

**U** How can genebanks  
double the diversity  
available for plant  
breeding?

**B**

**Nigel Maxted**

# What Are Genetic Resources and why important?

Definition of genetic resources: “Genetic material of animals and plants which is of value as a resource for the present and future generations of people.” (IBPGR, 1993)

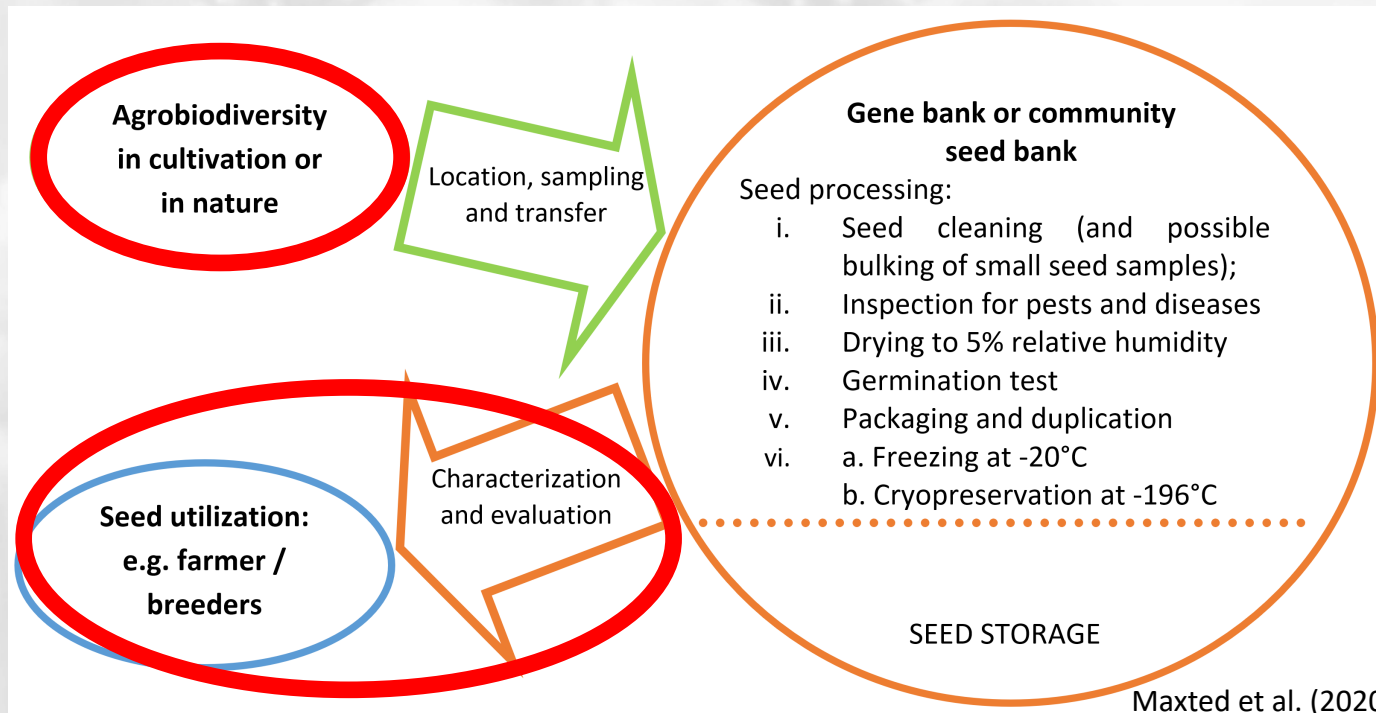
- Reduction of genetic vulnerability- **diversity** within a field or within a production system helps to **ensure stability** in overall food production by **reducing the risks** to agricultural production



- Using **crop gene pool diversity** is a key strategy for farmers around the world to guarantee their sustainability (= food security)

# Genetic conservation and the role of gene banks

“Role of gene bank is maximizing the **conservation, characterisation, documentation** and **use** of PGR diversity for the benefit of humankind”  
IBPGR (1991)



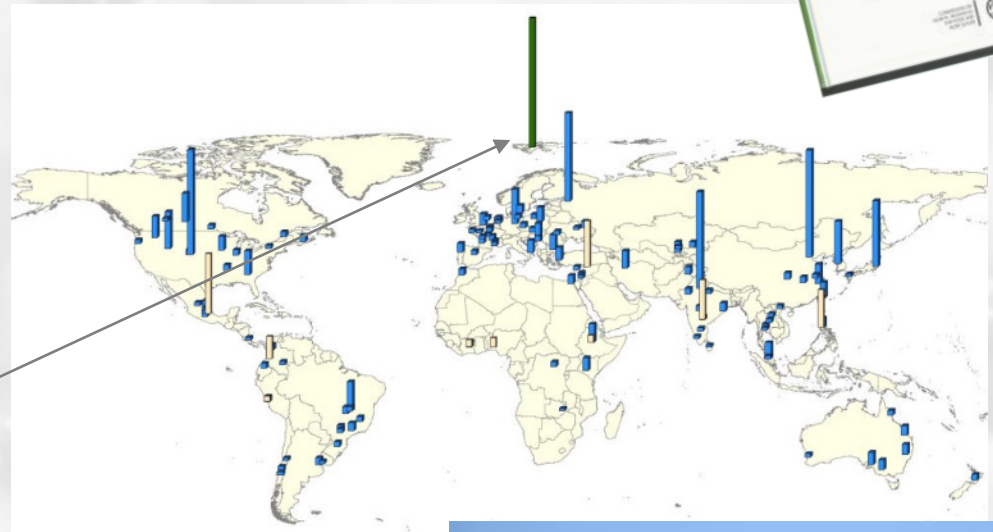
- To conserve the **broadest range of genetic diversity** found in the target species (as many **alleles** as possible, or as many **gene combinations** as possible)
- Primary (85%) method for conserving diversity of 'orthodox' seeded species is based on gene bank maintenance (FAO, 2010)

# State of *ex situ* conservation of plant genetic resources

Geographic distribution of genebanks with holdings of >10,000 accessions

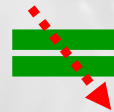


- Total number of germplasm accessions in *ex situ* collections is now about 7.4 million in  $\approx 1,750$  gene banks (FAO, 2010)
- Establishment of the Svalbard Global Seed Vault, a last resort safety back-up repository of genetic resources to safeguard humanity



