A global view on prioritizing genomic resources

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Content

- Domestication history – why to conserve
- Why prioritization is necessary
  - Tools with and without molecular data
  - FAO-ISAG
- Genomics in AnGR management
  - Current situation and constraints
- Conclusion and recommendation

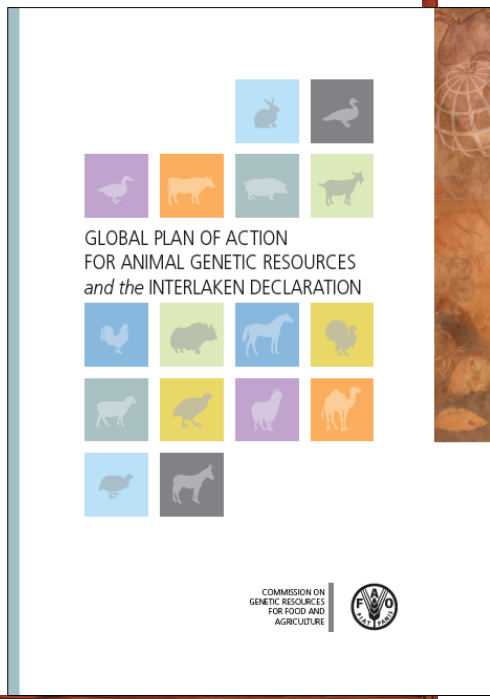
Framework - Global Plan of Action

The *Global Plan of Action for Animal Genetic Resources* was adopted by FAO members in 2007

- internationally agreed framework for the management of animal genetic resources

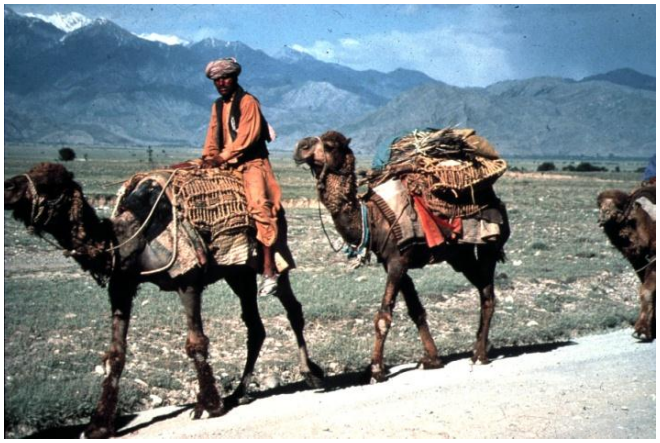
4 Strategic Priority Areas

1. Inventory, monitoring and characterization
2. Sustainable use
3. Conservation
4. Policy, institutions and capacity building



Promoting diversity

History – why conserve?



Domestication and breed history

Present AnGR diversity result of combination of forces

- domestication
- migration and genetic isolation
- environmental adaptation and selective breeding
- introgression and admixture of subpopulations

