UNIVERSITY OF BIRMINGHAM

Crop wild relatives and how to conserve them *in situ*

Nigel Maxted and friends

Forages 2020 workshop

9-11 November, NordGen, Alnarp, Sweden

The Point: why conserve CWR?

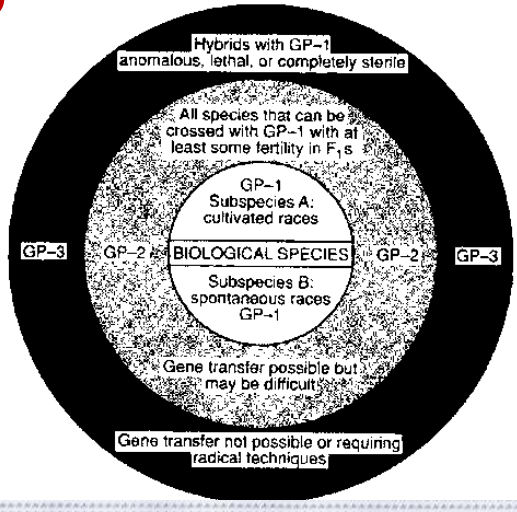
CWR have actual and potential value in plant breeding that can directly and indirectly benefit current and future generations

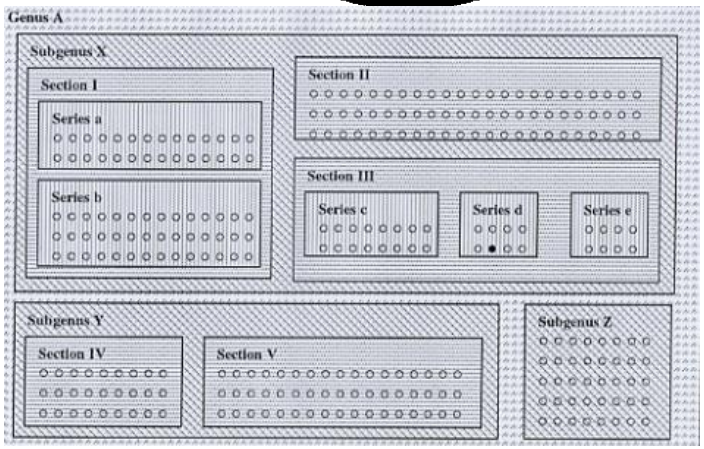
Talk overview

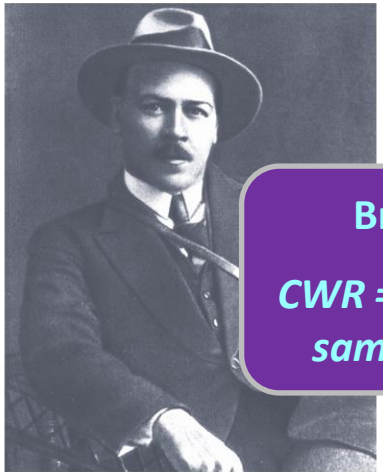
- What are CWR
- Why they are important – their value
- *In situ* networks of CWR populations
- *In situ* site management
- CWR conservation and use
- Lessons learnt

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







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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 a source of adaptive traits

CWR	Trait
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

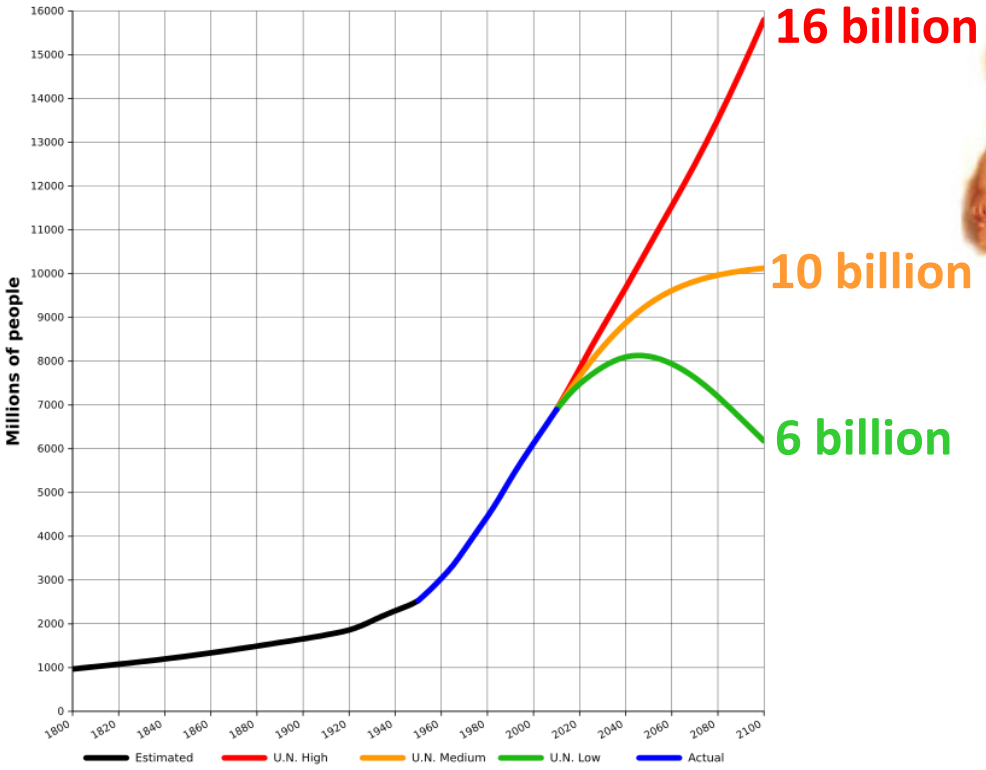
Aegilops speltoides (B-genome)

Wheat

$120 billion toward increased crop yields per year (PWC, 2013)

Why actively conserve ABD now?

- 7.37 billion humans in 2015 (02/11/15)
- 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)

Climate change has changed the game

Climate change reduce agricultural production by 2% per decade but demand increases 14%

Up to 40% of the world will develop unfamiliar climates by 2050 (IPCC, 2014)

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CWR may hold one key to human survival

- Wide genetic diversity of adaptive traits
- Tried, proven but still largely unapplied
- Technological advances in application

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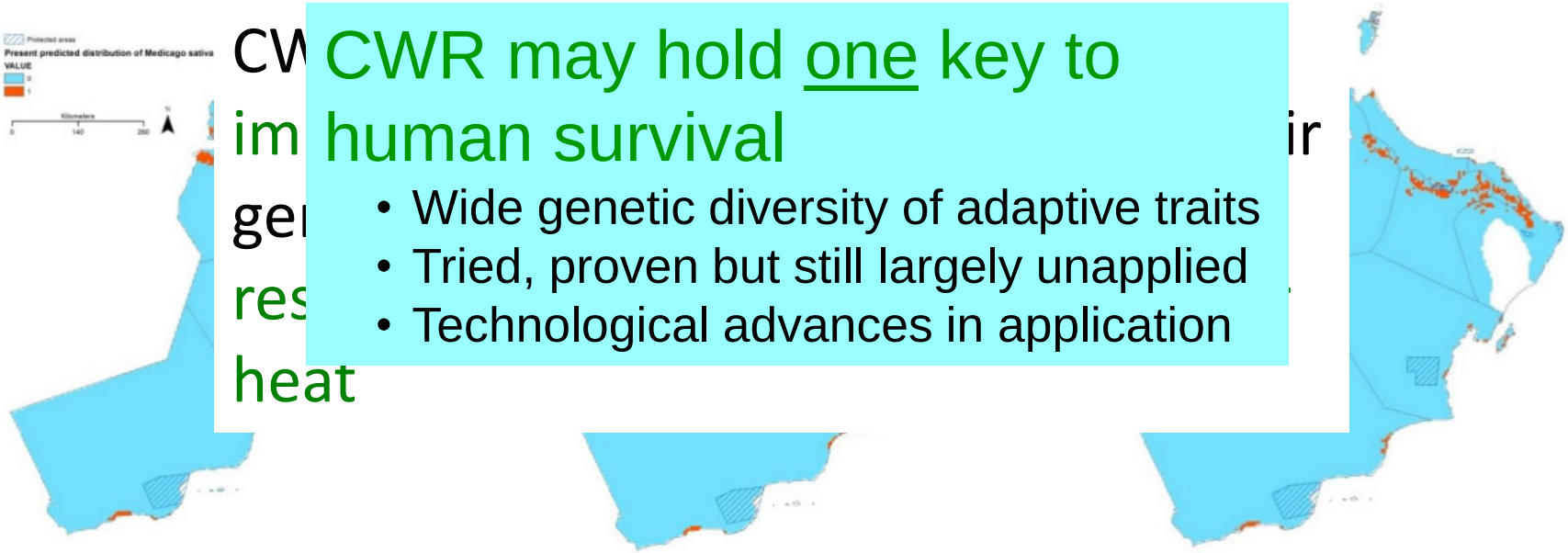