# Current challenge of climate change to breeding

- Lack of sufficient (access to) diversity is restricting plant breeding outcomes (Volbrecht and Sigmon, 2005; Feuillet *et al.*, 2008; Dwivedi *et al.*, 2008; McCouch *et al.*, 2013)
- CWR are suffering erosion and extinction – 16 to 35% are IUCN threatened (Bilz *et al.*, 2011; Kell *et al.*, 2012; Goettsch *et al.*, 2021)
- 99% of CWR conservation is *ex situ*, largely as seed in genebanks, it works, it **does** efficiently supply users with diversity (Maxted *et al.*, 2016)
- Analysis of CWR holdings shows  $\approx \frac{1}{3}$  unconserved,  $\approx \frac{1}{3}$  poorly conserved (<10 accessions) and 95% are under-collected (Castañeda *et al.*, 2016)
- Complementary conservation means applying *ex situ* and *in situ* techniques together, but *in situ* (incl. on-farm) conservation is almost completely ignored – a handful of active PA and OECM (Other Effective Area-based Conservation measures) for CWR and few long-term on-farm conservation sites
- Improve accessibility of PGR in gene banks, improved documentation informatics, characterisation and evaluation data and digitization of P+C+E data



# Policy context

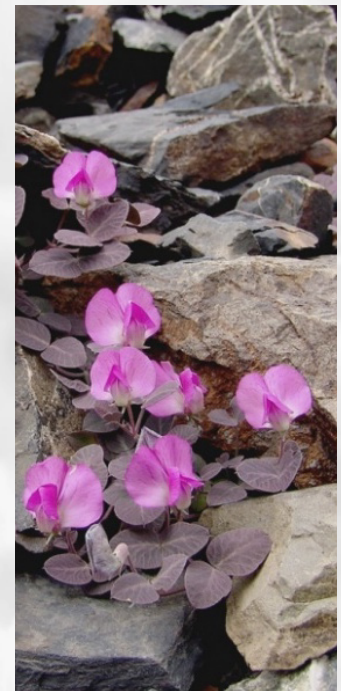
- **CBD DRAFT POST-2020 GLOBAL BIODIVERSITY FRAMEWORK (2022)** – By 2050

“Milestone A.3 - **Genetic diversity of wild and domesticated species** is safeguarded, with an increase in the proportion of species that have **at least 90 per cent of their genetic diversity maintained.**”

Target 4. Ensure active management actions to enable the recovery and **conservation of species and the genetic diversity of wild and domesticated species**, including through *ex situ* conservation, and effectively manage human-wildlife interactions to avoid or reduce human-wildlife conflict.

Target 13. Implement measures at global level and in all countries to facilitate **access to genetic resources and to ensure the fair and equitable sharing of benefits arising from the use of genetic resources**, and as relevant, of associated traditional knowledge, including through mutually agreed terms and prior and informed consent.

- **UN Sustainable Development Goals (2015)** highlighted the need of eradicating extreme poverty and hunger = Goal 1, 2 and 3, but particularly 2.5



*Vavilovia formosa*:  
CWR of garden pea

# Safety Duplication

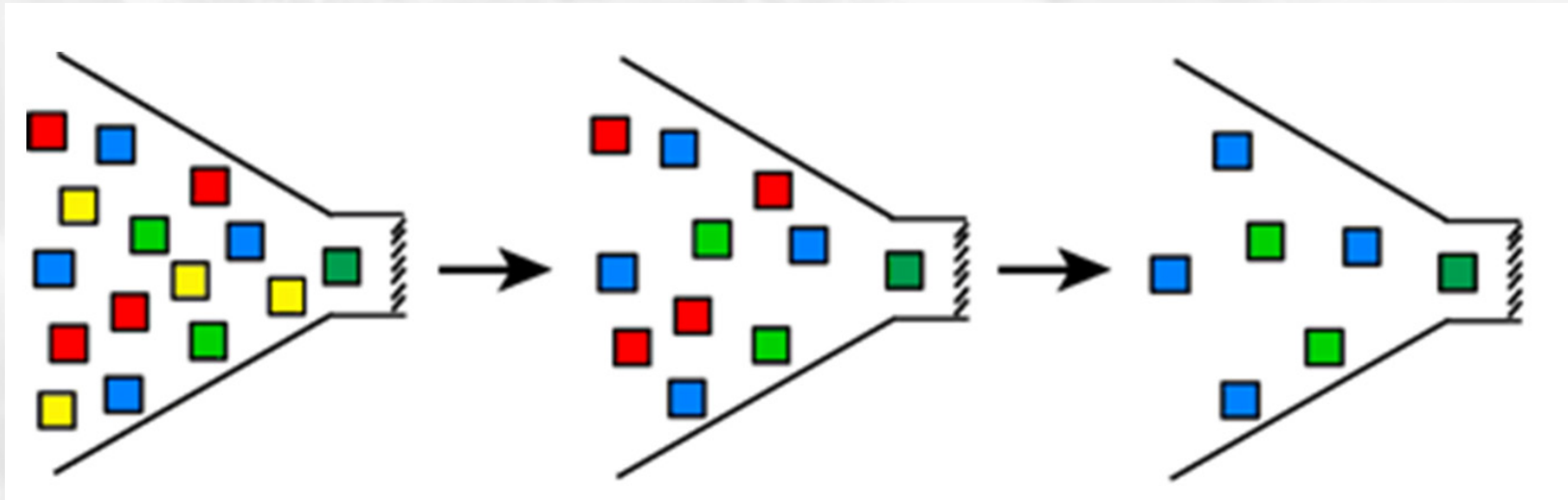
Don't put all your conservation eggs in one basket, apply *in situ* dynamic conservation can complement *ex situ*!



