# Gap Analysis

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**SADC Crop Wild Relatives Regional training workshop**
'*In situ* conservation of CWR including diversity assessment techniques'
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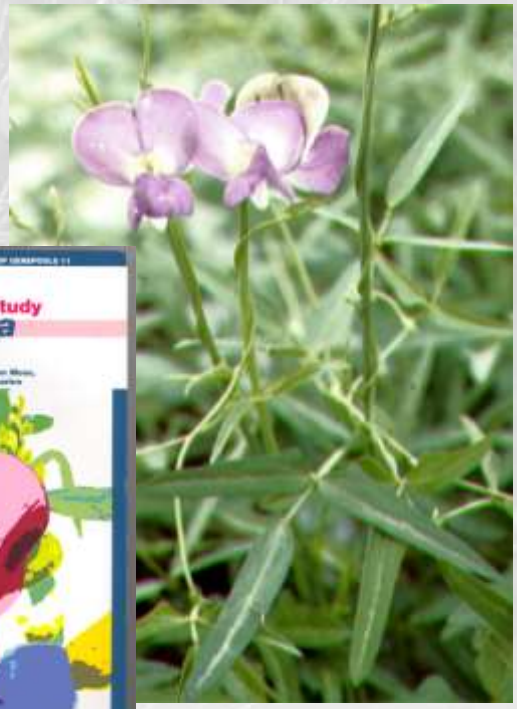
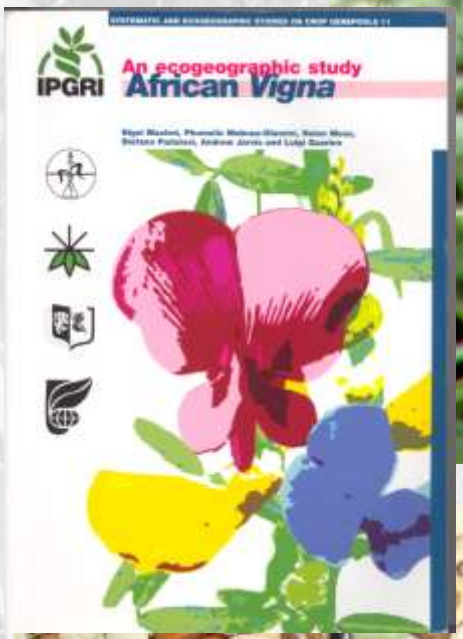
# Introduction

- Publications
  - Groom, Meffe & Carroll (2006) Chp 14
  - Maxted et al. (2008)
  - Maxted, N., Castañeda Álvarez, N.P., Vincent, H.A. and Magos Brehm, J.,(2012). Gap analysis: a tool for genetic conservation. In Guarino L, Ramanatha Rao V, Goldberg E (editors). Collecting Plant Genetic Diversity: Technical Guidelines. 2011 update. Bioversity International, Rome. Available online: http://cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=678






- Need to improve conservation through better prioritisation
- Exemplar: Cowpea and its relatives (*Vigna unguiculata*) in Africa

# The need for increased efficiency of conversation

“Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity.”

*Article 8 - CBD* (1992)

# 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

# Goal of Genetic Conservation

- “95% [most] of all the alleles at a random locus occurring in the target population with a frequency greater than 0.05 [not very rare]” Marshall and Brown (1975)

- Equates to approx.
  - *Ex situ* (plants) 50 sites x 100 plant collections
  - *In situ* 5,000 individuals in 1+ genetic reserves

- Post-CBD add “using a range of conservation techniques” = equates to complementary conservation

# Gap Analysis Methodology

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

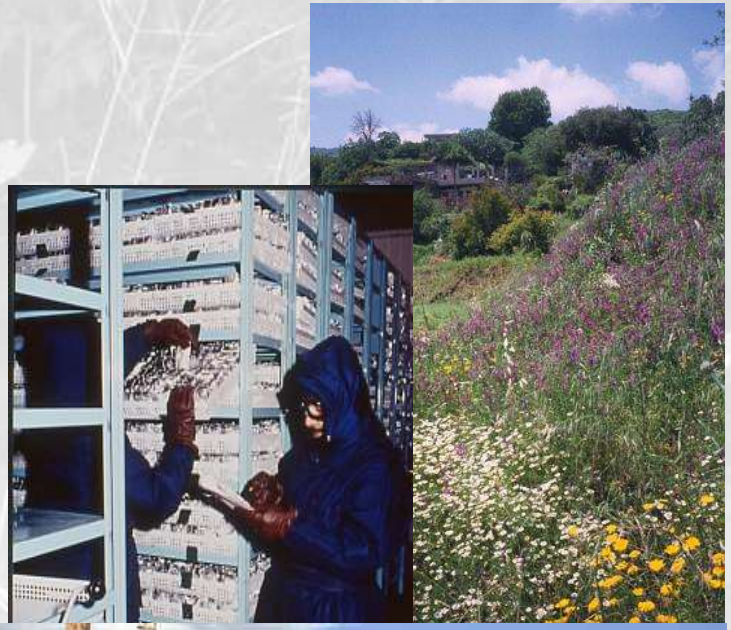
  1. Identify and classify biodiversity
  2. Locate areas managed primarily for biodiversity
  3. Identify biodiversity that is underrepresented in those managed areas, and
  4. Set priorities for conservation action.

- 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

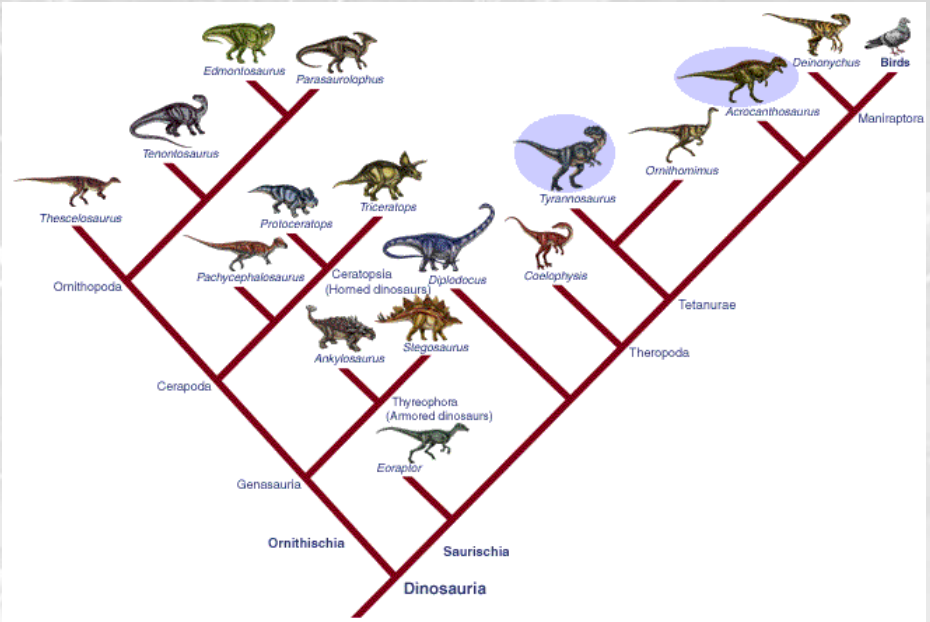
- 4a - *In situ* conservation priorities
- 4b - *Ex situ* conservation priorities

# 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


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

- Need to select a classification
  - List of accepted taxa
  - Descriptive data
  - Distributional data



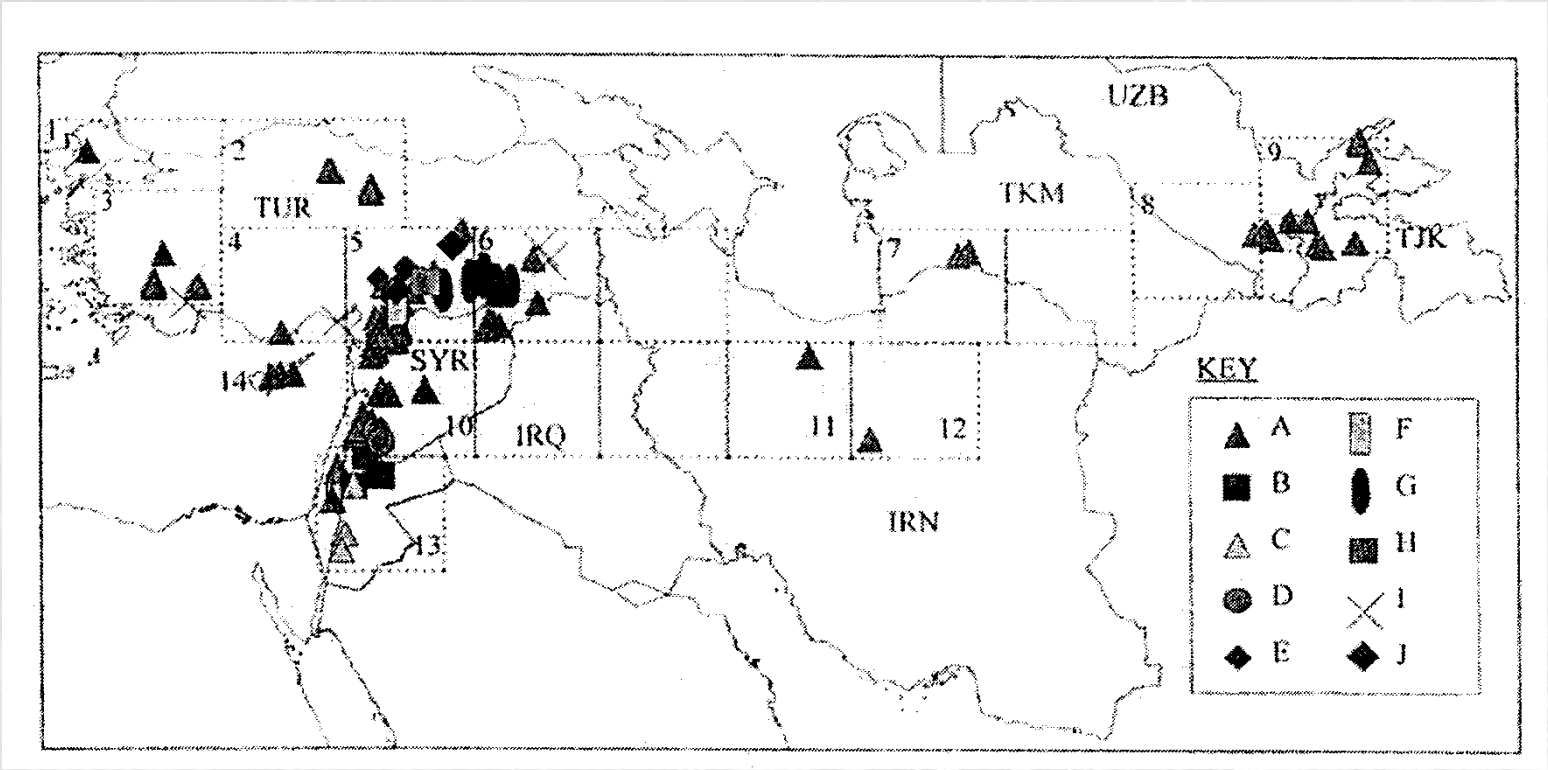

- How to find the appropriate classification
  - Specialist publications
  - Taxon experts
  - Various media searches (International Legume Database and Information Service (http://www.ildis.org/) or Species 2000 (http://www.sp2000.org/)

