Farming Systems Ecology

Towards ecological intensification of world agriculture

Prof. dr *ir*. Pablo A. Tittonell

Inaugural lecture upon taking up the position of Chair in Farming Systems Ecology at Wageningen University on 16 May 2013

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A recurring question…

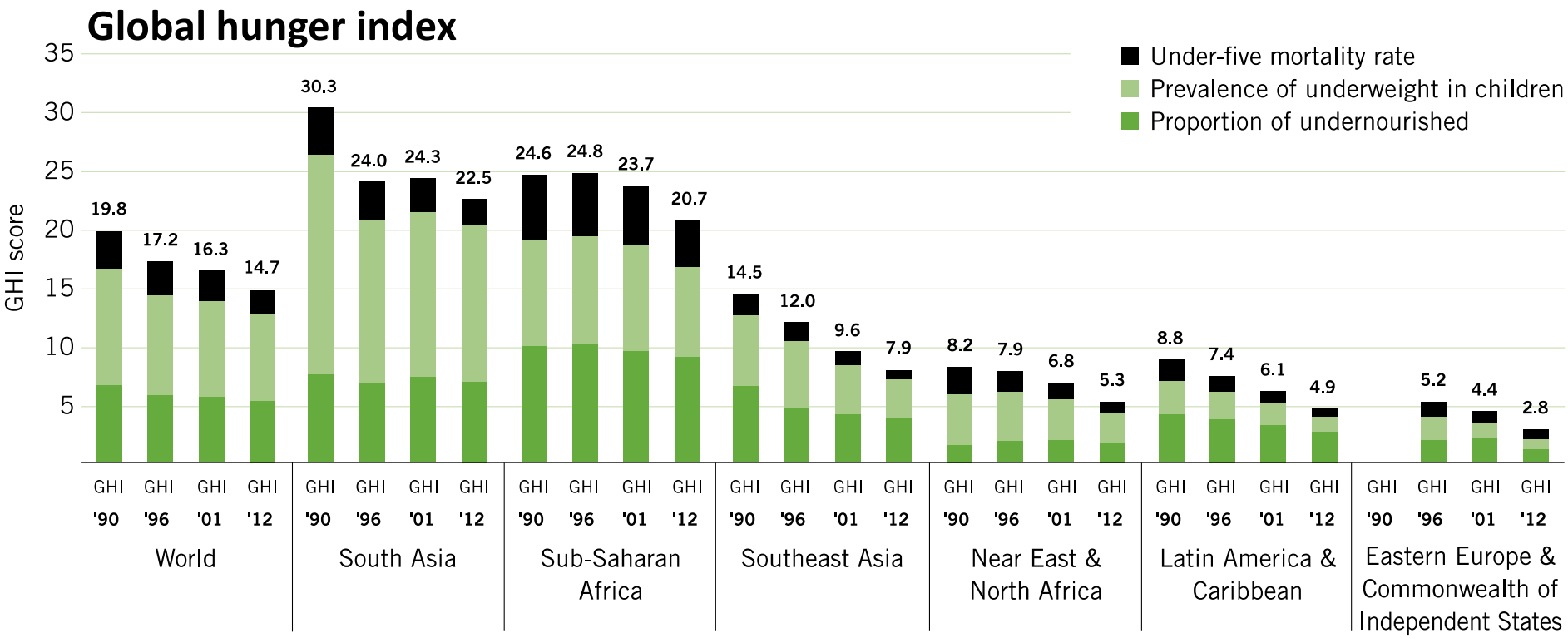
Can organic agriculture feed the world?

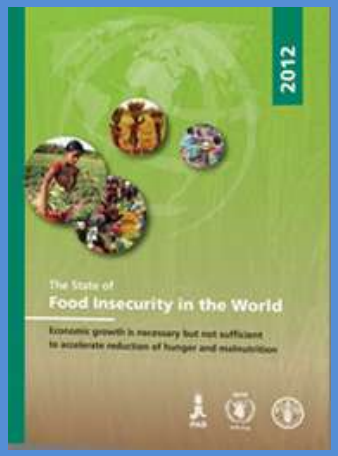
- Inappropriate – it deters any fruitful debate
- Misleading – complex problems require complex solutions
- Irrelevant – let’s turn it around…

Can conventional agriculture feed the world?



Can conventional agriculture feed the world?

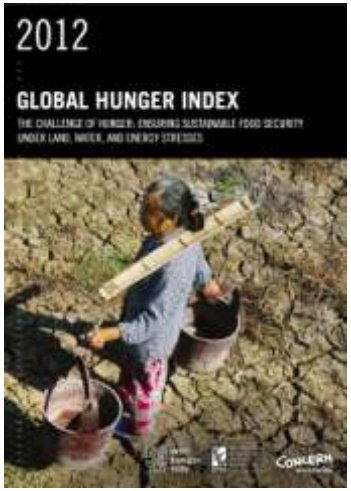




State of Food Insecurity in the World 2012

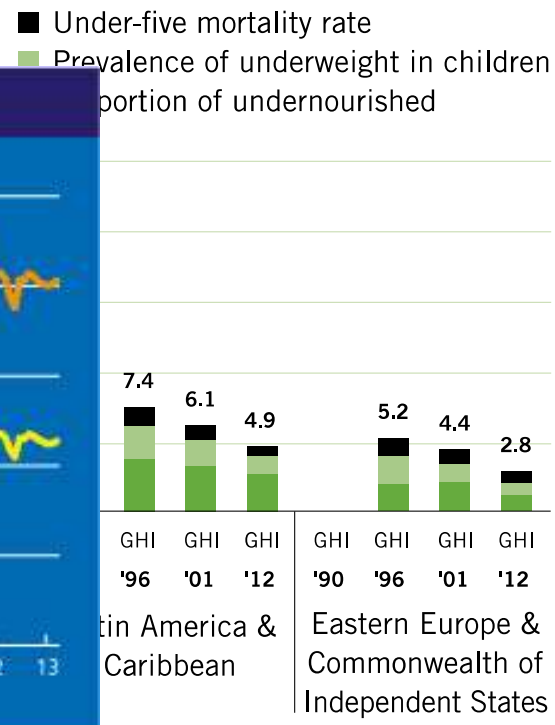
FAO, WFP, IFAD

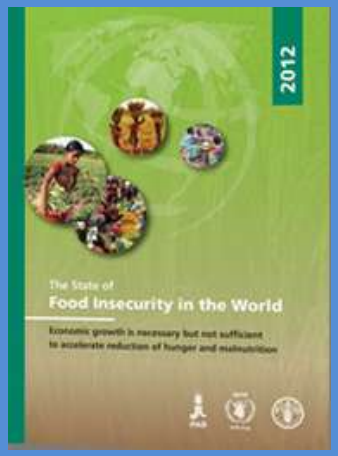
870 million people suffered from chronic undernourishment between 2010-12



Can conventional agriculture feed the world?

