In situ and *ex situ* gap analysis: an overview

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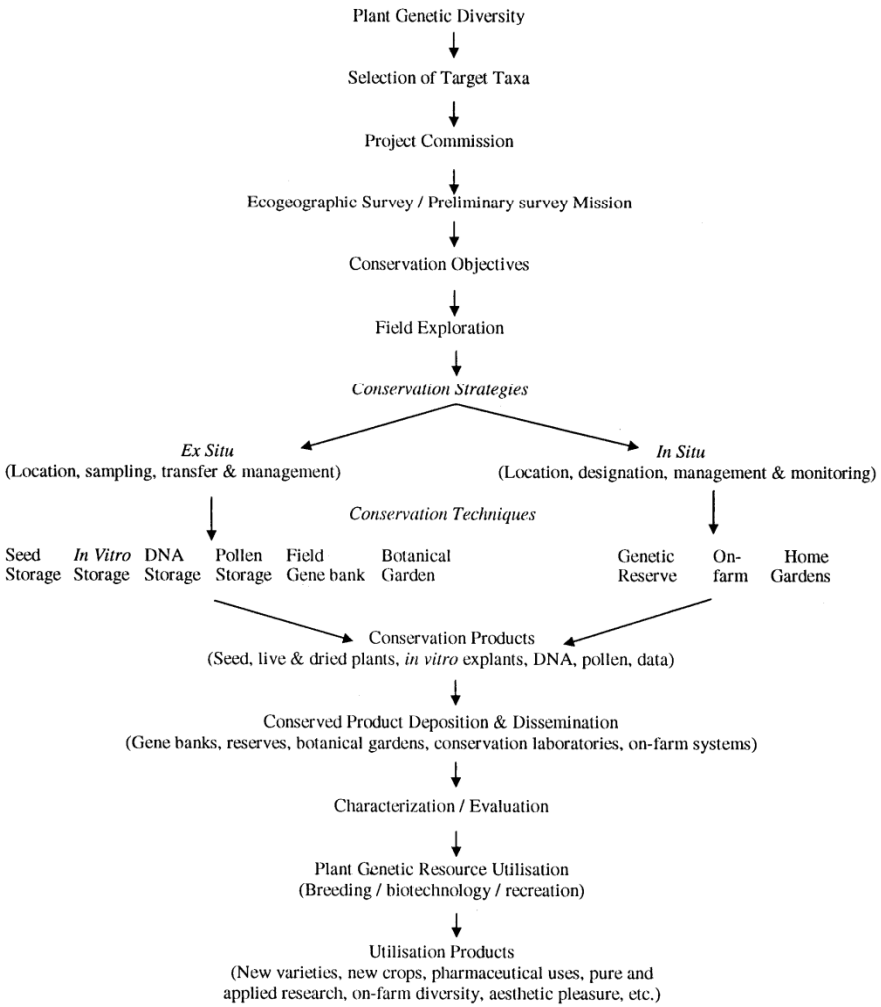
Objectives of this presentation

- What is gap analysis?
- How to do genetic gap analysis?
- Illustrated with the exemplar of African *Vigna*, cowpea and its relatives

Plant Genetic Conservation

- Objective: to ensure maximum range of genetic diversity is represented within the minimum number and size of *in situ* genetic reserves or *ex situ* accessions
- Complex goal - location, planning, establishment, sampling, management, monitoring and utilisation
- Guarino *et al.* (1995), Maxted *et al.* (1997), Smith *et al.* (2003) & Iriondo *et al.* (2008)
- Each requires an assessment of what is and what is not conserved to identify conservation priorities



What is ‘gap analysis’?

- ‘Gap analysis’ was initially associated with Margules *et al.* as a conservation evaluation technique

- Identifies areas with selected elements of biodiversity then compare with protected areas to identify under-represented areas or “gaps”

- Largely applied to indigenous forests, particularly on small islands rich in endemic species

Gap Analysis Methodology

- Burley (1988) identified four steps in traditional gap analysis:

  1. Identify and classify biodiversity
  2. Locate areas managed primarily for biodiversity
  3. Identify biodiversity that is underrepresented in those managed areas, and
  4. Set priorities for conservation action.

- Still applied to ecosystem conservation, now adapted for genetic conservation

Genetic Gap Analysis Methodology

Genetic gap analysis involves:

- Identify range of diversity
- Compare with conserved samples (*in situ* and *ex situ*) of that range of diversity
- The ‘analysis’ comes in the comparison
- Does the sample provide a efficient representation of the range of diversity?
- The diversity not represented in the samples = is the “gap”

Genetic Gap Analysis Methodology

Step 1:Circumscription of target taxon and target area

Step 2: Assessment of natural *in situ* diversity

- 2a - Taxonomic Diversity Assessment
- 2b - Genetic Diversity Assessment
- 2c - Ecogeographic Diversity Assessment
- 2d - Threat Assessment

Step 3:Assessment of current conservation strategies

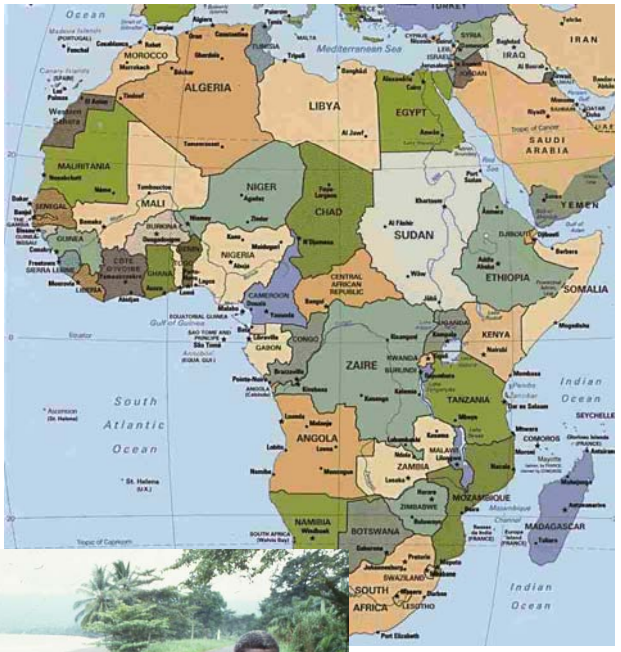
- 3a - *In situ* techniques
- 3b - *Ex situ* techniques

Step 4: Setting priorities for conservation action

- 4a - *In situ* conservation priorities
- 4b - *Ex situ* conservation priorities

