https://doi.org/10.3389/fpls.2024.1336876.

Armstrong HM, Thompson R, Holl K and Black B (2023) *Woodland Herbivore Impact Assessment Guide*. Version 5th April 2023. Available at https://www.forestry.gov.scot/publications/1480-the-woodland-herbivore-impact-assessment-method-user-guide/viewdocument/1480 (accessed 30 September 2025).

Arnaud E, Laporte MA, Kim S, Aubert C, Leonelli S, Miro B, Cooper L, Jaiswal P, Kruseman G, Shrestha R and Buttigieg PL (2020) The ontologies community of practice: a CGIAR initiative for big data in agrifood systems. *Patterns* **1**(7). https://doi.org/10.1016/j.patter.2020.100105.

Bevilacqua S, Anderson MJ, Ugland KI, Somerfield PJ and Terlizzi A (2021) The use of taxonomic relationships among species in applied ecological research: baseline, steps forward and future challenges. *Austral Ecology* **46**(6), 950–964. https://doi.org/10.1111/aec.13061.

Bioversity and The Christensen Fund (2009) *Descriptors for Farmers' Knowledge of Plants*. Rome, Italy: Bioversity International and California, USA: The Christensen Fund, Palo Alto. Available at https://alliancebioversityciat.org/publications-data/descriptors-farmers-knowledge-plants (accessed 15 December 2025).

Bioversity International (2007) *Guidelines for the Development of Crop Descriptor Lists*. Rome, Italy: Bioversity Technical Bulletin Series. Bioversity International. Available at https://alliancebioversityciat.org/publications-data/developing-crop-descriptor-lists-guidelines-developers (accessed 09 February 2026).

Bioversity International and University of Birmingham (2017) *Crop Wild Relative Checklist and Inventory Descriptors V.1*. Rome, Italy: Bioversity International. Available at https://alliancebioversityciat.org/publications-data/crop-wild-relative-checklist-and-inventory-descriptors-v1 (accessed 18 December 2025).

Cámara Ballesteros A, Aguayo Jara E, Verykaki ES, Pastor Del Olmo G, Moreno Vázquez S, Torres E and Wilkinson MD (2024) The FLAIR-GG federated network of FAIR germplasm data resources. *Scientific Data* **11**(1), 1386. https://doi.org/10.1038/s41597-024-04243-7.

Caproni L, Raggi L and Negri V (2020) *In Situ Landrace Propagation Management and Access Guidelines. Farmer's Pride: Networking, Partnerships and Tools to Enhance In Situ Conservation of European Plant Genetic Resources*. Birmingham, UK: Farmer's Pride project deliverable. University of Birmingham. Available at https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2020/09/D2.4_In_situ_landrace_propagation_management_guidelines.pdf (accessed 30 September 2025).

CBD (1992) *Convention on Biological Diversity: Text and Annexes*. Montreal, Canada: Secretariat of the Convention on Biological Diversity, pp. 1–34. Available at https://www.cbd.int/doc/legal/cbd-en.pdf (accessed 09 February 2026).

Ciancaleoni S, Raggi L, Barone G, Donnini D, Gigante D, Domina G and Negri V (2021) A new list and prioritization of wild plants of socio economic interest in Italy: toward a conservation strategy. *Agroecology and Sustainable Food Systems* **45**(9), 1300–1326. https://doi.org/10.1080/21683565.2021.1917469.

Darwin Core Maintenance Group (2025) *List of Darwin Core Terms. Biodiversity Information Standards (TDWG)*. Available at http://rs.tdwg.org/dwc/doc/list/ (accessed 06 February 2026).

ECPGR (2023) *European Genebank Managers Terms of Reference*. ECPGR Network of European Genebank Managers. Rome, Italy: ECPGR. Available at https://www.ecpgr.org/fileadmin/bioversity/publications/pdfs/Terms_of_Reference_for_an_ECPGR_Genebanks_Network_final.pdf (accessed 29 August 2025).

