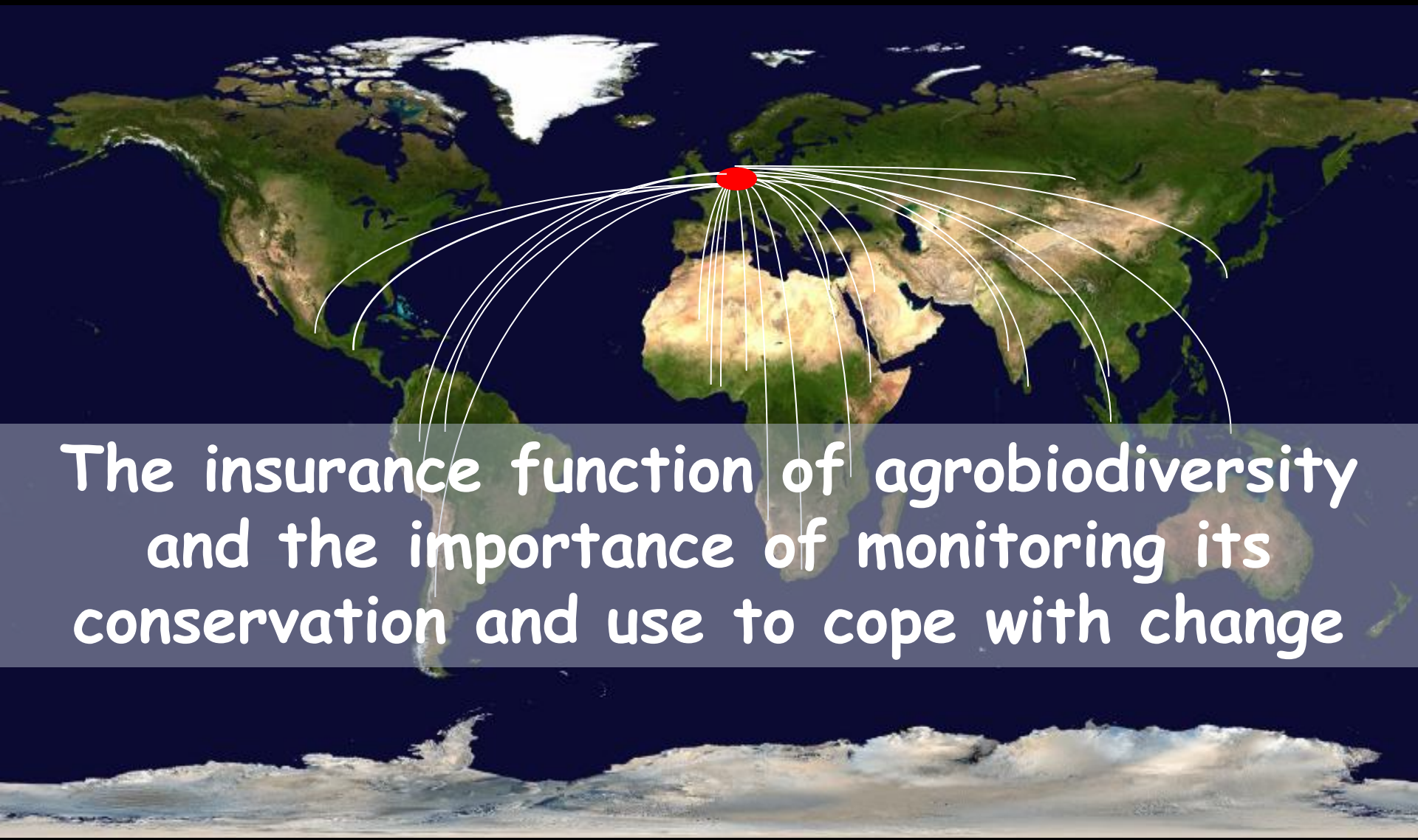
Tropical and Subtropical
Agriculture and Forestry

CeTSAF

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

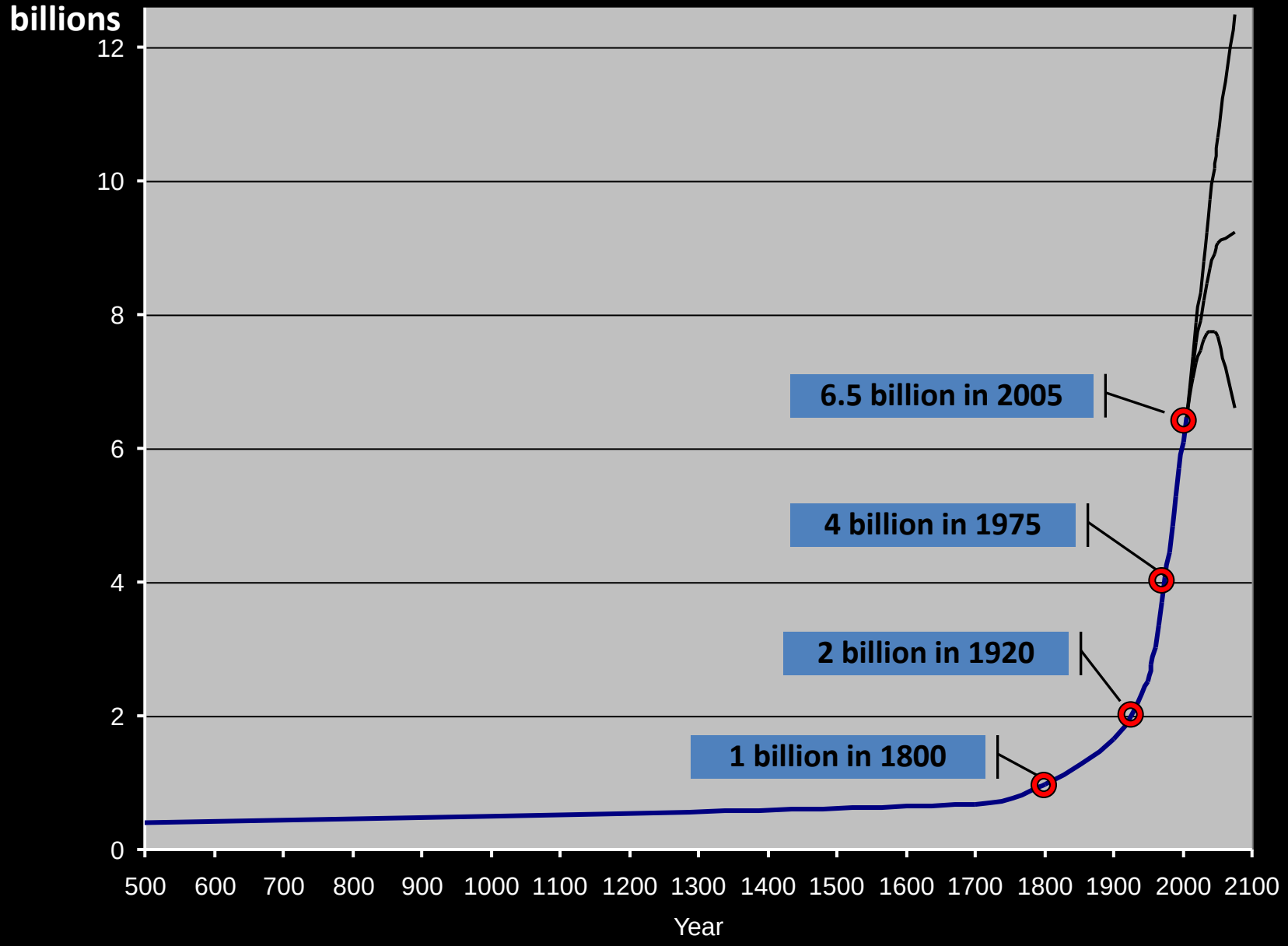


The insurance function of agrobiodiversity and the importance of monitoring its conservation and use to cope with change

Source: NASA

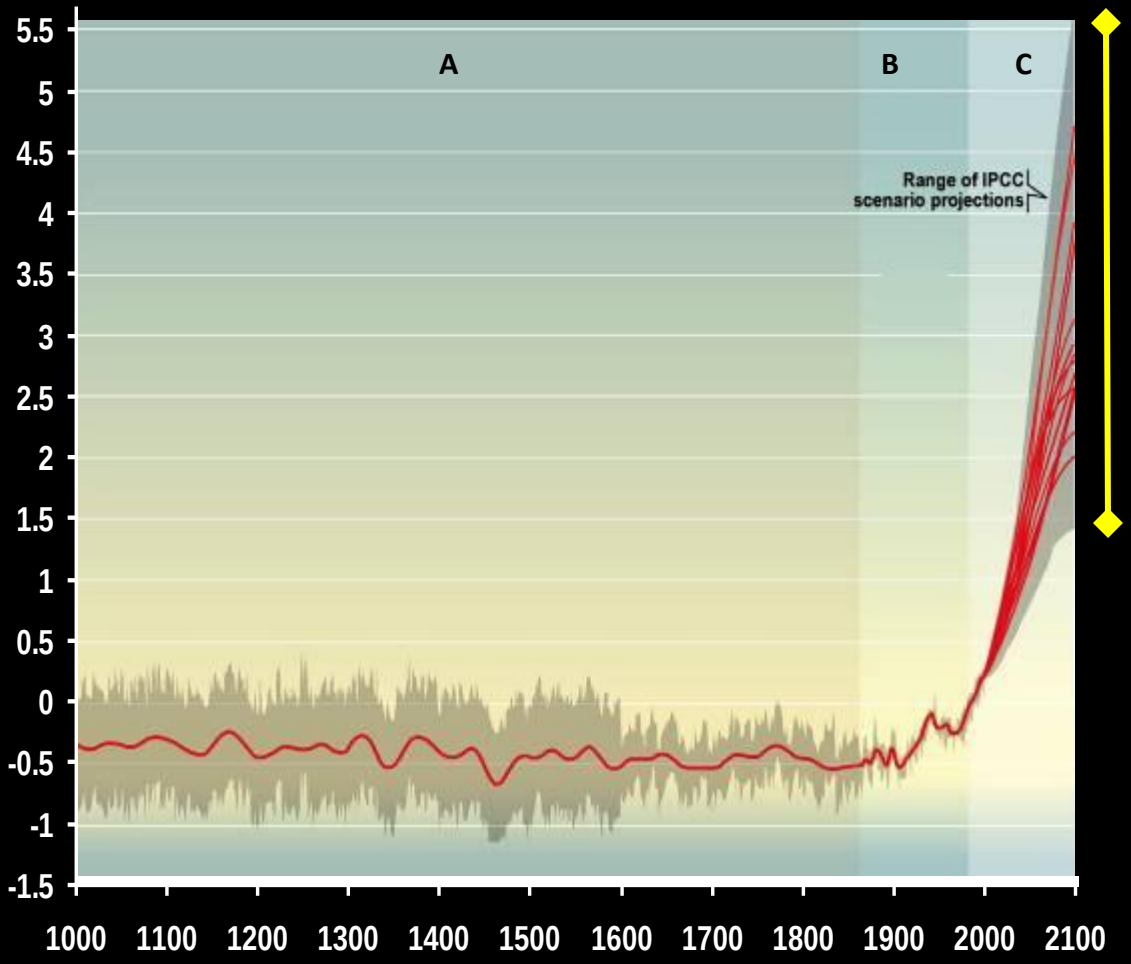
Prof. Dr. Kerstin Wydra

World Population Growth



Source: UN Population Division 2004; Lee, 2003; Population Reference Bureau

Temperature Change (°C) from 1990

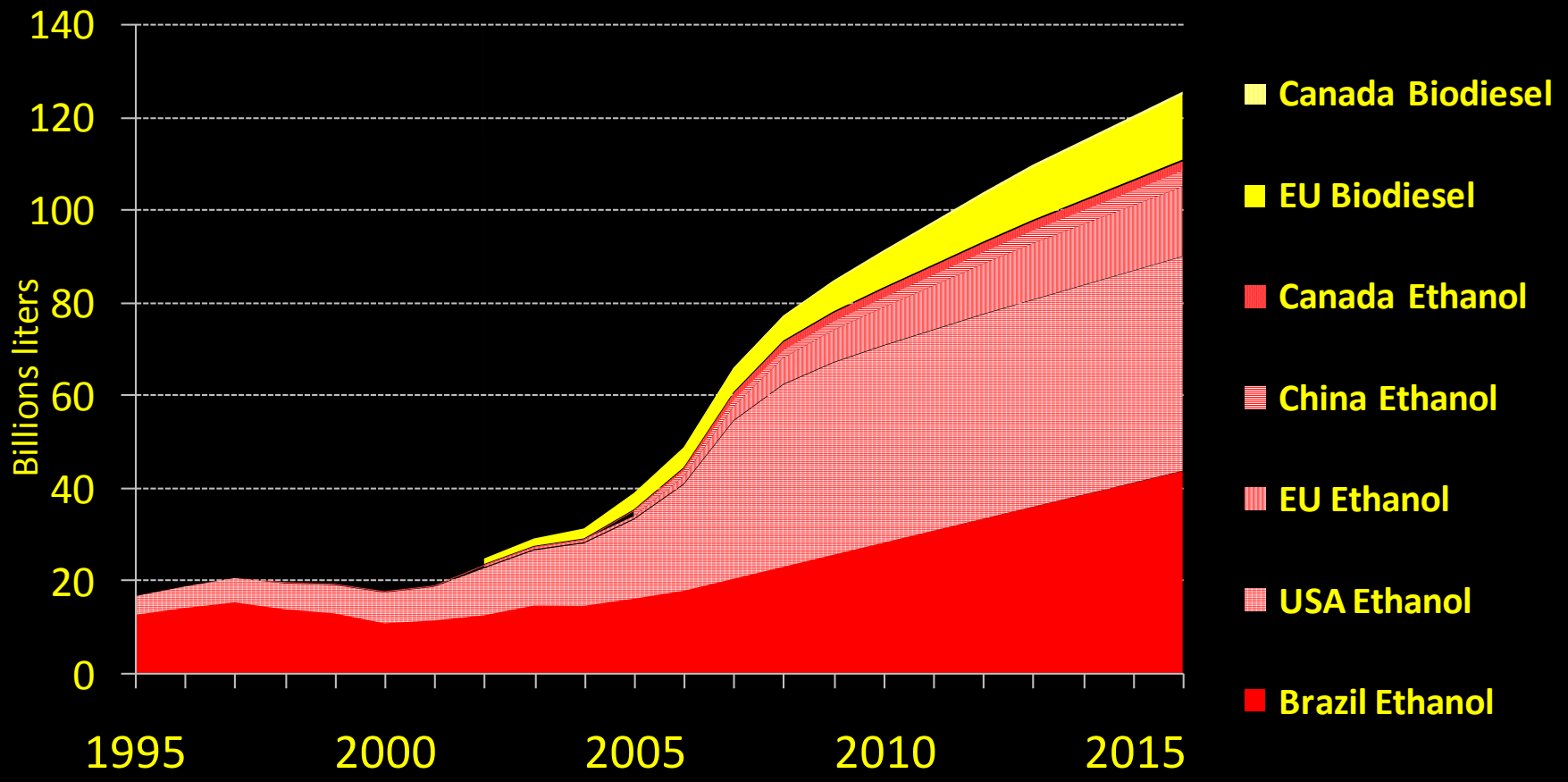


1.5 – 5.7 °C

A: Observations, Northern Hemisphere, Proxy data
B: Global Instrumental Observations
C: IPCC 2001 Scenario Projections (SRES)