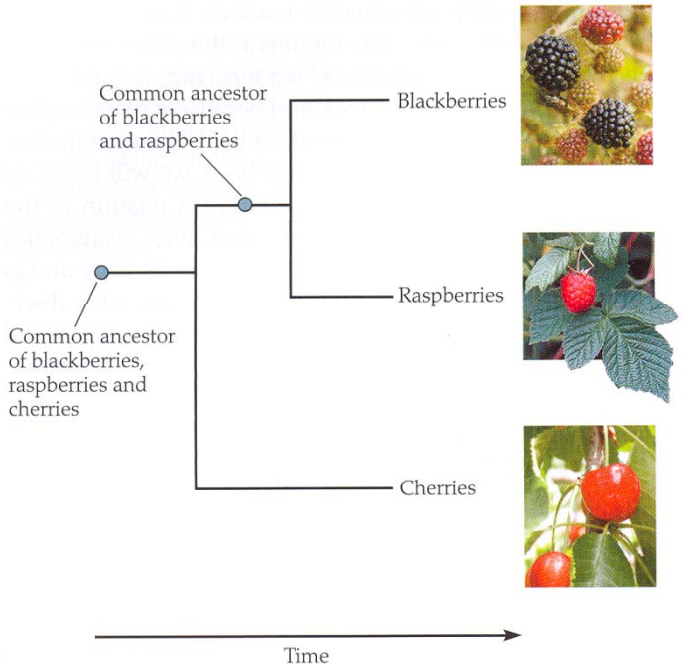
Step 1:Circumscription of target taxon and target area

- Defined by project commission for conservation action
  - Breadth of target taxon
  - Breadth of target area
- African *Vigna* Savi, cowpea and its relatives



Step 2: Assessment of natural *in situ* diversity
2a Taxonomic Diversity

- Need to select a classification
  - List of accepted taxa
  - Descriptive data
  - Distributional data
- How to find the appropriate classification
  - Specialist publications
  - Taxon experts
  - Various media searches (International Legume Database and Information Service (www.ildis.org), The Plant List (www.theplantlist.org), Species 2000 (www.sp2000.org)

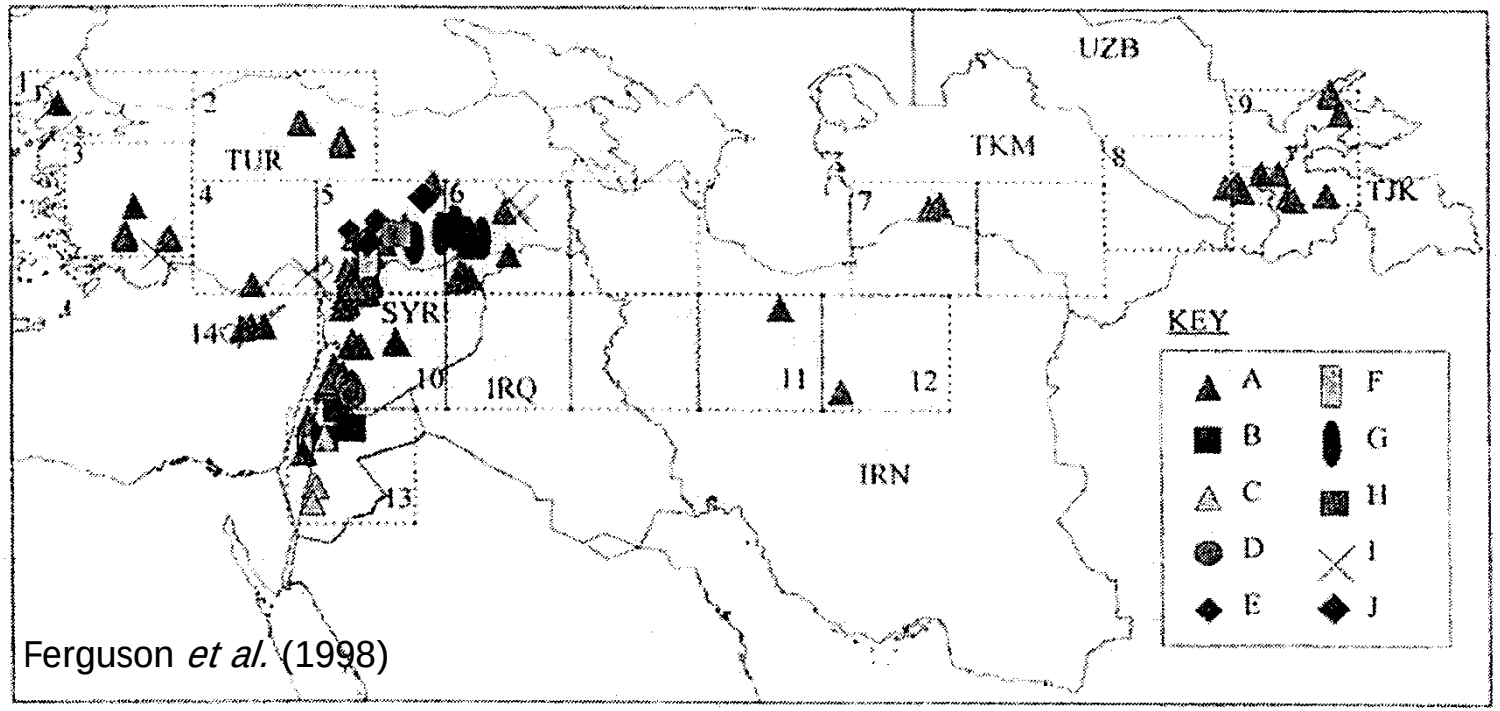


Step 2: Assessment of natural *in situ* diversity
2a Taxonomic Diversity: *Vigna* spp.

- Classification of African *Vigna*
  Savi
  - Maréchal *et al.* (1978) + subsequently described taxa
  - Pasquet (2001) conception of *V. unguiculata*
  - Tomooka *et al.* (2002) conception of subgenus *Ceratotropis*.
  - 61 species and 56 subspecific taxa for Africa

Step 2: Assessment of natural *in situ* diversity
2b - Genetic Diversity Assessment

- Need to understand patterns of genetic diversity for target taxa
  - Is it correlated with ecogeography or not?



Ferguson *et al.* (1998)

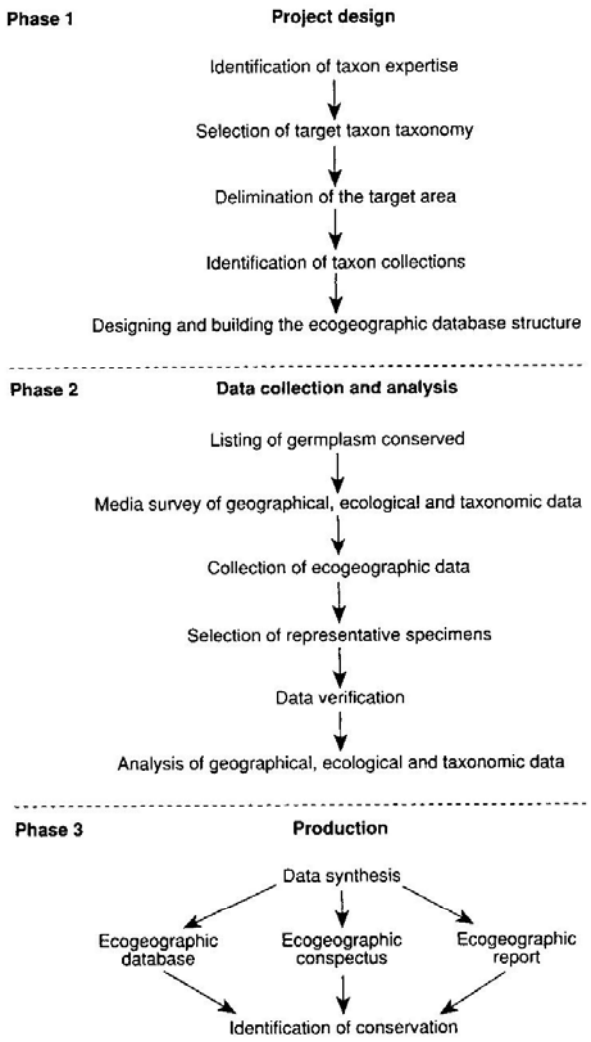
Step 2: Assessment of natural *in situ* diversity
2b - Genetic Diversity Assessment: *Vigna* spp.

