# Monitoring Crop Genetic Diversity

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# Global concern about the loss of genetic diversity

## (both *ex situ* collections and *in situ* populations)

- International Treaty on Plant Genetic Resources for Food and Agriculture

  "Alarmed by the continuing erosion of these resources" [i.e. PGRFA]

- Global Plan of Action on Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture

  "Genetic erosion is reported to continue many regions of the world and the genetic vulnerability of crops has further increased".

- Convention on Biological Diversity

  Aichi Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

No clear (rather conflicting) evidence of actual loss of diversity is occurring overall (van de Wouw *et al.* 2009)

- It is clear that genetic erosion is of concern but evidence is still lacking about:
  - rate of loss
  - variation among and between varieties,
  - economic implications

- Monitoring changes in genetic diversity and analyzing causes of change is still needed

# Changes in cultivation of maize hybrids and landraces over time in southwest China

| Year | | Guangxi (n=54) | Yunnan (n=54) | Guizhou (n=54) | Kruskal-Wallis test $\chi^2$ | Kruskal-Wallis test P |
|---|---|---|---|---|---|---|
| Percentage of land cultivated with hybrids | | | | | | |
| 1998 | | 35 | 16 | 19 | 3.6 | 0.1627 |
| 2003 | | 55 | 39 | 42 | 0.9 | 0.6374 |
| 2008 | | 93 | 82 | 63 | 5.9 | 0.0532 |
| Kruskal-Wallis test | $\chi^2$ | 31.9 | 47.1 | 20.7 | - | - |
| | P | 0.0001 | 0.0001 | 0.0001 | - | - |
| Percentage of land cultivated with landraces (including waxy and non-waxy landraces) | | | | | | |
| 1998 | | 65 | 84 | 81 | 12.7 | 0.0017 |
| 2003 | | 45 | 61 | 58 | 13.1 | 0.0015 |
| 2008 | | 7 | 18 | 37 | 26.5 | 0.0001 |
| Kruskal-Wallis test | $\chi^2$ | 13.7 | 26.4 | 5.2 | - | - |
| | P | 0.0011 | 0.0001 | 0.0756 | - | - |

(Jingson Li, 2012)

# Need for Better Monitoring

- Many studies have been undertaken to develop indicators for biodiversity, but only partly specifically dealing with agricultural biodiversity (Buiteveld et al., 2009).

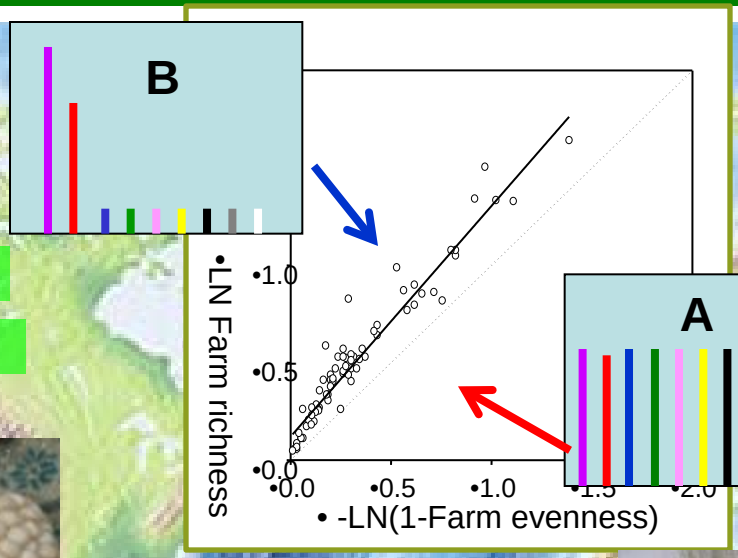
- There is no global, harmonized observation system for delivering regular, timely data on agricultural biodiversity change

- Different organizations and projects adopt diverse measurements, with some important biodiversity dimensions, such as genetic diversity, often missing

# Indicators of genetic diversity, genetic erosion and genetic vulnerability

- Concepts of diversity in terms of richness of diversity, and evenness of diversity (Brown, 2008)
- Many variables have been described as indicators of diversity,
- More practical ones are based on number of individuals or area occupied *in situ* and on the number of accessions and the number of gene banks *ex situ*.
- A set of 22 genetic indicators for both in situ and ex situ and for cultivated and wild plant species

# Global indicators: Significant traditional variety diversity continues to be managed by small scale farmers in the developing world.




