Agroforestry: key to the development challenge

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Who are we?

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

- One of the 15 CGIAR research centres
- employing about 500 scientists and other staff.
- We generate knowledge about the diverse roles that trees play in agricultural landscapes
- We use this research to advance policies and practices that benefit the poor and the environment.

Six Science Domains

- SD1 – Agroforestry Systems
- SD2 – Tree Products and Markets
- SD3 – Tree Diversity, Domestication and Delivery
- SD4 – Land Health and Management
- SD5 – Environmental Services
- SD6 – Climate Change

Our regional research nodes

We seek answers to this challenge:

"by 2050, we need to…

- *Double world food production on ~ the same amount of land*
- *Make farms, fields and landscapes more resistant to extreme weather, while…*
- *… massively reducing GHG emissions."*

Our core business

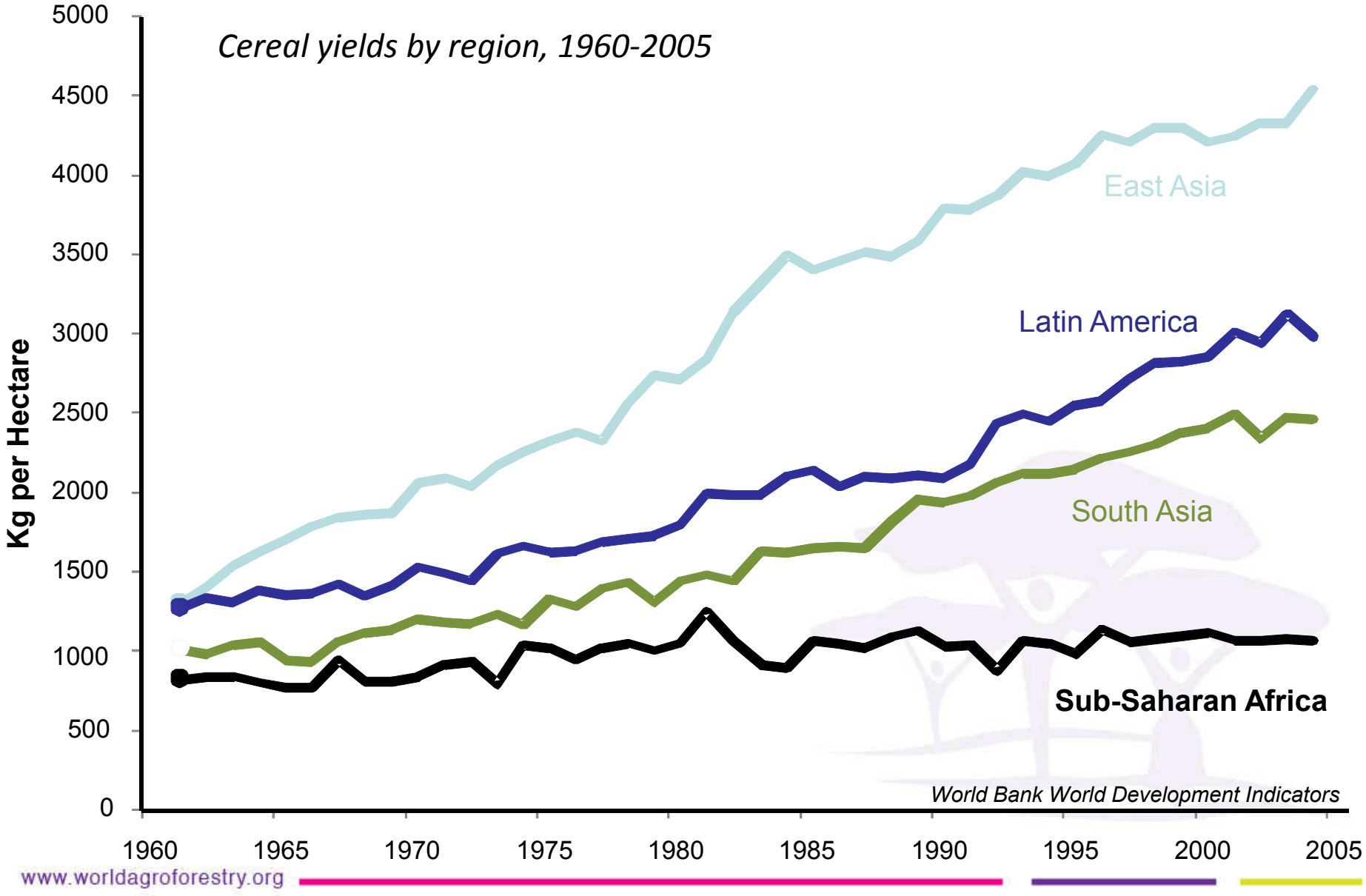
malnutrition

/malnjʊˈtrɪʃ(ə)n/

noun

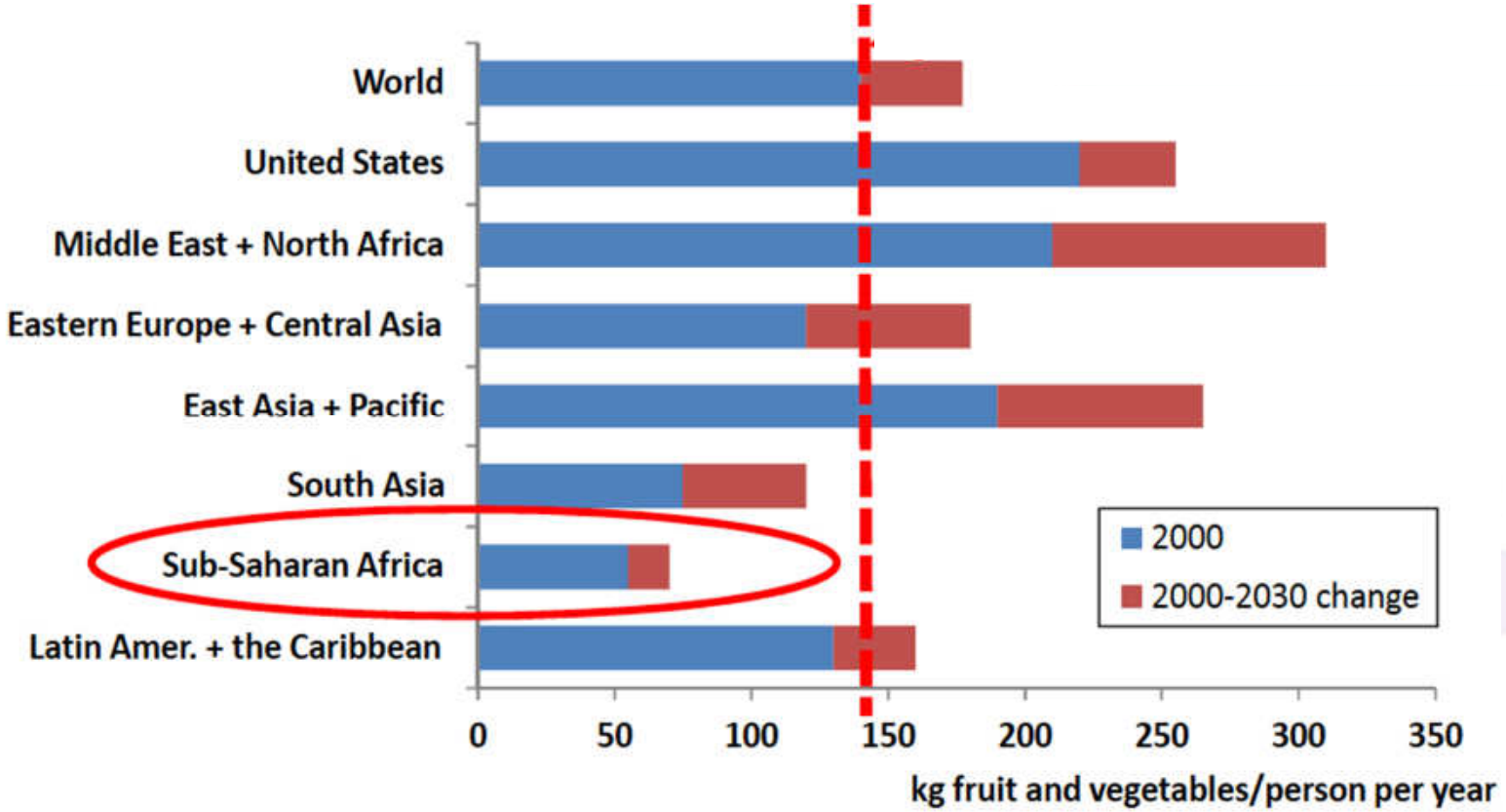
lack of proper nutrition, caused by not having enough to eat, not eating enough of the right things, or being unable to use the food that one does eat.
"over 40,000 children die every day from malnutrition and disease"
synonyms: undernourishment, malnourishment, poor diet, inadequate diet, unhealthy diet, lack of food, inanition; More

Malnutrition means not enough calories…



… and a lack of micronutrients

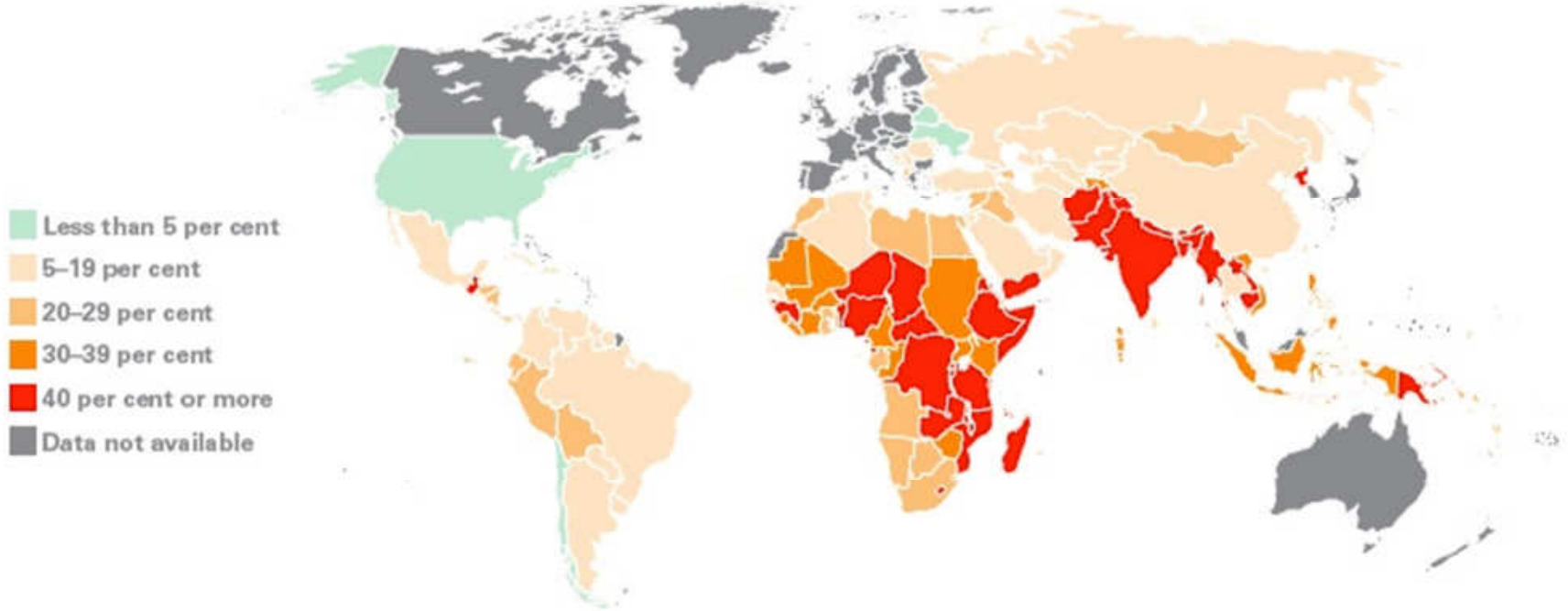
Fruit & veg consumption



Modified after: Msangi and Rosegrant 2011. Feeding the Future's Changing Diets.

Global stunting prevalence

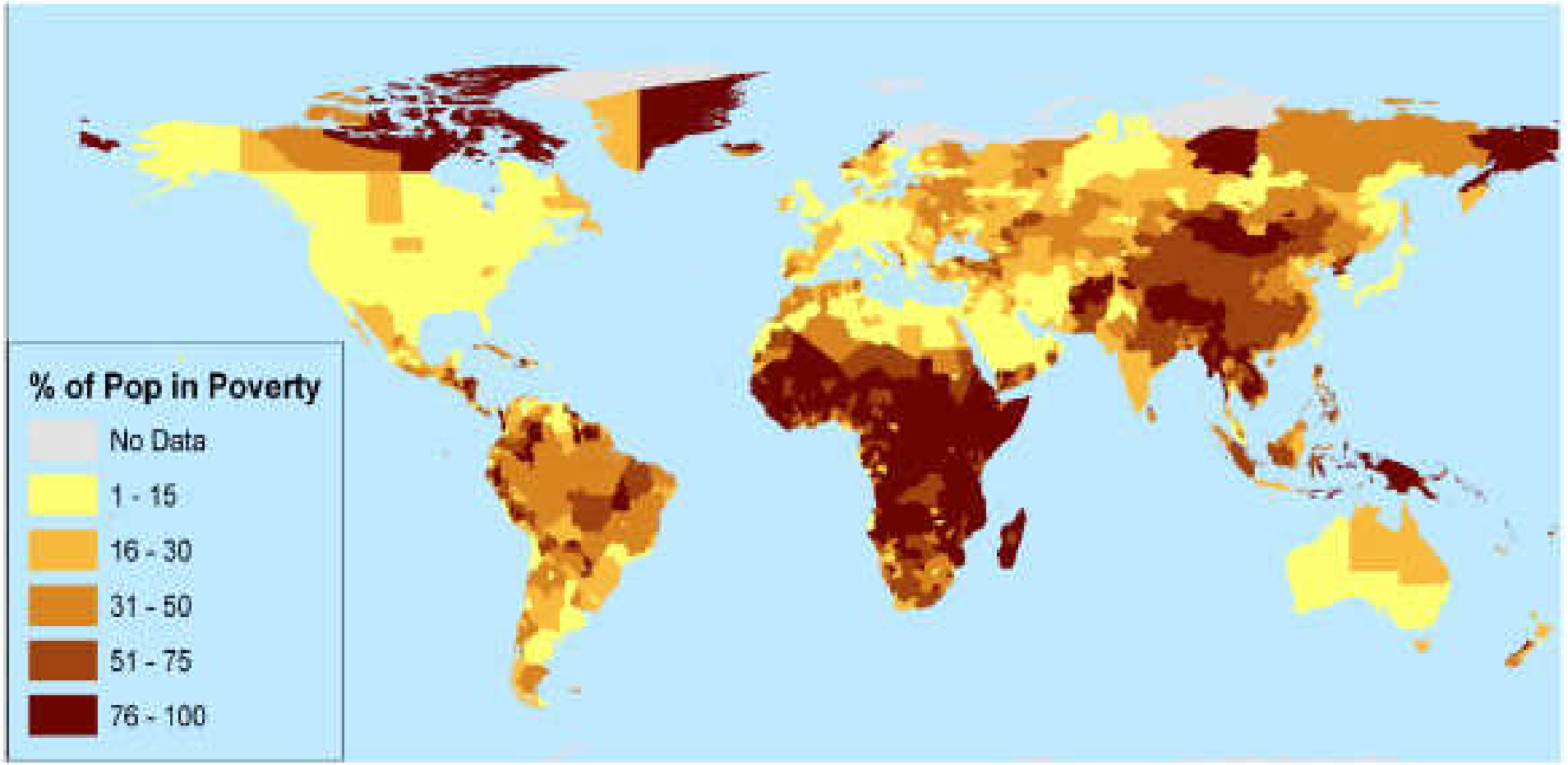
Percentage of children under 5 years old who are moderately or severely stunted



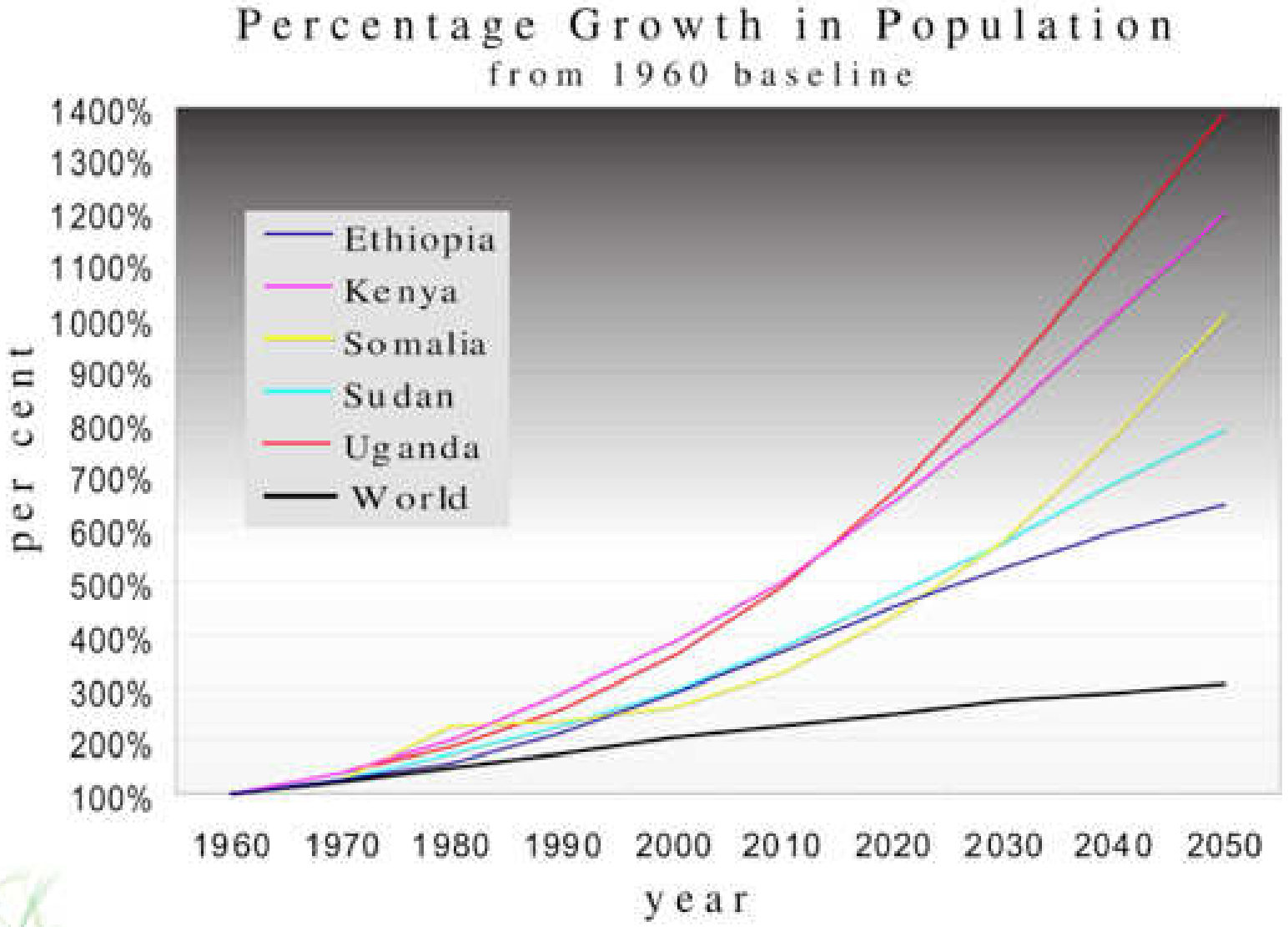
Notes for all maps in this publication: The maps in this publication are stylized and not to scale. They do not reflect a position by UNICEF on the legal status of any country or territory or the delimitation of any frontiers. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. For detailed notes on the map data, see page 42.

Sources for both maps on this page: MICS, DHS and other national surveys, 2003–2008.

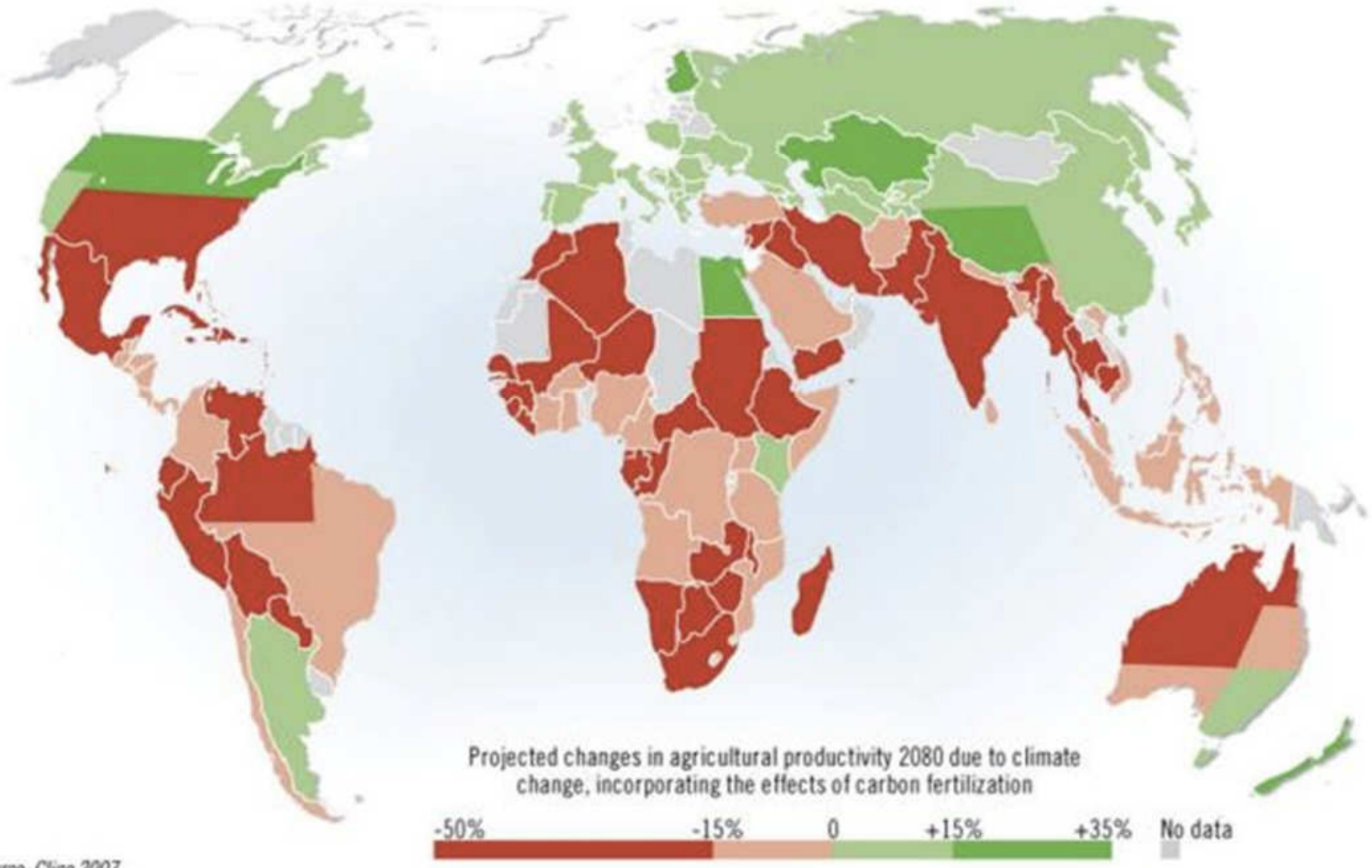
Poverty rates by administrative region



Selected population growth rates



PROJECTED CHANGES IN AGRICULTURE IN 2080 DUE TO CLIMATE CHANGE



Source: Cline 2007

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Changing these graphs is why we get out of bed in the morning.

~~Three~~ Four 2050 challenges:

- Produce 60% more food on ~ the same amount of land
- **Deal with massive malnutrition**
- Make farms, fields and landscapes more resistant to climate change
- Massively reduce GHG emissions from land use.

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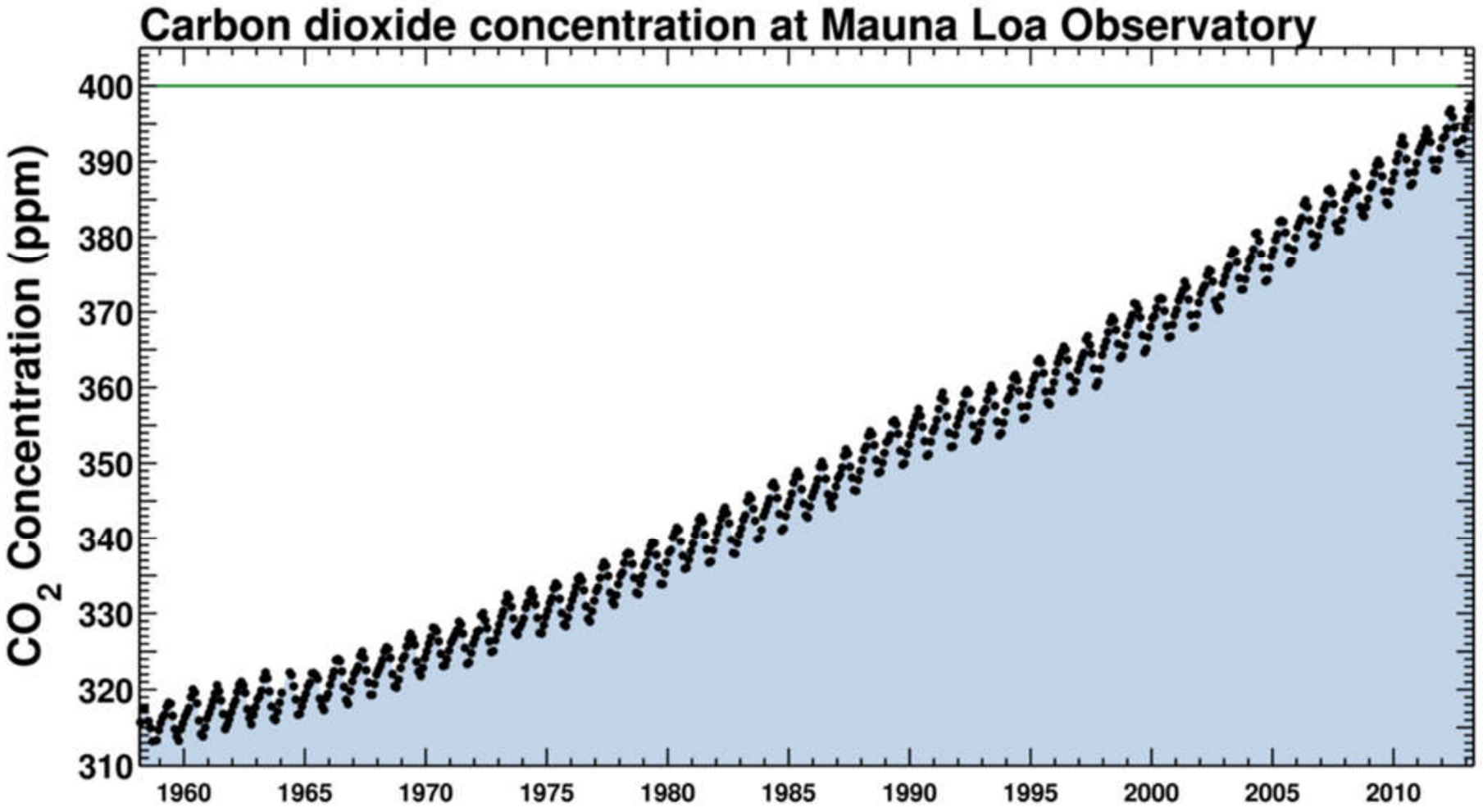
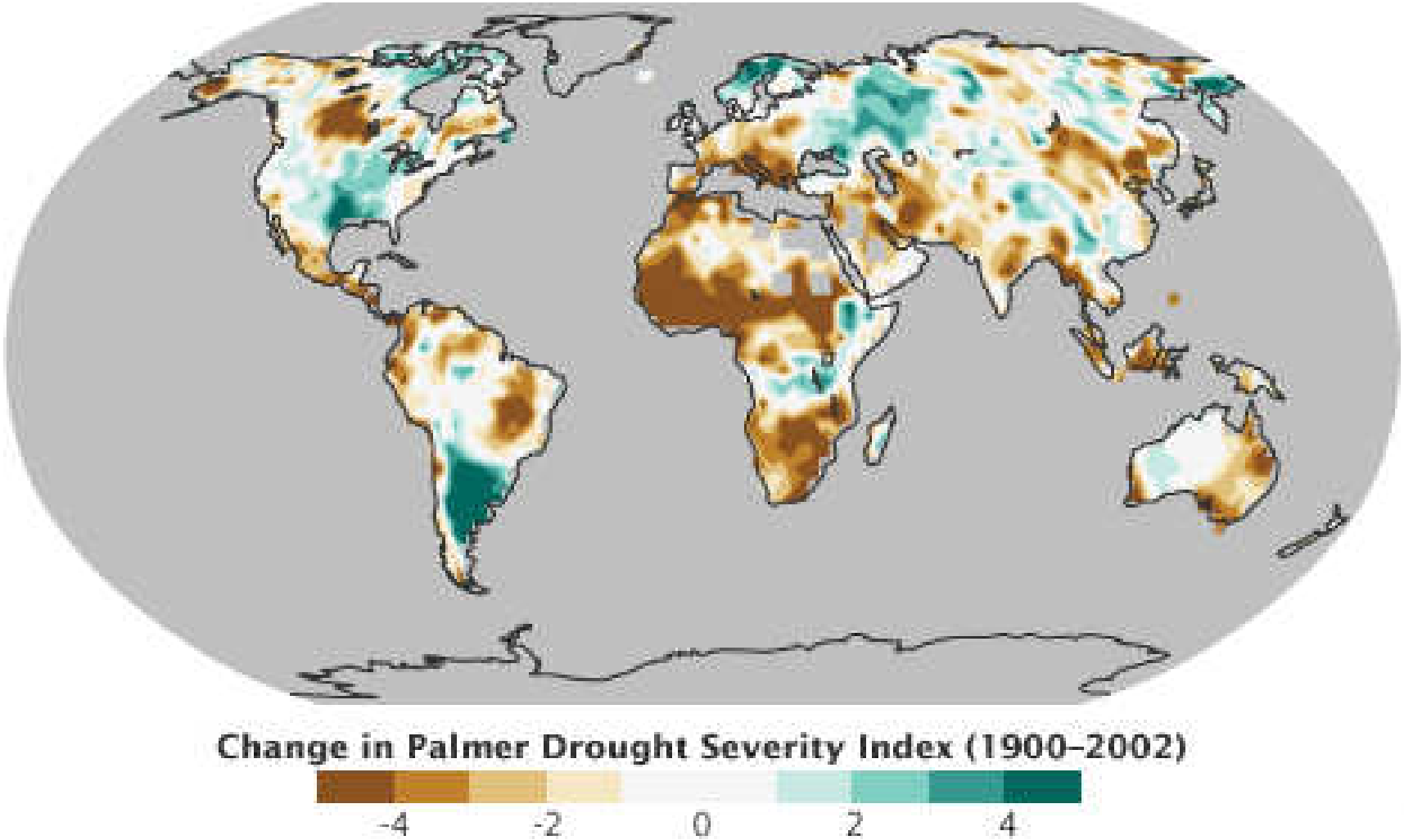
TRANSFORMING LIVES AND LANDSCAPES

Let’s spice things up a bit…

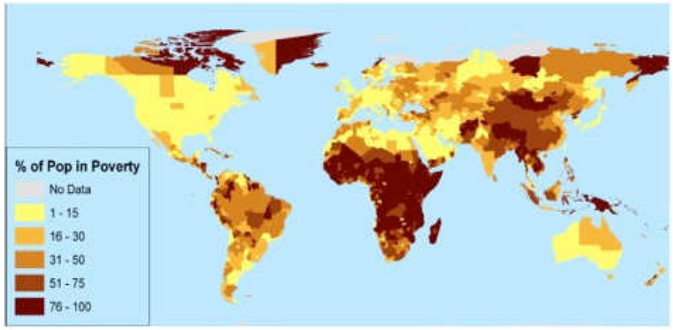

Carbon dioxide concentration at Mauna Loa Observatory
CO2 Concentration (ppm)
400
390
380
370
360
350
340
330
320
310
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

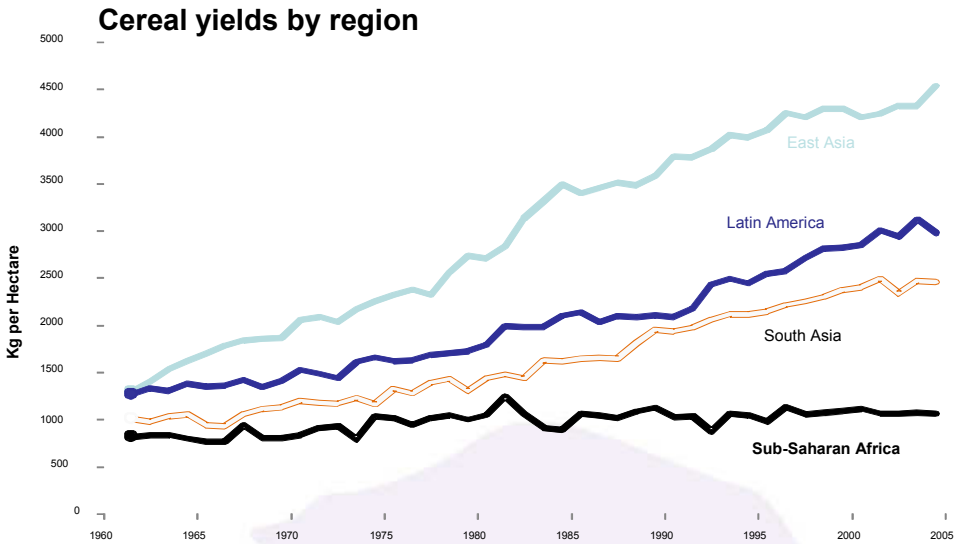
That is (probably) linked to...