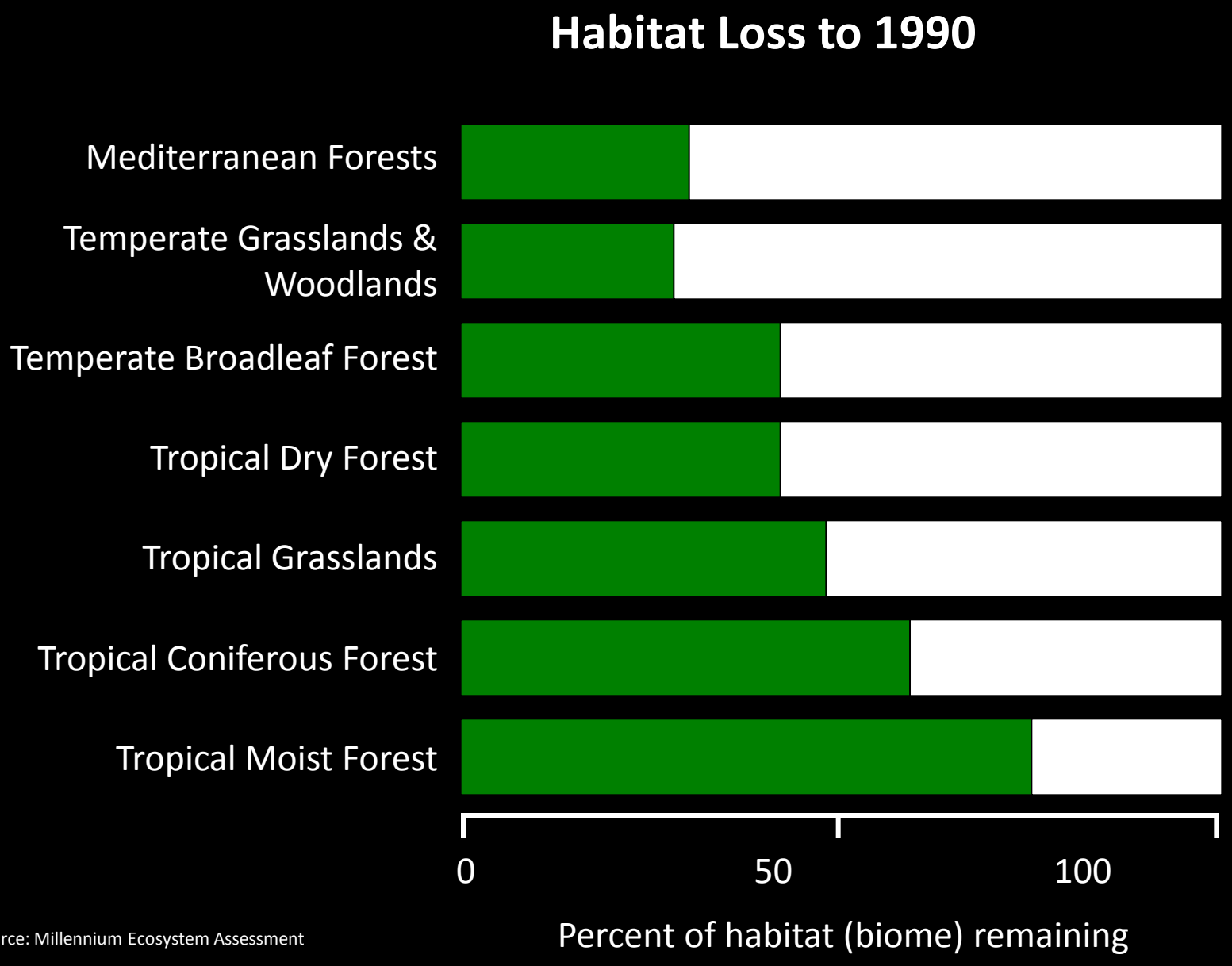
Source: IPCC 2001

Global biofuel production expanding



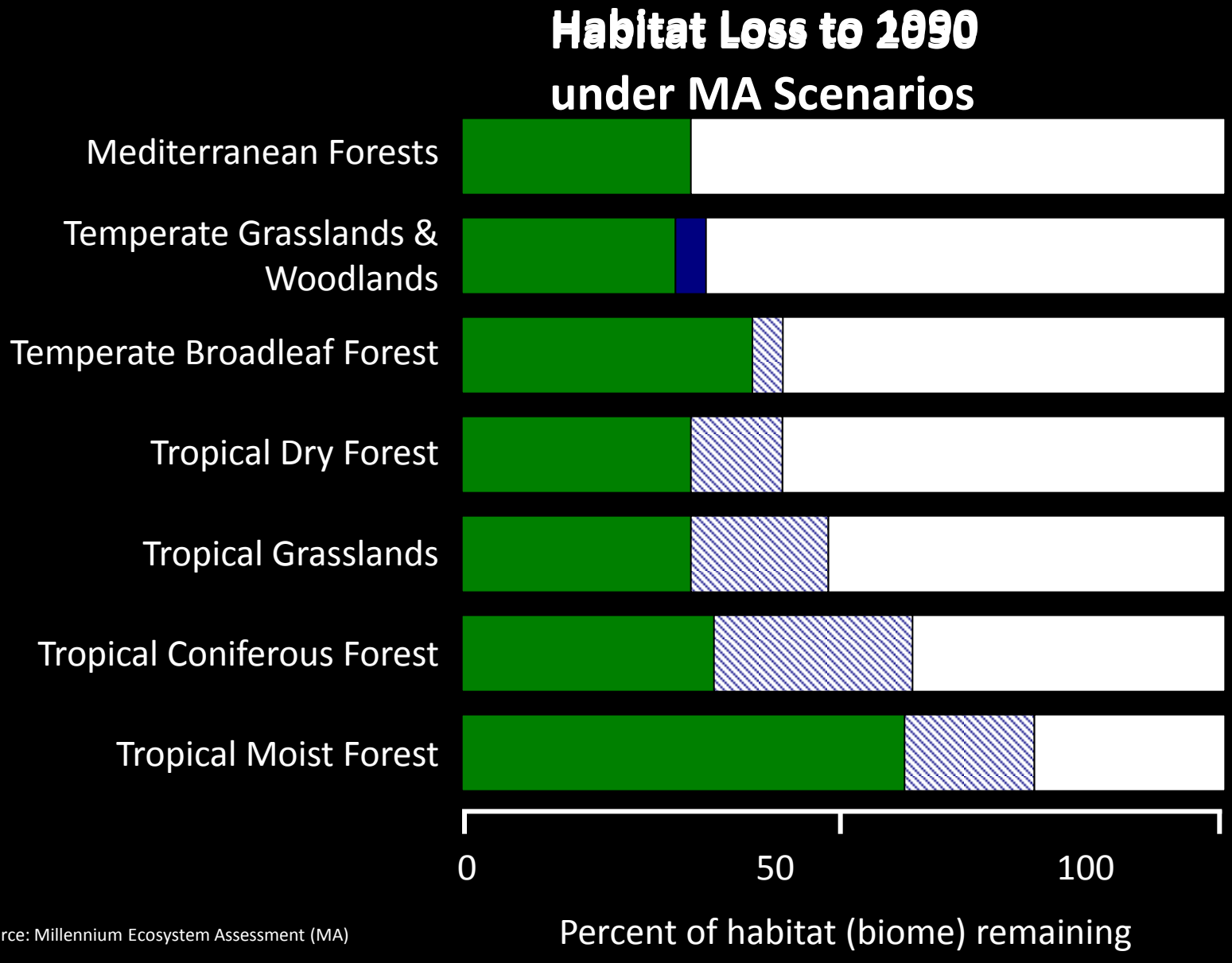
Source: OECD

Global change – ecosystem degradation



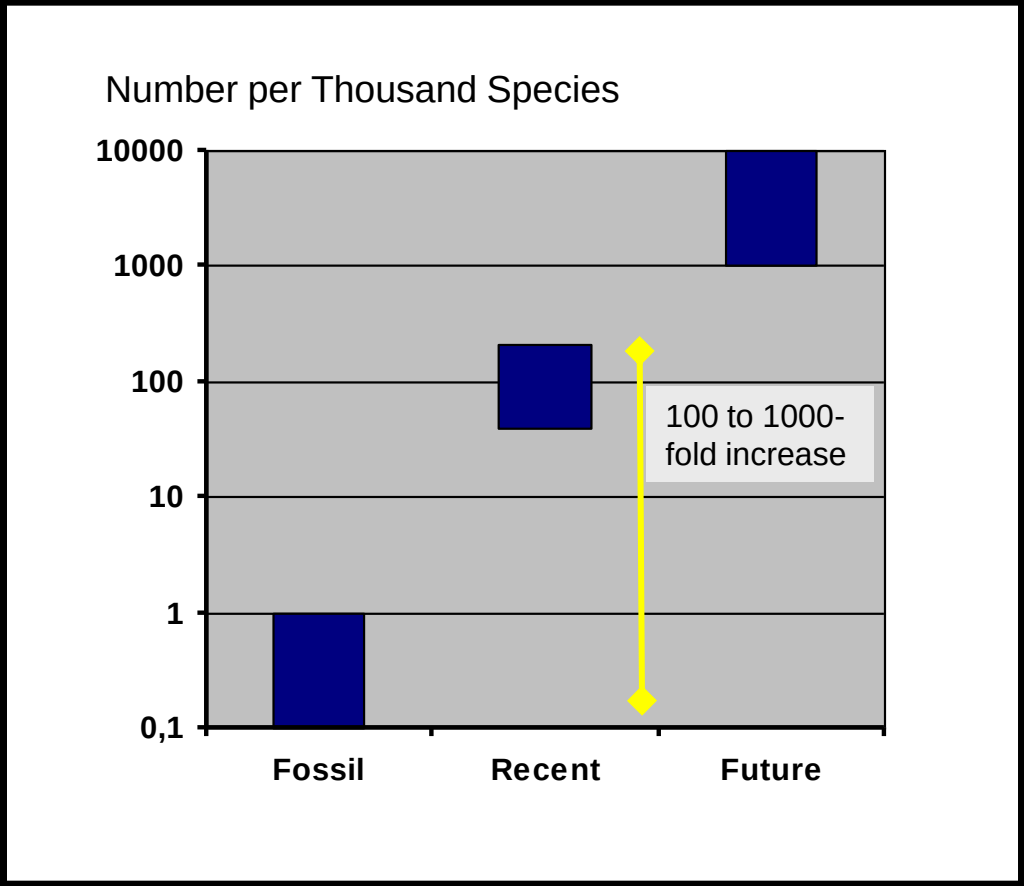
Source: Millennium Ecosystem Assessment

Global change – ecosystem degradation



Source: Millennium Ecosystem Assessment (MA)

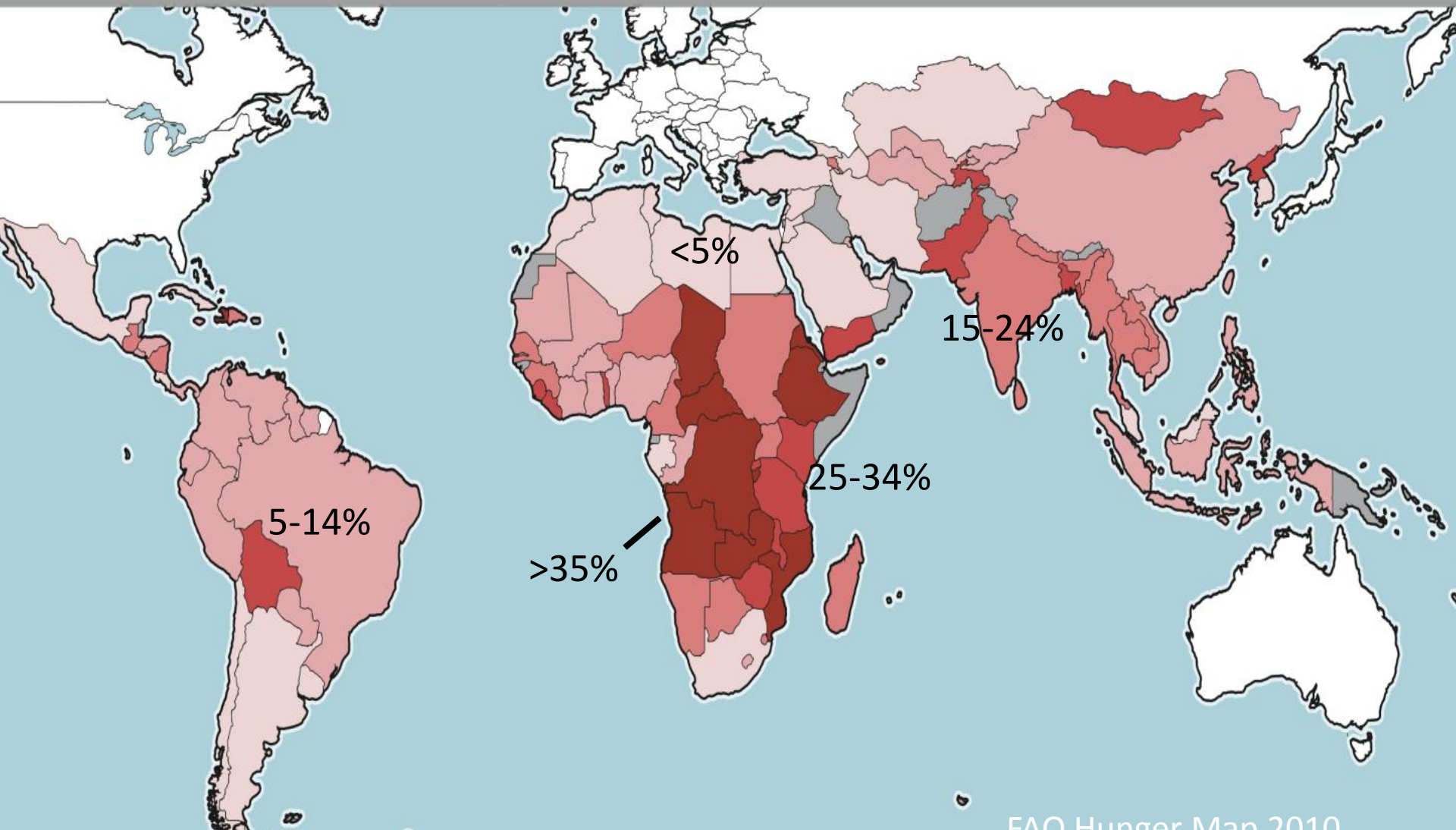
Change in Species Diversity



Extinctions
(per thousand years)

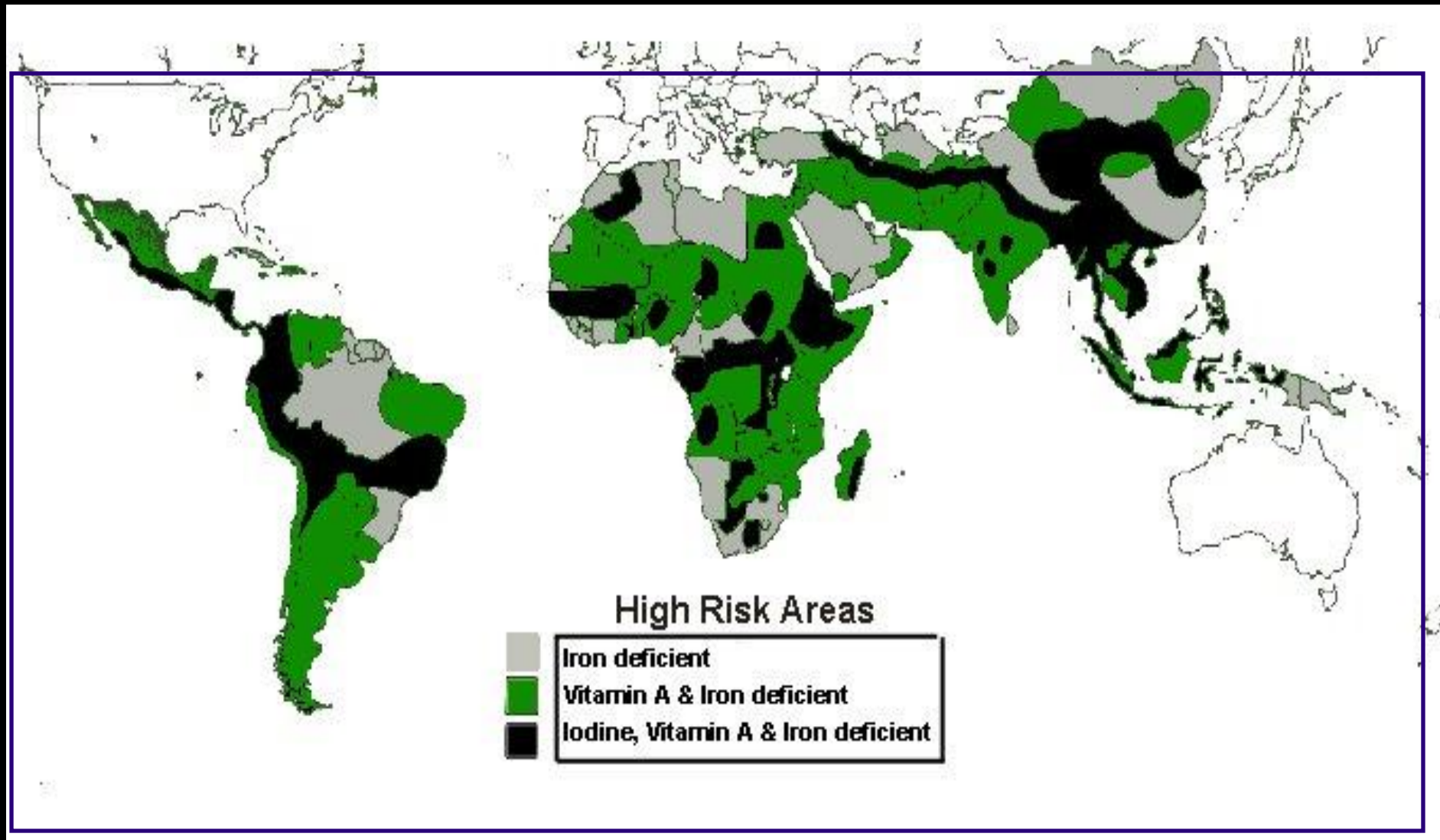
Source: Millennium Ecosystem Assessment

Prevalence of undernourishment in developing countries in 2010



FAO Hunger Map 2010

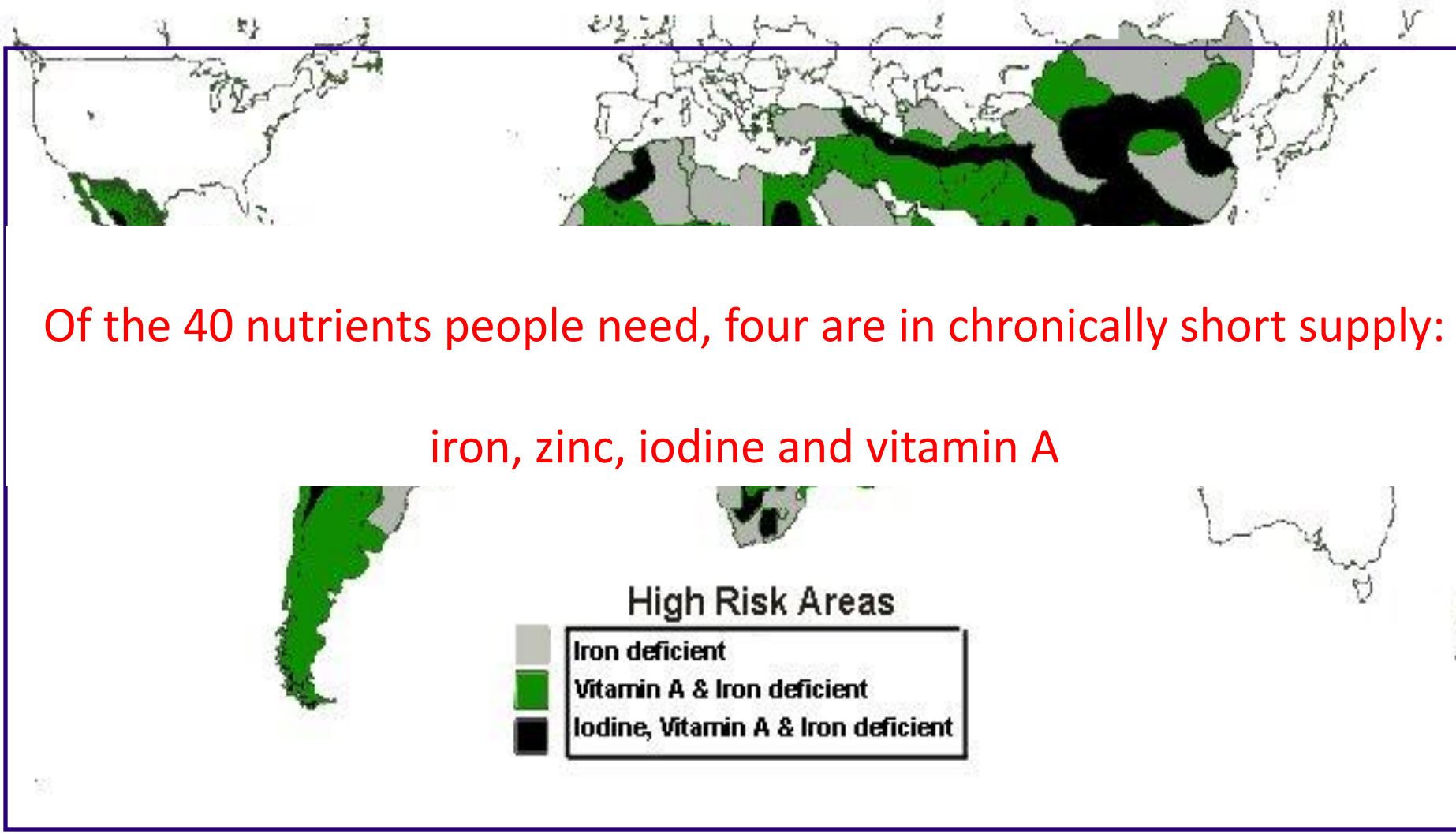
Global Micronutrient Deficiencies



(Map from USAID)