**Richness = 9**

**Evenness A > B**

**House Hold richness**

**Community Richness**

1-2
5-14

2-3
4-20

*Hungary, Mexico, Peru*

2-3
39-89

*Peru*

1-2
4-12

*Morocco, Ethiopia*

4-5
15-28

*Burkina faso*

2-3
9-18

*Uzbekistan*

3-5
6-19

4-5
9-74

*Nepal and Vietnam*

1-2
5-27

**Leading the collaboration of >60 institutes world wide**

Jarvis et al., 2009 PNAS

# FAO Indicators for implementation of Global Plan of Action

- 66 indicators covering 4 main areas viz.
  - In situ conservation and management (12 indicators)
  - Ex situ conservation (12 indicators)
  - Sustainable use (22 indicators)
  - Building institutional and human capacities (20 indicators)
- Three targets adopted at CGRFA-14
  - Conservation of PGRFA,
  - Sustainable use and
  - institutional and human capacities
- Composite Index for each of the targets

# UN- Strategic Plan for Biodiversity 2011-2020

## Aichi Biodiversity Targets

- Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society
- Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use
- Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity
- Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services
- Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building

- Aichi Target 13: By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

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ECOLOGY

# Tracking Progress Toward the 2010 Biodiversity Target and Beyond

Matt Walpole, [1*†] Rosamunde E. A. Almond, [1] Charles Besançon, [1] Stuart H. M. Butchart, [2] Diarmid Campbell-Lendrum, [3] Geneviève M. Carr, [45] Ben Collen, [6] Linda Collette, [7] Nick C. Davidson, [8] Ehsan Dulloo, [9] Asghar M. Fazel, [1] James N. Galloway, [10] Michael Gill, [11] Tessa Goverse, [12] Marc Hockings, [13] Danna J. Leaman, [14] David H. W. Morgan, [15] Carmen Revenga, [16] Carrie J. Rickwood, [517] Frederik Schutyser, [18] Sarah Simons, [19] Alison J. Stattersfield, [2] Tristan D. Tyrrell, [1] Jean-Christophe Vié, [20] Mark Zimsky[21]

In response to global declines in biodiversity, some 190 countries have pledged, under the Convention on Biological Diversity (CBD), to reduce the rate of biodiversity loss by 2010 (*1*, *2*). Moreover, this target has recently been incorporated into the Millen-

with which to measure progress toward the target at a global level (*4*, *5*). Countries are being encouraged to report progress at the national level using this framework, which is also being applied in regional initiatives such as "Streamlining European Biodiversity Indi-

**Biodiversity indicators**

**Components of biodiversity**

- Trends in extent of selected biomes, ecosystems, habitats
- Trends in distribution of selected species
- Coverage of protected areas
- Changes in status of threatened species
- Trends in Genetic Diversity

**Sustainable use**

- Area under sustainable management: certification
- Proportion of products from sustainable sources
- Ecological footprint and related

**Threats to biodiversity**

- Nitrogen deposition
- Invasive alien species

**Ecosystem integrity, goods and services**

- Marine Trophic Index
- Water quality
- Trophic integrity of other ecosystems
- Connectivity/fragmentation of ecosystems
- Human-induced ecosystem failure
- Health and well-being of communities
- Biodiversity for food and medicine