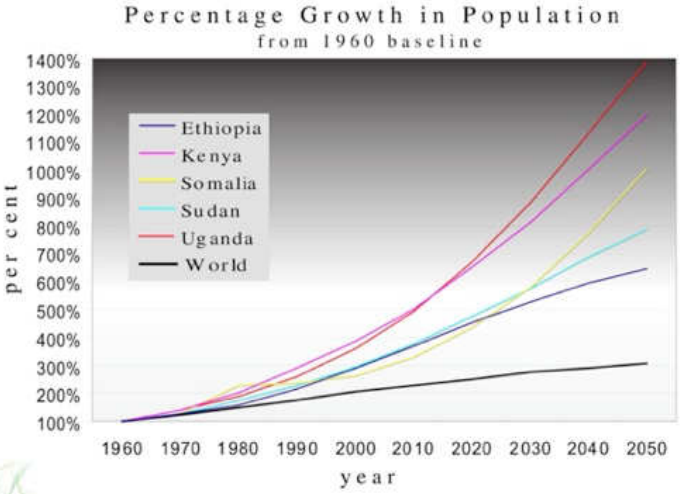


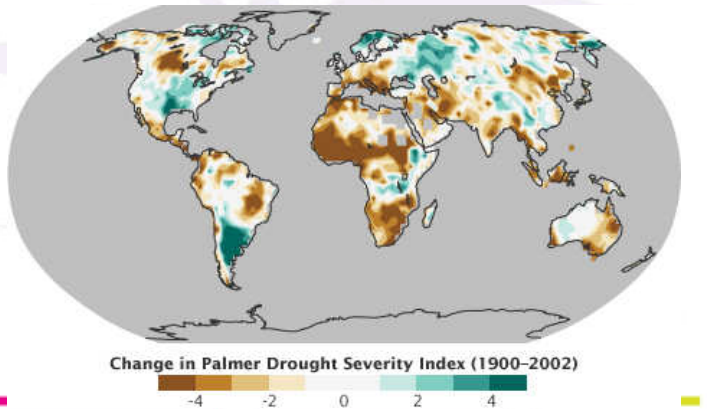
IPCC 4th assessement report

All these factors….

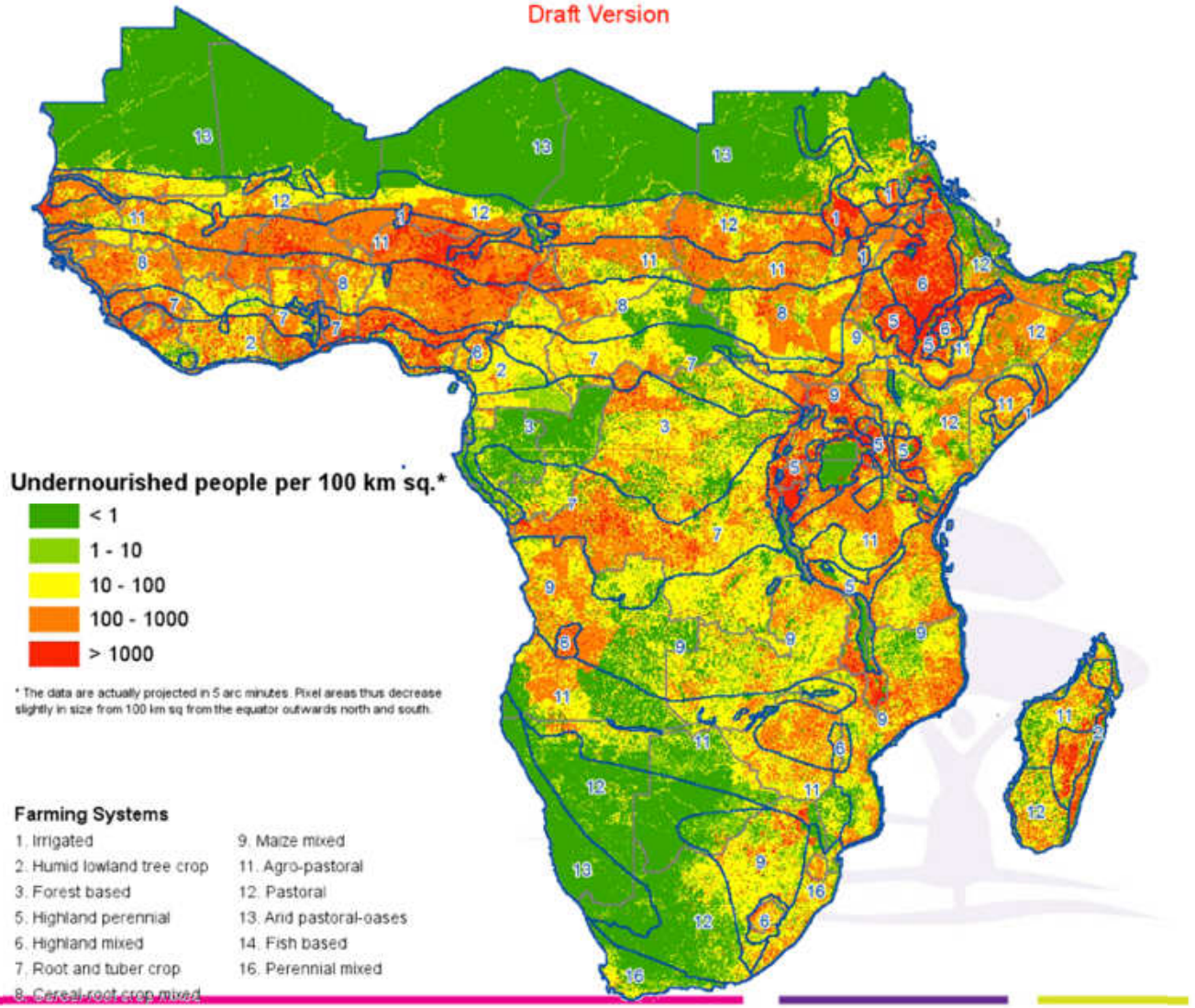




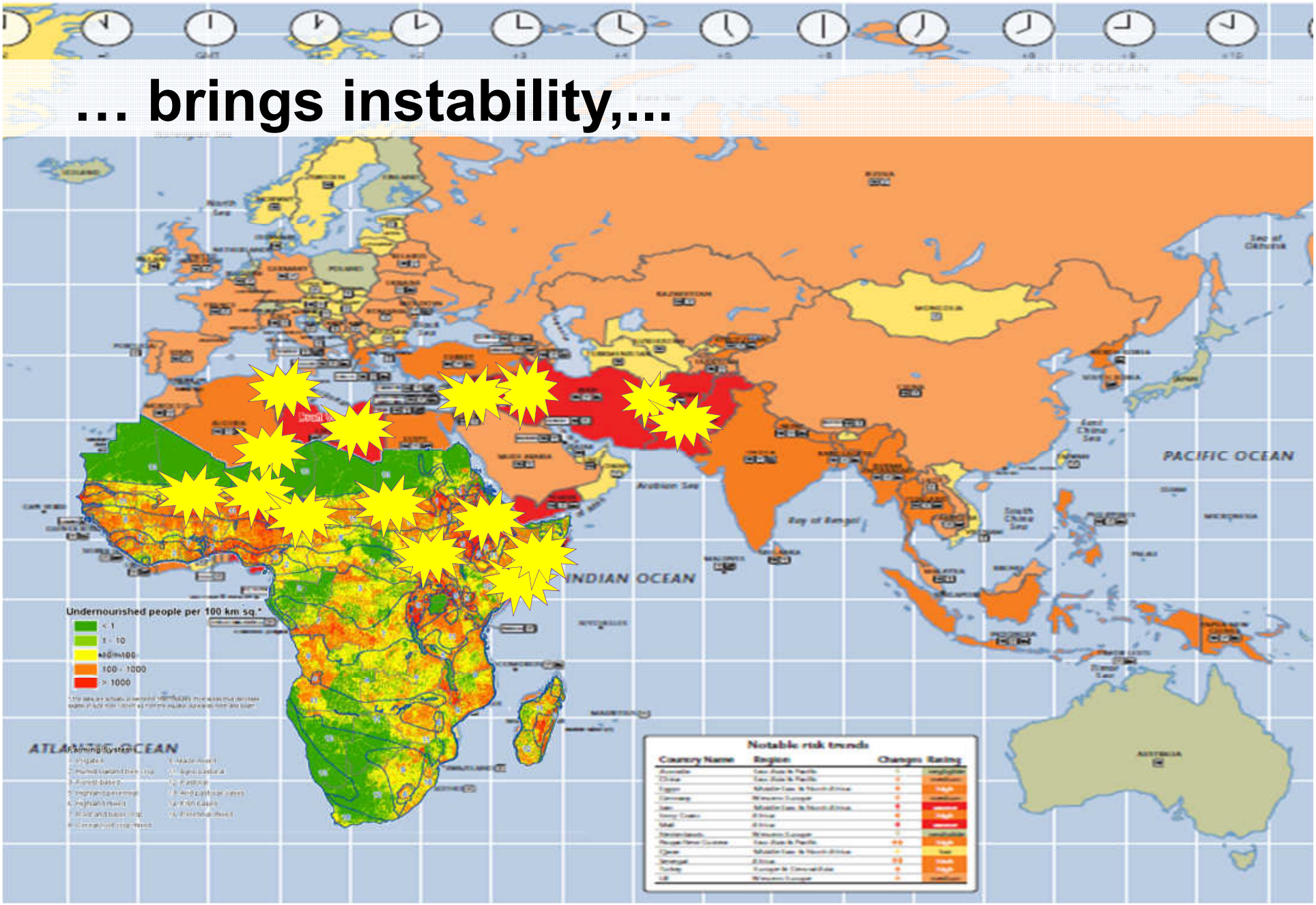




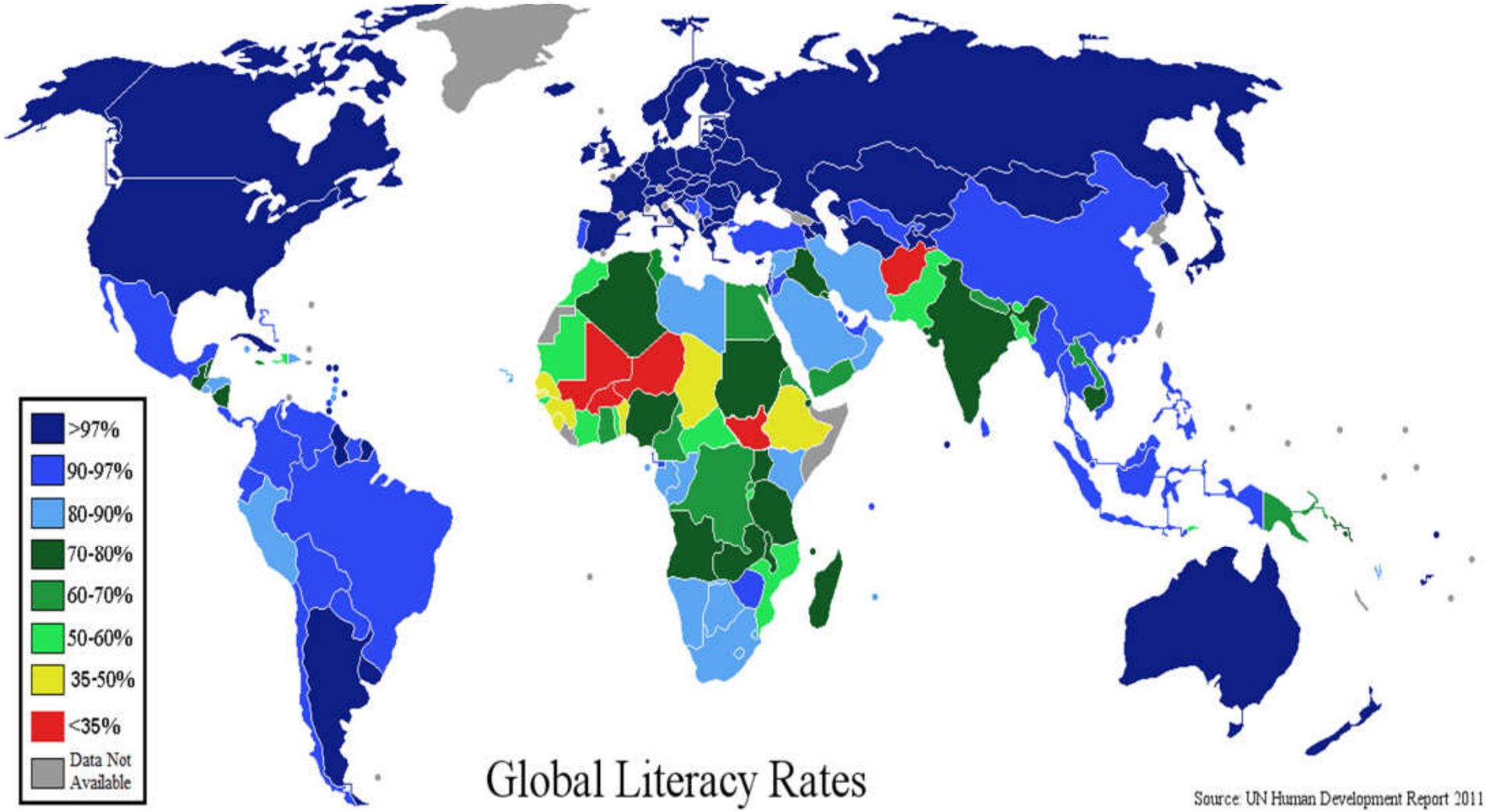
…lead to undernourishment, which...



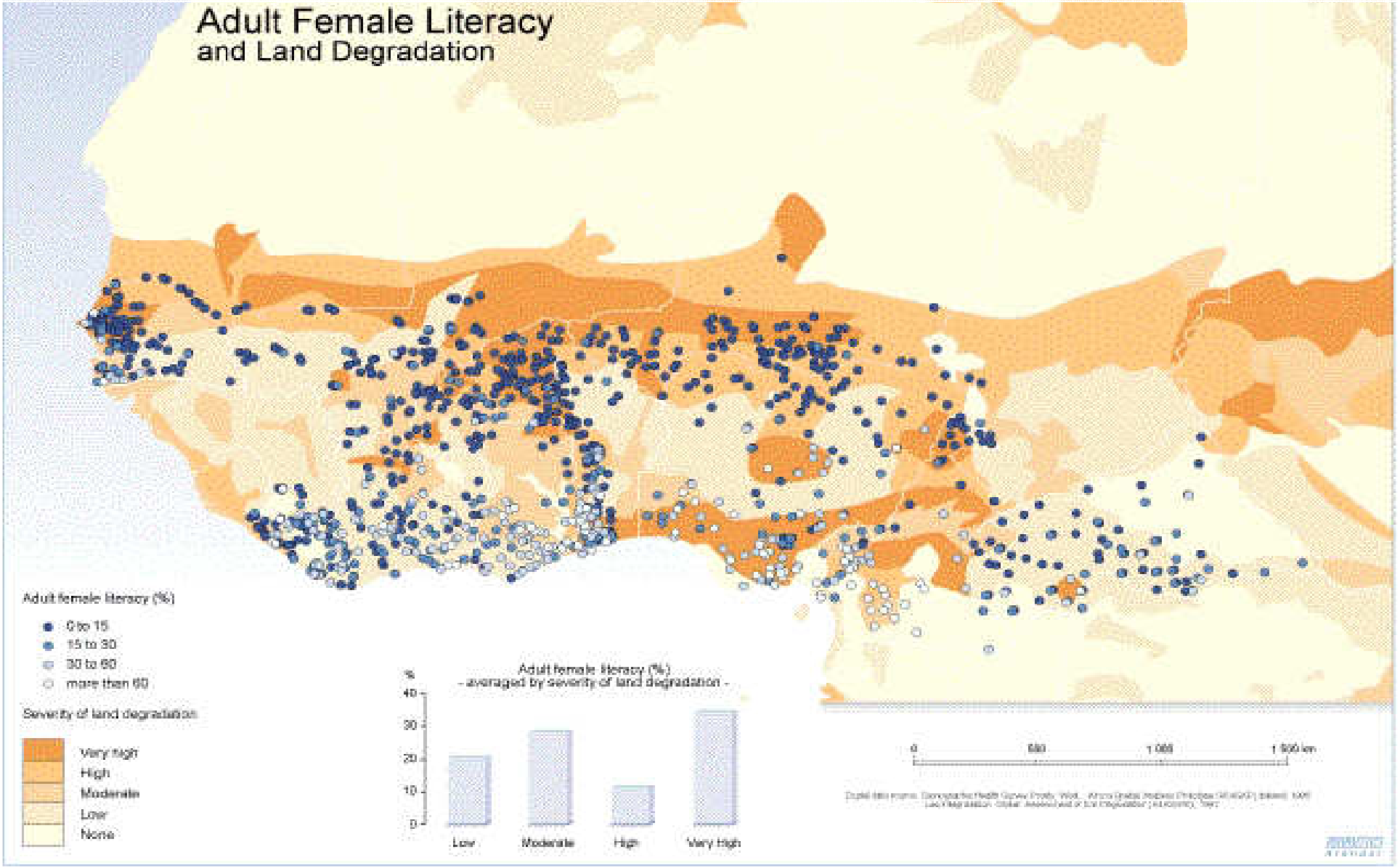
… brings instability,...



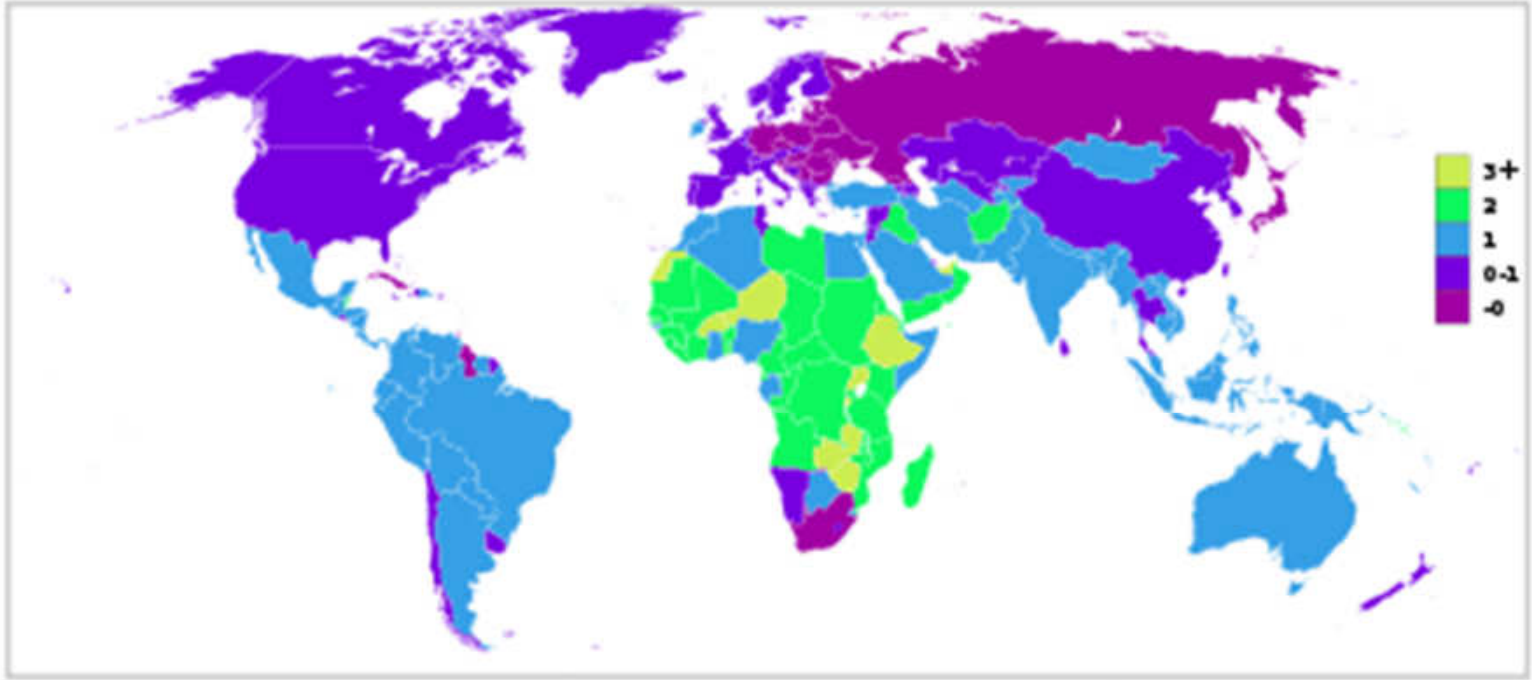
…low literacy...



…(especially among women)...

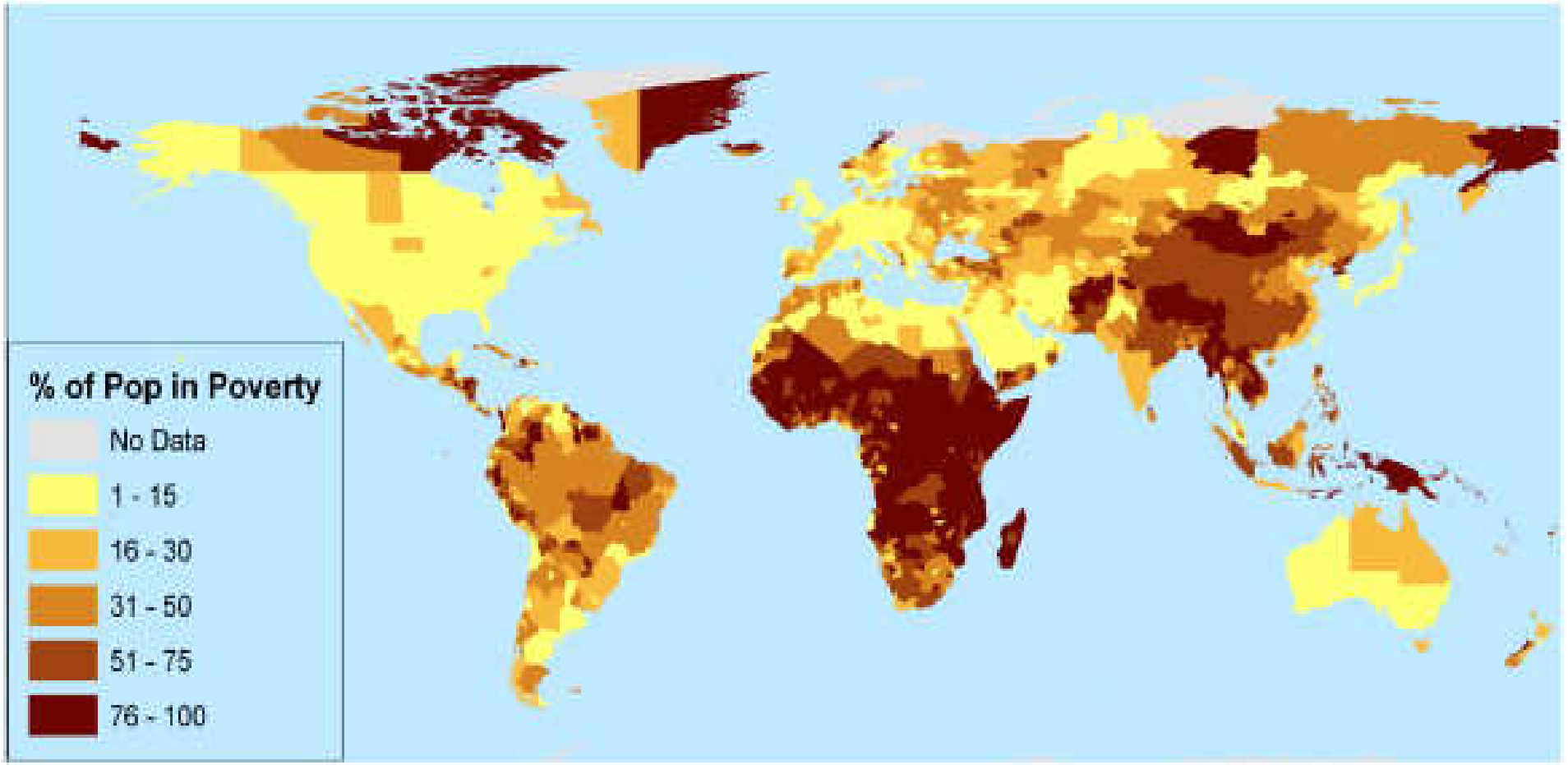


…thus huge population growth rates...

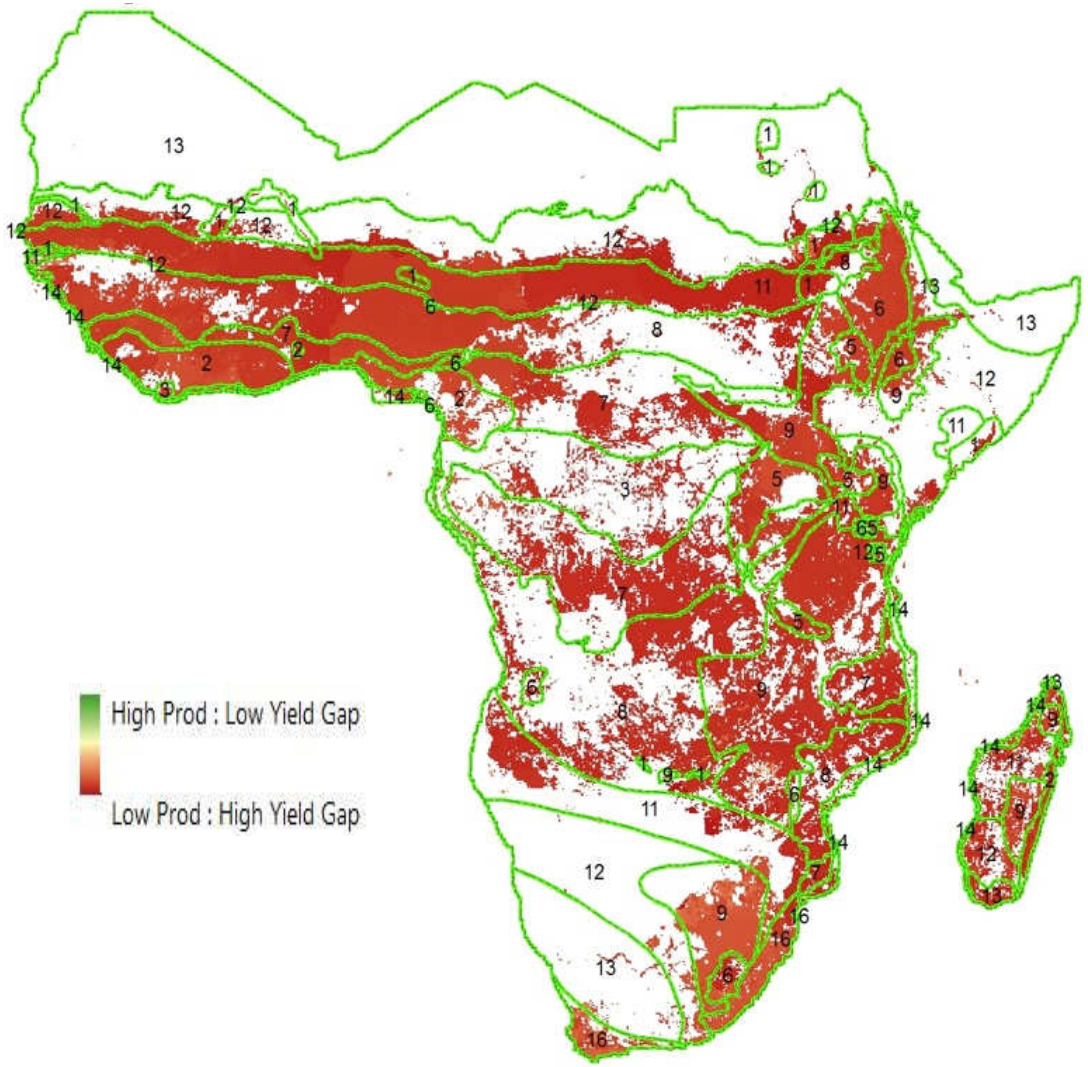


Annual population growth rate in percent, as listed in the CIA World Factbook (2011 estimate).[5]

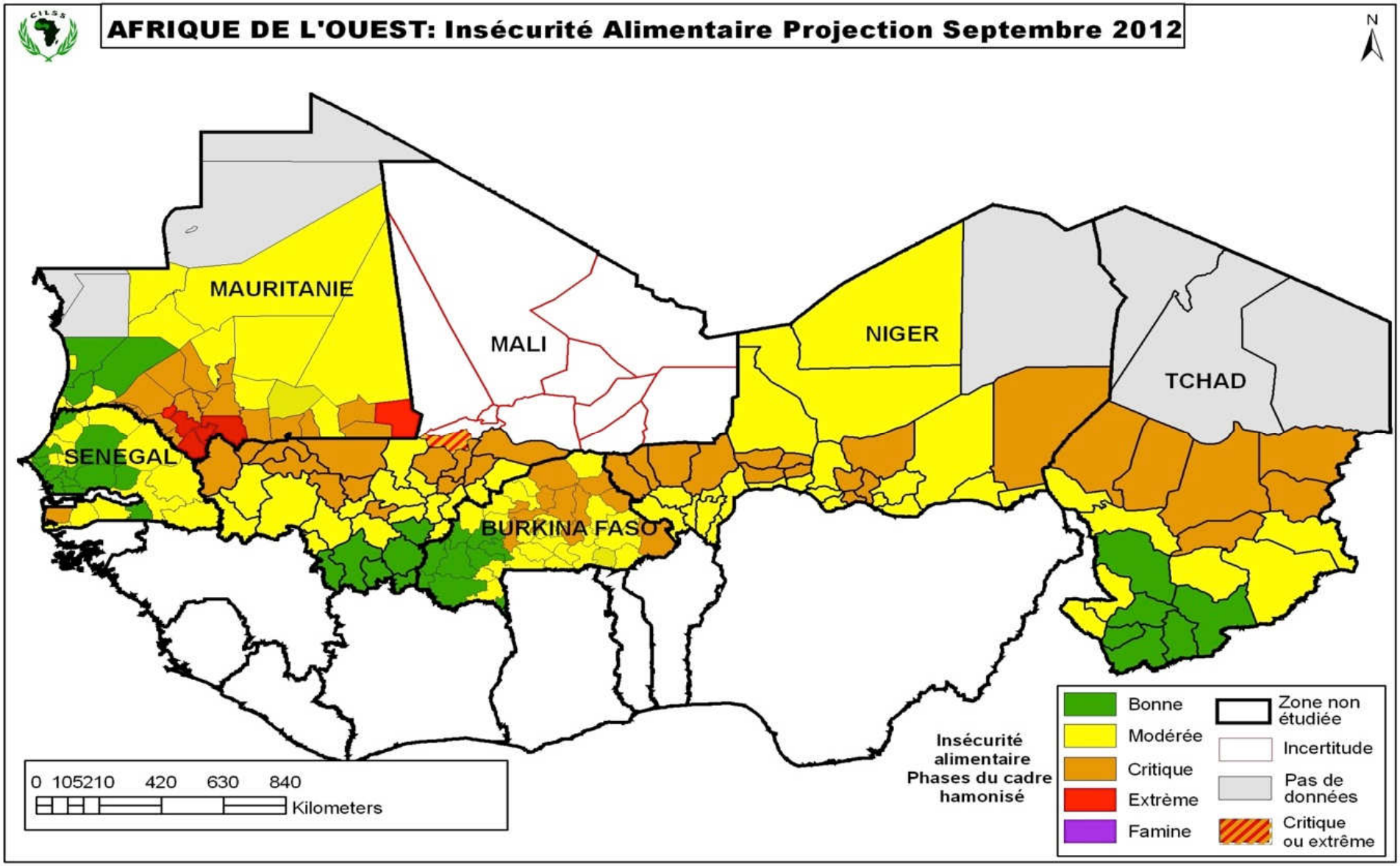
… and deep poverty ...