Global Food Price Index





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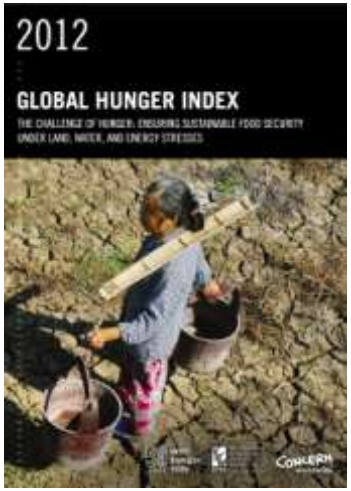

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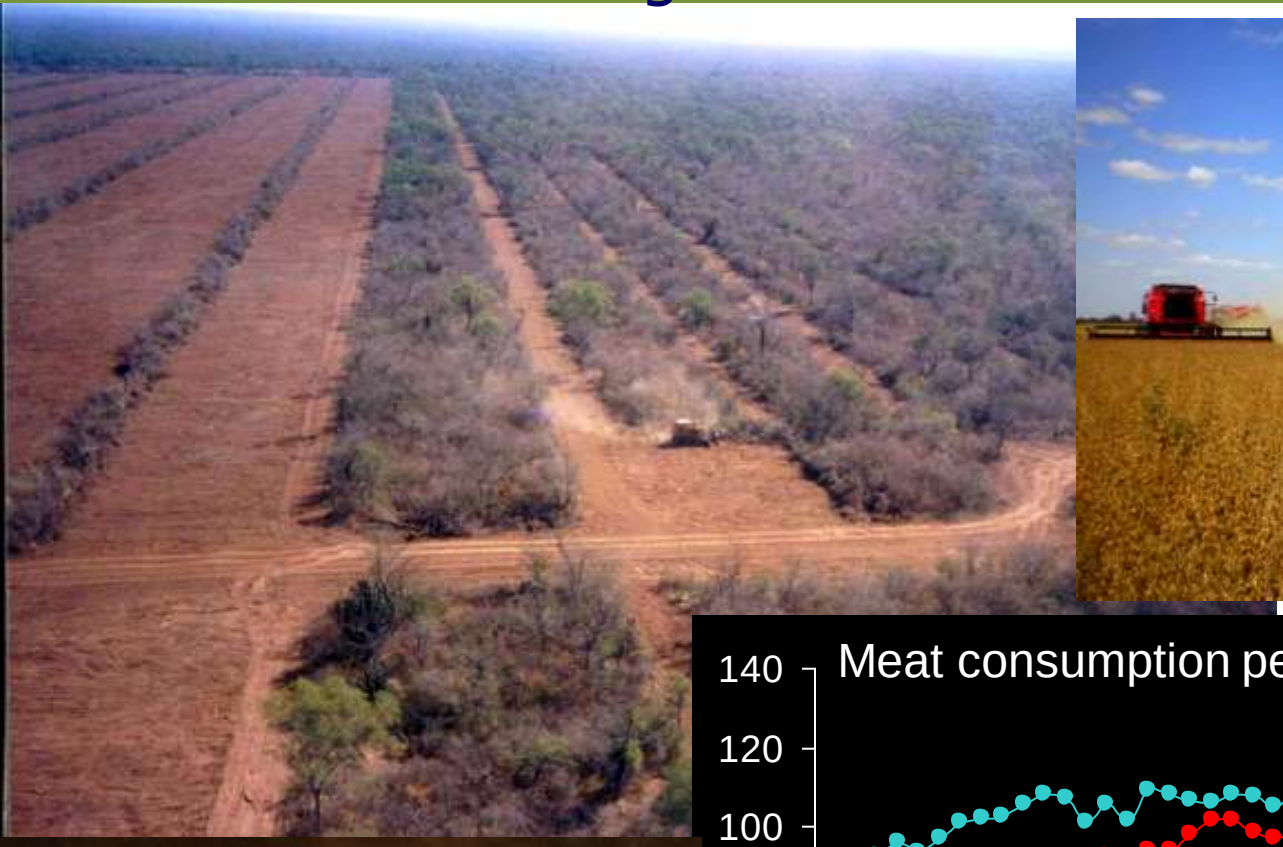
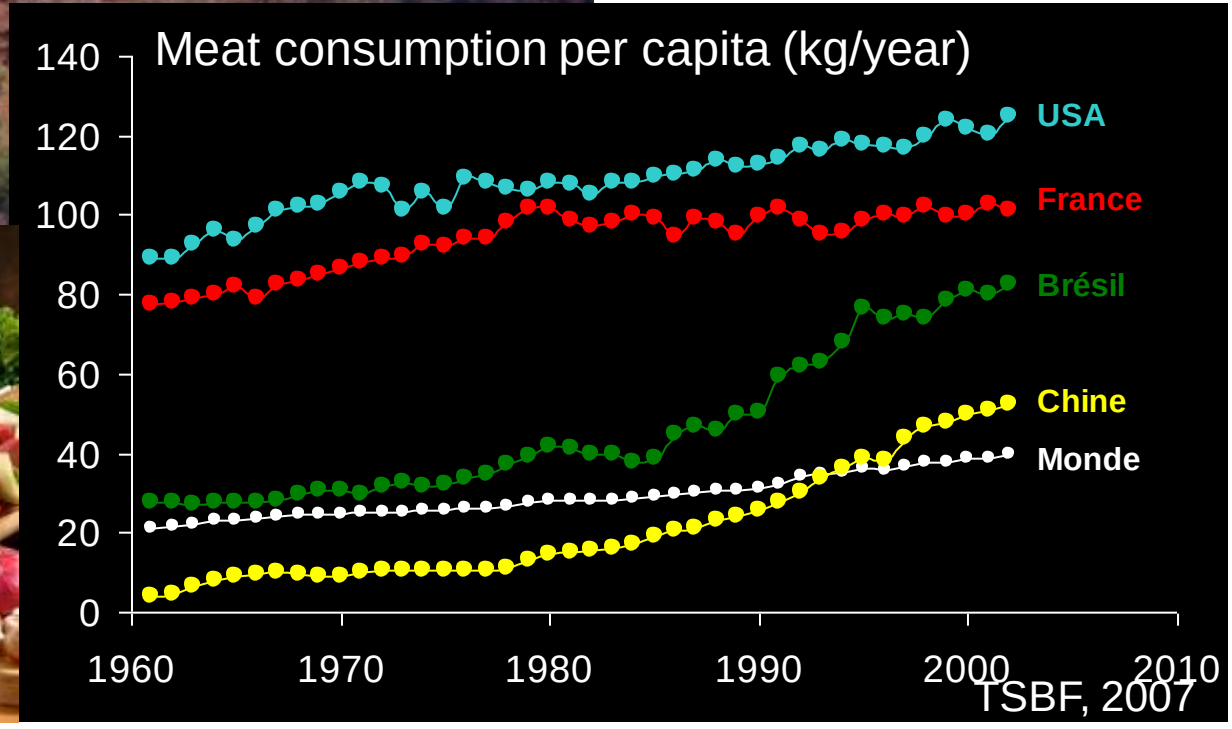
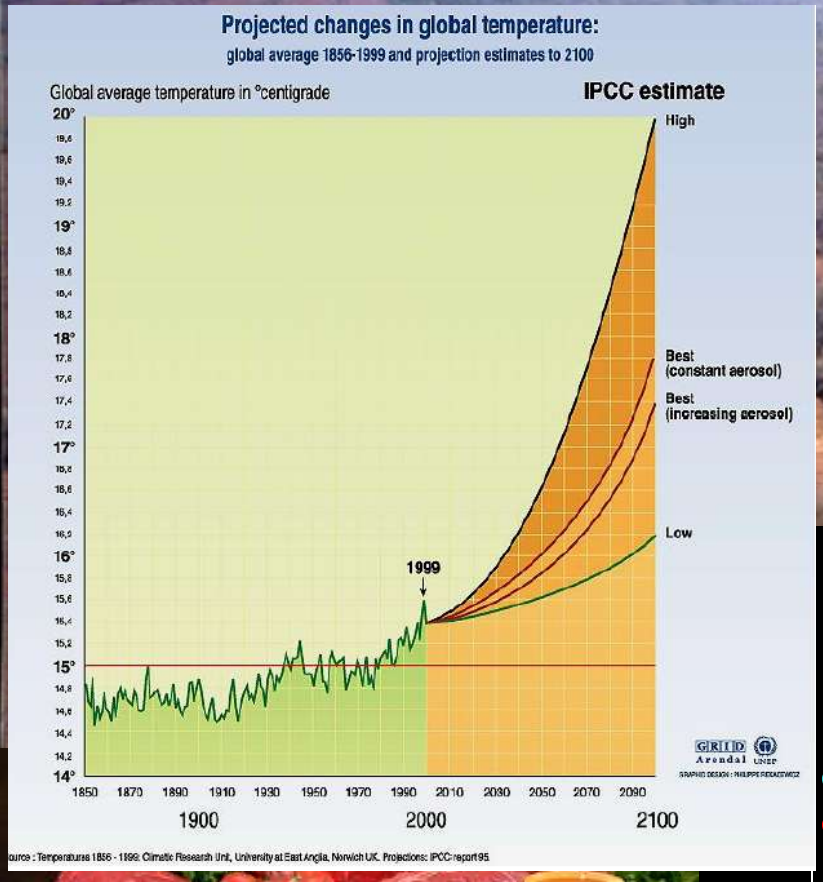
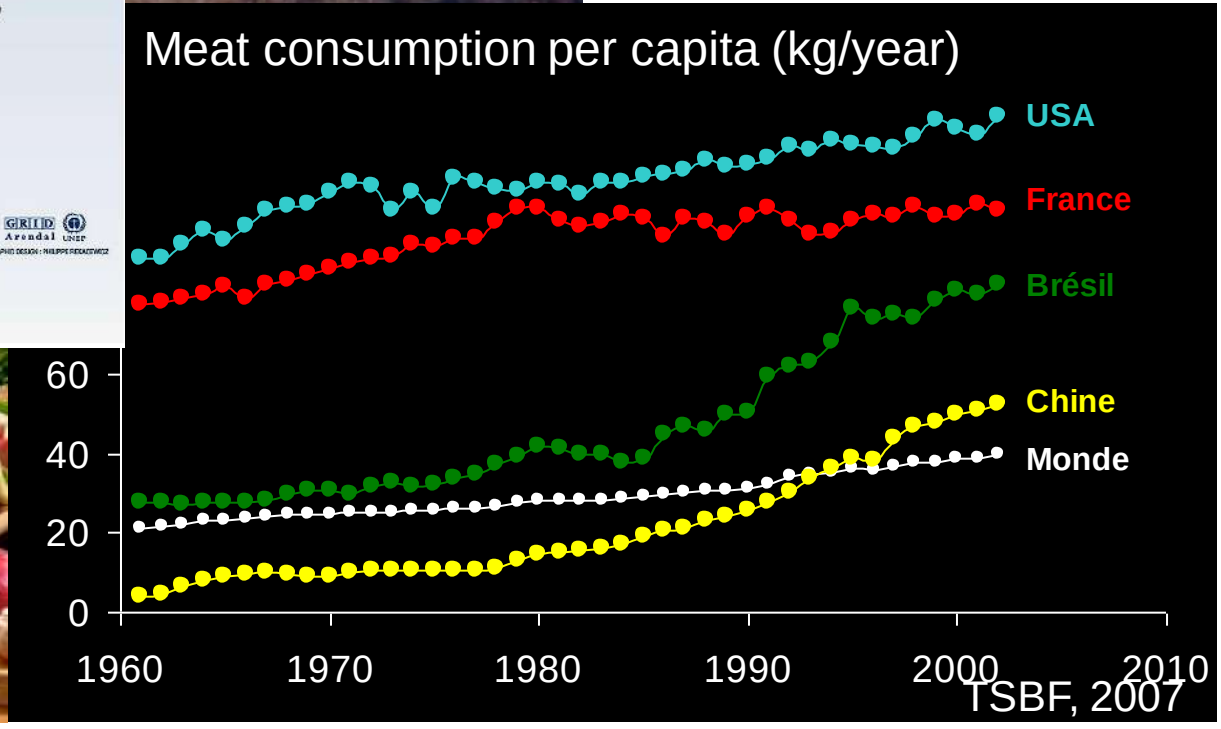