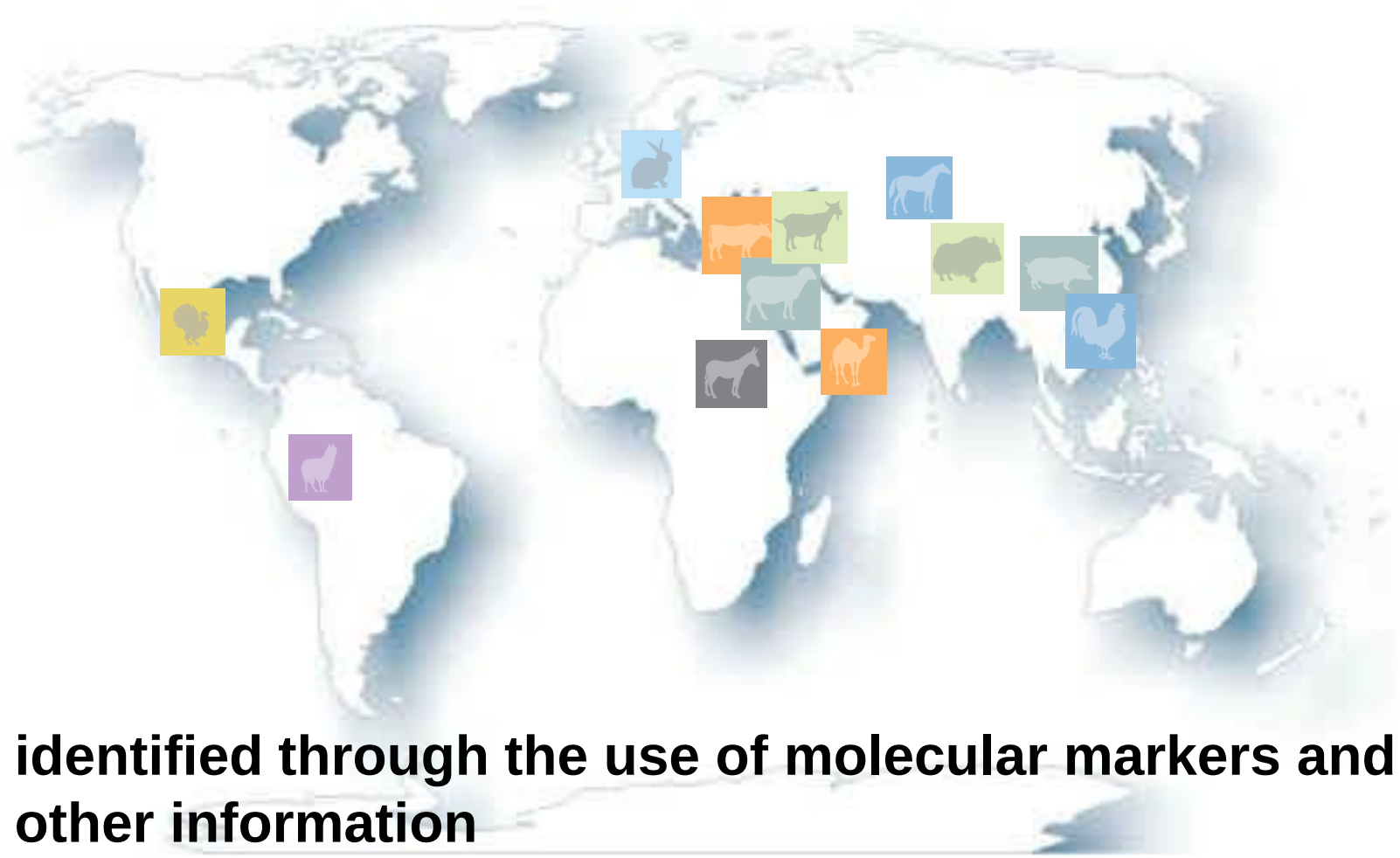
Molecular tools helped unravel history

- Contribute to current decision making

Domestication and breed history

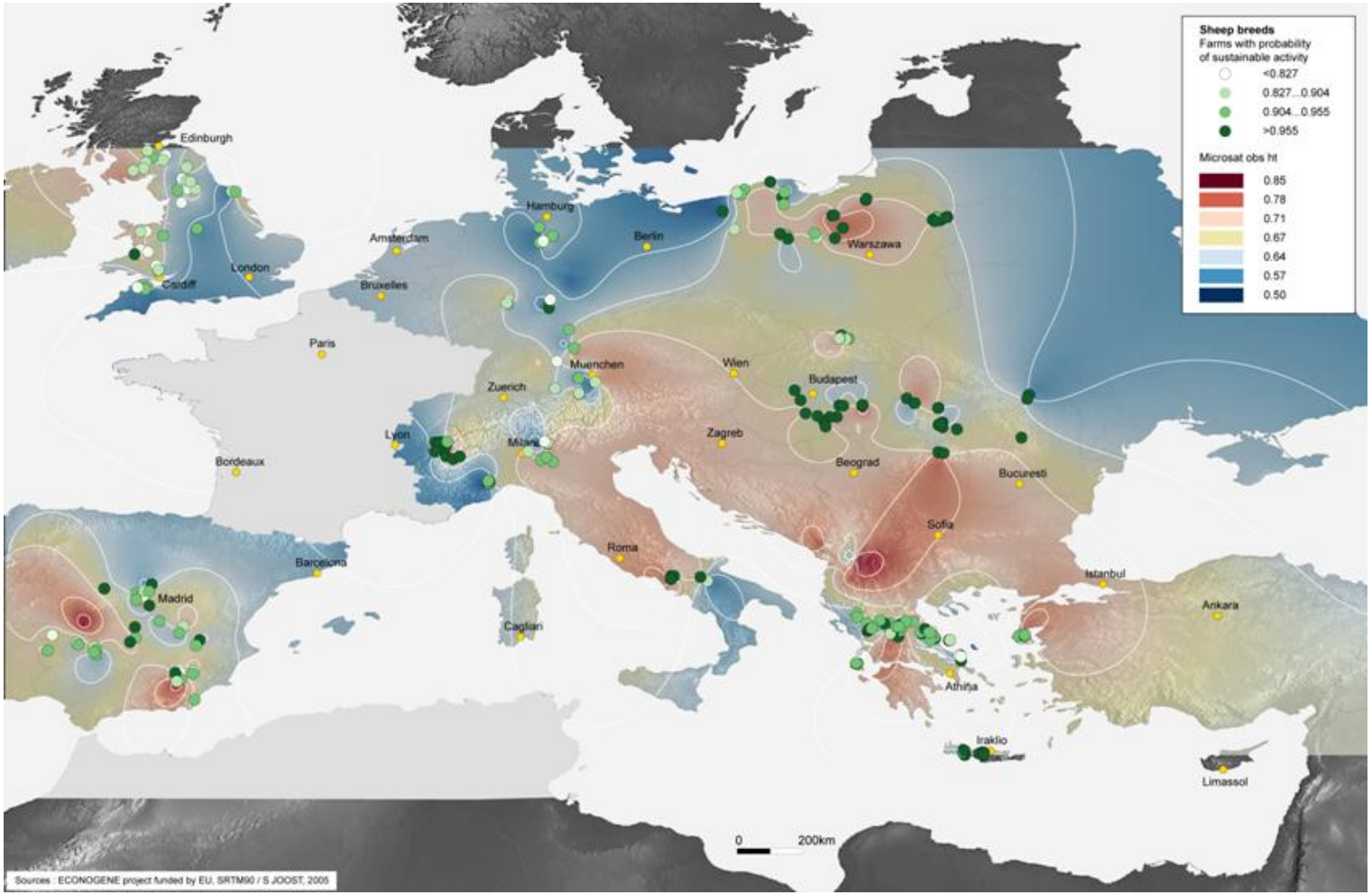
- Different marker types yield different information
- Mitochondrial DNA
  - Assumption is that domestication relied on keeping females
  - maternally-inherited → wild ancestral species
  - geographic variation on continental scale
- Y-chromosomal variation
  - highly informative on male introgression
    - breeds
    - species
- Autosomal DNA
  - within or across continents
  - neutral or selective variation