- Entirely restricted to cowpea gene pool studies
  - Eleven subspecies plus several varieties
  - Pasquet (1993a, 1993b, 1997)
  - Coulibaly *et al.* (2002)
- Is this situation typical?

Step 2: Assessment of natural *in situ* diversity
2c - Ecogeographic Diversity Assessment

- In the absence of genetic diversity data ecogeographic data provides the most appropriate proxy

- Established model for ecogeographic data collection, analysis and application, e.g. Maxted *at al.* (1995, etc.)

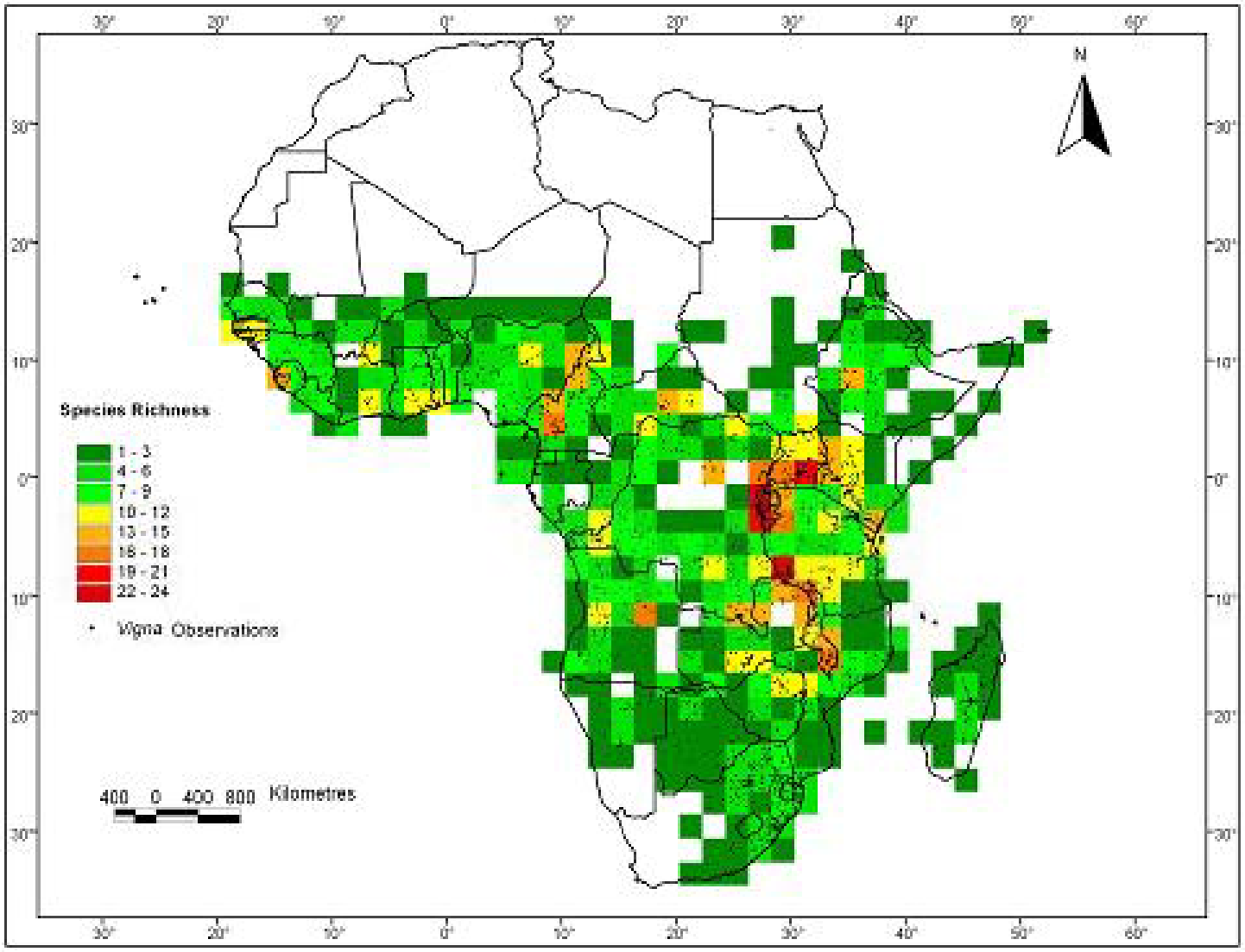


Step 2: Assessment of natural *in situ* diversity
2c - Ecogeographic Diversity Assessment: *Vigna* spp.

- Based on 7,300 herbarium specimens and 1,912 germplasm accessions
- Herbarium specimens from 30 herbaria in Africa, Europe and North America collected over 21 years
- Germplasm accessions from 4 gene banks (IITA, ILRI, CIAT and Jardin Botanique Nationale de Belgique)
- Forms the basis of analysis

