In situ conservation and use of crop wild relatives in three ACP countries of the SADC Region

Planning and Managing crop wild relative conservation

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Regional training workshop

In situ conservation of CWR including diversity assessment techniques

Le Meridien Ile Maurice, 10–13 November 2014

Talk overview

- Why CWR conservation and use at global, regional, national and local geographic scales
- Existing initiatives
- Future prospects
  - *In situ* networks of CWR populations
  - *Ex situ* targeted sampling
  - Predictive characterisation of desirable traits
  - User-based informatics
  - Policy framework for CWR conservation and use

Policy context

- CBD Strategic Plan agreed in Nagoya (2010) – Target 13 of 20

"Target 13. By 2020, The status of crop and livestock genetic diversity in agricultural ecosystems and of wild relatives has been improved. (SMART target to be developed at global and national levels) …. In addition, *in situ* conservation of wild relatives of crop plants could be improved inside and outside protected areas."

- CBD Global Strategy for Plant Conservation 2011 – 2020 (2010) – Target 9 of 16

Target 9: 70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge.

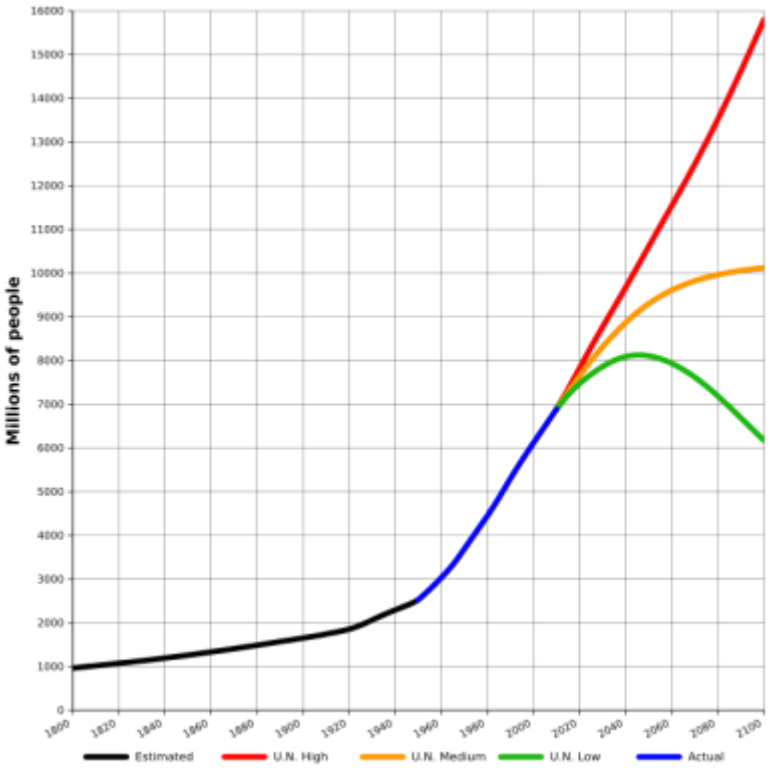
Target 1: An online flora of all known plants = inventory of CWR

Target 2: An assessment of the conservation status of all known plant species as guide conservation action = conservation status of CWR

UN Millennium Development Goals highlighted the need of eradicating extreme poverty and hunger = linked conservation and use of CWR

Threat: Why actively conserve CWR now?

- 7.27 billion humans in 2014 (21/09/14)
- 9.6 billion humans by 2050 (UN, 2014)



16 billion

10 billion

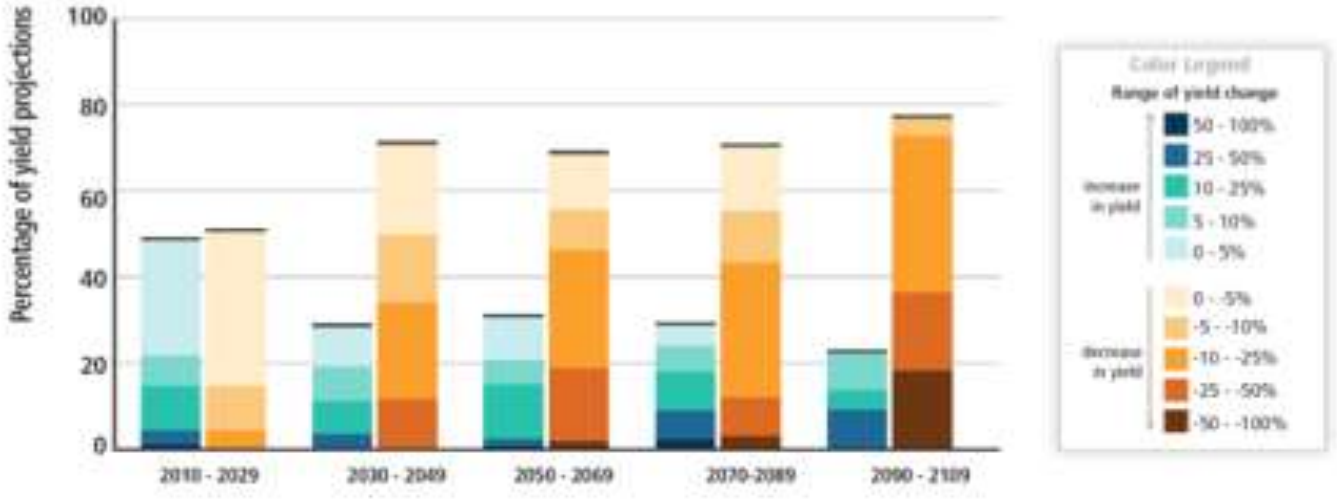
6 billion

- To feed the human population in 2050 we will require food supplies to increase by 60% globally, and 100% in developing countries (FAO, 2011)
- While climate change may reduce agricultural production by 2% each decade this century (IPCC, 2014)

Why crop wild relatives, now in SADC?

Climate change has changed the game

- Climate change may reduce agricultural production by 2% each decade while demand increases 14%. Up to 40% of the world will develop unfamiliar climates by 2050 (IPCC, 2014)



- Food insecurity and human malnourishment

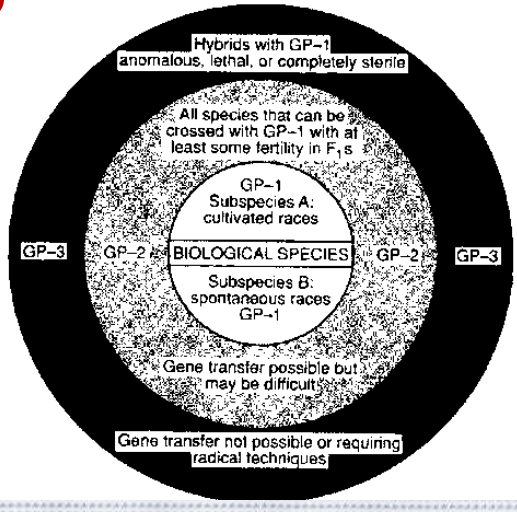
- But CWR may hold one key to our survival
  - Wide genetic diversity of adaptive traits
  - Tried, proven but still largely unapplied
  - Technological advances in application

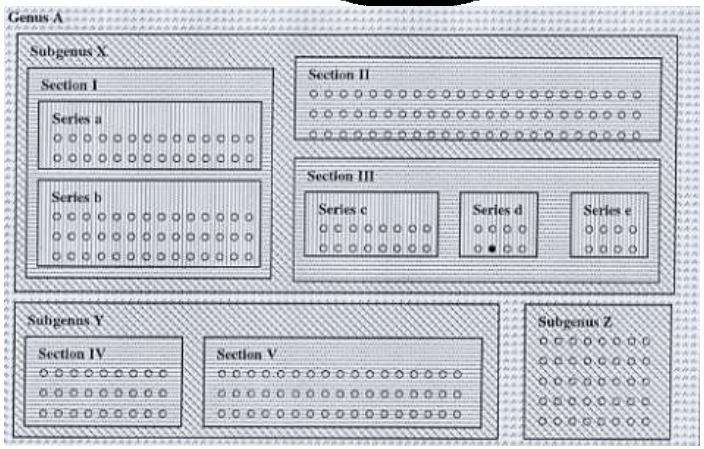
Threat: Why conserve CWR now in SADC?