# 2a Taxonomic Diversity: *Vigna*

- 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

# 2b - *Genetic Diversity Assessment*

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



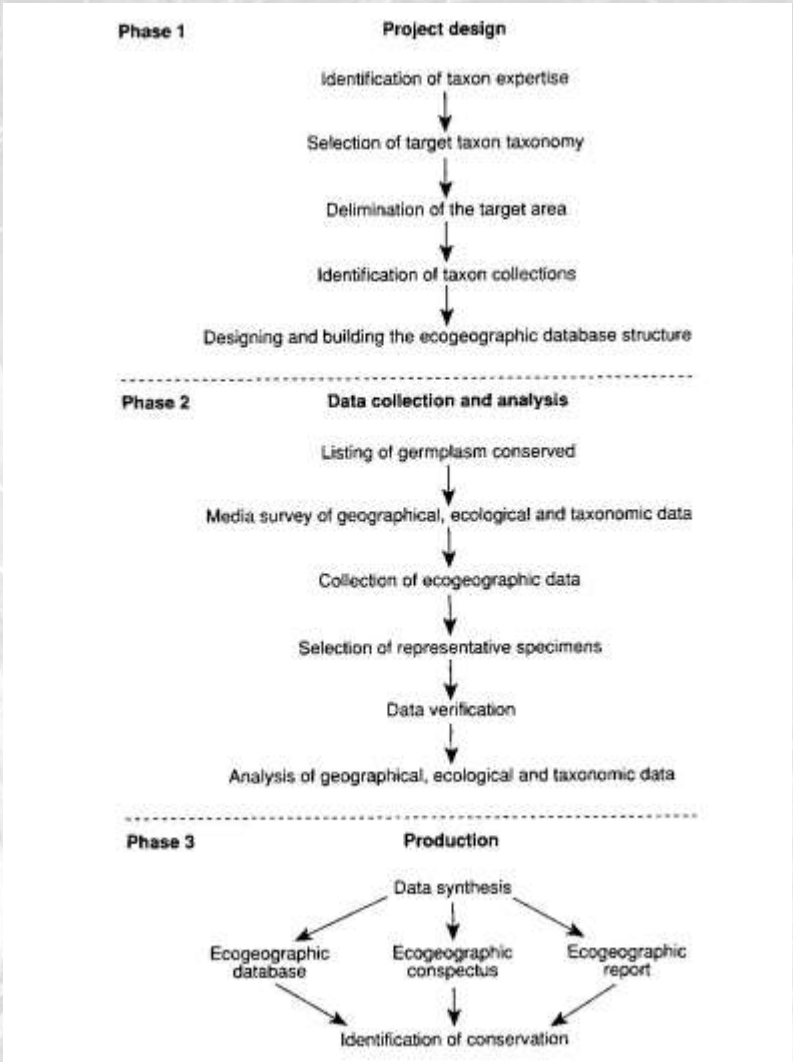
# 2b - Genetic Diversity Assessment: *Vigna*

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

# 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.)

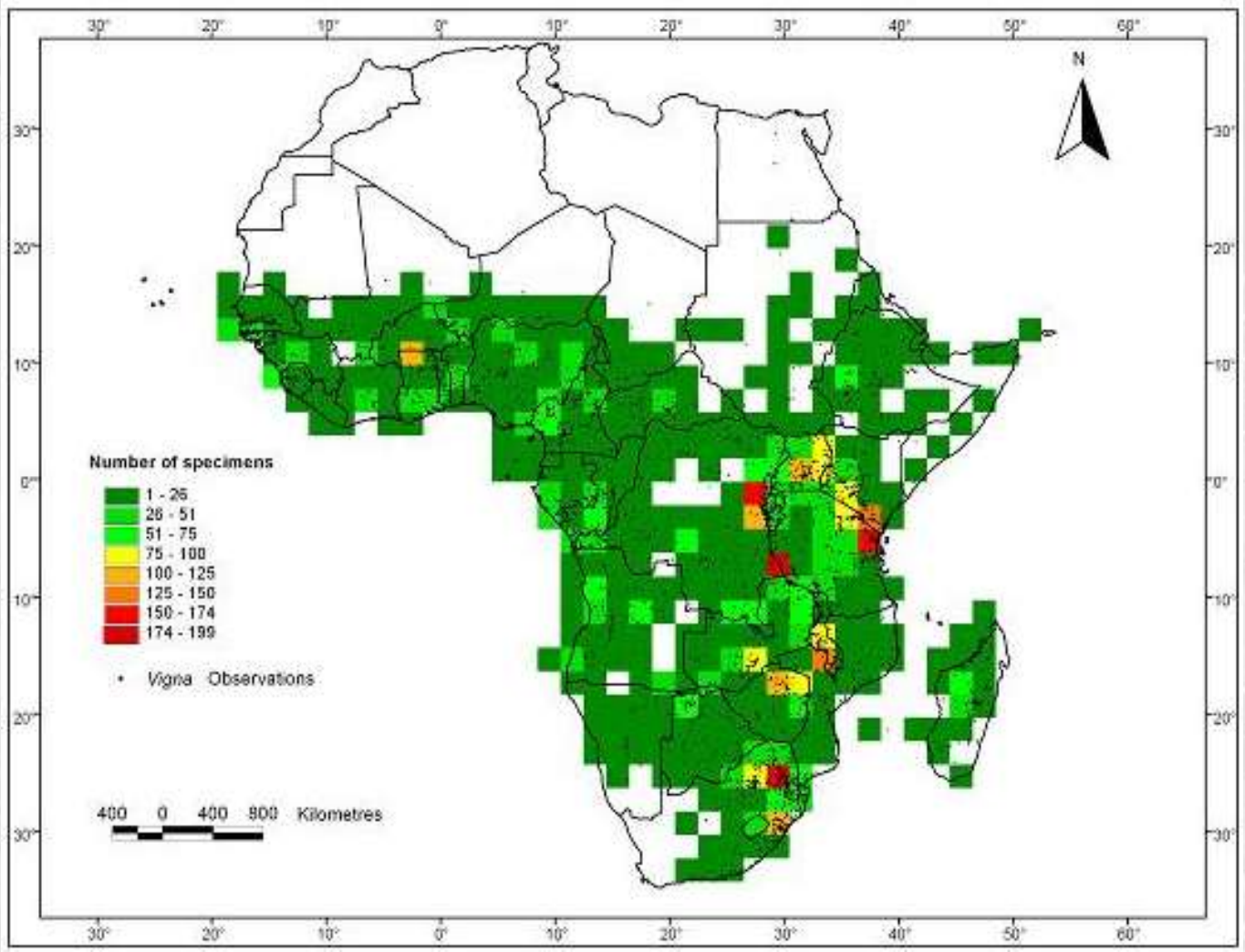


# 2c - Ecogeographic Diversity Assessment: *Vigna*

- 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

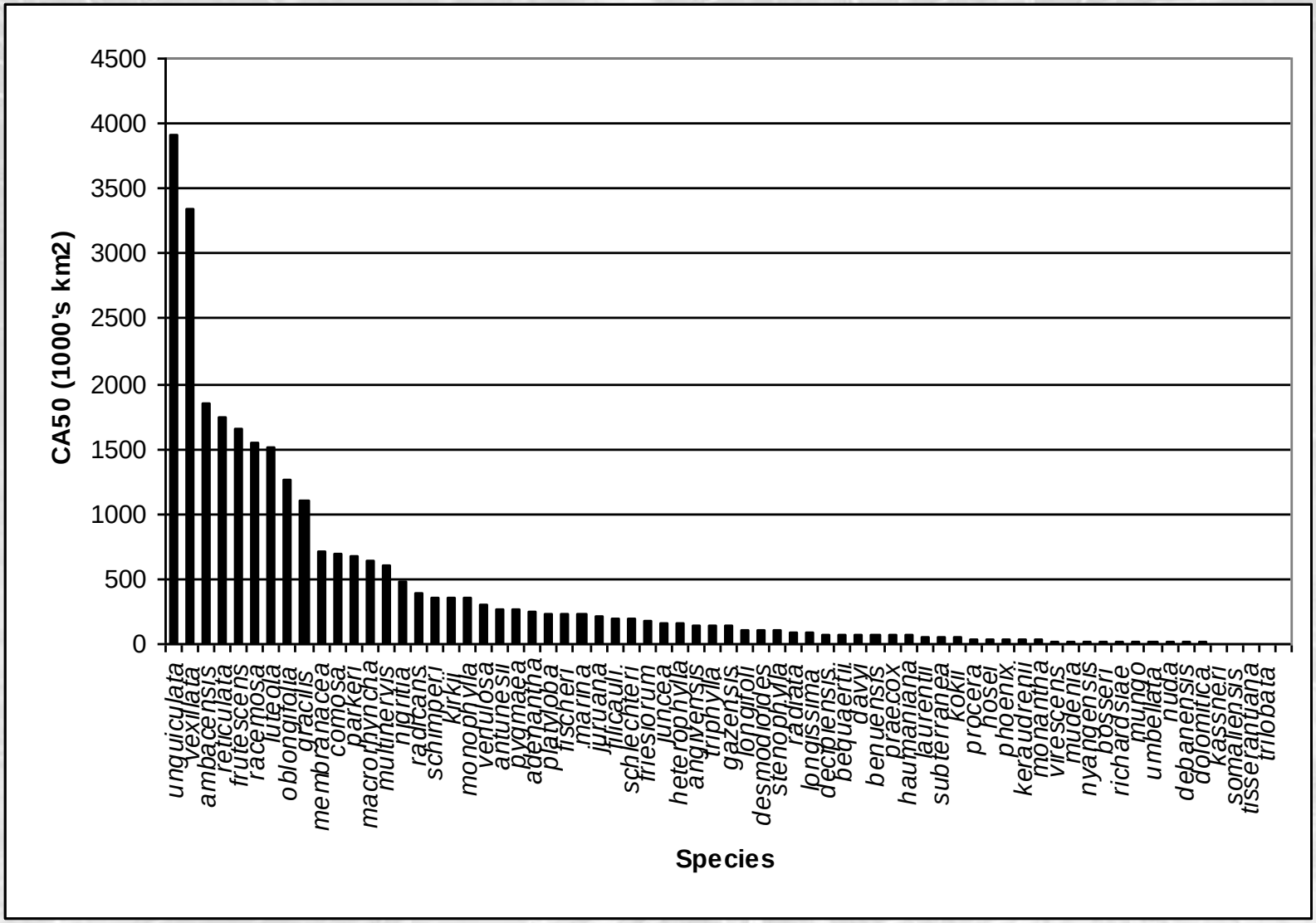
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Density of collections in 200 km x 200 km grid cells**
**= Observational richness**