**Status of knowledge, innovations, and practices**

- Linguistic diversity
- Indegenous and traditional knowledge

**Status of access and benefits sharing**

- Access and benefits sharing

**Status of resource transfers**

- Official development assistance
- Technology transfer

# BIP: Ex situ collection indicator

## Enrichment Index of ex situ crop collections as an indicator on the status and trend of crop genetic diversity

**Principle**: Accessions entering the collection can be characterized for their originality

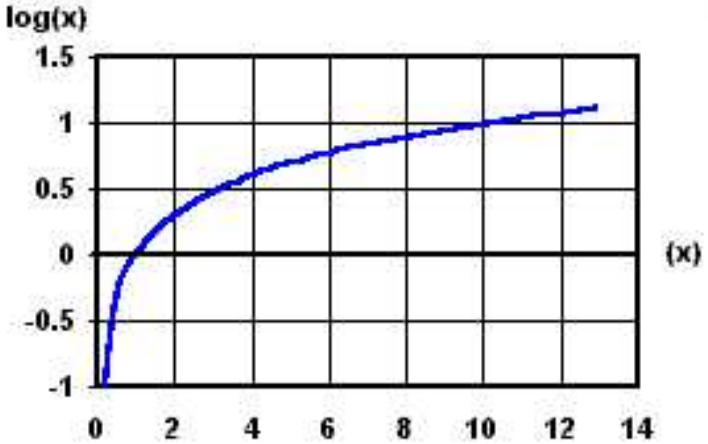
- No. of species
- No. of accessions within collections
- Geographical origin of accessions

**Index**: An integrative function reflecting the collection's enrichment

Any new accessions entering the collection at a given time is compared to the accessions already present:

- Is it a new species?
- Does it come from a new area?

The more original it is, the more weight it is given. The weight is based on a log function so that it decreases when a species is well represented.



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# Essential Biodiversity Variables

H. M. Pereira,[1*†] S. Ferrier,[2] M. Walters,[3] G. N. Geller,[4] R. H. G. Jongman,[5] R. J. Scholes,[3] M. W. Bruford,[6] N. Brummitt,[7] S. H. M. Butchart,[8] A. C. Cardoso,[9] N. C. Coops,[10] E. Dulloo,[11] D. P. Faith,[12] J. Freyhof,[13] R. D. Gregory,[14] C. Heip,[15] R. Höft,[16] G. Hurtt,[17] W. Jetz,[18] D. S. Karp,[19] M. A. McGeoch,[20] D. Obura,[21] Y. Onoda,[22] N. Pettorelli,[23] B. Reyers,[24] R. Sayre,[25] J. P. W. Scharlemann,[26,27] S. N. Stuart,[28] E. Turak,[29] M. Walpole,[26] M. Wegmann[30]

A global system of harmonized observations is needed to inform scientists and policy-makers.

## Essential Biodiversity Variables in Practice

We define an EBV as a measurement required for study, reporting, and management of biodiversity change. Hundreds of variables

EXAMPLES OF CANDIDATE ESSENTIAL BIODIVERSITY VARIABLES

| EBV class | EBV examples | Measurement and scalability | Temporal sensitivity | Feasibility | Relevance for CBD targets and indicators (*1,9*) |
|---|---|---|---|---|---|
| Genetic composition | Allelic diversity | Genotypes of selected species (e.g., endangered, domesticated) at representative locations. | Generation time | Data available for many species and for several locations, but little global systematic sampling. | Targets: 12, 13. Indicators: Trends in genetic diversity of selected species and of domesticated animals and cultivated plants; RLI. |

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# Proxy indicators for genetic diversity (Last et al, 2014)