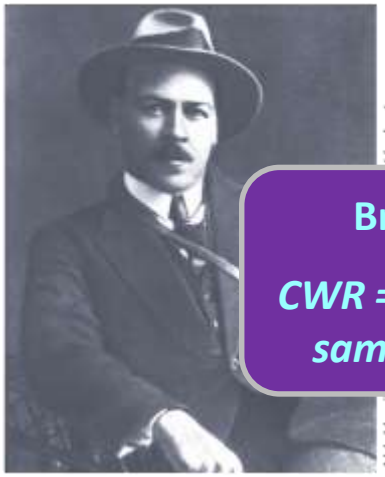
- CWR are each expected to be affected by climate change and their agro-environment;
- CWR like other wild species are threatened by the loss, degradation and fragmentation of their natural habitats and competition from alien species;
- CWR are often located in disturbed habitats (e.g. field margins, forest edges and roadsides), that are not being conserved by ecosystem conservation agencies;
- CWR each suffers lack of knowledge of their breadth, location and real use potential, they are largely uncharacterised, unevaluated and undervalued;
- MP and WHS are collected by destructive harvesting practices from wild coupled with habitat degradation, agricultural expansion, overgrazing and urbanisation threaten MP and WHS

What are crop wild relatives?

- 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
- They are an important socio-economic resource that offer novel genetic diversity required to maintain future food security







Broad definition:

CWR = all taxa within the same genus as a crop

Narrow definition:

A crop wild relative is a 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

Value of CWR:
as an ecosystem service

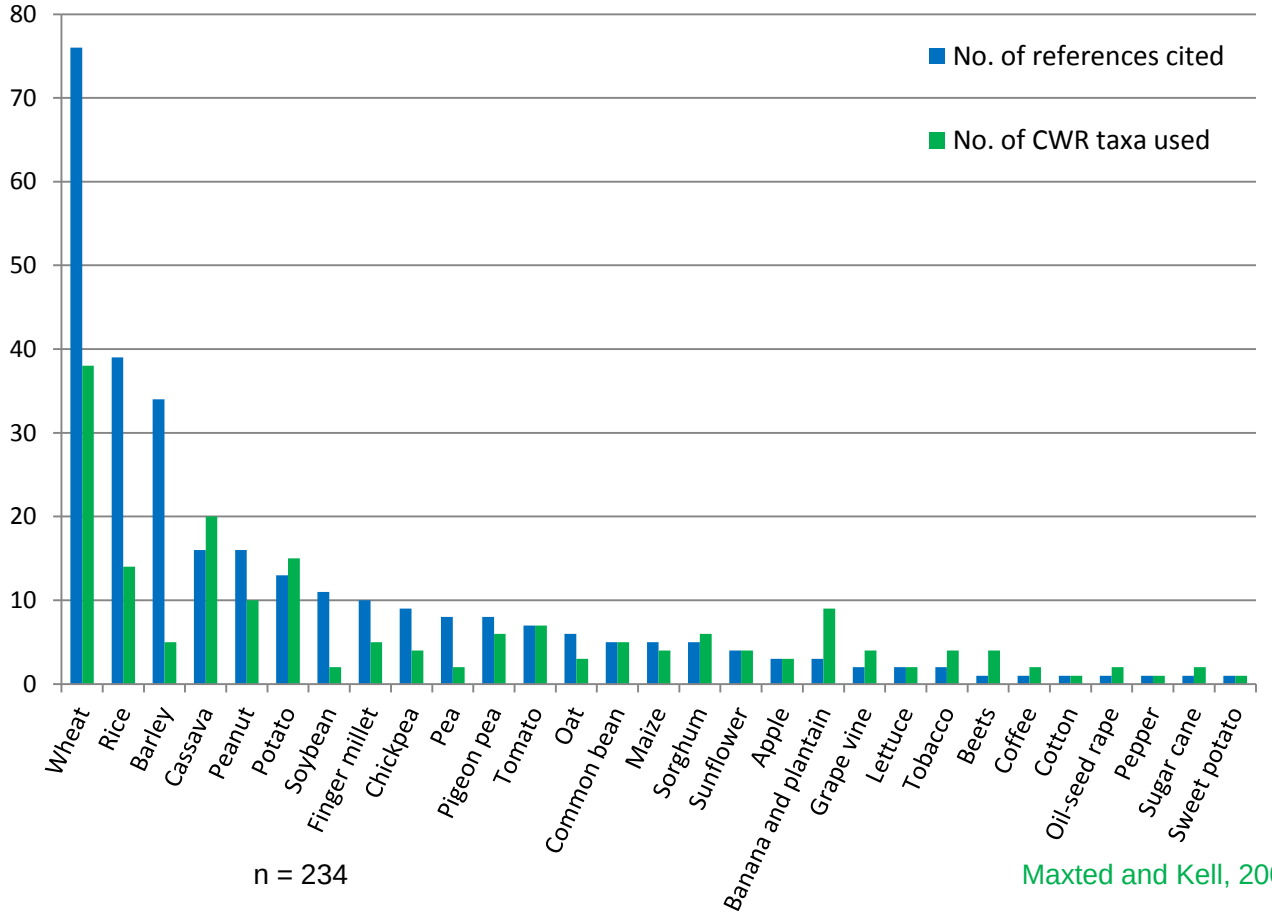
"The wide array of conditions and processes through which ecosystems, and their biodiversity, confer benefits on humanity; these include the production of goods, life-support functions, life-fulfilling conditions, and preservation of options." Daily and Dasgupta (2001)

- Ecosystem goods or extractive benefits (use direct):
  - Food (terrestrial animal and plant products, forage, seafood, spices)
- Preservation of options (future use):
  - maintenance of the ecological components and systems needed for future supply of these goods and services

Value of CWR:
as a source of adaptive traits

Aegilops tauschii	Rust
Ae. tauschii	Sprouting suppression
Ae. tauschii	Wheat soil-borne mosaic virus, wheat spindle-streak mosaic virus
Ae. tauschii	Agronomic traits, yield improvement
Ae. tauschii, T. turgidum	Yellow rust and leaf rust
Ae. tauschii, T. turgidum	Water-logging tolerance
Ae. variabilis	Powdery mildew resistance
Ae. variabilis	Root-knot nematode resistance
Ae. ventricosa	Cyst nematode resistance
Ae. ventricosa	Eye spot resistance
Agropyron elongatum, Ae. umbellulata	Leaf and stem rust resistance
Ag. elongatum	Drought tolerance
Agropyron sp.	Frost resistance
Secale cereale	Yield improvement
Triticum dicoccoides, T. timopheevii, T. monococcum, Ae. speltoides	*Fusarium* head blight
T. monococcum	Stem rust
T. turgidum subsp. dicoccoides	Protein quality improvement
T. turgidum subsp. dicoccoides	Powdery mildew
T. turgidum subsp. dicoccoides	Stem rust
T. urartu	Powdery mildew
Thinopyrum bessarabicum	Salt resistance
Th. intermedium, Th. ponticum	Barley yellow dwarf virus, wheat streak mosaic virus
Th. ponticum	*Fusarium* head blight resistance
Thinopyrum sp.	Greenbug resistance