2015 @ 12%/Oman 2020 @ 17.4%/Oman 2050 @ 2.3% of Oman

Food insecurity & human malnourishment is a real problem in our lifetimes

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 ABD

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

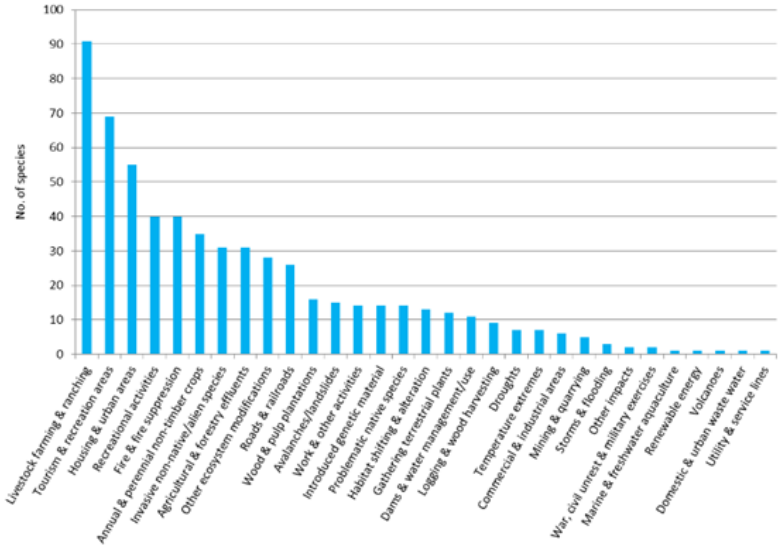
UN Millennium Development Goals highlighted the need of eradicating extreme poverty and hunger = linked conservation and use of ABD

UN adopts new Global Goals, charting sustainable development for people and planet by 2030

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

Approaches to CWR conservation

- Numerous diverse approaches that result in CWR conserved in (and outside) genetic reserves

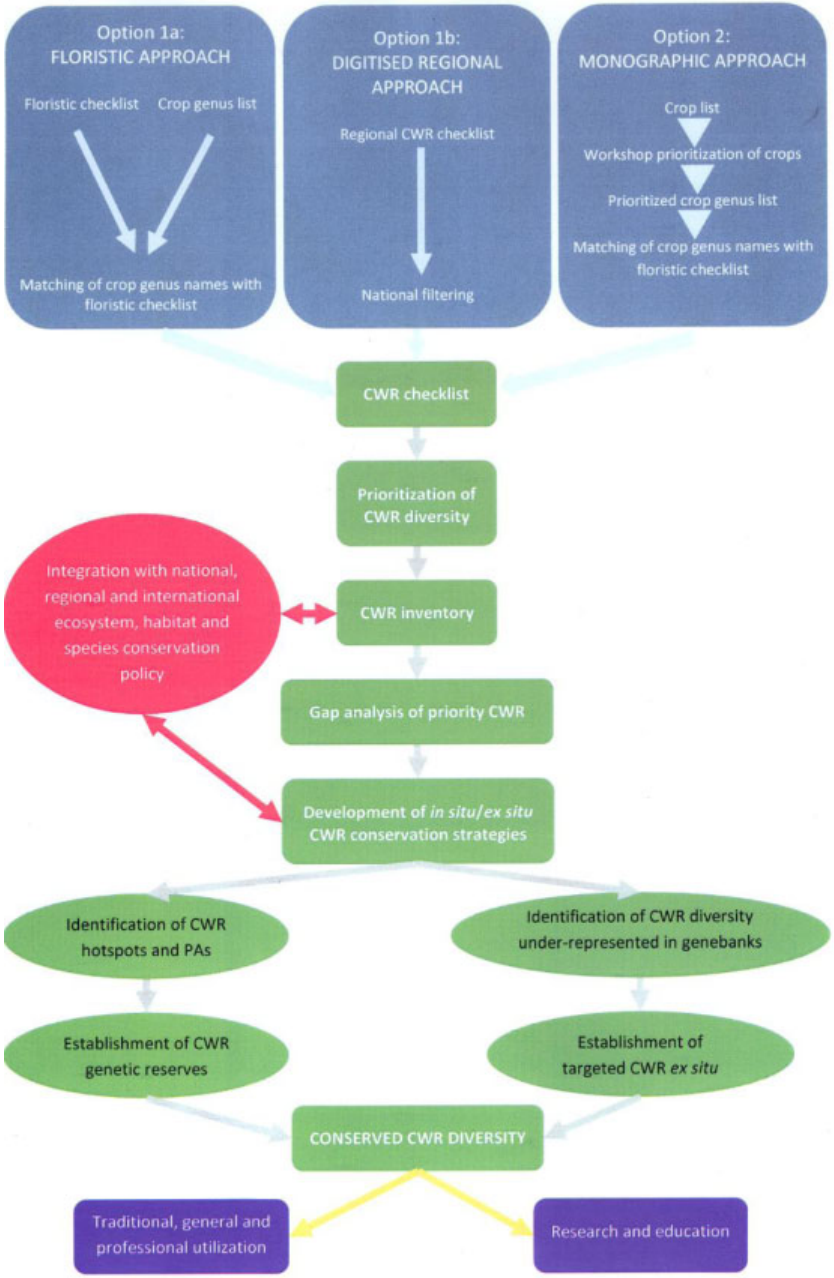
- Three basic approaches:
  - Individual
  - National
  - Regional
  - Global

- Each concludes with CWR diversity being actively conserved *in situ* in genetic reserves / informal conservation sites and population samples held in genebanks

Individual CWR genetic reserve

- Individual PA manager's involvement in CWR conservation
- Each individual PA may not be included in national or global CWR networks
- Adapt PA management plan can be adapted for CWR conservation
- Publicize the presence of CWR species in the protected area
  - General public see the link between their food and CWR conservation