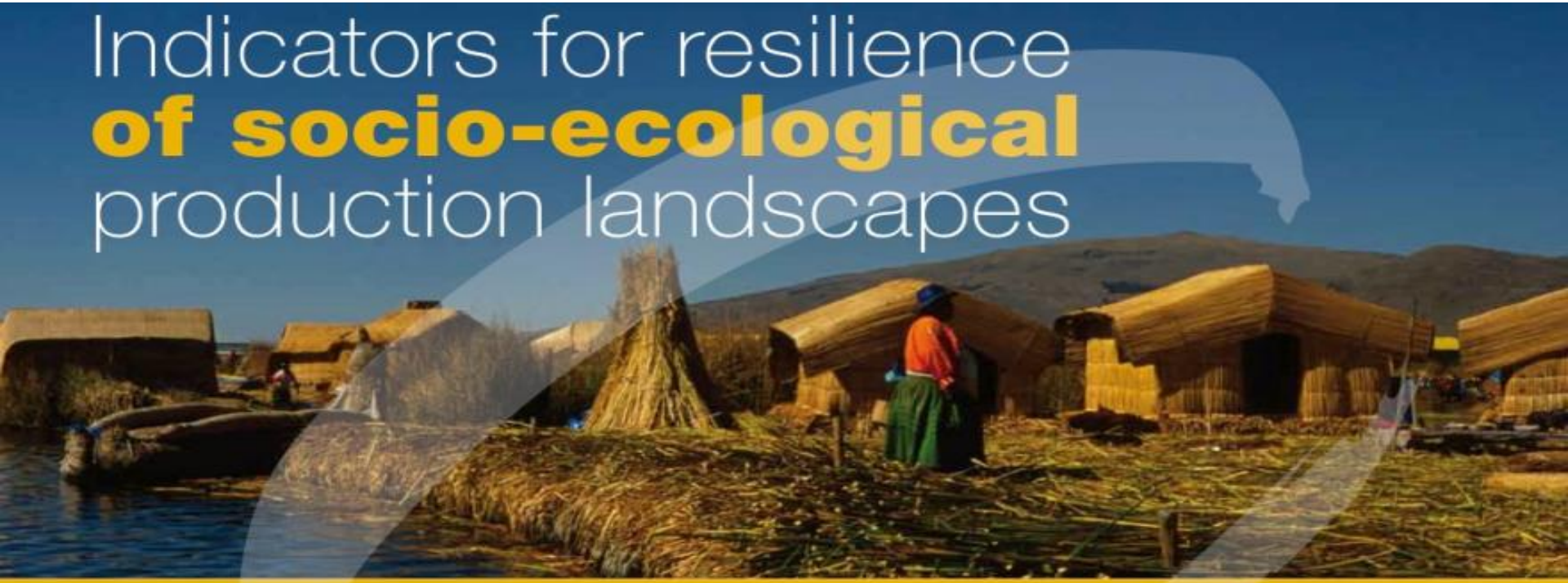
Five indicators for the estimation of genetic diversity, i.e. crop accession or breed diversity, at farm level.

- Crop-Species Richness',
- Crop-Cultivar Diversity', '
- Type of Crop Accessions',
- Livestock-Species Richness' and '
- Breed Diversity'.

Developed and tested through a participatory approach involving stakeholders from 12 European case studies and in Uganda.

# Streamlining European Biodiversity Indicators (SEBI)

- Set of biodiversity indicators for Europe to measure progress towards the target of holding biodiversity loss in Europe by 2010 (Biala *et al.*, 2012).
- SEBI aim was to build on current monitoring and available data to avoid duplication of efforts and to complement
- 26 indicators were developed using application of rigorous criteria thorough stakeholder-based process
- As such it should be recognized as a comprehensive peer group reviewed and validated set of indicators (Biala, 2012).