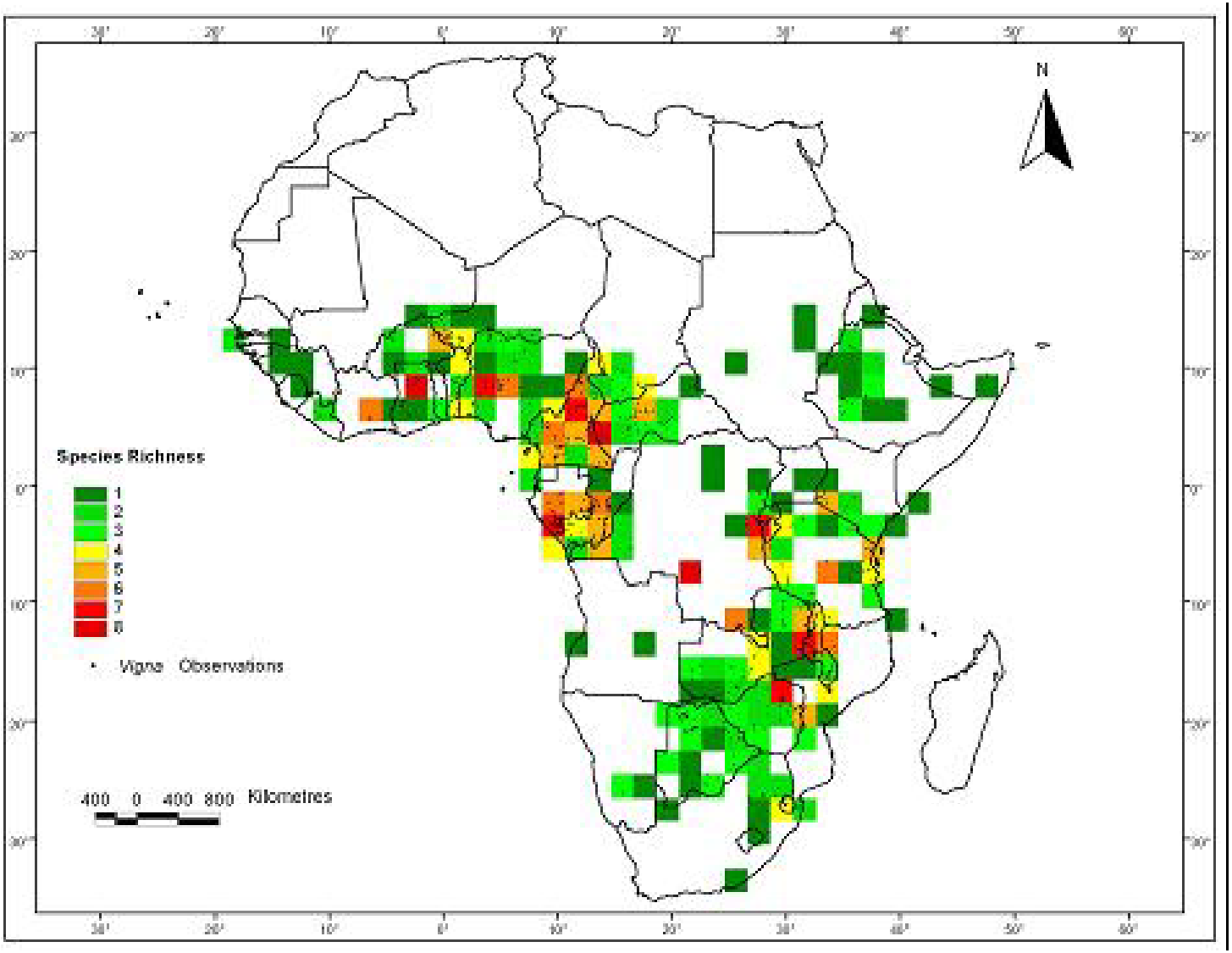
2c - Ecogeographic Diversity Assessment: *Vigna*

Absolute species richness based on herbarium collections only in 200 km^2 grid cells



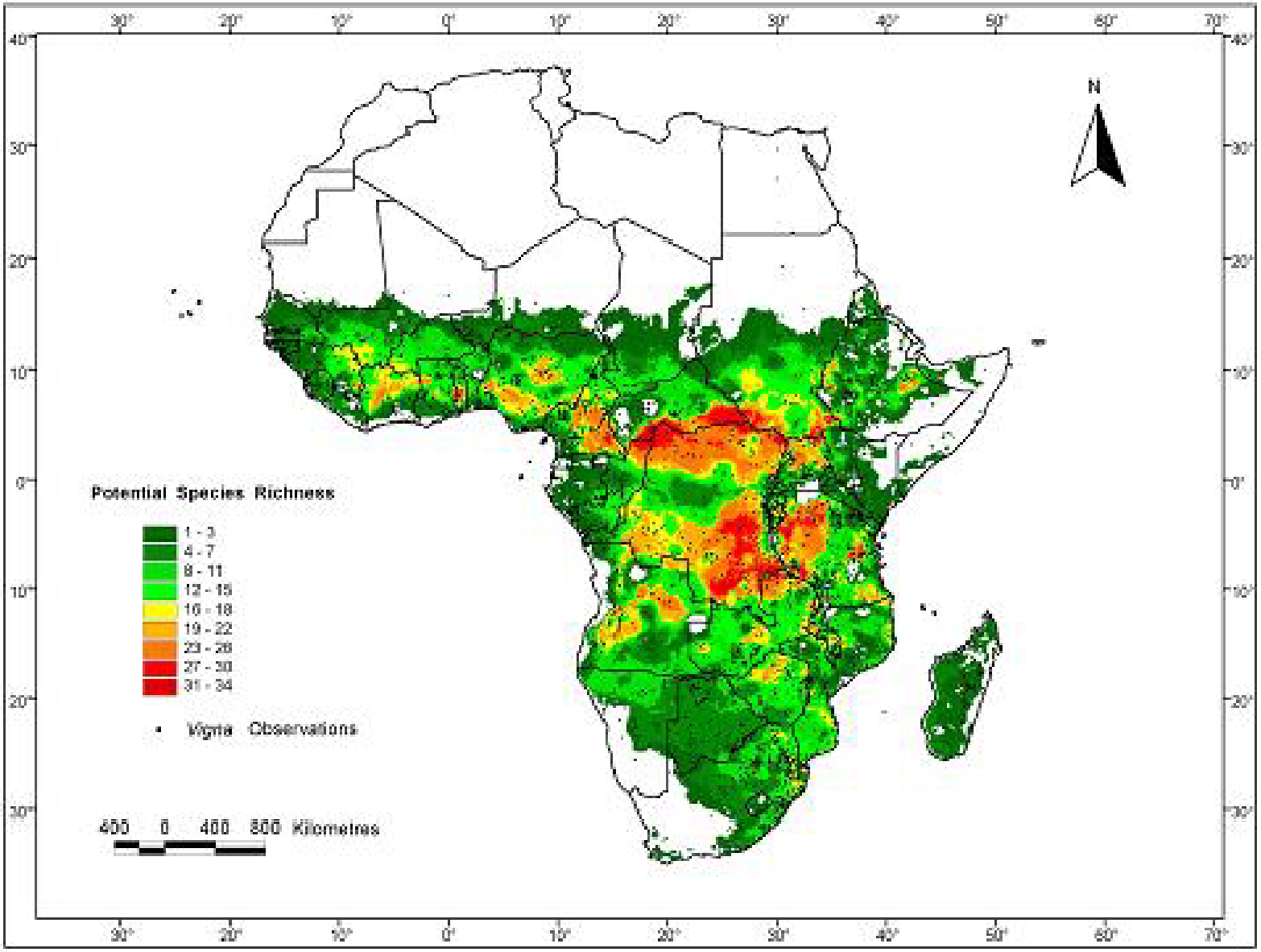
2c - Ecogeographic Diversity Assessment: *Vigna*

Absolute species richness of germplasm collections only in 200 km^2 grid cells



2c - Ecogeographic Diversity Assessment: *Vigna*

Predicted distribution of species richness



Step 2: Assessment of natural *in situ* diversity

2d - Threat Assessment

- Media reports
  - Target taxon specific
  - Region or nation specific

- IUCN categories
  - Need to understand that the base data is incomplete

Step 2: Assessment of natural *in situ* diversity
2d - Threat Assessment: *Vigna* spp.