Value of CWR:
as a source of adaptive traits



n = 234

Maxted and Kell, 2009

Citations:
- 2% <1970
- 13% 1970s
- 15% 1980s
- 32% 1990s
- 38% >1999

Use:
- 39% pest resistance
- 17% abiotic stress resistance
- 13% yield increase

Value of CWR:
the economic imperative

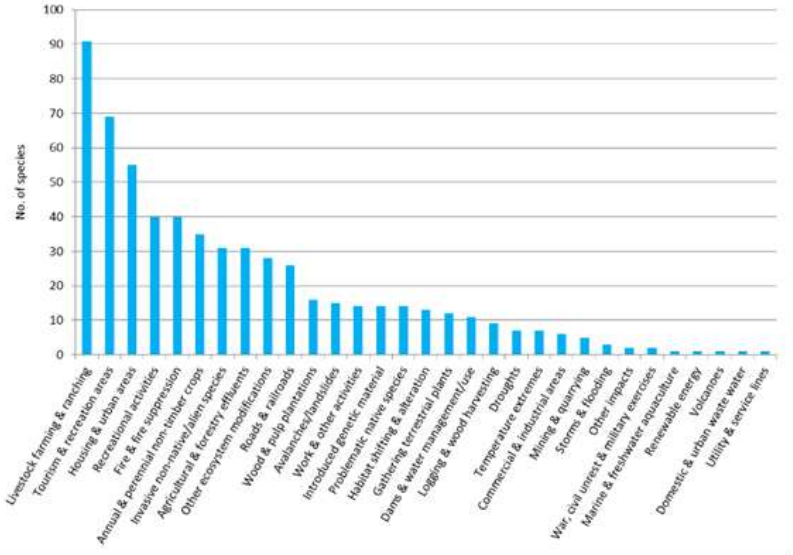
Value of CWR as actual or potential gene donors:

- $115 billion toward increased crop yields per year (Pimentel *et al.*, 1997)
- *Lycopersicon chmielewskii* sweetening tomato US $ 5-8m per year (Iltis, 1988)

Why crop wild relatives?

CWR are threatened and poorly conserved

- Red List assessments of 572 native European CWR in 25 Annex I priority crop gene pools
  - 16% of the species assessed are threatened or Near Threatened and 4% are Critically Endangered
- Yet analysis of European PGR *ex situ* collections found:
  - CWR taxa represent only **10%** of total germplasm accessions and only **6%** European CWR have any germplasm in gene banks
- Many CWR are found in existing protected areas, but they are not being actively monitored and managed
- Only a handful of CWR active genetic reserves have been established: *Triticum* CWR in Israel; *Zea perennis* in Mexico; *Solanum* CWR in Peru; wild Coffee CWR in Ethiopia; and *Beta patula* in Madeira



Kell et al. (2012) Red listed 571 European CWR species

Why crop wild relatives?
the economic imperative

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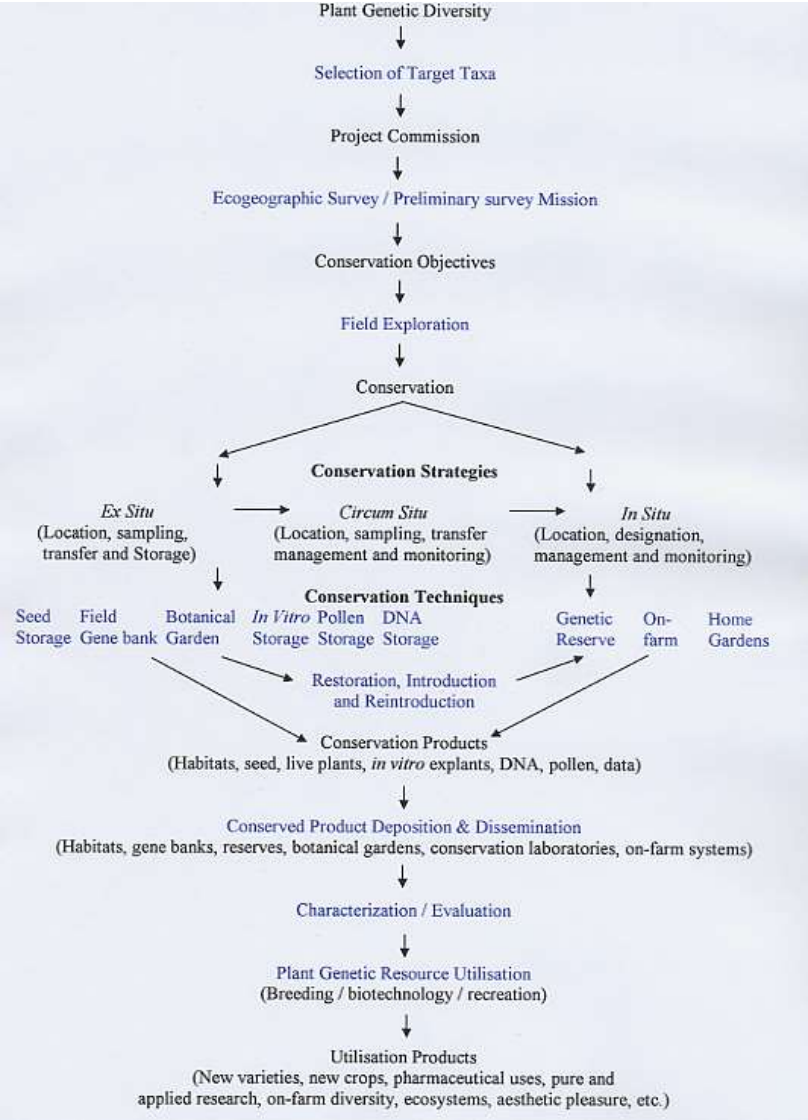
Why *in situ* conservation for CWR