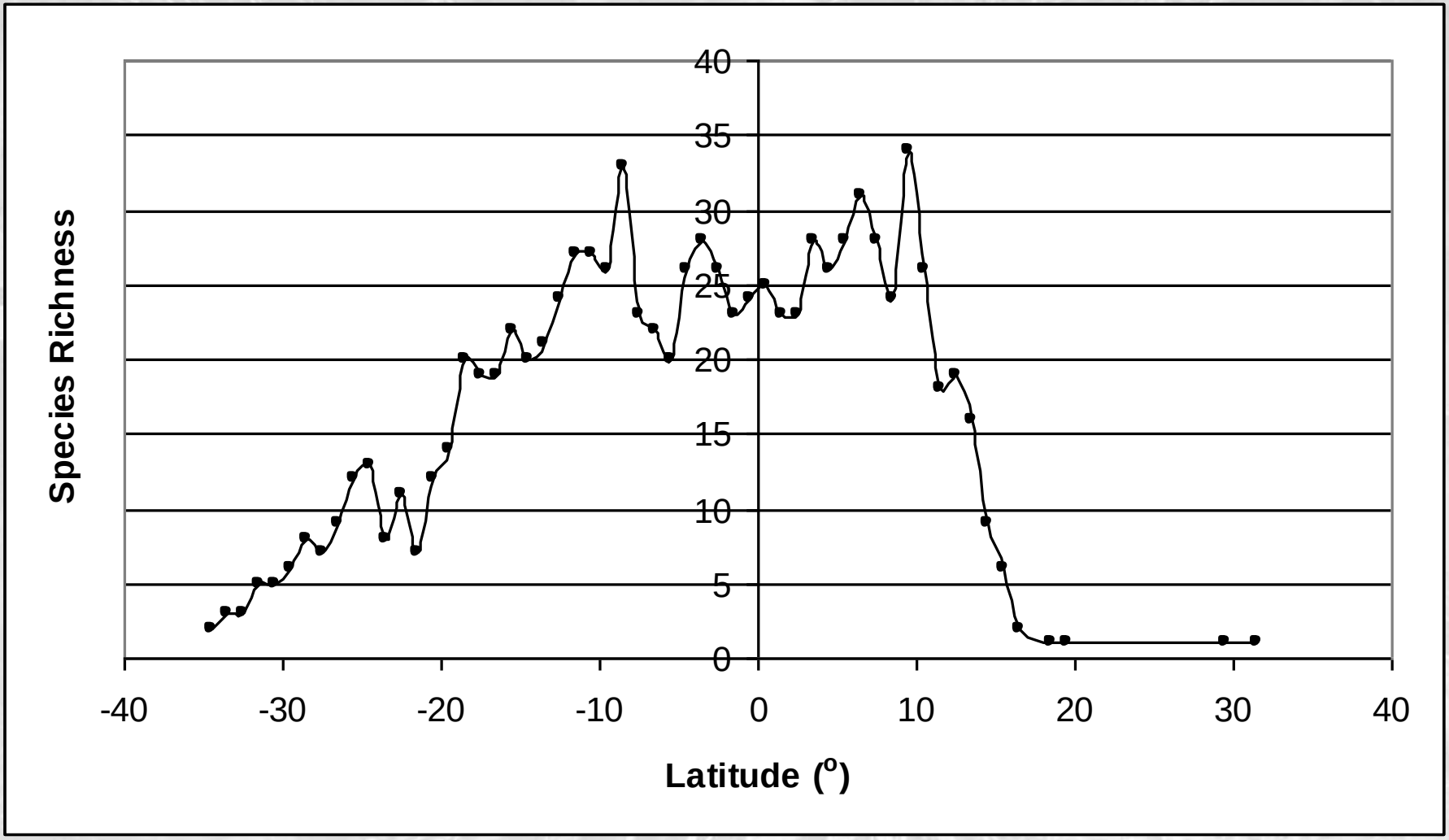
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Observed geographic area of distribution calculated using the Circular Area statistic with a 50km radius (CA50)**



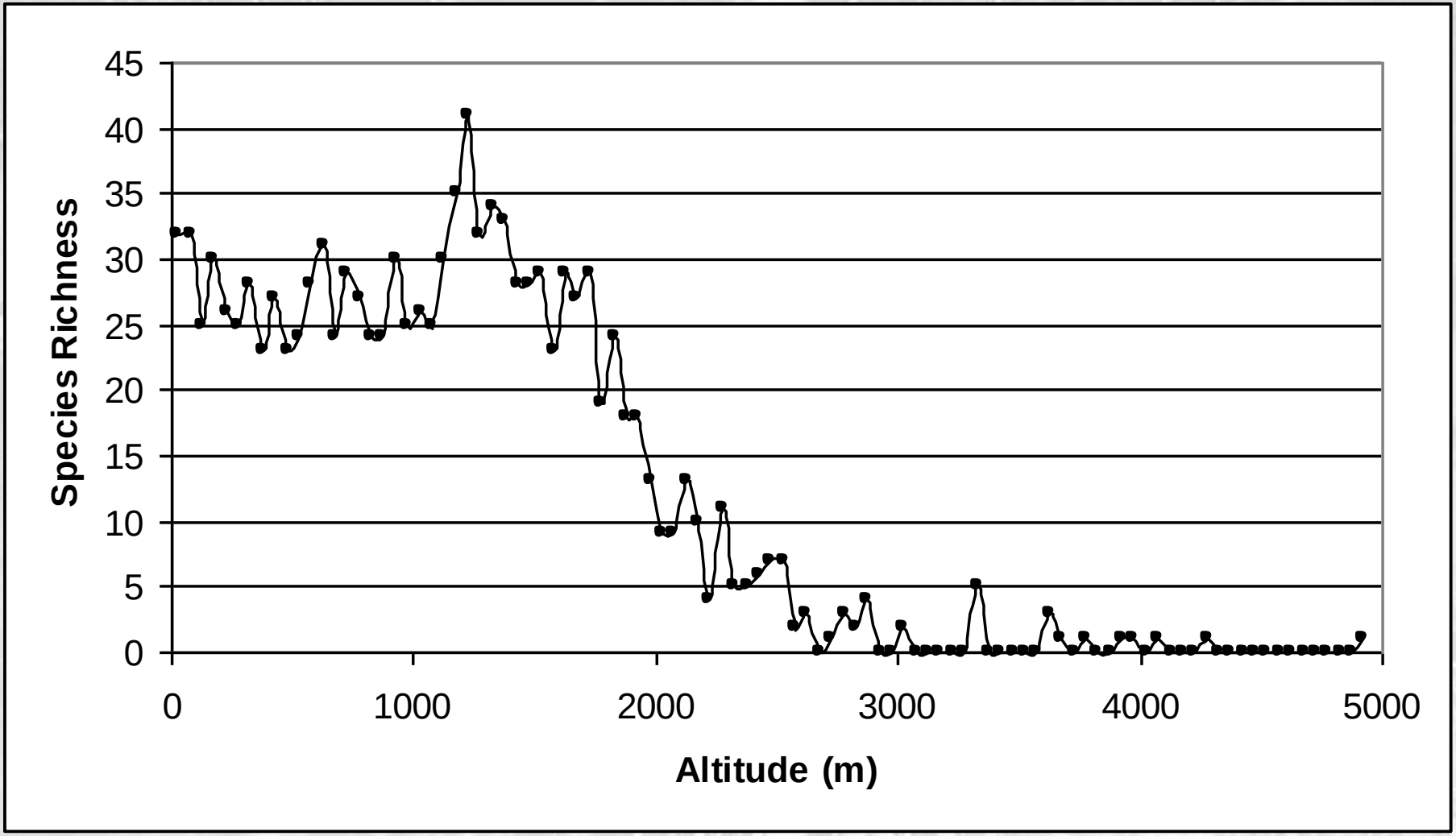
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Species richness per degree latitude**



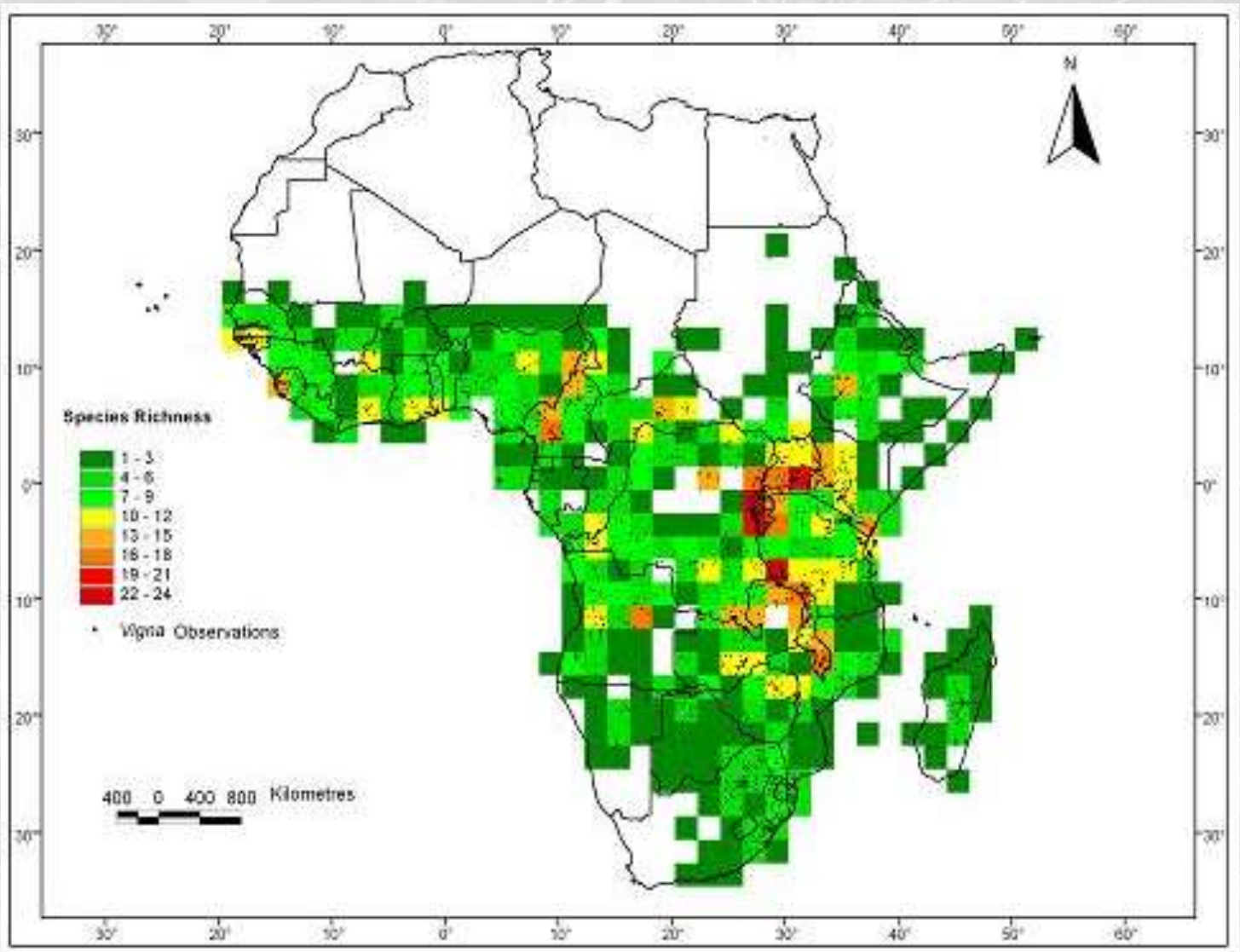
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Species richness per 50m altitude class**