Assessors	Red List Criteria Version	Categories
Walter and Gillett (1998)	Pre-1994	*V. debanensis* (Ethiopia) = Vulnerable *V. dolomitica* (Zaire) = Rare
Golding (2002)	1994	*Vigna comosa* subsp. *abercornensis* (Zambia) = Vulnerable
Maxted *et al.* (2005)	2001	6 *Vigna* = Critically Endangered 8 *Vigna* = Endangered 10 *Vigna* = Vulnerable 5 *Vigna* = Near Threatened 28 *Vigna* = Least Concern 4 *Vigna* = Data Deficient

Step 2: Assessment of natural *in situ* diversity
2d - Threat Assessment: *Vigna* spp.

Taxon Vulnerability Assessment

- IUCN Red Listing is best assessment, but not always sufficient data

- Can approximate vulnerability to genetic erosion:
  - rarity (number of collections)
  - distributional range (spread of collections)
  - gross representation of germplasm in *ex situ* collections
  - geographic coverage of germplasm in *ex situ* collections
  - utility
  - extinction assessment using Solow's (1993) equation (= collection timing, frequency and specimen number)

Step 2: Assessment of natural *in situ* diversity
2d - Threat Assessment: *Vigna* spp.

Taxon Vulnerability Assessment

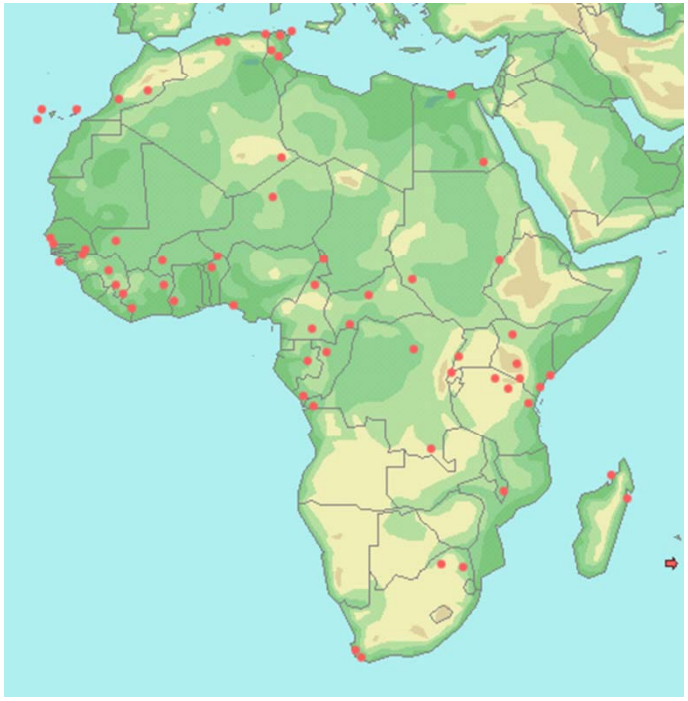
Species	Rarity	Distrib -ution	*Ex situ* holdings	*Ex situ* coverage	Taxon coverage	Use	Taxon extinction	TVA score
V. adenantha	5	2.5	9	8	0	4	4	4.6
V. ambacensis	1	0	2	4	0	10	1	2.6
V. angivensis	2	5	10	10	0	6	4	5.3
V. antunesii	3	2.5	10	10	0	0	3	4.1
V. benuensis	7	7.5	9	6	0	0	6	5.1
V. bequaertii	7	7.5	10	10	0	0	1	5.1
V. bosseri	10	10	10	10	0	0	9	7.0
V. comosa	2	0	8	6	10	0	1	3.9
V. desmodioides	7	5	10	10	0	0	4	5.1

Step 3: Assessment of current conservation strategies

- *In situ*
  - Genetic reserve of CWR
  - On-farm of landraces
- *Ex situ*
  - Seed bank of germplasm
  - Other techniques ?

Step 3: Assessment of current conservation strategies
3a - *In situ* techniques / reserve: *Vigna* spp.

- No ACTIVE genetic reserves for *Vigna* species in Africa
- PASSIVE conservation which is coincident with existing protected area
- Likely to establish reserve in existing protected area
  - Existing conservation ethos
  - Not subject to rapid management changes
  - Existing management plan can be amended
  - Reduces cost of establishment
- 54% of wild species *Vigna* are predicted to have populations present in at least one protected area



Step 3: Assessment of current conservation strategies

3a - *In situ* techniques / on-farm: *Vigna* spp.

- Find by literature / media / internet review
- Cowpea (*V. unguiculata*) is included in IPGRI's current on-farm conservation project in Burkina Faso (Jarvis and Ndungu-Skilton, 2000)
- Shea project in Uganda includes Bambara groundnut (*Vigna subterranea*)
- Community Technology Development Trust project in Zimbabwe includes *V. subterranea* and *V. unguiculata* (Odero, 2001)
- But no systematic on-farm conservation of *Vigna* in Africa

Step 3: Assessment of current conservation strategies

3a - *Ex situ* techniques: *Vigna* spp.

Review of gene bank holdings, SINGER, but little help for Africa

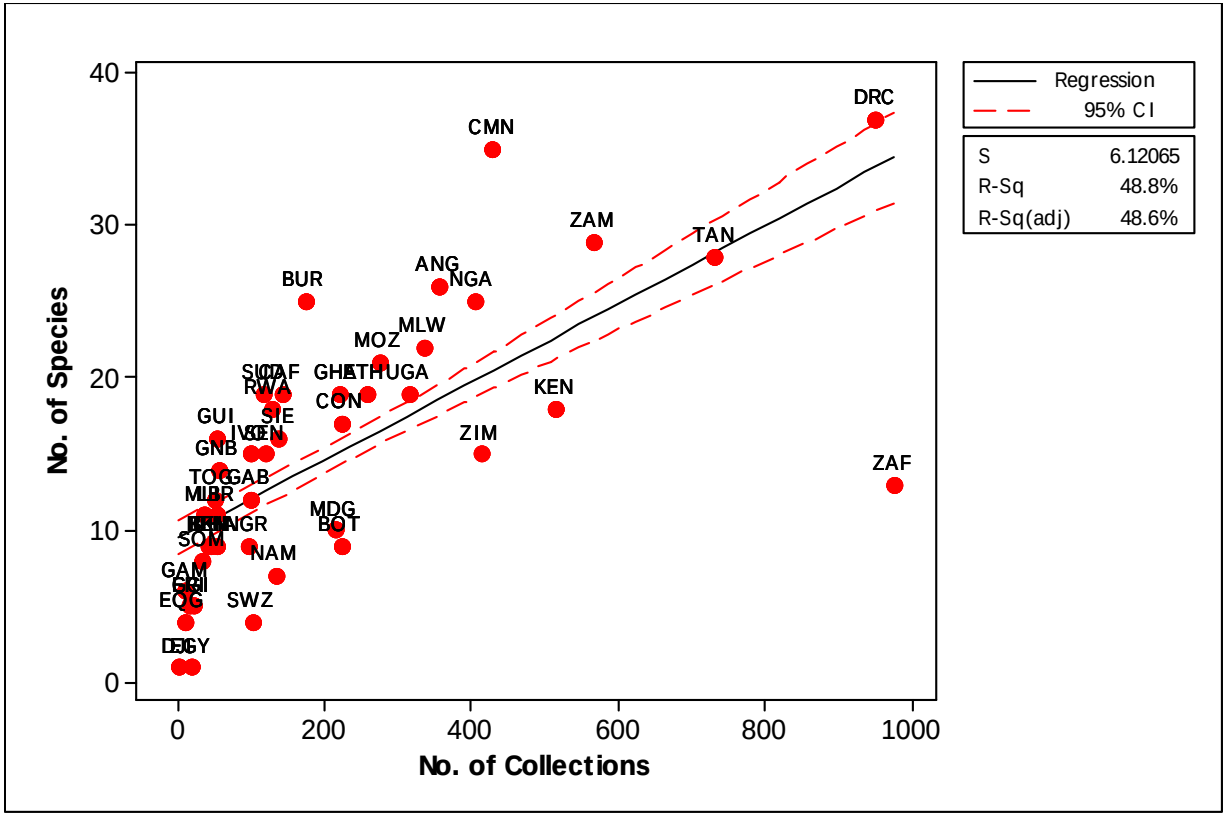
Species	IITA	NBGB	USDA	Other
V. unguiculata subsp. *unguiculata*	14,887	15	4,399	-
V. unguiculata wild	553	188	244	51
V. subterranea	2032	0	64	-
Other *Vigna* taxa	1216	304	50	111