> 3 billion people afflicted

Global Micronutrient Deficiencies



Of the 40 nutrients people need, four are in chronically short supply:

iron, zinc, iodine and vitamin A

(Map from USAID)

> 3 billion people afflicted

Source: NASA

Agricultural biodiversity

It includes all components of biological diversity of ***relevance to food and agriculture:***

the variety and variability of

plants, animals and micro-organisms

at genetic, species and ecosystem level

which are necessary to sustain

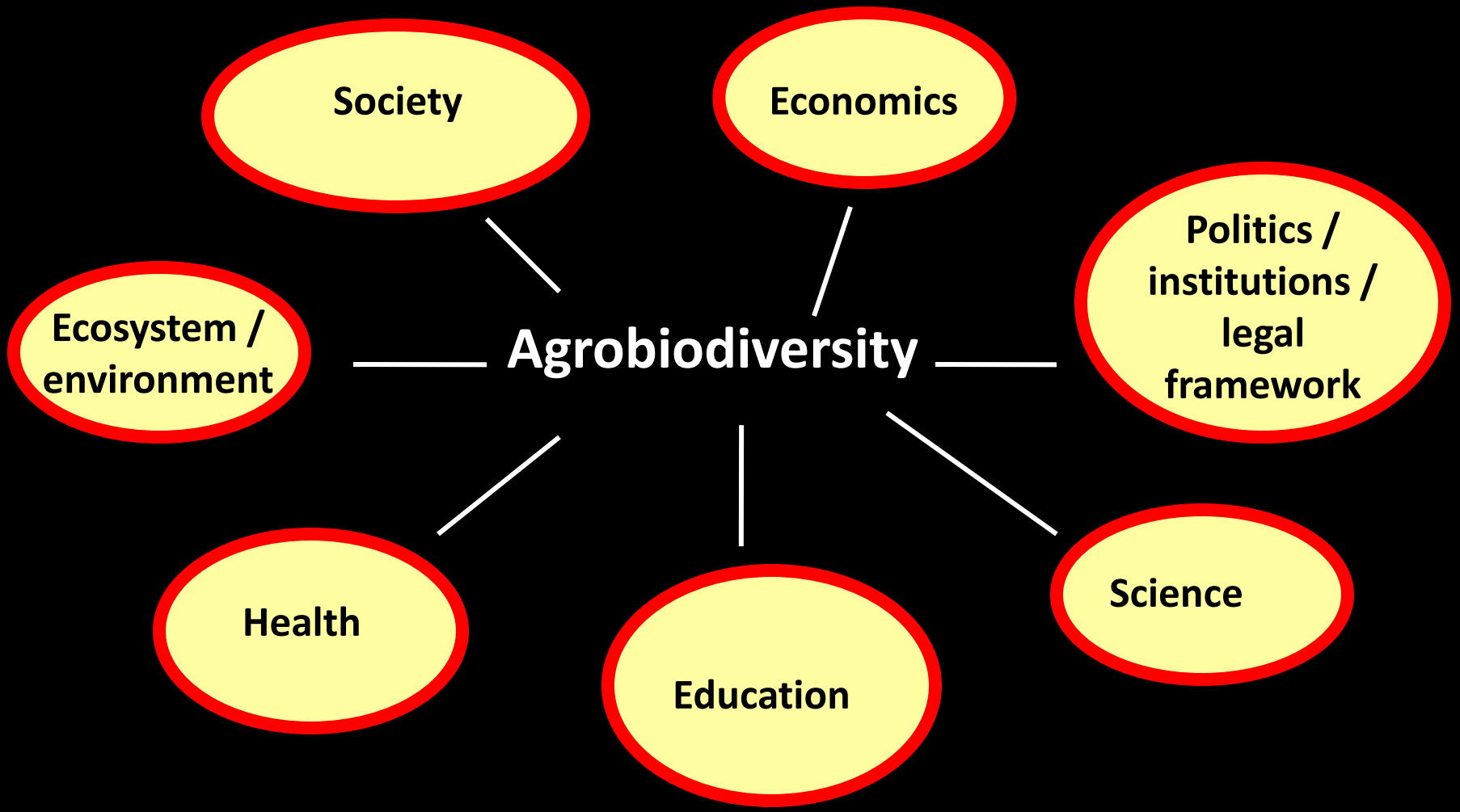
key functions *in the agro-ecosystem,*

its structures and processes.

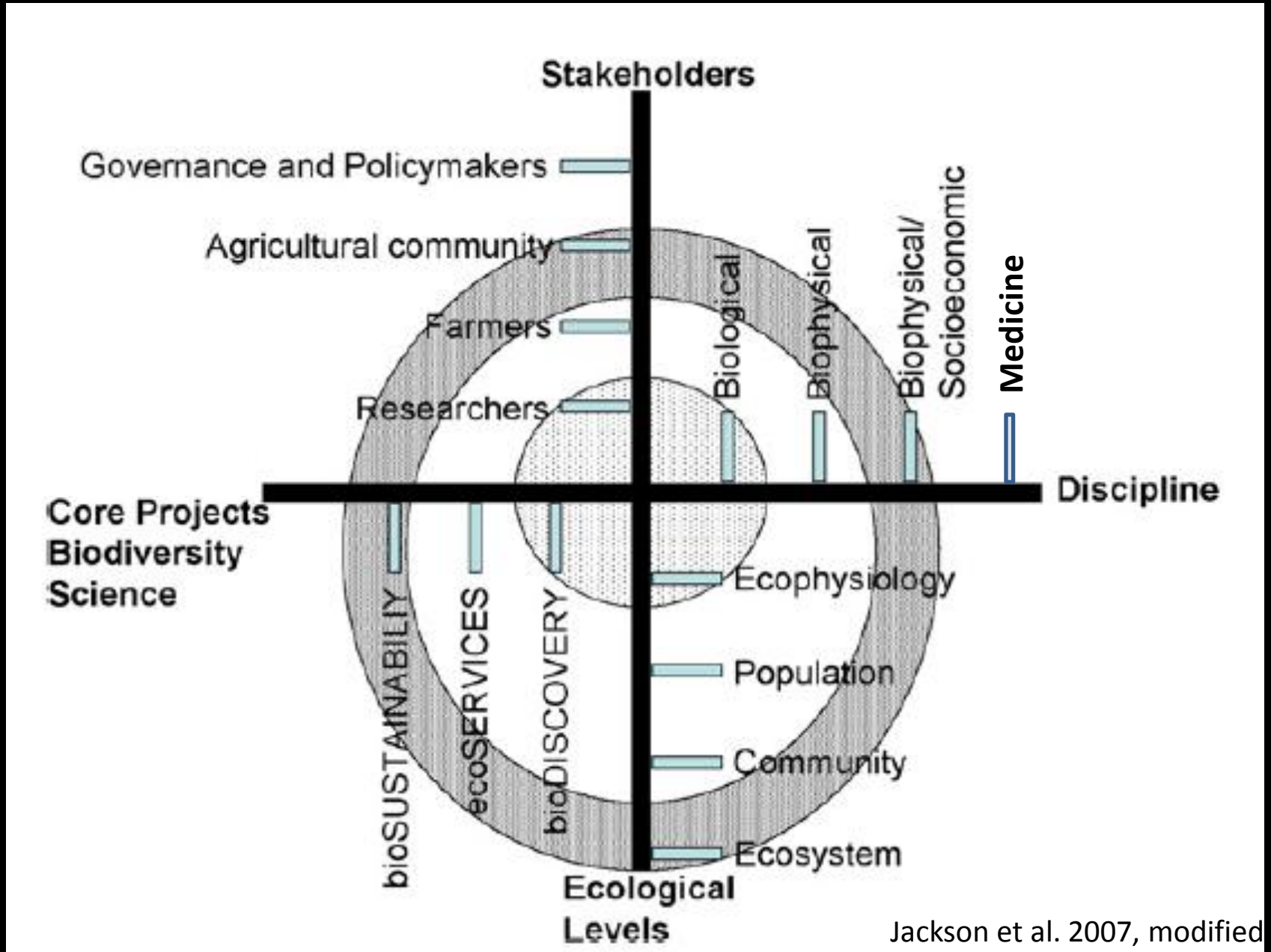
Local knowledge and cultural diversity can be considered an essential part of agrobiodiversity as it is the human activity of agriculture which conserves this biodiversity.

Fao

Agrobiodiversity: Linkages

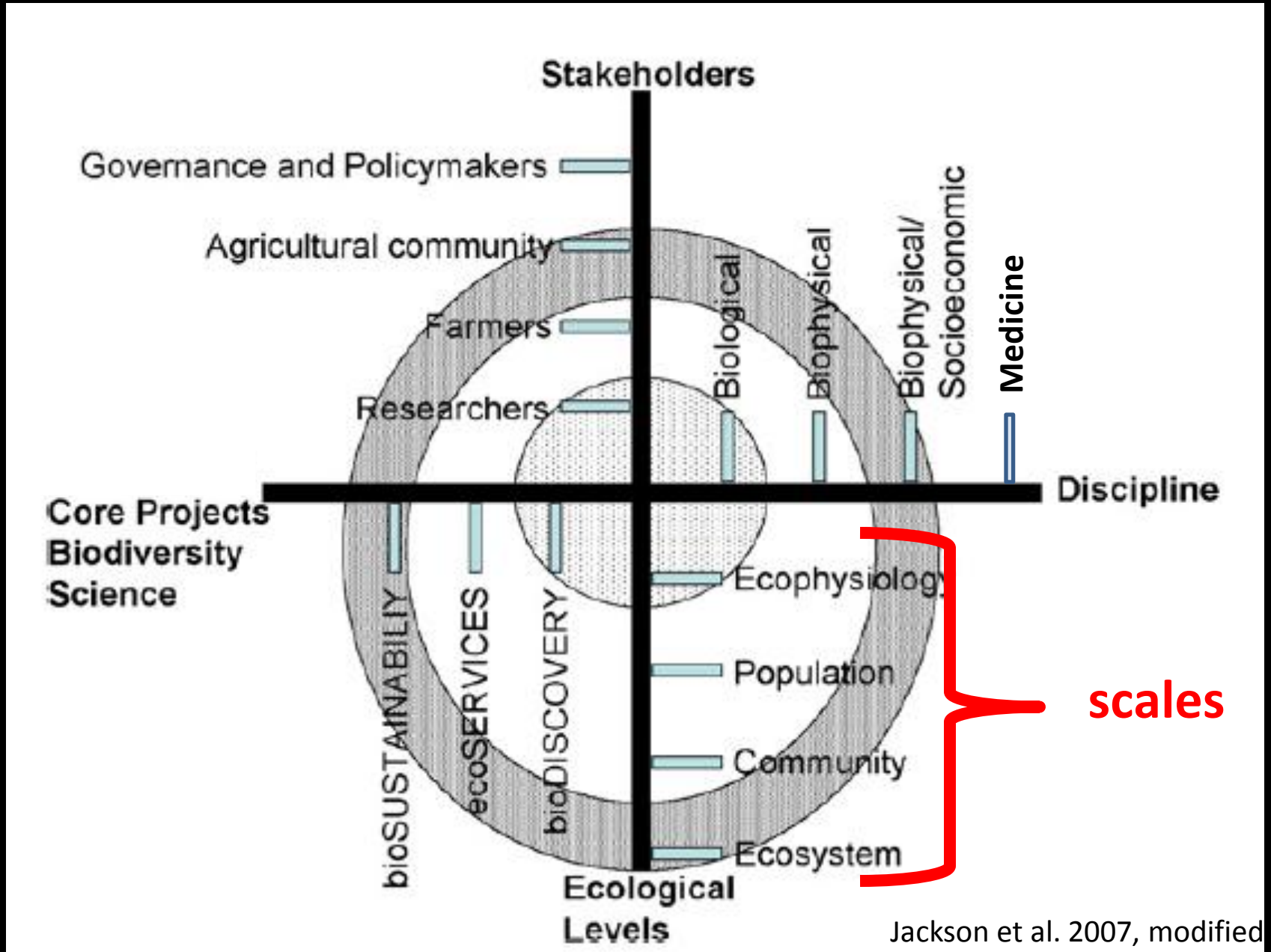


Agrobiodiversity: Linkages



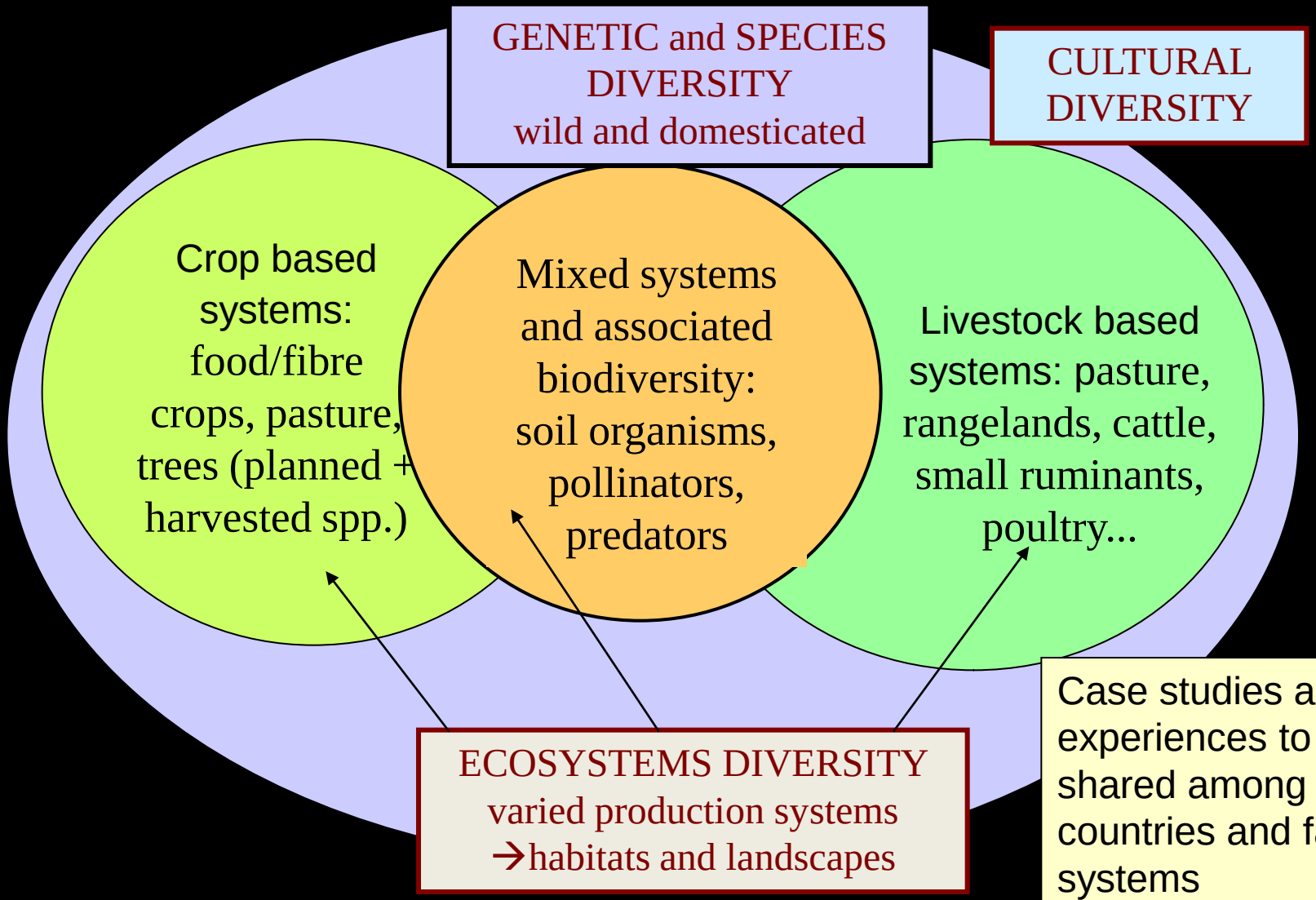
Jackson et al. 2007, modified

Agrobiodiversity: Linkages



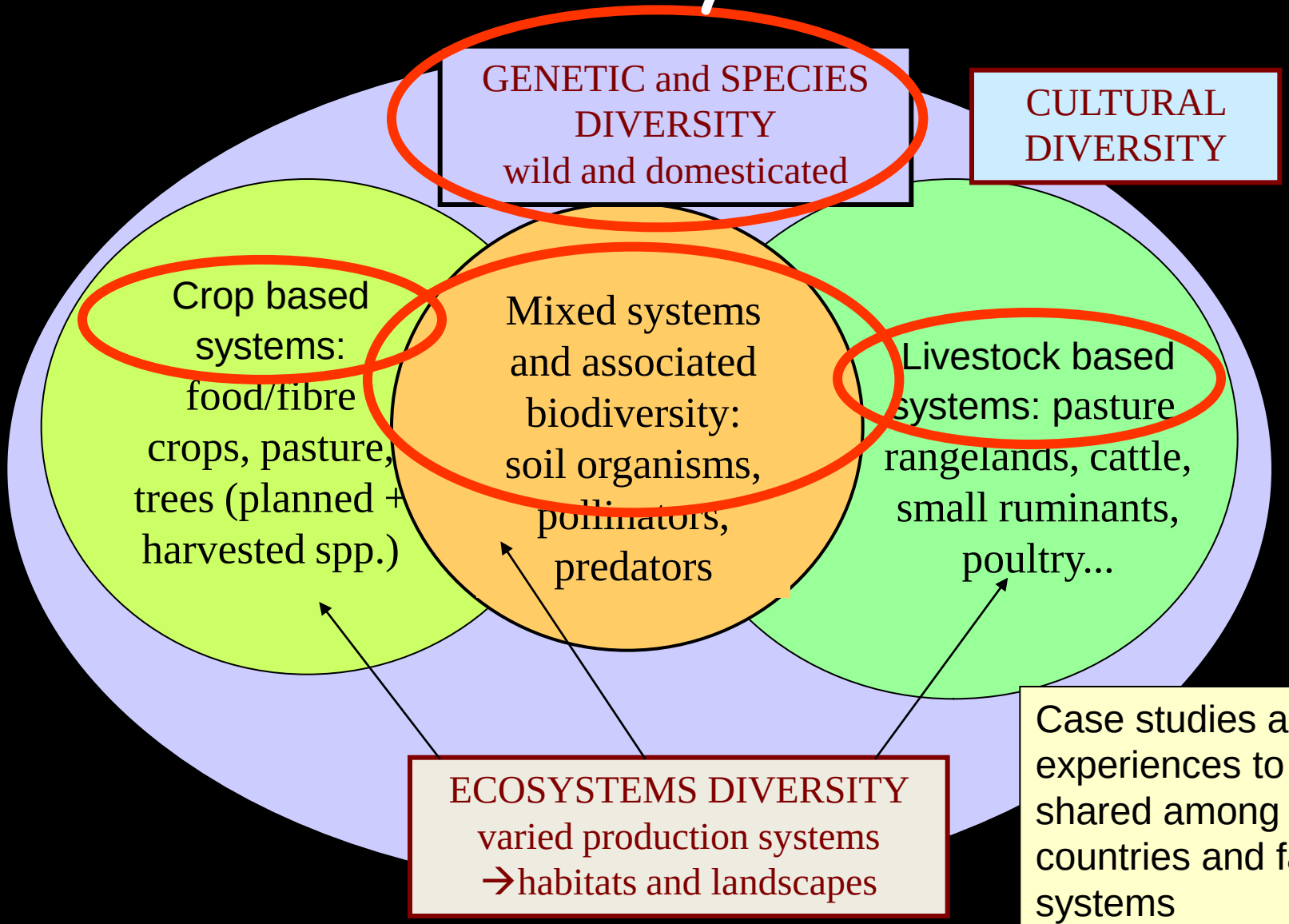
Jackson et al. 2007, modified

Agrobiodiversity: Scales
Production system level



Case studies and experiences to be shared among countries and farming systems

Agrobiodiversity: Scales
Production system level



Case studies and experiences to be shared among countries and farming systems

Agrobiodiversity: Scales

- Spatial scale
- Species scale
- Genetic scale
- Multitrophic scale
- Temporal scale
- Economic dimension