TSBF, 2007

Can conventional agriculture feed the world?





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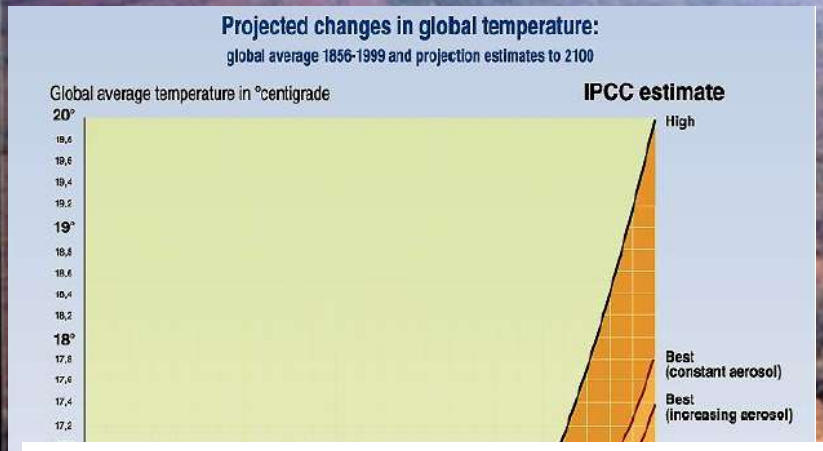
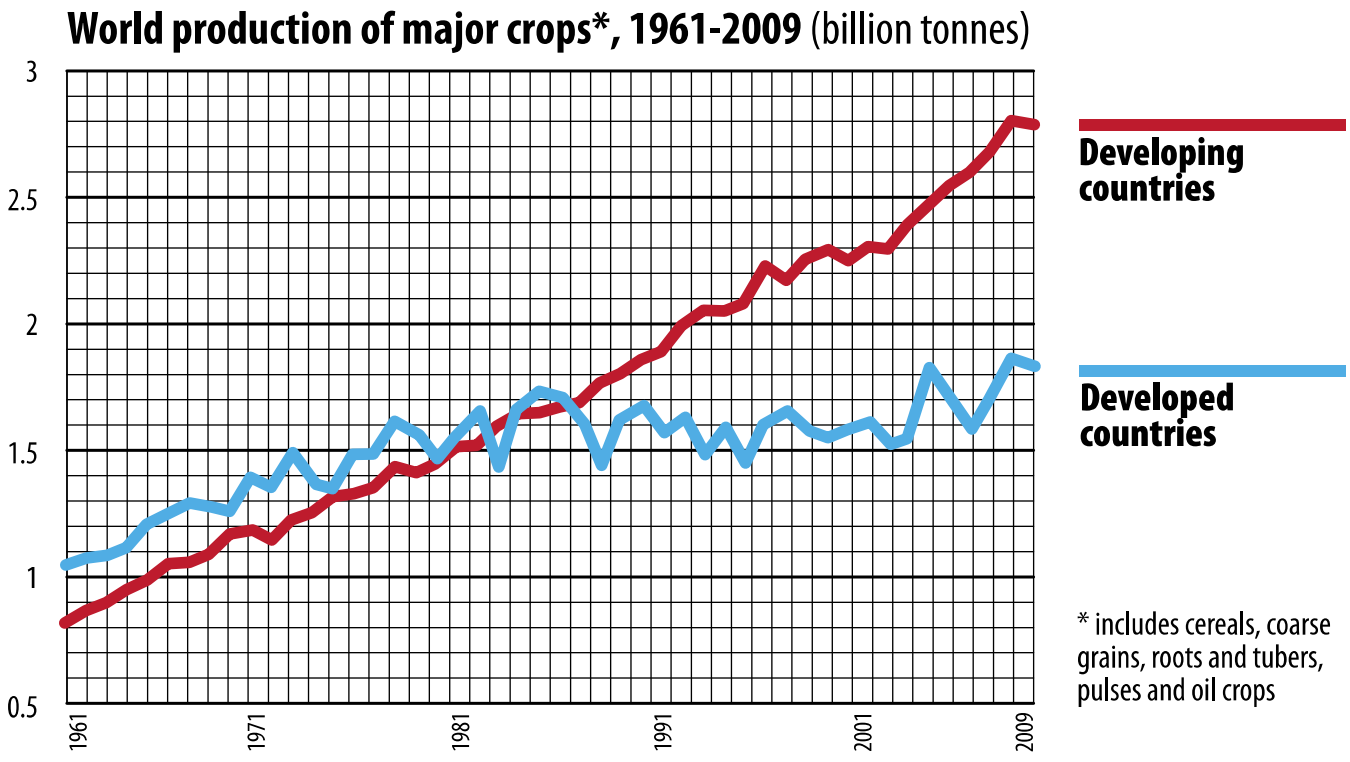




FAO. 2011.
FAOSTAT statistical database
(http://faostat.fao.org/).

Farming Systems Ecology

Towards ecological intensification of world agriculture

Outline:

1. Why does current agriculture fail at feeding the world?
2. Intensify, extensify, detoxify… (ecological intensification)
3. Farming Systems Ecology: systems, actors and landscapes

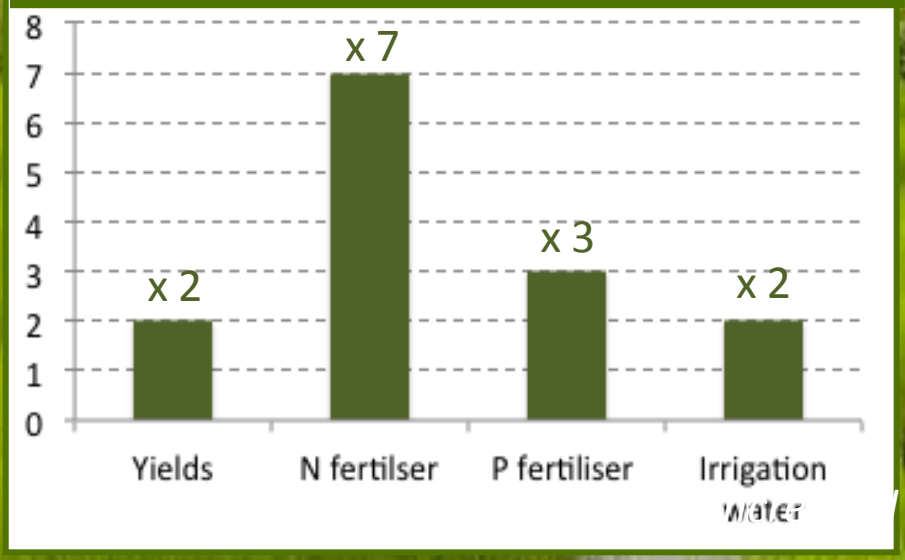
1. Why does current agriculture fail at feeding the world?

1. Worldwide, food is not produced where it is needed
2. Agricultural inputs not affordable to all farmers
3. Current diets not compatible with sustainable resource use
4. Ineffective market, storage and distribution chains

1. Why does current agriculture fail at feeding the world?

The green revolution

Green revolution cereals:



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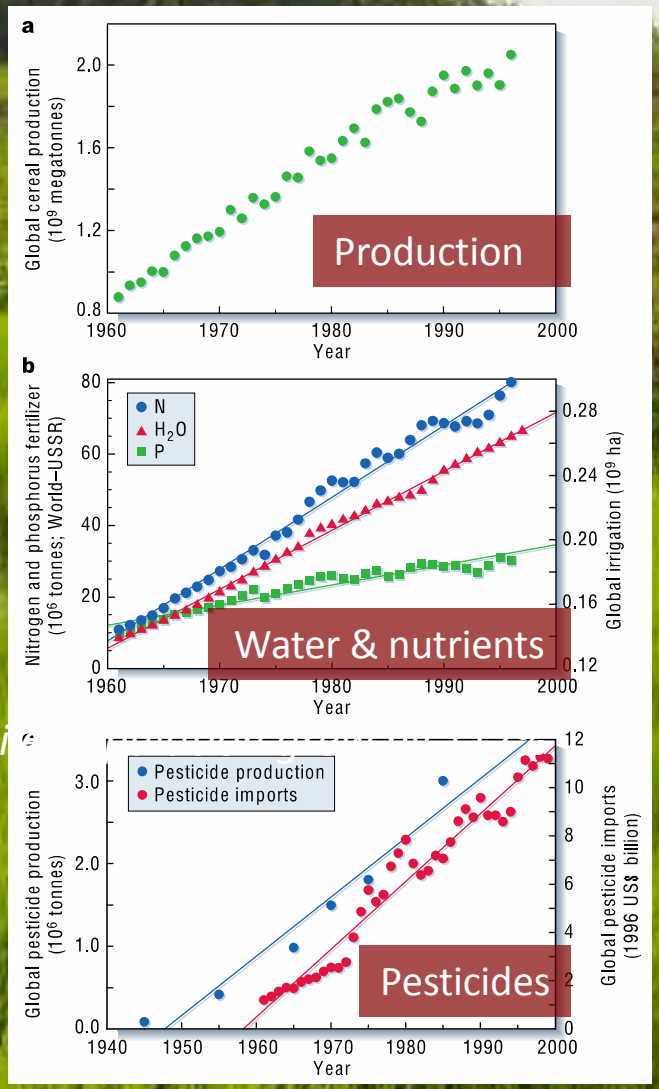

Figure 1 Agricultural trends over the past 40 years. **a**, Total global cereal production[2]; **b**, total global use of nitrogen and phosphorus fertilizer (except former USSR not included) and area of global irrigated land; and **c**, total global pesticide production[3] and global pesticide imports (summed across all countries)[2]. Parts **b** and **c** modified from ref. 4.