ECPGR (2025a) *In Situ Landraces: Best Practice Evidence-Based Database: A Tool for Promoting Landrace Conservation*. Rome, Italy: ECPGR. Available at https://www.ecpgr.org/in-situ-landraces-best-practice-evidence-based-database?qKey=dabf3b889dca3baf9c78d6c411e3857e (accessed 29 08 2025).

ECPGR (2025b) *Crop Wild Relatives in European Protected Areas: A Tool for Protected Area Managers*. Rome, Italy: ECPGR. Available at https://www.ecpgr.org/crop-wild-relatives-in-natura-2000?qKey=ace533f77da4f704651e42131375153c (accessed 29 08 2025).

EURISCO (2025) *Descriptors for Uploading In Situ CWR Passport Data to EURISCO*. Available at https://eurisco.ipk-gatersleben.de/apex/EURISCO_WEB.download_file?p_id=338 (accessed 26 09 2025).

FAO (1996) *Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture*. Rome, Italy: Food and Agriculture Organization of the United Nations, pp. 1–510. Available online https://openknowledge.fao.org/handle/20.500.14283/aj631e (accessed 11 09 2025).

FAO (2014) *Global Networking on In Situ Conservation and On-Farm Management of Plant Genetic Resources for Food and Agriculture*. Rome, Italy: Food and Agriculture Organization of the United Nations, p. 14. Available at http://www.fao.org/3/a-mm537e.pdf (accessed 09 12 2025).

FAO (2025) *The Third Report on the State of the World's Plant Genetic Resources for Food and Agriculture*. Rome, Italy: Food and Agriculture Organization of the United Nations. Available at https://openknowledge.fao.org/handle/20.500.14283/cd4711en (accessed 26 01 2025).

Gotor E, Alercia A, Rao VR, Watts J and Caraciolo F (2008) The scientific information activity of bioversity international: the descriptor lists. *Genetic Resources and Crop Evolution* **55**, 757–772. https://doi.org/10.1007/s10722-008-9342-x.

IPCC (Intergovernmental Panel on Climate Change) (2014) Summary for Policymakers. In Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR and White LL (eds), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press, pp. 1–32.

Iriondo JM, Maxted N, Kell SP, Ford-Lloyd BV, Lara-Romero C, Labokas J and Magos Brehm J (2012) Quality standards for genetic reserve conservation of crop wild relatives. In Maxted N, Dulloo ME, Ford-Lloyd BV, Frese L, Iriondo JM and Pinheiro de Carvalho MAA (eds), *Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces*. Wallingford: CAB International, pp. 72–77.

IUCN Red List Technical Working Group (2018) *Mapping Standard and Data Quality for the IUCN Red List Categories and Criteria*. Version 1.16. September 2018. Available at https://nc.iucnredlist.org/redlist/resources/files/1539098236-Mapping_Standards_Version_1.16_2018.pdf (accessed 26 09 2025).

JNCC (2004) *Common Standards Monitoring Guidance for Vascular Plant Species*. ISSN 1743-8160. Available at https://hub.jncc.gov.uk/assets/7c9d99fb-ad42-43ac-ba6d-18c2e3799e31 (accessed 26 09 2025).

Kotni P, van Hintum T, Maggioni L, Oppermann M and Weise S (2023) EURISCO update 2023: the European search catalogue for plant genetic resources, a pillar for documentation of genebank material. *Nucleic Acids Research* **51**(D1), D1465–D1469. https://doi.org/10.1093/nar/gkac852.

Magos Brehm J, Kell SP, Thormann I, Gaisberger H, Dulloo E and Maxted N (2017a) *Occurrence Data Collation Template V.1*. Harvard Dataverse, V1. https://doi.org/10.7910/DVN/5B9IV5.

Magos Brehm J, Kell SP, Thormann I, Maxted N and Dulloo E (2017b) *Template for the Preparation of a Technical Background Document for a National Strategic Action Plan for the Conservation and Sustainable Use of Crop Wild Relatives*. Harvard Dataverse, V2. https://doi.org/10.7910/DVN/VQVDFA.