Eski Foğa, Izmir province, Turkey

**Complementary Conservation**

# Maximizing diversity focused conservation on adaptive diversity?



Wild species

Landraces

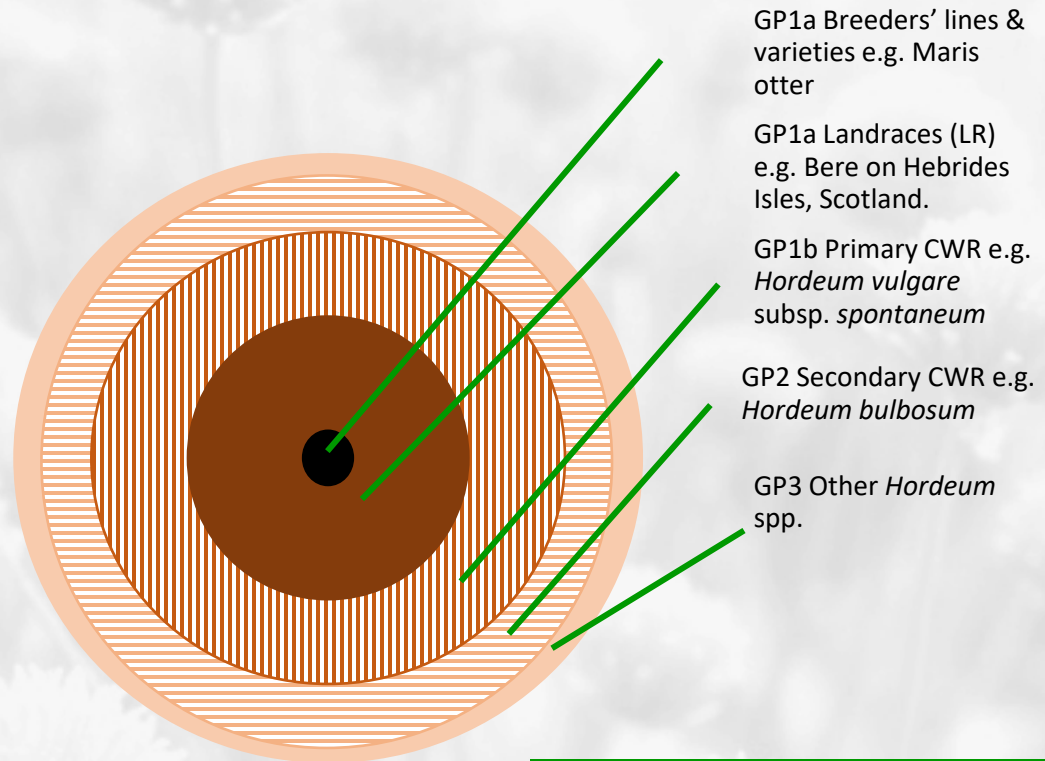
Modern varieties

Domestication = loss of genetic diversity .... For tomato 95% of genetic diversity in genepool is located in wild *Lycopersicon* / *Solanum* spp. (Tanksley and McCouch, 1997)



# Making the argument for crop wild relatives and *in situ* conservation?

- Crop wild relatives (CWR) are wild plant species closely related to crops, including wild **ancestors**
- They have an indirect use as **gene donors** for crop improvement due to their relatively close genetic relationship to crops and high level of genetic diversity as they have not gone through the **domestication 'bottle neck'** causing loss of diversity
- Definition (Maxted *et al.*, 2006)
  - **Broad definition:** *all taxa within the same genus as a crop*
  - **Precise definition:** *wild plant taxon that has an indirect use derived from its relatively close genetic relationship to a crop; this relationship is defined in terms of the CWR belonging to gene pools 1 or 2, or taxon groups 1 to 4 of the crop*



Usable relative genetic diversity held at each level of the barley gene pool



# Our GOAL: Implement *In situ* CWR conservation and sustainable use

- The aim is to create a permanent 'system' for *in situ* conservation of plant genetic resources, including associated complementary conservation *ex situ*, and critically, to promote and facilitate the use of more diversity for the benefit of all countries
- It is anticipated that the system / network will comprise:
  - a) specific localities where usually multiple CWR populations are maintained to agreed minimum standards
  - b) the custodians of those populations
  - c) Genetic Resources Centres to hold back-up samples and facilitate *in situ*-user linkage
  - d) other stakeholders with an interest in the conservation and sustainable use of plant genetic resources
- Organizations, networks and individuals would both be able to join the network