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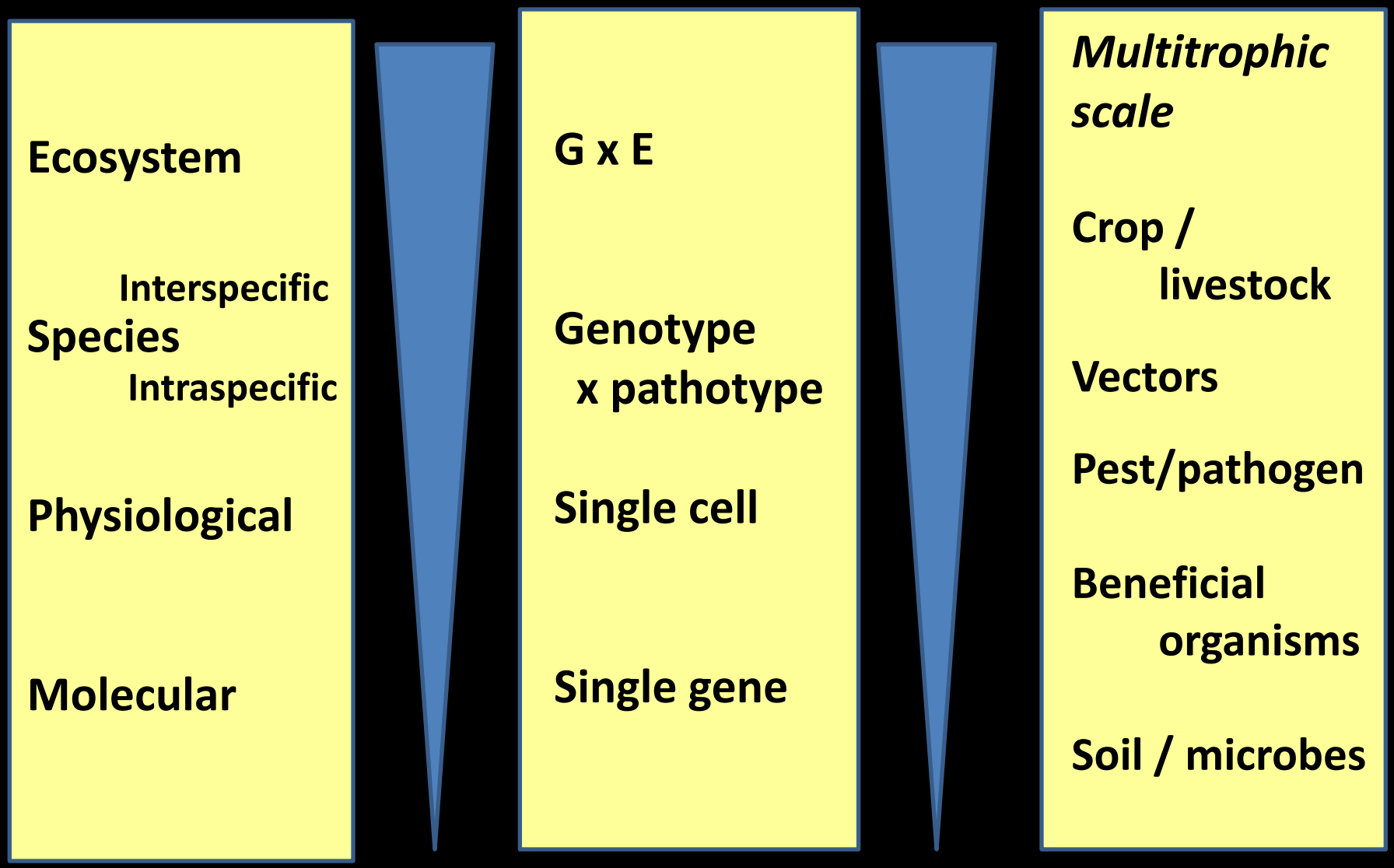
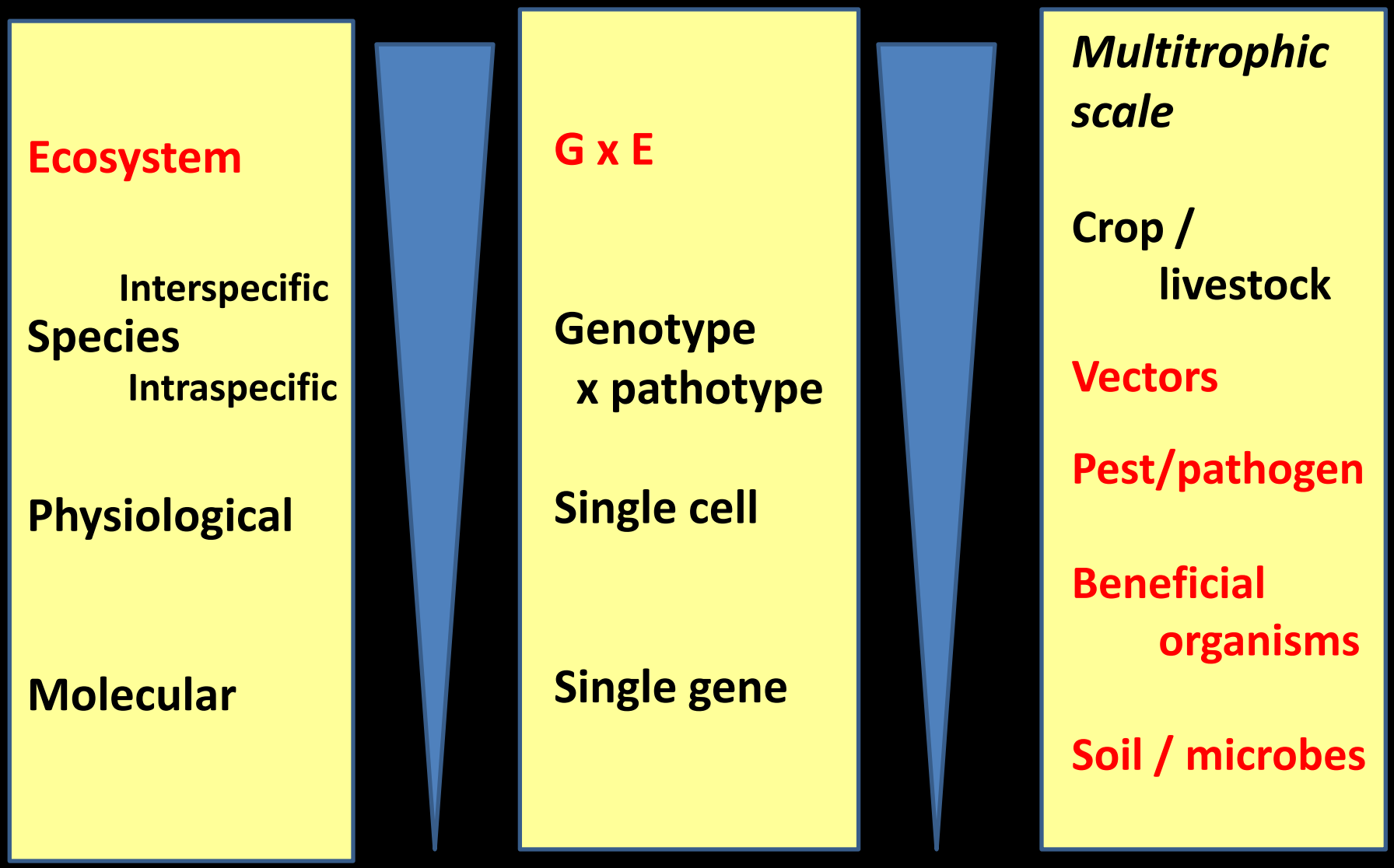
Agrobiodiversity: Scales



Agrobiodiversity: Scales



Agrobiodiversity: Spatial scale

Ecosystem

- Landscape-wide biodiversity
  - spill-over across managed and natural habitats

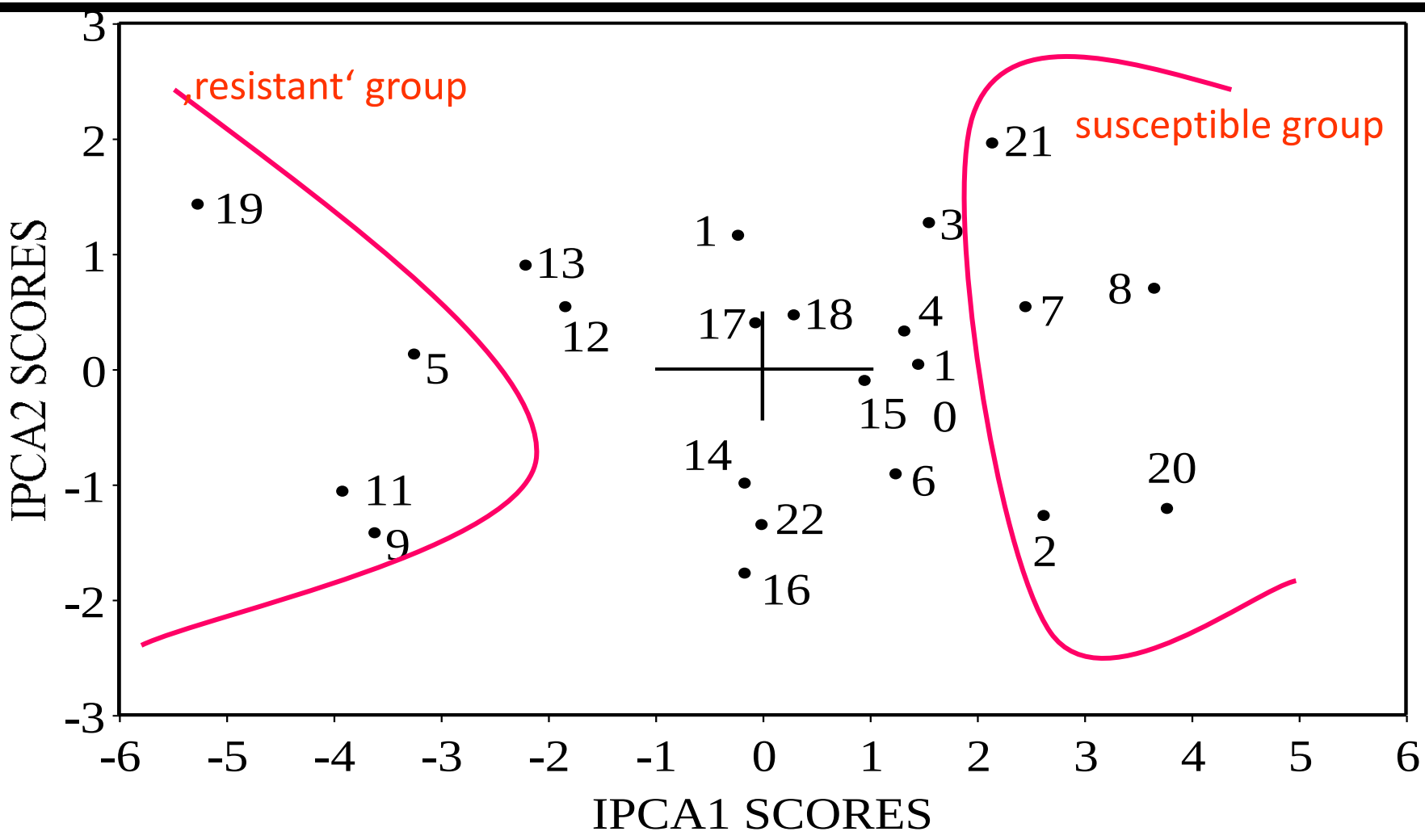
with

- Regulating services
  - natural enemies/antagonists for pests and diseases
  - soil / water / erosion
  - buffering of extremes & unpredictable changes in climate/wheather

- Providing services
  - e.g. pollination

Managed and natural habitats

Genotype X Environment:
Interaction of 22 cassava genotypes in 10 environments: disease severity



(Banito et al. 2010)

Cassava disease severity in relation to ecological, agronomic and plant variables

	CBB (r^2=0.36)	
	Slope	**SS^{2d}**
Age	0.06	169***
Crop system	-0.23	57***
Soil texture	-0.31	56***
Variety mixt.	-0.32	28***
Ecozone	-0.10	18***

Cassava bacterial blight

Stepwise regression

(Wydra & Verdier 2002, Agric. Ecos. Environm. 93,211-226)

Agrobiodiversity: Species scale

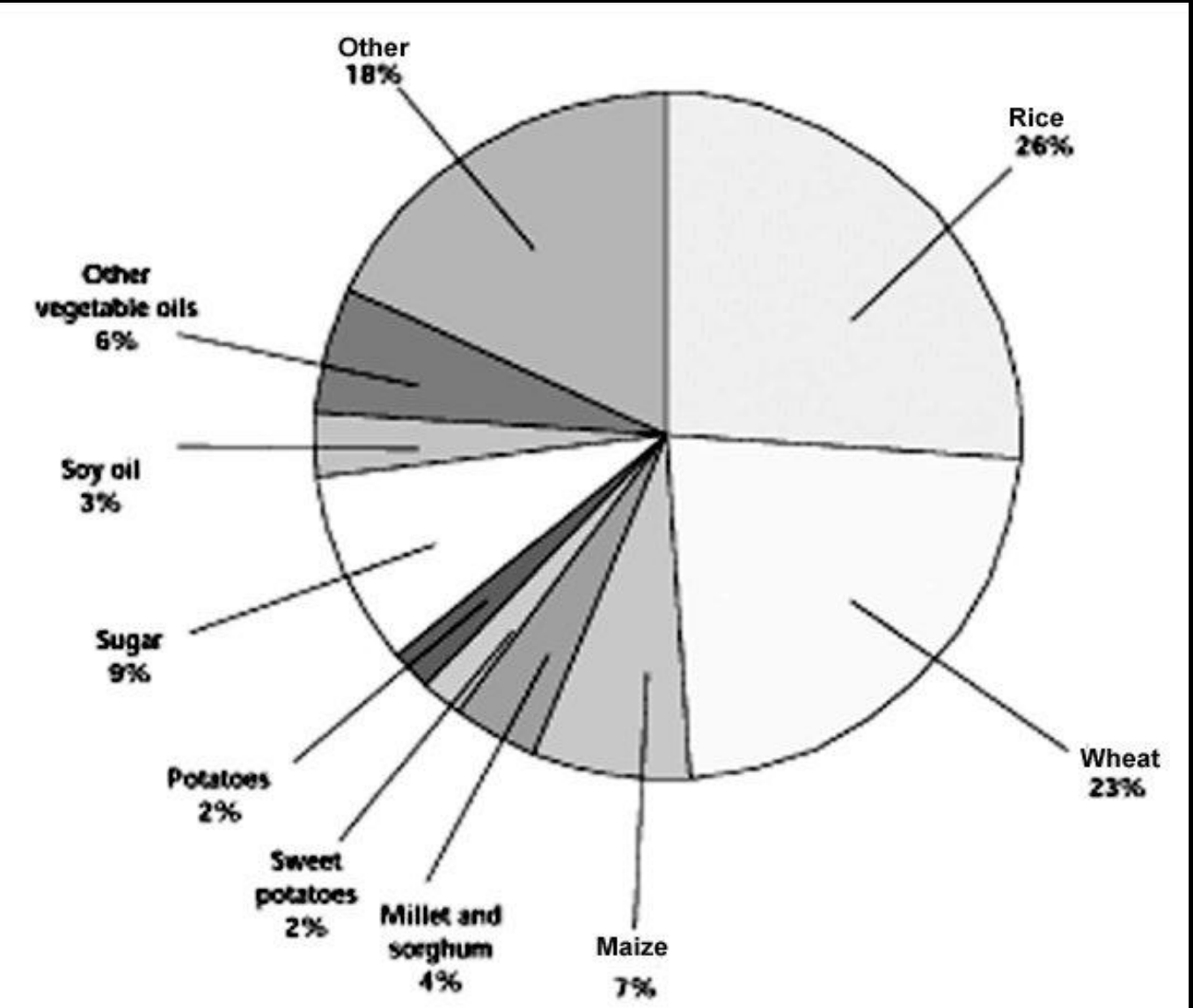
Inter/intraspecific

- Crop wild relatives / traditional breeds

- Intraspecific genetic variation
  - landraces, neglected varieties / races
  - higher yield, tolerance to biotic & abiotic stress, functional traits, adaptation to low-input

Novel genetic variation can be introduced from a gene pool to a breeding pool

Most Important Food Crops Globally



Source: FAO. *Food balance sheets 1994-1996*. Rome.

rice
+ wheat
+ maize

56%

Use of agrobiodiversity to increase nutrition/health status

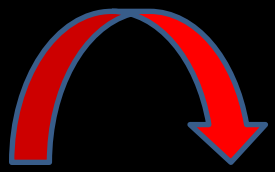
Use of agrobiodiversity to increase nutrition/health status

Inter / intraspecific diversity:

- **Important traits** exist in wild species, wild crop relatives or neglected gentoypes