Maxted N, Adam-Blondon A, Aguilar CH, Barata AM, Bartha B, Bocci R, De Paola D, Fitzgerald HS, Fresta LJ, Fusani P, Giuliano G, Guzzon F, Holzherr P, Holubec V, Iriondo Alegría JM, Labokas J, Maggioni L, Magos Brehm J, Palmé A, Phillips J, Prohens J, Raggi L, Ralli P, Rungis D, Sarikyan K, Šuštar Vozlič J, Thormann I and Zdunić G (2025) A significantly enhanced role for plant genetic resource centres in linking *in situ* and *ex situ* conservation to aid user germplasm access. *Genetic Resources* **S2**, 203–222. https://10.46265/genresj.UNVV5571.

Maxted N, Adam-Blondon AF, Aguilar CH, Barata AV, Bartha B, Bocci R, De Paola D, Fitzgerald H, Fresta LJ, Fusani P, Guzzon F, Heywood VH, Holzherr P, Holubec V, Iriondo Alegria JM, Labokas J, Maggioni L, Magos Brehm J, Nazri D, Palmé A, Prohens J, Raggi L, Rungis D, Phillips J, Sarikyan K, Šuštar Vozlič J, Thormann I and Zdunic G (2024) *Systems for Describing, Managing, and Accessing In Situ Conserved Populations and Interfacing Them with EURISCO*. Roma, Italy: Deliverable 1.3 EC funded Pro GRACE Project. Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile, pp. 1–99. Available at https://www.grace-ri.eu/fileadmin/user_upload/Pro-grace/Img/Deliverables/D1.3.pdf (accessed 09 12 2025).

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

Maxted N, Avagyan A, Frese L, Iriondo JM, Magos Brehm J, Singer A and Kell SP (2015) *Preserving Diversity: a Concept for In Situ Conservation of Crop Wild Relatives in Europe Version 2* Rome, Italy: *In situ* and On-farm Conservation Network, European Cooperative Programme for Plant Genetic Resources.

Maxted N, Ford-Lloyd BV and Hawkes JG (1997) Complementary conservation strategies. In Maxted N, Ford-Lloyd BV and Hawkes (eds), *Plant Genetic Conservation: The In Situ Approach*. London: Chapman & Hall, pp. 20–55.

Maxted N, Ford-Lloyd BV, Jury S, Kell S and Scholten M (2006) Towards a definition of a crop wild relative. *Biodiversity and Conservation* **15**, 2673–2685. https://doi.org/10.1007/s10531-005-5409-6.

Maxted N, Hunter D and Ortiz Rios RO (2020) *Plant Genetic Conservation*. Cambridge: Cambridge University Press, p. 560.

Maxted N and Magos Brehm J (2023) Maximizing the crop wild relative resources available to plant breeders for crop improvement. *Frontiers in Sustainable Food Systems* 7. https://doi.org/10.3389/fsufs.2023.1010204.

McCouch S, Baute GJ, Bradeen J, Bramel P, Bretting PK, Buckler E, Burke JM, Charest D, Cloutier S, Cole G, Dempewolf H, Dingkuhn M, Feuillet C, Gepts P, Grattapaglia D, Guarino L, Jackson S, Knapp S, Langridge P, Lawton-Rauh A, Lijua Q, Lusty C, Michael T, Myles S, Naito K, Nelson RL, Pontarollo R, Richards CM, Rieseberg L, Ross-Ibarra J, Rounsley S, Sackville Hamilton RS, Schurr U, Stein N, Tomooka N, van der Knaap E, van Tassel D, Toll J, Valls J, Varshney RK, Ward Waugh R, Wenzl P and Zamir D (2013) Agriculture: feeding the future. *Nature* **499**(7456), 23–24. https://doi.org/10.1038/499023a.

Moore JD, Kell SP, Iriondo JM, Ford-Lloyd BV and Maxted N (2008) CWRML: representing crop wild relative conservation and use data in XML. *BMC Bioinformatics* **9**, 116. https://doi.org/10.1186/1471-2105-9-116.

Negri V, Maxted N, Torricelli R, Heinonen M, Veteläinen M and Dias S (2012) *Descriptors for web-enabled national in situ landrace inventories*. Birmingham, UK: PGR Secure project deliverable. University of Birmingham. Available at http://vnr.unipg.it/PGRSecure/data/LRDESCRIPTORS_PGRSECURE.pdf (accessed 26 09 2025).