National CWR Strategy



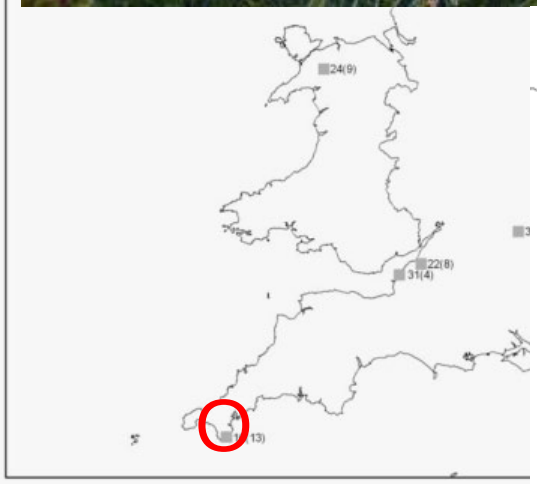
Progress in Europe: Albania, Azerbaijan, Belarus, Bulgaria, Cyprus, Czech Rep., Finland, Greece, Ireland, Italy, Portugal, Norway, Spain, Sweden and United Kingdom

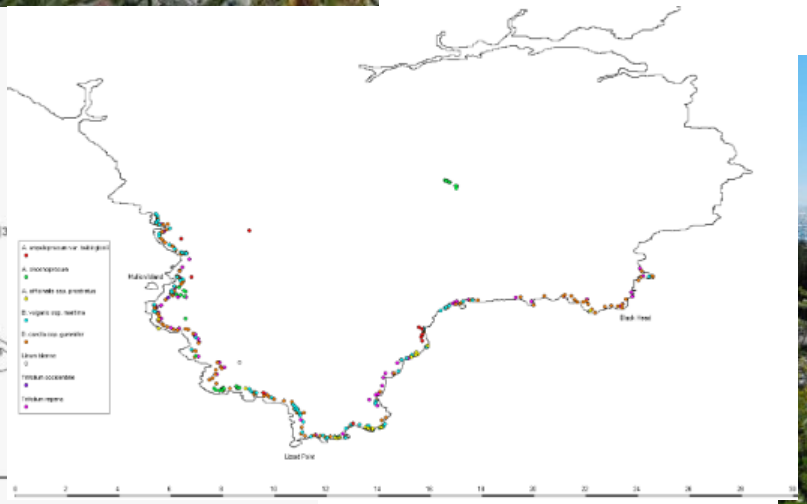
Progress in outside Europe: Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan, Middle East, Mexico, Peru, India

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*





Regional CWR conservation strategies (e.g., Europe)

- European Cooperative Programme for Plant Genetic Resources (ECPGR) *In Situ* and On-Farm Conservation Network established 2000
- Two working groups:
  - Wild species conservation in genetic reserves
  - On-farm conservation
- Initiated EC-funded projects PGR Forum, AEGRO and PGR Secure
- Published CWR and LR conservation *in situ* methodologies

www.pgrsecure.org/

http://www.ecpgr.cgiar.org/working-groups/wild-species-conservation/

http://www.ecpgr.cgiar.org/working-groups/on-farm-conservation/

CWR and LR conservation *in situ* concepts

European Cooperative Programme for Plant Genetic Resources
ECP/GR

CWR *in situ* conservation concept (March, 2015)

ECPGR Concept for *in situ* conservation of crop wild relatives in Europe

Nigel Maxted, Alvina Avagyan, Lothar Frese, José Iriondo, Joana Magos Brehm, Alon Singer and Shelagh Kell

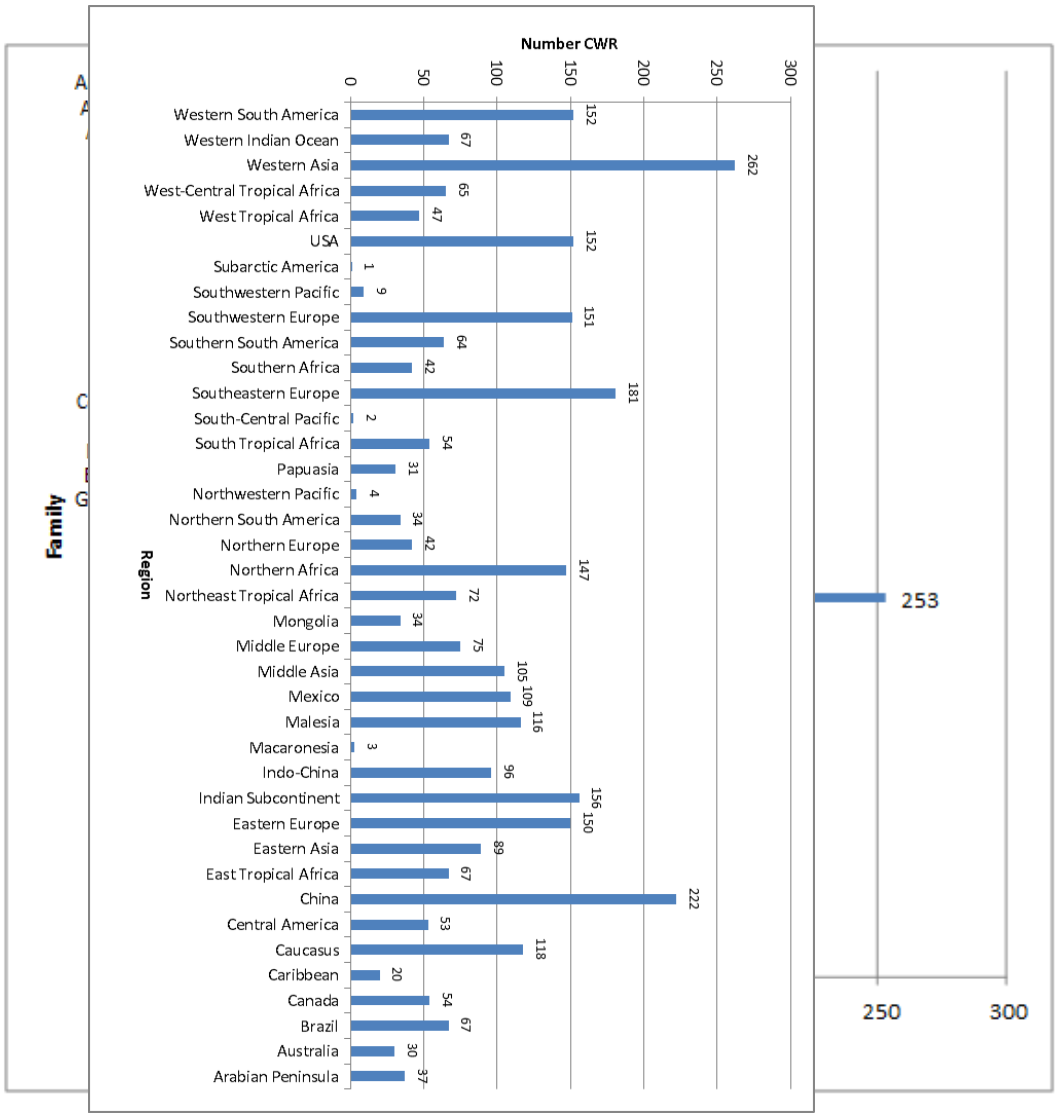
Endorsed by the ECPGR Steering Committee in March 2015

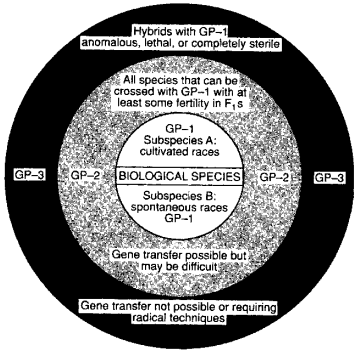
http://www.ecpgr.cgiar.org/fileadmin/templates/ecpgr.org/upload/WG_UPLOADS_PHASE_IX/WILD_SPECIES/Concept_for_in__situ_conservation_of_CWR_in_Europe.pdf