Step 3: Assessment of current conservation strategies

3a - *Ex situ* techniques: *Vigna* spp.

Regression of *Vigna* species against herbarium specimens and gene bank accessions from each country

Results indicate Botswana, Namibia, South Africa and Swaziland were over-collected, while Angola, Burundi, Cameroon, Democratic Republic of the Congo, Djibouti, Nigeria, Tanzania and Zambia remain under-collected.



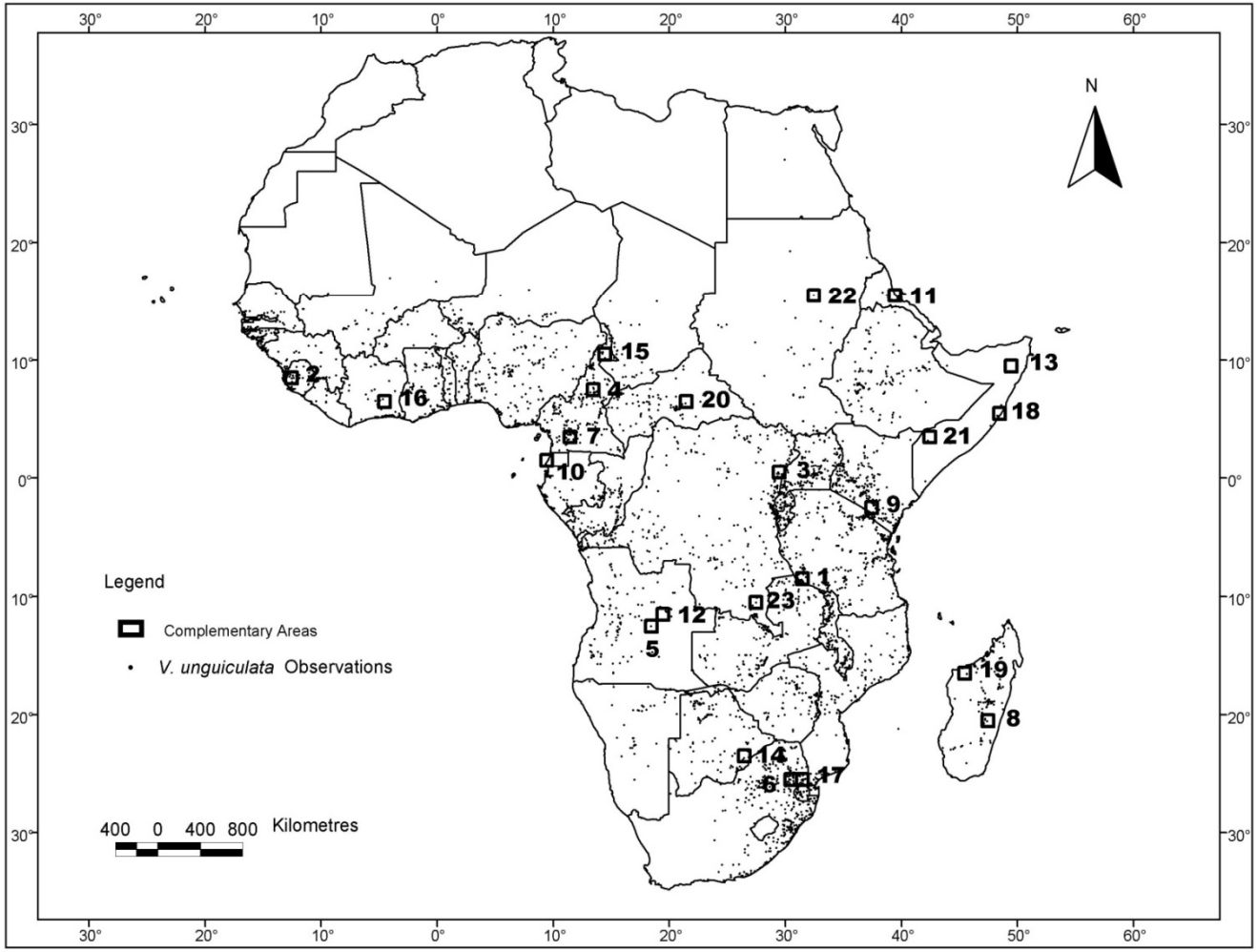
Step 4: Setting priorities for conservation action

- Having provided
  - The best possible picture of *in situ* natural diversity
  - A review of current *in situ* and *ex situ* conservation actions
- Comparison of the two identifies the ‘Gaps’