*Beta vulgaris* subsp. *maritima*



Sugarbeet



# Why now?

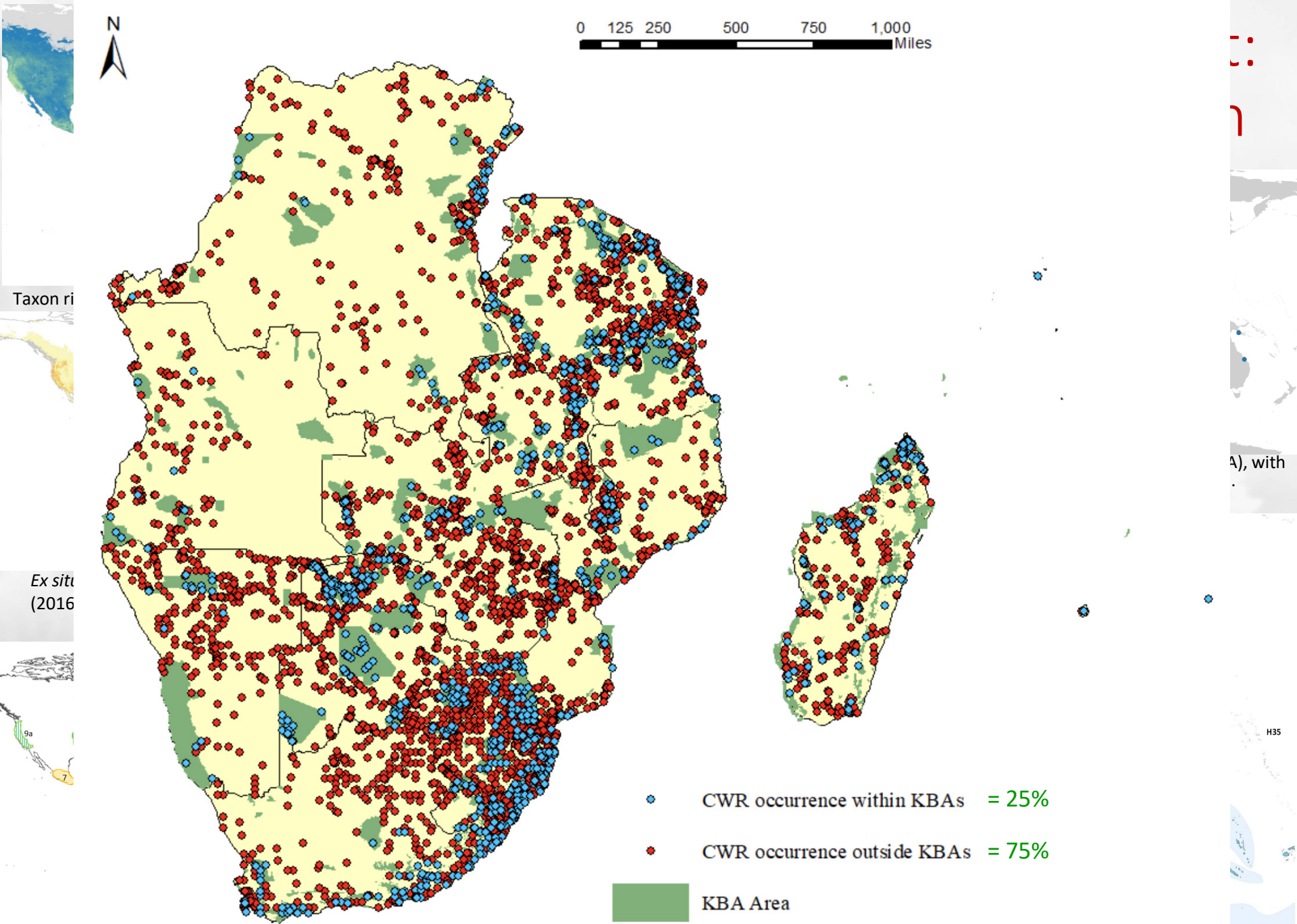


*Allium ampeloprasum* var. *babingtonii*

- Meet breeders' need for more diversity to adapt to climate change
- Improve genetic diversity conservation of threatened resources globally, regionally and nationally (not just hotspot)
- Fill the conservation gaps (*in situ* and *ex situ*)
- Fill the germplasm availability gaps (*in situ* and *ex situ*) to meet users needs
- Re-focus PGR activities toward complementary conservation at global, regional and national levels
- Meet policy and legislative obligations (SDGs, GPA, CBD, European Green Deal, including the Biodiversity and Farm to Fork Strategies)



- CWR conservation and use is critical to future global, regional and national food security

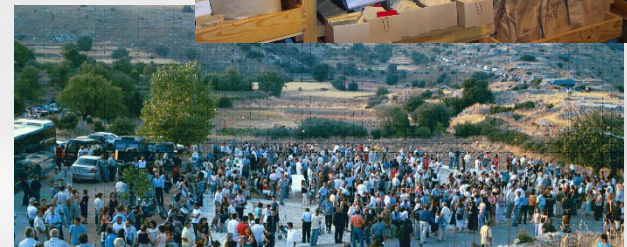


CWR and KBA occurrence in Southern Africa (Saunders, Magos Brehm & Maxted, In Prep.)

# *In situ* sites as STANDALONE or a NETWORK?

## Network is preferable – why?

- Facilitate *systematic coordination and reporting* (e.g. GPA)
- Foster *stronger partnerships and mutual support*
- Integrate *global, regional and national actions*
- Link *local communities of practice with common goals*
- *Facilitate ABS* for protected areas and farmers / farming communities
- Enable integrated, long-term *complementary in situ–ex situ* conservation
- Promote *access to PGR* held in protected areas and farmers / farming communities via Genetic Resource Centres
- Safeguard *evolving in situ PGR populations* for perpetuity





# Benefits of network membership



Paul Watkins  
(Suffolk, UK)

- ✓ **Kudos and prestige** of belonging to an international community of appreciation, **legislative protection of site** and concern for the value of PGR diversity
- ✓ Make a **contribution to something bigger / stronger partnerships**
- ✓ **Assistance in adding value** to your work, **developing markets** and fostering greater **cross-sector collaboration**, and **sustainable use** activities – such as increased opportunities for **improved marketing through a certification schemes**
- ✓ Offer **technical support** and **training** for *in situ* plant genetic resources conservation and sustainable use activities, as well as **guidance in seeking funds** and **agri-environmental schemes** to support specific initiatives, such as **management interventions and research**
- ✓ Ensure that *in situ* PGR populations are **securely backed** up in a genebank and provide an **emergency repatriation service** when a population is under threat
- ✓ **Assistance with ABS**, so custodians can be secure that the genetic diversity they share and is used will benefit them
- ✓ For users – facilitate **access to a greater breadth of plant genetic resources** in accordance with the requirements of the ITPGRFA and the CBD Nagoya Protocol
- ✓ **Coordination of network activities: monitoring, documentation and reporting**
- ✓ **Safeguarding important PGR and provisioning ecosystem services in perpetuity**



# Useful tools

- CAPFITOGEN tools for CWR and landrace conservation planning [capfitogen.net/](http://capfitogen.net/)
- Concept for an extension of EURISCO for *in situ* crop wild relative and on-farm landrace data [https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2021/09/D2.5 EURISCO in situ extension concept.pdf](https://more.bham.ac.uk/farmerspride/wp-content/uploads/sites/19/2021/09/D2.5_EURISCO_in_situ_extension_concept.pdf)
- *In situ* CWR population look-up tool [ecpgr.cgiar.org/cwr-tool](http://ecpgr.cgiar.org/cwr-tool)
- [CWR \*in situ\* population management guidelines pdf](#): online toolkit [cwrpopulation-toolkit.cropwildrelatives.org/](http://cwrpopulation-toolkit.cropwildrelatives.org/)



# Where to manage *in situ* populations to maximize genetic diversity maintenance?

## Existing PA networks for CWR

- a. sites already have **long-term conservation ethos**
- b. sites less prone to **hasty management changes** associated with private land or roadside where population sustainability is not normally a consideration
- c. it is **relatively easy to amend the existing site management** to facilitate genetic conservation of wild plant species
- d. creating novel conservation sites **avoids prohibitive cost** of acquiring previously non-conservation managed land, and
- e. CWR are present in **existing PAs** in significant numbers

## Other Effective Area-based Conservation measures (OECMs)

- a. **CWR found outside PA** in anthropogenic environments;
- b. Official designated / governed as a site for active biodiversity conservation, but **less formal** & not necessarily its prime focus
- c. Geographically defined area with a managed regime for long-term active biodiversity conservation of the target taxa, **legally binding agreements with landowners**
- d. **Complementary to existing PAs**