Centres of Domestication



identified through the use of molecular markers and other information

Geographical gradients

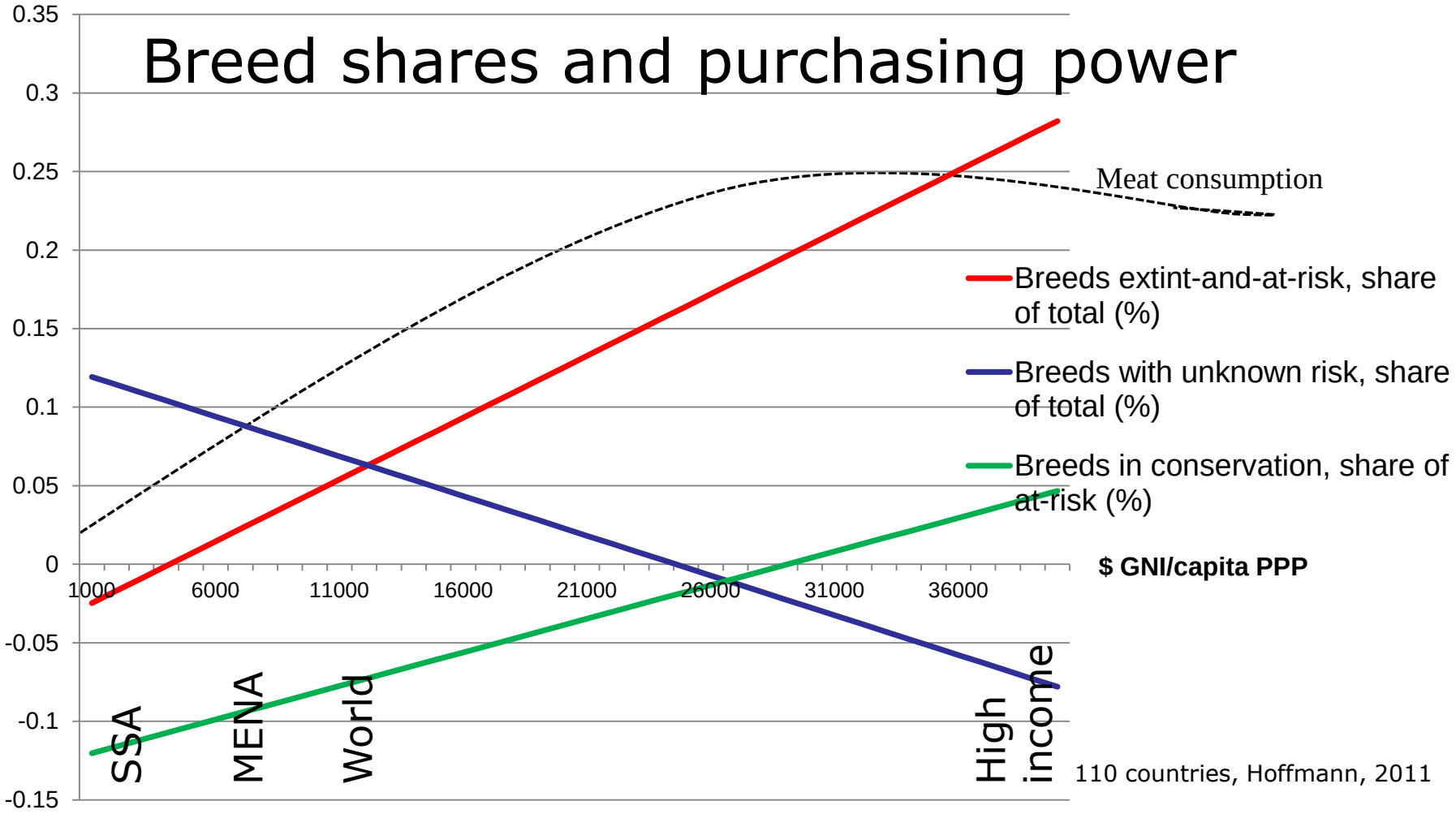


(courtesy Econogene project, S. Joost)

Why is conservation important?

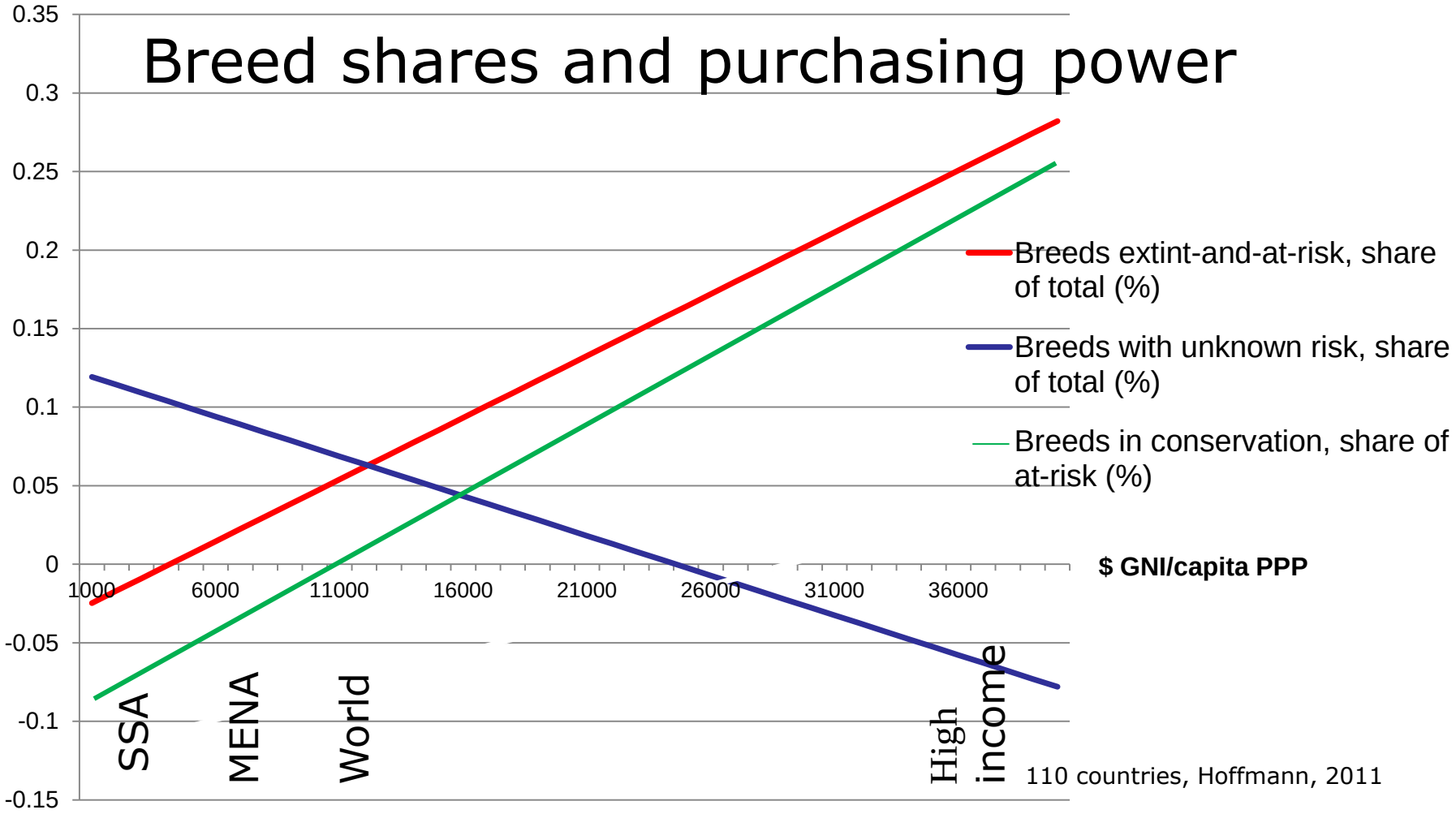
- Genetic diversity is necessary for adaptation
  - changing environments
    - production systems
    - climate
  - changing markets
- Genetic diversity is necessary for continued genetic improvement
- Cultural and historical reasons