Phillips J, Magos Brehm J, Adam-Blondon AF, Avagyan A, Clarke G, Fresta L, Forycka A, Gailīte A, Gay L, Iriondo JM, Labokas J, Palmé A, Raggi L, Thormann I, Weise S, Zdunic G and Maxted N (2025) *Plant Genetic Resource Consolidated In Situ Descriptors*. Harvard Dataverse, V1.2. https://doi.org/10.7910/DVN/V6RLCO.

Škofič M and Dias S (2014) *PGR Diversity Gateway–Ontology Conceptualization, Description and Approach*. PGR Secure project deliverable. Birmingham, UK: University of Birmingham. https://doi.org/10.13140/RG.2.1.1490.8320.

Stephenson PJ and Stengel C (2020) An inventory of biodiversity data sources for conservation monitoring. *PLoS One* **15**(12). https://doi.org/10.1371/journal.pone.0242923.

Thormann I, Alercia A and Dulloo ME (2013) *Core Descriptors for In Situ Conservation of Crop Wild Relatives V.1*. Rome, Italy: Bioversity International. Available at https://alliancebioversityciat.org/publications-data/core-descriptors-situ-conservation-crop-wild-relatives-v1 (accessed 09 02 2026).

Thormann I, Kell S, Magos Brehm J, Dulloo E and Maxted N (2017) *CWR Checklist and Inventory Data Template V.1*. Harvard Dataverse, V4. https://doi.org/10.7910/DVN/B8YOQL.

van Hintum T and Iriondo J (2022) *Principles for the Inclusion of CWR Data in EURISCO*. Available at https://www.ecpgr.org/resources/ecpgr-publications/publication/principles-for-the-inclusion-of-cwr-data-in-eurisco-2022 (accessed 26 09 2025).

van Hintum T and Wijker E (2024) Quality management in a genebank environment: principles and experiences at the centre for genetic resources, The Netherlands (CGN). *Genetic Resources* **S2**, 6–12. https://doi.org/10.46265/genresj.RFXB3570.

Weise S, Kreid S and Maxted N (2020) *Concept for a Possible Extension of EURISCO for In Situ Crop Wild Relative and On-Farm Landrace Data*. Farmer's Pride: Networking, partnerships and tools to enhance *in situ* conservation of European plant genetic resources. Birmingham, UK: University of Birmingham. Available at https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2021/09/D2.5_EURISCO_in_situ_extension_concept.pdf (accessed 26 09 2025).

Wieczorek J, Bloom D, Guralnick R, Blum S, Döring M, Giovanni R, Robertson T and Vieglais D (2012) Darwin core: an evolving community-developed biodiversity data standard. *PLoS ONE* **7**(1), e29715. https://doi.org/10.1371/journal.pone.0029715.

Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten JW, da Silva Santos LB, Bourne PE, Bouwman J, Brookes AJ, Clark T, Crosas M, Dillo I, Dumon O, Edmunds S, Evelo CT, Finkers R, Gonzalez-Beltran A, Gray AJG, Groth P, Goble C, Grethe JS, Heringa J, Hoen PAC, Hooft R, Kuhn T, Kok R, Kok J, Lusher SJ, Martone ME, Mons A, Packer AL, Persson B, Rocca-Serra P, Roos M, van Schaik R, Sansone SA, Schultes E, Sengstag T, Slater T, Strawn G, Swertz MA, Thompson M, van der Lei J, van Mulligen E, Velterop J, Waagmeester A, Wittenburg P, Wolstencroft K, Zhao J and Mons B (2016) The FAIR guiding principles for scientific data management and stewardship. *Scientific Data* **160018**(3-1), 2052–4463. https://doi.org/10.1038/sdata.2016.18.

Wilkinson MD, Sansone SA, Méndez E, David R, Dennis R, Hecker D, Kleemola M, Lacagnina C, Nikiforova A and Castro L (2022) Community-driven governance of FAIRness assessment: an open issue, an open discussion. *Open Research Europe* **146**(2). https://doi.org/10.12688/openreseurope.15364.1.

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