# Indicators for Resilience in SEPLs: Development and Field Testing

SATOYAMA INITIATIVE

UNITED NATIONS UNIVERSITY
UNU-IAS

Bioversity International

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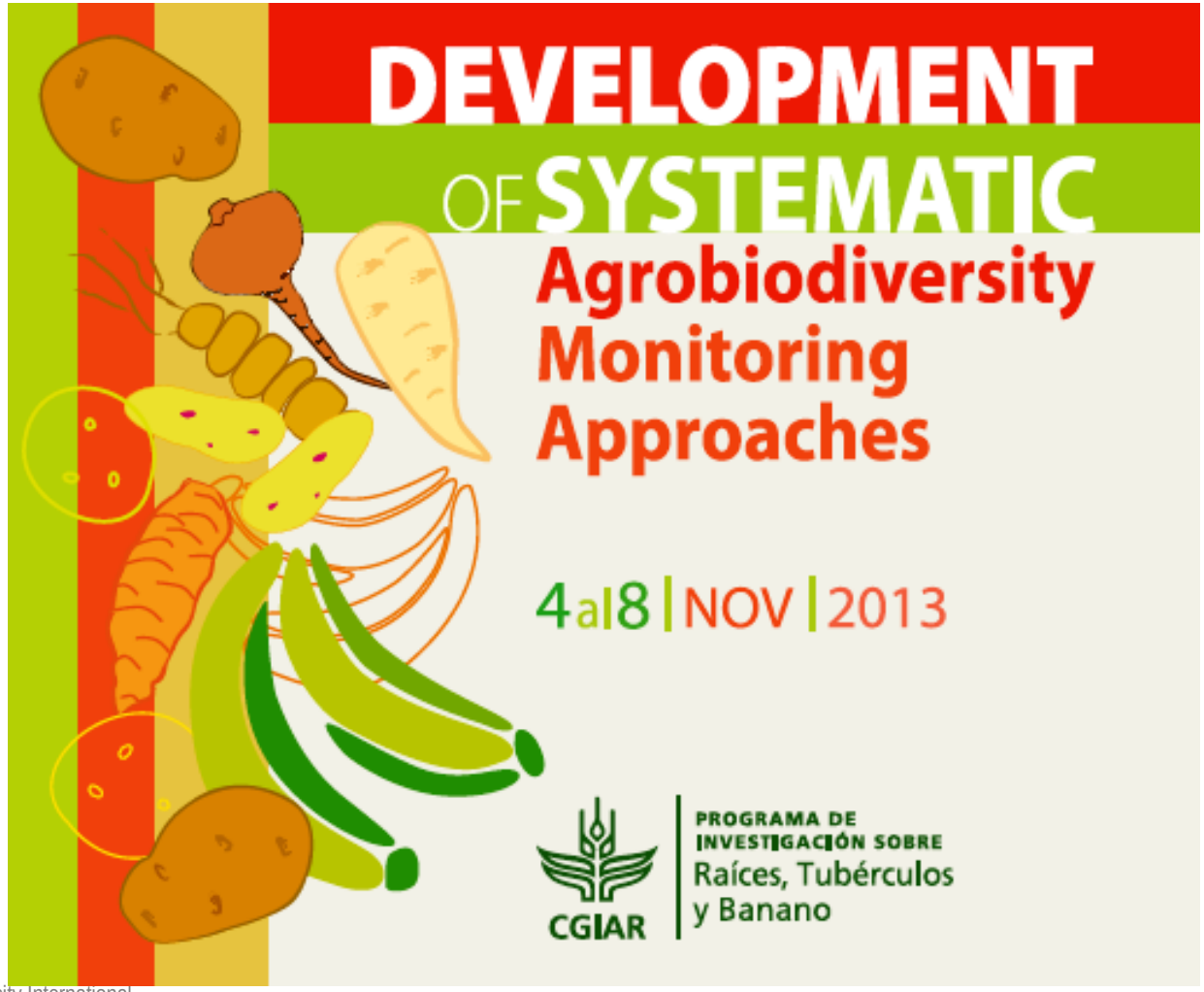
# Socio-ecological resilience indicators

- Measuring community's capacity to adapt to change while maintaining biodiversity.

- Four categories comprising 20 indicators on:
  - Ecosystems protection and the maintenance of biodiversity
  - Agricultural biodiversity
  - Knowledge, learning and innovation
  - Social equity and infrastructure

- Developing strategies for
  - Conserving biodiversity at various scales (from genetic to landscape level)
  - Sustaining evolution and adaptation processes that maintain and generate diversity
  - Empowering local communities and strengthening their role as innovators and custodians of biodiversity