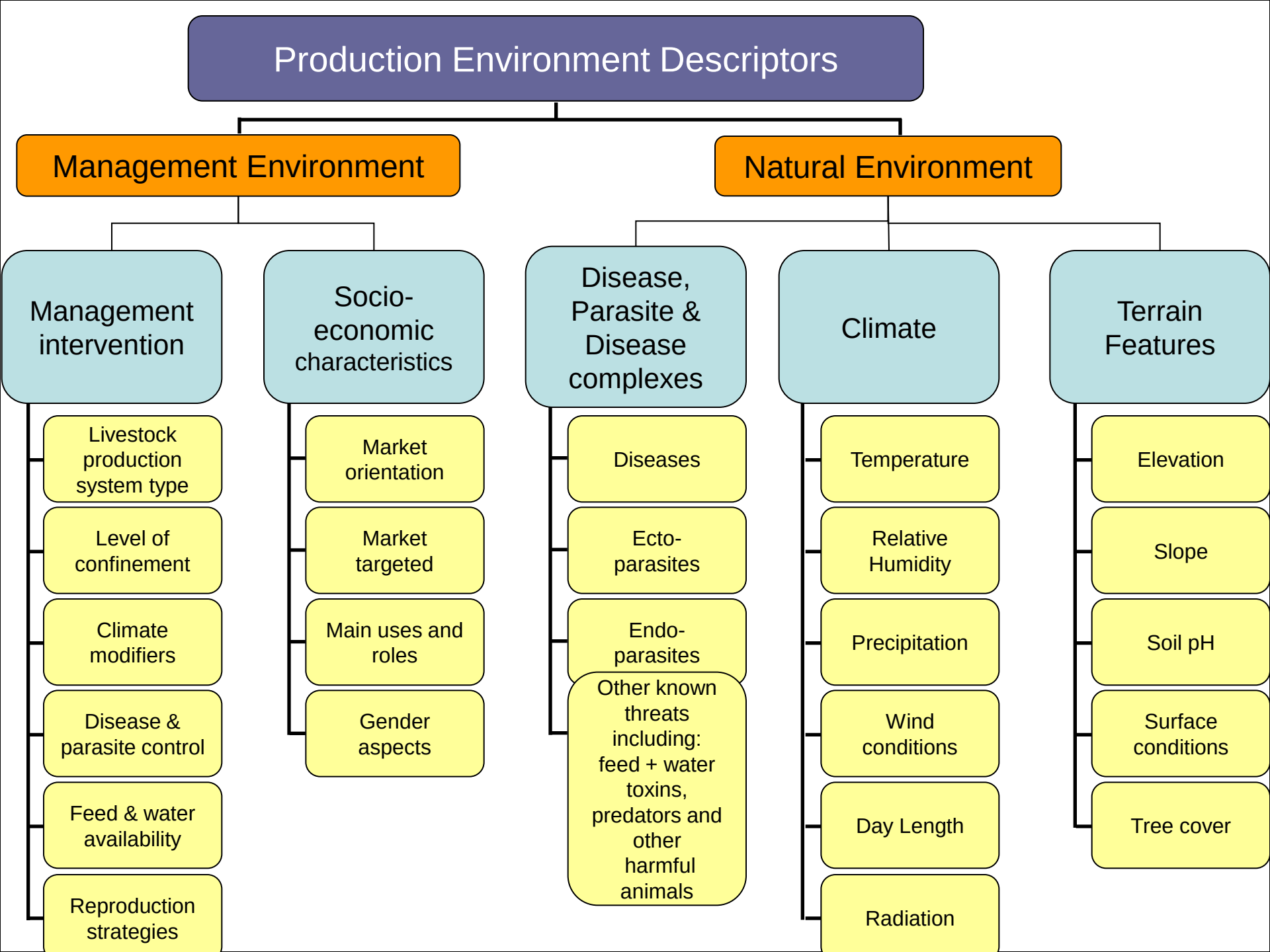
Information on sustainability



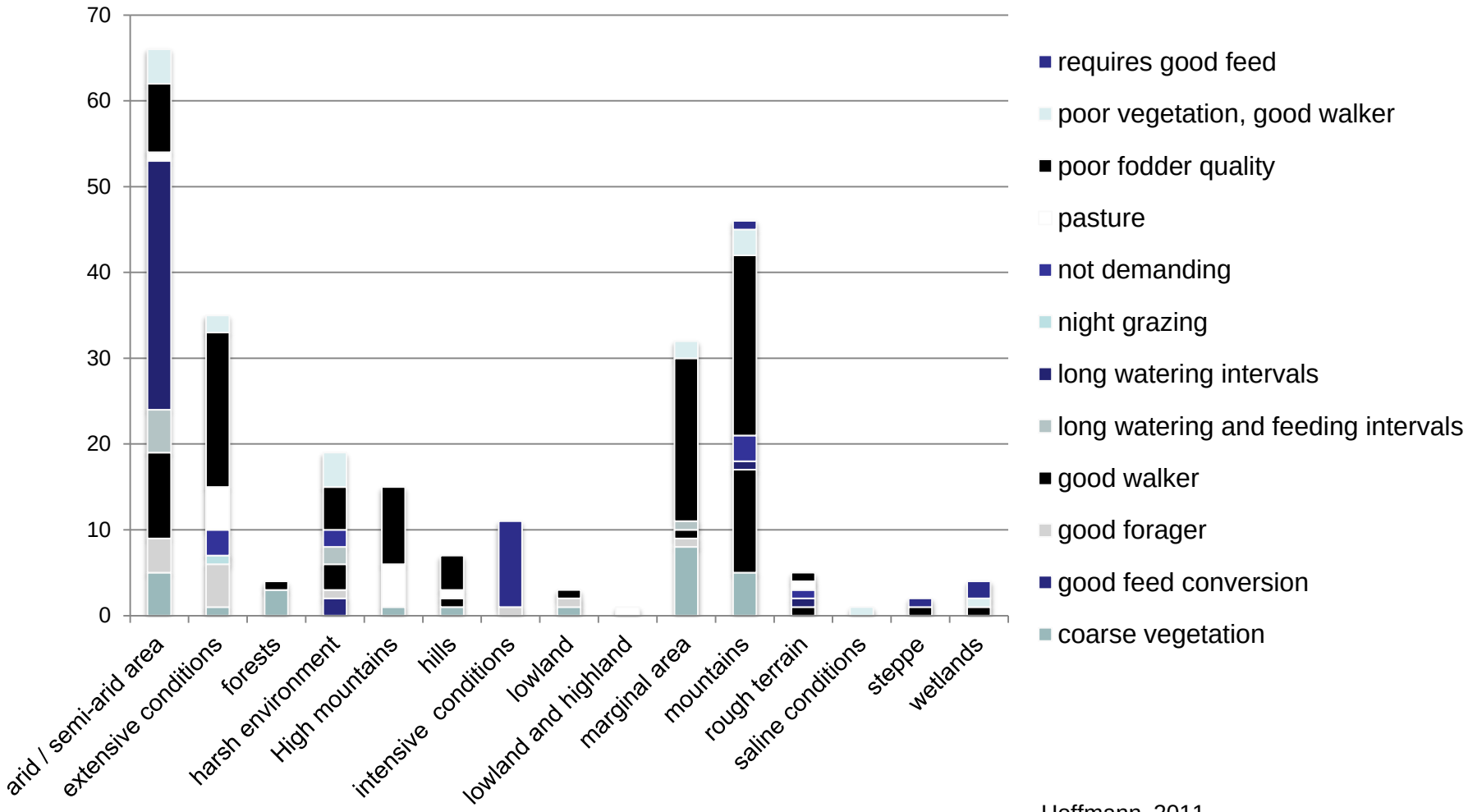
110 countries, Hoffmann, 2011

Information on sustainability

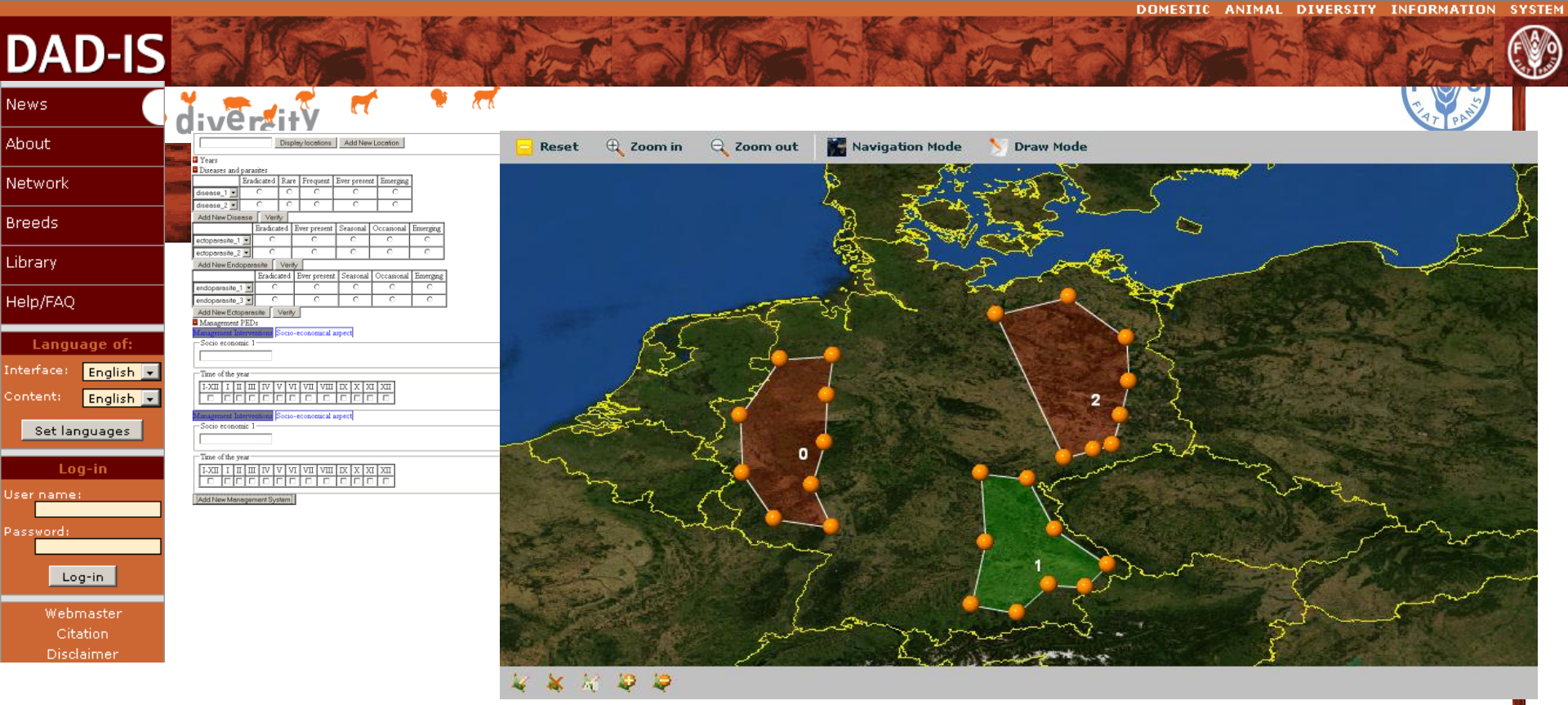



Production Environment Descriptors
Management Environment
Natural Environment
Management intervention
Socio-economic characteristics
Disease, Parasite & Disease complexes
Climate
Terrain Features
Livestock production system type
Level of confinement
Climate modifiers
Disease & parasite control
Feed & water availability
Reproduction strategies
Market orientation
Market targeted
Main uses and roles
Gender aspects
Diseases
Ecto-parasites
Endo-parasites
Other known threats including: feed + water toxins, predators and other harmful animals
Temperature
Relative Humidity
Precipitation
Wind conditions
Day Length
Radiation
Elevation
Slope
Soil pH
Surface conditions
Tree cover

No. of national breed populations of selected species by ascribed habitat and fodder/feeding adaptation