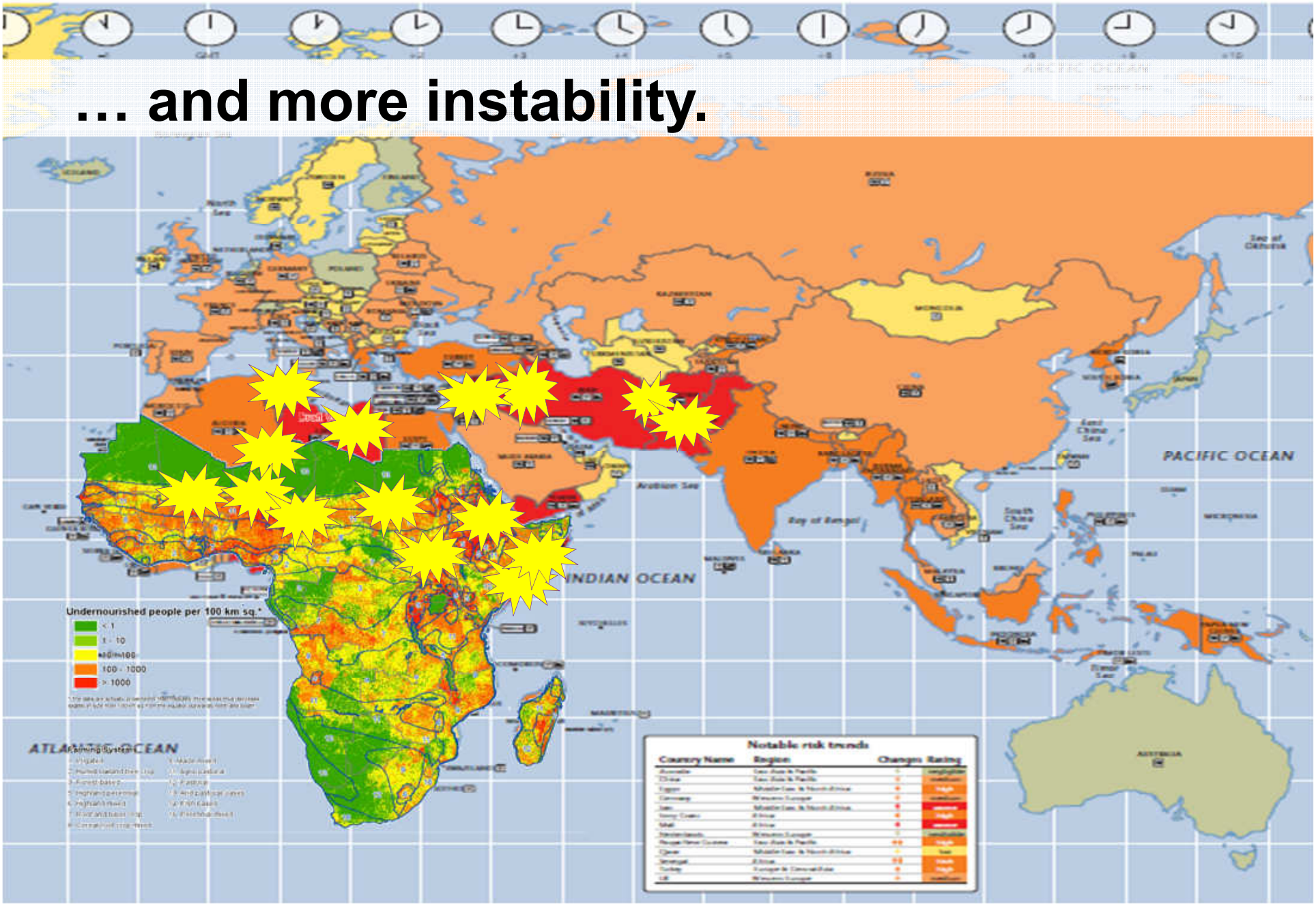
… hence huge yield gaps…



… and thus hunger.



… and more instability.



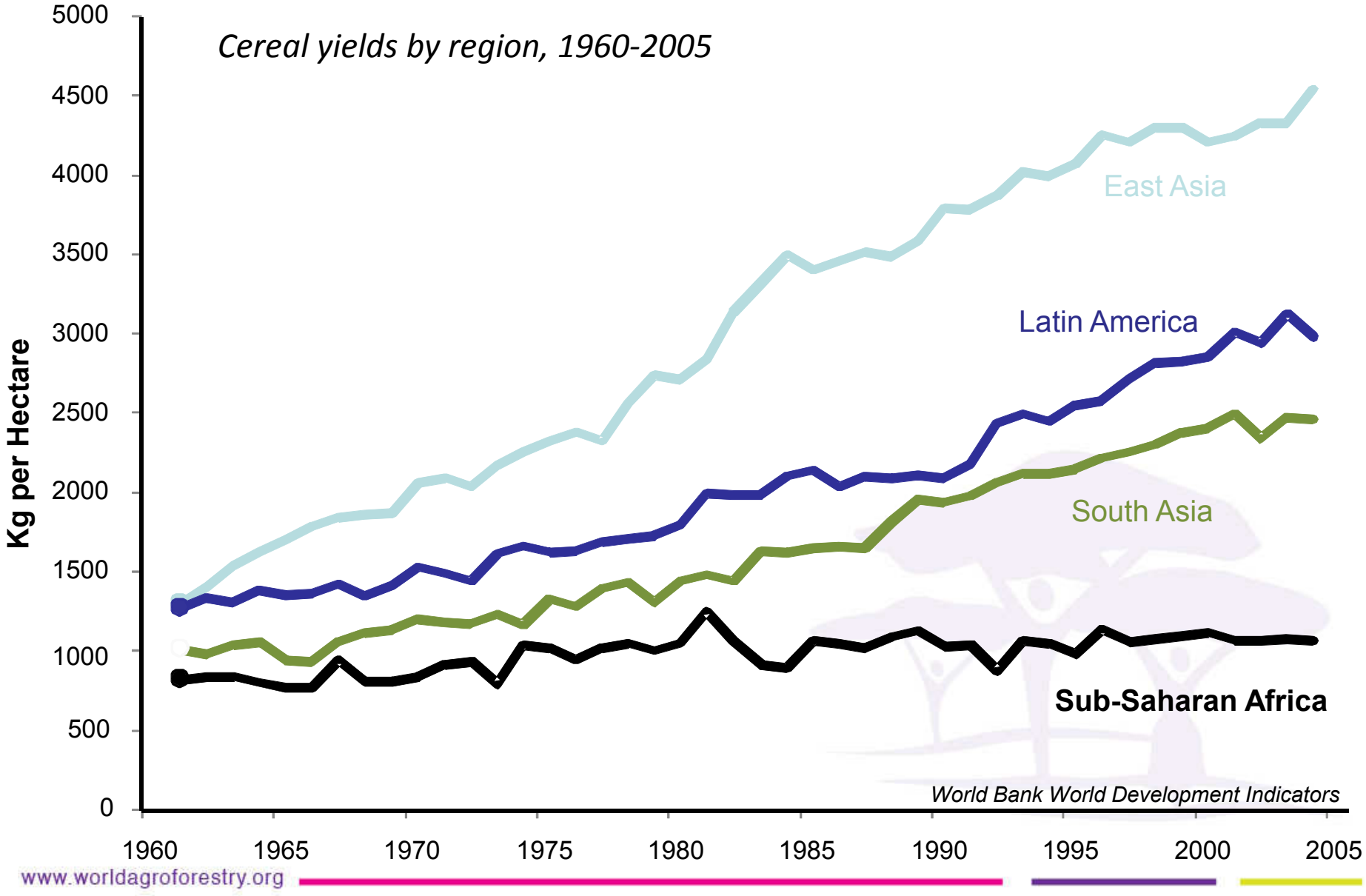
Oh, and lest we forget…

Africa is gigahumongonormous!.

Do we still want to get out of bed?

Yes. Here’s why.

First issue: yields.



African farm facts

- Population growth has rendered fallowing impossible in many communities
- Land overuse is depleting soil organic matter, soil carbon and soil microbiology
- Consequently, across drylands Africa, soil fertility is dropping by 10-15% a year *(Bunch, 2011)*
-

Where will soil fertility, soil organic matter and extreme weather resilience come from ?

From this ?

Two problems: first…

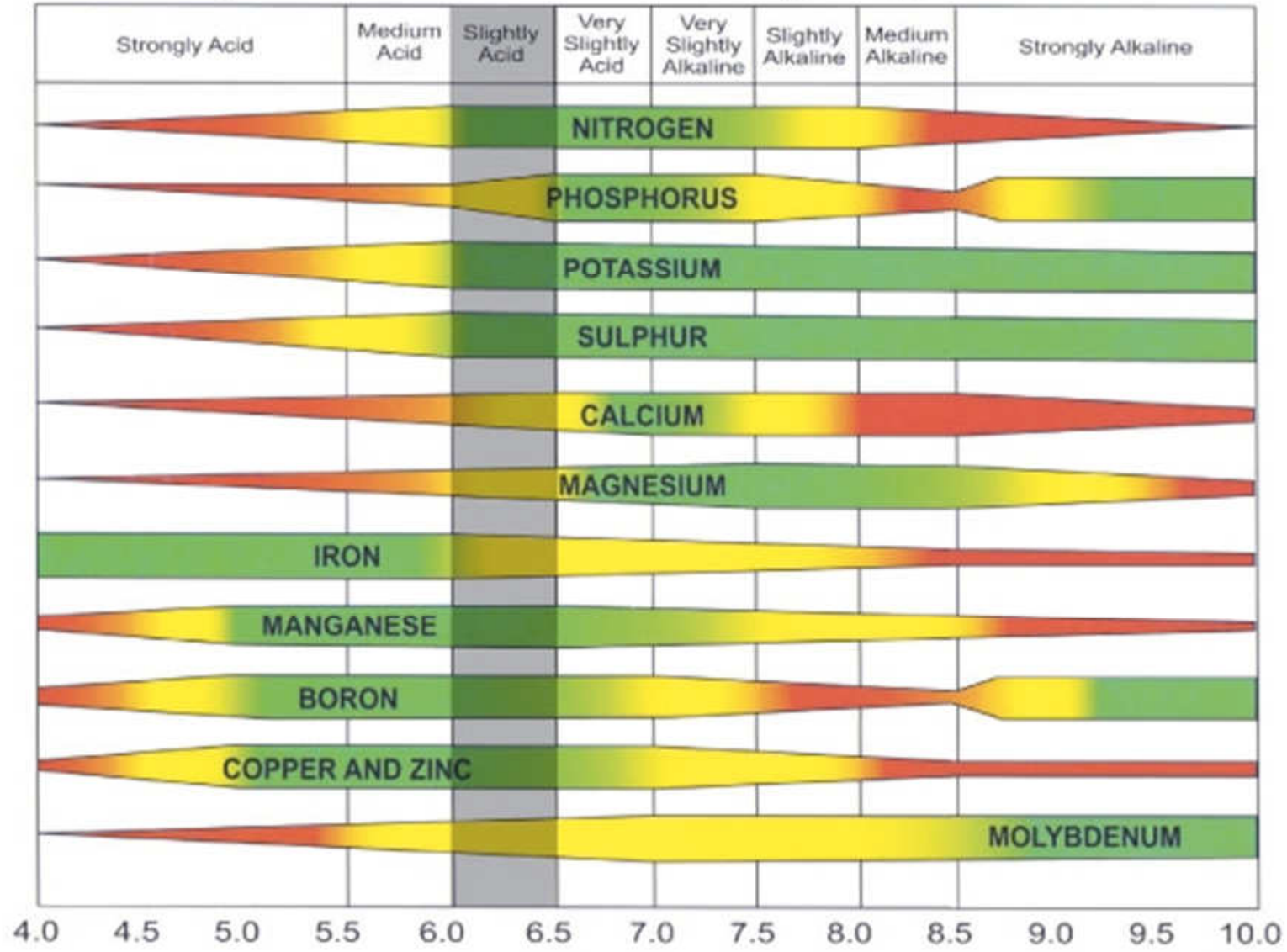
Fertilizers with High Ammonium Content Acidify Soils

- Soil bacteria oxidize ammonium (NH_4^+) to nitrate (NO_3^-) - ***Nitrification***

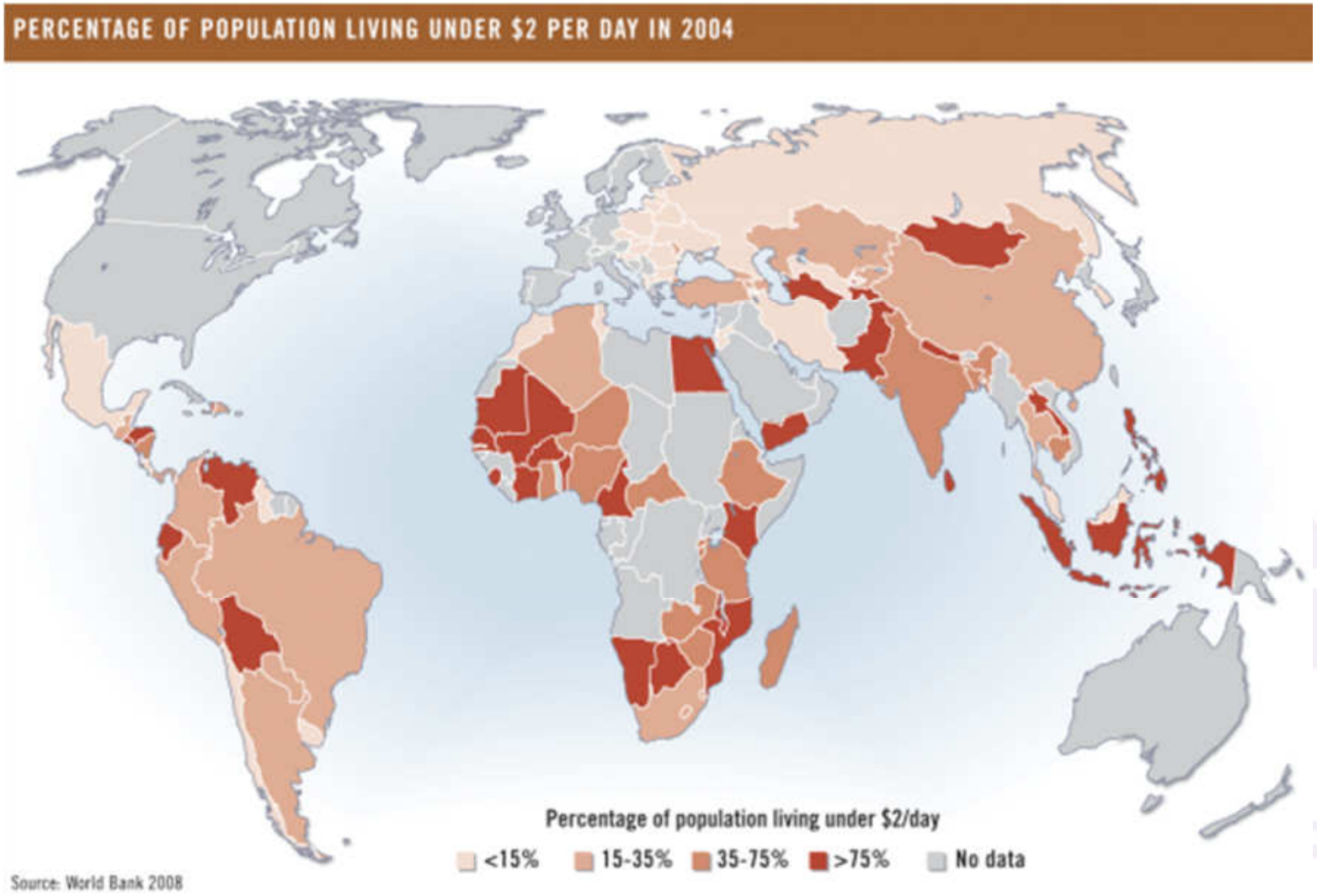
- The process produces two hydrogen ions (H^+)

$$NH_4 + 2\,O_2 \longrightarrow NO_3 + H_2O + 2H^+$$

How soil pH affects availability of plant nutrients



Second…


PERCENTAGE OF POPULATION LIVING UNDER $2 PER DAY IN 2004
Percentage of population living under $2/day
<15%
15-35%
35-75%
>75%
No data
Source: World Bank 2008

African farm facts

- Population growth has rendered fallowing impossible in many communities
- Land overuse is depleting soil organic matter, soil carbon and soil microbiology
- Consequently, across drylands Africa, soil fertility is dropping by 10-15% a year *(Bunch, 2011)*
- Deep poverty and logistical bottlenecks makes fertiliser unaffordable for most
- Funding for fertiliser subsidies is scarce and fickle

Where will soil fertility, soil organic matter and extreme weather resilience come from ?

From trees.

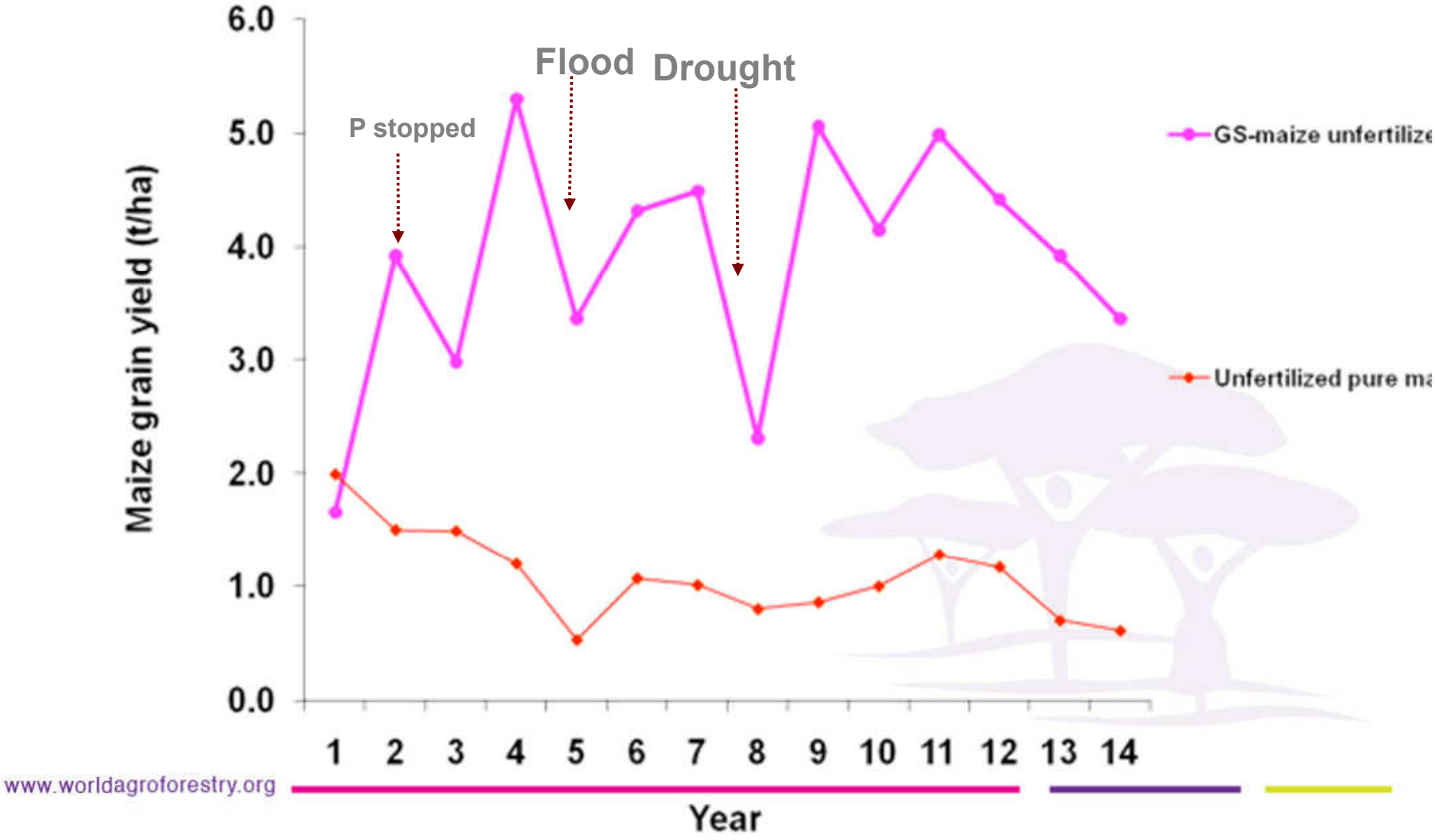
Faidherbia Albida in teff crop system in Ethiopia

Impact of fertilizer trees on maize yield under farmer management

	maize yield (t/ha)
Maize only	1.30
Maize + fertilizer trees	3.05

2011 Survey of farms in six Malawi districts (Mzimba, Lilongwe, Mulanje, Salima, Thyolo and Machinga)

Long-term maize yield without fertilizer in a *Gliricidia* system



Fertilizer trees perform better than NPK.

2009/2010 season; data from 6 Malawi districts

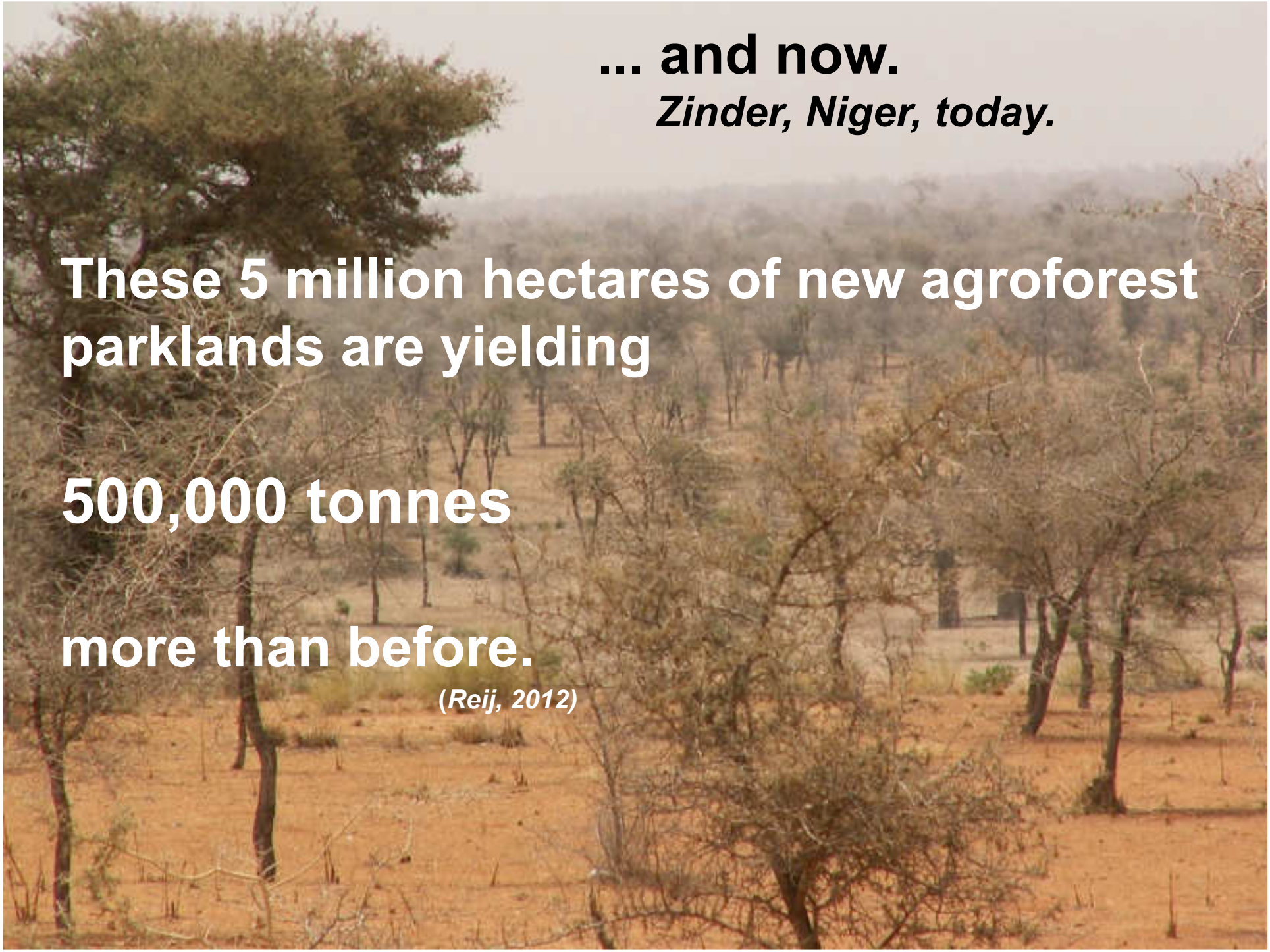
Plot management	Sampling Frequency	Mean (Kg/Ha)	Standard error
Maize without fertiliser	36	**1322**	220.33
Maize with fertiliser	213	**1736**	118.95
Maize with fertiliser trees	72	**3053**	359.8
Maize with fertiliser trees & fertiliser	135	**3071**	264.31

Mwalwanda, A.B., O. Ajayi, F.K. Akinnifesi, T. Beedy, Sileshi G, and G. Chiundu 2010

Farmer-Managed Natural Regeneration

Zinder, southern Niger in the 1980s

In FMNR, farmers will select the best shoots from trees regrowing naturally from stumps and eliminate the rest. This promotes the growth of vigorous new trees adapted to local conditions.


... and now.
Zinder, Niger, today.
These 5 million hectares of new agroforest parklands are yielding
500,000 tonnes
more than before.
(Reij, 2012)

Kantché district, Zinder, Niger

District of 350,000 people, with high tree on-field densities.
Rainfall averages ca. 350 mm per year, typical of Sahel drylands.

Annual district-wide grain surplus:

2007	21,230 tons
2008	36,838 tons
2009	28,122 tons
2010	64,208 tons
2011	13,818 tons

Kantché produces grain surpluses even in drought years.

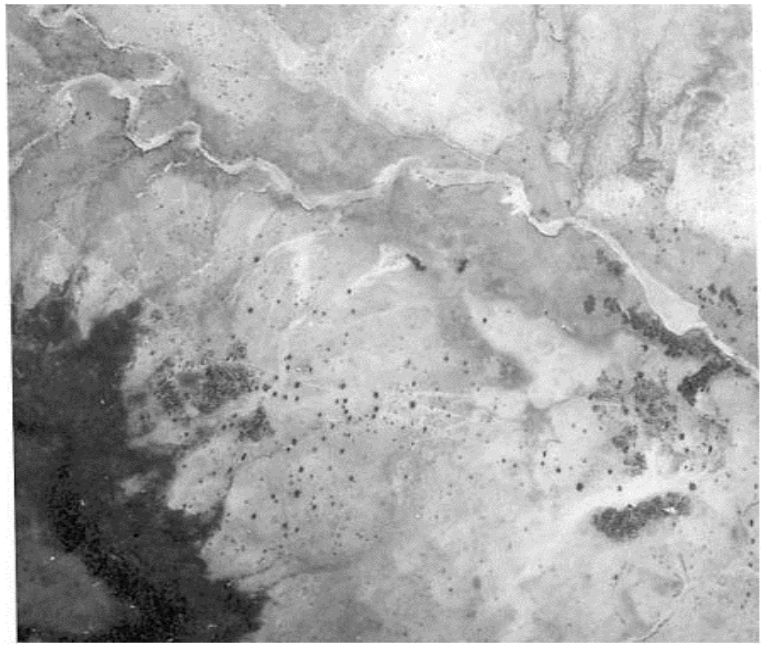
Yamba & Sambo, 2012

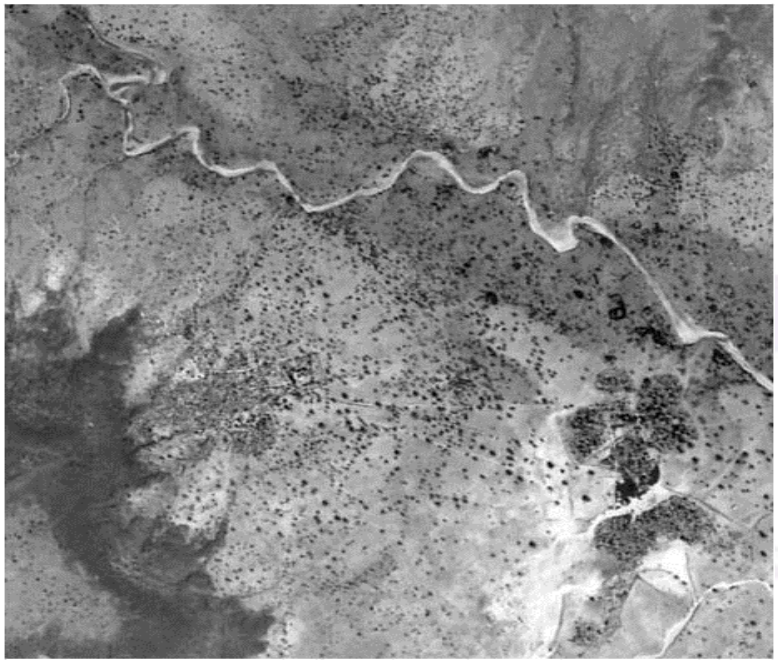
Impact of skills & expertise

Impact of Policy Changes

Restrictive forest codes in the Sahel were beginning to be relaxed in Niger so that trees planted or managed on farmers' fields could remain the property of the farmer and not revert to the government.