- **Biofortification** – micronutrients, vitamin A

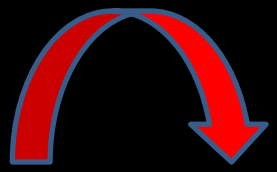
- **Tolerance** to abiotic and biotic stress: drought, salt stress, pests and diseases



adaptation of crops to climate change

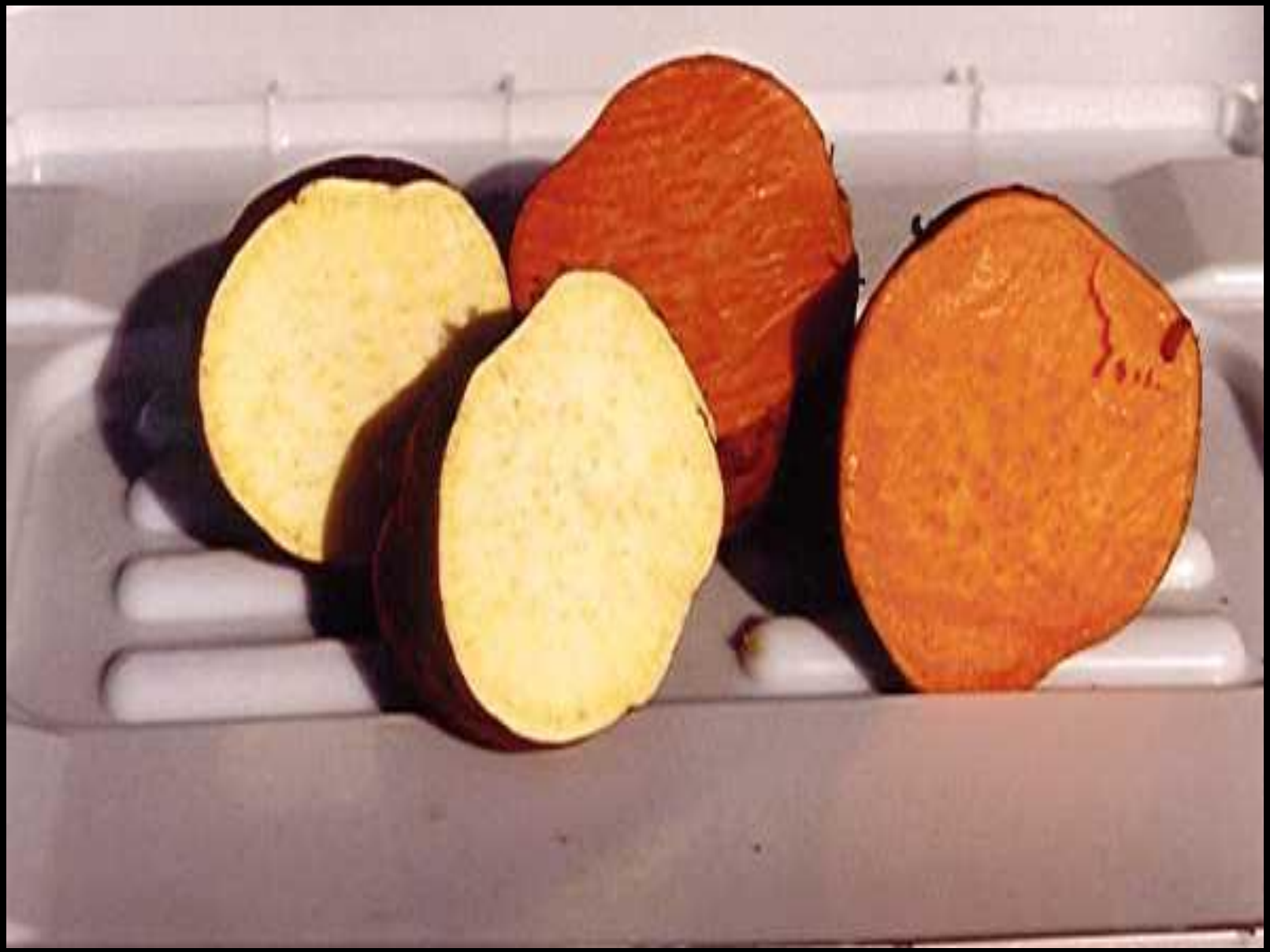
Nutrients Targeted in Crops

- Rice - Zinc and iron
- Wheat - Zinc and iron
- Maize - β -carotene and zinc
- Cassava – β -carotene
- Beans - Iron
- Sweet potato - β -carotene
- Pearl Millet - Iron and zinc
- Banana and Plantain - β -carotene
- Lentil - Iron
- Potato - Iron
- Sorghum - Iron

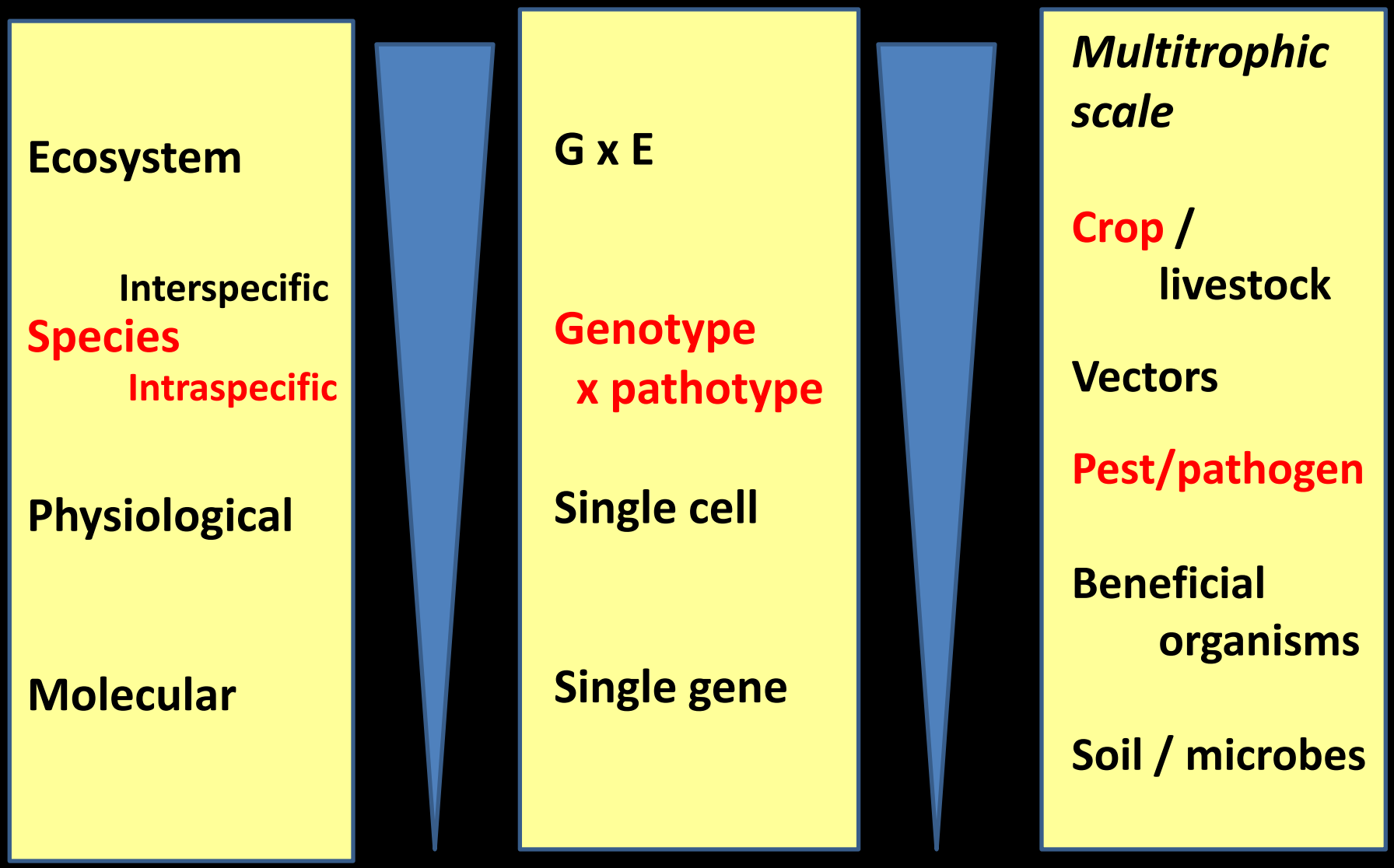


Introgression of traits from wild relatives / neglected varieties

Orange-fleshed sweet potato: β -carotene-rich

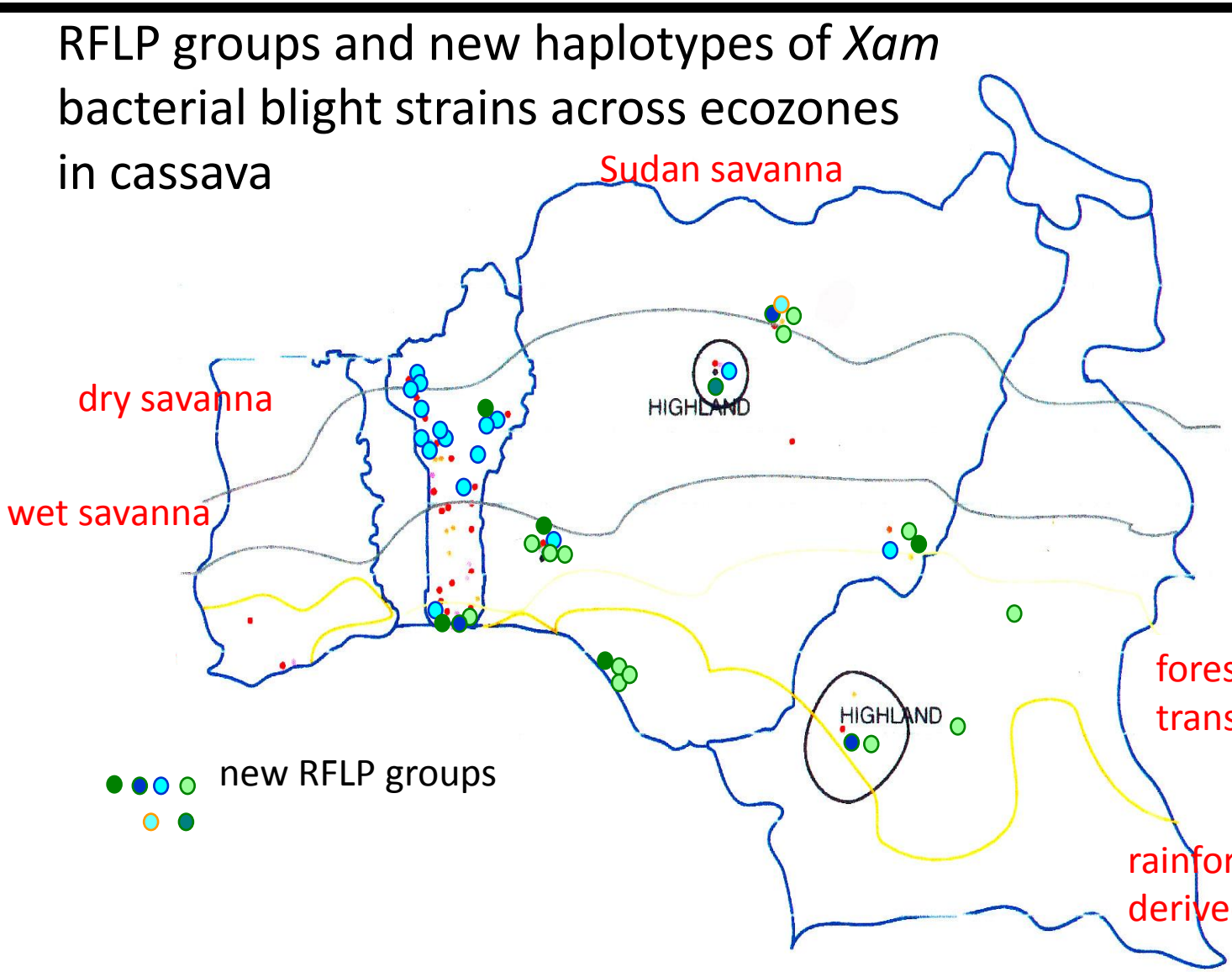


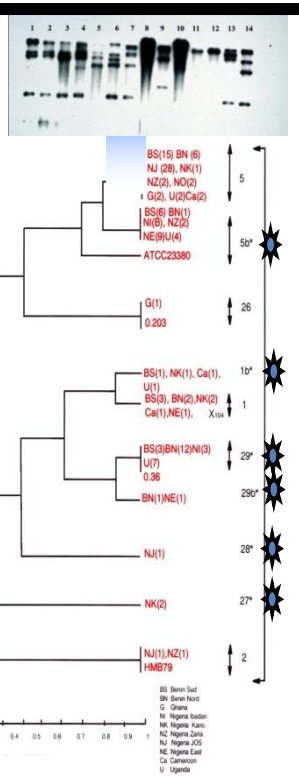
Agrobiodiversity: Scales



New pathogen strains develop - host resistance breakdown

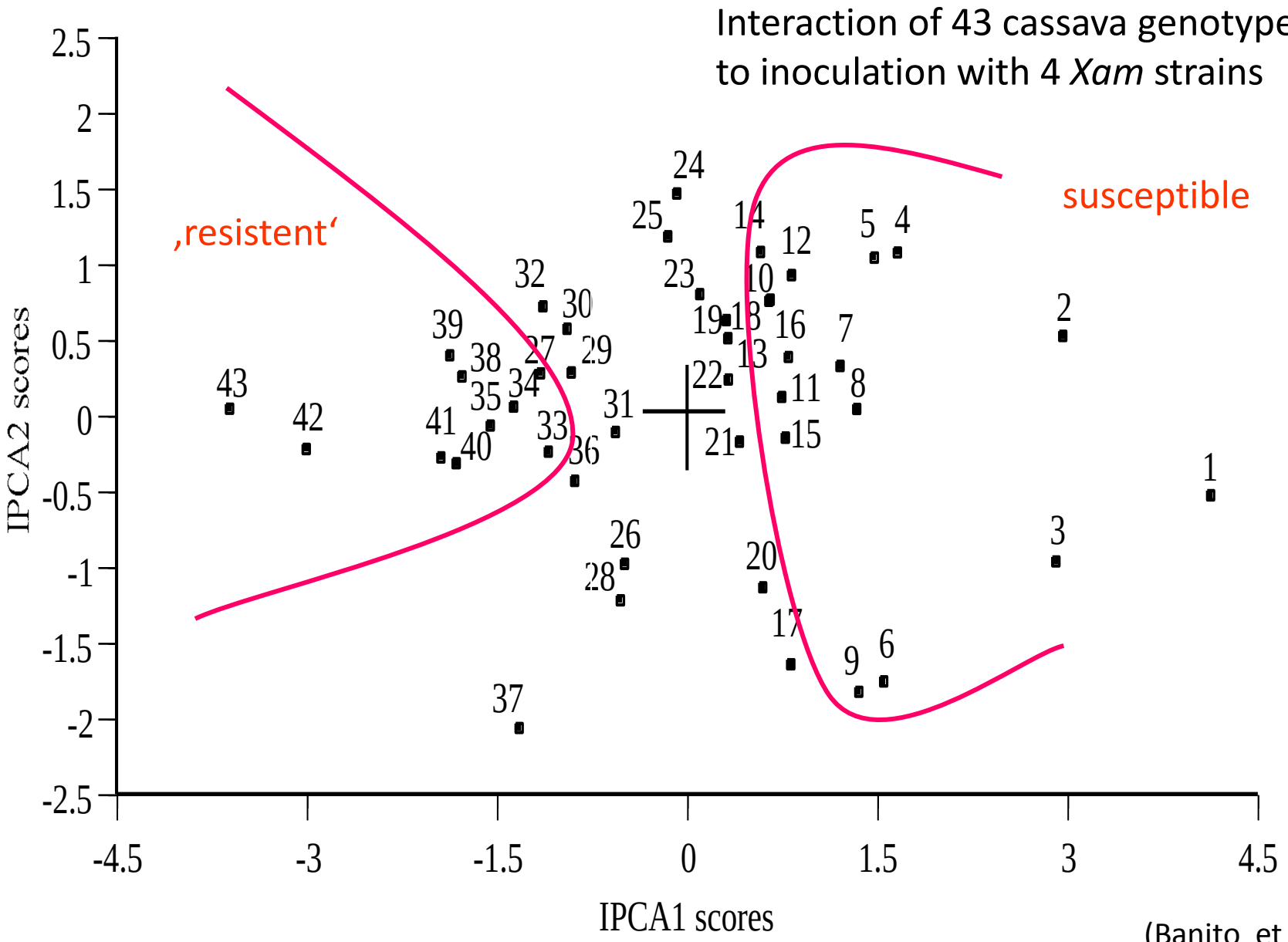
RFLP groups and new haplotypes of *Xam* bacterial blight strains across ecozones in cassava





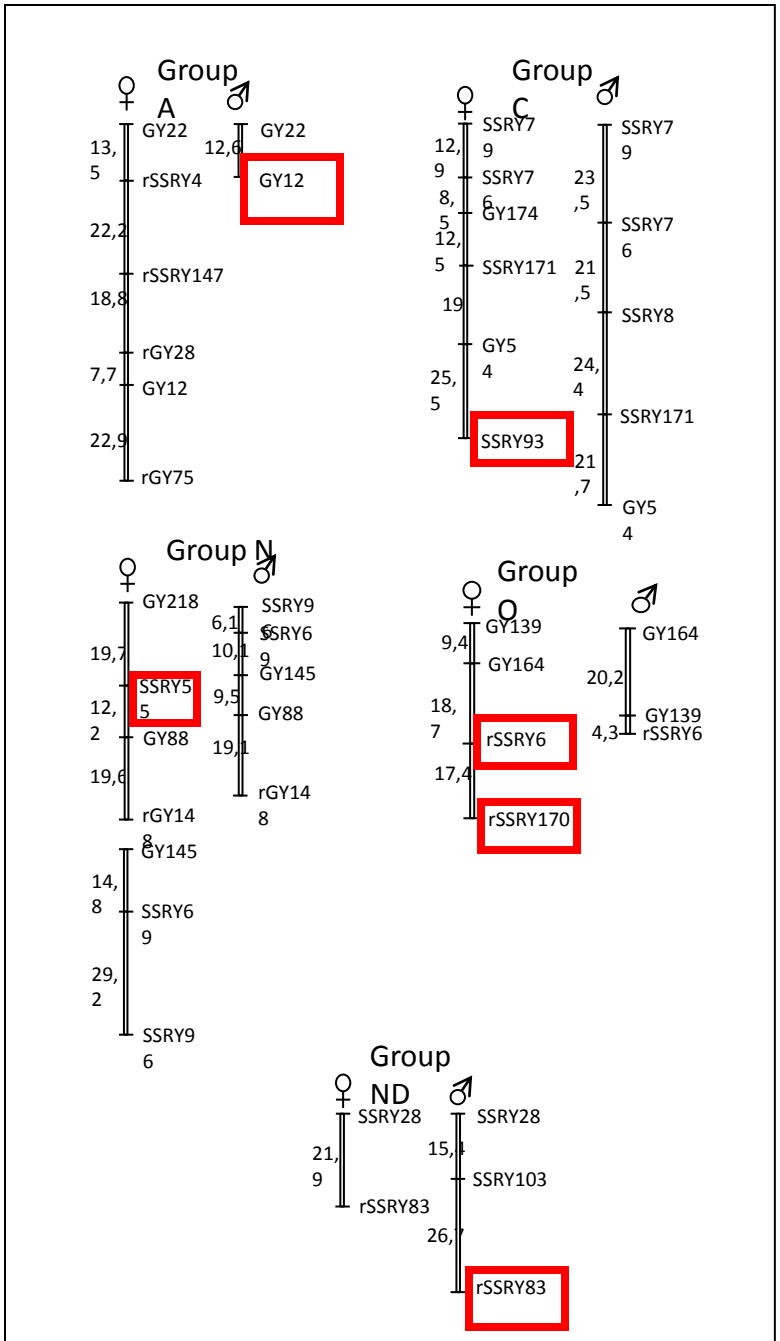
(Assigbétsé et al. 1998)