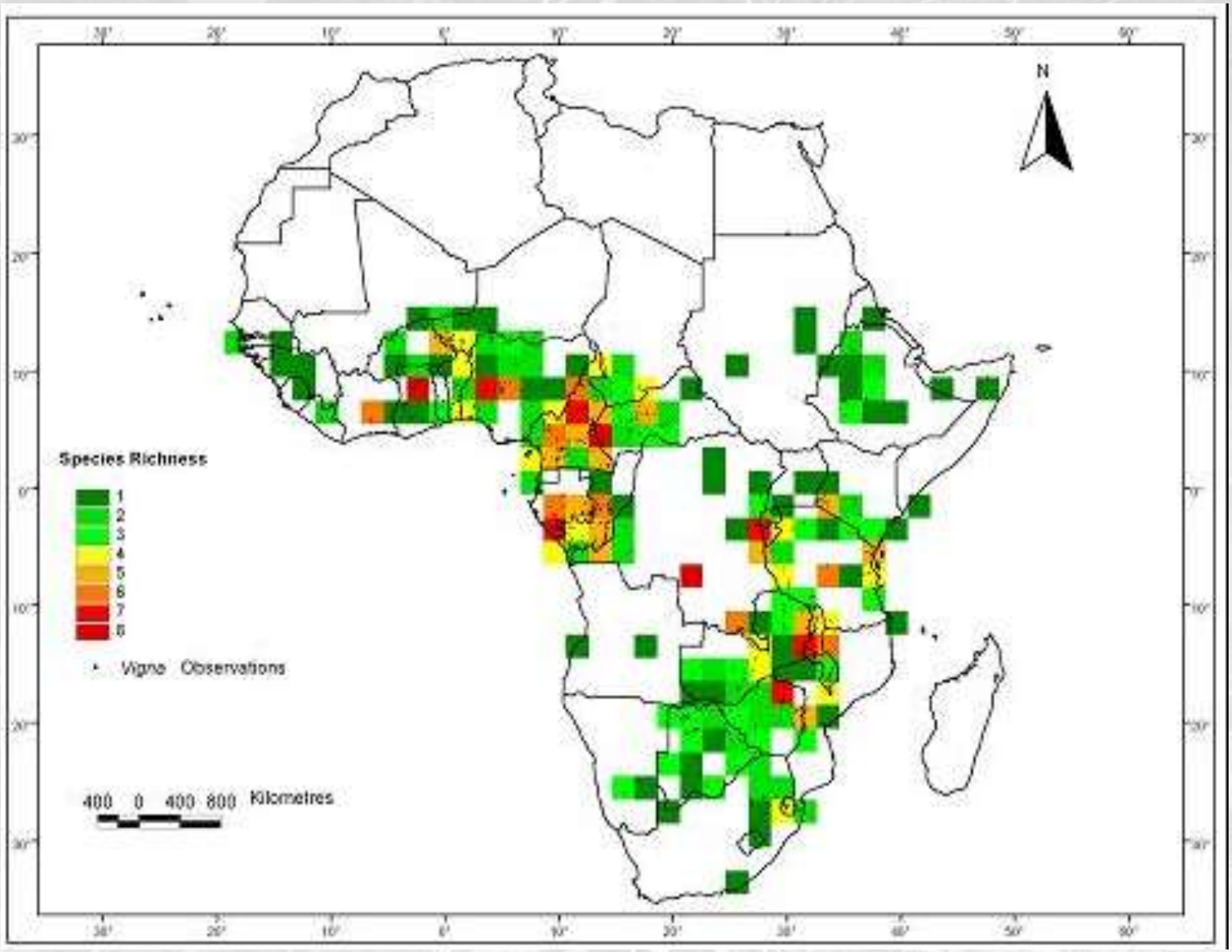
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Absolute species richness based on herbarium collections only in 200 km² grid cells**



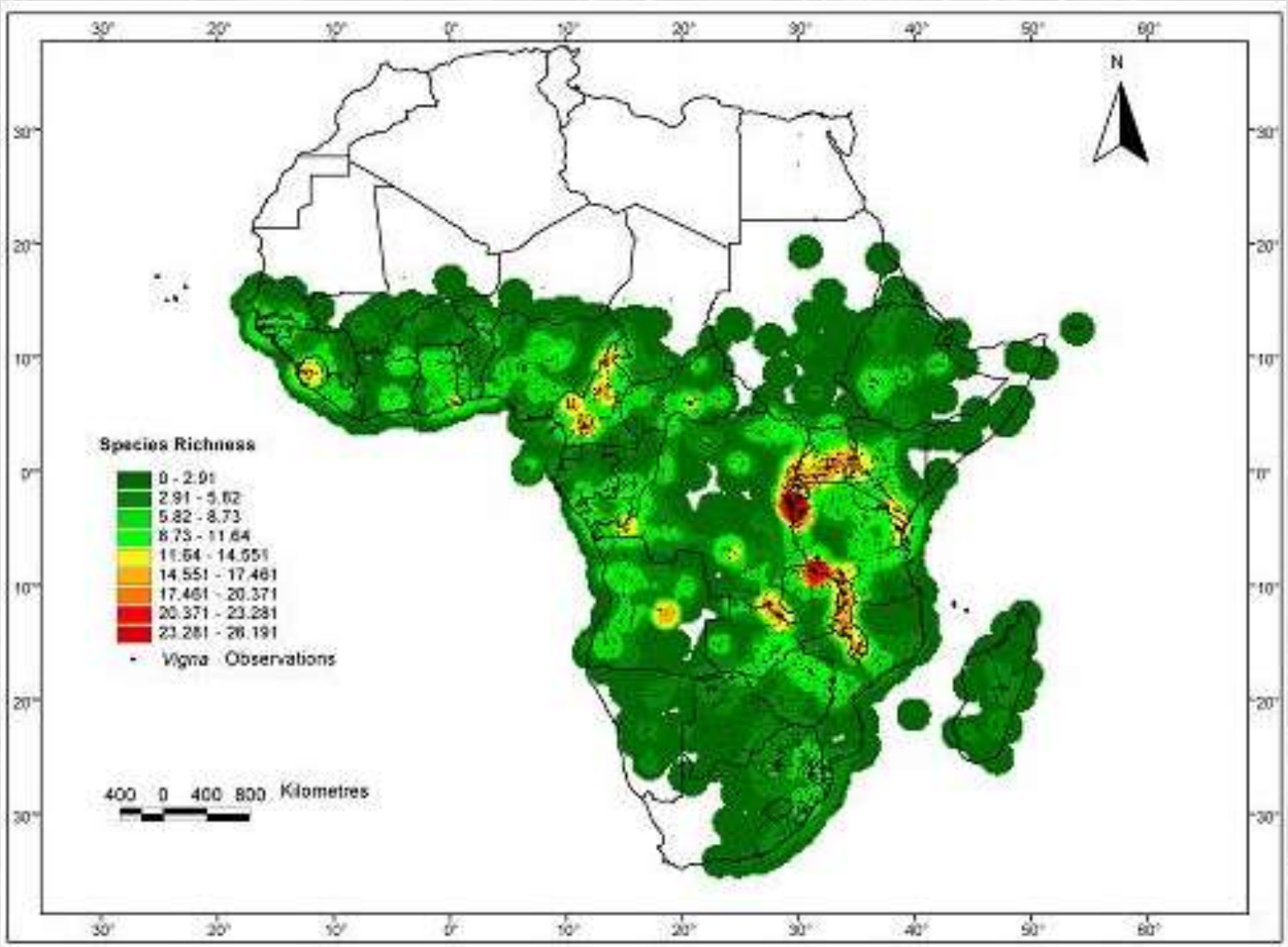
# 2c - Ecogeographic Diversity Assessment: *Vigna*

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



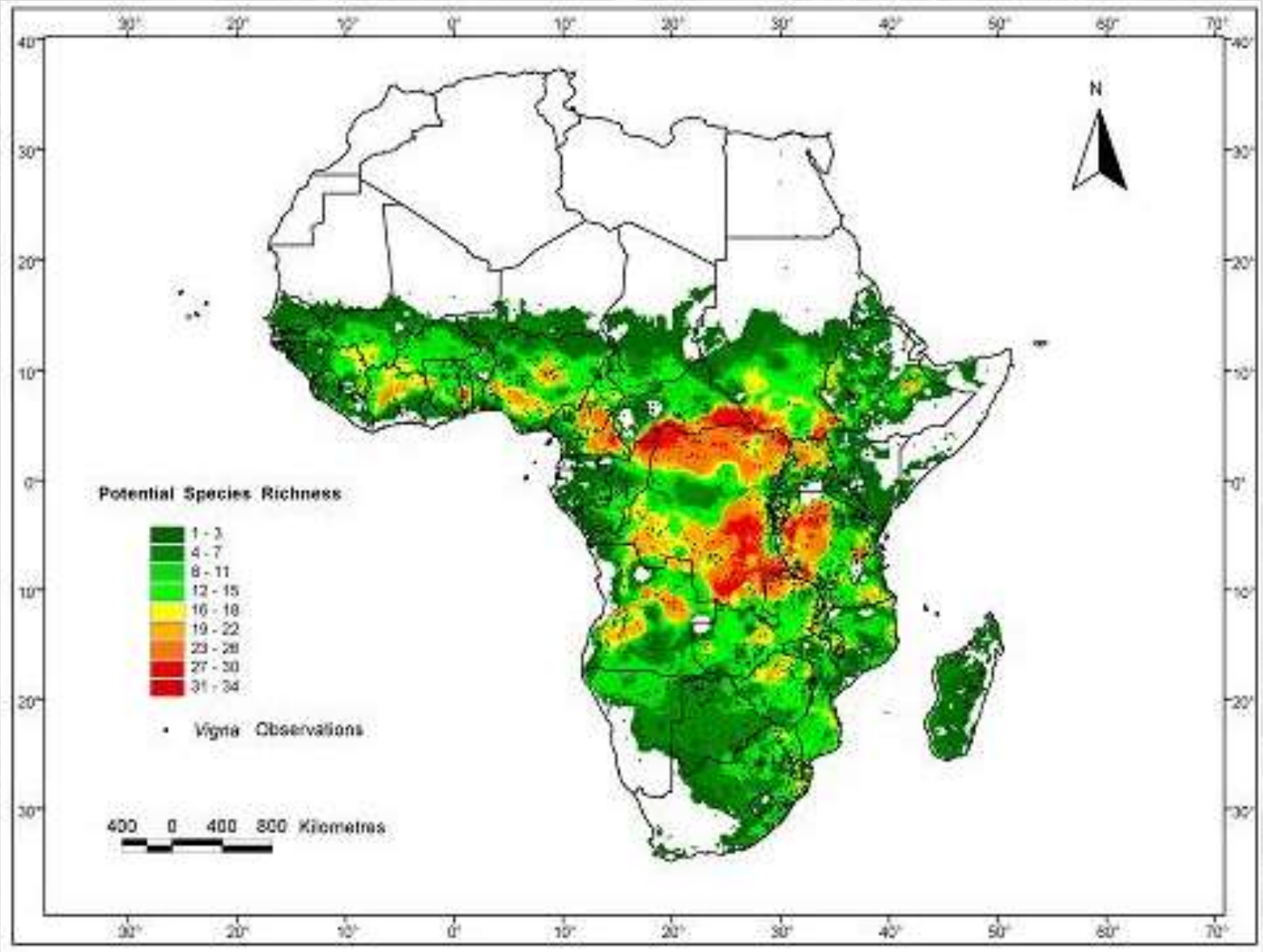
# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Species richness of *Vigna* in 20 km x 20 km grid cells smoothed using inverse distance weighting and a window of 200 km radius**