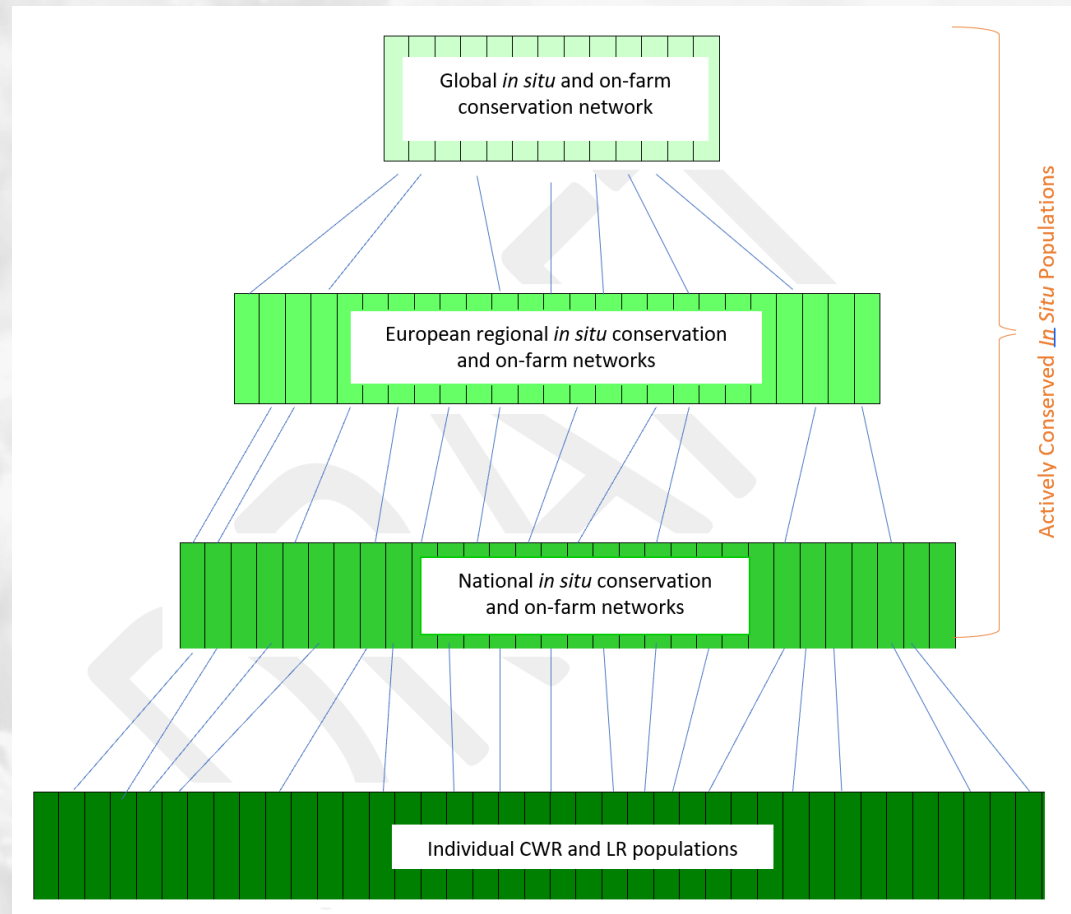


# *In situ* networks of CWR/LR populations

## Structure – geographic scale



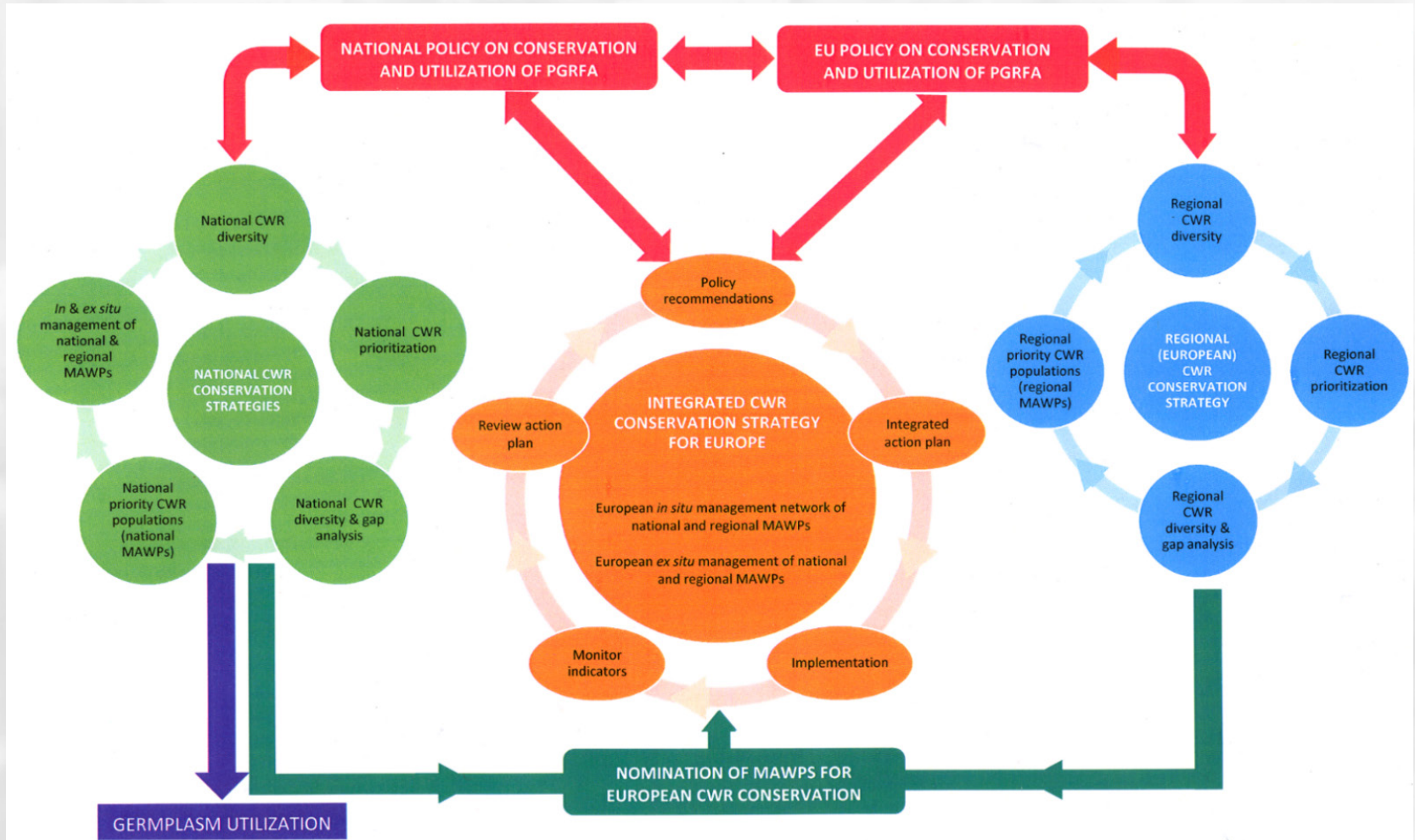
Linking global, regional and national *in situ* conservation actions