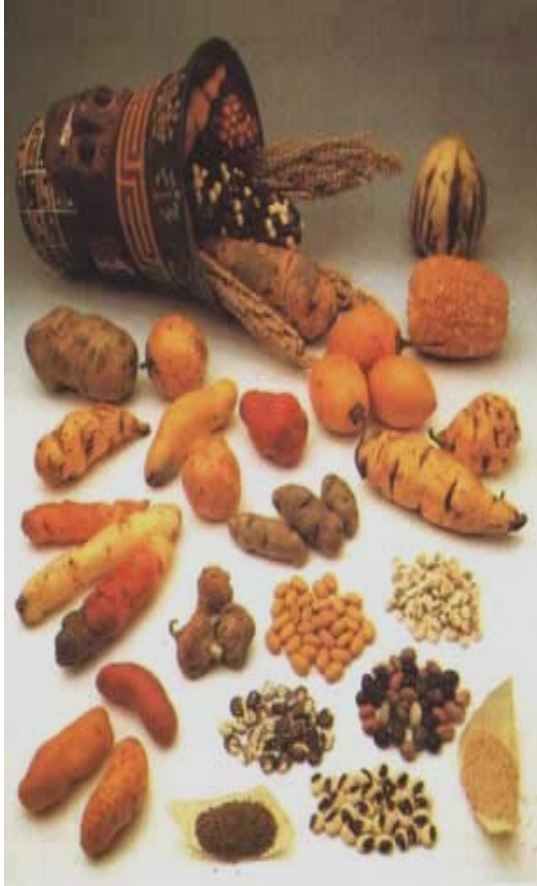
# International Expert Meeting, Huacanyo, Peru



# Approach

Monitoring required at different levels:

- Genetic
- Species/variety
- Landscape
- Traditional knowledge and cultural practices



# A New Integrated indicator

- HT Integrated Indicator- Bonneuil et al. (2012)
  - Varietal richness, Spatial evenness; Effect of between-variety genetic diversity; Within- variety genetic diversity
- Tested against a historical dataset on bread wheat varieties dating back to 1878: Allelic diversity; Acreage share of each variety; Contribution of within variety diversity to total genetic diversity
- More varieties (the varietal richness factor) can mean less diversity when

  (i) their genetic structure is more similar (the effect of between-variety genetic diversity), or

  (ii) when more diverse landraces are replaced by many homogeneous lines (the effect of within-variety genetic diversity) or

  (iii) when one or a few varieties become hegemonic in the landscape (the spatial evenness effect)

# Monitoring crop genetic diversity- a case study- barley in Jordan

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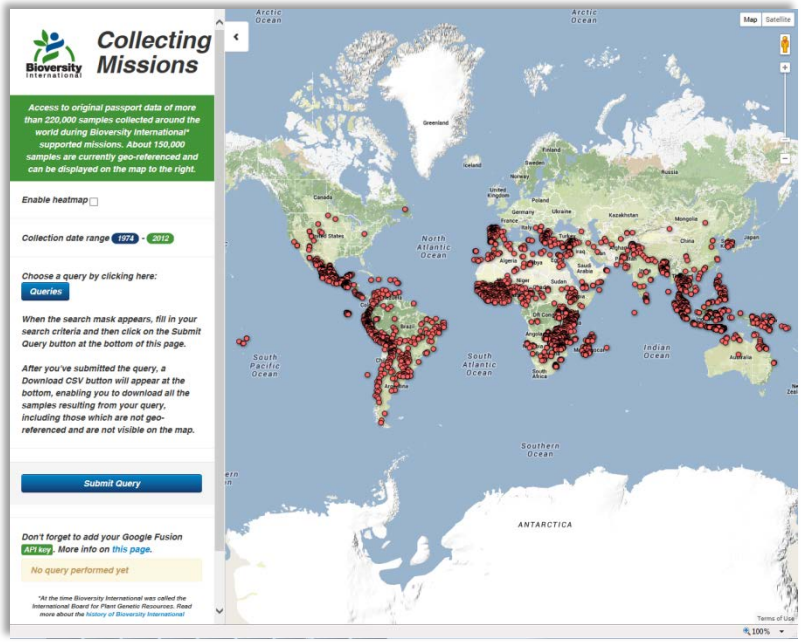
# Assessing and monitoring trends and loss in genetic diversity