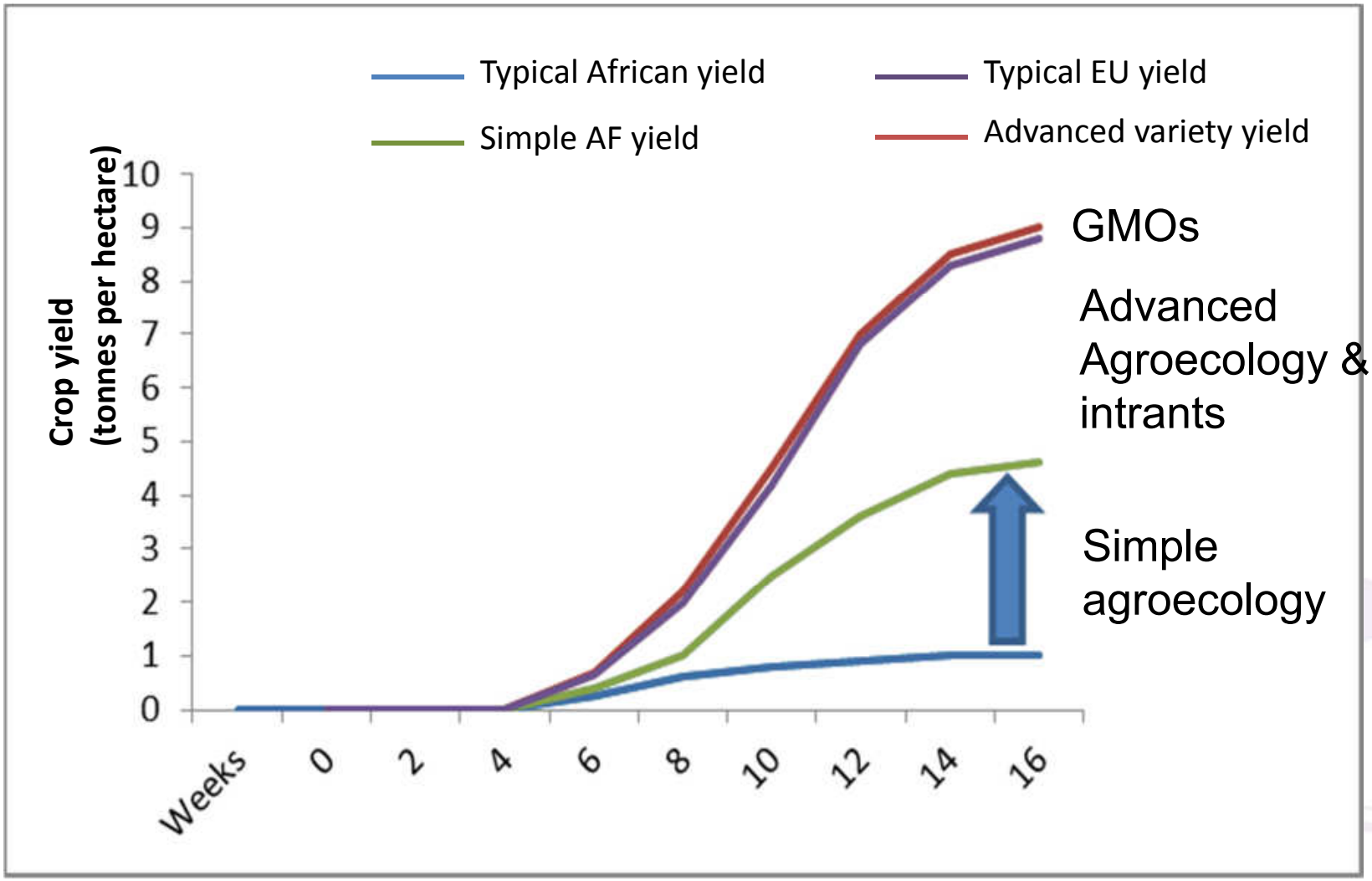
Galma, Niger **1975** **2003**



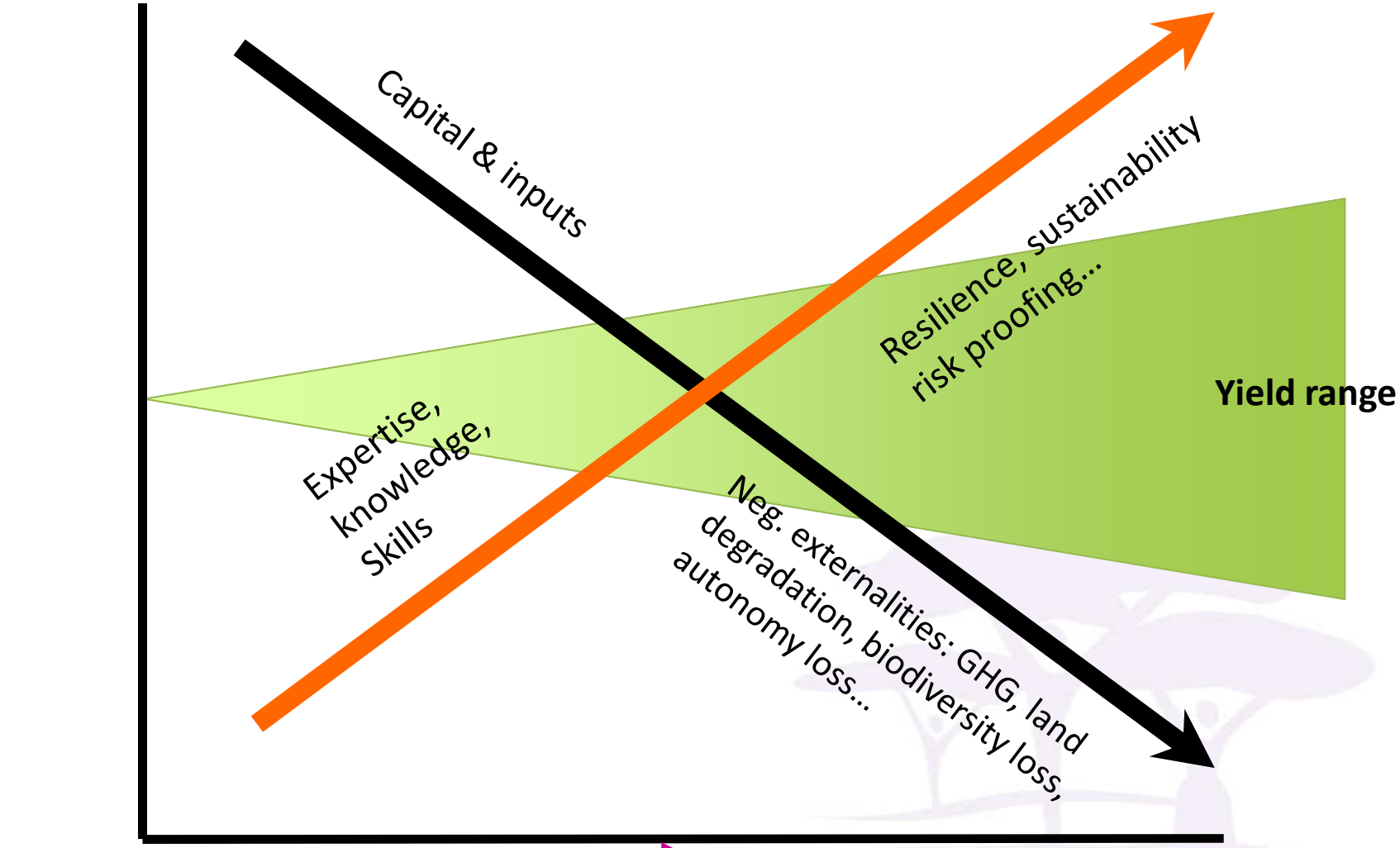


Source: World Vision Australia

The yield gap lesson



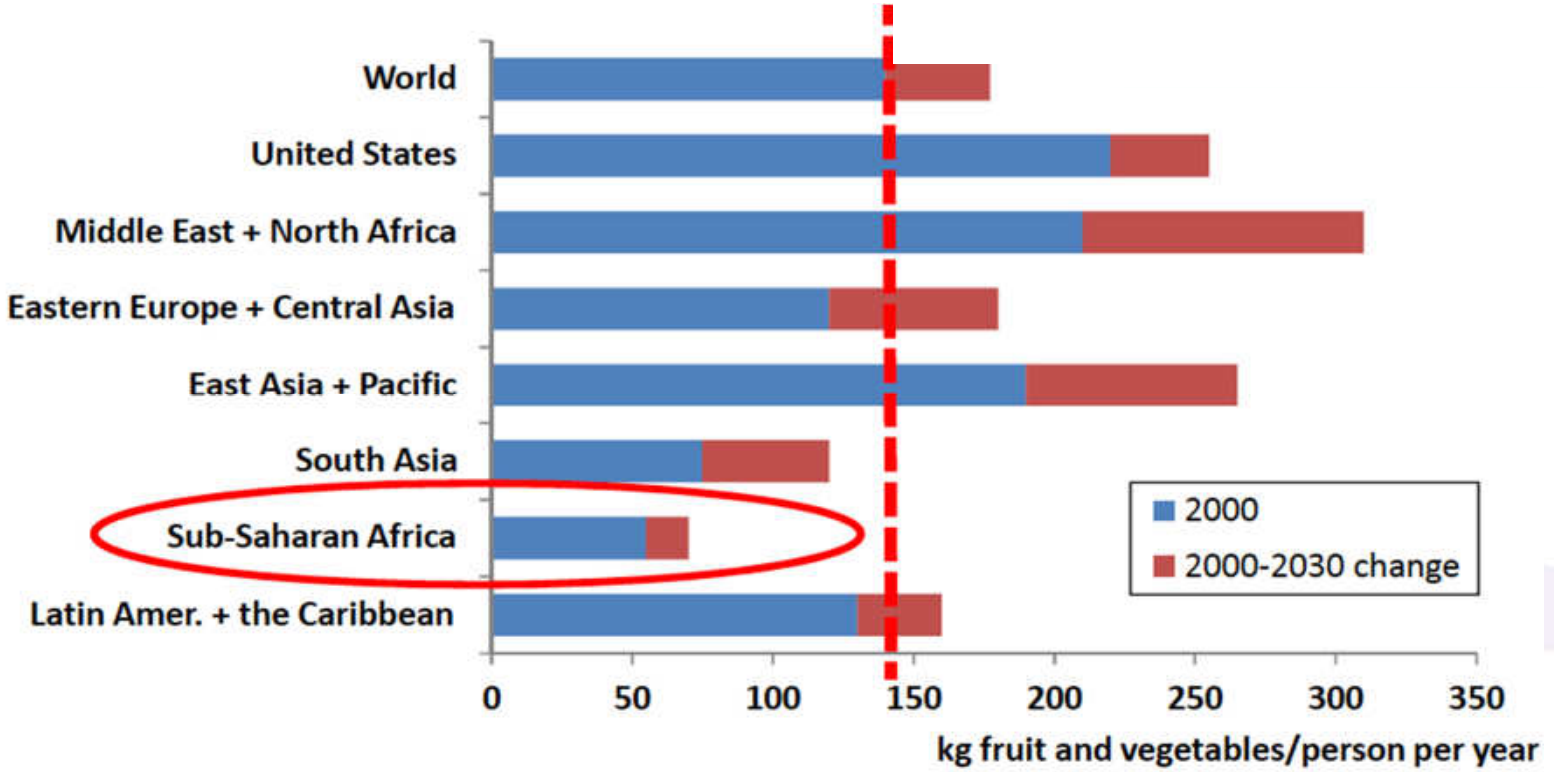
The transition to sustainability



Four 2050 challenges:

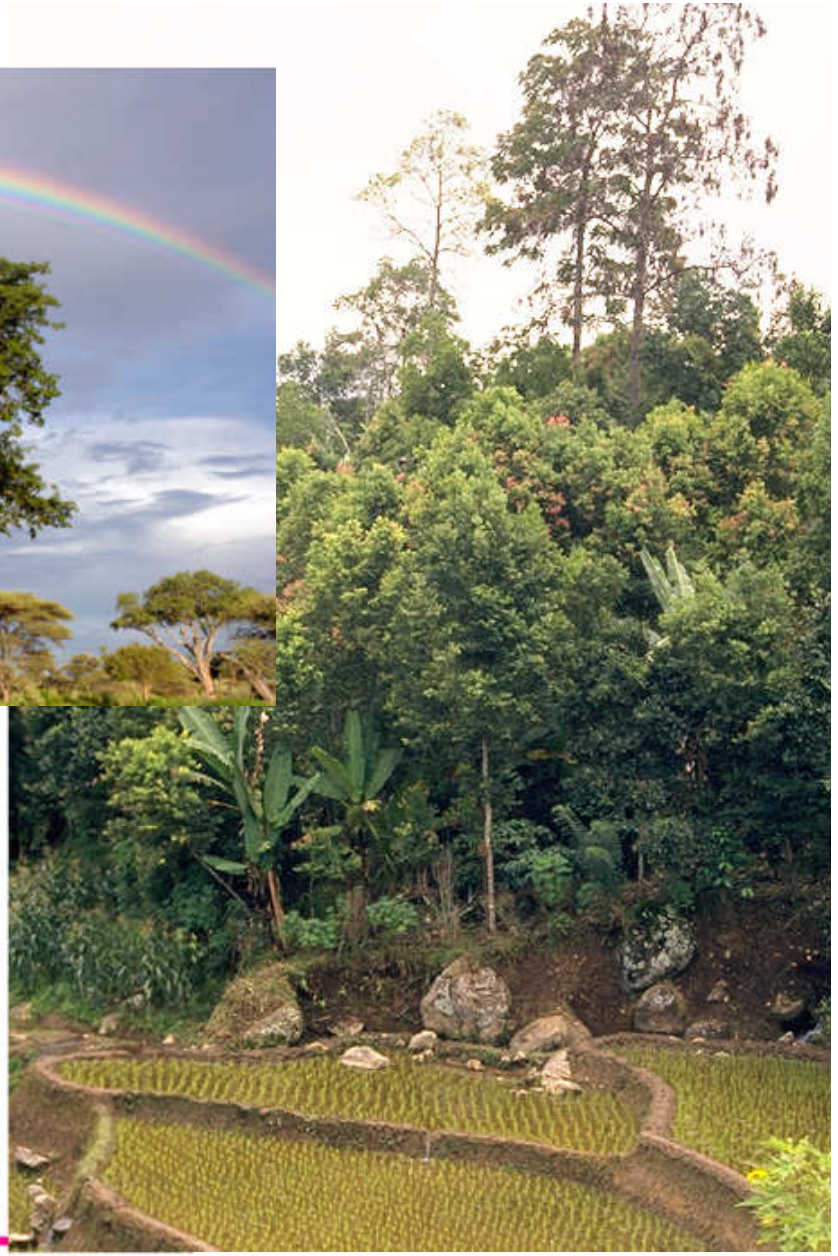
- ✔ Produce 60% more food on ~ the same amount of land
- Deal with massive malnutrition
- Make farms, fields and landscapes more resistant to climate change
- Massively reduce GHG emissions from land use.

Second issue. Where will micronutrients come from?



Modified after: Msangi and Rosegrant 2011. Feeding the Future's Changing Diets.

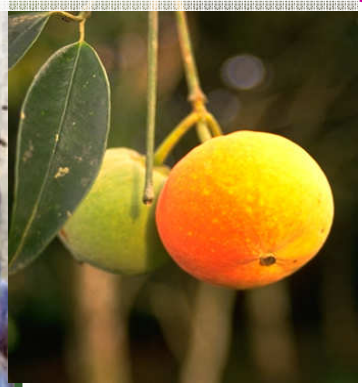
From trees, too.

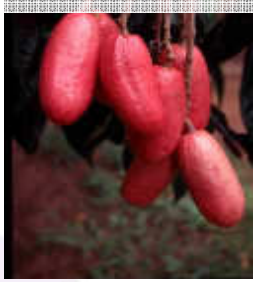


www.worldagroforestry.org



Indigenous trees.




Why? Because indigenous fruits beat exotics.

Species	Vit C (mg/100 g)	Vit A (mg/100 g)	Iron (mg/100 g)	Calcium (mg/100 g)
Adansonia digitata	150-500	0.03-0.06	1.7	360
Grewia tenax	N.A.	N.A.	7.4	610
Tamarindus indica	3-9	0.01-0.06	0.7	260
Ziziphus mauritiana	70-165	0.07	1.0	40
Mango	28	0.04	0.1	10
Orange	51	0.07	0.2	54

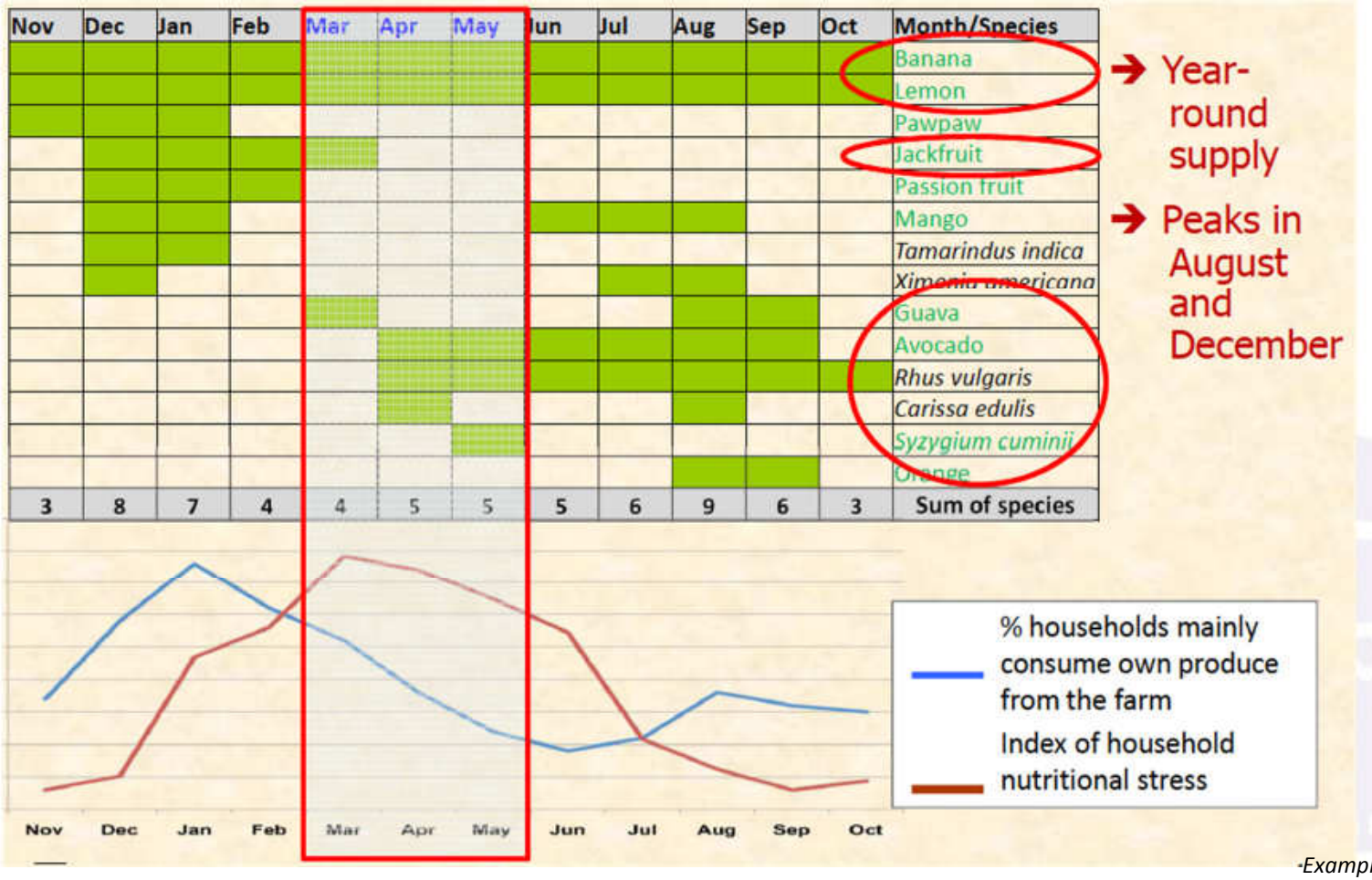
Sources: Freedman (1998) Famine foods. http://www.hort.purdue.edu/newcrop/FamineFoods; Fruits for the Future Series, ICUC; Fineli (http://www.fineli.fi/), etc.

They beat staples, too.

Species	*Dacroydes edulis* fruit (88% dm)	*Irvingia gabonensis* kernels (88% dm)	Maize grain (86% dm)	Rice grain	Cassava tuber (30-35%dm)
Carbohydrates	14	26-39	66-76	46-59	24-31
Fats/oils	**32**	**51-72**	**2-6**	**1-2**	**<1**
Protein	**26**	7.4	**5-14**	**4-8**	**1**
Fibre	**18**	1	**1-3**	**1-4**	**1-2**

in Leakey 1999, Food Chemistry 64, 1-14.

They can be harvested year round (here, in western Kenya...)



Example from western Kenya

… and in west and central Africa.

Tree species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Irvingia wombolu	■	■	■									■
Cola spp.			■	■	■	■	■	■	■			
Dacryodes edulis				■	■	■	■	■	■	■		
Garcina kola						■	■	■	■			
Irvingia gabonensis						■	■	■	■	■	■	
Ricinodendron heudelotii								■	■	■	■	

What trees, exactly?

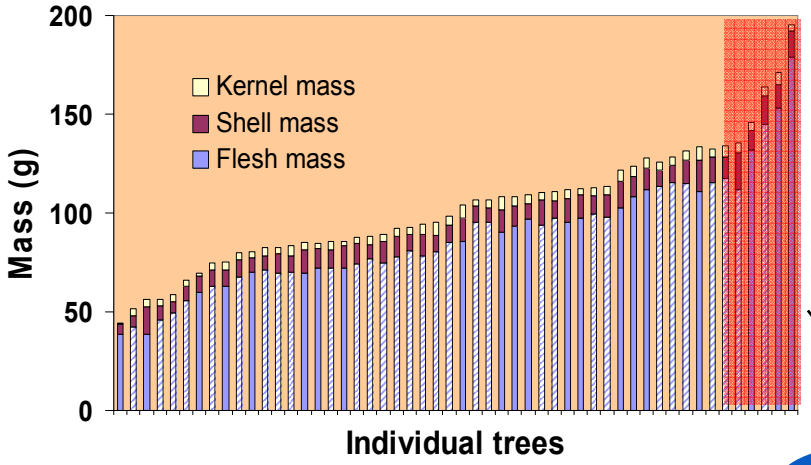
Mostly undomesticated indigenous trees.

Wild trees are unreliable trees.

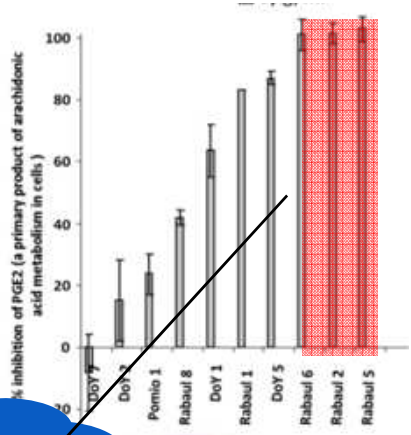
Tree-to-tree variation within the population of one single village.

Farmers choose key traits. We quantify them.

Fruit morphology

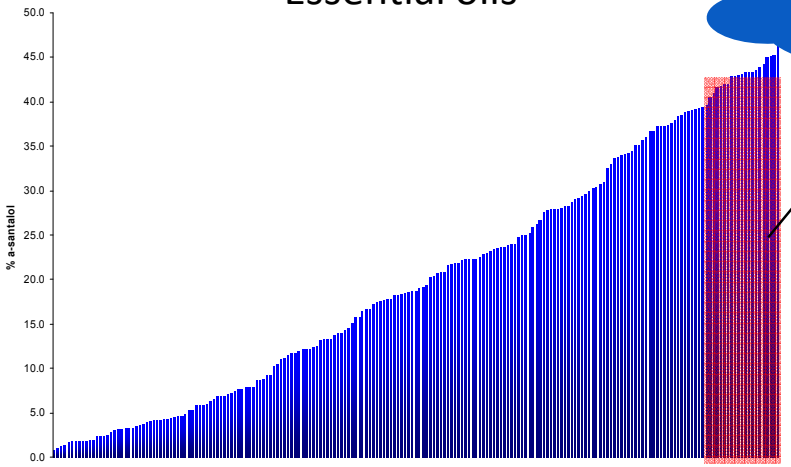


Medicinal properties

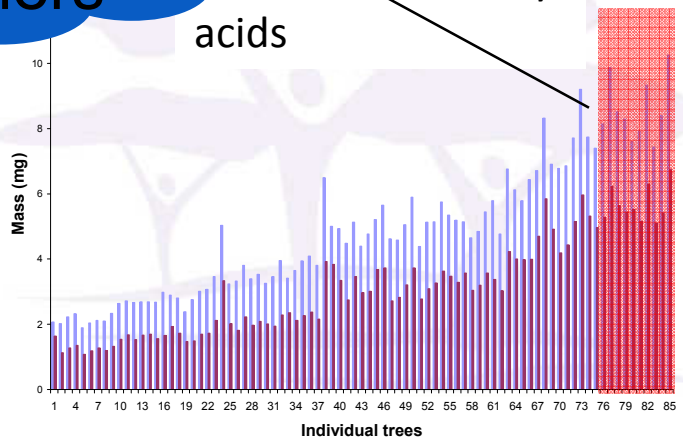


Desirable outliers

Essential oils



…dible oils and fatty acids



Techniques allow multiple trait selection for different markets

Participatory Tree Domestication

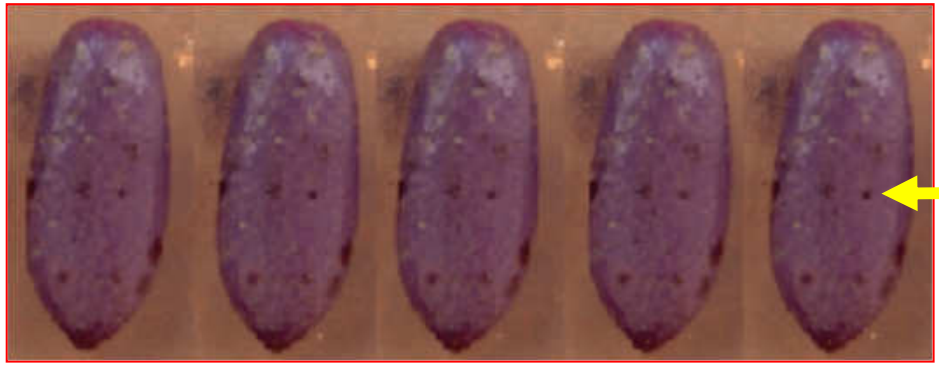
- communities select, propagate and manage high-value indigenous fruit trees and medicinal plants and integrate them in their farming systems,
- Species for domestication are mainly selected encompassing indigenous knowledge and genetic selection based on scientific principles
- A strong partnership is developed with scientists, civic authorities and private companies.

•PTD is farmer driven and market led.