# 2c - Ecogeographic Diversity Assessment: *Vigna*

**Predicted distribution of species richness**



# 2d - *Threat Assessment*

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


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

# IUCN Threat Assessment for *Vigna*

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

# *Taxon Vulnerability Assessment*

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

- Can approximate vulnerability to genetic diversity and even extinction using seven criteria:
  - 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)

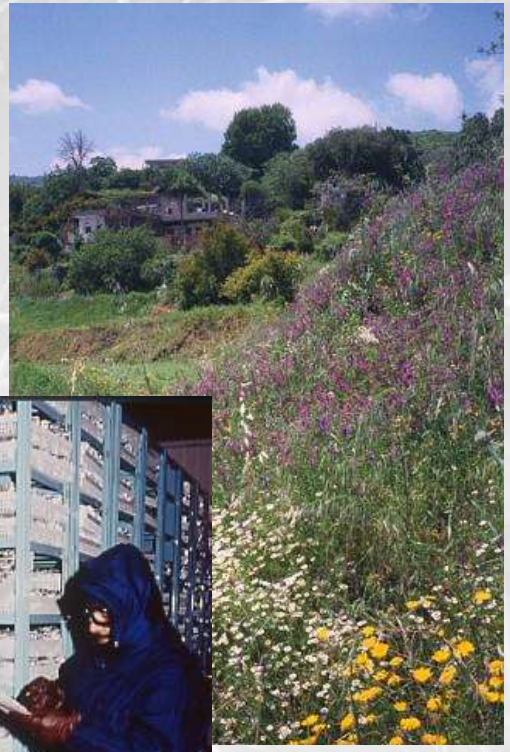
- Crude measure

# *Taxon Vulnerability Assessment : Vigna*

| 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



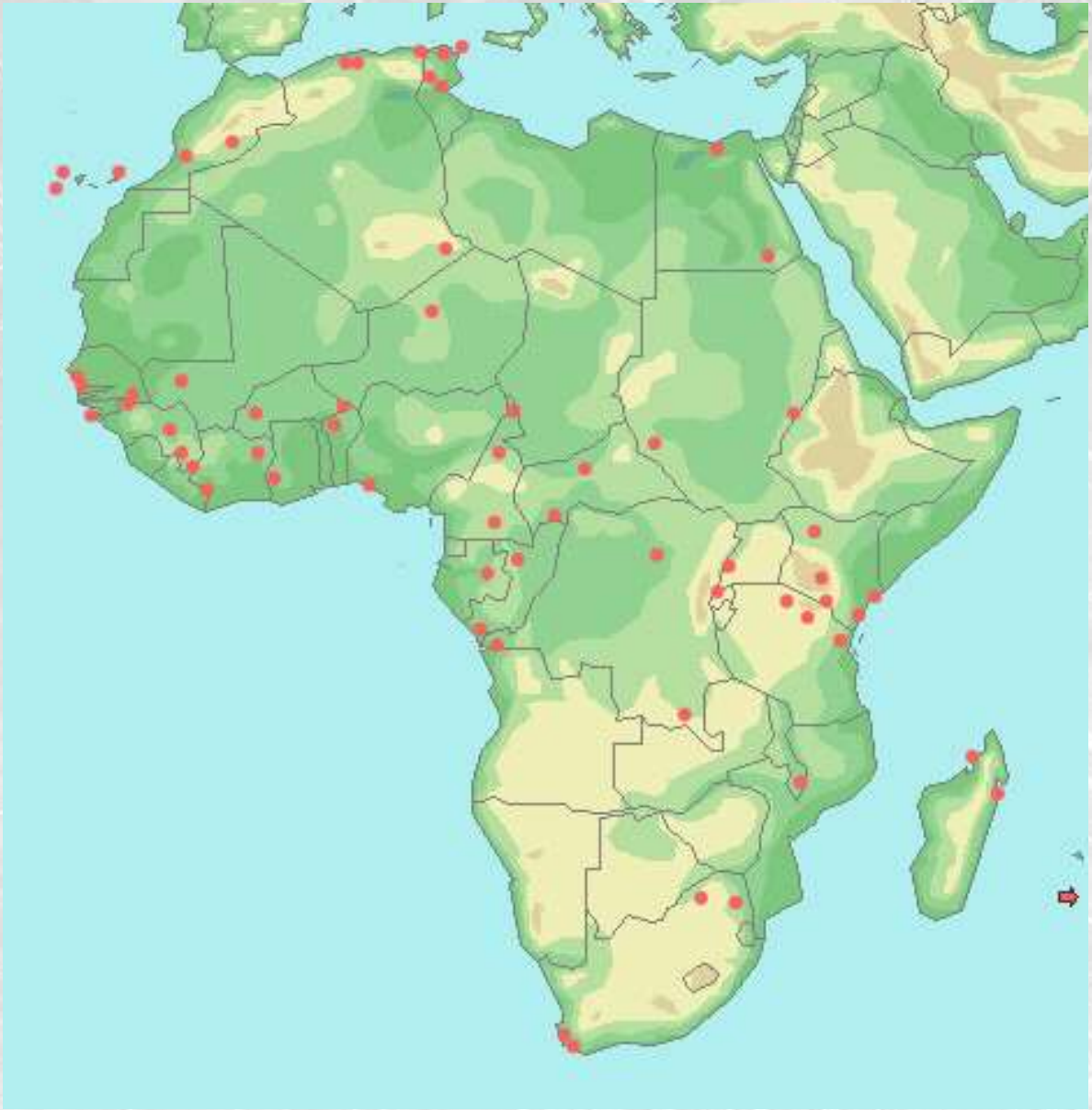
- *Ex situ*
  - Seed bank of germplasm
  - Other techniques ?

# 3a - In situ *techniques / reserve*

- 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

# MAB Protected Areas in Africa



# 3a - In situ *techniques / reserve*

- MAB not only protected areas, many other see IUCN listing of National Parks and Protected Areas
- Few countries have adequate represented of protected areas like Kenya, Guinea and South Africa
- 54% of wild species *Vigna* are predicted to have populations present in at least one protected area
- In reality, the number and ecogeographic diversity of African *Vigna* species makes *in situ* conservation the only practical conservation option for adequate conservation of the broadest gene pool
- Need to match distribution to existing protected areas

# 3a - In situ *techniques / on-farm*

- 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

# 3b - *Ex situ* techniques

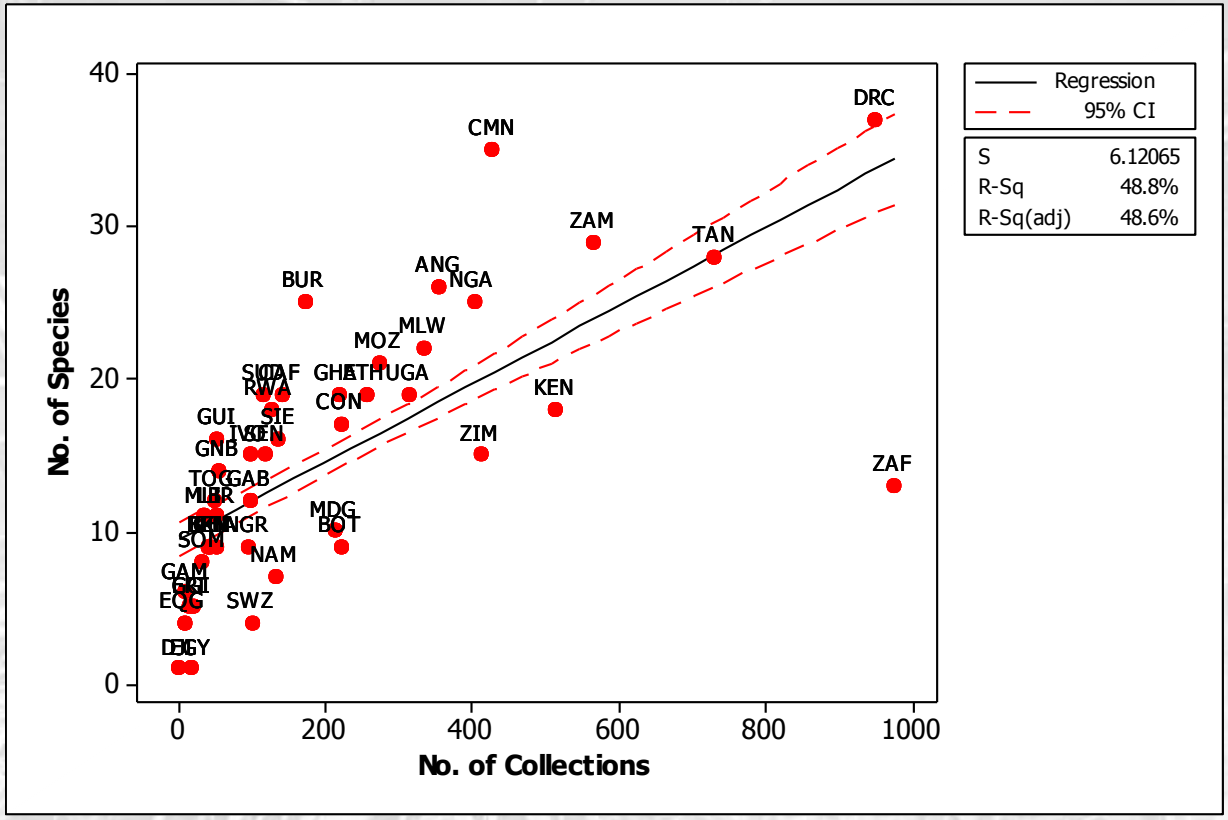
Review of gene bank holdings, GENESYS, but little help for Africa

| **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 |

# 3b - *Ex situ* techniques

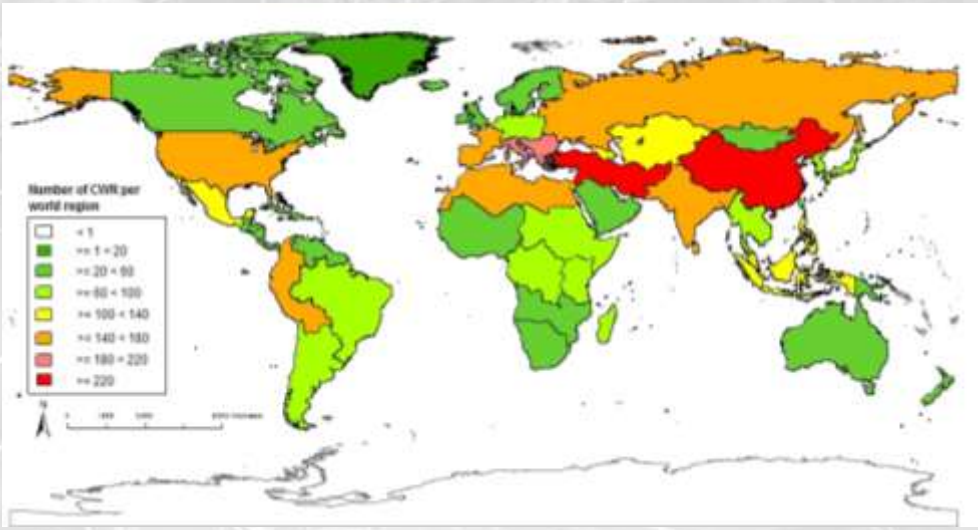
**Regression of *Vigna* species against herbarium specimens and gene bank accessions from each country**