Agricultural sustainability and intensive production practices

David Tilman*, Kenneth G. Cassman‡, Pamela A. Matson§‖, Rosamond Naylor‖ & Stephen Polasky†

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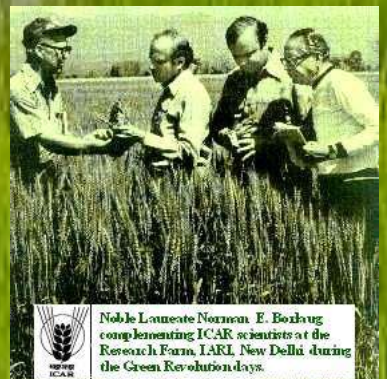
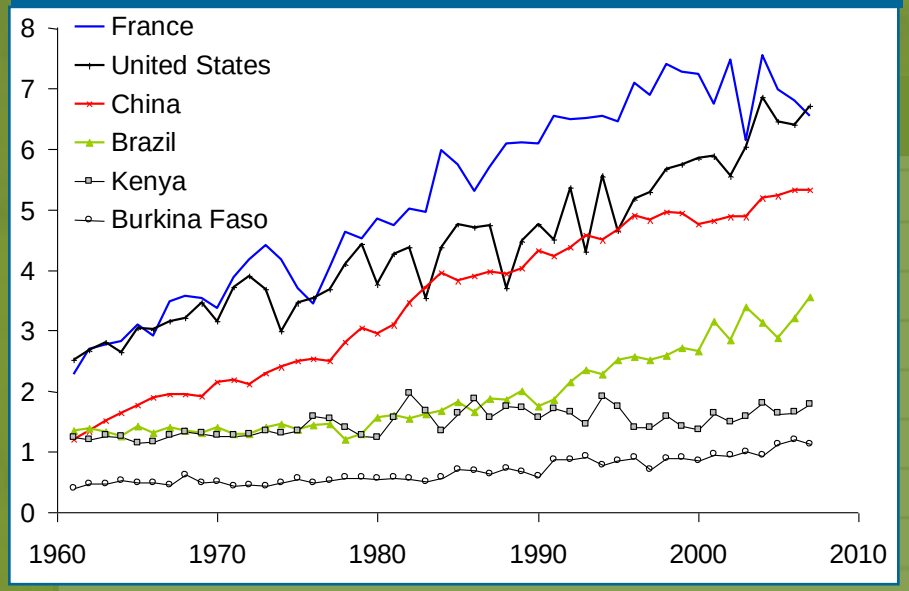
A doubling in global food demand projected for the next 50 years poses huge challenges for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services they provide to society. Agriculturalists are the principal managers of global useable lands and will shape, perhaps irreversibly, the surface of the Earth in the coming decades. New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if we are to meet the demands of improving yields without compromising environmental integrity or public health.

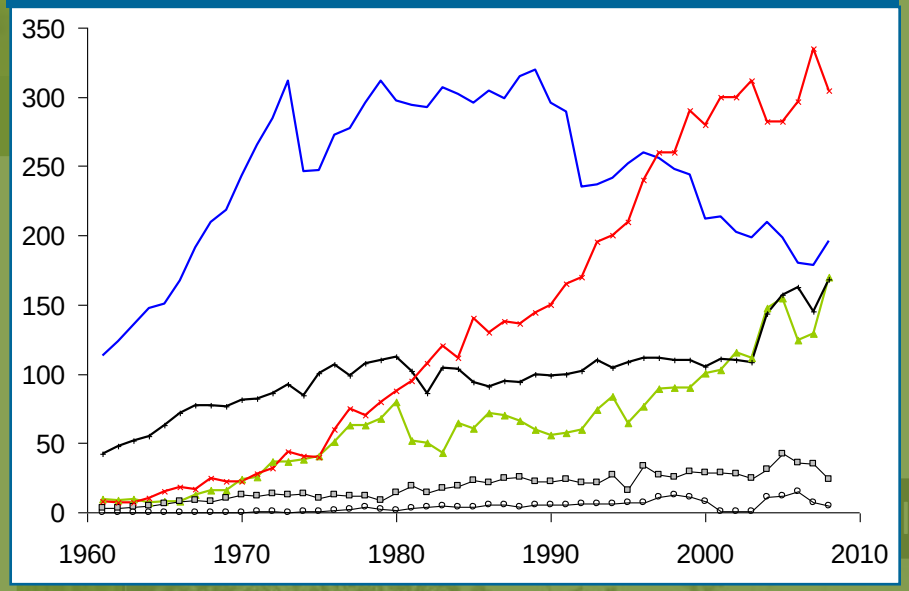


The green revolution

Cereal productivity (t ha^{-1} yr^{-1})



Fertiliser use intensity (kg ha^{-1} yr^{-1})



Fertiliser N use efficiency in China (Ju et al., 2009)

Year	Grain Production (M tonnes)	N fertiliser (M tonnes)	PFP_N (kg/kg)
1977	283	7.07	40.0
2005	484	26.21	18.5
% change	71%	271%	-54%

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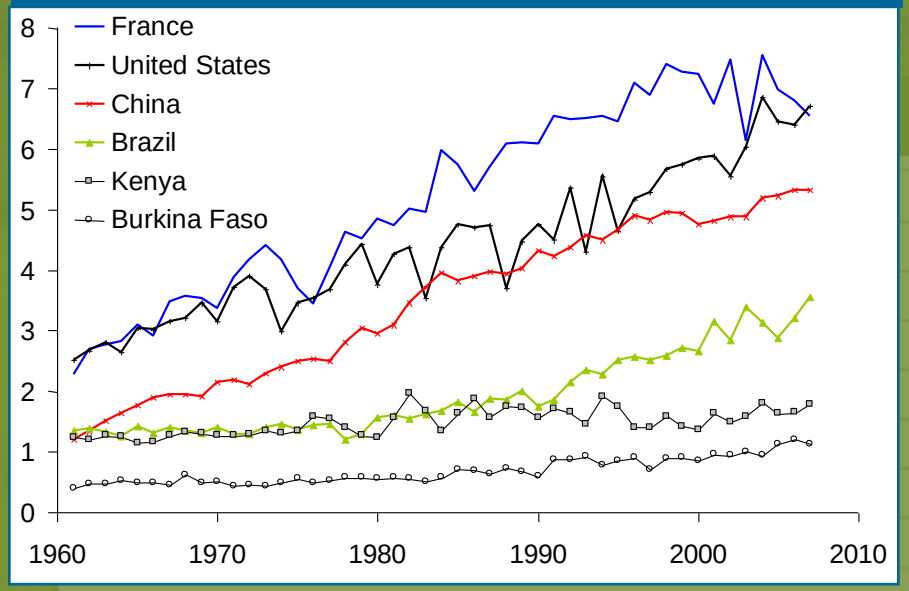