Step 4: Setting priorities for conservation action

4a - *In situ* conservation priorities

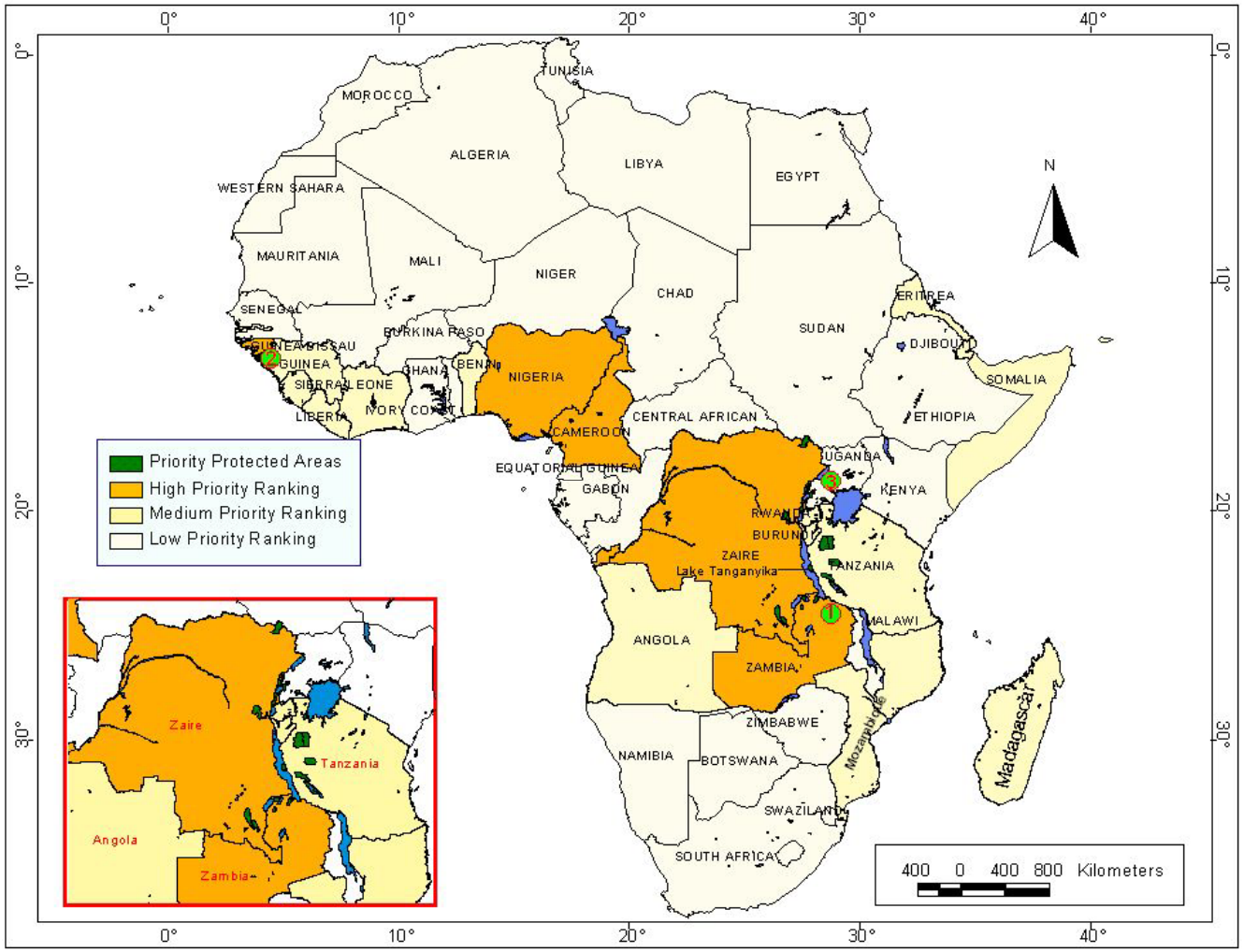
Complementarity analysis using DIVA GIS



Step 4: Setting priorities for conservation action

4a - *In situ* conservation priorities

Areas of Africa where *in situ* Vigna conservation action is required

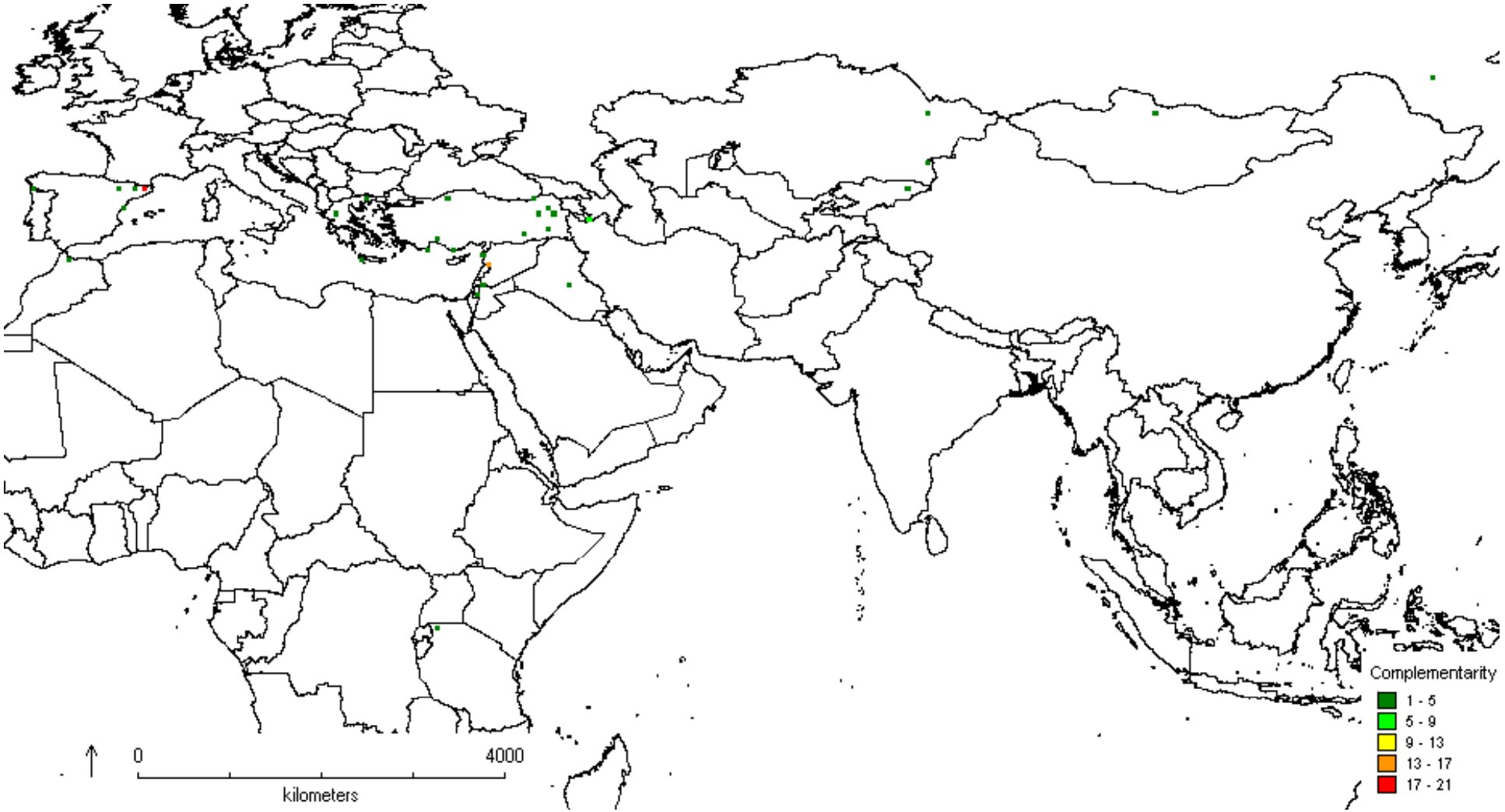


Step 4: Setting priorities for conservation action

4a - *In situ* conservation priorities

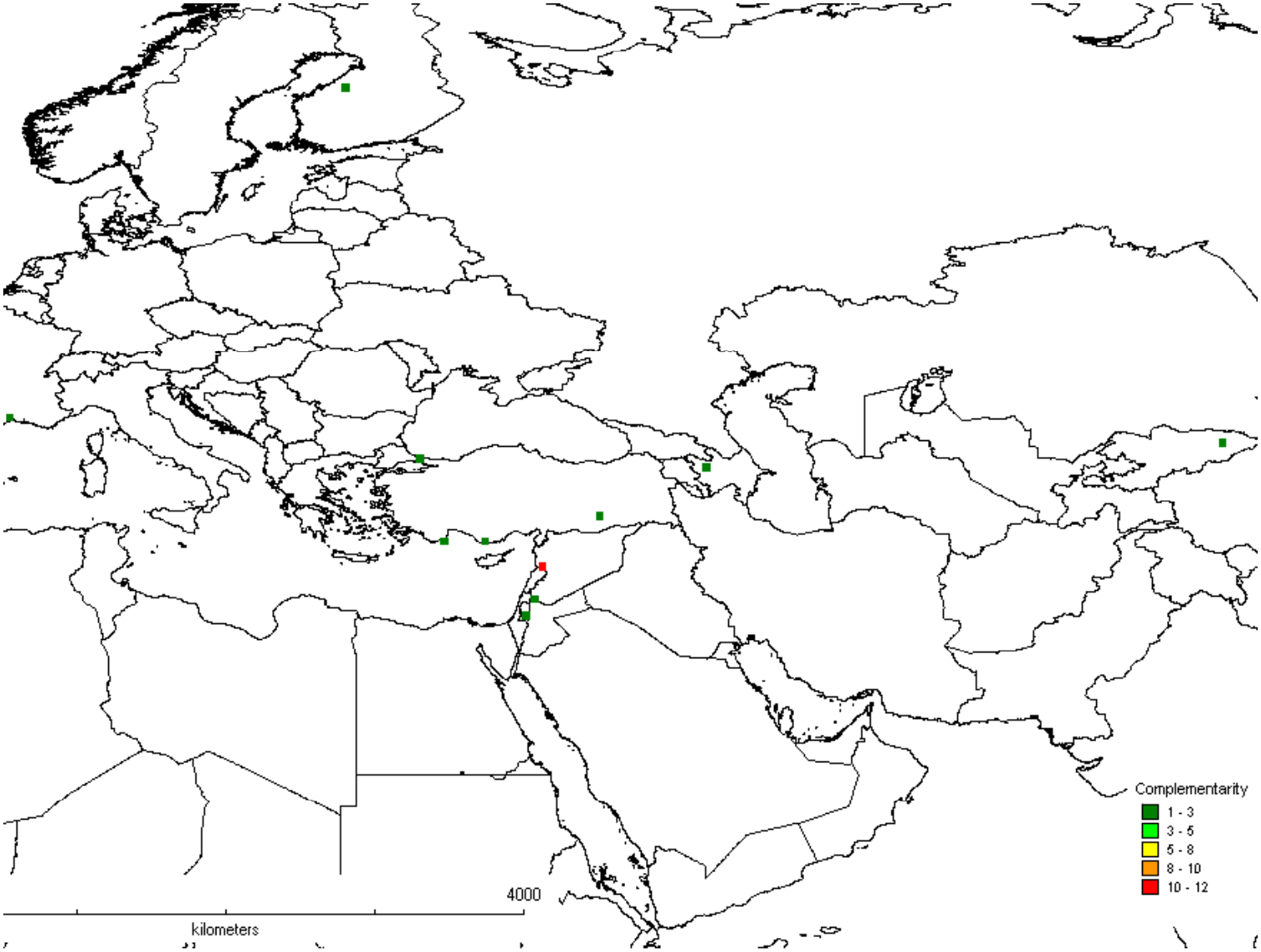
Country	Protected area name	Type of protected area	IUCN protected area categories	Location	Area (km^2)
Zambia	Lusenga Plain	National Park	II	9°23'S/ 29°13'E	88,000
	Mweru-Wantipa	National Park	II	8°44'S/ 29°38'E	313,400
	Nsumbu	National Park	II	8°47'S/ 30°30'E	206,300
Tanzania	Uwanda	Game Reserve	IV	8°32'S/ 32°08'E	500,000
	Katavi	National Park	II	6°53'S/ 31°10'E	225,300
	Mahale Mountain	National Park	II	6°10'S/ 29°50'E	157,700

An aside:
All *Lathyrus* species Complementarity Analysis



An aside:

Priority *Lathyrus* species Complementarity Analysis



Step 4: Setting priorities for conservation action

4a - *In situ* conservation priorities: on-farm

- With 23 of the 61 African *Vigna* species being utilised and many of the species have multiple uses within subsistence agriculture, on-farm conservation should be a priority!

- Inevitably it will focus initially on the two most widely cultivated grain legume species, *V. subterranea* and *V. unguiculata*

- But a more geographically systematic approach that considers full taxonomic breadth is required

Step 4: Setting priorities for conservation action
4b - *Ex situ* conservation priorities

Country based priorities