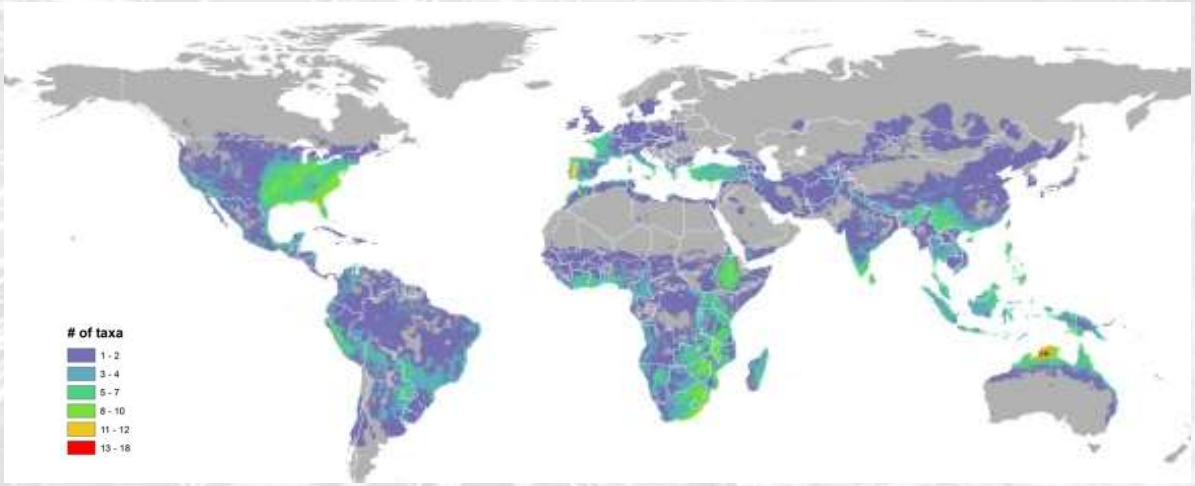
Results indicate Botswana, Namibia, South Africa and Swaziland were over-collected, while Angola, Burundi, Cameroon, Democratic Republic of the Congo, Djibouti, Nigeria, Tanzania and Zambia remain under-collected.



# Scientific approach to global CWR conservation: *ex situ* conservation strategy

- Global Crop Diversity Trust project (Norwegian govt. funding)
- Primarily use orientated, but *ex situ* collecting in first 5 years:
  1. List of gene pools and taxa to collect 26 + 66 (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



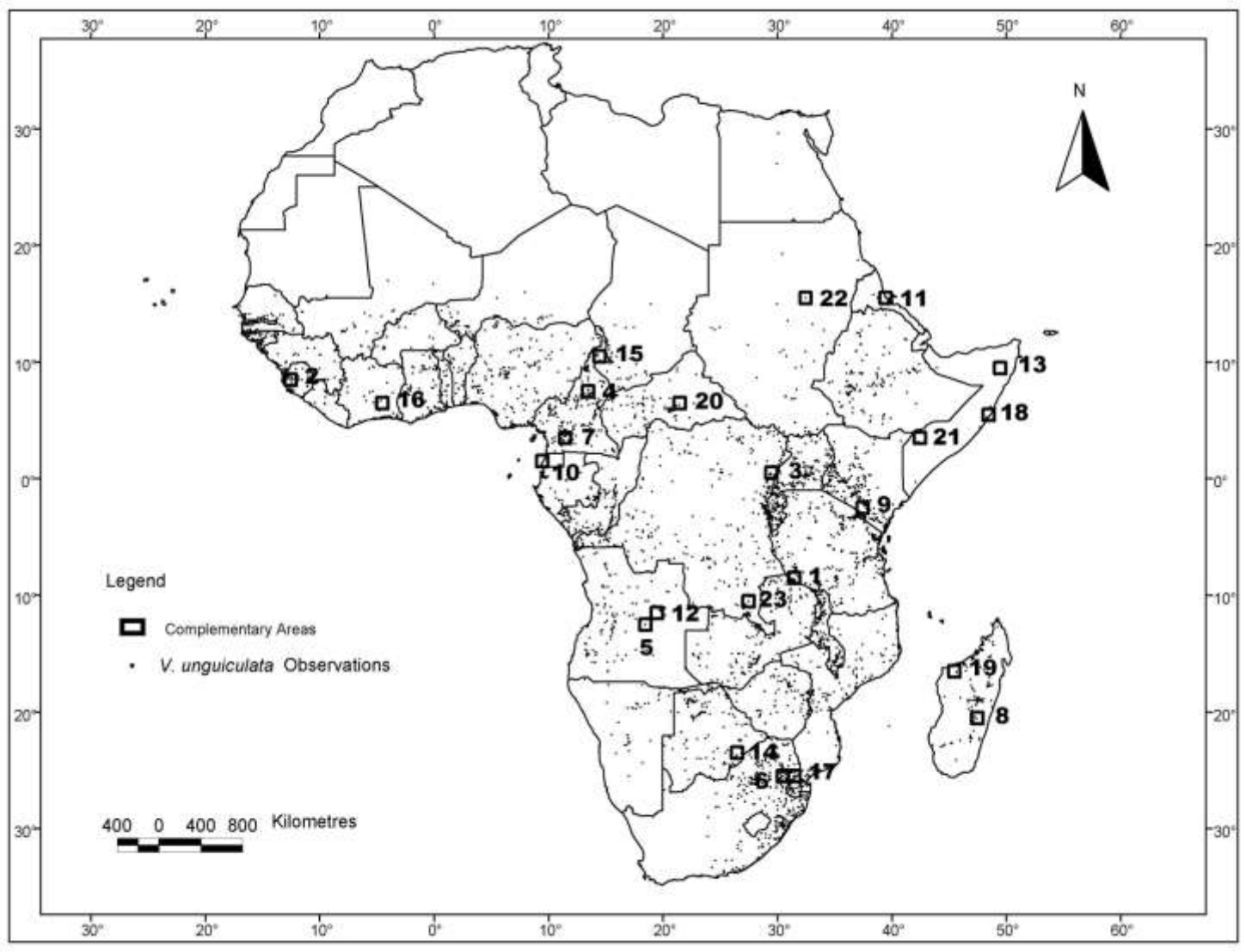



# Step 4: Setting priorities for conservation action

- 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 'Gaps'

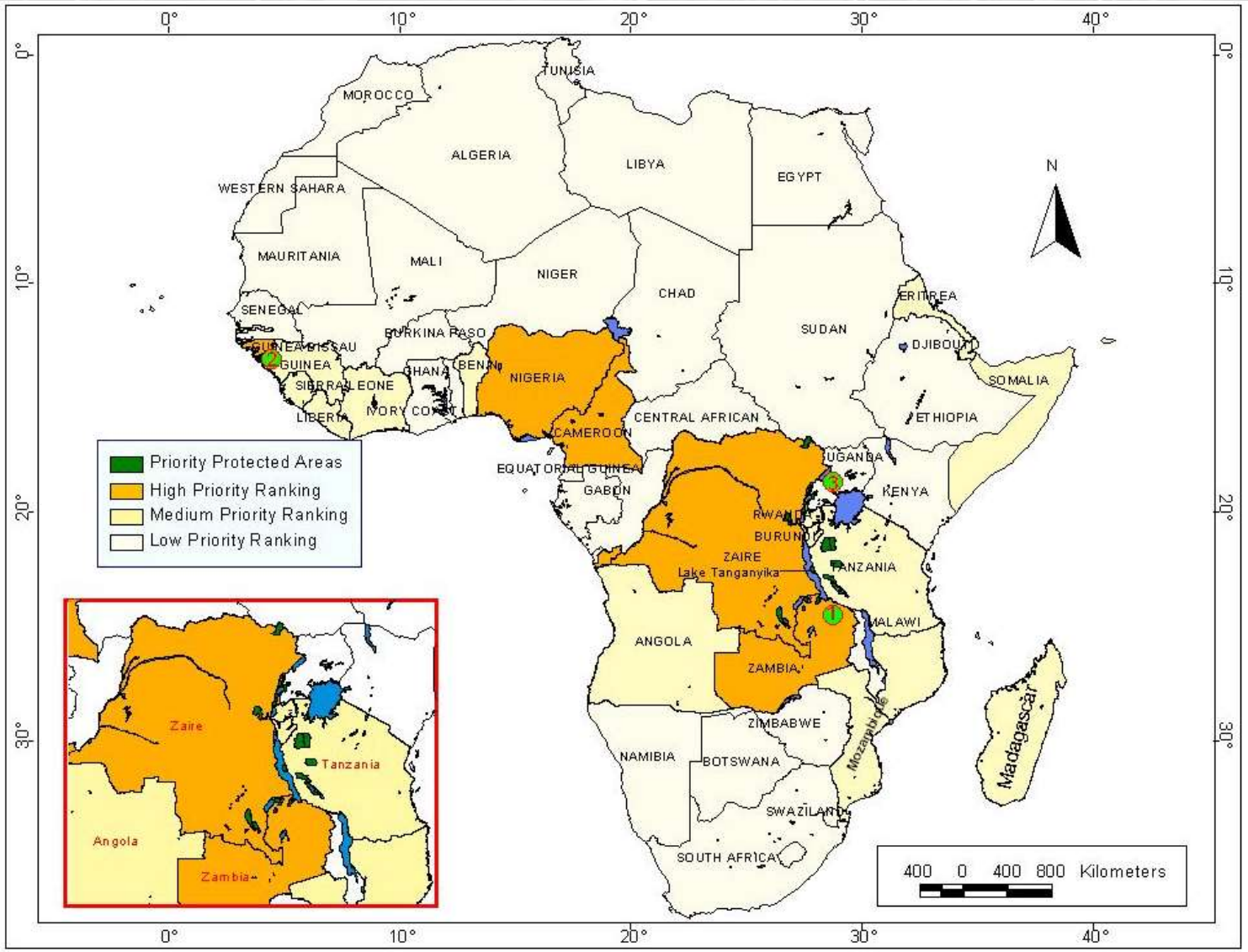
# 4a - *In situ* conservation priorities