Pathogen diversity X host plant diversity



(Banito et al. 2010)

Identification of new QTL resistance markers for African pathotypes

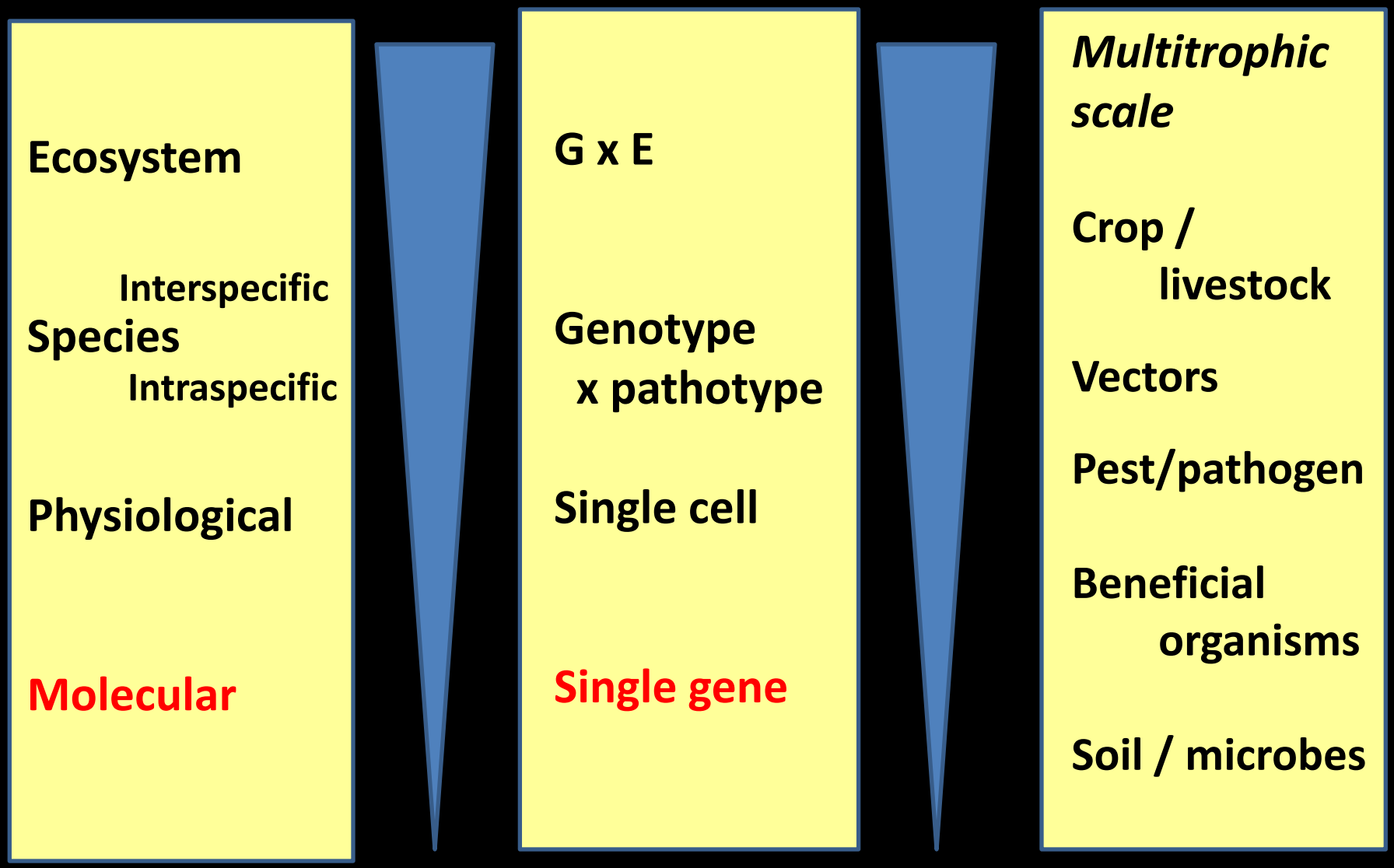


Cassava /
X. axonopodis
pv. *manihotis*

- 11 markers identified (16 -33.3 % of phenotypic variance of AUDPC)
- 5 markers associated with resistance to four strains of *Xam*

(Wydra et al. 2004, Phytopathol 94,1084-1093)

Agrobiodiversity: Scales



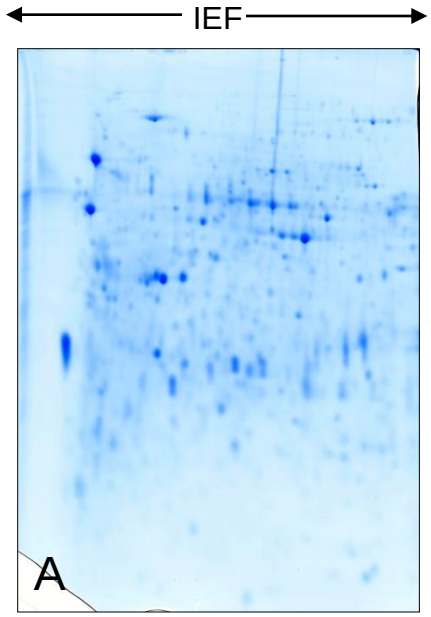
Agrobiodiversity: Genetic scale

Cell / single gene level

- Identification of genes with useful traits
- Use of molecular high-througput technologies for screening/monitoring of diversity
- Molecular methods for monitoring to avoid redundancies

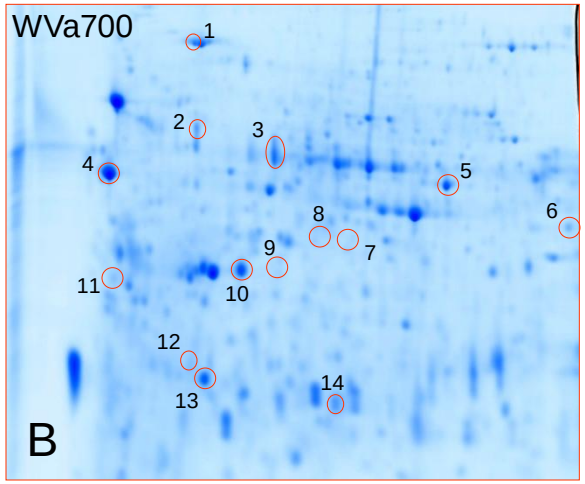
Functional genomics / proteomics

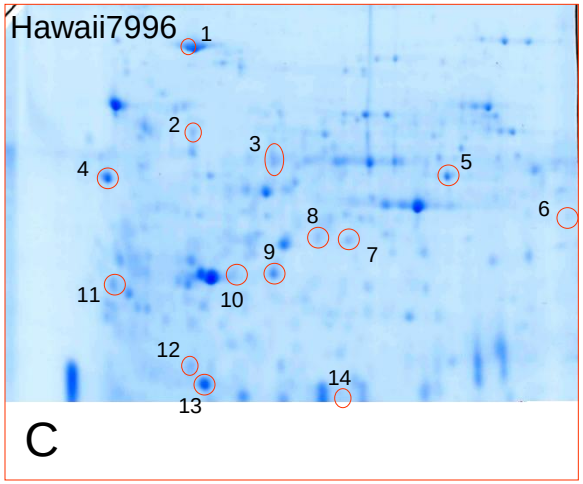
Tomato WVa700 vs Hawaii7996



2-D gels

Protein variation between Genotypes

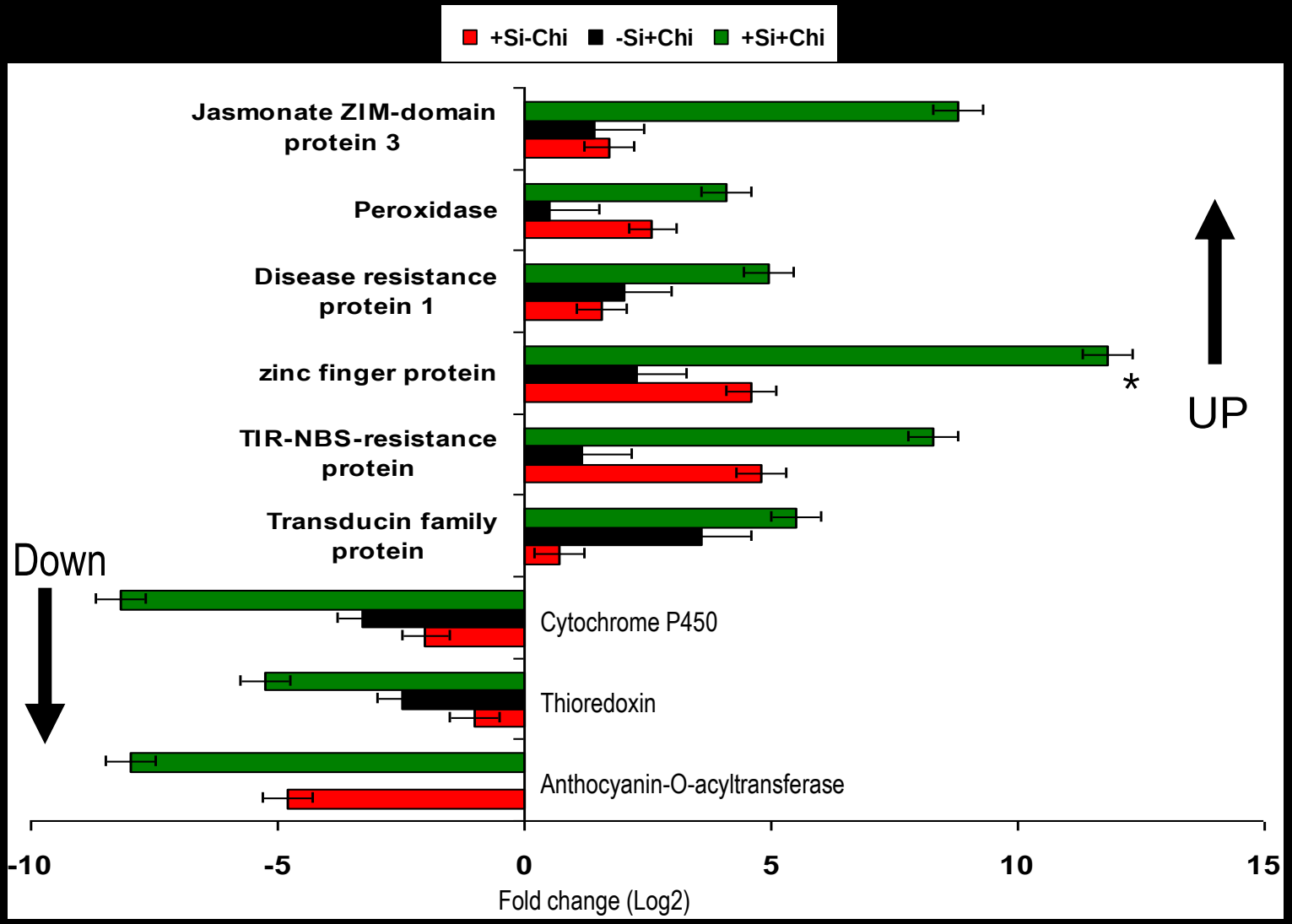




Susceptible → Protein list ← Resistant

Dahal et al. 2009, 2010

Gene expression / microarrays



Identification of induced, defense related genes

Kiirika & Wydra, 2010

Agrobiodiversity: Multitrophic scale

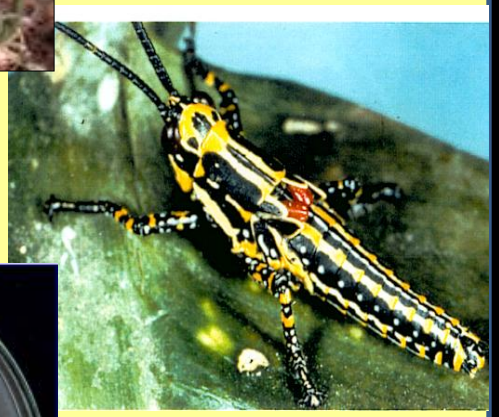
Crop / livestock

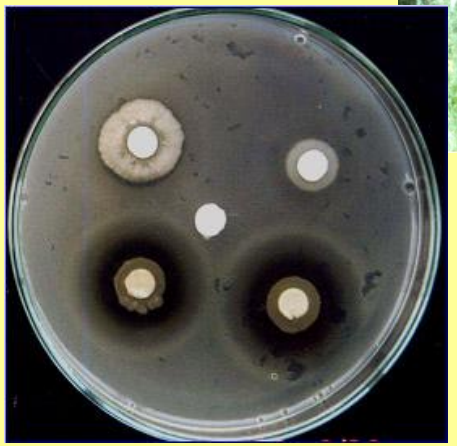
Vectors

Pest/pathogen

Beneficial organisms

Soil / microbes





Agrobiodiversity: Scales

- Spatial scale
- Species scale
- Genetic scale
- Multitrophic scale
- Temporal scale
- Economic dimension

Agrobiodiversity: Temporal scale

Short-term / long-term

- Maintain adaptive capacity
  - conservation of crop wild relatives & genetically distinct animal breeds
- Possibility of realizing a value in future
- Valuation of biodiversity in agricultural landscapes
  - short-term, long-term time scales
- Evolution
  - evolutionary breeding

Agrobiodiversity: Economic dimension

Use value

- Underutilized species (NUS)
  Food security, nutrition, health, income generation

- Gene pool components
  Populations, species, genotypes, allels, genes with useful traits to develop gene pool portfolio for resilience of breeding

Non-use value

- Ethical value, food culture, etc.

Option value

- Possibility of realizing a value in future
- Generation of novel genetic variation through evolution

Agrobiodiversity: Insurance function

Agrobiodiversity: Insurance function

Insurance hypothesis

Increased resilience and capacity to recover from disruption of functions and the mitigation of risks caused by disturbances

(Tscharntke et al. 2005, Jackson et al. 2007)

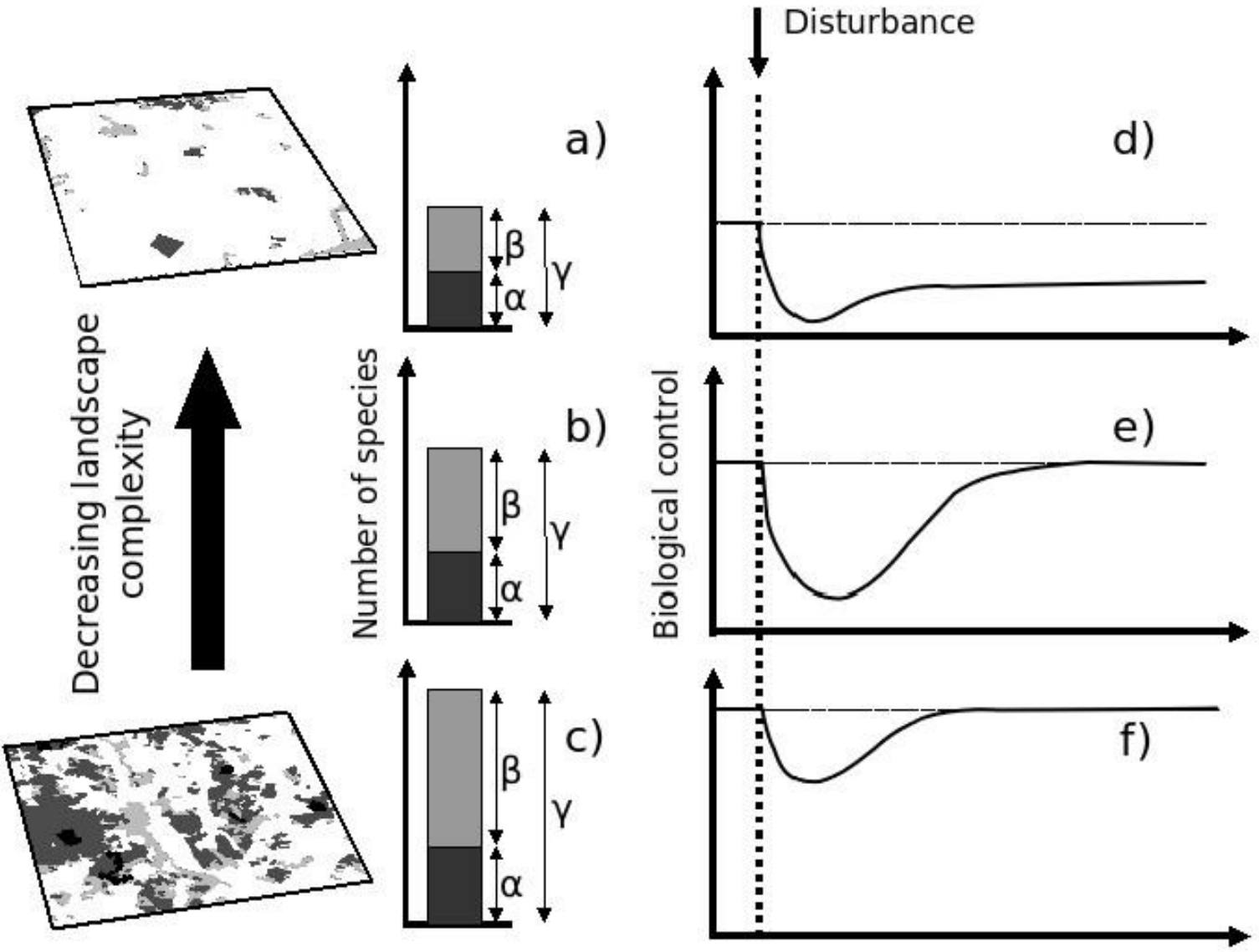
Greater variety of species increases probability that at least some will continue to provide functions (Neam & Li 1997)

- Food insurance
- Income insurance

against - environmental and socio-economic risk

through - provision of ecological resilience, regulating services, adaptation to climate change, protection of crop and livestock health, beneficial organisms , improved soil quality, etc

Landscape-mediated insurance hypothesis



Tscharntke et al. 2007
Biol Control

Spatiotemporal landscape heterogeneity may guarantee resilience, the capacity to reorganize after disturbance

Agrobiodiversity: Insurance function ctd

Economic dimension

- Risk / Vulnerability / Risk management - / Portfolio approach

Farm level

- *natural* insurance through biodiversity and *financial* insurance are substitutes

- higher agro-biodiversity may increase mean level, and decrease the variance of crop yields and farm income