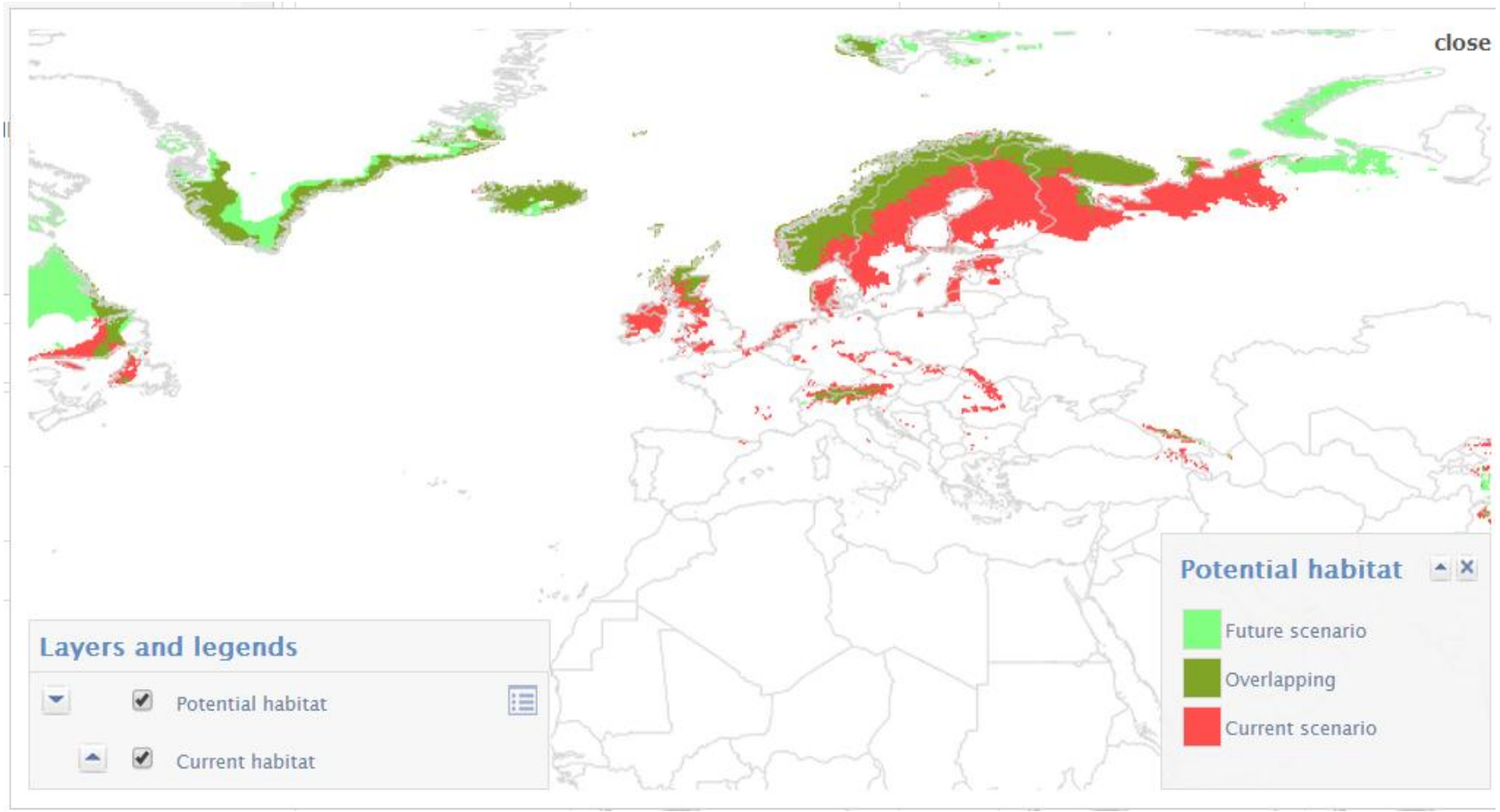
Hoffmann, 2011



- Management intervention
- Socio-economic aspects
- Natural production environment

Climate change modeling - **Norwegian Red cattle**

2050 – most optimistic scenario



Model: HadGEM2-ES, rcp26

FAO, 2014

Climate change modeling - **Norwegian Red cattle**

2070 – most pessimistic scenario

Which breeds currently in the same habitat shrink / expand differently and why?

Model: HadGEM2-ES, rcp85

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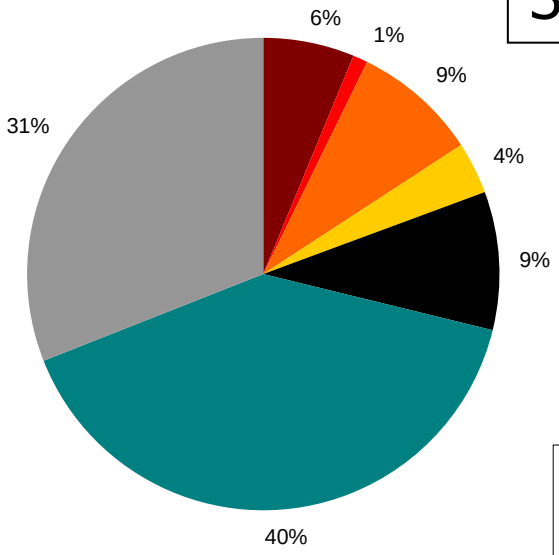
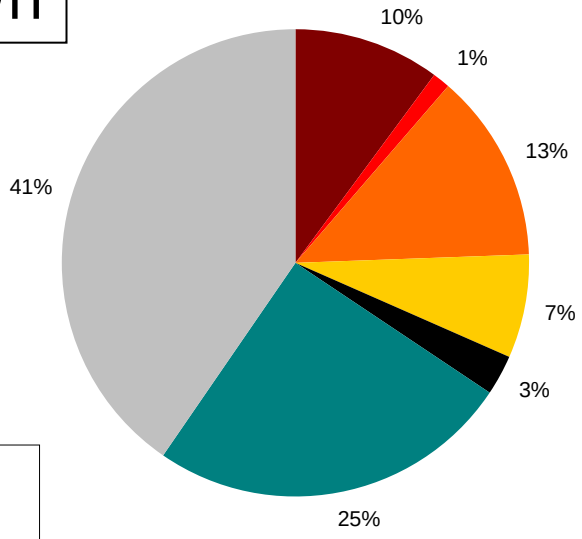
Risk status - the global picture (2012)

8% extinct
22% at risk
34% unknown

Mammalian species



Avian species



- critical
- critical-maintained
- endangered
- endangered-maintained
- extinct
- not at risk
- unknown

FAO, 2014

Promoting diversity

Conservation programmes: Changes since 2005

	Number of countries reporting		Proportion of countries with *in situ* conservation programmes		Proportion of countries with *in vitro* conservation programmes	
	SoWAnGR 1	SoWAnGR 2	SoWAnGR 1	SoWAnGR 2	SoWAnGR 1	SoWAnGR 2
Africa	42	40				
East Africa	7	8				
North & West Africa	24	20				
Southern Africa	11	12				
Asia	25	20				
Central Asia	6	4				
East Asia	4	4				
South Asia	7	6				
Southeast Asia	8	6				
Southwest Pacific	11	7				
Europe & the Caucasus	39	35				
Latin America & the Caribbean	22	18				
Caribbean	3	5				
Central America	9	5				
South America	10	8				
North America	2	1				
Near & Middle East	7	7				
World	148	128				

FAO, 2014

Why is prioritization necessary?

Conservation of all breeds impossible

- Many breeds and limited financial resources
  - Food security more important in developing countries
  - Short-term economic return more important in industrialized countries

Wholesale conservation not scientifically justified

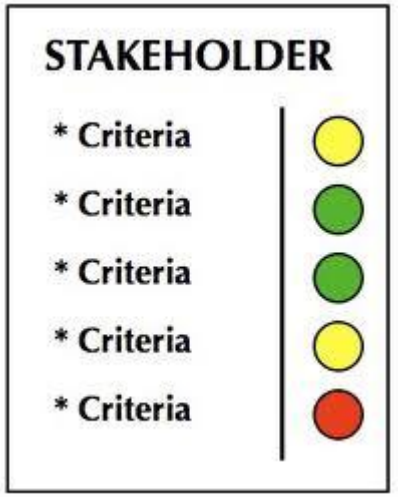
- Breed may have no apparent short- or long-term value
- Breeds may be effectively the same genetically

Decision support may be needed

- many factors to consider simultaneously

Objective approaches have been proposed

- use of genetic markers to measure diversity



Factors influencing conservation priority

- Risk of extinction
  - Breed demographics
    - number and distribution
- Genetic variability (seek to maximize)
  - Genetic distance
    - distinctiveness
  - Allelic diversity
    - diversity and distinctiveness
  - Kinship
    - diversity within and across breeds
- Genetic diversity will rarely be only criterion

Factors influencing conservation priority

- Phenotype
  - genetic merit for productivity
- Unique traits
  - adaptive traits
  - environment interaction
- Historical and cultural importance
- Practical considerations
  - species and ease of conservation
  - chance for success

Prioritization without molecular data

Use single criterion

- Risk of extinction or carrier of unique trait or cultural value

Multivariate statistical methods

- Correspondence or principal components analysis
  - reduce many variables to smaller number
- Cluster analysis
  - assign breeds to similar groups
  - choose single breed from each group
- Multivariate Index
  - assign different weights to characteristics of breeds

Farmer Choice models (Zander and Drucker 2008)