Complementarity analysis using DIVA GIS



# 4a - *In situ* conservation priorities

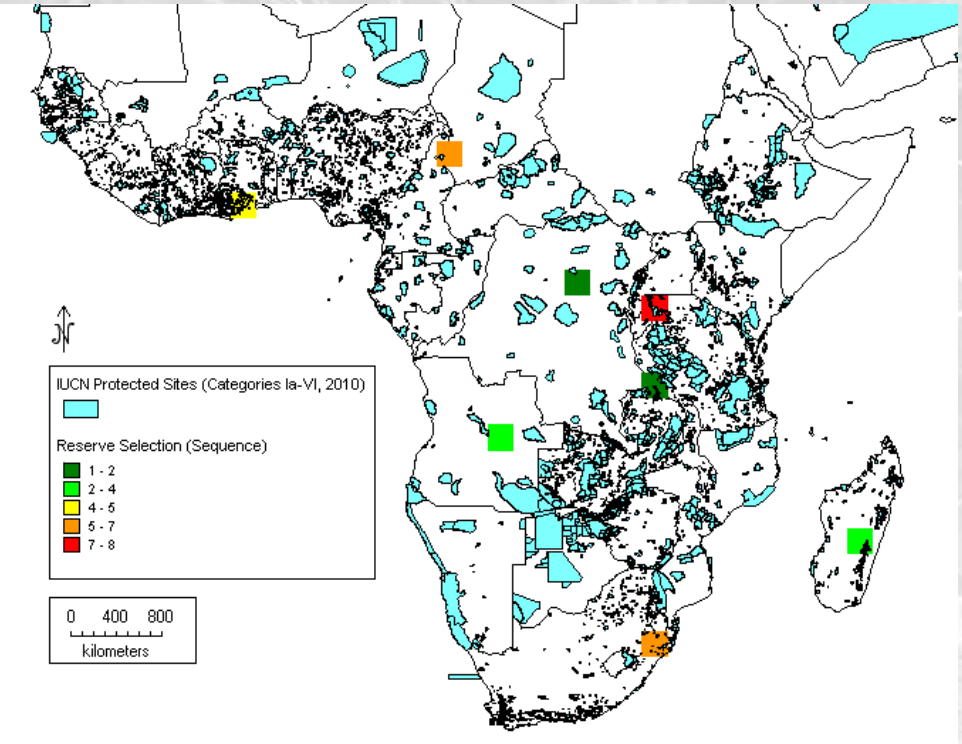
*Areas of Africa where* in situ Vigna *conservation action is required*



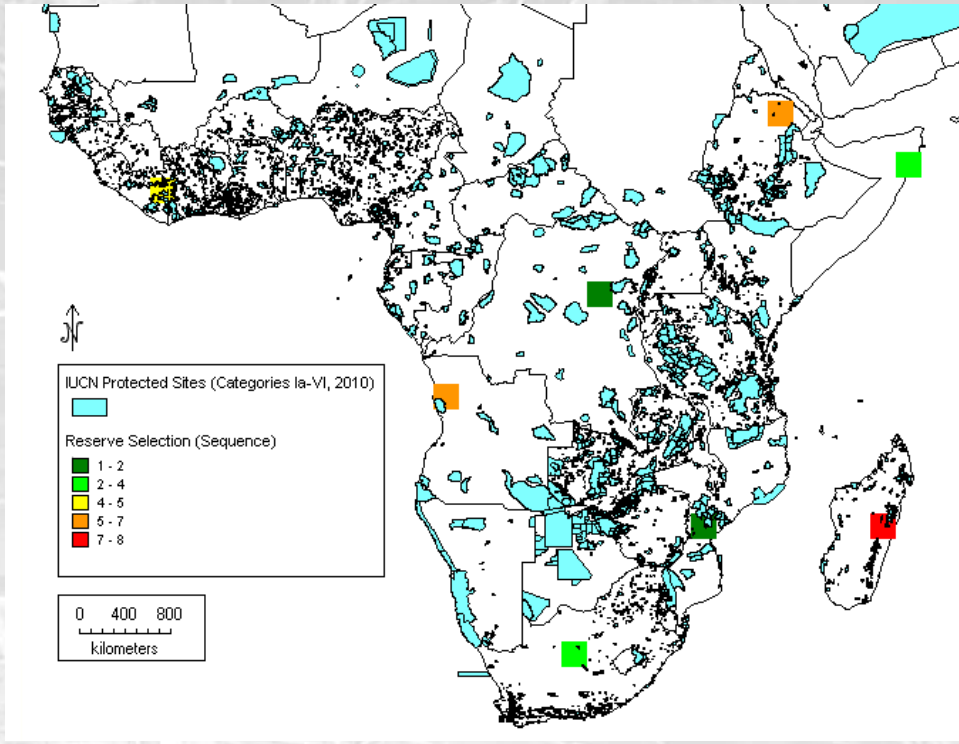
# 4a - Ecogeographic Diversity Assessment: *Vigna*

**Complementarity analysis plus existing protected areas**

http://protectedplanet.net




Complementary analysis for all 124 African *Vigna* taxa



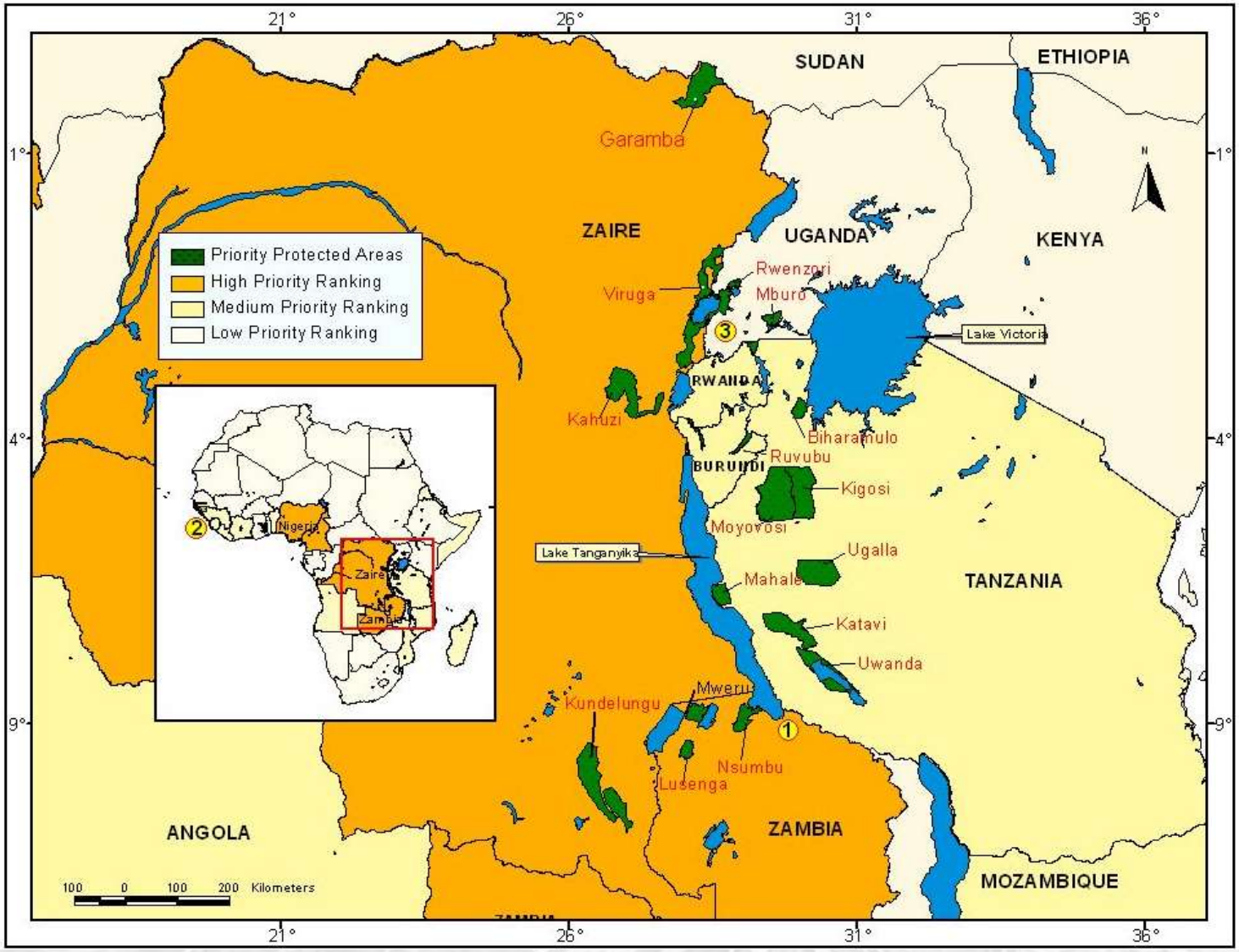

Complementary analysis for 14 priority African *Vigna* taxa (primary and secondary CWR taxa)

# 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 |


# 4a - *In situ* conservation priorities

Existing protected areas where in situ *Vigna* reserves could be established



# 4a - *In situ* conservation priorities

**Existing protected areas on edge of habitat types maximise *in situ* conservation!**

| | | |
|---|---|---|
| Beetle | Beetle | Beetle |
| Butterfly | Butterfly | Butterfly |
| Lizard | Lizard | Lizard |
| Toad | Toad | Toad |
| Tortoise | Tortoise | Tortoise |