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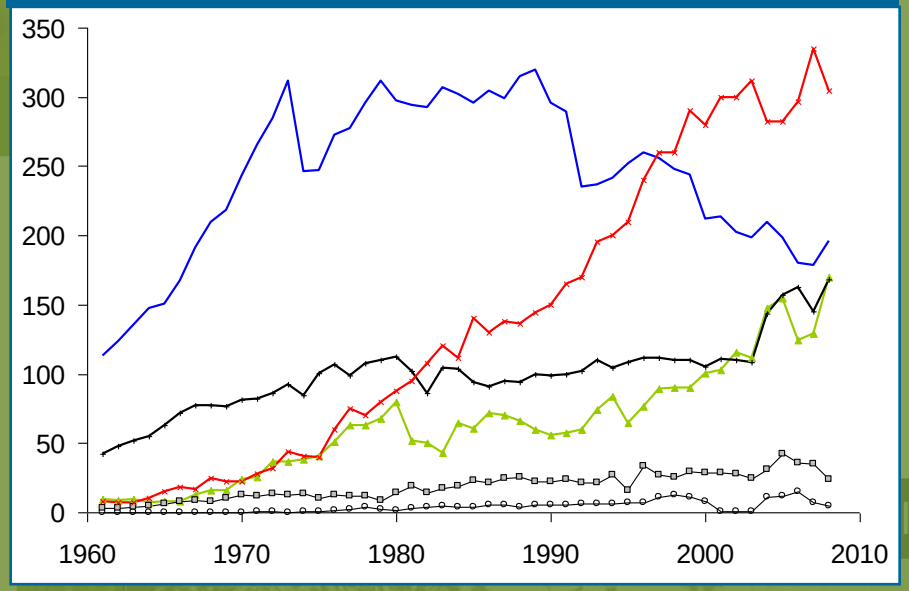


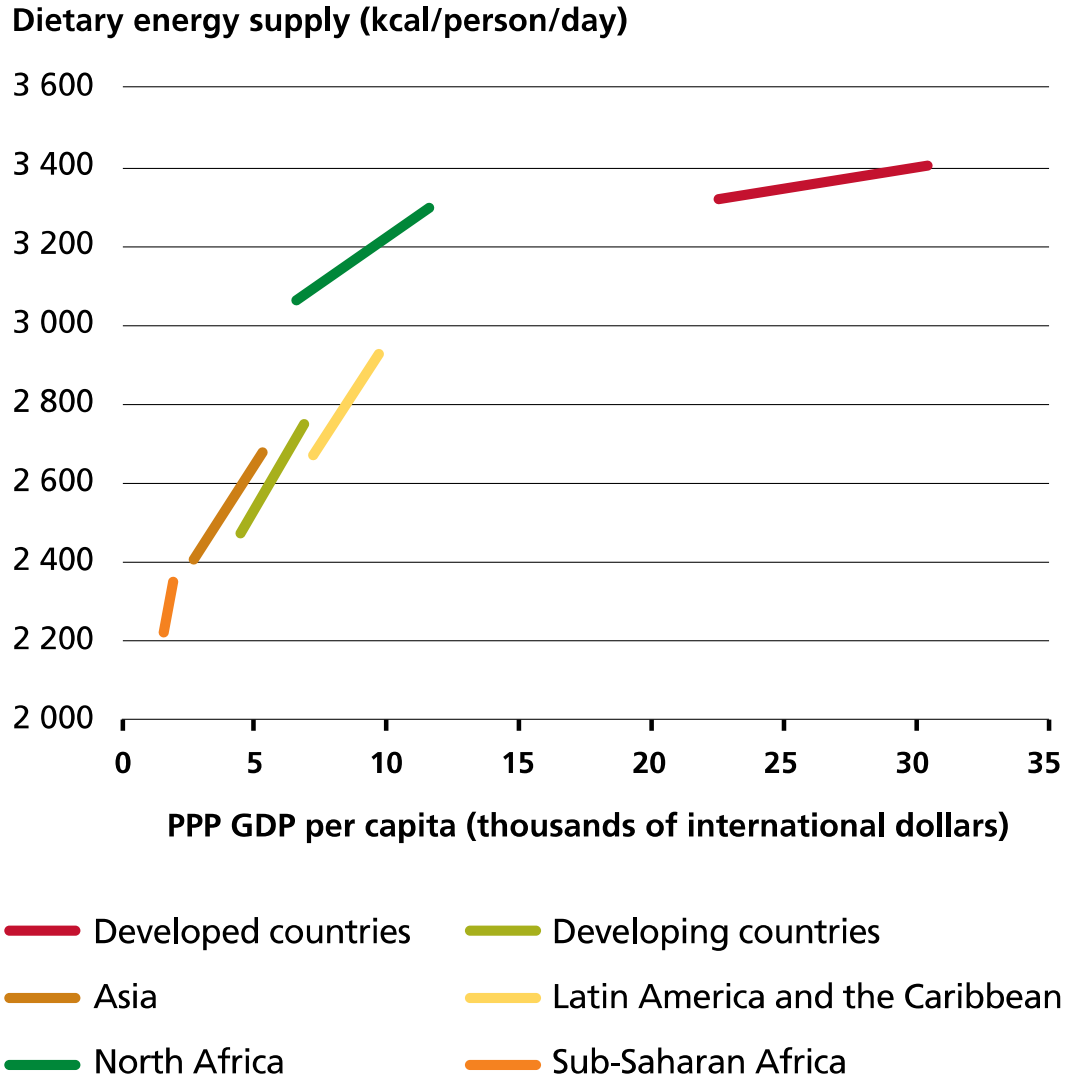
Fertiliser N use efficiency in China (Ju et al., 2009)

Year	Grain Production (M tonnes)	N fertiliser (M tonnes)	PFP_N (kg/kg)

With the excess fertiliser used by Chinese farmers it is possible to fertilise the whole of SS Africa at a rate of 60 kg/ha (Ju et al., 2009)