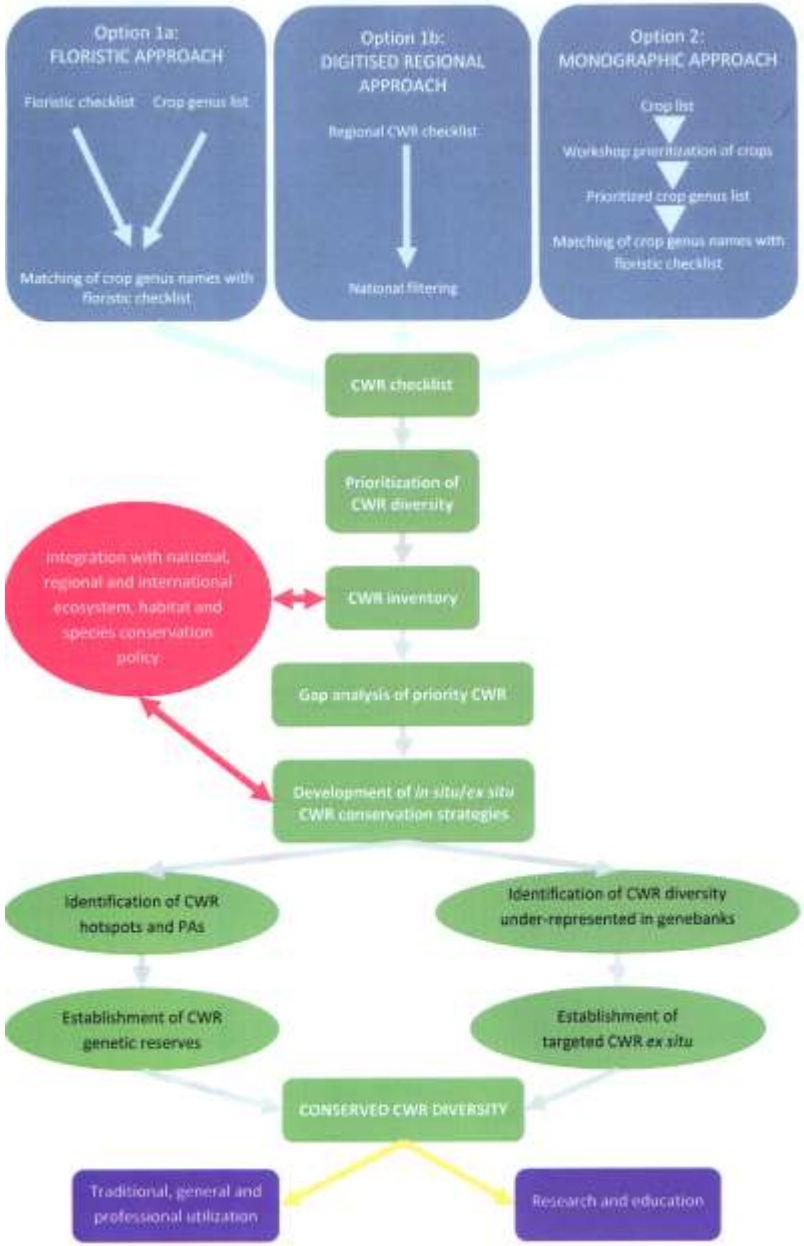
- Complementary conservation but ….
- Continued evolution of diversity *in situ* alongside synecological biotic and abiotic diversity
- Unlikely to know in advance which CWR adaptive traits required by breeders
- Sheer numbers of CWR taxa, combined with the need to sample genetic diversity, means *ex situ* will be hit and miss
- But ….
- "weak links between the 'site-selection and / or management-recommendations' process and the 'official-protected-site and / or management-change-designation' process" (Meilleur and Hodgkin, 2004)
- Even weaker link between *in situ* and utilisation
- Climate change will impact *in situ* but not *ex situ* conserved diversity

Need complementary conservation *in situ* conservation with *ex situ* back-up

Holistic CWR conservation / Use



National CWR Strategy



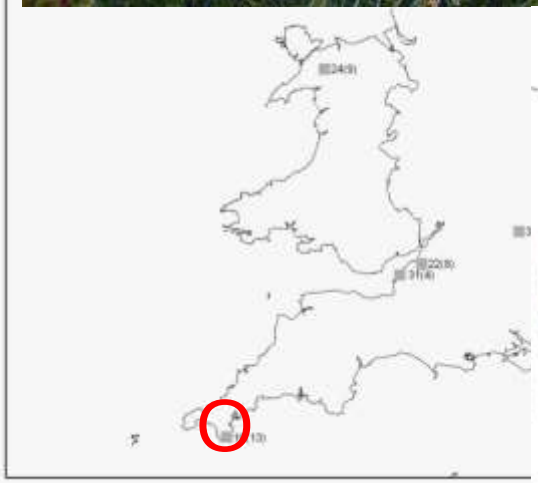
Progress in Europe: Albania, Azerbaijan, Belarus, Bulgaria, Cyprus, Czech Rep., Finland, Greece, Ireland, Italy, Portugal, Norway, Spain, Sweden and United Kingdom

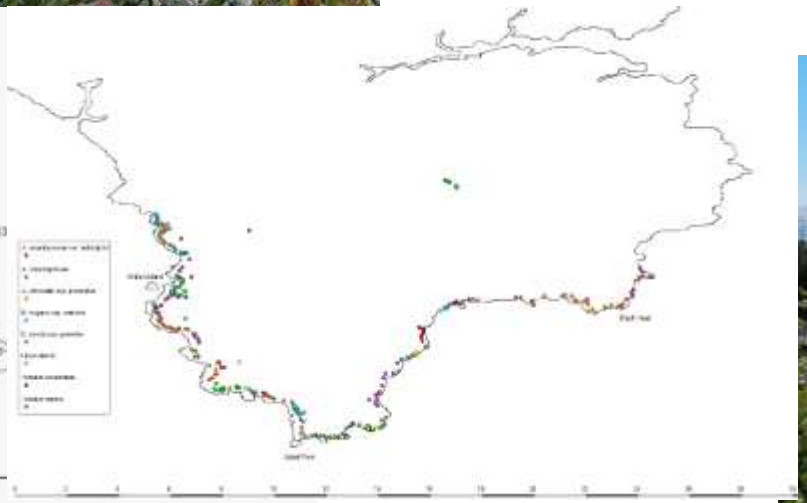
Progress in outside Europe: Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan, Middle East, Mexico, Peru, India

Establishing the first CWR genetic reserve in the UK

The Lizard NNR in Cornwall SW England: survey of CWRs Spring 2010

- *Allium ampeloprasum* var. *babingtonii*
- *Allium schoenoprasum*
- *Asparagus officinalis* subsp. *prostratus*
- *Beta vulgaris* subsp. *maritima*
- *Daucus carota* subsp. *gummifer*
- *Linum bienne*
- *Trifolium occidentale*
- *Trifolium repens*





SADC Regional CWR conservation strategies

- European Cooperative Programme for Plant Genetic Resources (ECPGR) *In Situ* and On-Farm Conservation Network established 2000
- Initiated EC-funded projects PGR Forum, AEGRO and PGR Secure
- Published CWR and LR conservation methodologies