•It focuses on species farmers consume best with high potentials for local, regional and international market

Simple and appropriate propagation technology

Creation of early fruiting, low stature, productive cultivars with high quality and uniformity

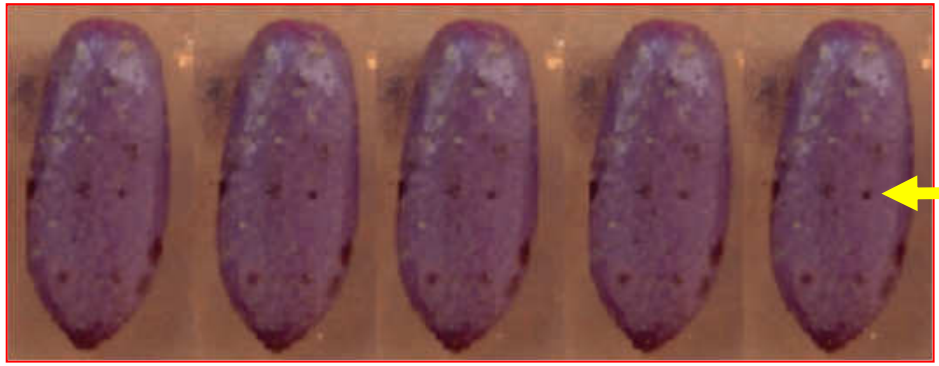


Cultivar meeting market specifications

Fruiting cultivar

Farmers have 50+ species under domestication

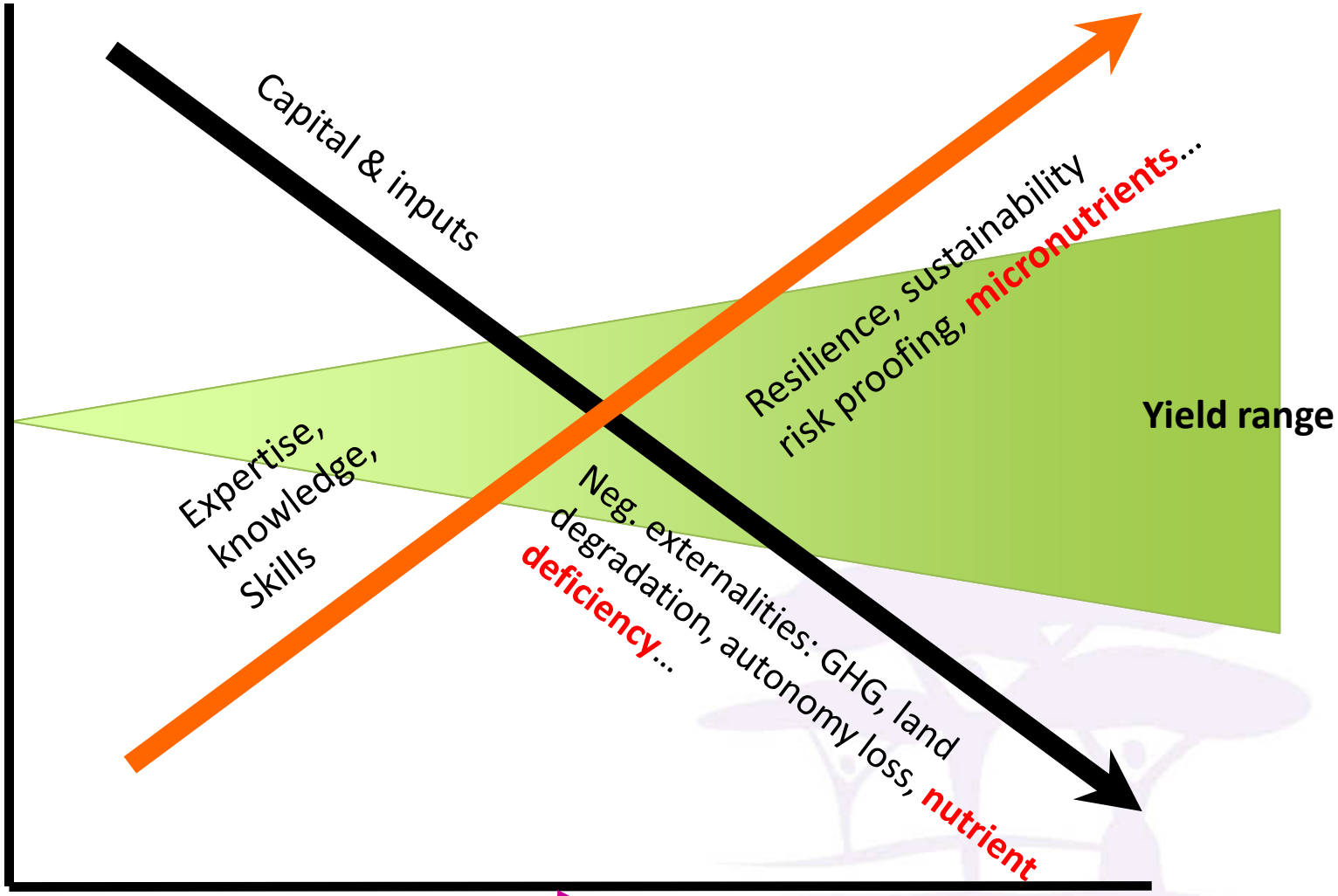
Simple and appropriate propagation technology



Cultivar meeting market specifications

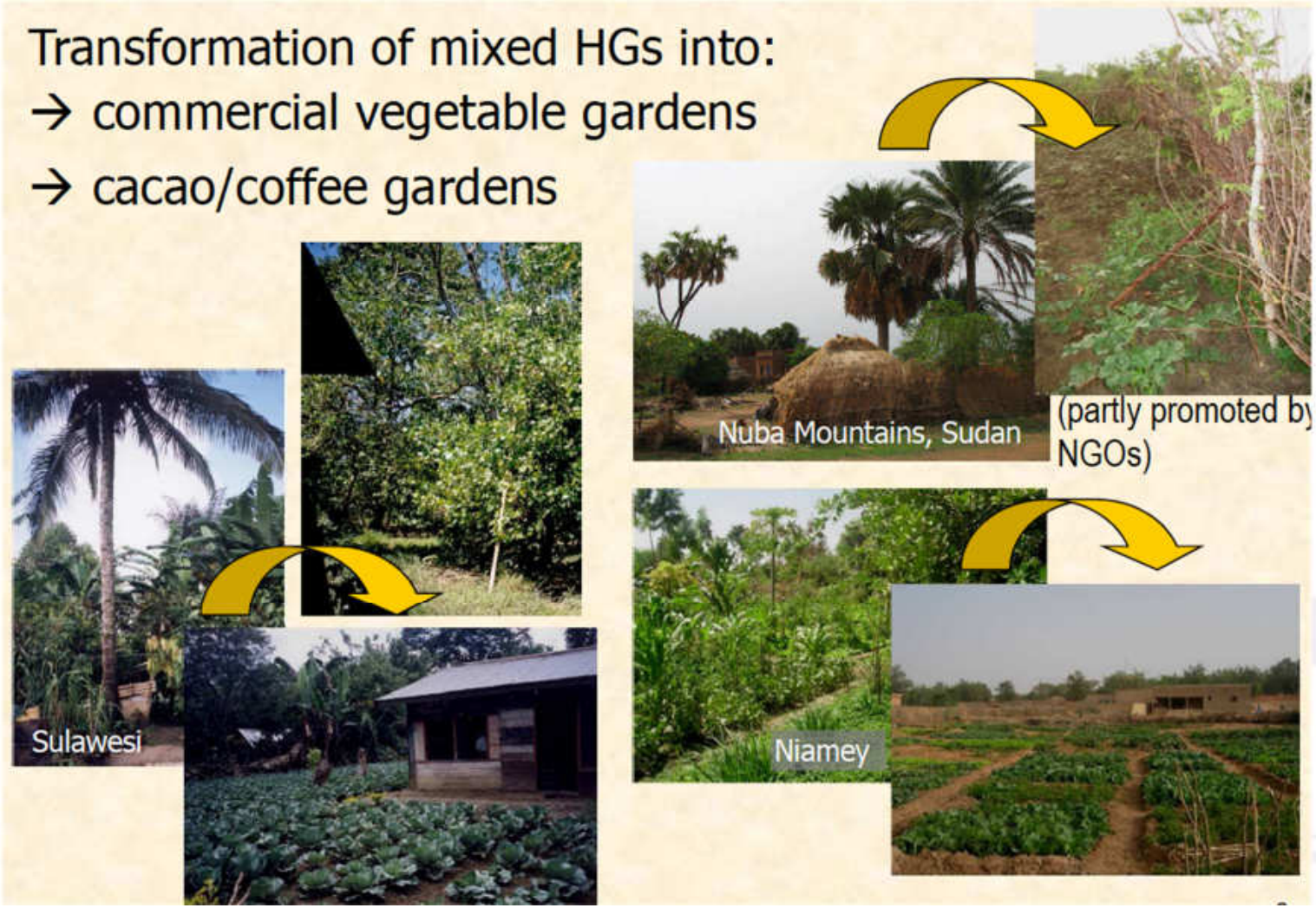
Fruiting cultivar

The transition to sustainability



Maize farming in a *Faidherbia* agroforest in Mbarali District, Southern Highlands, Tanzania. 2008
Photo: Saidi Mkomwa

And yet…


Transformation of mixed HGs into:
→ commercial vegetable gardens
→ cacao/coffee gardens
Nuba Mountains, Sudan
(partly promoted by NGOs)
Sulawesi
Niamey

Fighting ignorance: the rural resource centres

RRCs expose farmers to updated technologies in domestication and agroforestry.

Demonstration plots help farmers acquire skills in production and marketing knowledge

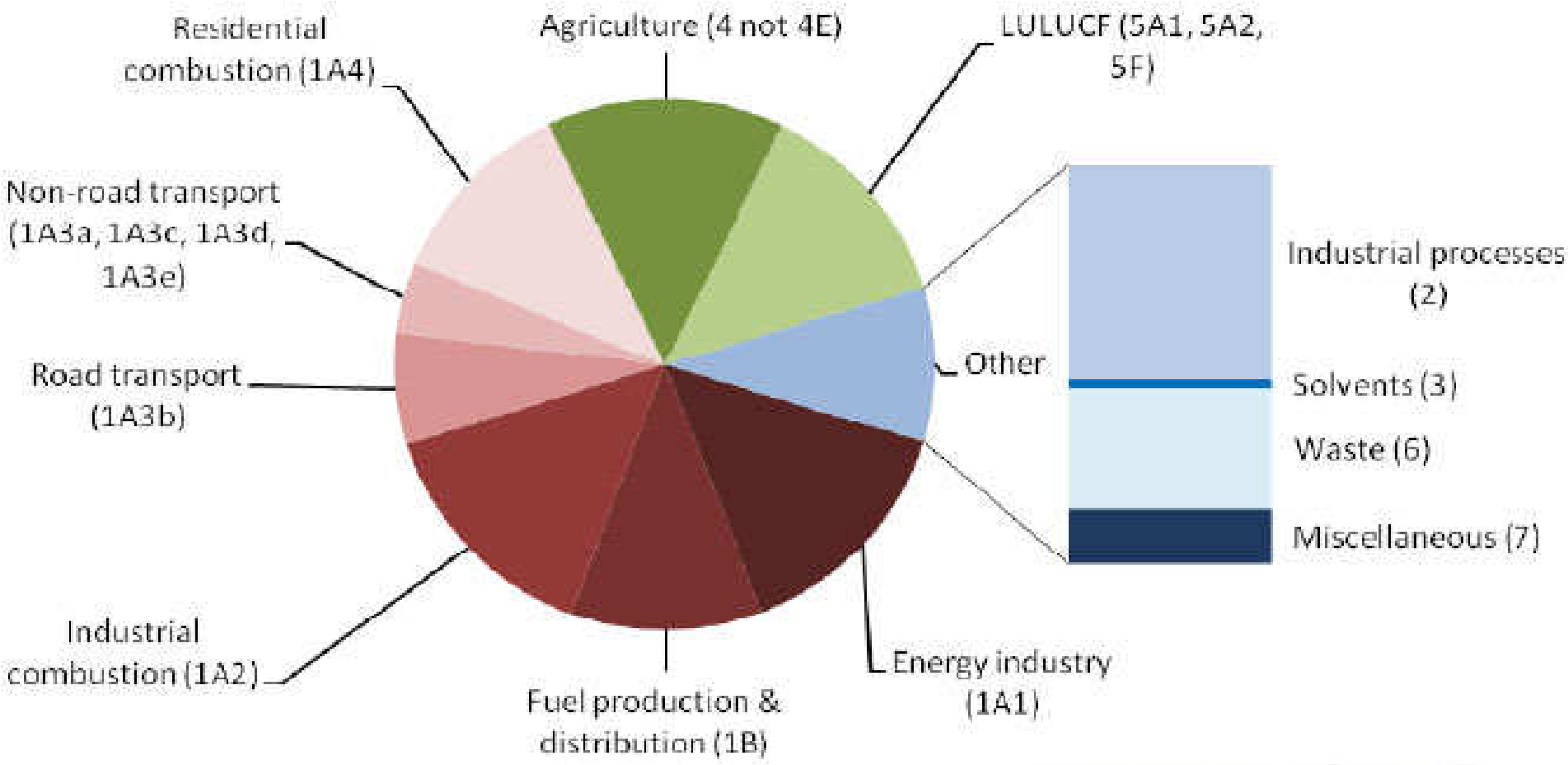
.

Four 2050 challenges:

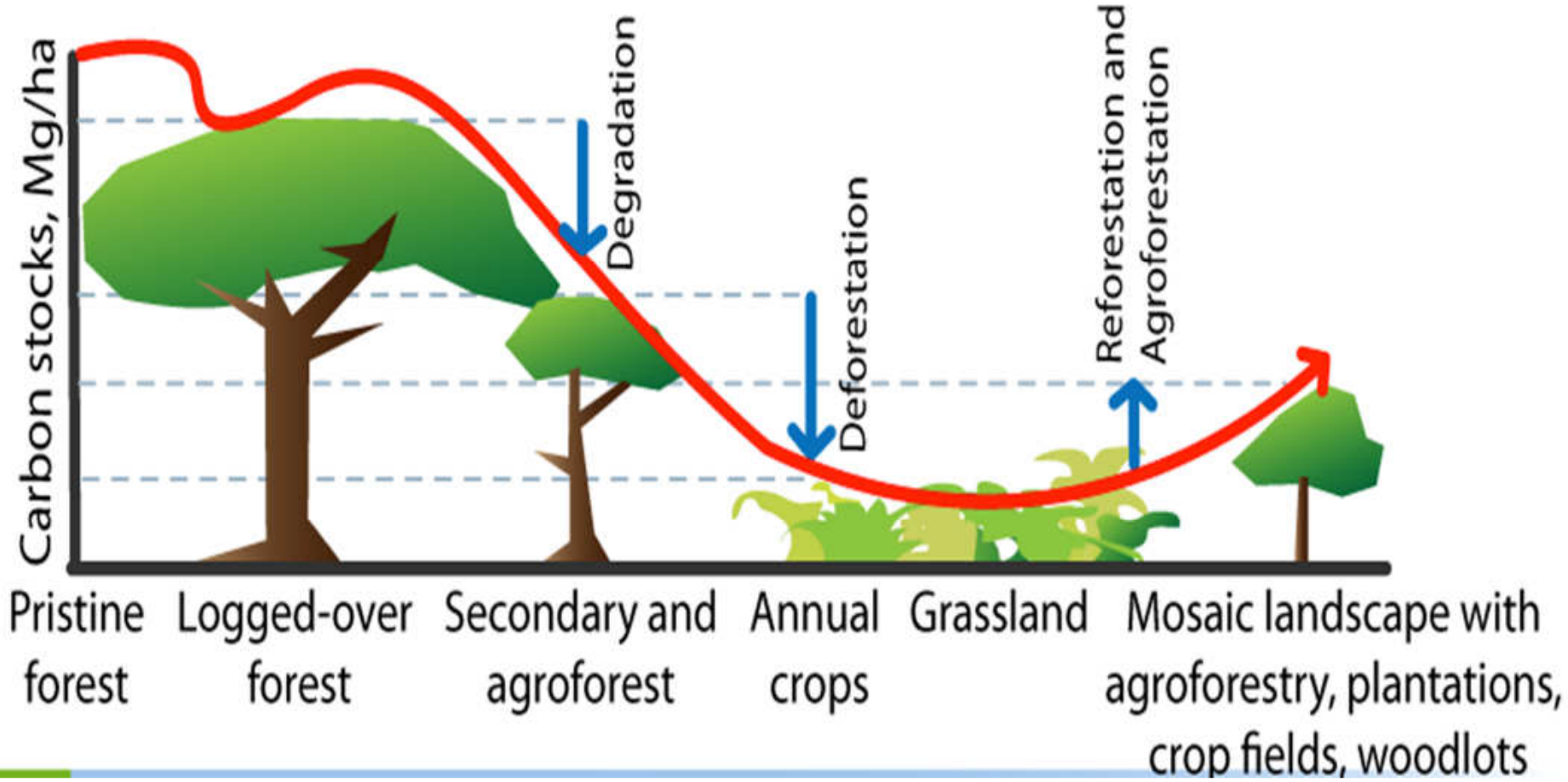
- ✔ Produce 60% more food on ~ the same amount of land
- ✔ Deal with massive malnutrition
- Make farms, fields and landscapes more resistant to climate change
- Massively reduce GHG emissions from land use.

Climate

Wanted: a mitigation strategy



Trees should help, right?



Right.

Land Use Policy 31 (2013) 584–594

Contents lists available

The potential of 1566 million tonnes CO_2-eq/year is huge. As a comparison, the EU-27 has set a unilateral target to reduce its GHG-emissions with 20% by 2020 as compared to the 1990 level of 5564 million tonnes CO_2-eq/year. This implies a reduction of the

applying agroforestry on one hectare has a value of 282 euro in 2012 and of 1007 euro in 2030.

As a comparison the average gross value of the production of wheat and temporary grassland in Flanders (Belgium) in the

Table 2
The external value of carbon sequestration of the agricultural measures, on a per hectare basis and total potential value for EU-27, in 2012 and 2030.

Measure	Potential per ha per year (tonnes CO_2-eq)	Estimated value/ha in 2012	Estimated value/ha in 2030	Potential EU-27 (million tonnes CO_2-eq/year)	Estimated value for EU-27 in 2012 (million euro)	Estimated value for EU-27 in 2030 (million euro)
Agroforestry on arable land	10.065	282	1007	906	25,364	90,585
Agroforestry on pastures	10.065	282	1007	503	14,091	50,325
Hedge rows	0.366	10	37	65	1824	6515
Cover crops	0.586	16	59	70	1951	6969
Low/no tillage	0.366	10	37		615	2196
All				1566	43,845	156,589

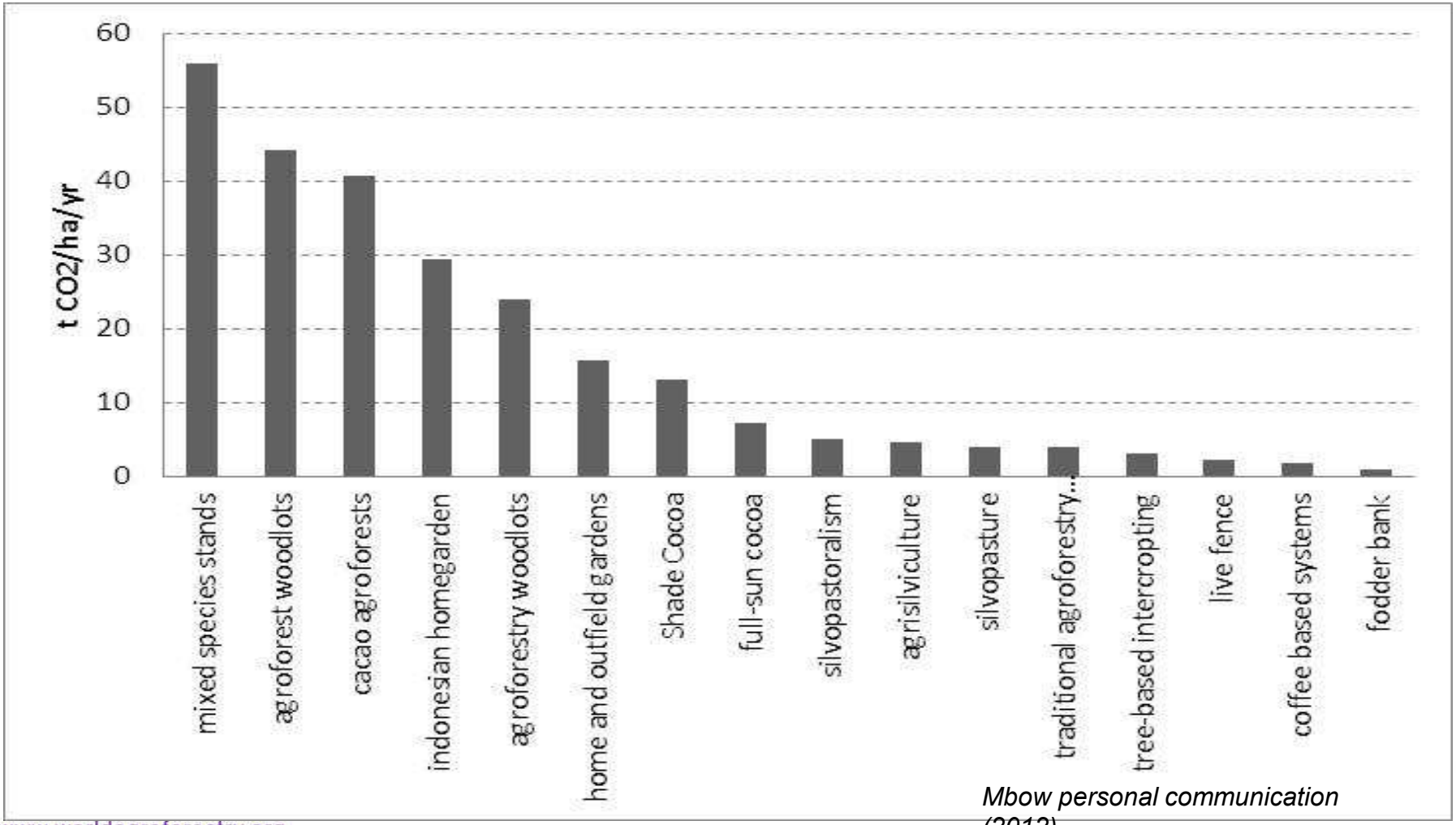
...ures in sequestering carbon as ...ociety is estimated.

...y, introducing hedges, low and no tillage and cover ...ease carbon sequestration. The total technical potential in the ...illion tonnes CO_2-equivalent per year. This corresponds to 37% of all CO_2-... in the EU in 2007. The introduction of agroforestry is the measure with the highest ..., i.e. 90% of the total potential of the measures studied. Taking account only of the value for climate change mitigation, the introduction of agroforestry is estimated to have a value of 282 euro/ha in 2012 that will gradually increase to 1007 euro/ha in 2030.

Major conclusions: This implies that there is a huge potential which represents an important value for society in general and for the agricultural sector in specific. At the European level, only in the last few years policy makers have recognized the important benefits of agroforestry. In their rural development programmes some European countries now support farmers to introduce agroforestry. But still the current level of support is only a small fraction of the societal value of agroforestry. If this value would be

Mitigation through trees

Carbon potential in various agroforestry systems

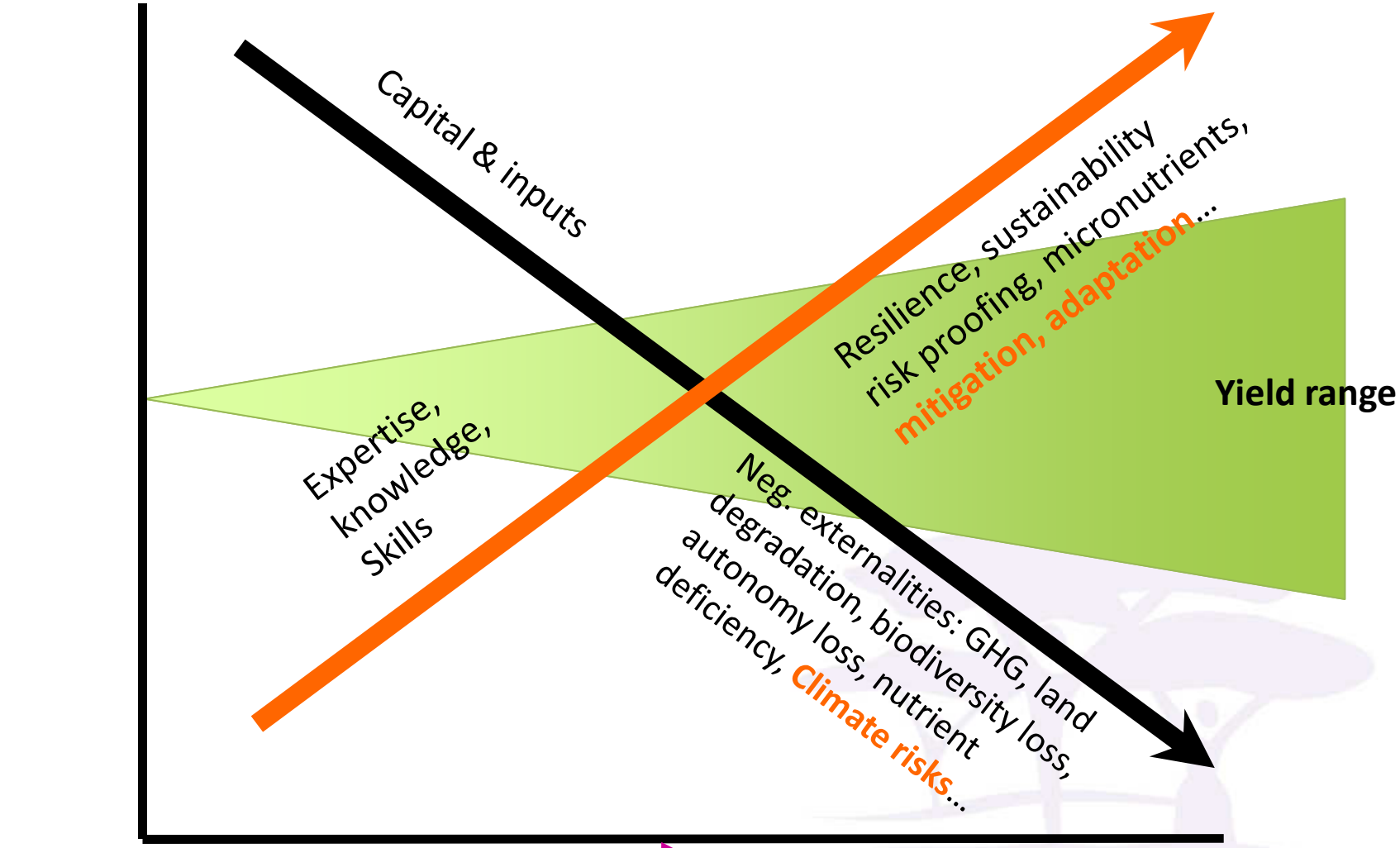


Mbow personal communication (2012)

Adaptation through trees

- **Food security**: organic matter, nutrients, microclimate
- **Nutrition**: fruits, fodder, multi-crop system support
- **Weather resilience**: roots pump water, trees offer shade and windbreaks
- **Insurance**: in hard times, farmers can sell timber
- **Income diversification:** crops, fuel, fodder, timber, fruits
- **Health**: medicinal barks and leaves, nutrition
- **Energy resources**: fuelwood, charcoal
- **Higher biodiversity**
- **Reduced deforestation**
- **Soil restoration**
- **Carbon sequestration**

The transition to sustainability



Four 2050 challenges:

- ✔ Produce 60% more food on ~ the same amount of land
- ✔ Deal with massive malnutrition
- ✔ Make farms, fields and landscapes more resistant to climate change
- ✔ Massively reduce GHG emissions from land use.

Other reasons to like trees:

Water availability

WATER RESOURCES RESEARCH, VOL. 46, W09525, doi:10.1029/2010WR009127, 2010

Origin and fate of atmospheric moisture over continents

Rudi J. van der Ent,[1] Hubert H. G. Savenije,[1] Bettina Schaefli,[1] and Susan C. Steele-Dunne[1]

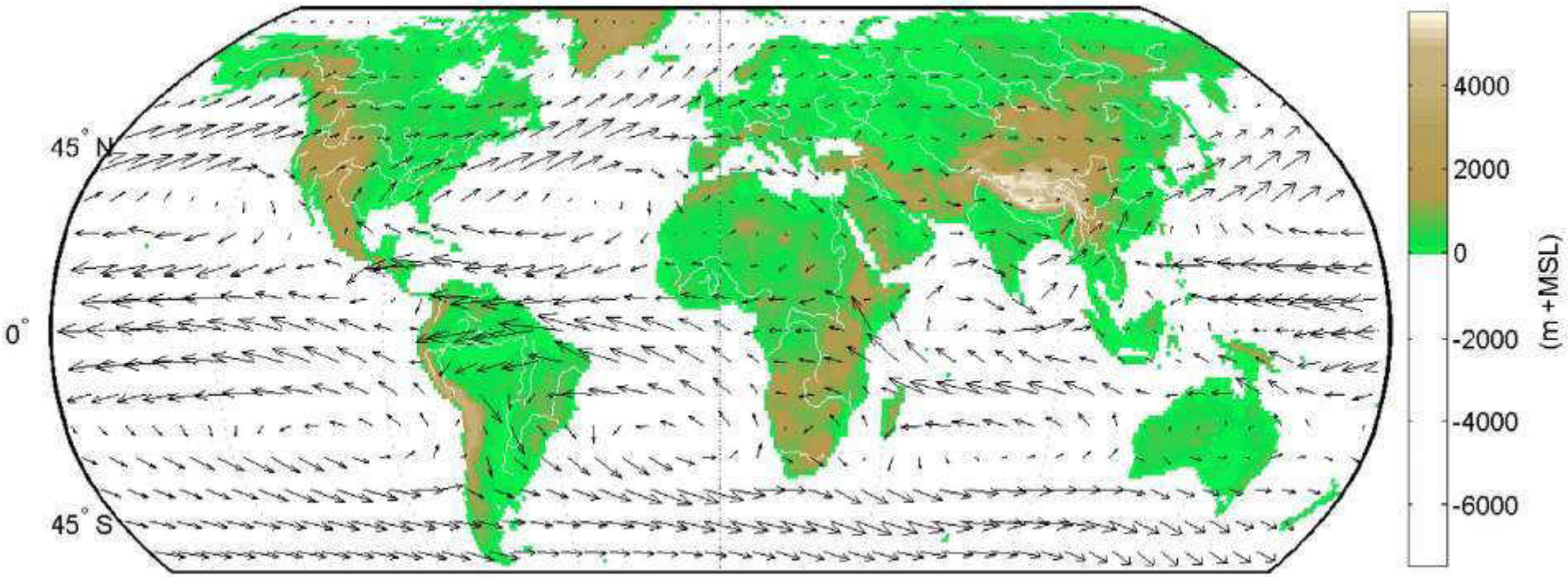


Figure 1. Global topography: height above Mean Sea Level (MSL), major rivers, and average horizontal (vertically integrated) moisture flux (1999–2008).