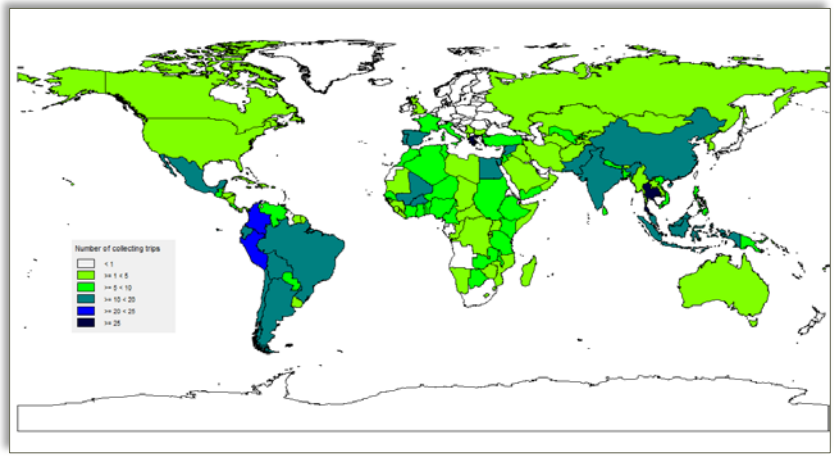
- Temporal dimension: requires to compare assessments (snapshots of diversity) across time
- Potential sources:
  plant germplasm collections can provide past snapshots of diversity and data for re-collection for assessment of current diversity
- One example: Bioversity collecting mission database




http://bioversity.github.io/geosite/

# Bioversity collecting database

- > 1000 collecting trips between 1975 and 2012
- Focus: landraces and CWR threatened by genetic erosion and/or of major food crops
- 226,618 samples collected, of which ca. 85% between 1975-1995
- 27% of collected samples are wild species
- 25% of trips collected only wild species
- Passport data and collecting mission reports for most samples available

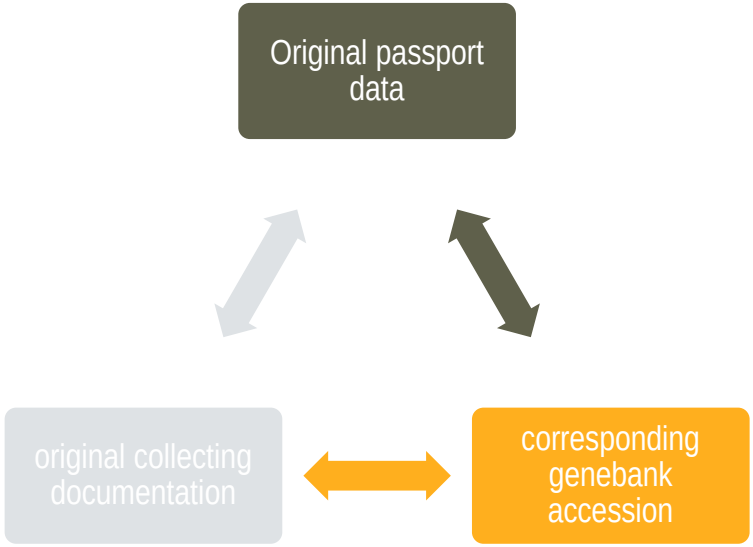



- For 35% of all samples one or more accessions have been identified as deriving from a specific sample