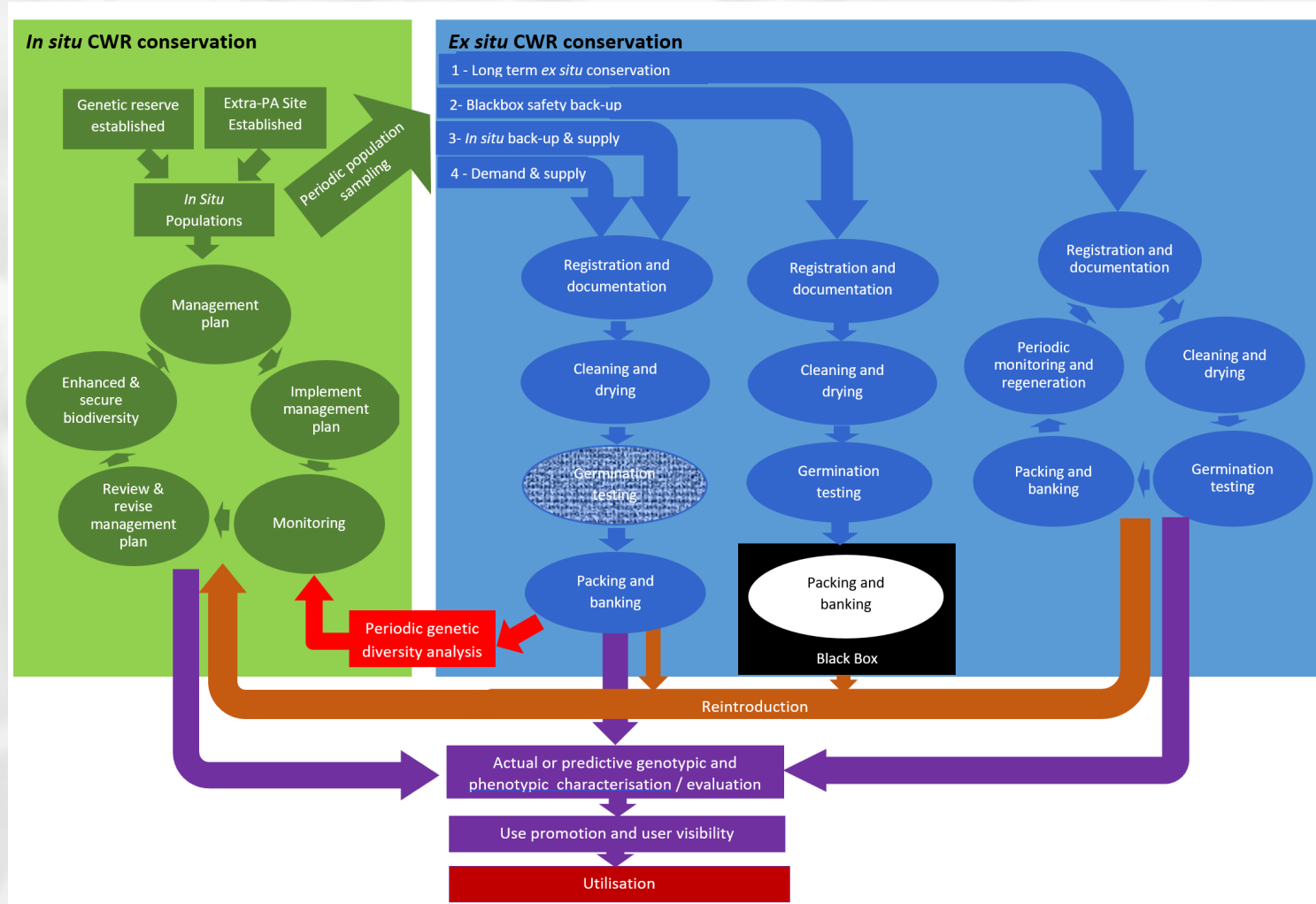
# *In situ* networks of CWR / LR populations

## Structure



# In situ networks of CWR/LR populations

## Structure – linking *in situ*, *ex situ* and use





# *In situ* network of CWR/LR populations

## Governance – basic concepts

What is governance?

“Governance is the way the rules, norms and actions are structured, sustained, regulated and held accountable. As such, governance may take many forms ....” Wikipedia (Sept. 2016)

Geopolitical and administrative scales – who provides oversight?

- National options — National PA Agency, National PGR Agency
- European options — ECPGR, EEA, EC (Natura 2000), Europarc?
- International options — FAO Globally Important Agricultural Heritage Systems, FAO ITPGRFA, CGIAR Centres, UNESCO Man and Biosphere Programme, UNESCO World Heritage Sites, CBD Programme of Work on Protected Areas, IUCN Key Biodiversity Areas?

National sovereignty over genetic resources (CBD & ITPGRFA) – who controls sites?

- All sites nominated by national PGRFA coordinators
- All sites remain under the jurisdiction of national agencies
- Access to material controlled by national authorities via national PGR Centre and SMTA



# *In situ* networks of CWR/LR populations

## Governance – management and coordination



### Minimum inclusion criteria for network:

- Initial minimum inclusion criteria (Maxted, 2014)
  - The CWR population is **native** at that location or if introduced has existed at that location for **at least fifteen generations**.
  - The population contains **distinct or complementary genetic diversity** (ecogeographic diversity may be used as a proxy for genetic diversity) or specific traits of interest that enhances the overall value of the network.
  - The population is actively and sustainably managed according to the **minimum quality standards for genetic reserve conservation** (Iriondo *et al.*, 2012).
  - The population is **routinely sampled** and held in a backup *ex situ* facility every fifteen generations.
  - The population is **'healthy' with a good chance of long term survival** (normally thought to mean 100 years) and so **threats from development or climate change** are minimal.
  - The **population is accessible** for research or utilisation in accordance with the International Treaty via the appropriate national agencies and samples must be available on request from a specified *ex situ* facility as part of the multilateral system.
  - The population is **nominated by the appropriate national PGR authority** for inclusion in the Network.
- Periodically **review whether individual sites meet minimum criteria** for inclusion in network and fulfil reporting obligations.



# *In situ* networks of CWR/LR populations

## Governance – management and coordination



### Minimum quality standards for genetic reserve conservation (Iriondo *et al.*, 2012)

#### Location

- Located following rigorous scientific process
- Located in a protected area network

#### Spatial structure

- Polygon of the genetic reserve should be clearly defined
- Sufficient extent to conserve CWR populations and natural processes.