(Di Falco et al. 2007, Baumgärtner & Quaasb 2007)

- optimization of both biodiversity and crop production benefits is possible

(Clough et al., PNAS 2011)

Society

- Reducing uncertainty in provision of public-good ecosystem services

(Baumgärtner & Quaasb 2007)

Agrobiodiversity: Monitoring

Agrobiodiversity: Monitoring

- Data on biodiversity *needs*
- Data on

  - *in-farm*: amount & distribution of crop genetic diversity
  - *in-landscape:* biodiversity resources
  - characterstics of genepools (crop,livestock,wild relatives)
  - management practices for diversity maintenance

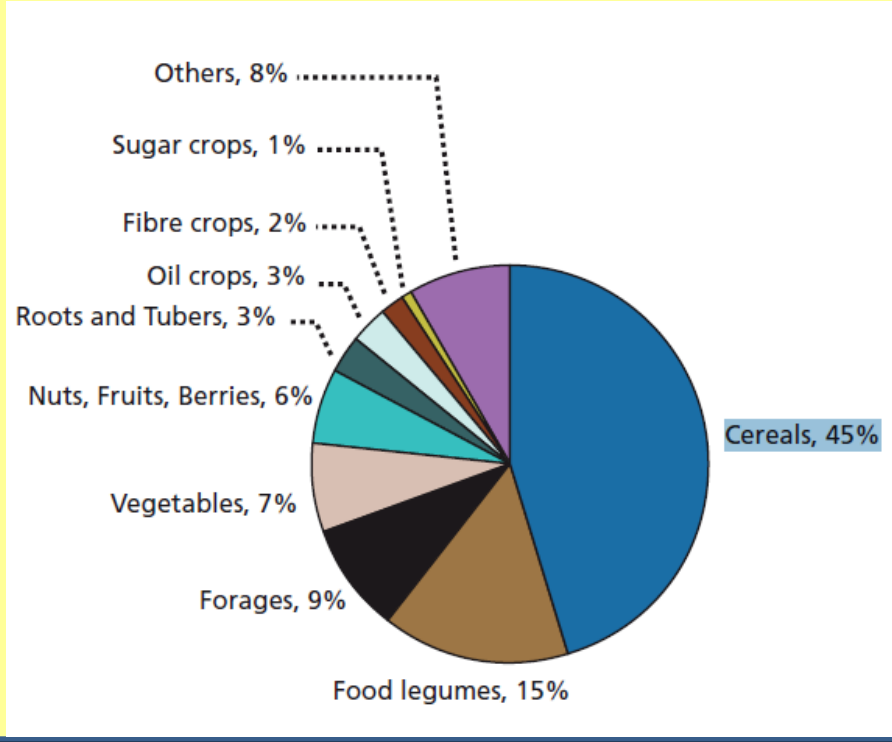
- Research
  - identification of desired genes in neglected/wild genotypes
  - high throughput screening using molecular techniques
    - to avoid redundancies
    - to avoid loss of valuable traits

- Create data platform: mapping & documenting

Agrobiodiversity: Conservation

Agrobiodiversity: Conservation

- Genetic and population diversity provides the essential basis for continuing crop and livestock improvement (Jackson et al. 2007)
- **Ex situ**:
  - Cereals 45%, tubers 3%, …
  - Landraces 44%, wild plants /crop relatives 15%
  - 25-30% is unique, rest is duplicates (FAO 2010)
- in national and international gene banks



Agrobiodiversity: Conservation

- **In situ**

Options to support the conservation of diversity

- Adding value through characterizing local materials
- Improving local materials: breeding, seed processing
- Participatory monitoring and breeding
- Increasing consumer demand through market incentives and public awareness

Agrobiodiversity: Conservation

- **In situ**

Options to support the conservation of diversity

- Adding value through characterizing local materials
- Improving local materials: breeding, seed processing
- Participatory monitoring and breeding
- Increasing consumer demand through market incentives and public awareness
- Improved access to information and materials
- Supportive policies, legislation and incentives

Agrobiodiversity: Conservation

- **Policies and institutions**
  - Devise and implement national development strategies and agricultural policies
  - Legal frameworks and regulations that promote the use of PGRFA, including appropriate *seed legislation*
  - Public institutions should monitor state of genetic diversity

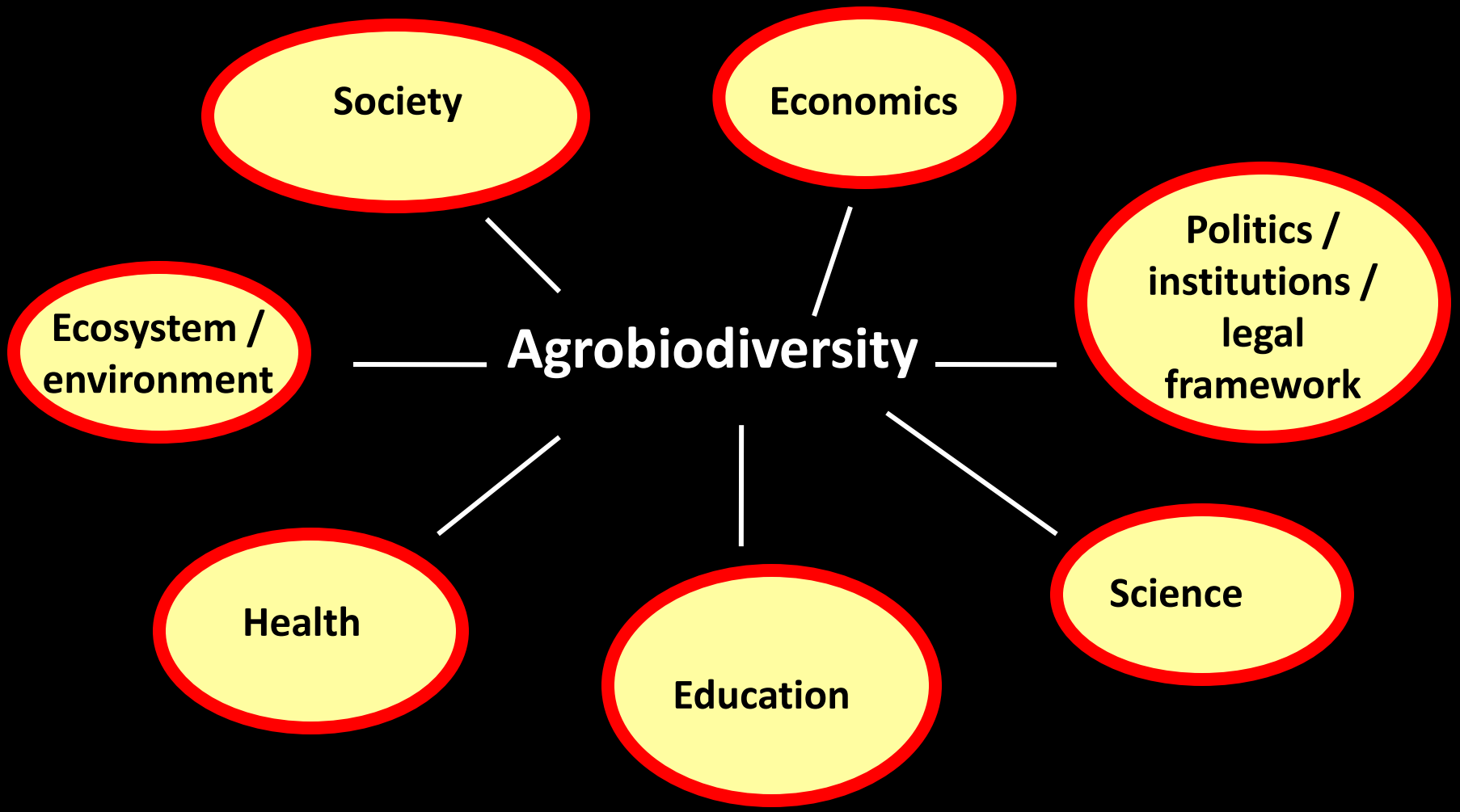
Agrobiodiversity: Networking

Agrobiodiversity: Networking

Collaboration is needed on all levels

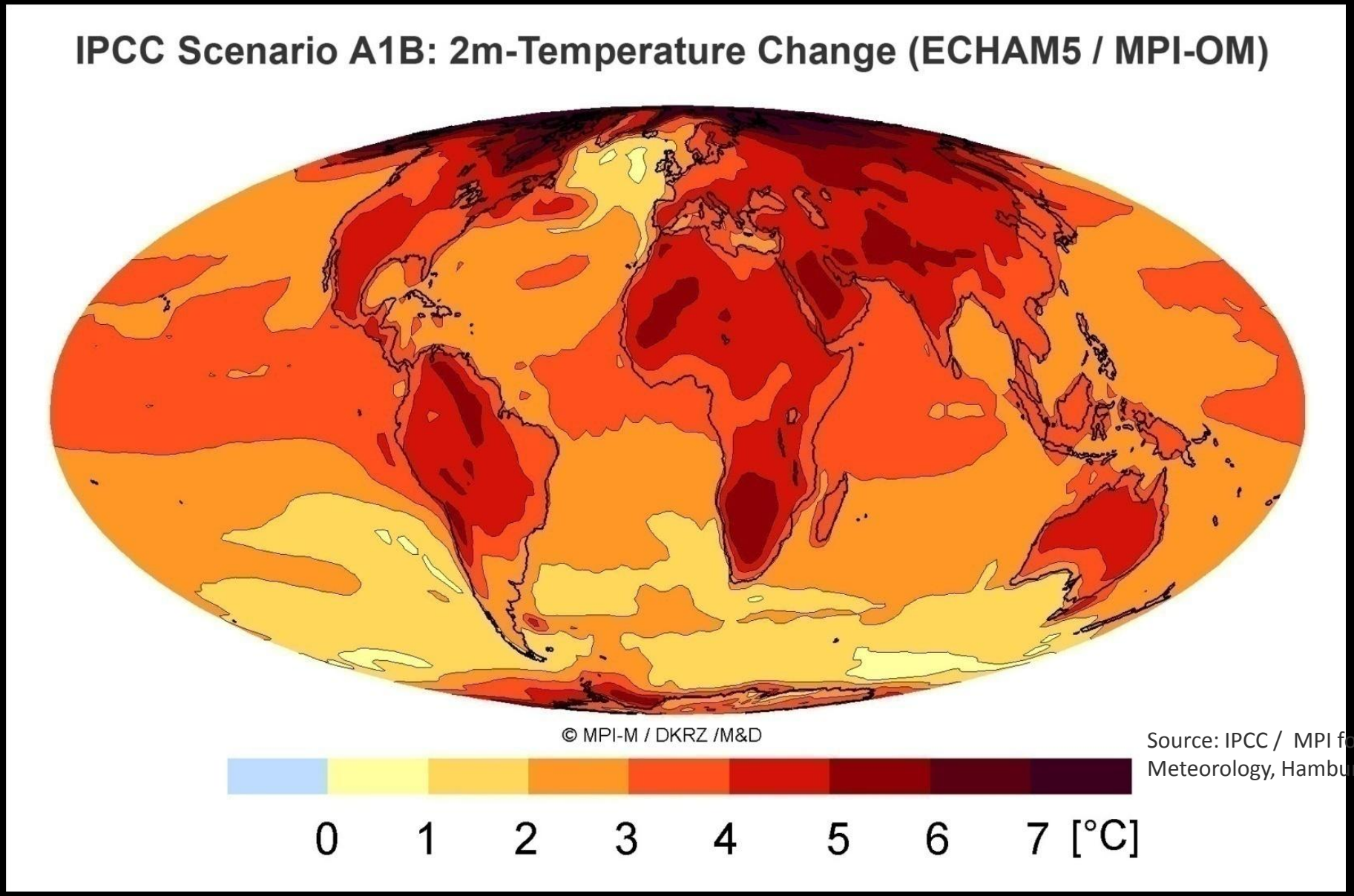
- Farmers – involve in national adaptation strategies
- NGOs
- Science/researchers
- Political institutions / government
- Education institutions
- National / International – networks and initiatives

Agrobiodiversity: Linkages



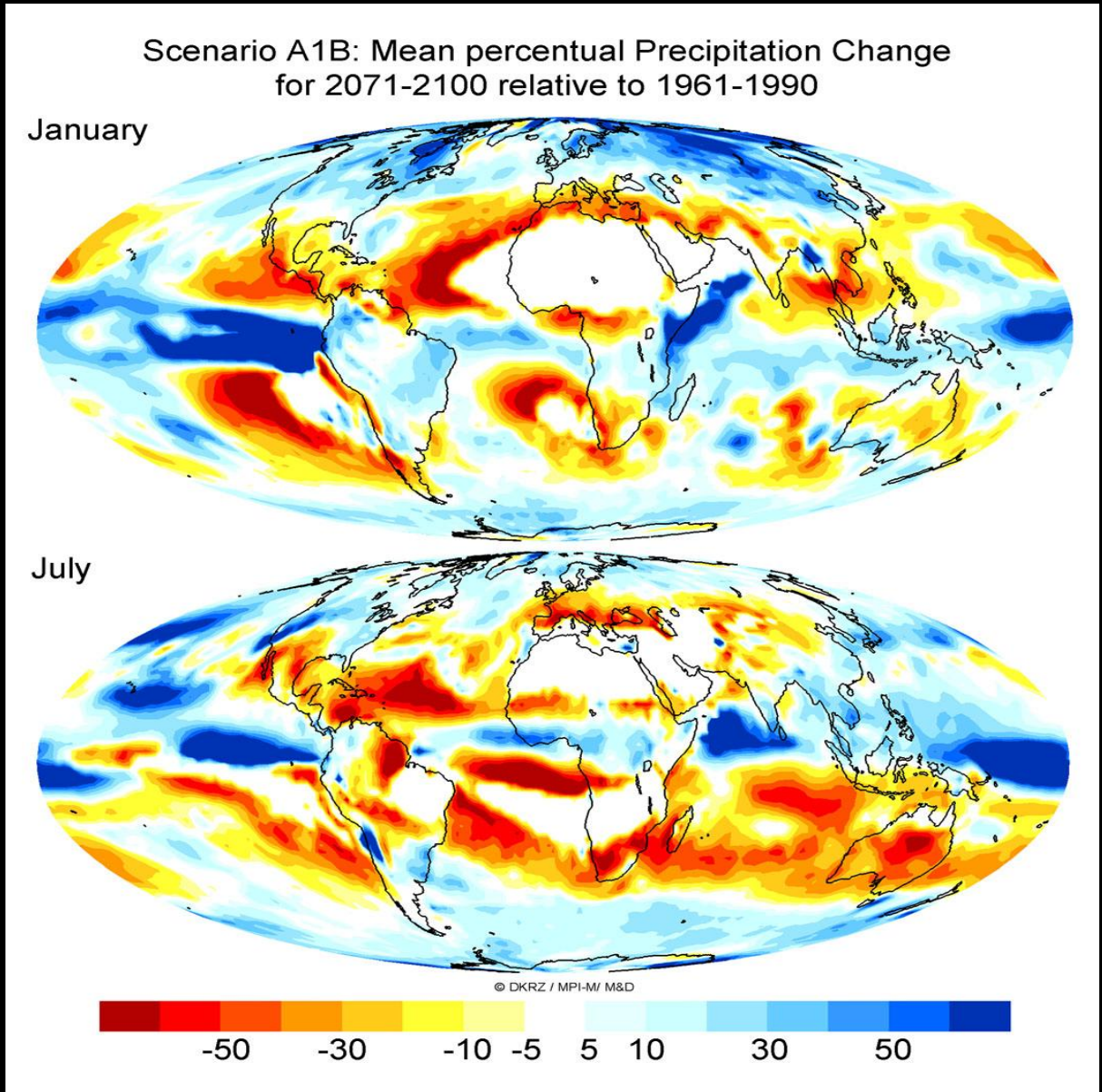
Thank you

Predicted Temperature Change (IPCC)



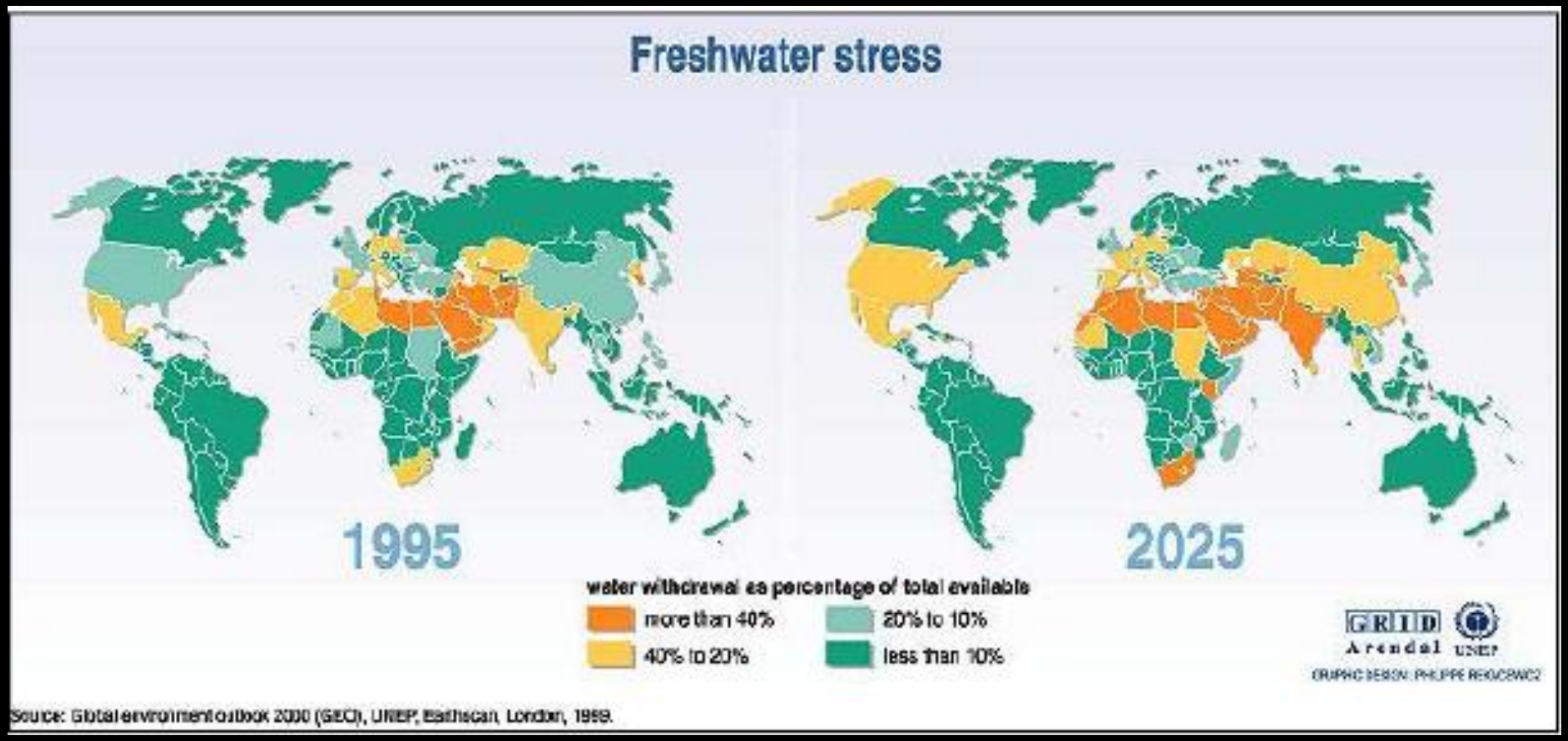
Source: IPCC / MPI for Meteorology, Hamburg