# Methodology and potential applications

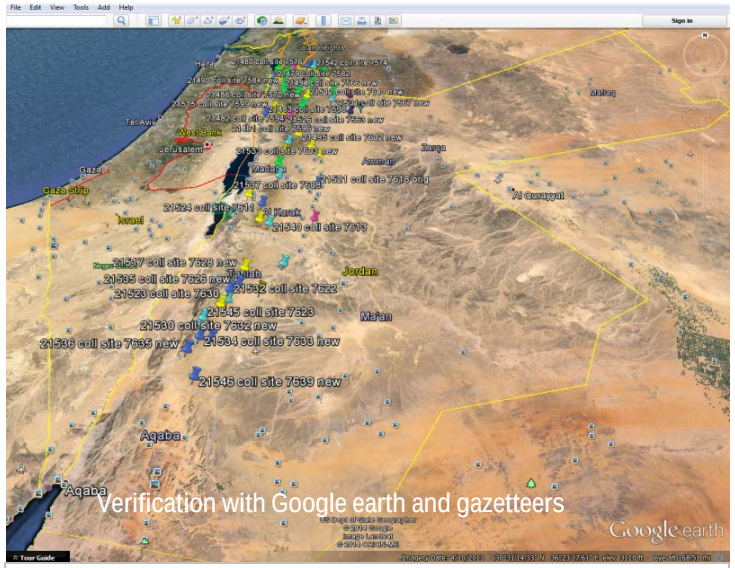
Unique link between original passport data, additional collecting documentation and genebank accession numbers allows to:

- Identify coherent set of samples/sites collected at the same time/way (historic snapshot of diversity)
- Re-visit old collecting sites and re-sample CWR
- Retrieve original material in genebanks
- Assess temporal variation in genetic diversity and current vulnerability and threat
- Inform conservation actions

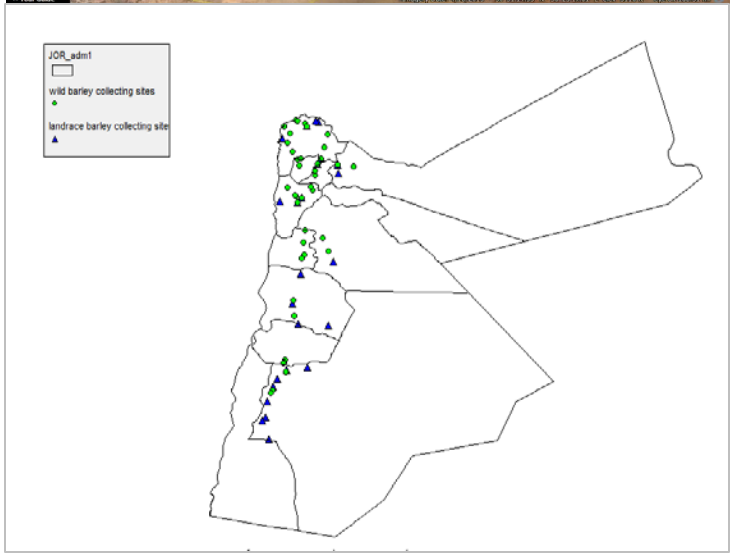


# Successful implementation: re-collection of barley in Jordan

- Re-visiting in 2012 the sites collected in 1981
  - Verification of collecting sites based on coordinates and location description
  - Re-collection of wild barley from 32 old sites
  - Collecting of wild barley samples also from additional sites in reserves
  - Re-collection of landraces from 26 old sites
- Tracking of 1981 seed material in genebanks
- First common garden in IPK in 2013







# Tracking of 1981 samples: distribution and conservation of samples in genebanks

??

Jordan?

July 1982

LR in1981; CWR in 1982; about 50-60 g/acc

NordGen
Sweden

ICARDA
Syria

repatriation after 1996;
100 seeds/acc?

NCARE
Jordan

R = 0
never integrated in collection, kept in freezers

R = 1- 2
LR in 1985 or 1996;
CWR in 1994. R = 2 for some CWR

R = 0

transfer in 2012

IPK
Germany

R = regeneration or multiplication cycles
LR = landrace
CWR = crop wild relative

# Conclusion

# What metrics should be used in monitoring genetic diversity

- Considerable debate over what are the most effective monitoring metrics for population-level genetic diversity.
- What metrics to used – direct genetic measure (allelic diversity) or proxy measures (varietal diversity)?
- Neutral markers v/s markers for functional diversity?
- Are they affordable?
- Can they be used at global scale?

# Thank you

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