Obesity outweighs hunger

Food demand increases as incomes rise



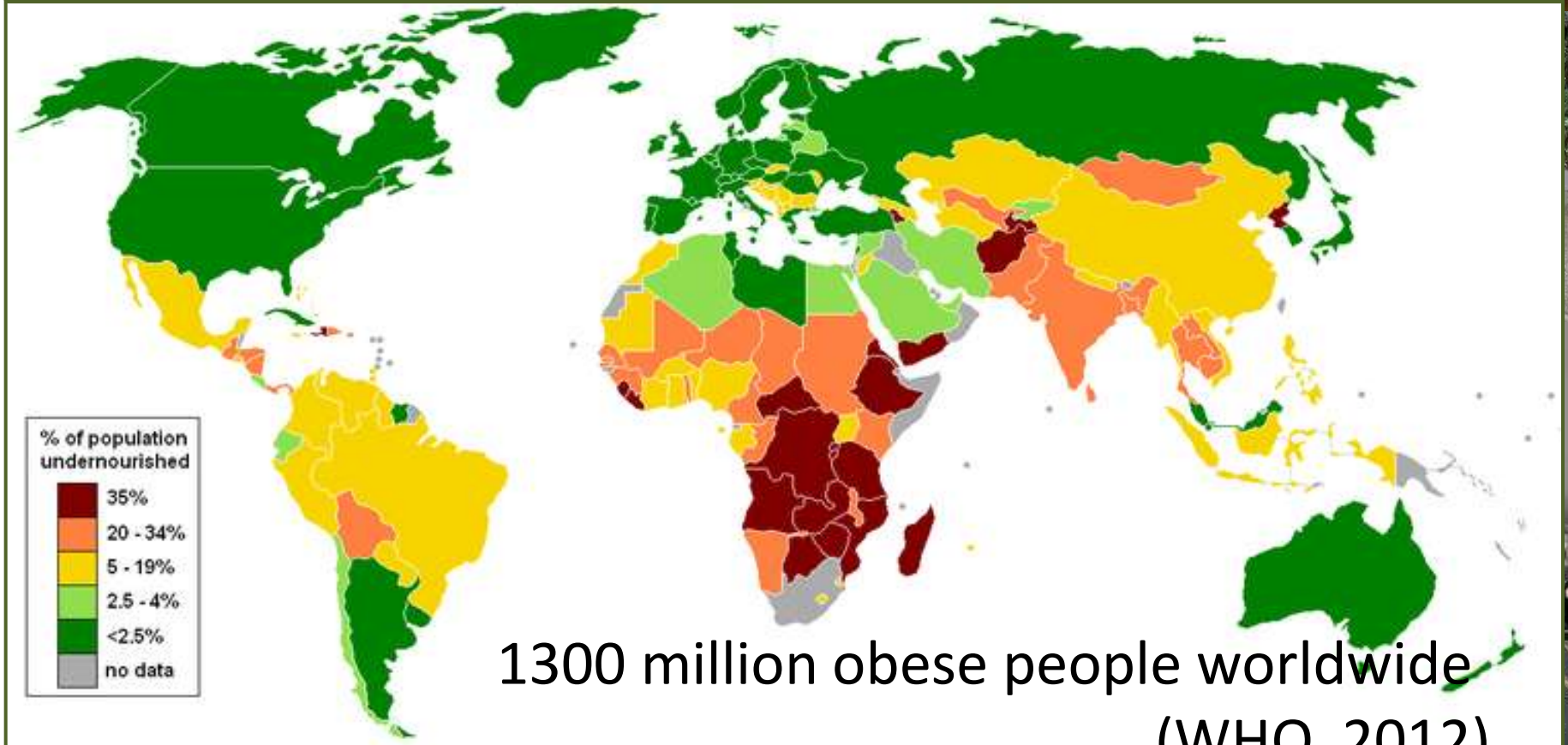
Notes: PPP = purchasing power parity. Regional aggregates include only developing countries.
Sources of raw data: FAO and World Bank.

Obesity outweighs hunger

Food demand increases as incomes rise

Dietary energy supply (kcal/person/day)

Prevalence of undernourishment



1300 million obese people worldwide (WHO, 2012)

North Africa Sub-Saharan Africa

Notes: PPP = purchasing power parity. Regional aggregates include only developing countries.
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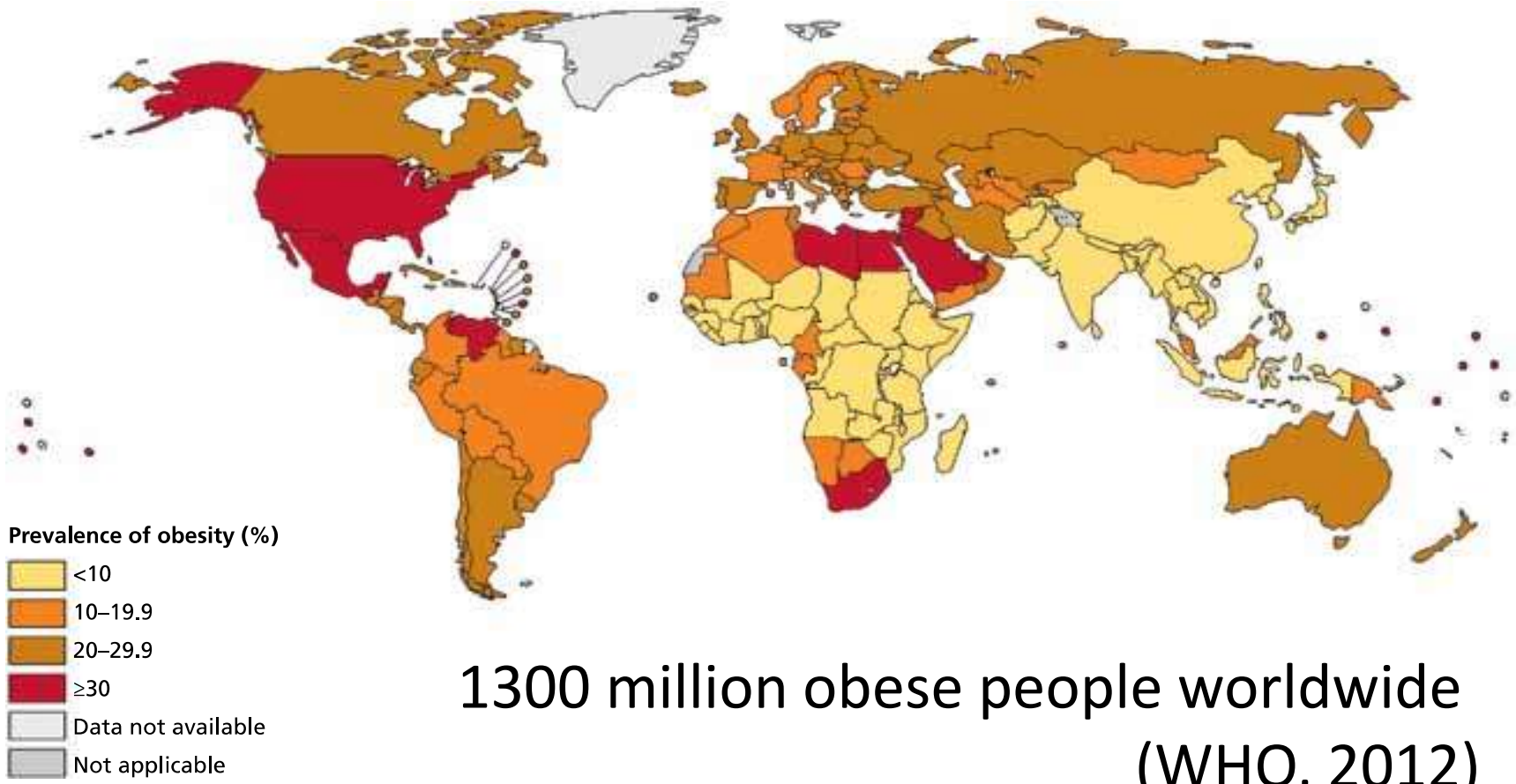
Prevalence of obesity



1300 million obese people worldwide (WHO, 2012)

Notes: Data refer to adults of both sexes aged 20+, age standardized, in 2008. Obesity is defined as BMI ≥30kg/m².
Source: World Health Organization.

Sources of raw data: FAO and World Bank.