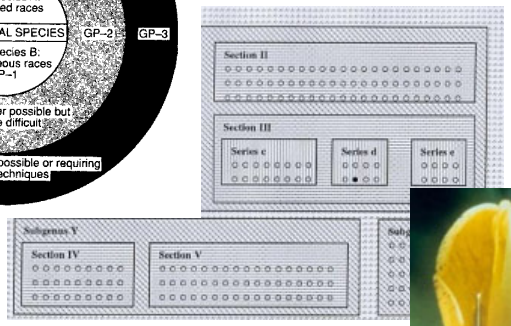
Ex situ targeted CWR sampling

- 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

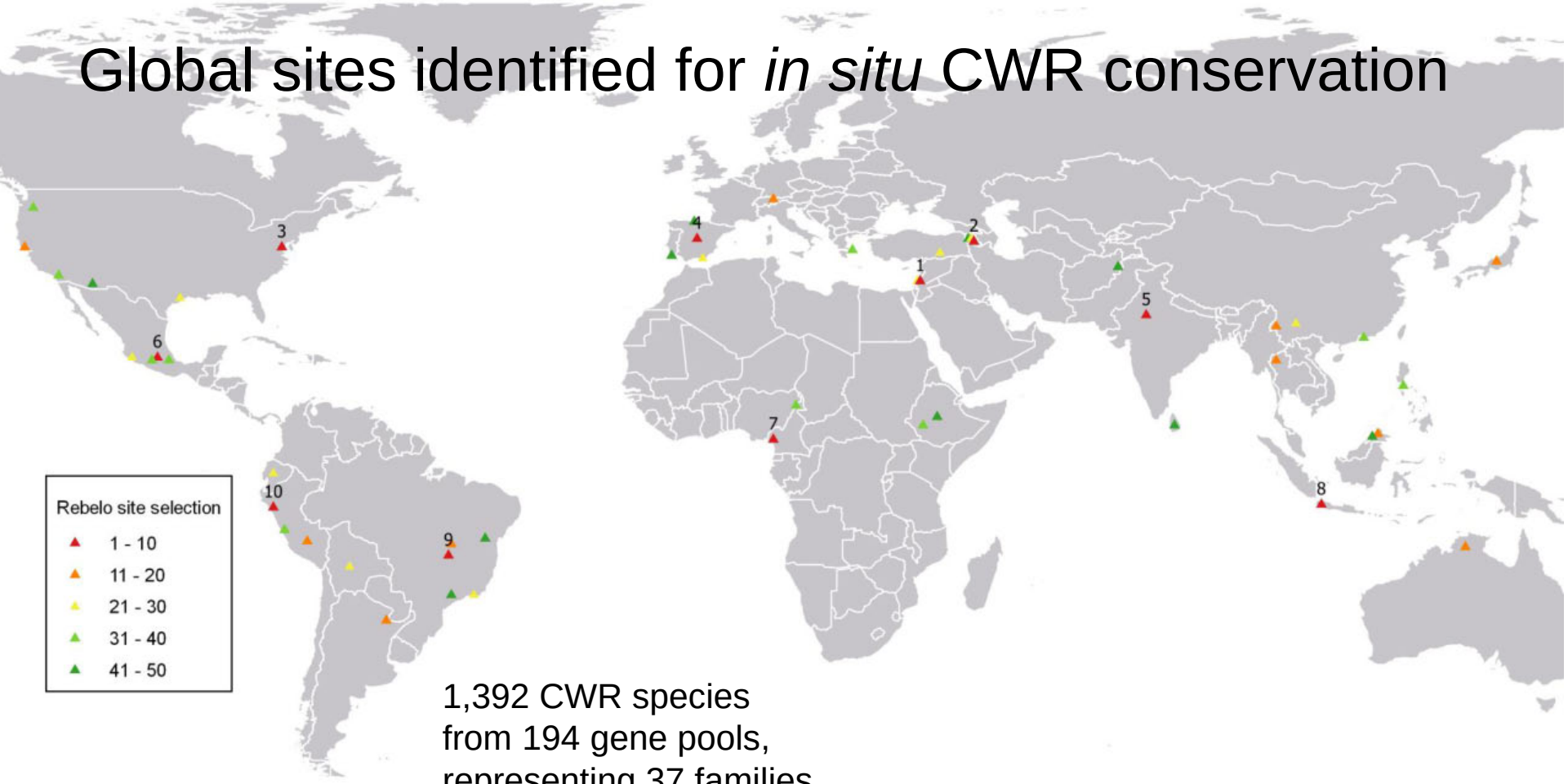
Vincent *et al.* (2012)

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

Recommendations for *in situ* and *ex situ* conservation action

Global CWR conservation strategy

Global sites identified for *in situ* CWR conservation



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Vincent *et al.,* 2016

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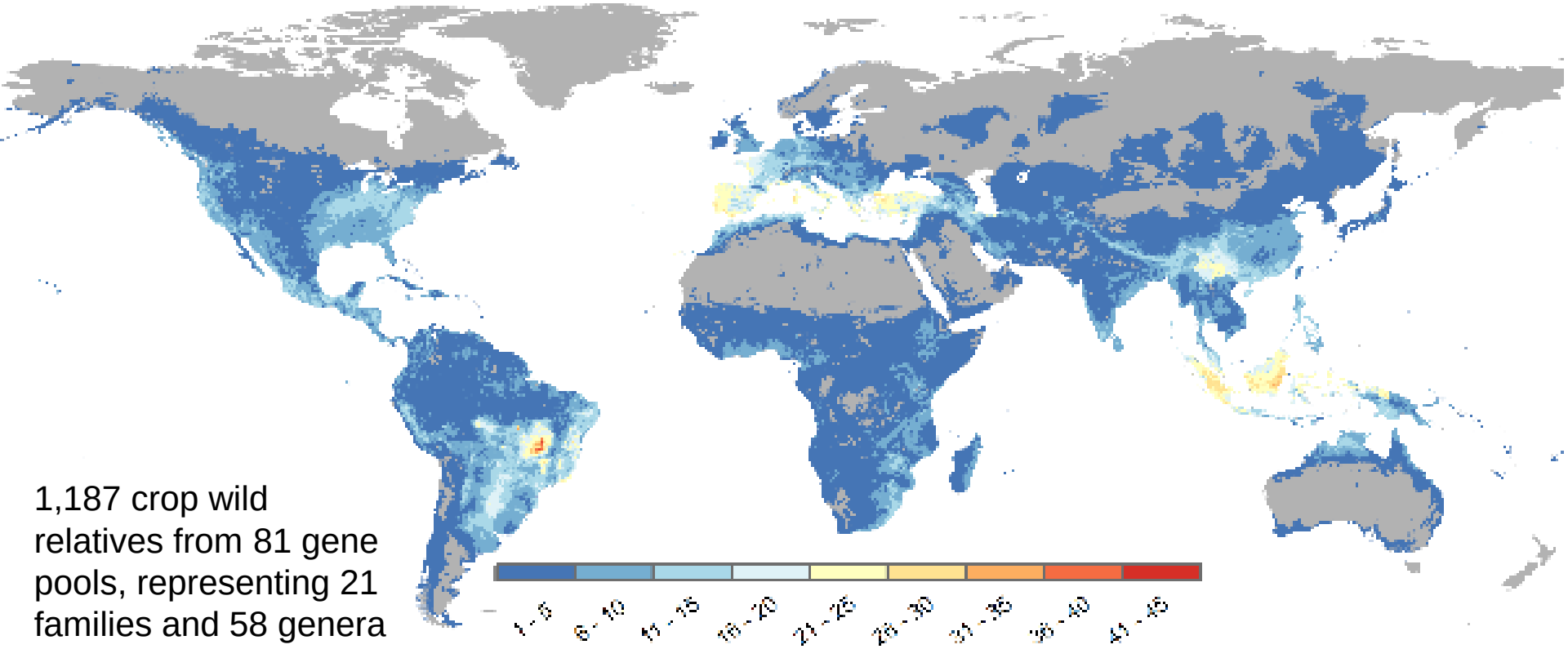
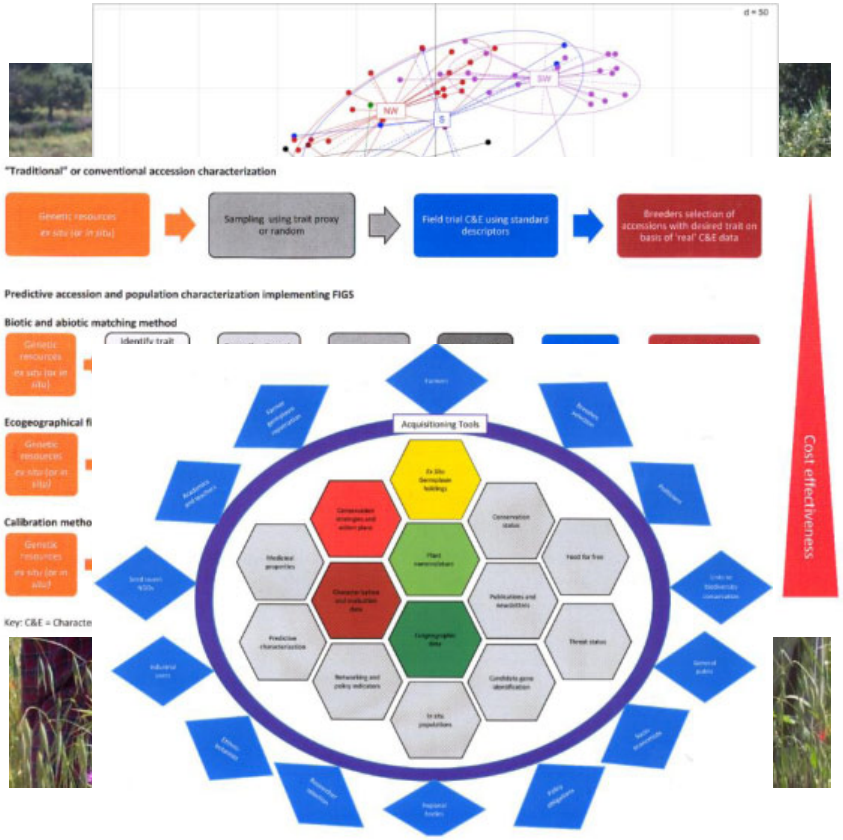