Continental precipitation recycling ratio ρ_c

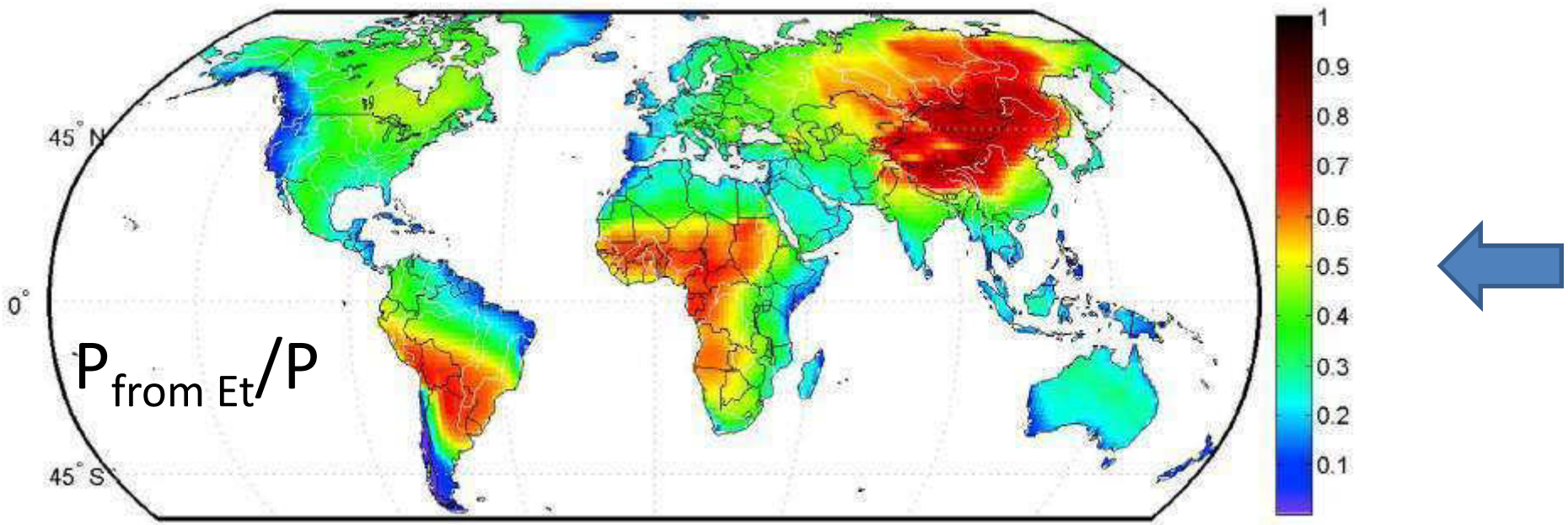


Figure 3. Average continental precipitation recycling ratio ρ_c (1999–2008).

van der Ent RJ, Savenije HHG, Schaefli B, Steele-Dunne SC, 2010. Origin and fate of atmospheric moisture over continents. Water Resources Research 46, W09525,

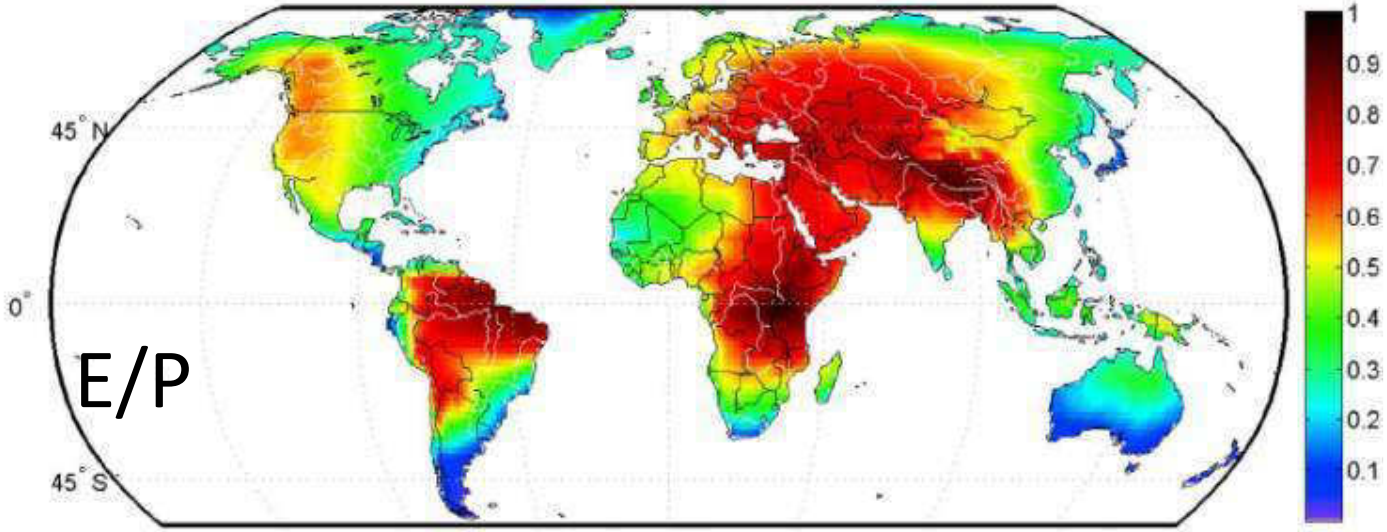
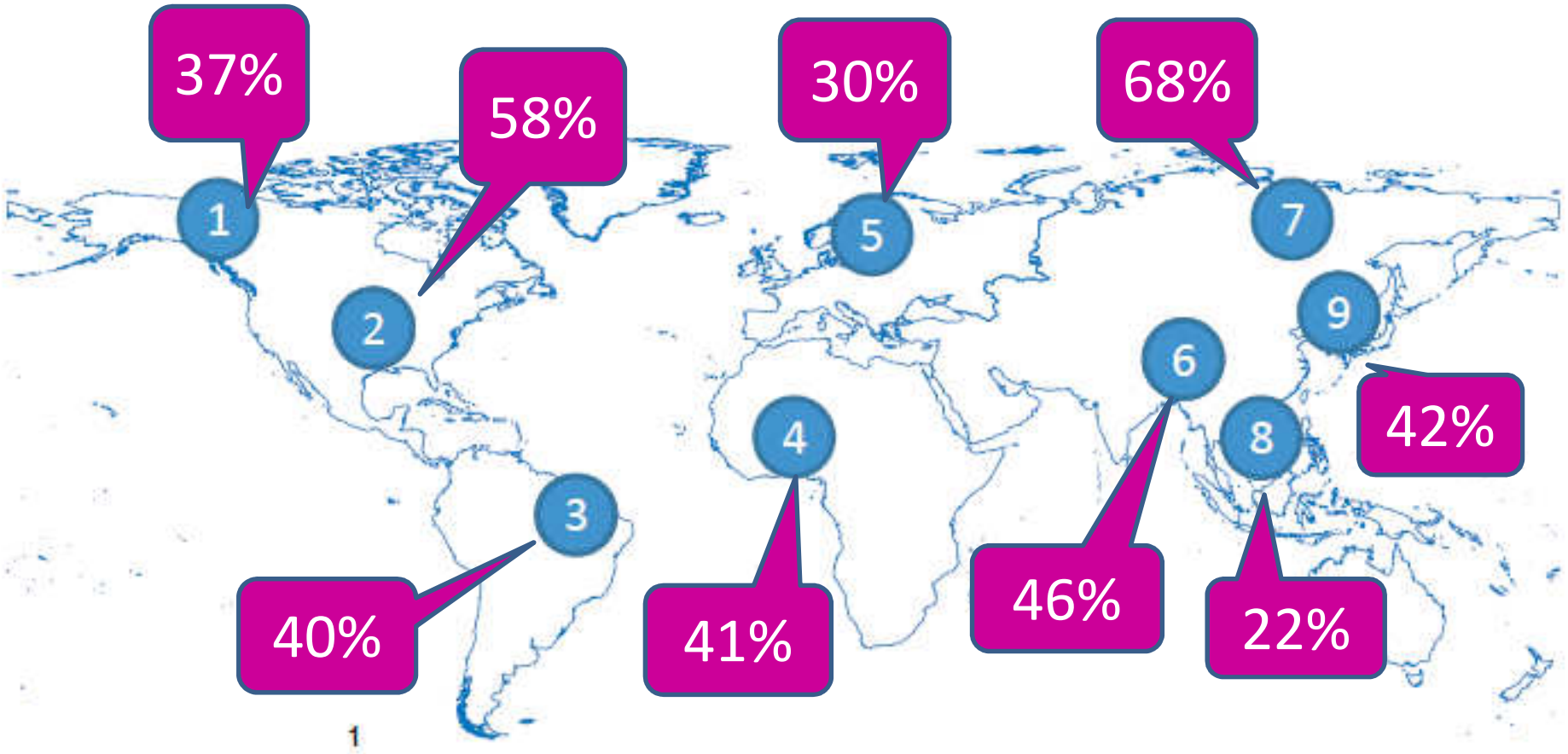


Figure 4. Average continental evaporation recycling ratio ε_c (1999–2008).

% of rainfall derived from ‘short cycle’ terrestrial origins

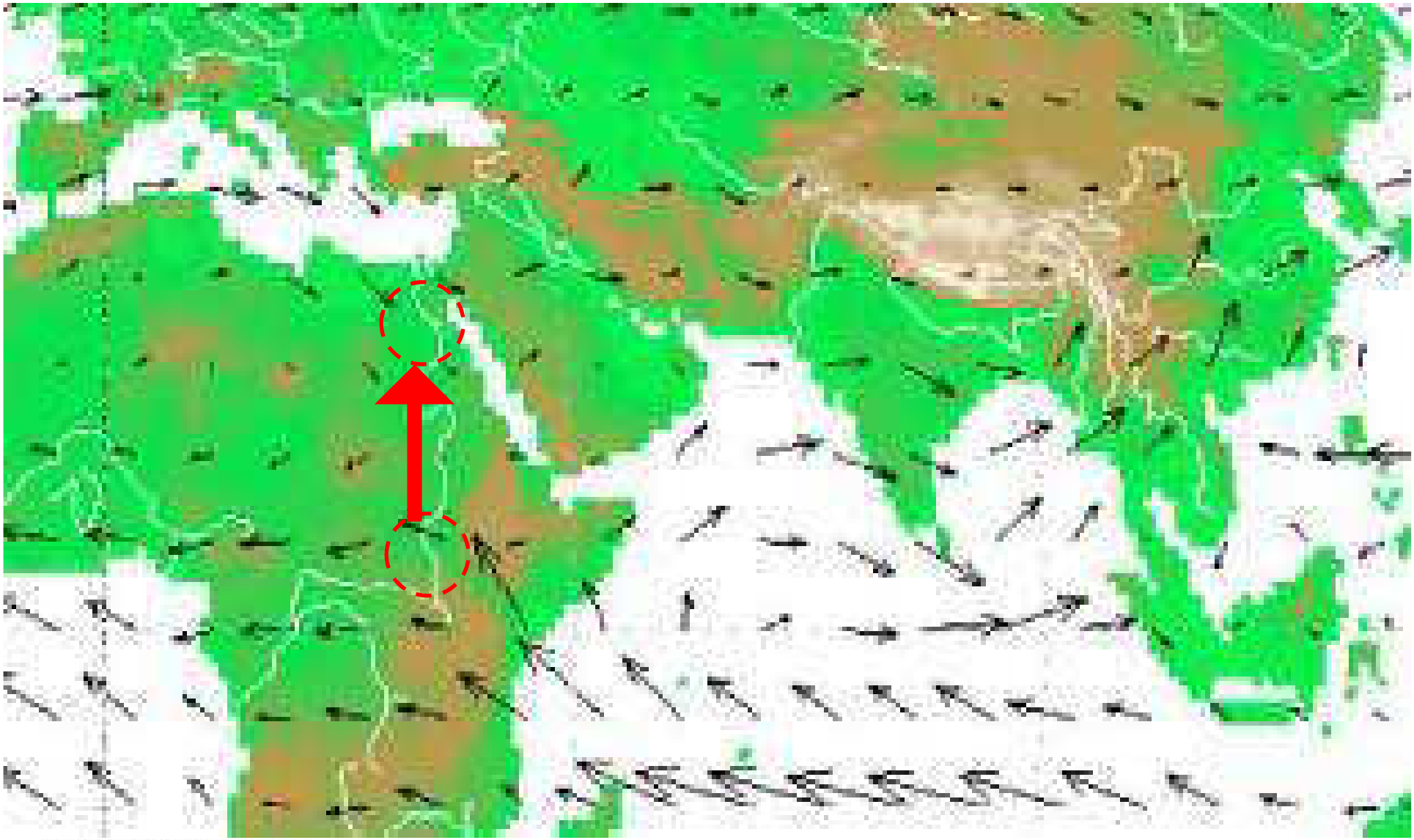
Ellison D, Futter MN, Bishop K, 2011.On the forest cover–water yield debate: from demand- to supply-side thinking. Global Change Biology, doi: 10.1111/j.1365-2486.2011.02589.x

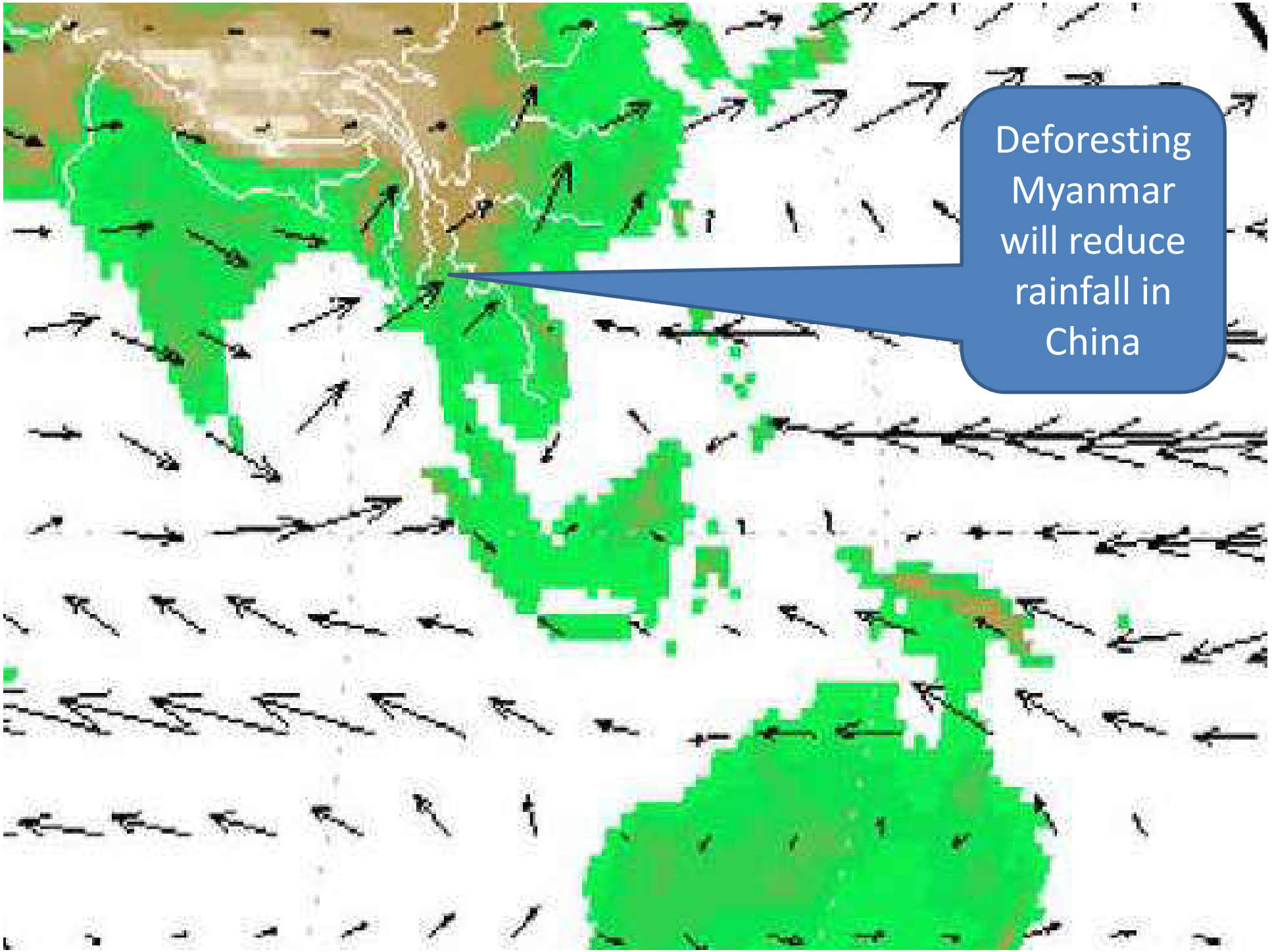


1) Mackenzie river basin, 2) Mississippi river basin, 3) Amazon river basin, 4) West Afri-ca, 5) Baltics, 6) Tibet, 7) Siberia, 8) GAME (GEWEX Asian Monsoon Experiment) and 9) Huaihe river basin.

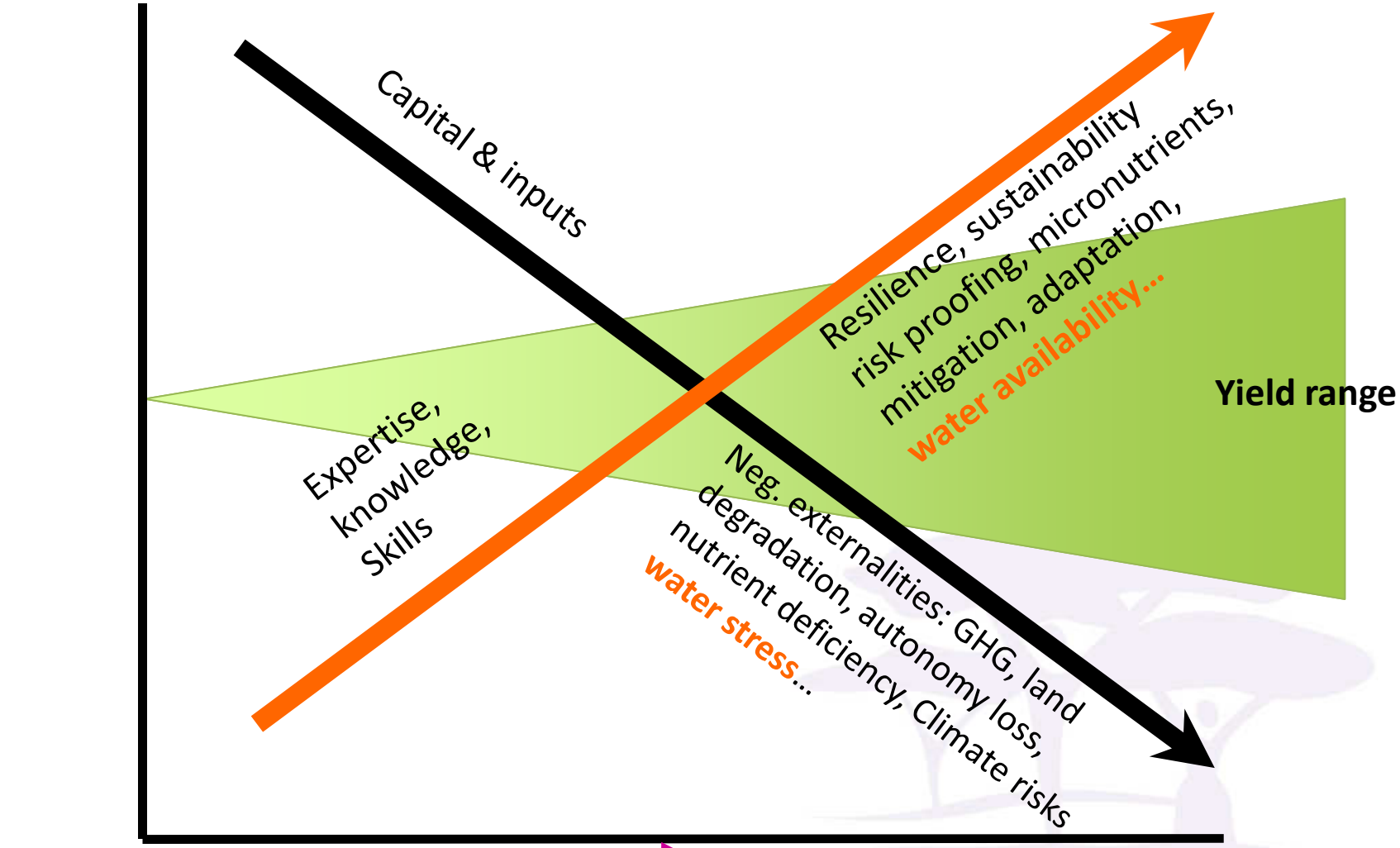
(recalculated from Basilovich et al.)

Why India and China should invest in draining the Sudd and letting the water evaporate in Egypt instead… and why West Africa should be opposed to it




Deforesting Myanmar will reduce rainfall in China

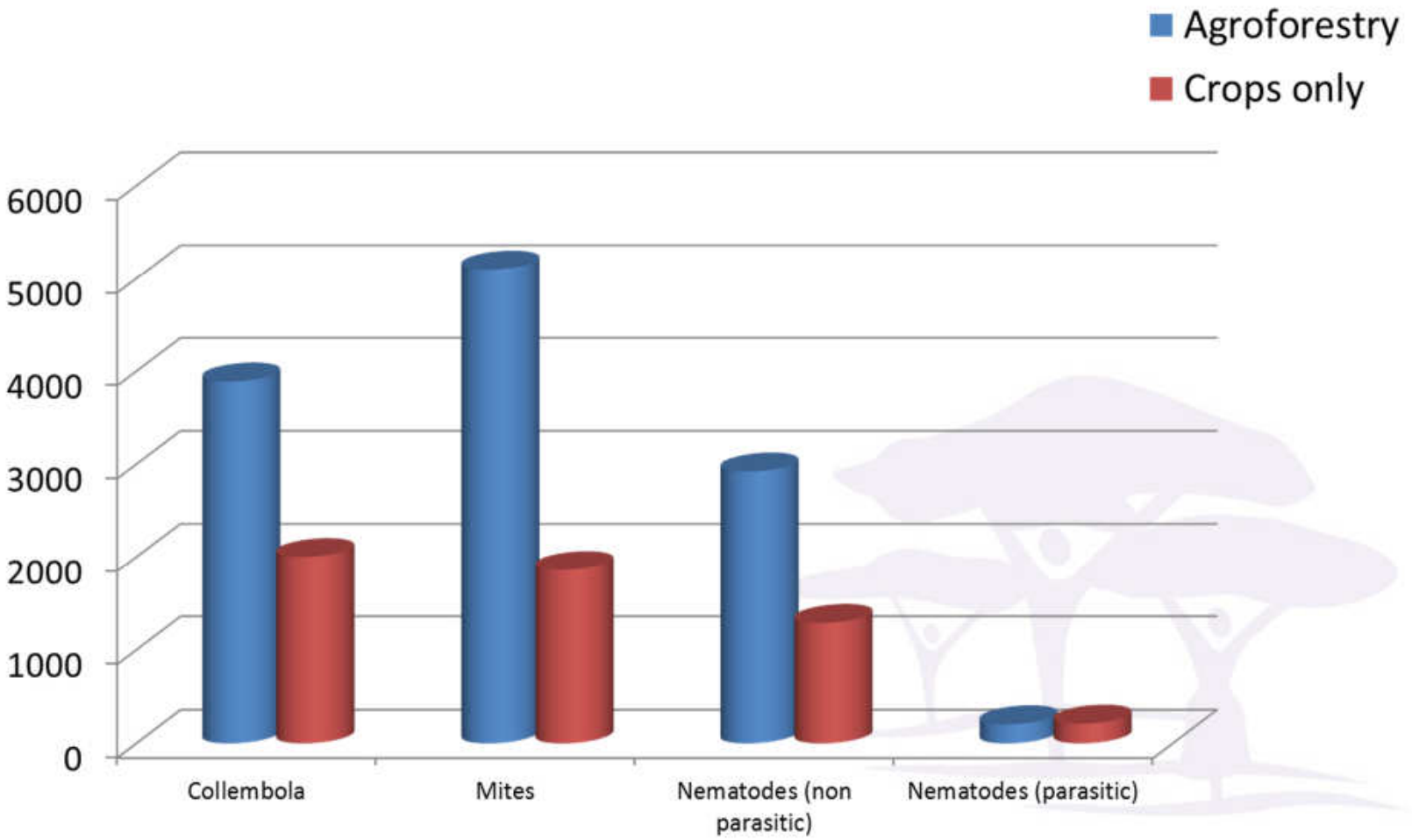
The transition to sustainability



Biodiversity

Soil biota density under crops compared with agroforestry

Number per m^2 (Barrios et al 2012)



Soil biota density under crops compared with agroforestry

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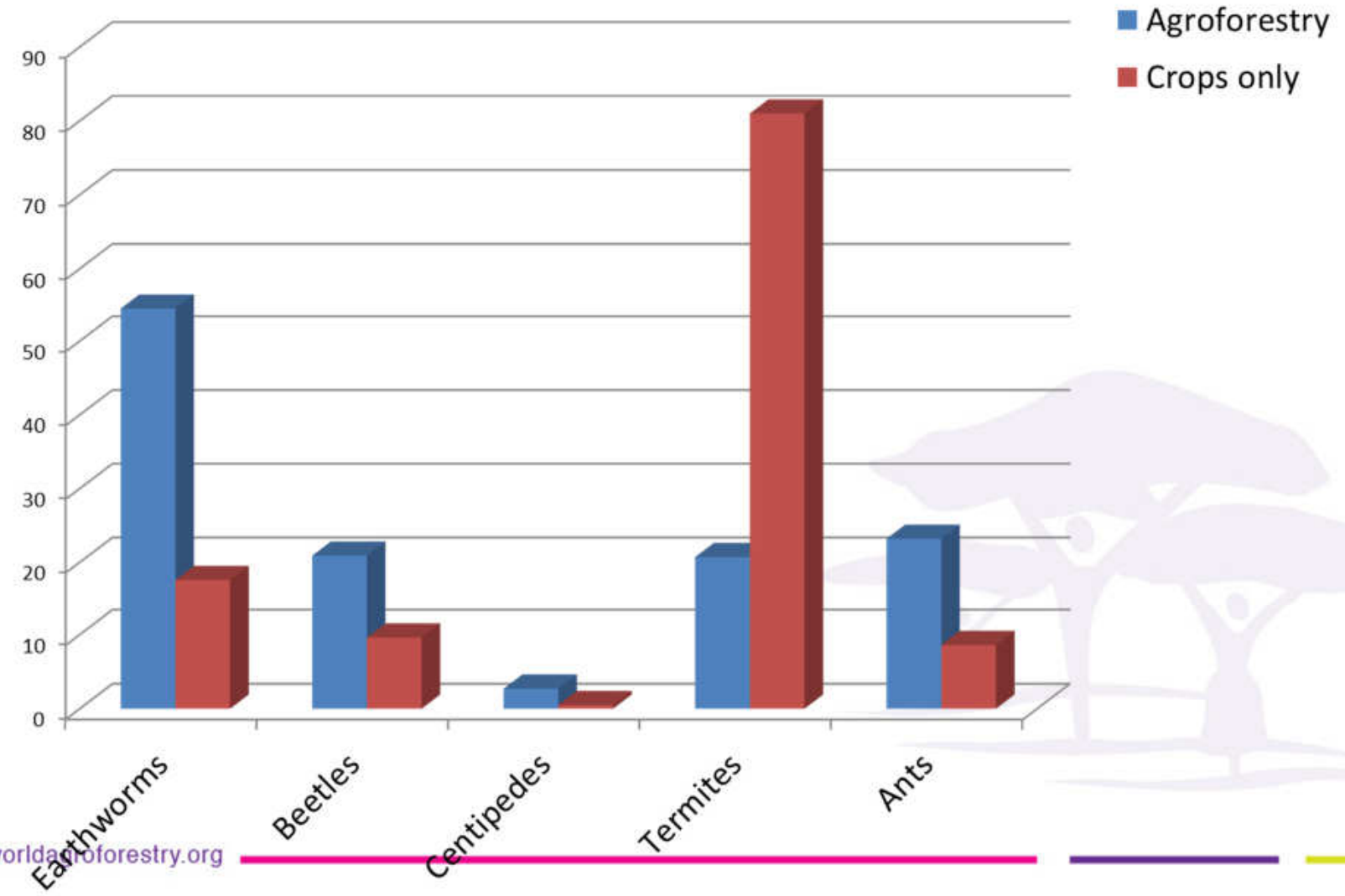
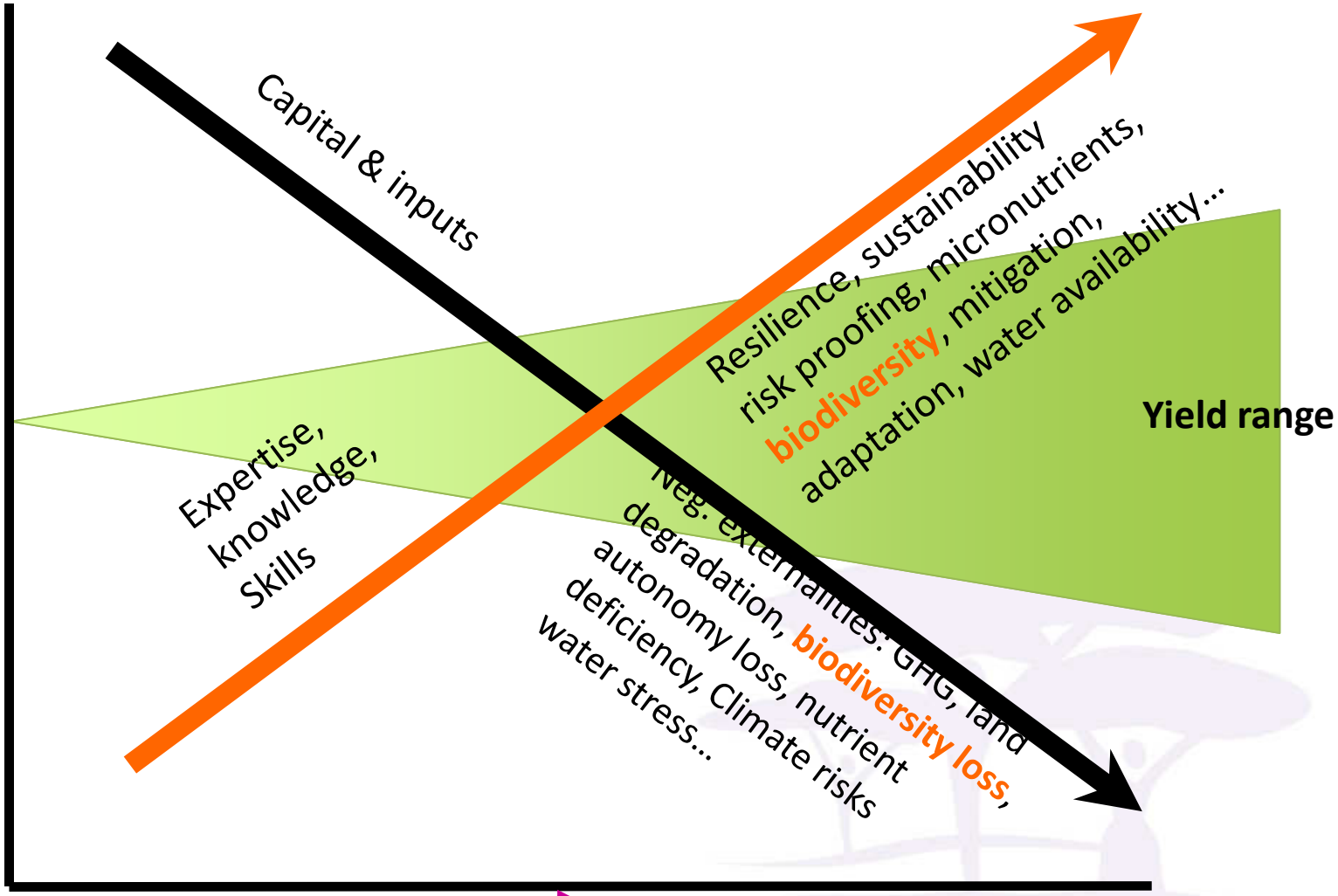


The transition to sustainability



Income

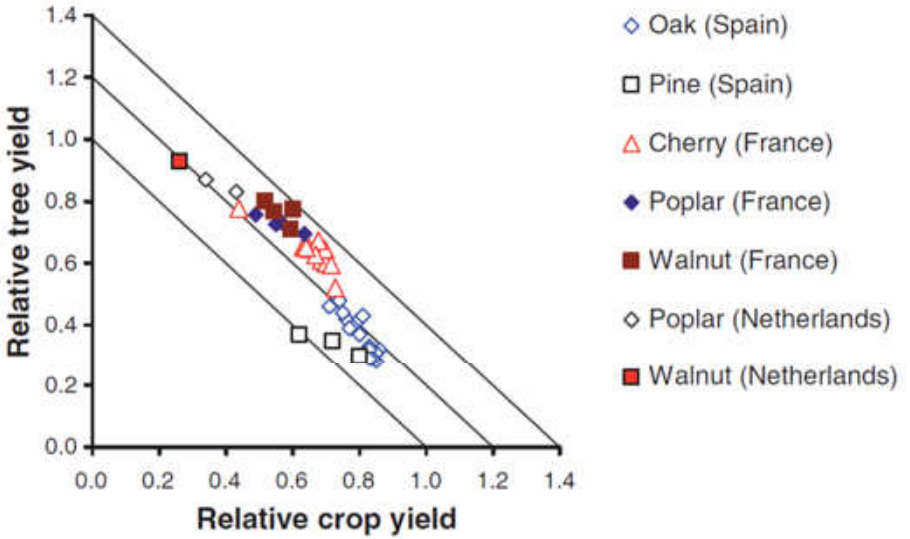
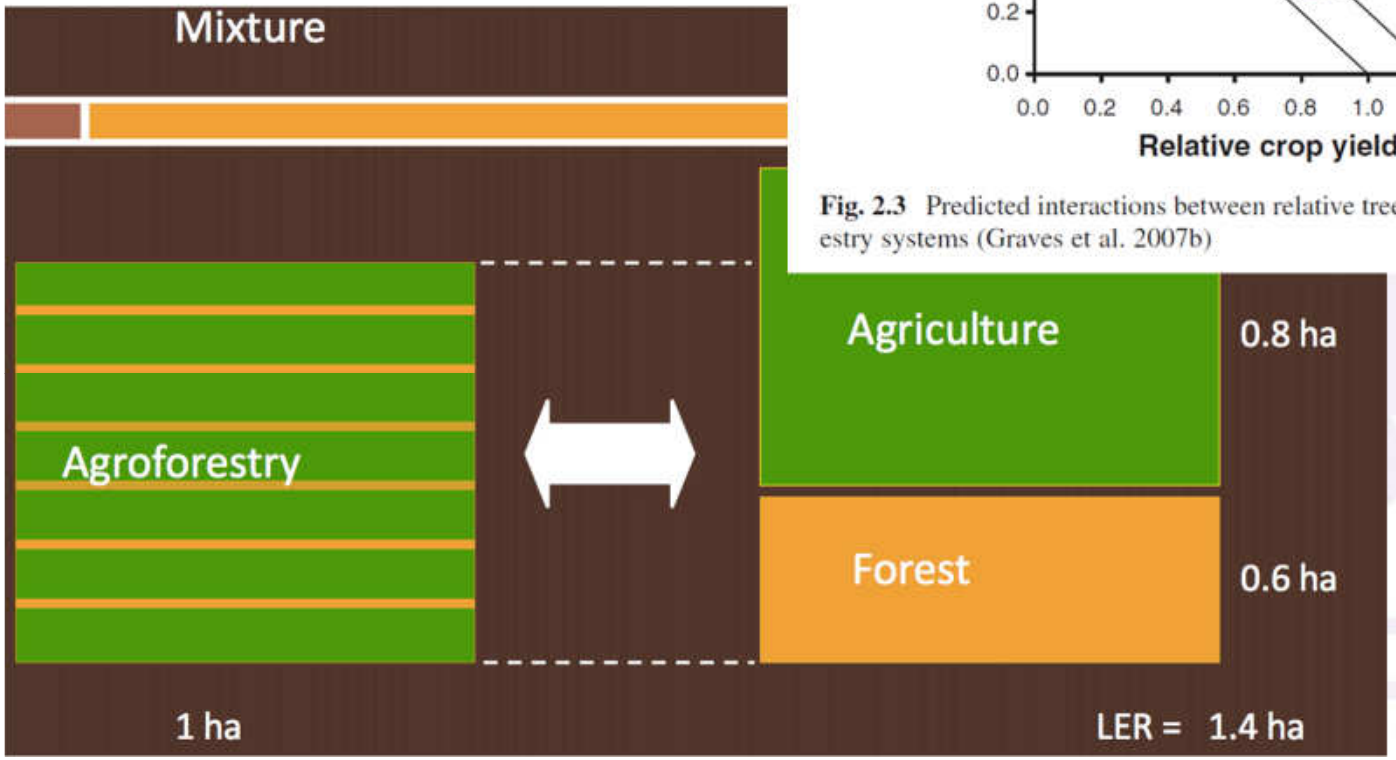