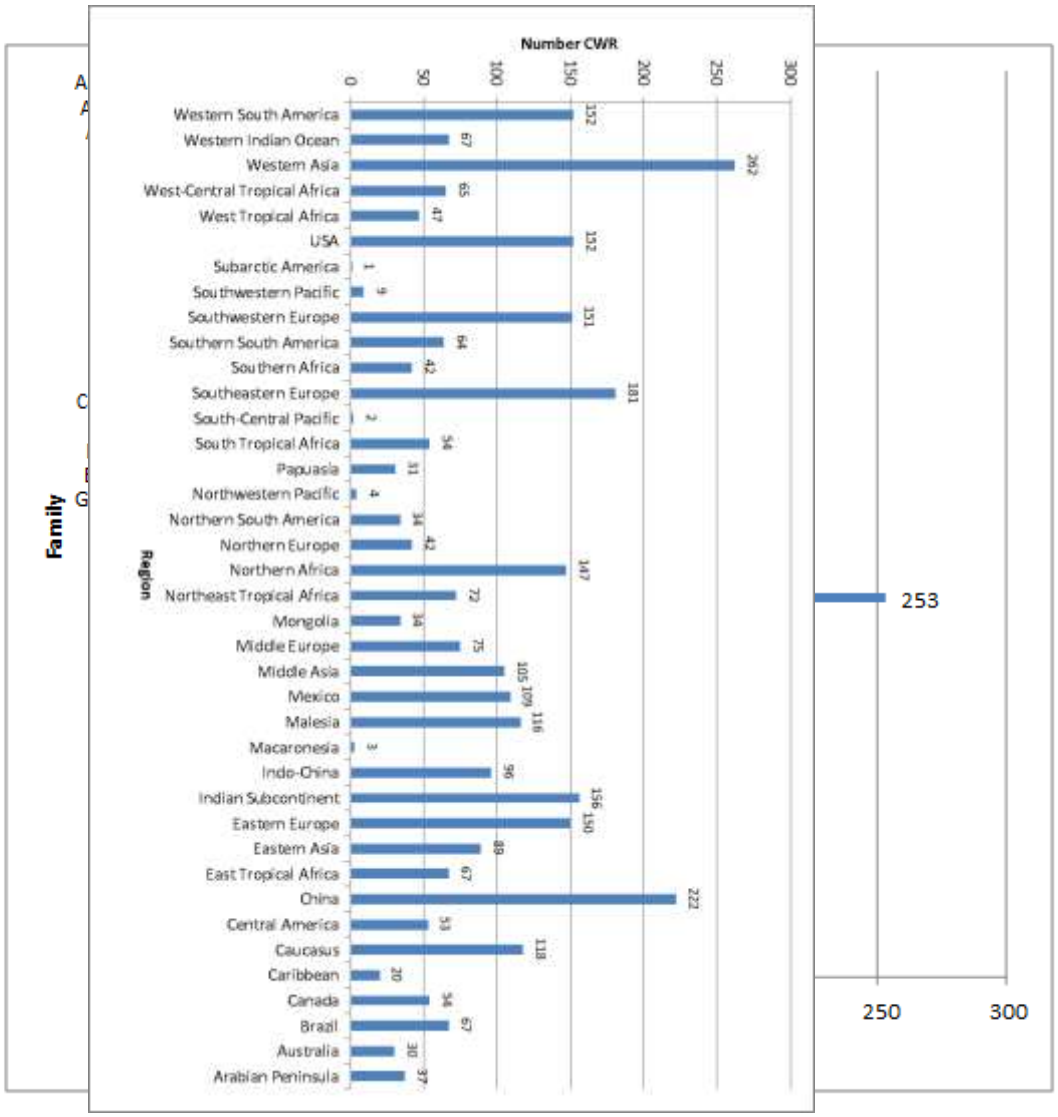
www.ecpgr.cgiar.org/networks/in_situ_and_on_farm.html

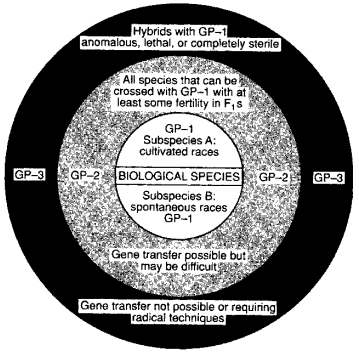
www.pgrsecure.org/

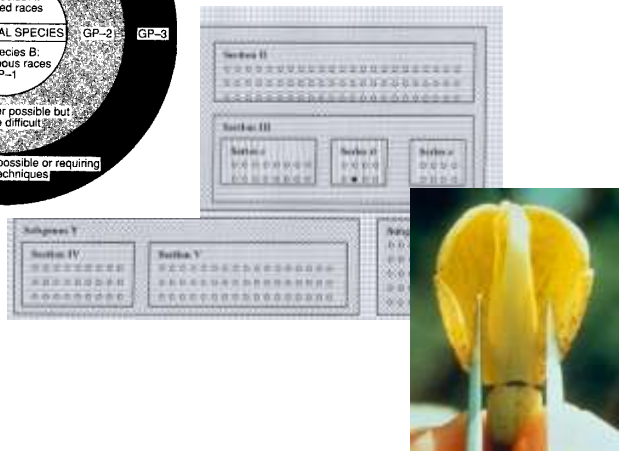
Ex situ targeted CWR sampling

- Global Crop Diversity Trust project with Norwegian Gov. funding
- Primarily use orientated, but 8m$ for *ex situ* collecting in first 3 years:
    1. List of gene pools and taxa to collect 92 genera with crops
    2. Ecogeographic data collection
    3. Gap analysis using Maxted *et al.* (2008) / Ramírez-Villegas *et al.* (2010) methodology
    4. Field collection
    5. *Ex situ* storage