1,187 crop wild relatives from 81 gene pools, representing 21 families and 58 genera

Castenada Alvarez *et al.*, 2016

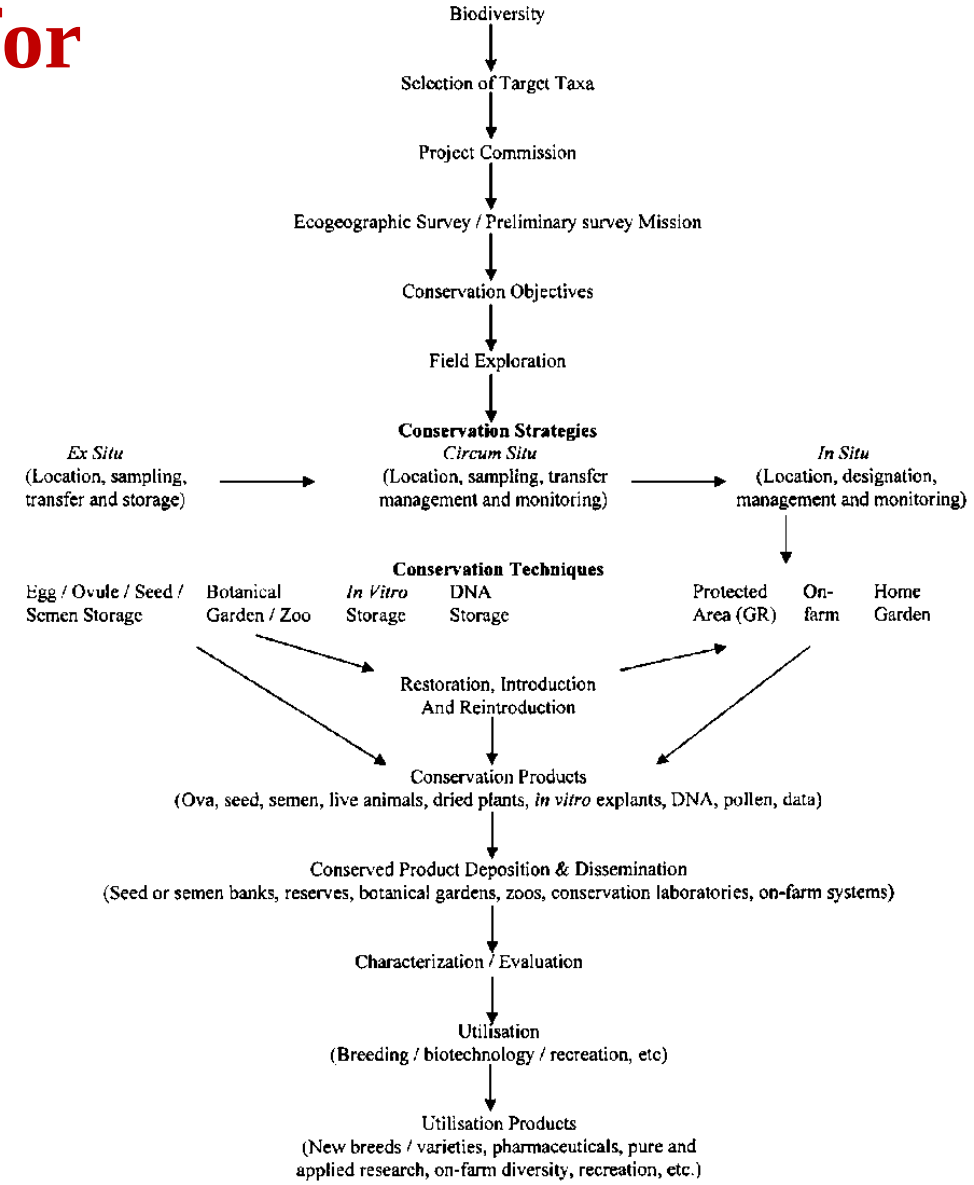
Promotion of Sustainable CWR Use

- Conventionally ABD are obtained by breeders, farmers and other users from *ex situ* genebanks, but also from *in situ* genetic reserves (is *in situ* untenable without active link to user)
- How?
  - Novel omics approaches to characterization and evaluation;
  - Predictive characterization for mining genetic resources;
  - (e.g. GLIS + extension) End user-orientated informatics .
- Establish a *modus operandi* for the routine use of CWR diversity found *in situ* in genetic reserves or ex situ in genebanks



In Situ Genetic Reserve Conservation of CWR for forages in Europe

- Objective: to ensure maximum range of genetic diversity is represented within the minimum number and size of *in situ* genetic reserves
- Complex goal - location, planning, establishment, management, monitoring and utilisation
- Gadgil *et al.* (1996), Safriel *et al.* (1997), Maxted *et al.* (1997) & Iriondo *et al.* (2008)
- Model for genetic reserve conservation



Forage CWR Strategy for Europe: Definition of *In Situ* Conservation Techniques

"*Genetic Reserve Conservation* - the location, management and monitoring of genetic diversity in natural wild populations within defined areas designated for active, long-term conservation.