Fig. 2.3 Predicted interactions between relative tree yield and crop yield within selected agroforestry systems (Graves et al. 2007b)



Rubber systems, Sumatra

800 $ / Ha / year	3,000 $ / Ha / year
High social costs	No social costs
High environmental costs	Low environmental costs

Leakey, 2012

Kantché district, Zinder, Niger

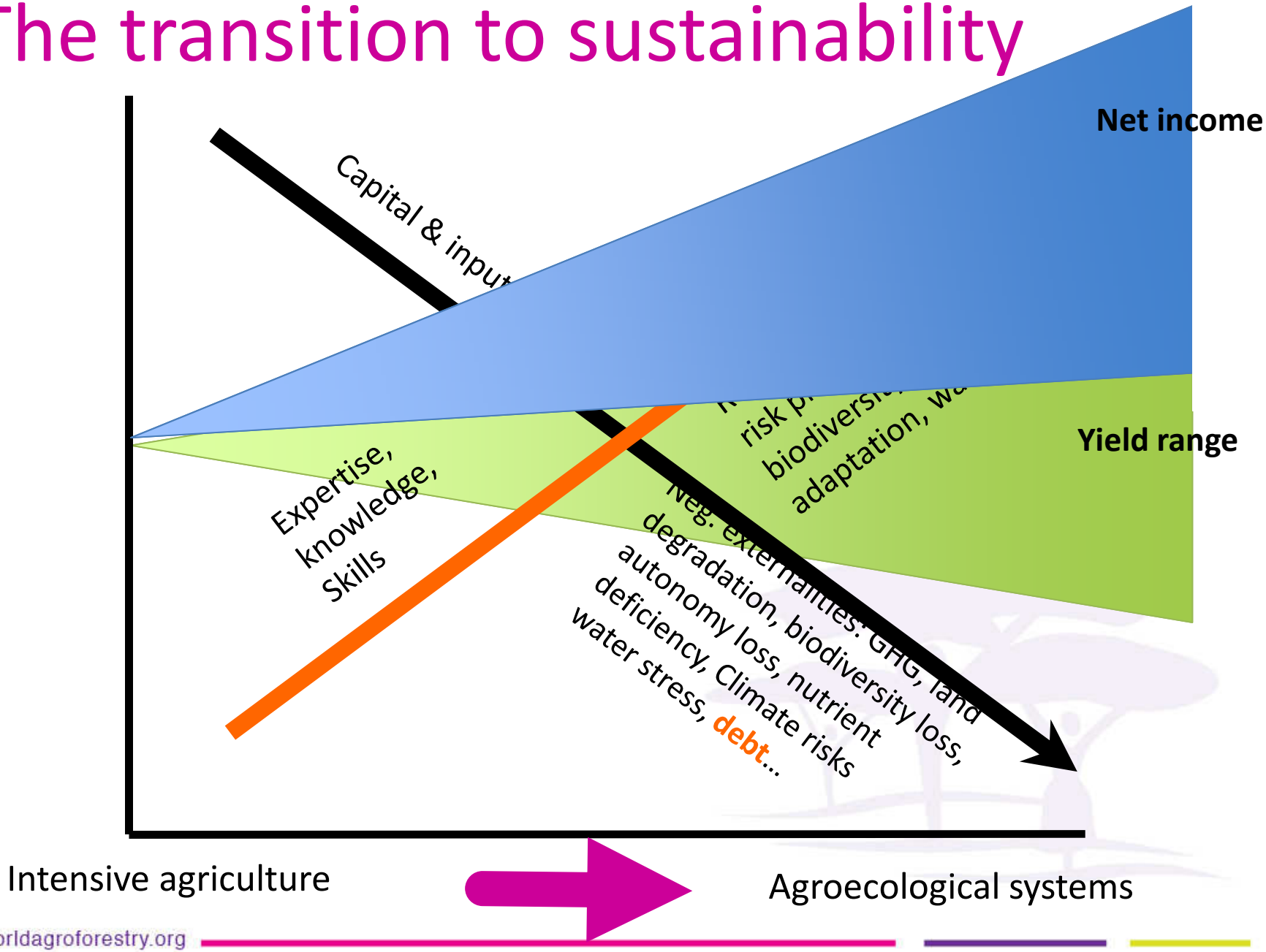
District of 350,000 people, with high tree on-field densities. Rainfall averages ca. 350 mm per year, typical of Sahel drylands.

- Annual district-wide grain **surplus**:
- 2007 21,230 tons
- 2008 36,838 tons
- 2009 28,122 tons
- 2010 64,208 tons
- 2011 13,818 tons

Kantché produces grain surpluses even in drought years. ***This is mostly exported to northern Nigeria, providing cash revenue.***

Yamba & Sambo, 2012

The transition to sustainability



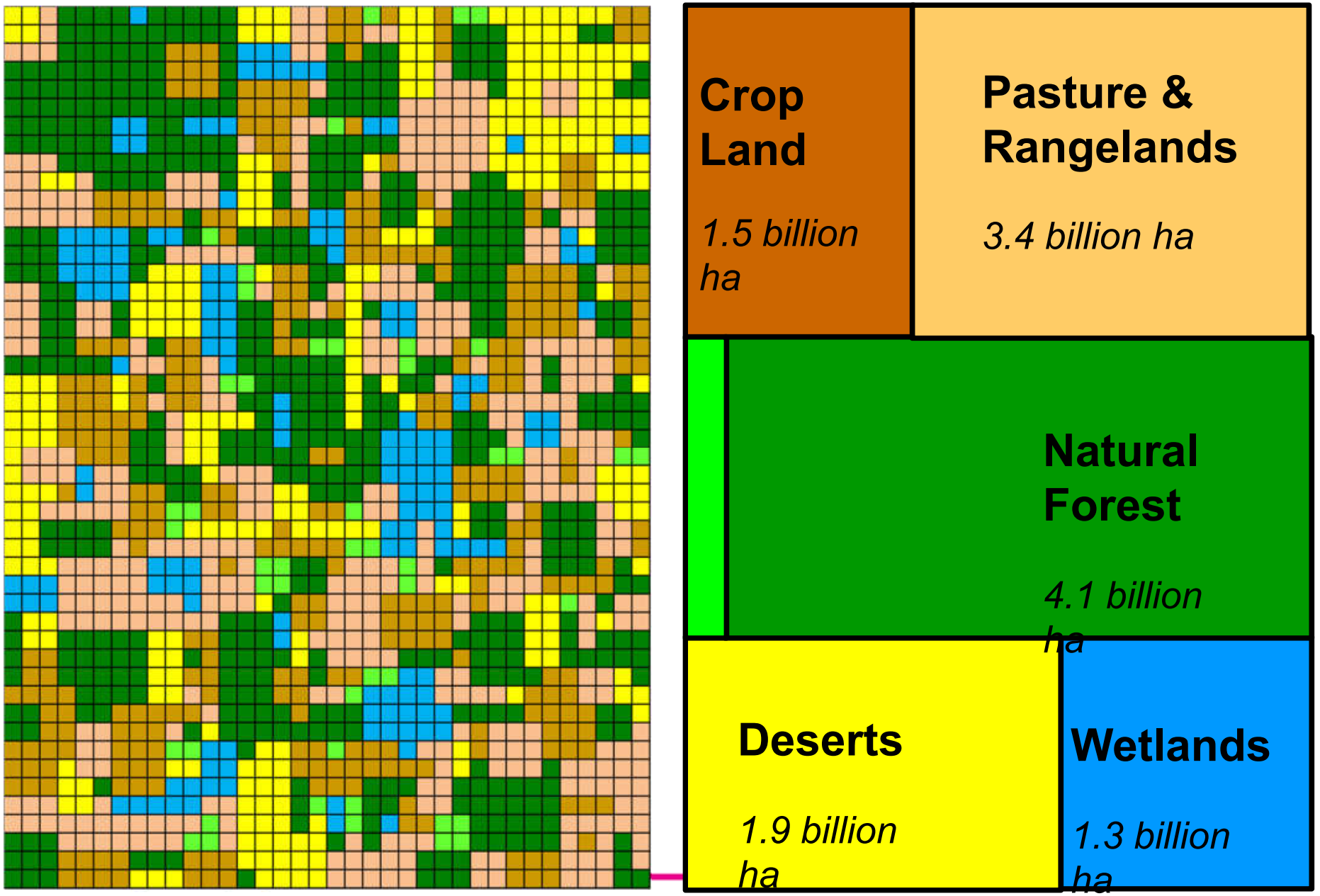
What trees give to farms:

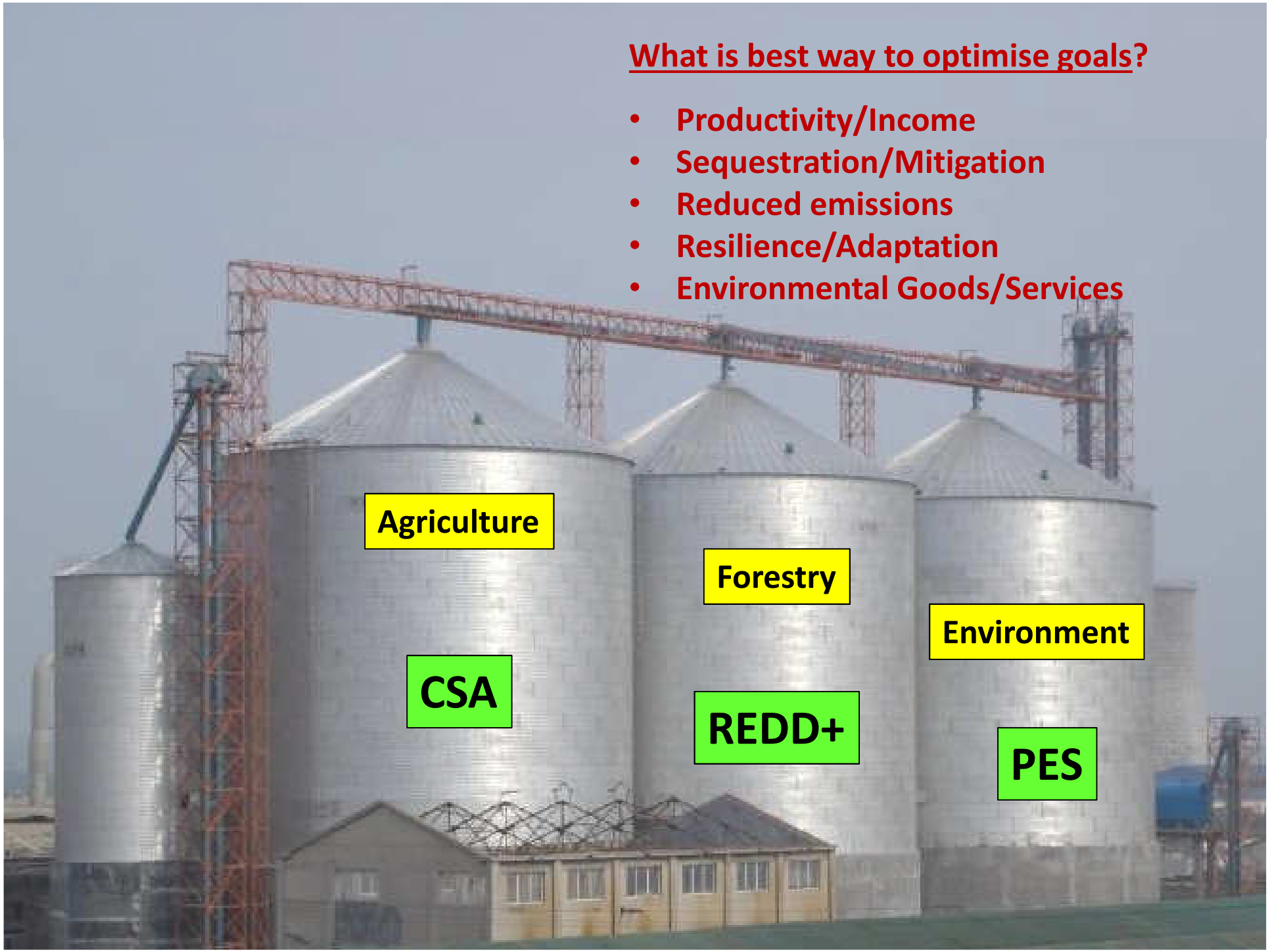
- Increased **crop nutrient availability** in rainfed food crop systems
- **Improved microclimate** and soil water relations conveying greater adaptation to climate change
- Increased and more stable **food crop productivity**
- Increased **food micronutrient** availability (fruits)
- Enhanced **dry season fodder** availability
- Dramatically **increased carbon accumulation** in food crop systems: 6-10 tons of CO_2 per hectare per year are common
- Enhanced **biodiversity**
- **Reduced deforestation** due to on-farm fuelwood and timber production
- Increased **extreme weather resilience**
- Diversified and increased **income streams**


This is the future.

So why this?


Investment in
“normal” agriculture
Investment in agroforestry


Crop Land
1.5 billion ha
Pasture & Rangelands
3.4 billion ha
Natural Forest
4.1 billion ha
Deserts
1.9 billion ha
Wetlands
1.3 billion ha


What is best way to optimise goals?
• Productivity/Income
• Sequestration/Mitigation
• Reduced emissions
• Resilience/Adaptation
• Environmental Goods/Services
Agriculture
Forestry
Environment
CSA
REDD+
PES

800 $ / Ha / year

High social costs

High environmental costs

3,000 $ / Ha / year

No social costs

Low environmental costs

Leakey, 2012

… and in Europe.

World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

Thank you!

(if you're still hungry, I have more on making this happen)

For more information

Patrick Worms, World Agroforestry Centre
Email:p.worms@cgiar.org
Tel: +32 495 24 46 11
www.worldagroforestrycentre.org

Getting there

- Enabling policies
- Improved genetics
- Farmer information

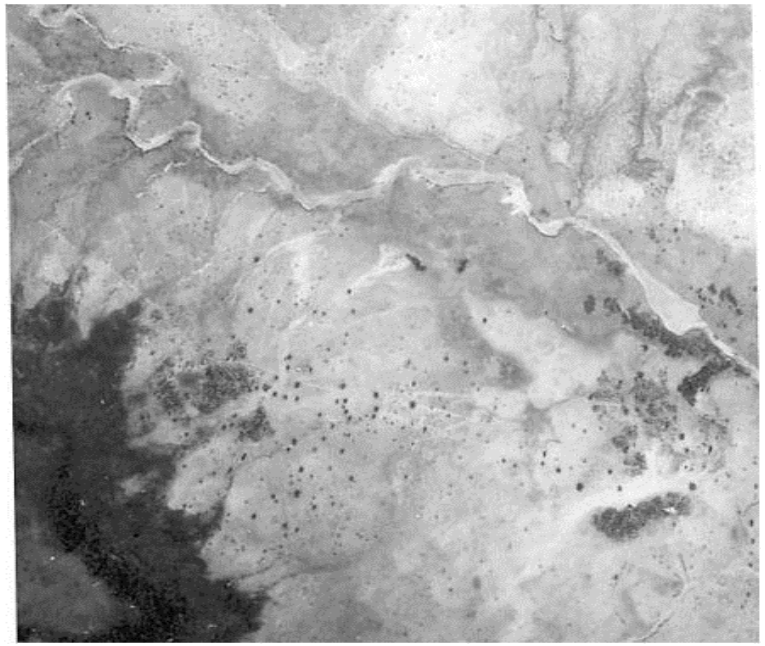
Getting there

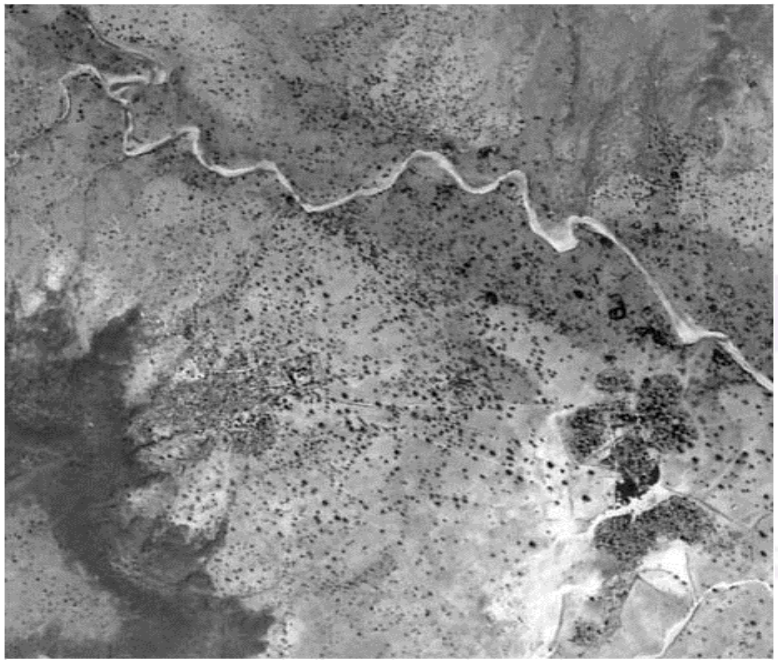
- Enabling policies
- Improved genetics
- Farmer information

Impact of Policy Changes

Restrictive forest codes in the Sahel were beginning to be relaxed in Niger so that trees planted or managed on farmers' fields could remain the property of the farmer and not revert to the government. The change in three decades, was dramatic.

Galma, Niger **1975** **2003**





Source: World Vision Australia

Tenure effects on land productivity and investment

Lake Basin, Kenya. Mixed agriculture with fruit trees and smallholder tea

Source: Ecosystems Ltd

Adjudicated under the Land Adjudication Act CAP 284 1968, intensive smallholder cultivation with clear freehold title

Un-adjudicated land:

no firm legal title

Norton-Griffith, in preparation

The Landscape Approach

Five underlying Principles:

1. Make sense and operate across nested and interacting social and political scales (village, district, country)

2. Make sense and operate across nested and overlapping biophysical scales (e.g. farm, watershed, basin)

3. Involve multiple and defined sectors and stakeholders

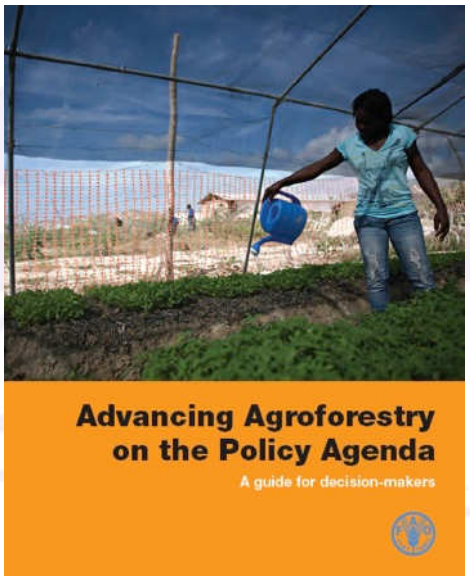
4. Seek synergies and reduce tradeoffs

5. Monitor and evaluate baselines, interventions, counterfactuals, policies

People-Place-Purpose

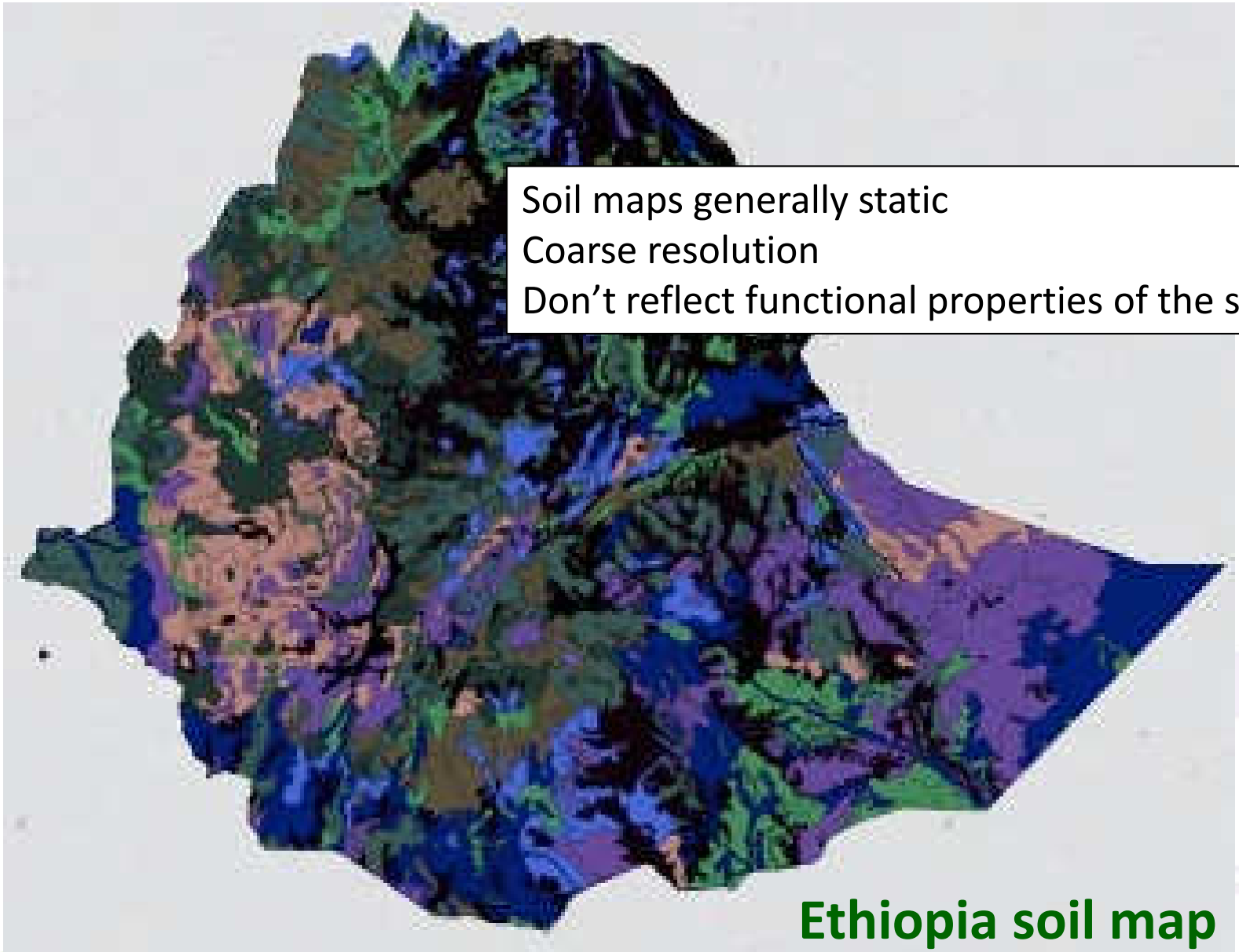
Policy Conflict

- Natural forest protection
- Tree growing



Basic problem

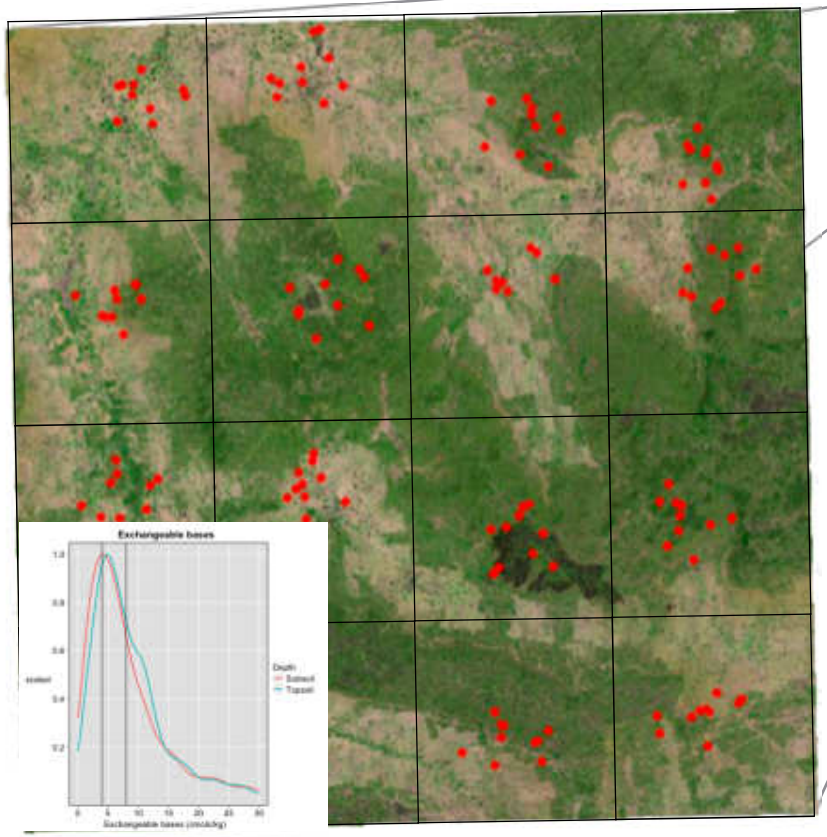
There is a lack of coherent and rigorous sampling and assessment frameworks that enable comparison of data across a wide range of environmental conditions and scales



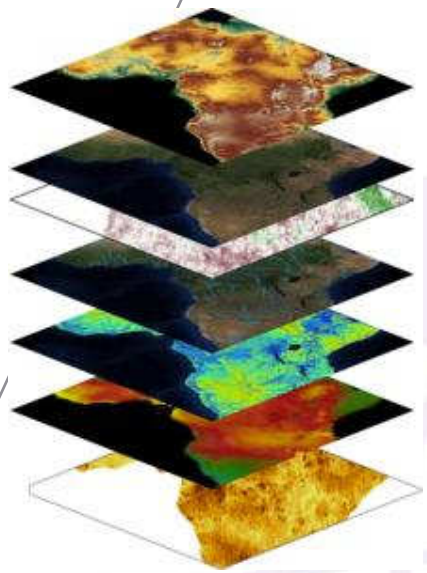
Soil maps generally static
Coarse resolution
Don’t reflect functional properties of the soil

Ethiopia soil map

Surveillance science
Land health metrics



Prevalence, Risk factors, Digital mapping

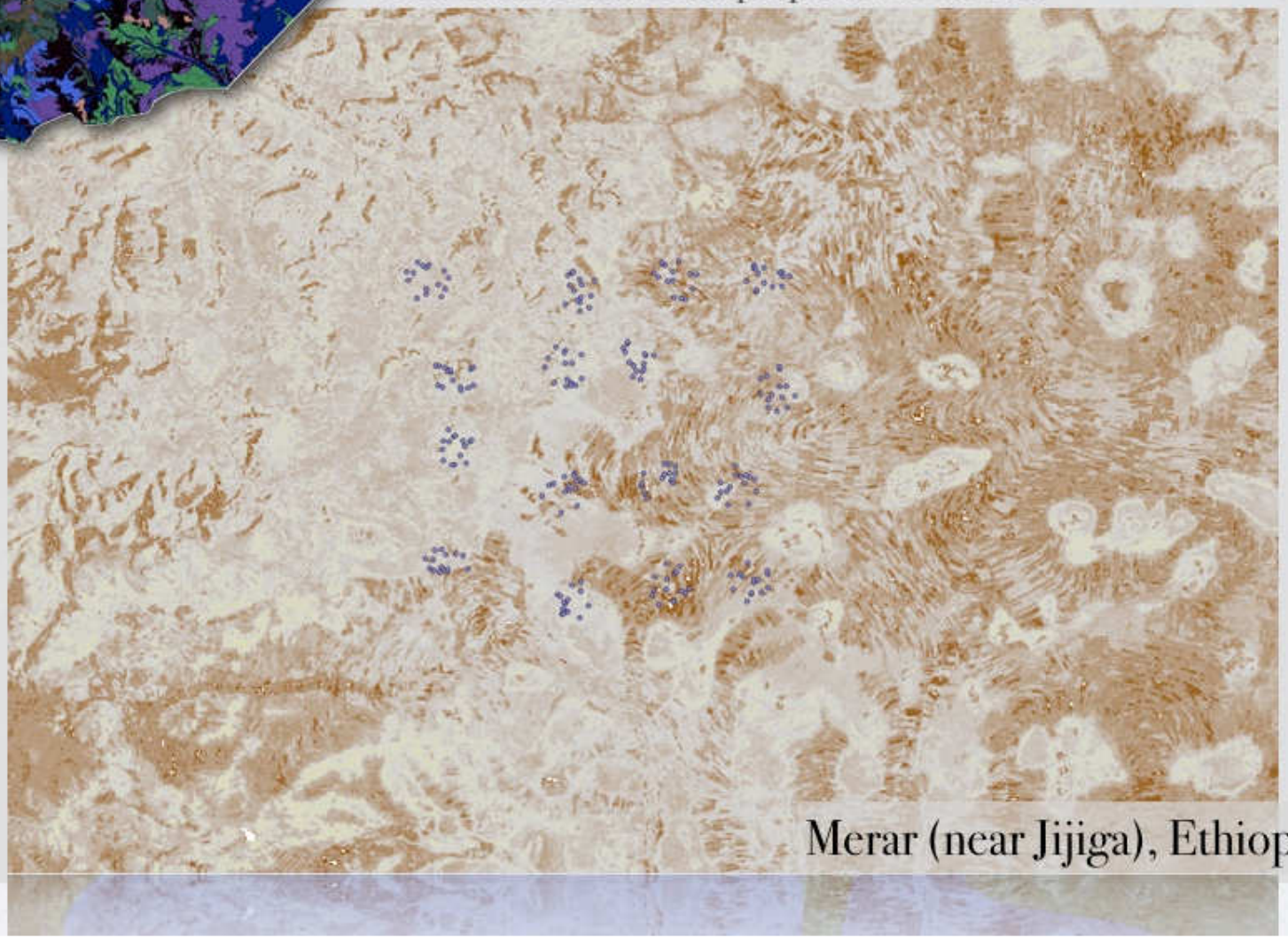


Coupling with remote sensing

Consistent field protocol

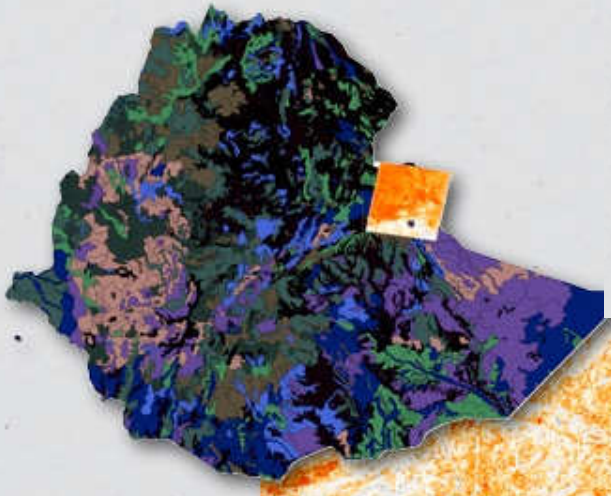
Soil spectroscopy

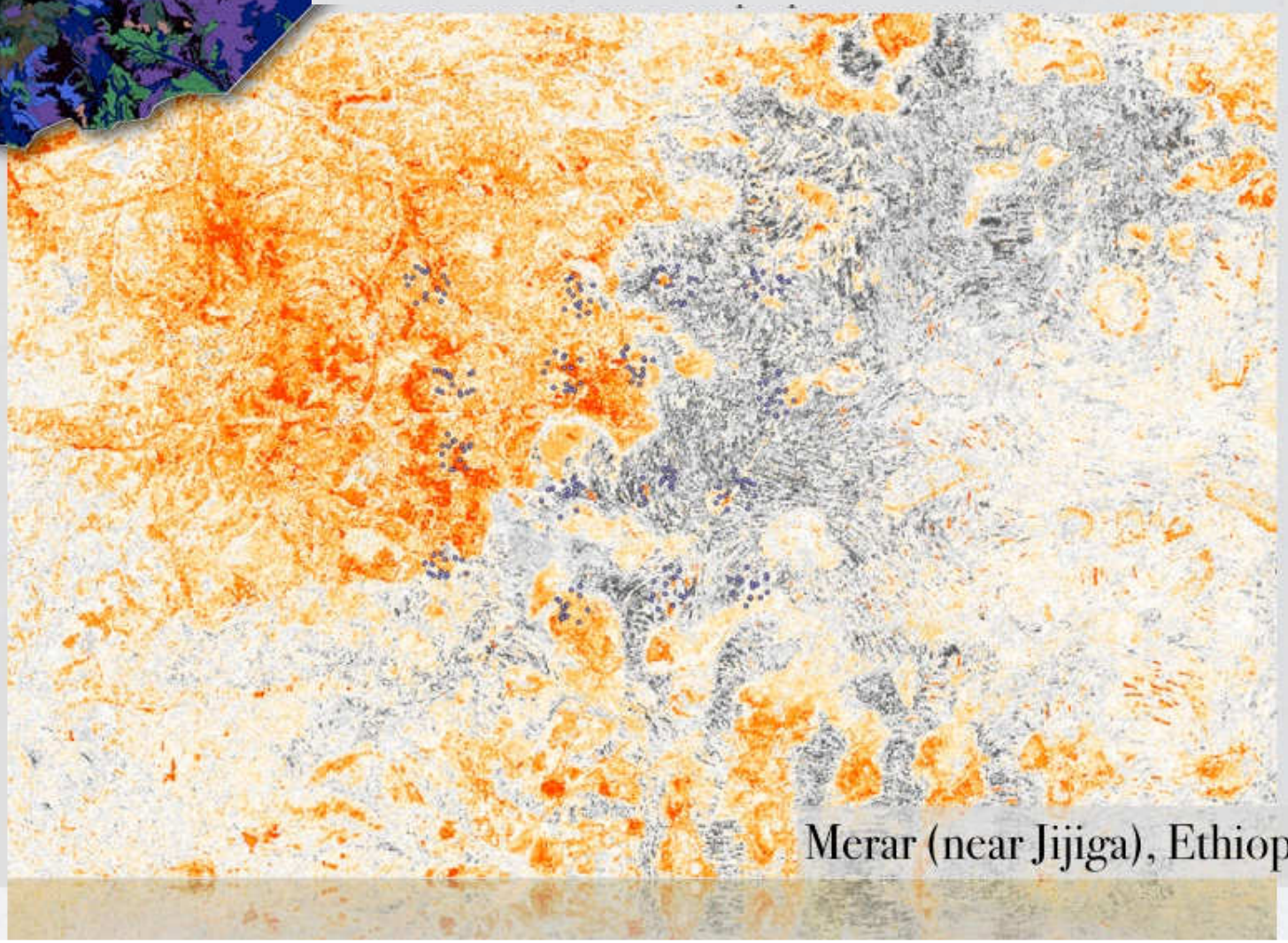
Soil Carbon (30m x 30m)