Consumer WTP

Geographical approaches valuable when no formal "breeds" exist

Use of formal approaches to prioritize breeds for conservation

Regions and sub regions	Number of countries	Percentage of countries with formal conservation priorization approaches	Criteria for breed conservation priorization. Percentage of countries using each criteria among countries reporting formal approaches for conservation.						
			Risk of extinction	Genetic uniqueness	Genetic variation within breed	Production traits	Non-production traits	Cultural or historical importance	Probability of success
Africa	**40**	**58**	**78**	**87**	**35**	**70**	**30**	**74**	**52**
East Africa	8	50	75	100	50	50	75	100	75
North & West Africa	20	65	69	77	31	77	15	77	46
Southern Africa	12	50	100	100	33	67	33	50	50
Asia	**20**	**70**	**71**	**86**	**71**	**93**	**64**	**79**	**71**
Central Asia	4	100	25	75	50	100	50	75	100
East Asia	4	50	100	100	100	100	50	50	100
South Asia	6	67	100	75	50	75	50	75	25
Southeast Asia	6	67	75	100	100	100	100	100	75
Southwest Pacific	**7**	**43**	**67**	**100**	**100**	**100**	**67**	**100**	**33**
Europe & the Caucasus	**35**	**89**	**100**	**71**	**74**	**55**	**52**	**87**	**39**
Latin America & the Caribbean	**18**	**56**	**100**	**80**	**60**	**80**	**40**	**110**	**40**
Caribbean	5	60	100	67	33	67	67	100	33
Central America	5	40	100	100	100	100	50	150	100
South America	8	63	100	80	60	80	20	100	20
North America	**1**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Near & Middle East	**7**	**29**	**100**	**100**	**100**	**100**	-	**50**	**50**
World	**128**	**66**	**88**	**81**	**63**	**71**	**46**	**85**	**49**

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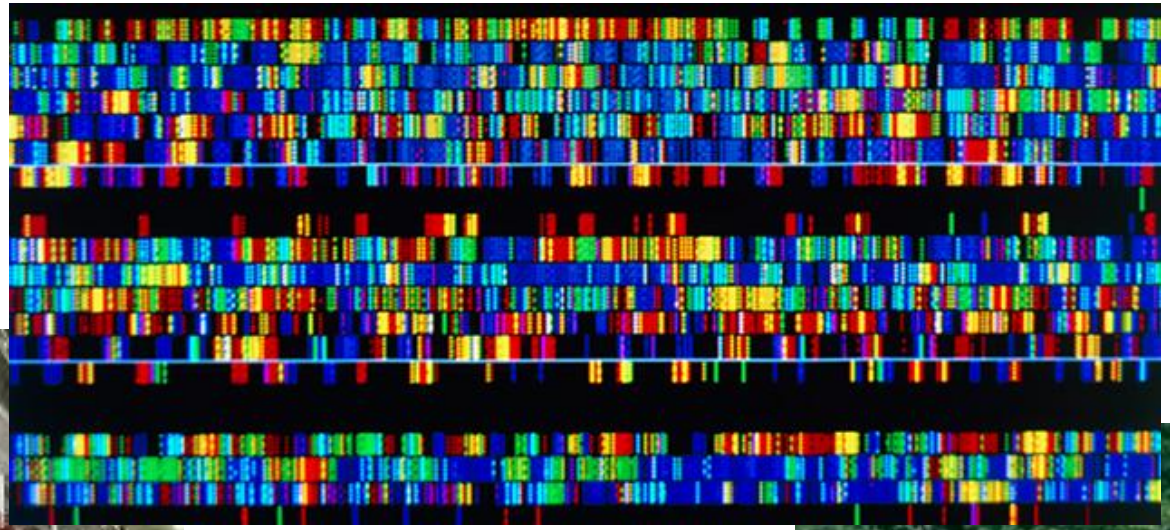
Promoting diversity

Genomics



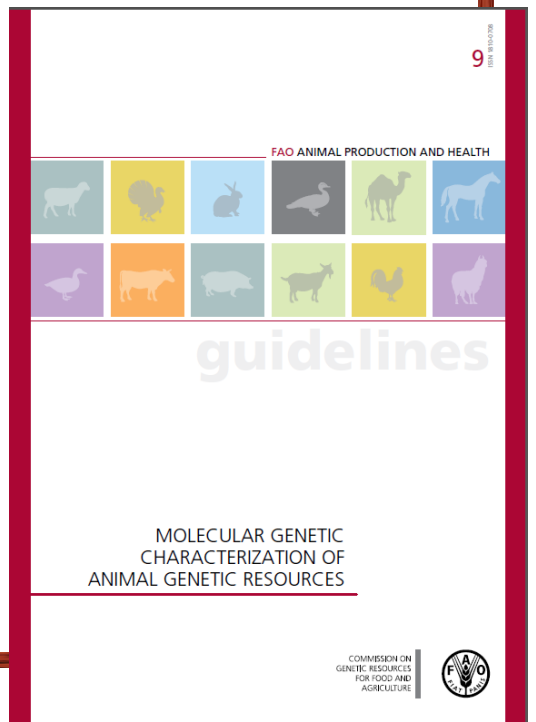
Prioritization with molecular data

Molecular data is mainly used to measure breed diversity and relationships among breeds

- ↑ diversity = ↑ priority
- ↑ distinctiveness = ↑ priority

History – Use of genetic information

- Measurement of Domestic Animal Diversity (MoDAD)
- ISAG-FAO advisory group on animal genetic diversity
  - 1998 Standardized microsatellite lists proposed
    - cattle, chicken, sheep, swine
  - 2004 new microsatellite lists
    - 4+ Buffalo, goat, horse, donkey, camelids
- Scope of utilization increased
  - several multi-country projects
  - Problems to link studies



Current Situation

- DNA analysis technologies have rapidly advanced
  - more information
  - greatly reduced costs
- Technological advances allow for expansion of objectives beyond those foreseen for MoDAD
  - functional and neutral variation
  - genetic profiling of individuals rather than breeds
- FAO is implementing "Production Environment Descriptors" in DAD-IS
  - Study of links between genomes and environments

Genomics

- "Genomics Revolution" could increase the utility of molecular genetics in management of AnGR
- Genomics – study of genomes of organisms
  - Study of entire sequence
    - Variability in multiple genome regions
  - Fine scale genetic mapping
  - Interactions between genes and their products
- Prompted by large-scale declines in cost of obtaining information

Sustainable Use and Development

- Recent biotechnological advances
  - efficient sequencing
  - increased information about polymorphism in genome
  - denser maps at lower cost = ↑ increased precision
- Single Nucleotide Polymorphisms (SNP)
  - causative variants of simply-inherited traits
  - genome-wide selection within breeds
  - selection signatures across breeds
  - increased biological knowledge