In situ protected areas and nominated informal PAs

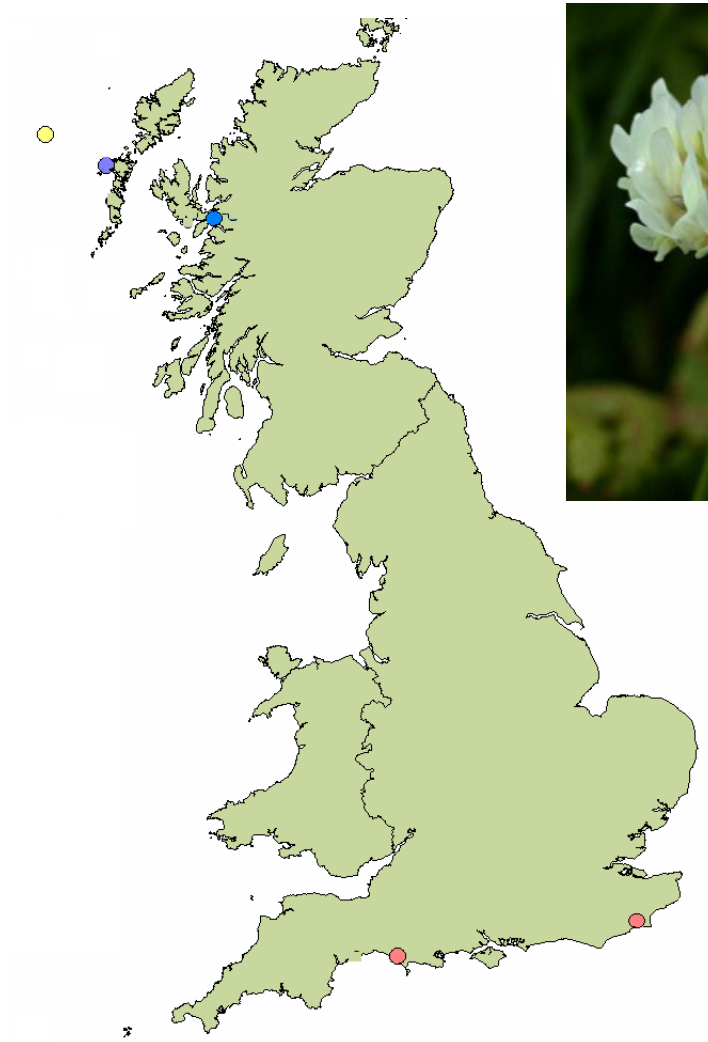
Maxted *et al.* (1997)

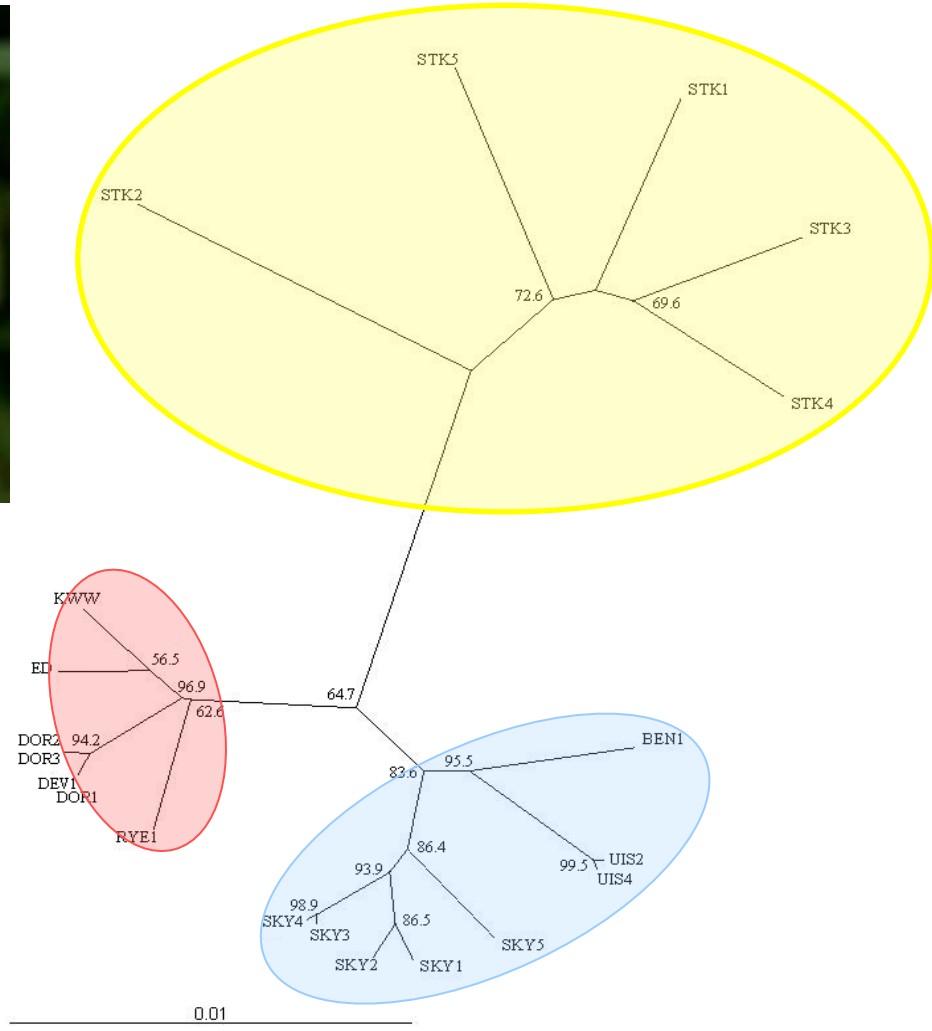
Forage CWR Strategy for Europe

- Are forages and food crop CWR essentially different?
  - Many forage are crops and wild species because of selection history
  - Genetic pollution / introgression
  - Closer link between *in situ* PA, non-PA and on-farm conservation for forages