# 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

# 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.

# 4b - *Ex situ* conservation priorities

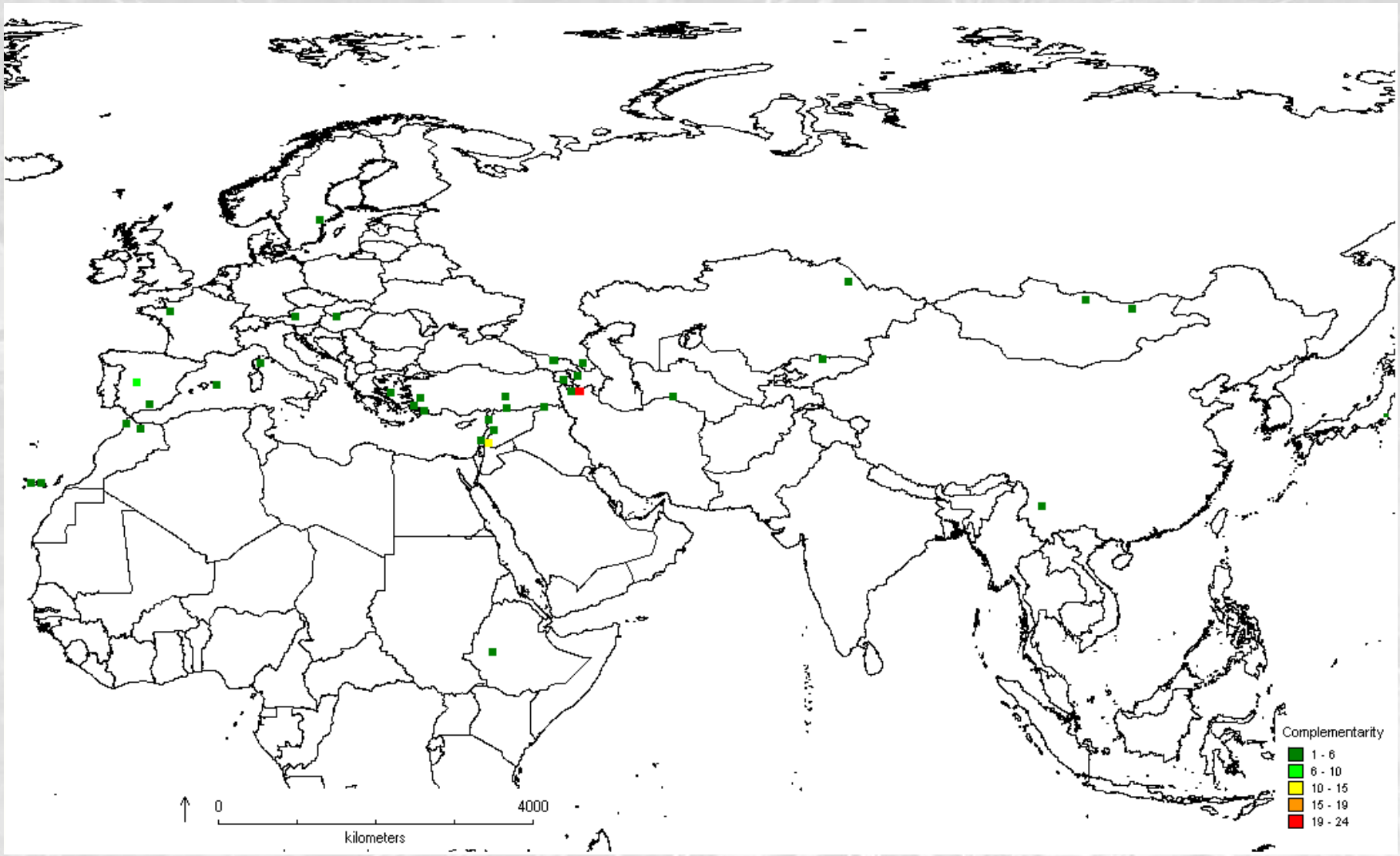
| **Priority Rating** | ***Vigna* taxa** |
|---|---|
| High priority | *V. dolomitica*, *V. haumaniana* var. *pedunculata*, *V. monantha*, *V. nuda*, *V. richardsiae*, *V. somaliensis*, *V. stenophylla*, *V. subterranea* var. *spontanea*, *V. unguiculata* subsp. *unguiculata* var. *spontanea*, *V. unguiculata* 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*. |

# Analysis: Temperate Legumes

**All 150 species Species Richness for *Vicia* species**

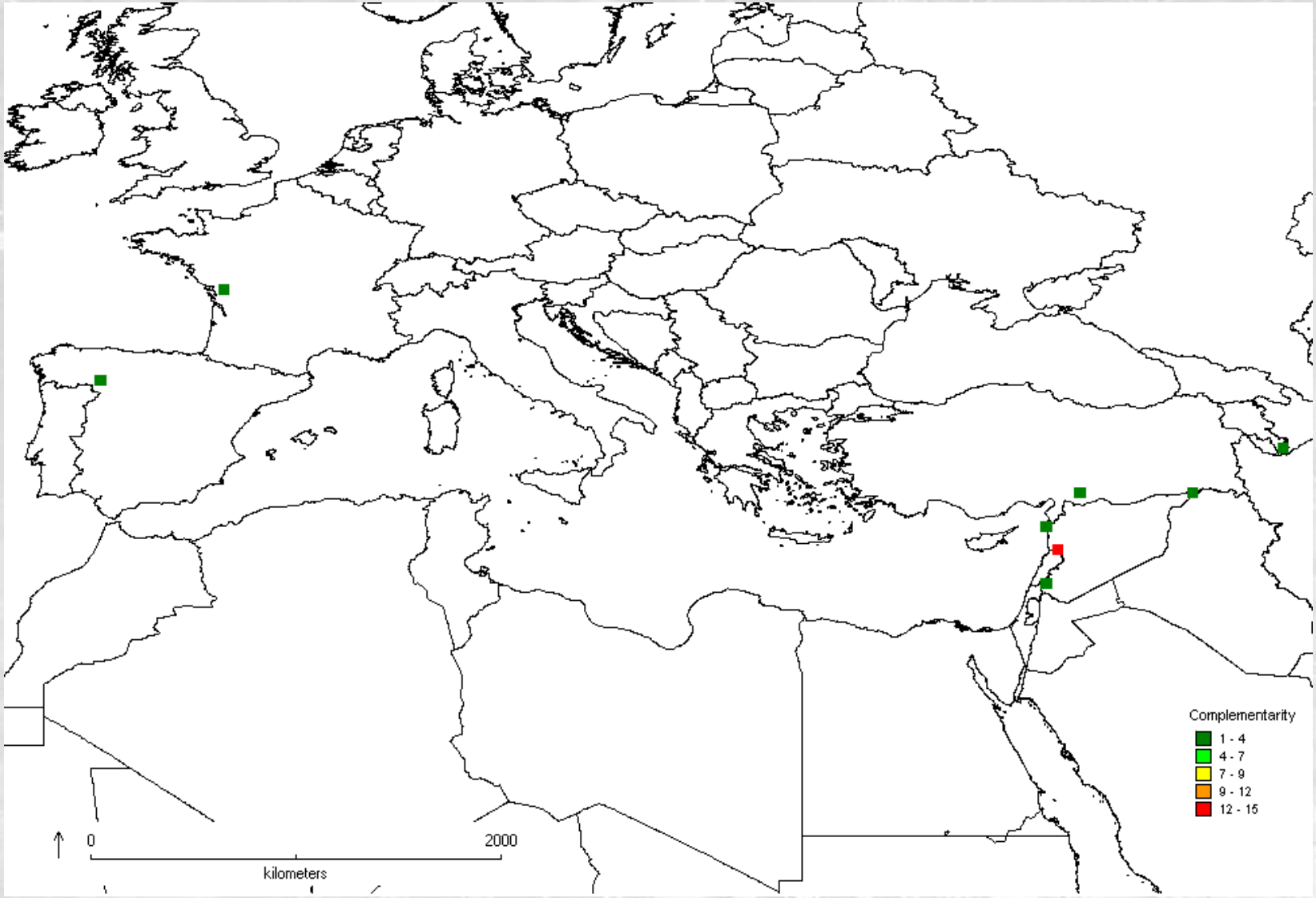
# Analysis: Temperate Legumes

**All 150 species Complementarity Analysis for *Vicia* species**



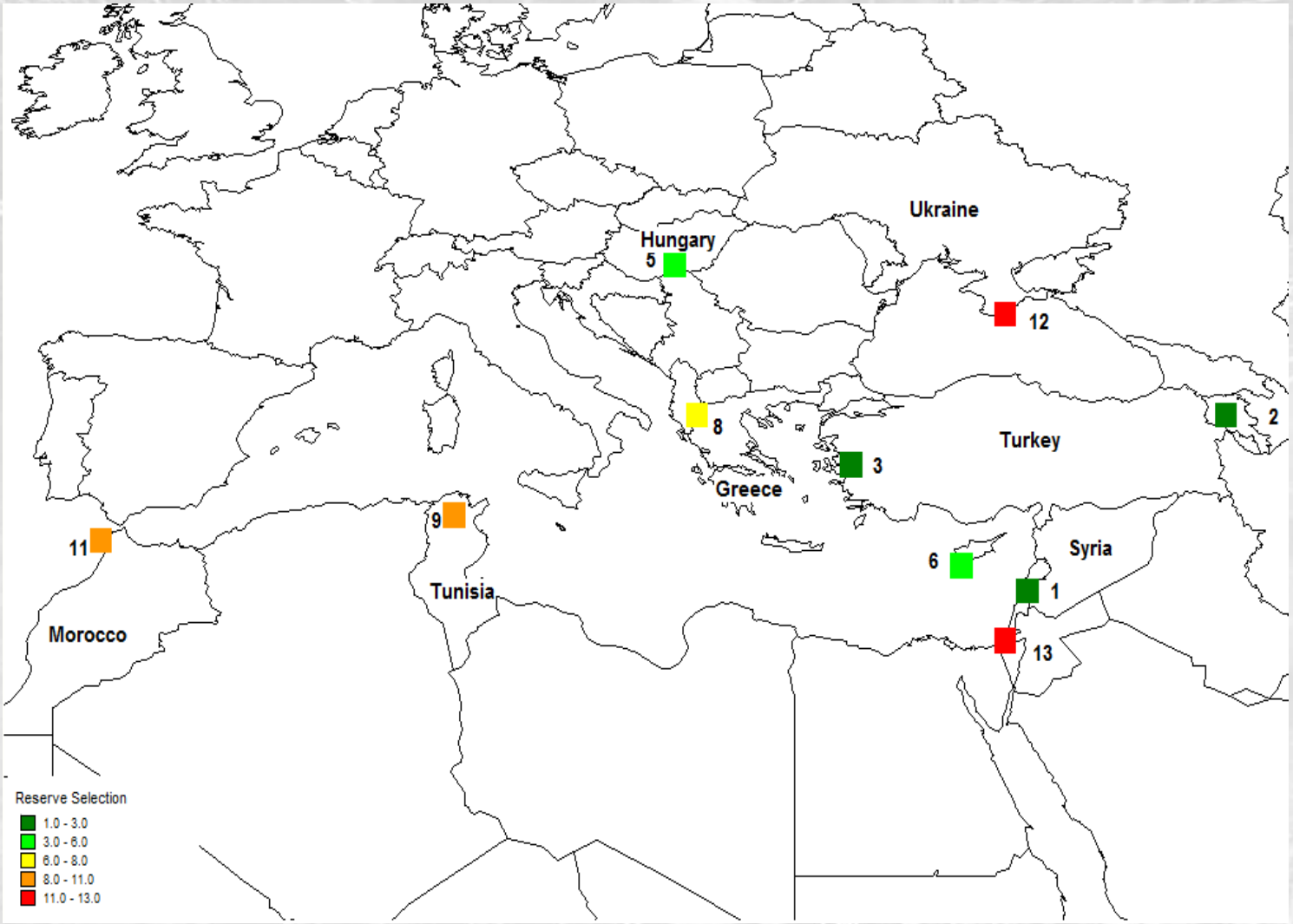
# Analysis: Temperate Legumes

**Priority 31 species Complementarity Analysis for *Vicia* species**



# Analysis: Temperate Legumes

**112 Priority species Complementarity Analysis for *Cicer*, *Lathyrus*, *Lens*, *Medicago*, *Pisum* and *Vicia* species**



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Analysis results:

1.Gap analysis is a useful tool for identifying *ex situ* and *in situ* conservation priorities

2.Complementarity analysis of multiple gene pools shows priority location overlap (making possible multi-gene pool sites for *in situ* conservation)

3.All species and priority species complementarity analysis results can be different

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