#### Target taxa

- Genetic reserves are designed to capture maximum genetic diversity
- Demographic survey of target CWR taxa

#### Populations

- Population sizes are large enough to sustain long-term populations

#### Management

- Site recognised by the appropriate national agencies
- Management plan formulated
- Monitoring plans are designed and implemented
- Local community involved in site management
- Clearly-defined procedure to regulate the use of genetic material

#### Quality standards for the protected areas selected for the establishment of genetic reserves

- Site has legal foundation
- Site governance ensures continuing commitment to *in situ* CWR conservation
- Site management plan acknowledges genetic
- Inventory of all CWR present

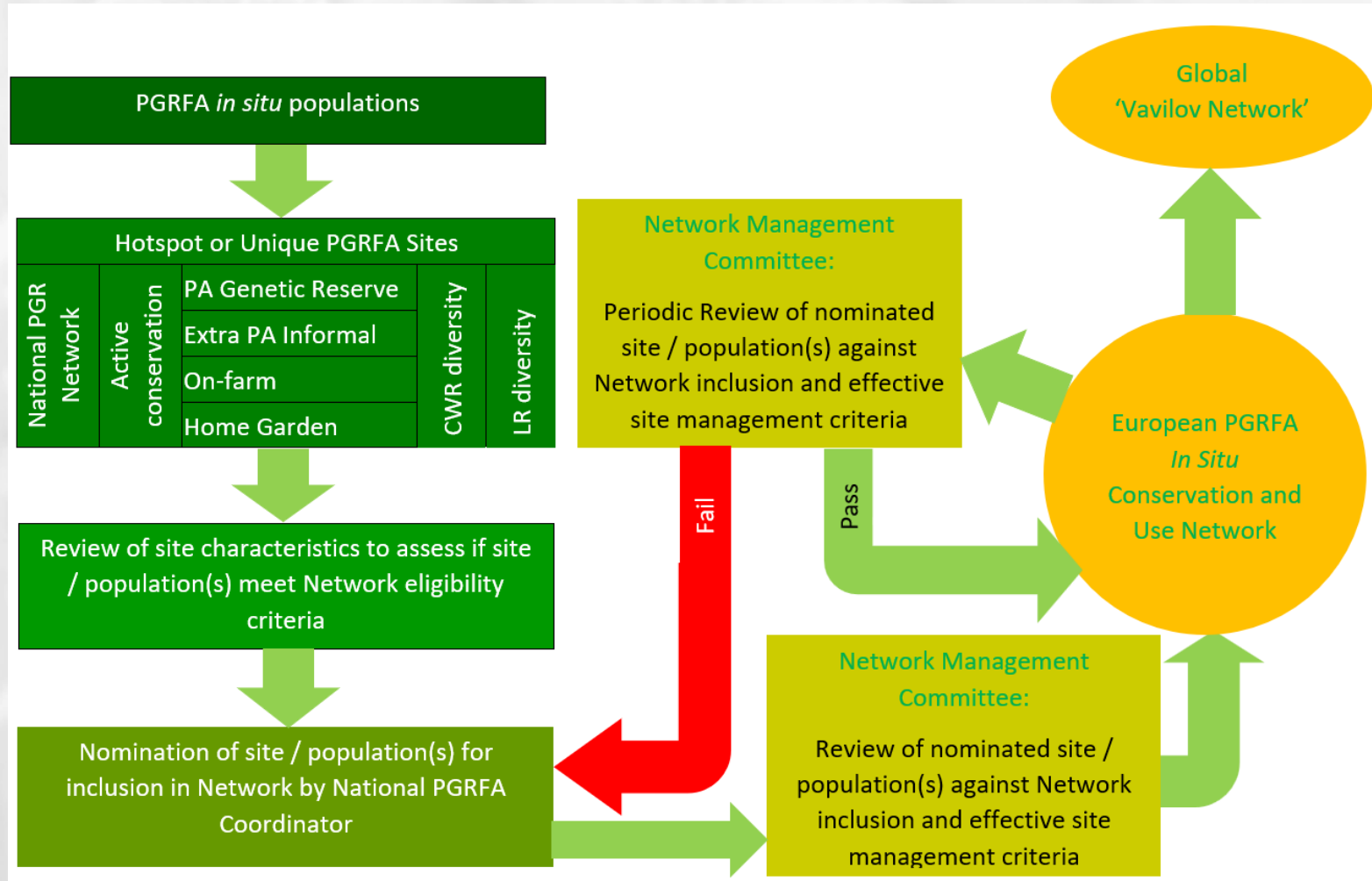


Wild chives, *Allium schoenoprasum*



# *In situ* networks of CWR populations

## Governance: a work in progress ....



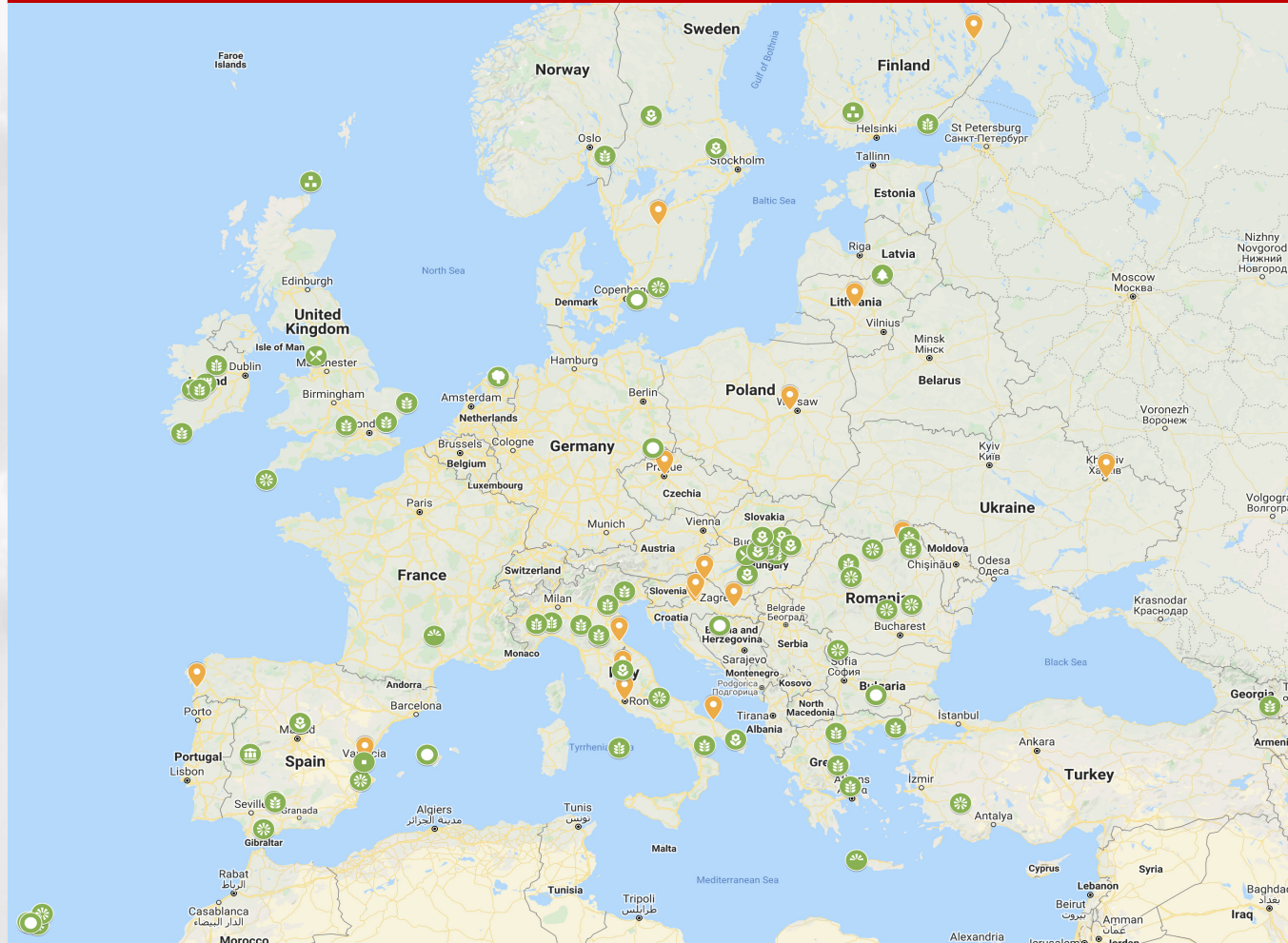
# Moving towards network establishment



## Commitments to *in situ* networking

### PGR custodians

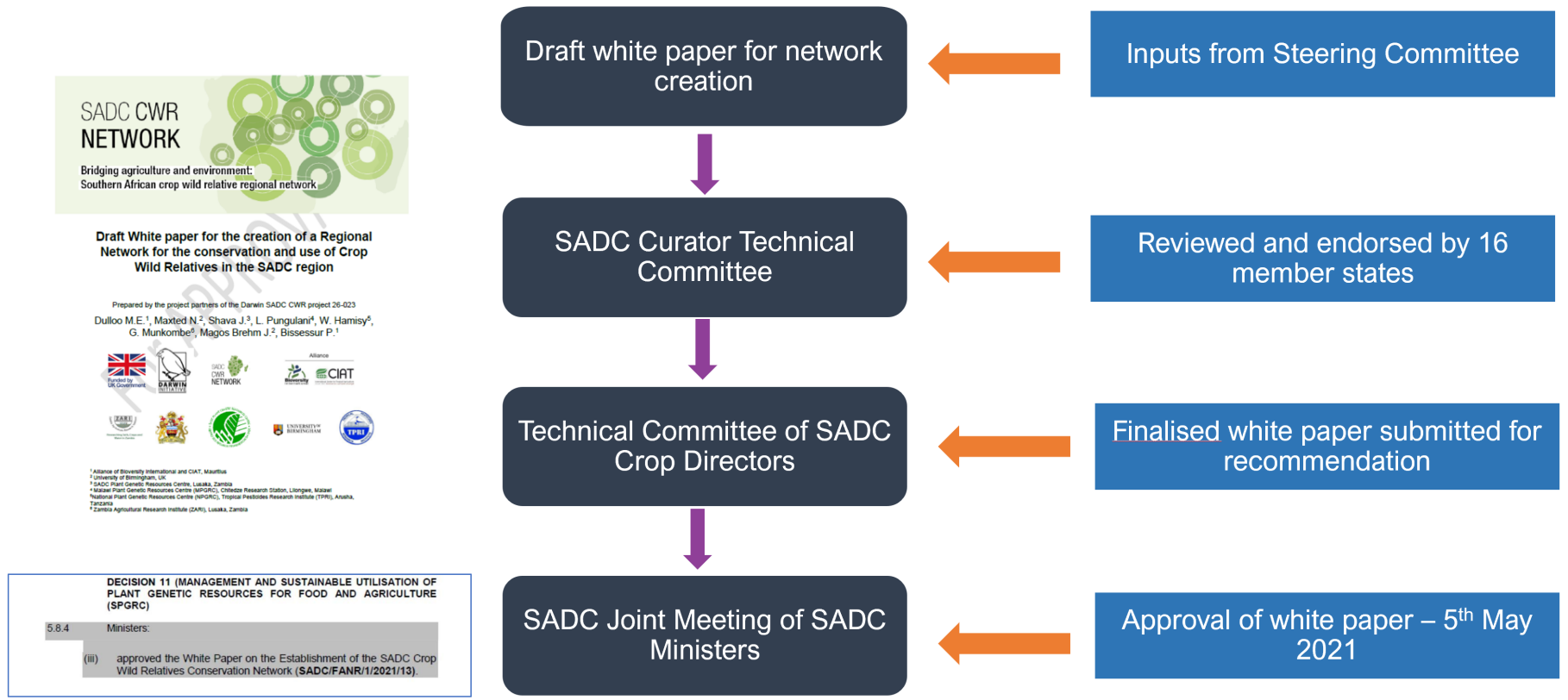
- Farm/smallholding
- Allotment/home garden
- Protected area
- Market garden
- Unprotected wild/semi-wild habitat
- Farmers network
- National Genebank
- Heritage Orchard
- Historic garden
- Managed forest
- Plant micro-reserves
- National Coordinator or Institute





# SADC countries have taken the lead

## Roadmap for SADC CWR Network Creation



- Hawkes (1991) concluded *in situ* was in its infancy
- This is no longer the case at least for *in situ* conservation of CWR diversity

# How can genebanks double the diversity available for plant breeding?

- PGR Centres become *in situ* active
  - Actively **engaged in *in situ* planning** with and without the PA community
  - Actively **engaged in *in situ* conservation**, specifically acting a conduit for CWR genetic diversity transfer to CWR users
- YES there will be a **cost incurred**
- But there is also a **benefit** = a ‘doubling’ of the diversity available for plant breeding
- The additional **benefit far exceeds the additional costs**, and climate change means this is a request from the **850M people suffering malnourishment today** (FAO, 2021)



CG genebank's role?