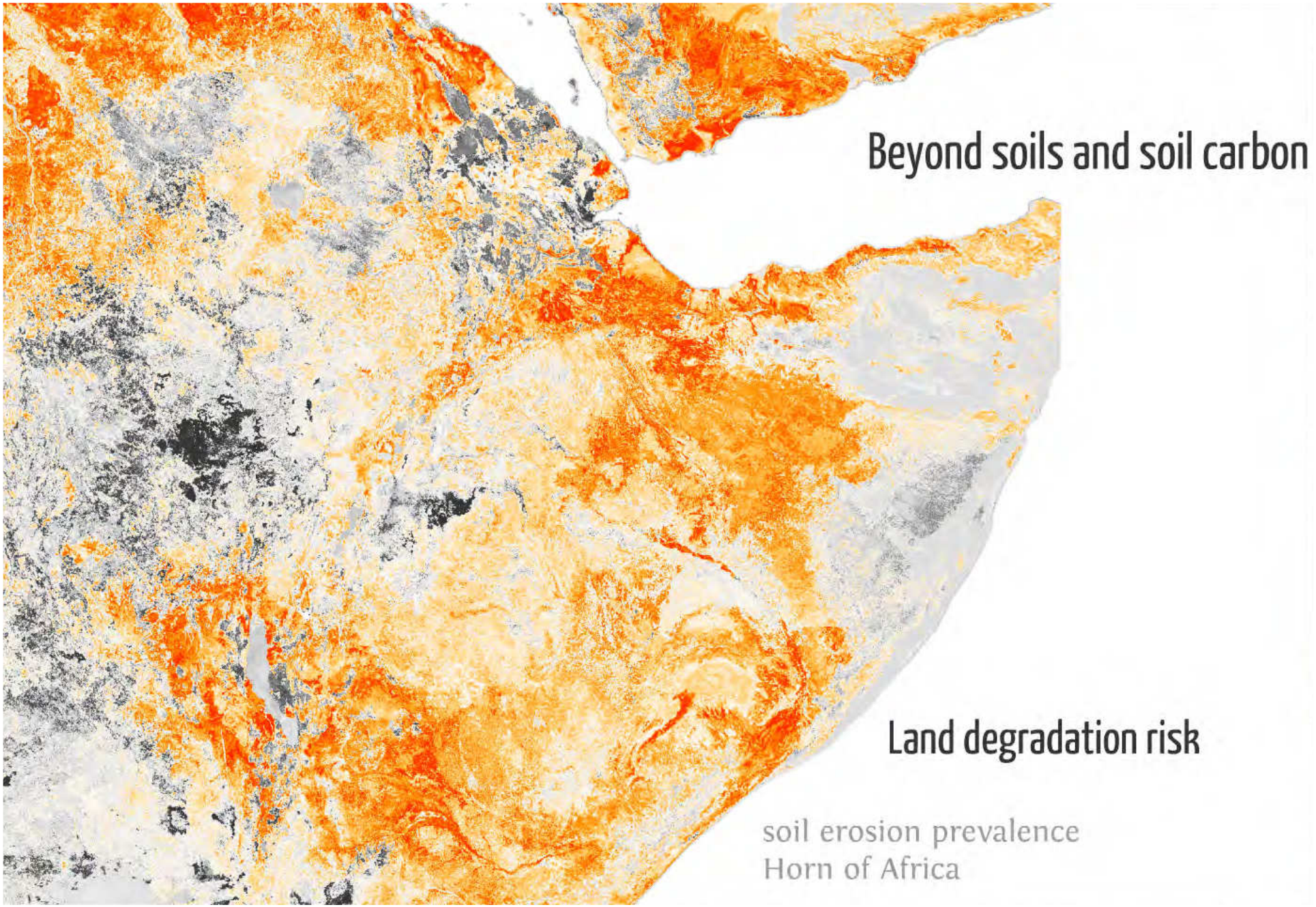
Merar (near Jijiga), Ethiopia

Soil Erosion prevalence





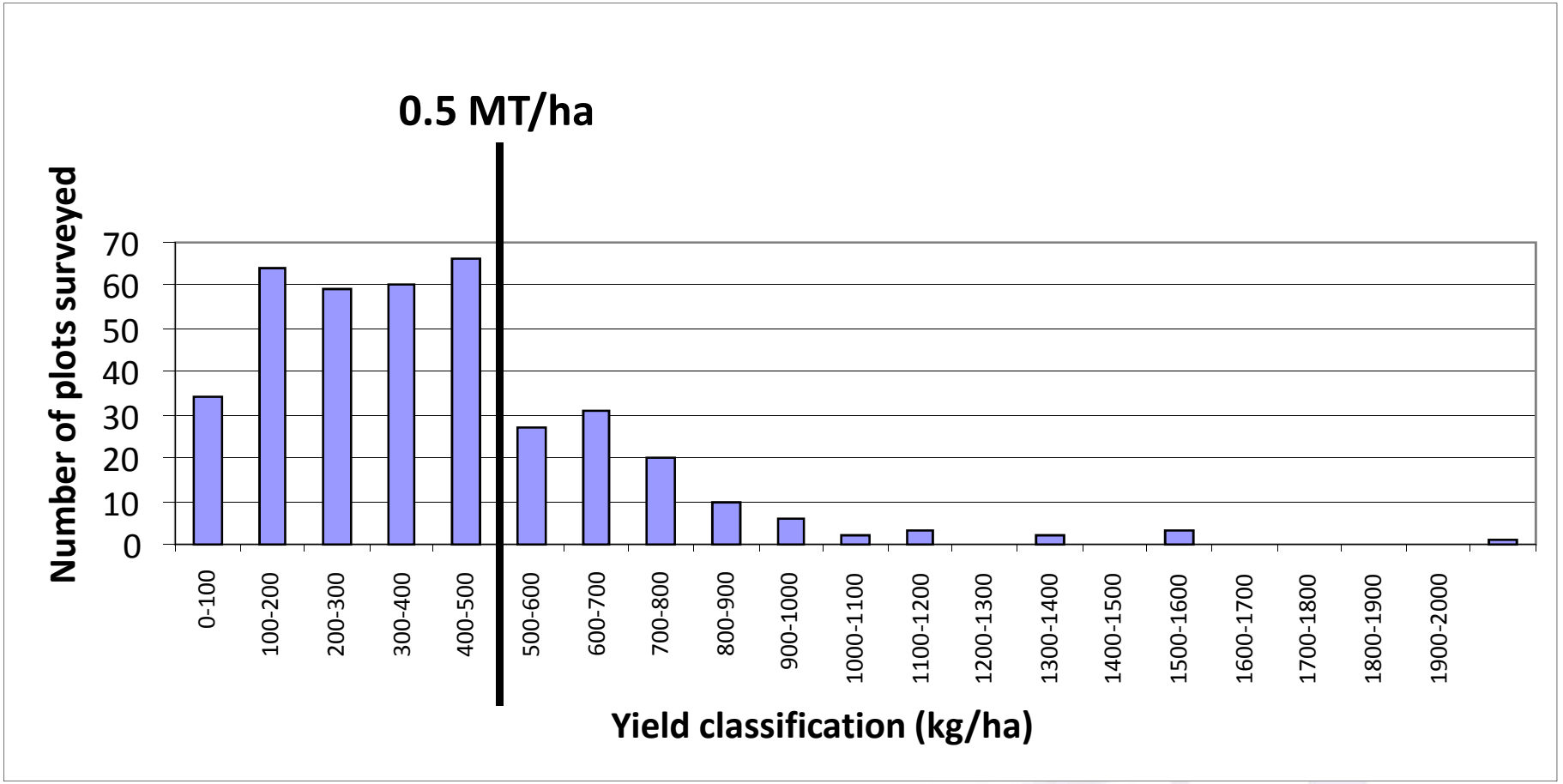
Merar (near Jijiga), Ethiopia


Beyond soils and soil carbon
Land degradation risk
soil erosion prevalence
Horn of Africa

Getting there

- Enabling policies
- Improved genetics
- Farmer information

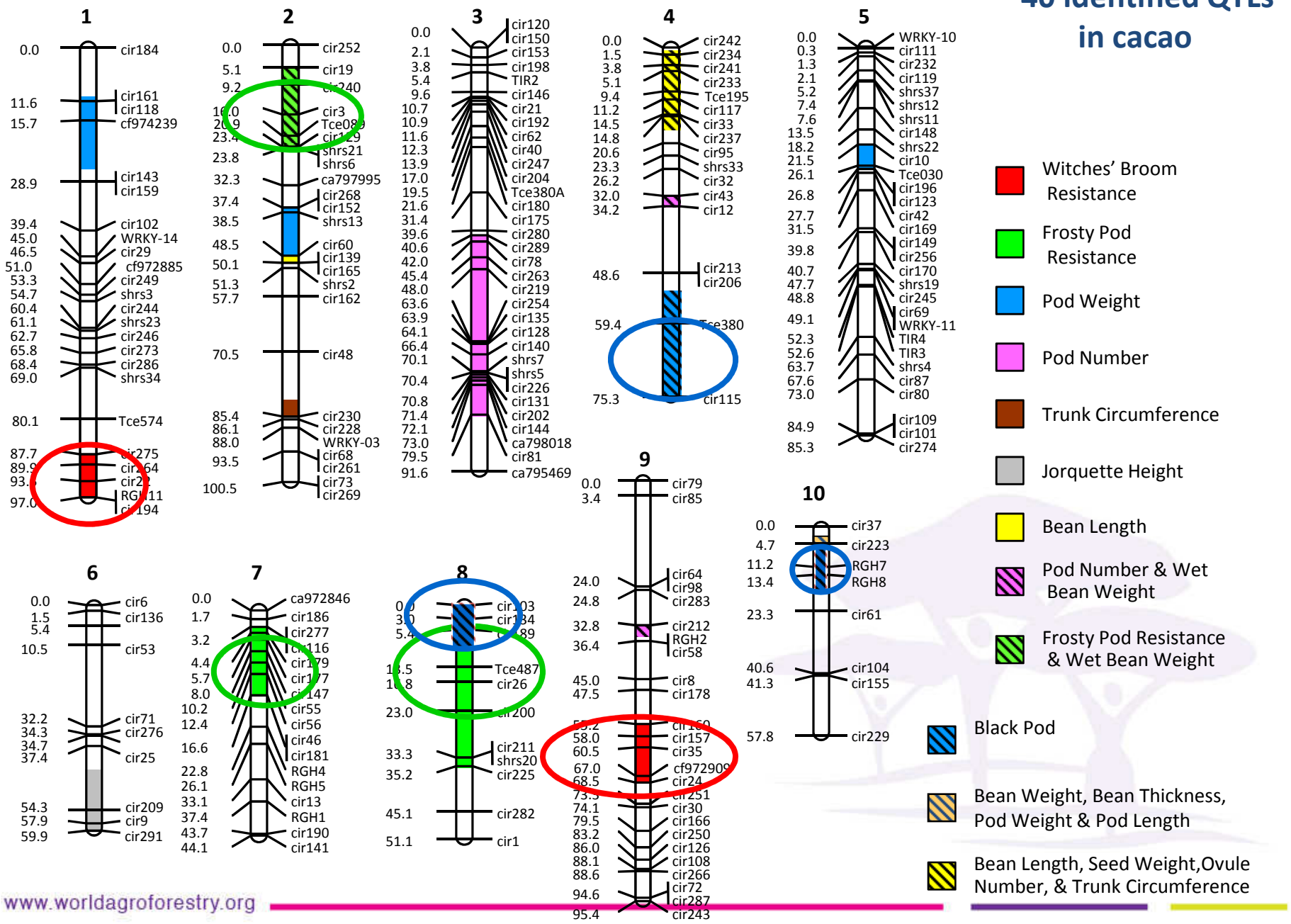
Cocoa Yields are too low



Source: *Etude sur les revenus et les investissements des producteurs de café et de cacao en Côte d'Ivoire,* Agrisystems Consortium, 2008

MARS-ICRAF-CDI Government Public Private Partnership

~40 identified QTLs in cacao

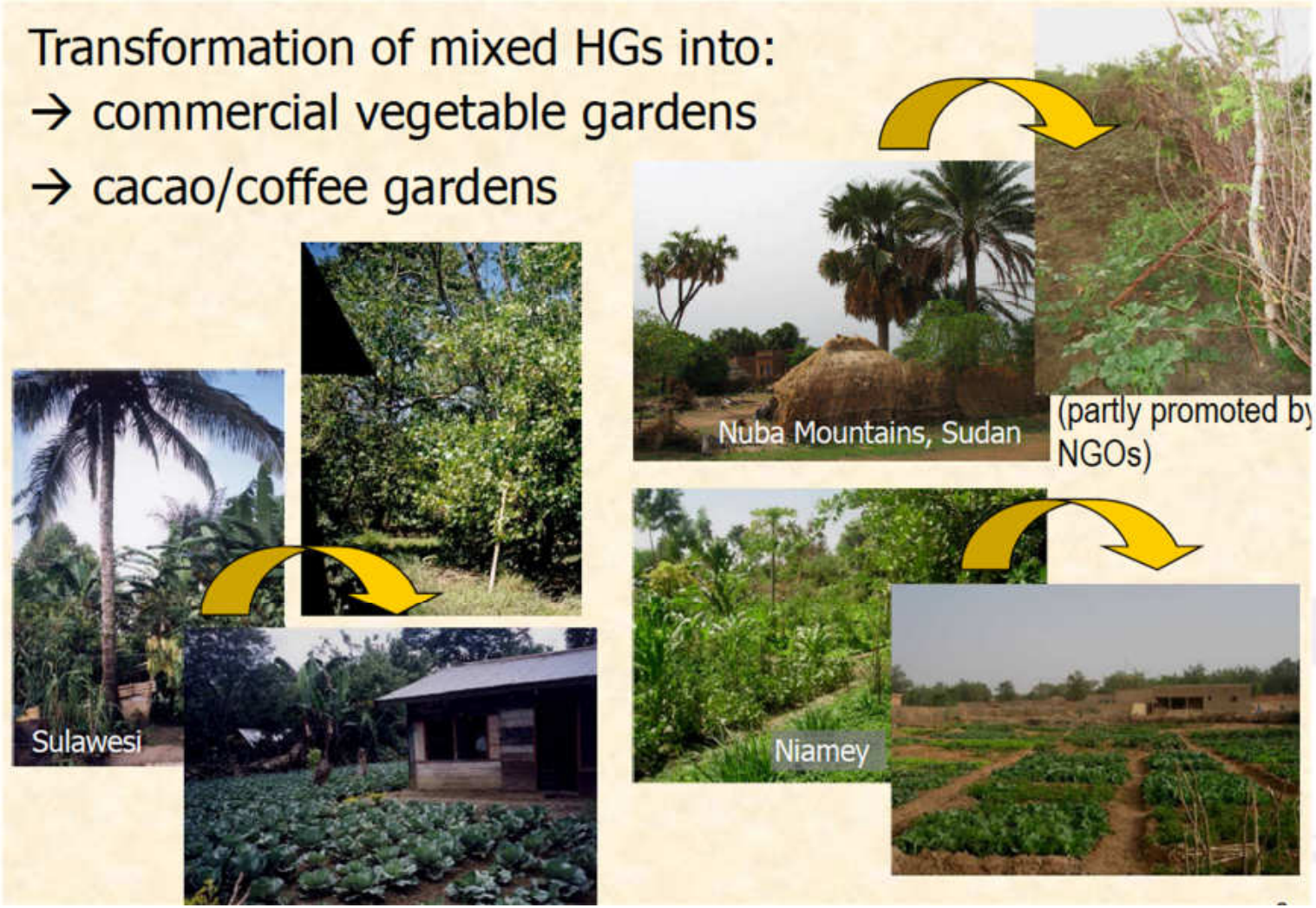


22 months after side grafting, from 4-5 pods to 30 pods per tree

Getting there

- Enabling policies
- Improved genetics
- Farmer information

The enemy: ignorance.



Fighting ignorance: the rural resource centres

RRCs expose farmers to updated technologies in domestication and agroforestry.

Demonstration plots help farmers acquire skills in production and marketing knowledge

.

RRCs: not ye olde extension service.

- More scope for joint research, adaptation, training, sharing and diffusion of good practices and technologies
- Better partnership between research, civil society organisations and farmers
- More flexibility in activities, room for testing and adaptation
- Gradual development
- Efforts to be self-sustaining

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Email:p.worms@cgiar.org
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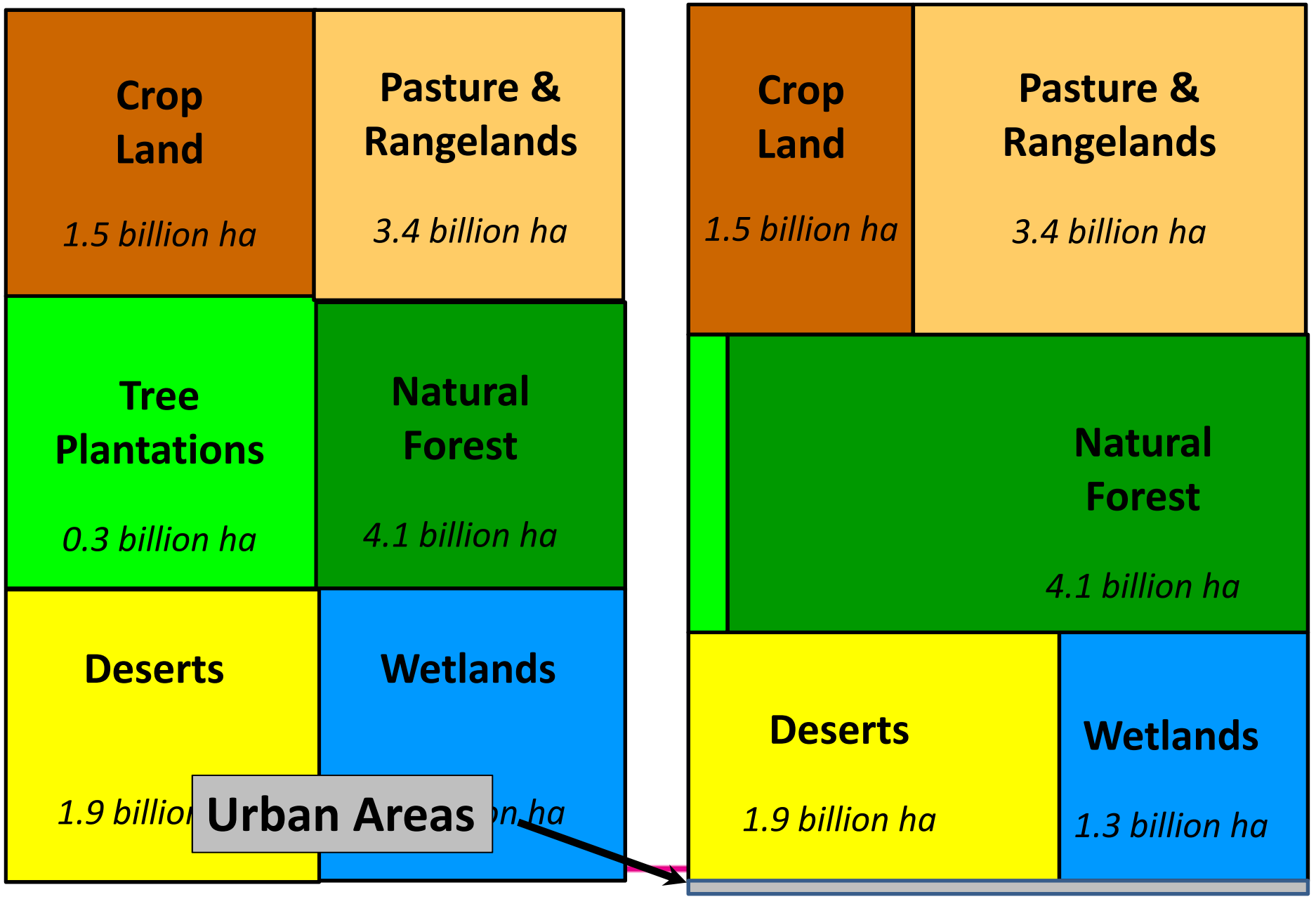
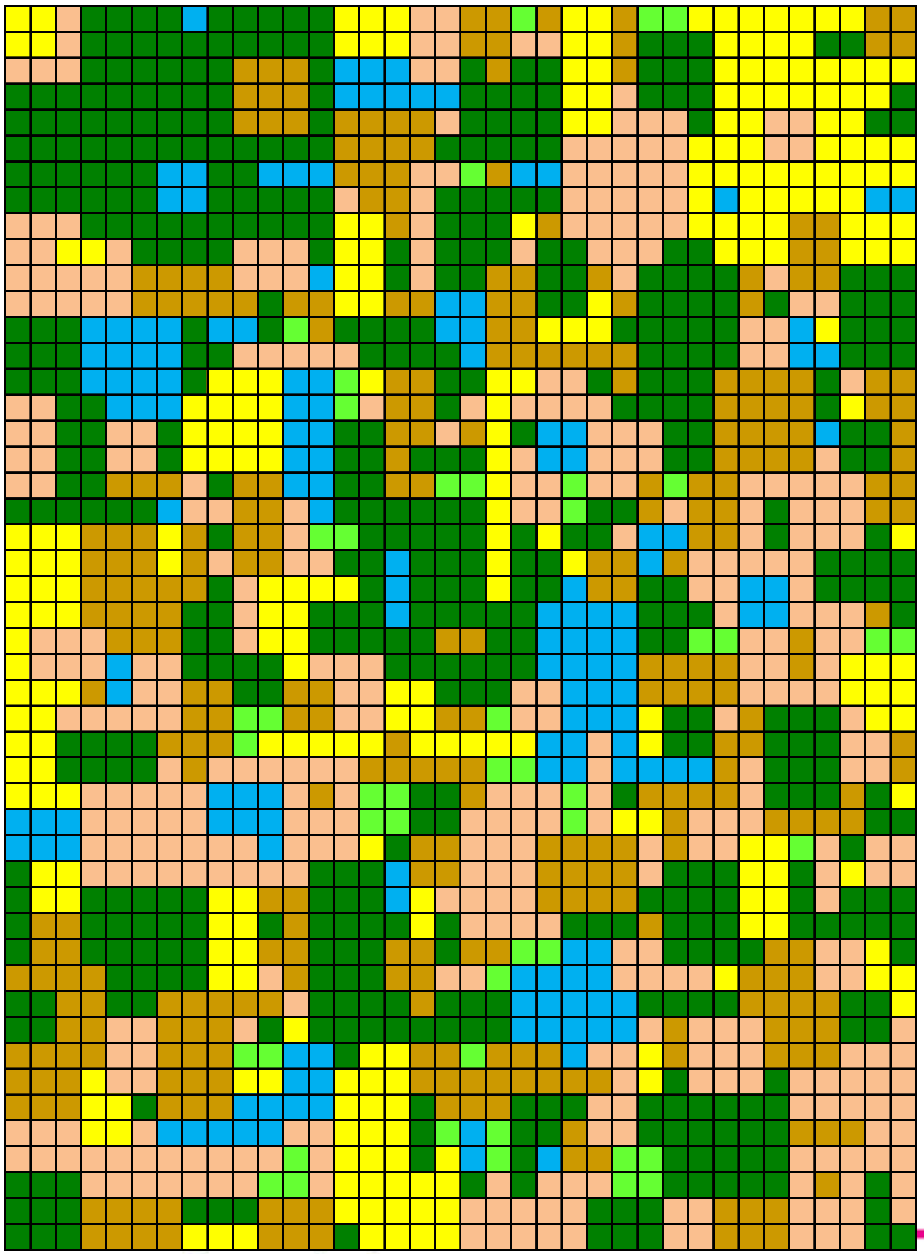
Global Land Area



Global Land Area - proportional



Crop Land

1.5 billion ha

Pasture & Rangelands

3.4 billion ha

Natural Forest

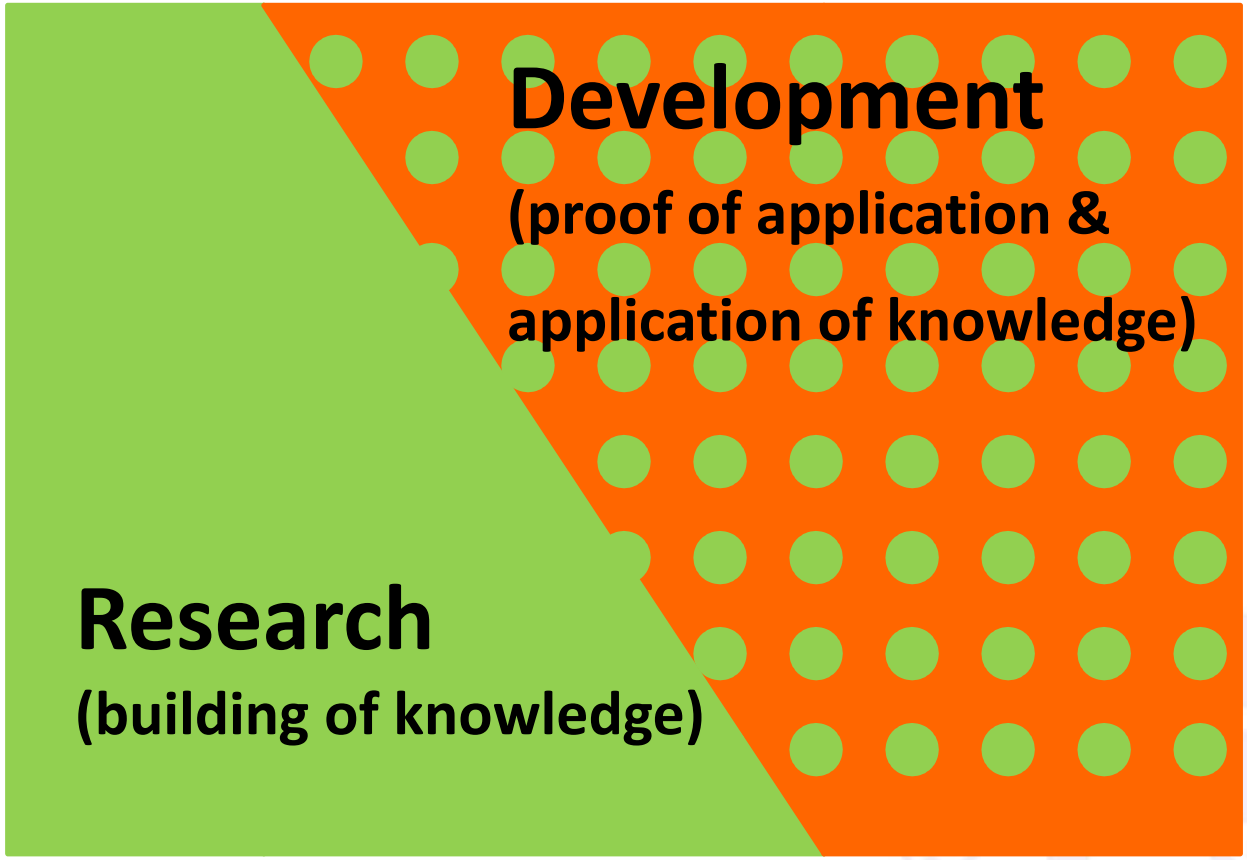
4.1 billion ha

Deserts

1.9 billion ha

Wetlands

1.3 billion ha



New Impact Pathway Paradigm

Time (years)