Global Crop Diversity Trust: global *ex situ* CWR conservation





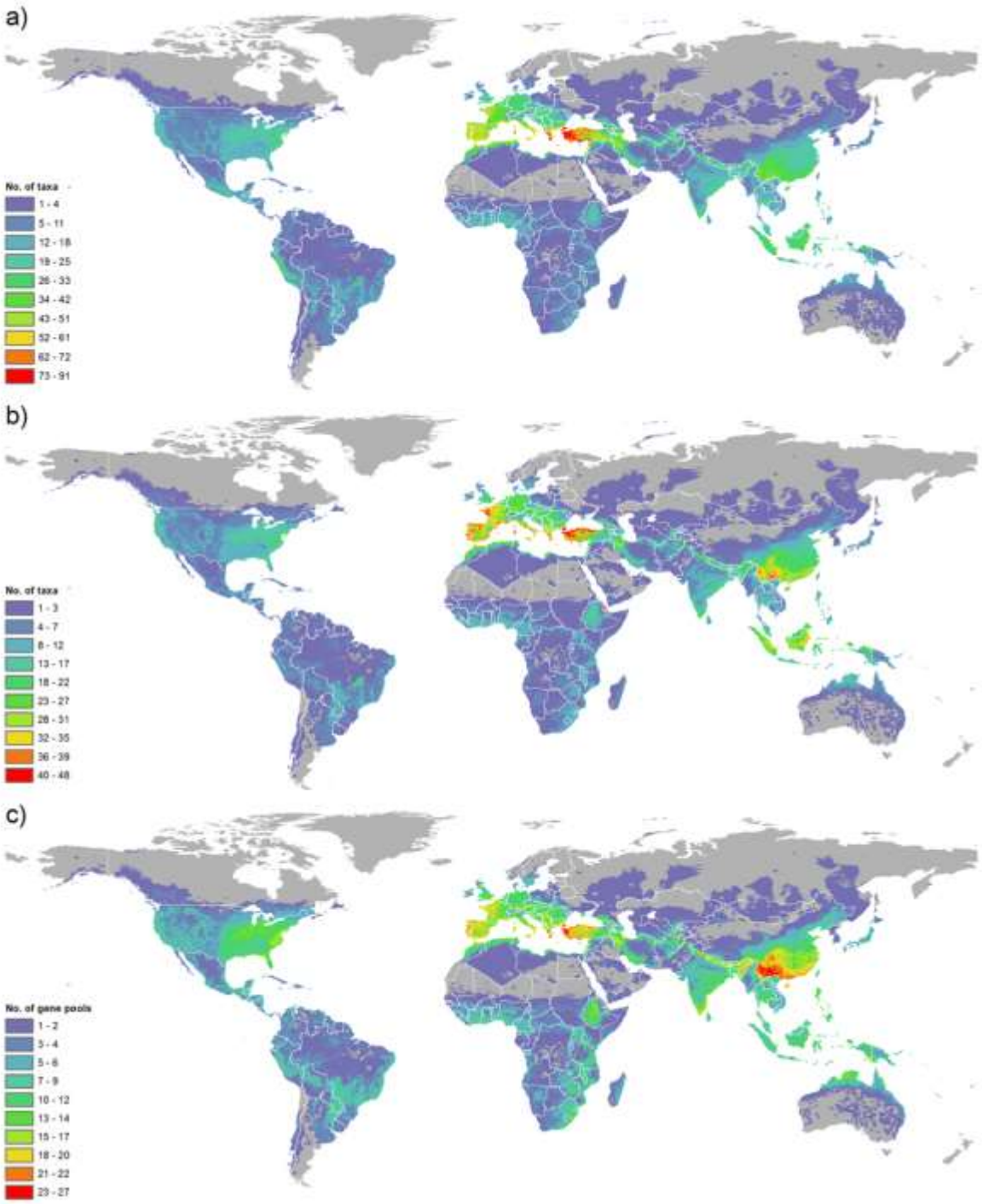


1,667 priority CWR taxa from 194 crops

- 37 families
- 109 genera
- 1,392 species
- 299 sub-specific taxa

Vincent *et al.* (2012)

http://www.cwrdiversity.org/checklist/



a. Taxon richness map

b. Collecting hotspots per taxa combined;

c. Collecting hotspots per crop gene pools combined.

1,187 crop wild relatives from 81 gene pools, representing 21 families and 58 genera

FAO National CWR 'Toolkit'

- Aim: A *Conservation Toolkit* that will aid national PGRFA programmes formulate and enact a National Strategy for *in situ* CWR and LR conservation
- It will provide an interactive array of options for the national PGRFA programmes, particularly in Developing Countries, to formulate and enact a National Strategy for *in situ* CWR and LR conservation, and so through systematic conservation to enhance CWR/ LR exploitation and engender national and global food security.

http://www.pgrsecure.bham.ac.uk/sites/default/files/documents/helpdesk/FAO_Toolkit_DRAFT_Oct_12.pdf

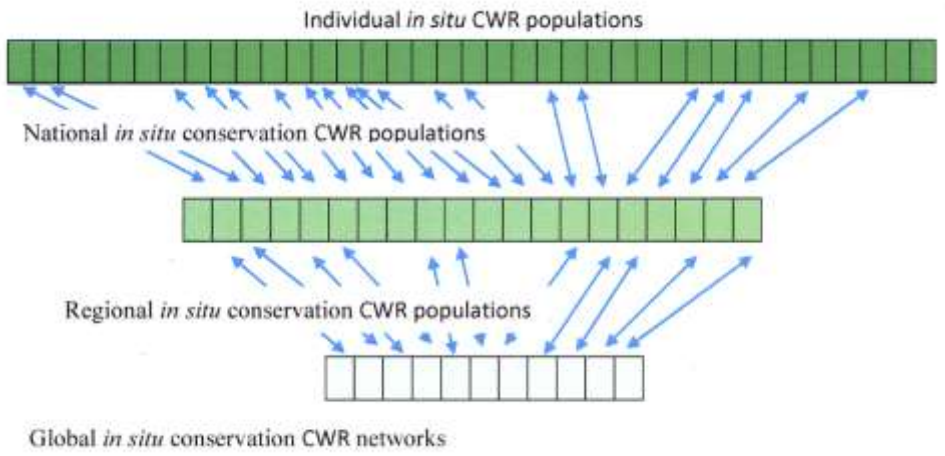
Future:
In situ CWR networks of populations
Addressing a need

- Global: 13th Regular Session of FAO CGRFA (2011) recognised the need to pay greater attention to crop diversity essential for food security … recognized that a global network for *in situ* conservation necessary to address challenges facing agricultural production including climate change

- European: 13th meeting of ECPGR Steering Committee (2012) recognised importance of *In situ* conservation and recommended the development of a concept for *in situ* conservation of Crop Wild Relatives in Europe

- Both recommended a Network of Networks, broad, decentralized participation approach

CWR Populations



Option Nos.	Option Description	Advantages	Disadvantages
1	Physical global network(s)	• Ease of application of cross network management regimes	• Significant resource investment in designated sites by Gov. Body • Less involvement of site host country conservation agencies
2	Virtual global network(s)	• Limited financial resource investment in designated sites by FAO • Greater involvement of site host country conservation agencies	• Less control over Network operation by Gov. Body • Slow Network establishment and possible poor global coverage