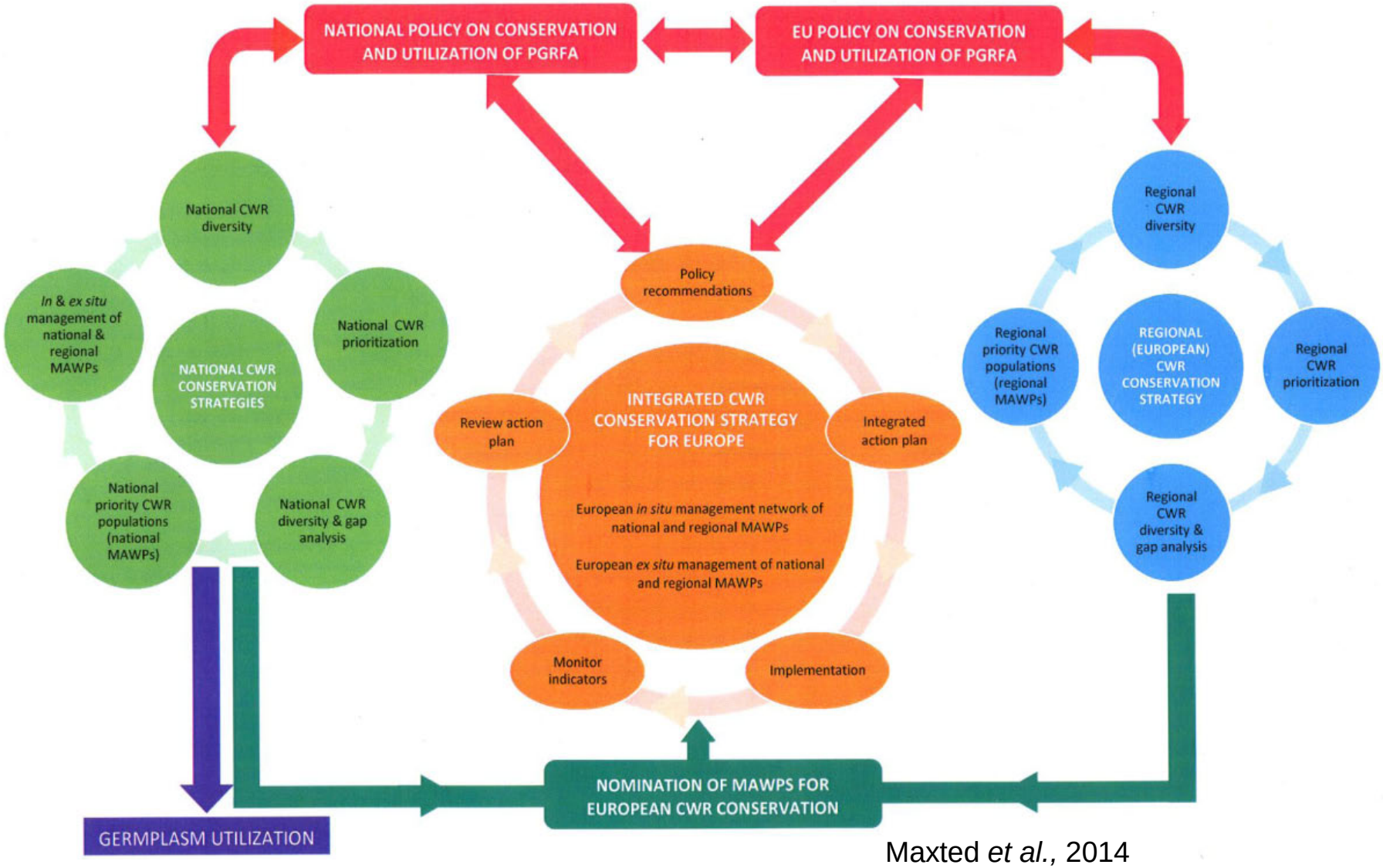
Genetic pollution / introgression: a particular problem for forages?

Cluster analysis of wild *Trifolium repens* from St. Kilda and wild and landrace material from north western Scotland and southern England based on 408 AFLP markers (Hargreaves *et al.* 2007).





CWR Strategy for Europe: *In situ* networks of CWR populations



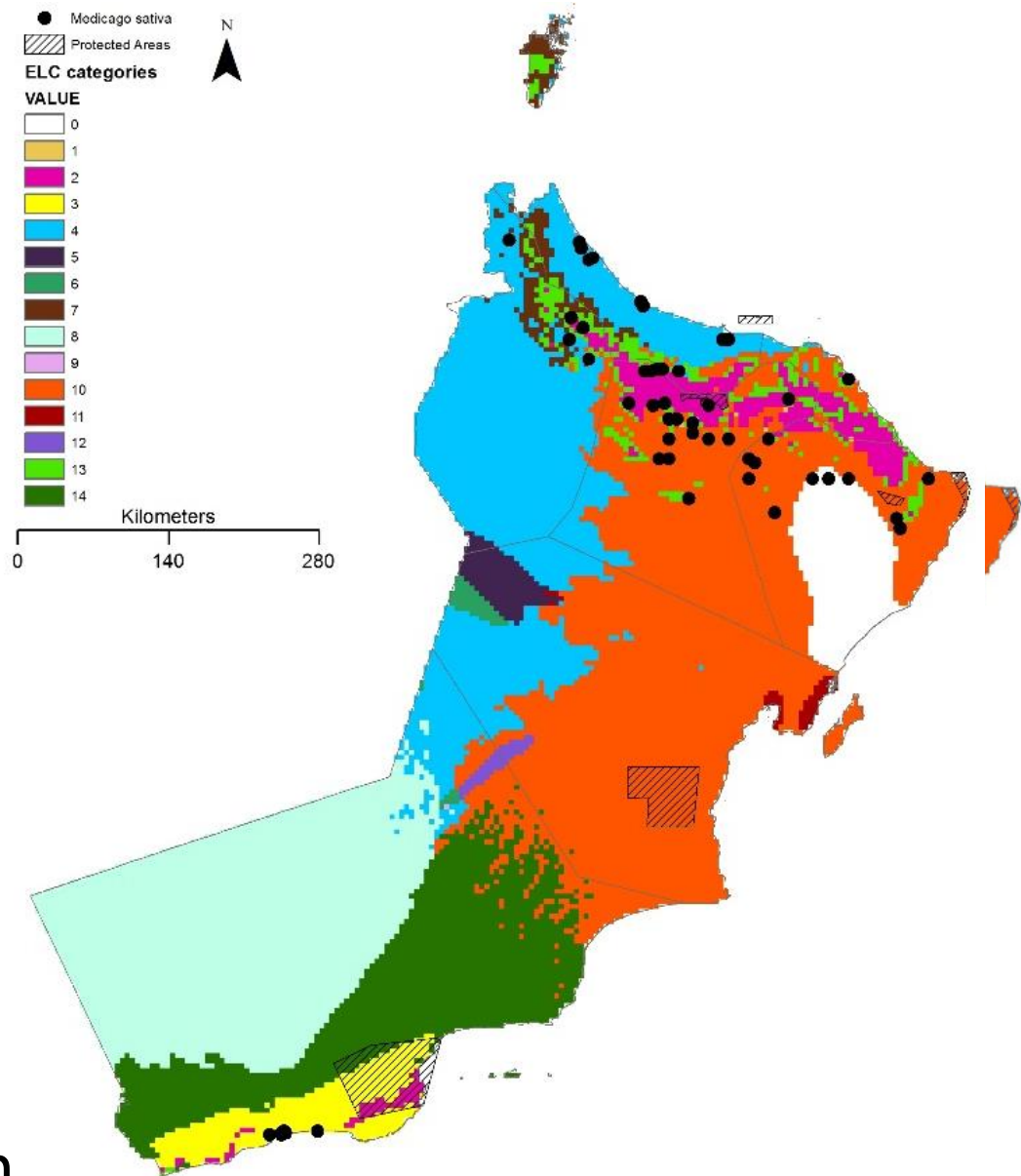
Maxted *et al.*, 2014

Ecogeographic and Genetic Analysis of Priority CWR:

Example: *Medicago sativa*

Methodology

- ELC Map for plant species of Oman produced using CAPFITOGEN tools
- 14 (out of 103) variables from bioclimatic, geophysical and edaphic components



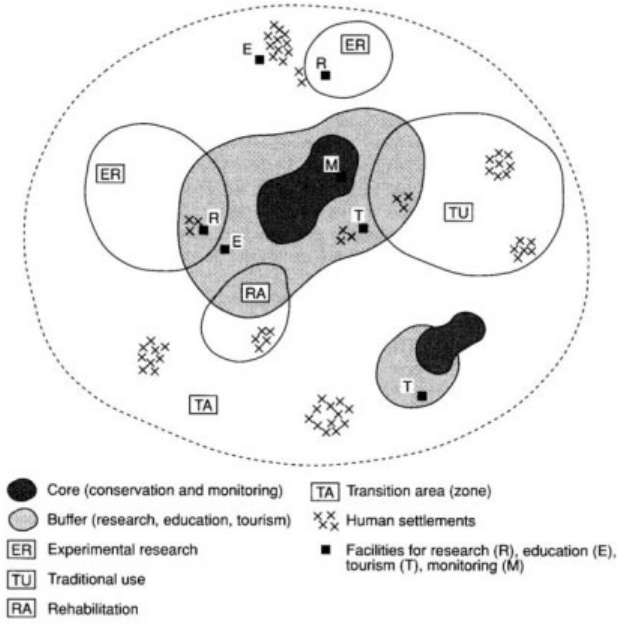
Specific ELC projection for *M. sativa* locations in