Conservation

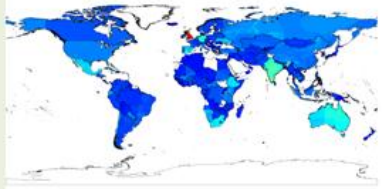
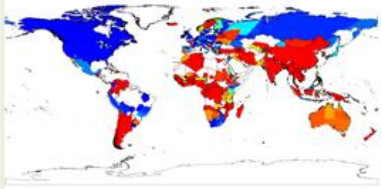
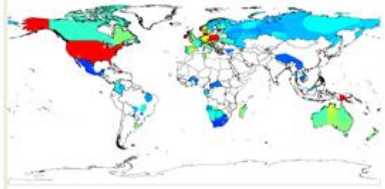
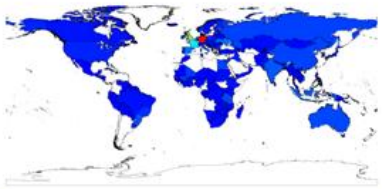
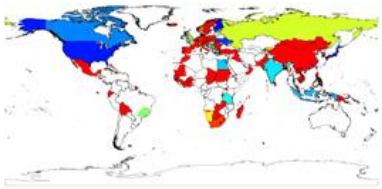
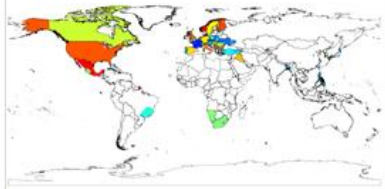
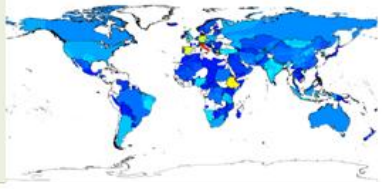
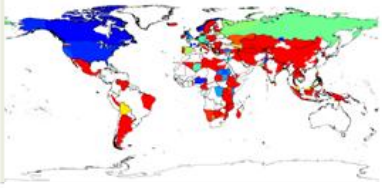
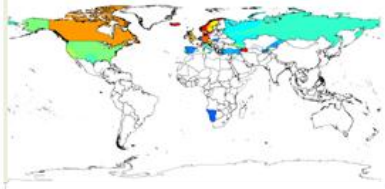
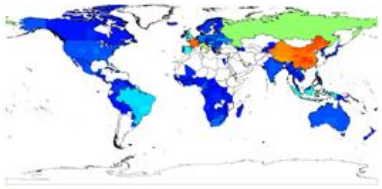
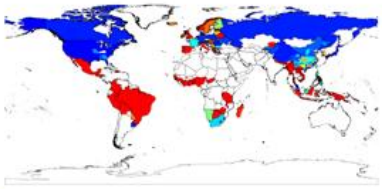
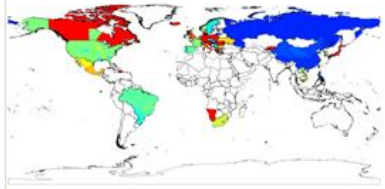
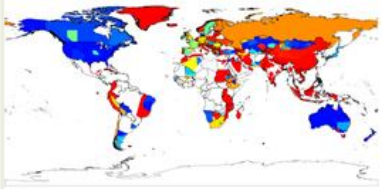
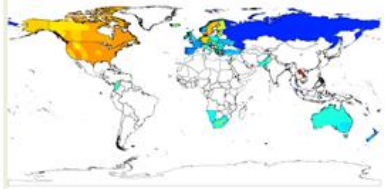
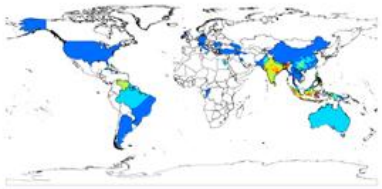
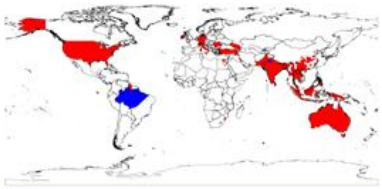
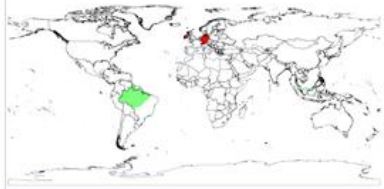
- "Conservation Genomics" = new field
- Improved accuracy of haplotype reconstruction
  - Diploid with linked loci
  - Assign loci to parental origin
- Increased precision of parameter estimates
  - Population structure, Effective population size
  - Direction of migration
- Substitution for pedigree information
  - When not available
  - For refinement for animals with equal pedigree relatedness

Conservation and Selection

- Improve phenotype of conserved breed to improve productivity
  - Genomic selection to increase accuracy
  - Overcome lack of routine phenotypic data collection
- Overcome effects of inbreeding depression
  - Identify loci responsible for inbreeding depression
    - Increase variability
  - Select for positive alleles
- Introgression
  - Keep desired genes from outside breed
- Recovery from unwanted hybridization
  - Eliminate in general genes from outside breed

Conservation and Distinctiveness

- Take advantage of a breed's uniqueness
- Selection signatures
  - Identify genes responsible for unique phenotypes
- Local breeds tend to be better adapted to harsh environments
- Integrate genomic with other sources of data
  - Phenotypes
  - Climatic variables
  - Geographic data
  - Zones of epidemic disease

CGRFA description	number of locally adapted breeds	proportion of the total population accounted for by locally adapted and exotic breeds	number of breeds classified as at risk, not at risk and unknown
implementation	absolute number of locally adapted breeds	locally adapted breeds' total population size and exotic breeds' total population size ratio	number of locally adapted breeds classified as at risk and number of locally adapted breeds ratio
Cattle			
Chicken			
Goat			
Pig			
Sheep			
Buffalo			

Breed diversity hotspots

FAO, 2014

Constraints

- Costs
  - Prices are continually decreasing, but many applications are still "out of reach" for many countries
- Data
  - Genomic selection procedures rely on bank of phenotypic data
  - Cannot easily use data from other populations
    - Linkage phase
    - G x E
  - Data "overload"
- Ascertainment bias
  - Incorrect estimates of genetic variability

Conclusions

- Genomics can be a powerful tool in management of AnGR
  - abundance and precision of data will only increase
  - New standards (SNP, full genome sequencing?)
- Technology can not solve all problems
  - Avoid raising false hopes
  - Raise awareness on importance of non-genomic data
  - Need phenotypes
- Gap in capacity for developing countries

Recommendations

- Reach consensus on diversity measure
  - "Balanced" approaches
- Improve characterization
  - molecular for estimation of diversity
  - phenotypic for consideration of other information
  - Carrier of specific alleles (adaptedness, disease-resistance, selection signatures….)
- Improve population monitoring
  - identify breeds at risk or of specific value (unique traits)
  - Link of breeds with production systems
- Continued and increased international collaboration and capacity building

Promoting diversity