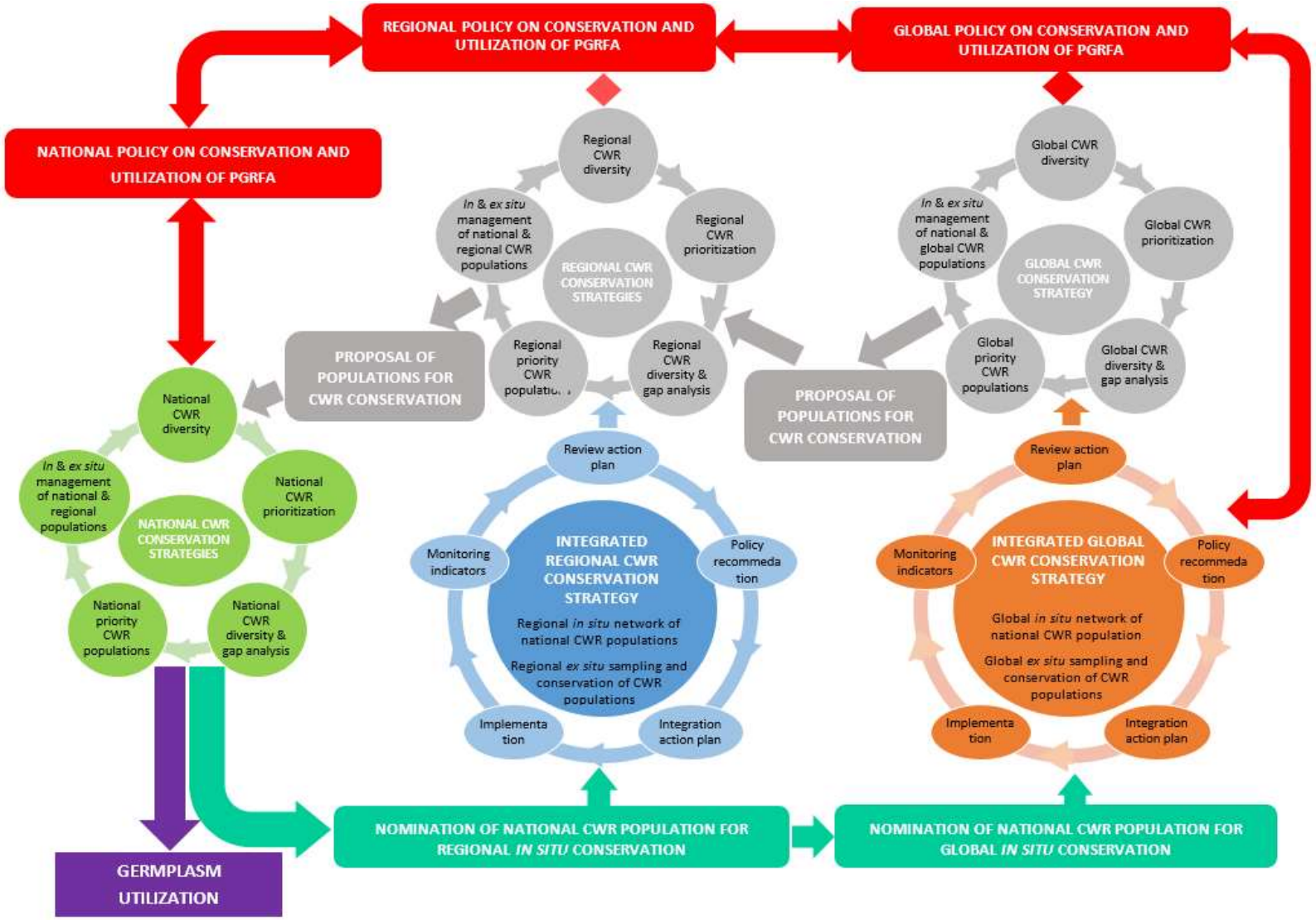
In situ networks of CWR populations

Function

- **Coordination** of *in situ* conservation even linked to on-farm management of PGRFA;
- Fostering **stronger partnerships (funding)**;
- **Impacting positively on activities at country-level** providing support the ultimate custodians of PGRFA, the **local communities**;
-
- **Safeguarding in perpetuity of important genetic resources** for use either directly by famers or by plant breeders;
- **Better linkages between conservation and sustainable use** of PGRFA for the benefits of current and future generations.

In situ networks of CWR populations

Structure



In situ networks of CWR populations

Governance

- Geopolitical and administrative scales
  - International agency (FAO Globally Important Agricultural Heritage Systems, FAO IT, CG Centres, UNESCO Man and Biosphere Programme, UNESCO World Heritage Sites, CBD Programme of Work on Protected Areas, IUCN Key Biodiversity Areas)
- Physical versus virtual management
  - Novel stand alone sites or existing sites
- National sovereignty over genetic resources
  a. all sites nominated by national PGRFA coordinators,
  b. all sites remain under the jurisdiction of national agencies,
  c. access to material controlled by national authorities
- Management and coordination responsibilities
  - Maintain minimum criteria for inclusion in global network(s);
  - Coordinate and provide expertise and access to *in situ* conservation;
  - Promote access to *in situ* conserved populations linked to benefit sharing;
  - Increase awareness of value of CWR for agriculture and the environment
- One network or two?

N.I. Vavilov

= Vavilov Network

In situ networks of CWR populations

Governance

Minimum criteria for inclusion in global network (Iriondo *et al.* 2012, Fielder *et al.* 2014)

- **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 diversity
  - Inventory of all CWR present in the site

In situ networks of CWR populations

Finance

		USD (x000)	USD (x000)	USD (x000)
International costs	Research global priority sites to establish CWR genetic reserves for IT Annex 1 CWR taxa	800		
	Initial set of 50 CWR genetic reserves for IT Annex 1 CWR taxa established within 10 years of global network(s) @ 100,000 USD per CWR genetic reserve	5,000		
	Network(s) Secretariat staff and a Managerial Committee for first 10 years of global network(s) @ 250,000 USD per annum	2,500		
	Total international costs		8,300	
National costs	Production of national CWR conservation strategies for 30 countries in Vavilov Centres @ 100,000 USD per national CWR conservation strategy	3,000		
	Running costs of 50 national genetic reserves @ 20,000 USD per CWR genetic reserve for 10 years	1,000		
	Total national costs		4,000	
	Total costs of global network(s)			12,300

Potential sources of funding: GEF, Treaty, UNEP, Foundations, *In Situ* Trust

Conservation linked to USE

- Use of genetic resources is associated with characterisation and evaluation
- SoW1 (FAO, 1998) 35% of countries reported lack of C/E data as a major constraint on germplasm use
- SoW2 (FAO, 2010) “Country reports were virtually unanimous in suggesting most significant obstacle for greater use of PGRFA is the lack of adequate C/E data”
- Conventional field C/E for crop material has failed to meet the demand, for CWR untried but surely not a serious option?