Precipitation change
2071-2100 relative to 1961-1990

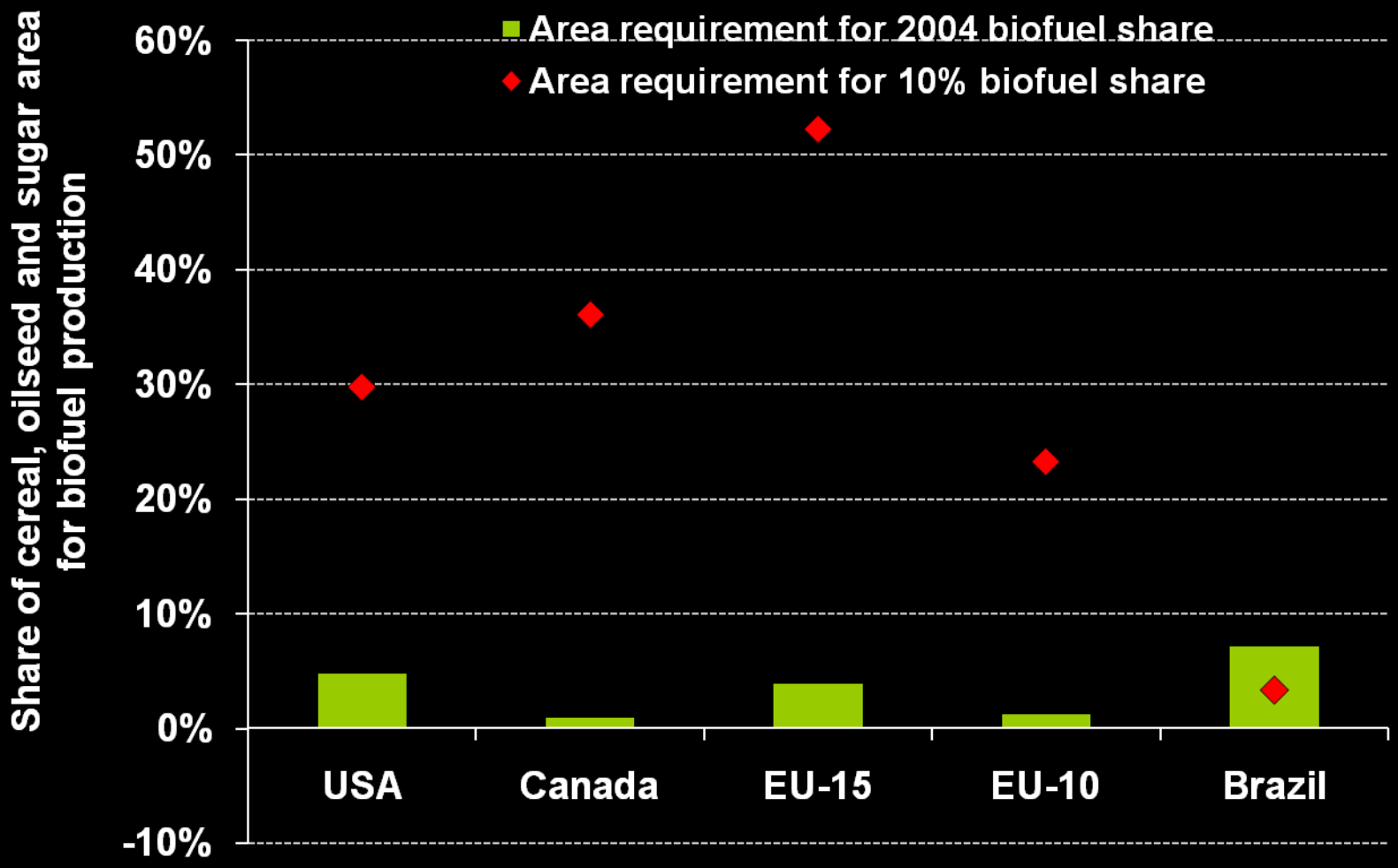


Source: IPCC / MPI for Meteorology, Hamburg

Freshwater stress

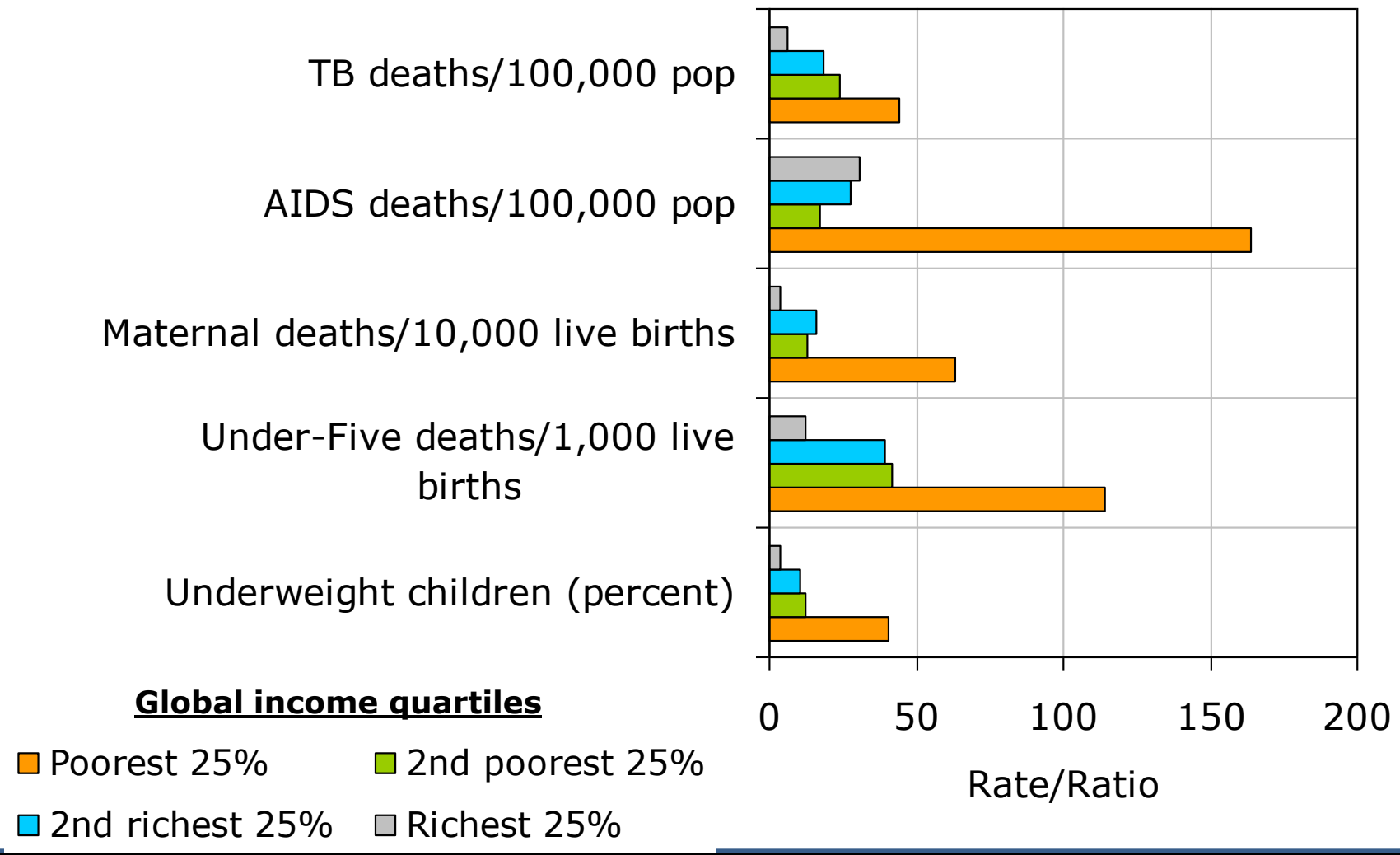


Large area requirements for higher biofuel shares



Source: OECD

'It's the world's poor who die earlier'



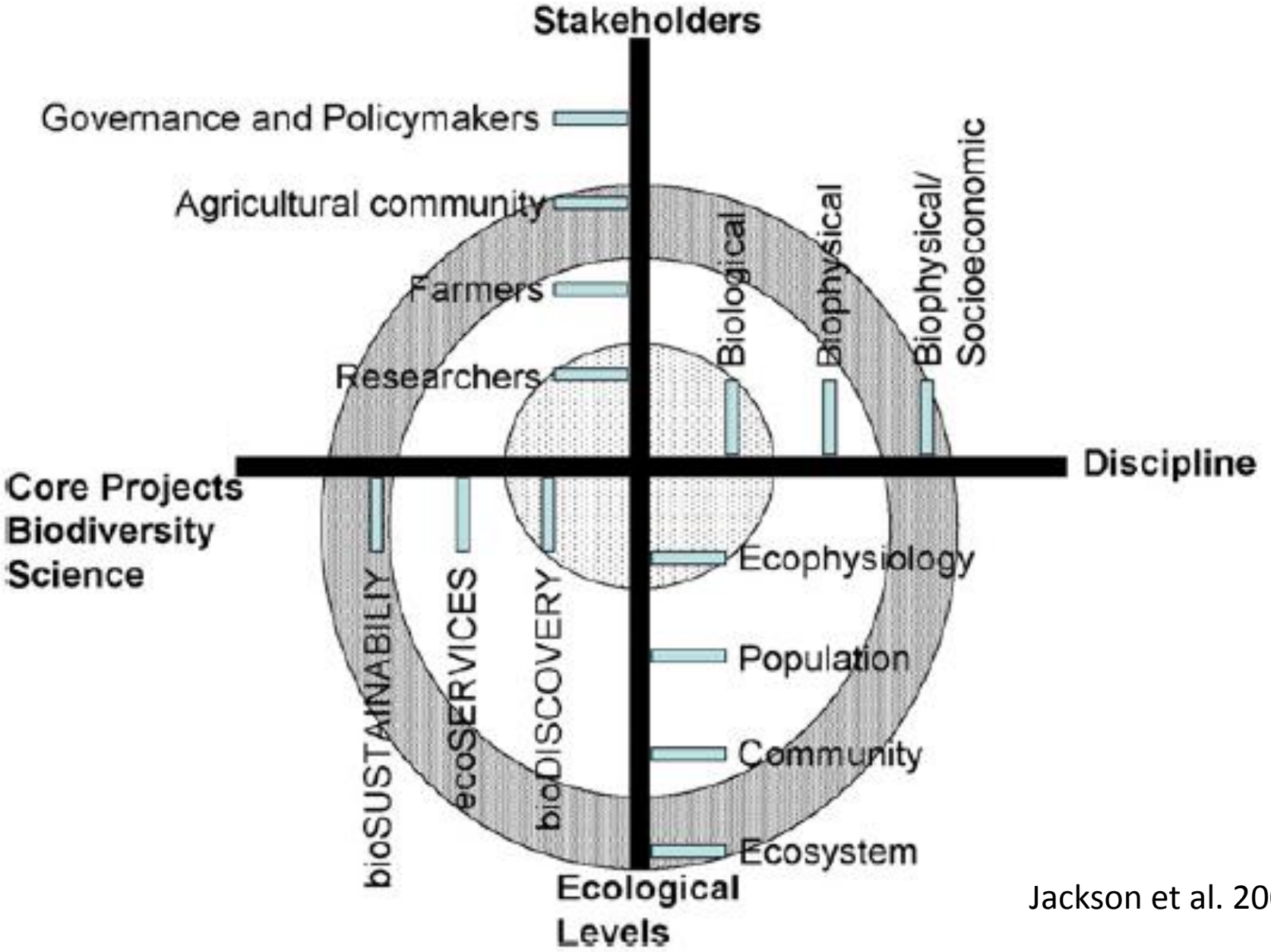
A value chain approach

(FARA 2010)

A value chain approach

(FARA 2010)

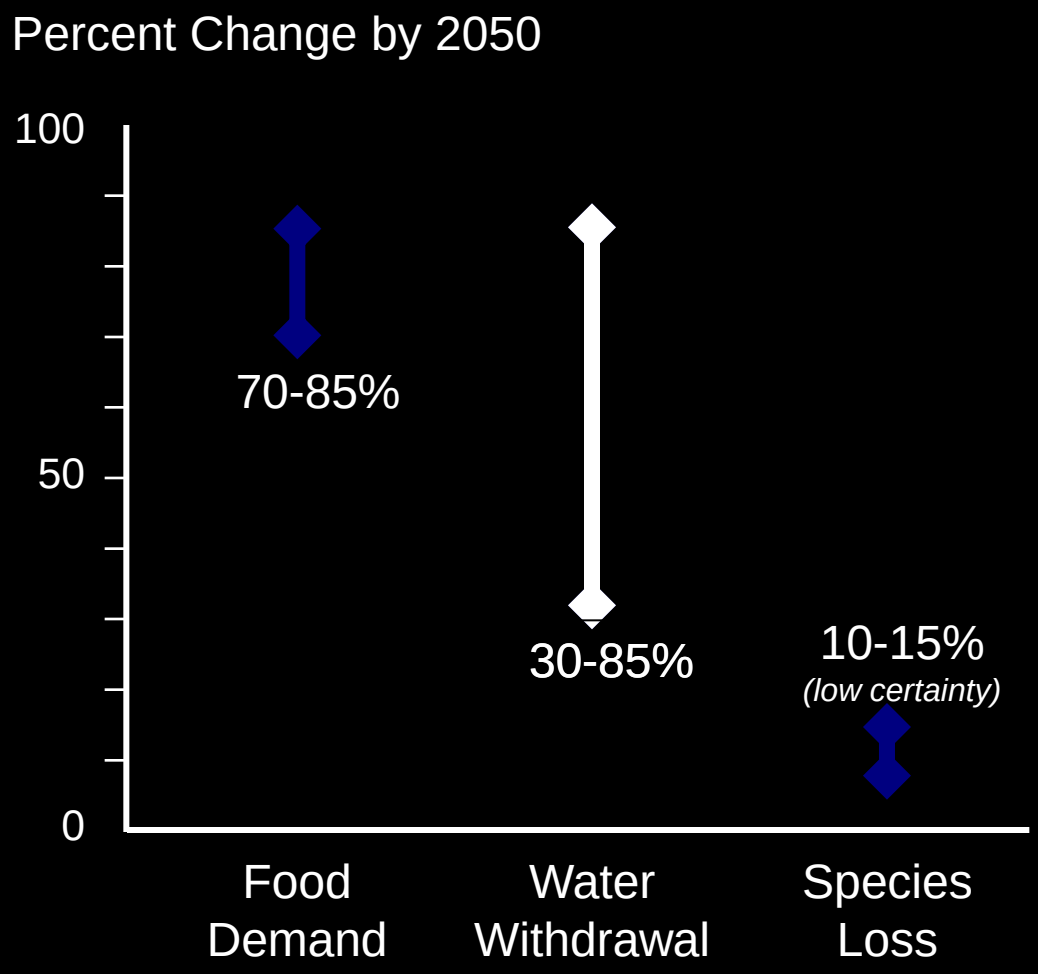
Agrobiodiversity: Networking



Jackson et al. 2007

Global change – ecosystem degradation

Scenarios



Source:

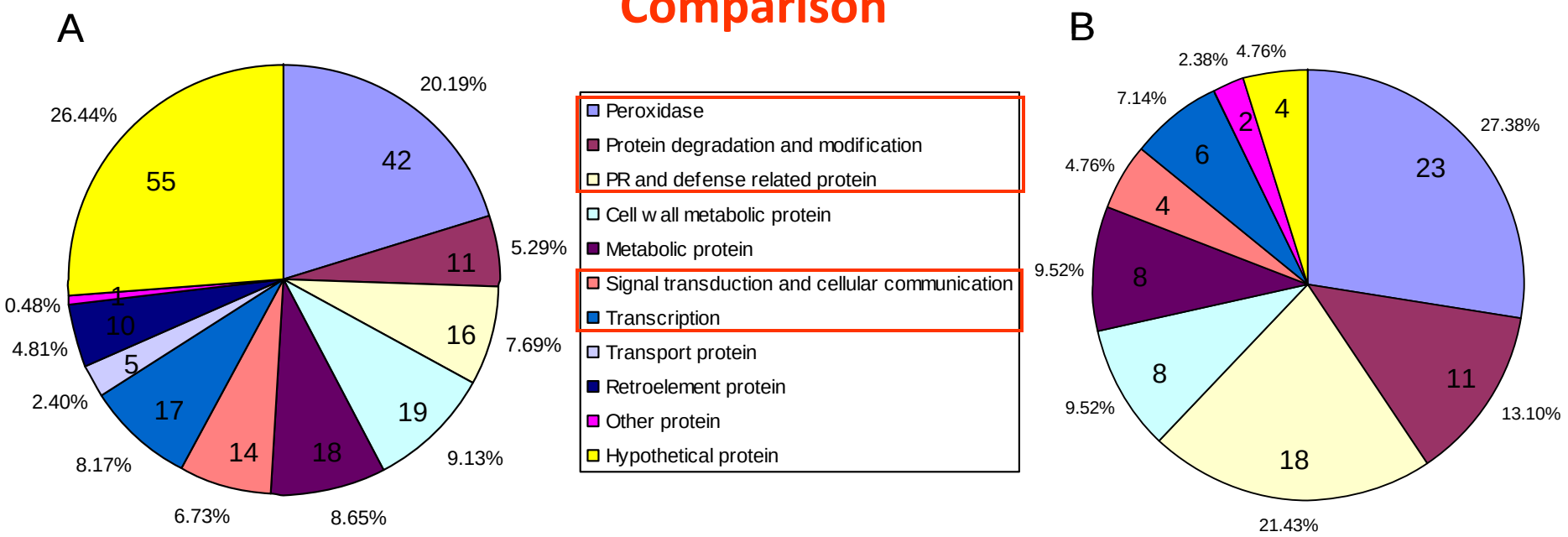
Millennium Ecosystem Assessment

Functional genomics / proteomics

A. WVa700
Susceptible

Protein composition Comparison

B. Hawaii7996
Resistant



Higher number of proteins

- Higher % of signalling protein, Transcription related protein

- Higher % of **defense related protein**

Peroxidase, Protease & Metabolic proteins

Dahal et al. 2009, 2010