CWR *In Situ* sites: Assessment of Local Socio-economic and Political Factors

- Establish in existing PA if possible
- Major cost of reserve establishment
- Voluntary or legal protection
- Sustainability
  - Current usage
  - Proposed development
    - Dams
    - Changes in agricultural practice
  - Trained staff (problems / ID, surveying techniques)
  - Balance development, traditional agriculture and conservation

CWR *In Situ*: Reserve Design

- Factors to consider:
  - Reserve structure
  - Size
  - Single large or multiple small
  - Use of corridors or stepping stones
  - Reserve shape
  - Environmental heterogeneity
  - Potential user communities



- Structure to follow UNESCO man and the biosphere programme
- 1000-5000 potentially breeding individuals

CWR *In Situ*: Formulation of the Management Plan

- Site selected because abundant and genetically diverse populations of the target taxon
- Goal to maintain anthropogenic, biotic and abiotic dynamics of the site
- Target priority CWR taxa
  - Wild and weedy species of disturbed land
  - Very vulnerable to changes in human activity
- Pre-climax community
  - Active management

CWR *In Situ*: Management Plan

- Depends on location, target species, organisation, staff, etc.
- Contents
  - Conservation objectives
  - Site anthropogenic, biotic and abiotic description
  - Site history
  - Public interest
  - Factors influencing management
  - Ecological and genetic survey
  - Budget
  - Manpower
  - Management prescription and monitoring schedule

- Monitoring of target populations

Minimum criteria for inclusion in global network (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.

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

- *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

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

- *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

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

- *Quality standards for the protected areas selected for the establishment of genetic reserves*
  - Site has legal foundation
  - Site management plan acknowledges genetic

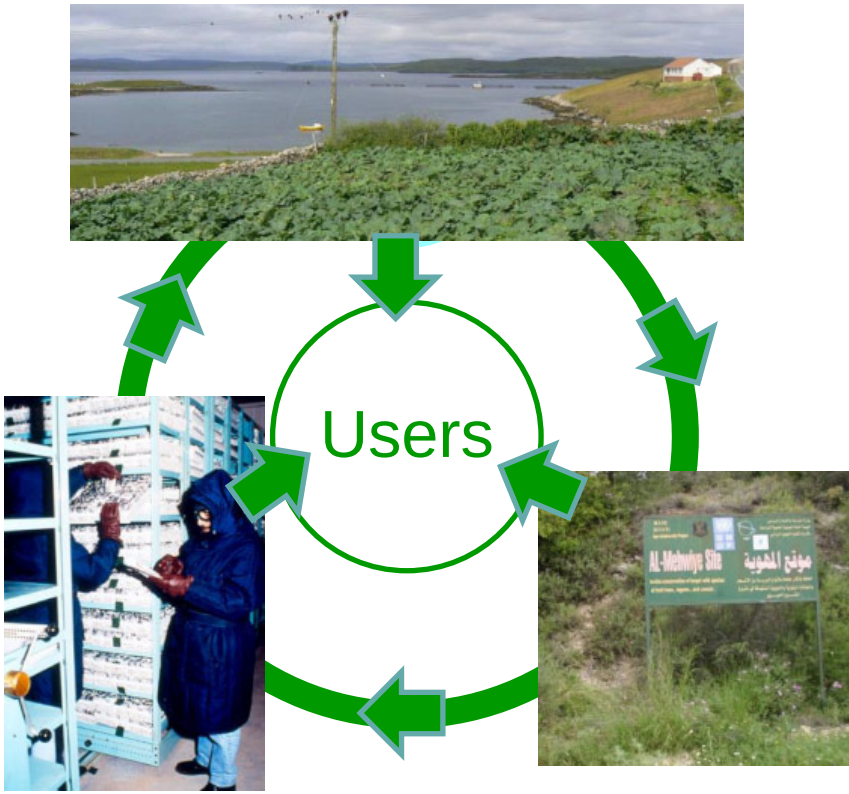
Monitoring *in situ* populations

- Monitoring plans
  - annual species
    - demographic every 5 yrs
    - genetic every 5–10 yrs
  - biennial and perennial species
    - demographic every 8 yrs
    - genetic every 25 yrs
- Initial ‘baseline’ storage in first two years of the *ex situ* establishment a genetic reserve.

Hannah with *Beta vulgaris* subsp. *maritima* specimen

CWR complementary approach

- Why CWR in *in situ* genetic reserves because of management control;
- Genetic reserves are likely to be established in existing protected areas
  a. sites have long-term conservation ethos so less prone to hasty management changes,
  b. relatively easy to amend existing site management plan,
  c. Avoids cost of establishing novel conservation sites;
- But it does require collaboration between the biodiversity and agro-biodiversity communities;
- Who are partners:
  - Biodiversity = protected area managers (+ local communities)
  - Agro-biodiversity = ? (~~academics~~ + genebanks)
- GRC refocus their attention on meeting users needs, not just genebanks, whether from *ex situ* or *in situ* sources!



CWR In Situ Network: practical issues

1. Which priority CWR should be included (all forage or subset, if prioritised on what basis)?

2. Completion of identification of priority sites (finishing work on all priority sites or Phase progress)?

3. Unified Network management (how unified, who should oversee Network and ensure sustainability, links to other Networks e.g. ECPGR, Globally Important Agricultural Heritage Systems, World Heritage Sites)?

4. Local management of sites (Who is involved? How financed? What are site management goals? Inside and outside of protected areas?)

5. How will national PGR programmes be involved (for the Network to be sustainable their involvement is critical)?

6. What links to *ex situ* conservation (where duplicated, how often to sample and duplicate)?

7. How to promote use of conserved diversity by breeders and farmers (use is the end goal not conservation)?

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

Key Lessons learned from other CWR projects

1. Local communities are the key custodians of local agrobiodiversity
2. Local knowledge is invaluable in developing strategies and implementing legislation
3. Globally important CWR are increasingly threatened by natural habitats fragmentation and destruction
4. Creation of formal genetic reserves to protect threatened CWR species
5. Creation of informal genetic reserves along field and road edges can serve to preserve local agrobiodiversity and on-farm for forages
6. Management plans should include economic, technological and policy options which can combine conservation, sustainable use and improvement of the livelihoods of local communities

Take home message

- CWR diversity is a critical resource for food security and human well being!
- CWR diversity is seriously threatened
- Systematic and complementary in situ and ex situ conservation action is urgent; we have the knowledge and protocols!
- Strengthen weak existing links between plant biodiversity and agro-biodiversity communities
- Enhanced use is as important as conservation—through use comes sustainability

Forage *In Situ* Activities

Country		Forage taxa				
	National CWR Inventory	List of Priority Forage taxa	Gap analysis undertaken	*Ex situ* cons. of priority taxa	*In situ* cons. of priority taxa	On-farm cons. of priority taxa
Germany	Not yet	Yes - Beko-report 2008-2014 p.66-67, table 12 published (Download: https://beko-pgr.genres.de/)	Partial	Yes	Not yet, in discussion - Management plan of protected areas prepared	No
Hungary	Partial	Partial	No	Yes	Partial	Partial
Lithuania	No	*Medicago sativa, Trifolium pratense, Dactylis glomerata, Festuca pratensis, Festuca rubra, Festuca arundinacea, Phleum pratense, Poa pratensis.*	No	Yes	No	No
Switzerland	Forage plant inventory (in situ part of www.bdn.ch)	Yes (those searchable under “Category” in search menu of BDN	no	Partial (those in situ sites where a link to an accession is given)	Under discussion at a political level	In situ = on farm in the case of forage plants
UK	Yes	Yes?	Yes?	Partial	No	No