Conservation linked to USE

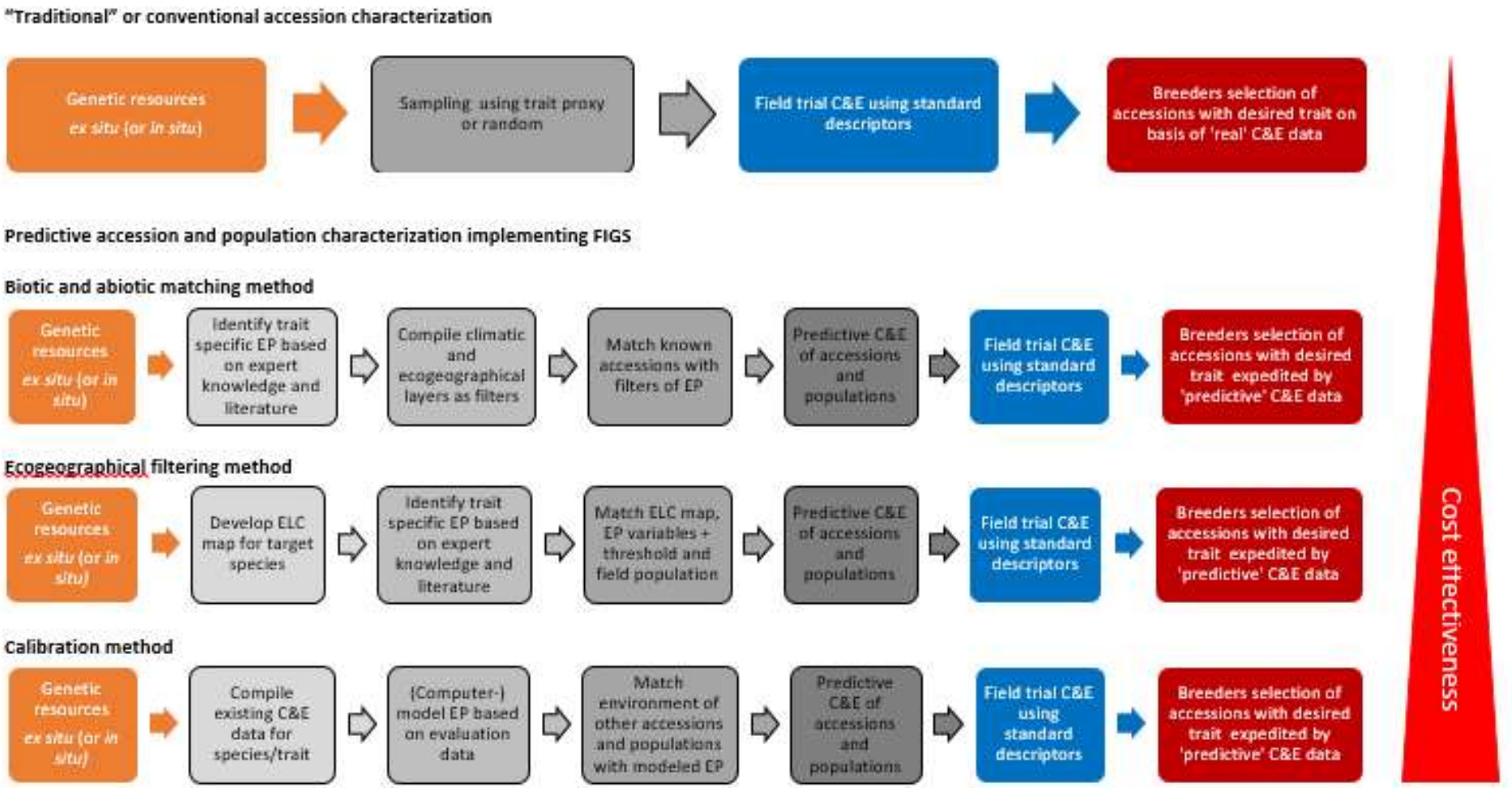
Omics

- CWR challenge
  - There are 1,392 priority CWR species
  - How many populations, genes, gene variants, traits of interest?
  - The challenge is ‘high-throughput’
  - How do we ensure the effective conservation and use of all potentially valuable genes across all CWR and make best use of them (and manage the data effectively)?
- Improved technology
  - Whole genome resequencing: Next Generation Sequencing and Third Generation, single molecule sequencing
  - SNP detection and Genome-wide Association Studies
  - Gene-chips, RNA-Seq: whole genome expression studies
  - Phenomics
  - High-throughput approach e.g. ‘3000 Rice Genomes Project’ (CAAS, IRRI and BGI)

Future?

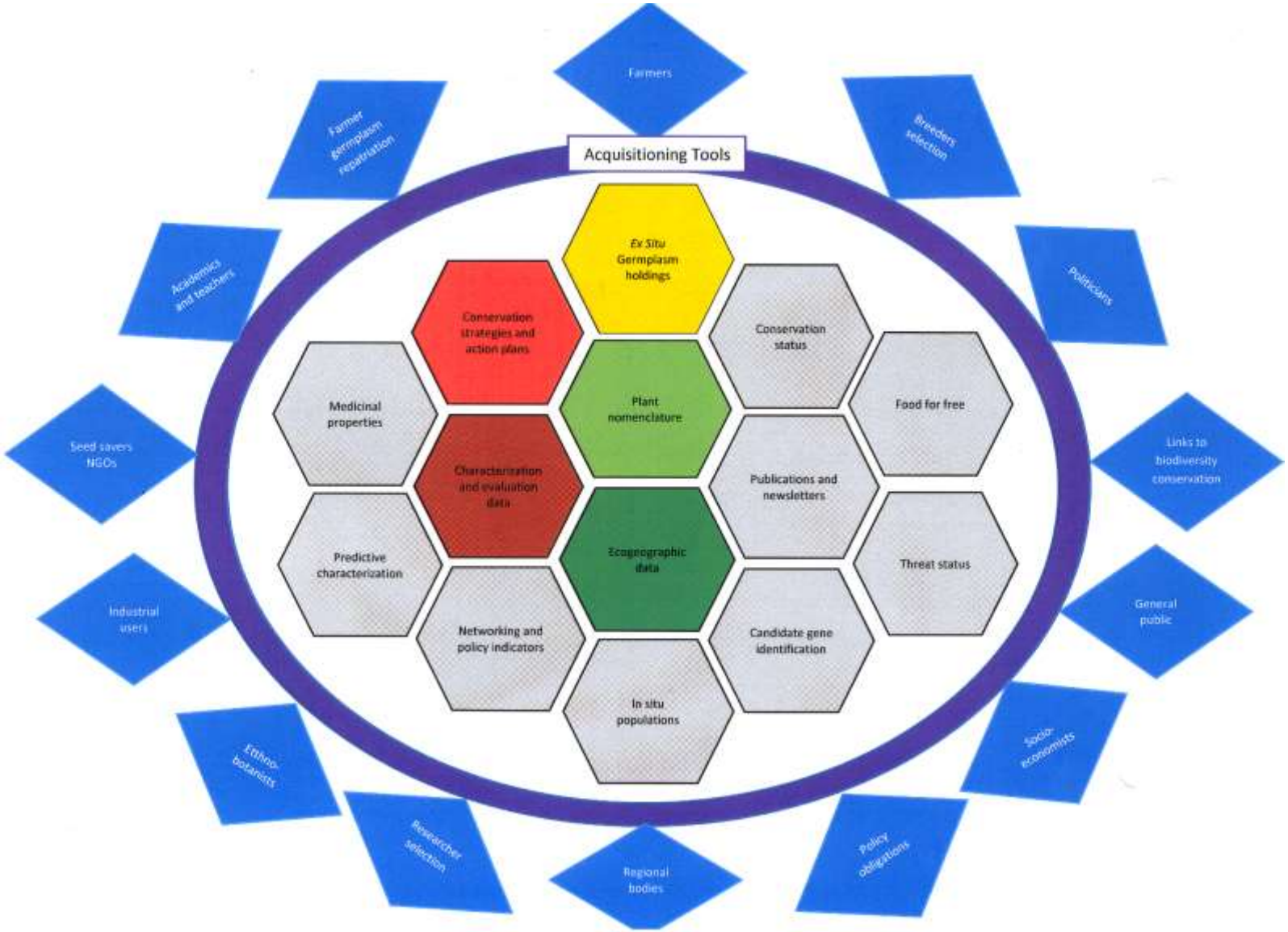
- —High-throughput genomics and phenomics but 1,392 may still be too many at 172 genotypes of each CWR species
- —Merged into one ‘composite genome’?

Conservation linked to USE
Predictive characterisation



Key: C&E = Characterization and Evaluation; EP = Environmental Profile; ELC = Ecogeographical Land Characterization; FIGS = Focused Identification of Germplasm Strategy

End user-orientated informatics



Good news story

CWR found and not lost?

- In 1987 near Cavus, Antalya province, Turkey while collecting for food, fodder and forage legume species we found a new species that we named *Lathyrus belinensis* by Maxted and Goyder (1988).
- Single population growing alongside new road between Kumluca and Tekirova, especially around an ungrazed village graveyard in Belin, we and other have searched elsewhere but it has not been found away from this location
- Species was a member of *Lathyrus* section *Lathyrus* and most closely related to *L. odoratus* (sweet pea), being just as scented as sweet pea but with yellow flower, so was an opportunity for horticulturalists to breed a yellow sweet pea
- Attending a conference in 2010 in Antalya I decided to drive across to see my species—the original type location had been completely destroyed by earthworks associated with the building of a new police station
- Although a few plants were found in the area and seed is held *ex situ*, the richest area within the site had been lost.
- To draw attention to the species I applied the IUCN Red List Criteria and found to be Critically Endangered—the most highly threatened category
- The species has significant economic potential but is very near extinct in the wild. Only time will show if action can be taken before we lose the opportunity to fully exploit this natural resource!

Take home message

- CWR have significant value for food security and human well being but are underutilized and threatened

- Increased global attention to *in situ* and *ex situ* CWR conservation

- To achieve goal will require collaboration
  - Geographic level
  - Biodiversity and agrobiodiversity
  - Conservationists and germplasm users

- For *in situ* conservation need global decentralized network to strengthened partnerships and linkages = “networks of networks”
  - Identify existing Governing Body to host Secretariat to facilitate the work of the global network.
  - Find CWR budget US$ 12.3M for first 10 years of operation

- Re-visit conservation action to better serve users