- Highest priority: Cameroon, Democratic Republic of the Congo, Guinea Bissau, Nigeria and Zambia

Nsumbu National Park

- Other priorities: Angola, Benin, Burundi, Cameroon, Cote d'Ivoire, the Democratic Republic of the Congo, Djibouti, Eritrea, The Gambia, Guinea, Guinea Bissau, Liberia, Madagascar, Mozambique, Nigeria, Rwanda, Sierra Leone, Somalia, Tanzania and Zambia.

Step 4: Setting priorities for conservation action

4b - *Ex situ* conservation priorities

Taxon based priorities

Priority Rating	***Vigna* taxa**
High priority	*V. dolomitica*, *V. haumaniana* var. *pedunculata*, *V. monantha*, *V. nuda*, *V. richardsiae*, *V. somaliensis*, *V. stenophylla*, *V. subterranea* var. *spontanea*, *V. unguiculata* subsp. *unguiculata* var. *spontanea*, *V. unguiculata* subsp. *aduensis*, *V. unguiculata* subsp. *baoulensis*, *V. unguiculata* subsp. *burundiensis*, *V. vexillata* var. *dolichonema* and *V. virescens*.
Medium Priority	*V. bequaertii*, *V. comosa* subsp. *comosa* var. *lebrunii*, *V. desmodioides*, *V. haumaniana*, *V. haumaniana* var. *haumaniana*, *V. hosei*, *V. laurentii*, *V. multinervis*, *V. parkeri* subsp. *parkeri*, *V. phoenix*, *V. procera*.
Low priority	*V. adenantha*, *V. angivensis*, *V. antunesii*, *V. bosseri*, *V. comosa*, *V. comosa* subsp. *abercornensis*, *V. fischeri*, *V. frutescens*, *V. frutescens* subsp. *kotschyi*, *V. gazensis*, *V. juncea*, *V. juncea* var. *corbyi*, *V. juruana*, *V. keraudrenii*, *V. kokii*, *V. longifolia*, *V. longissima*, *V. macrorhyncha*, *V. membranacea* subsp. *macrodon*, *V. microsperma*, *V. monophylla*, *V. mudenia*, *V. parkeri*, *V. praecox*, *V. pygmaea*, *V. schimperi*, *V. triphylla* and *V. venulosa*.