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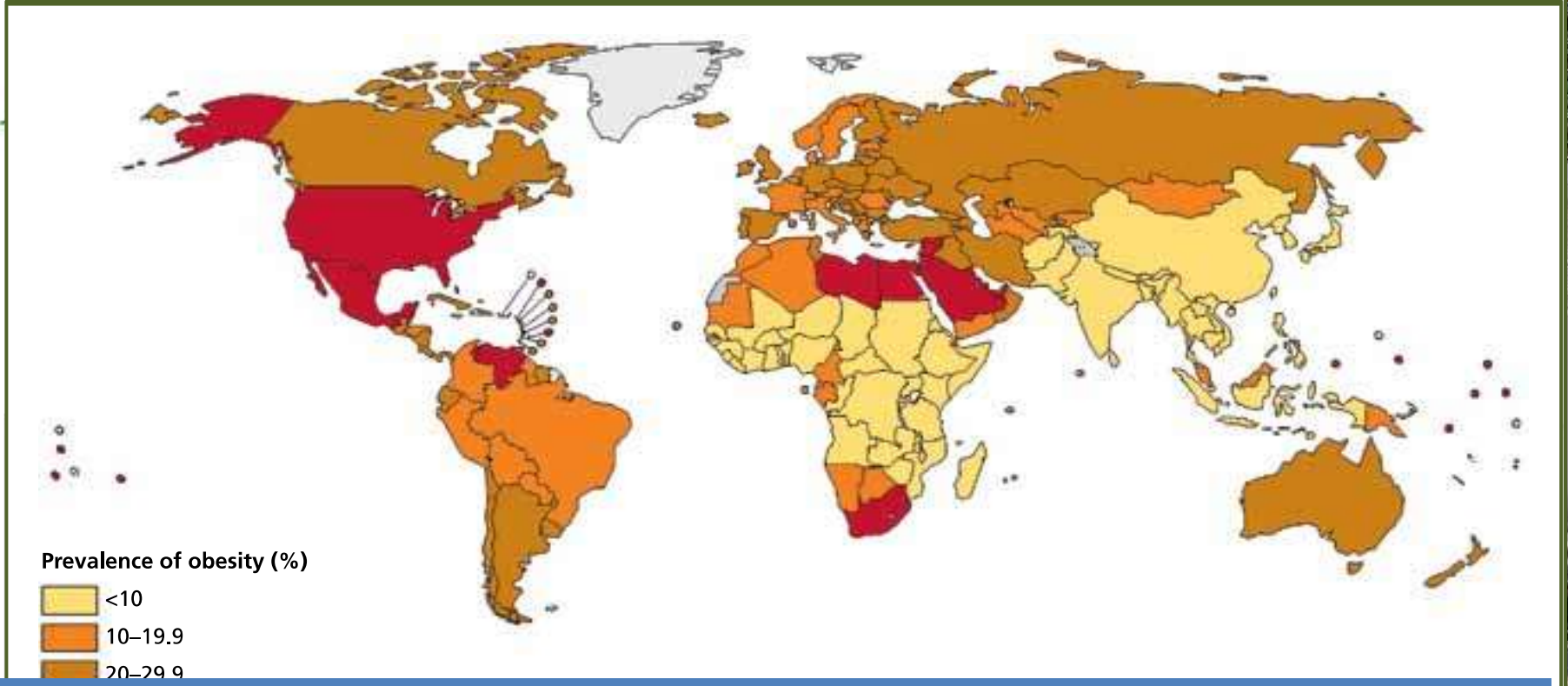


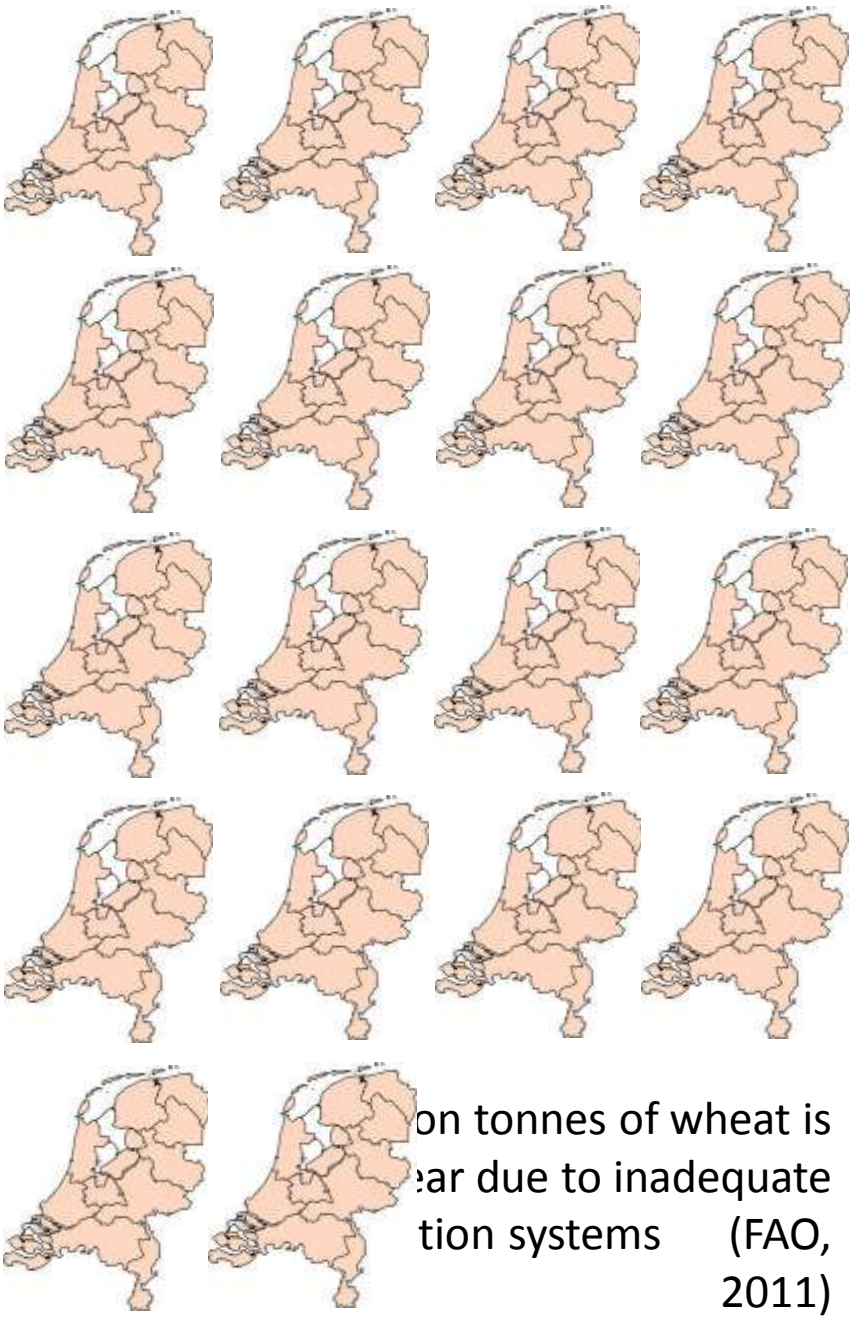
65% of the world population lives in countries where obesity kills more people than hunger

(WHO, 2012)

Waste causes hunger

In India, 21 million tonnes of wheat is wasted each year due to inadequate storage and distribution systems (FAO, 2011)

Waste causes hunger



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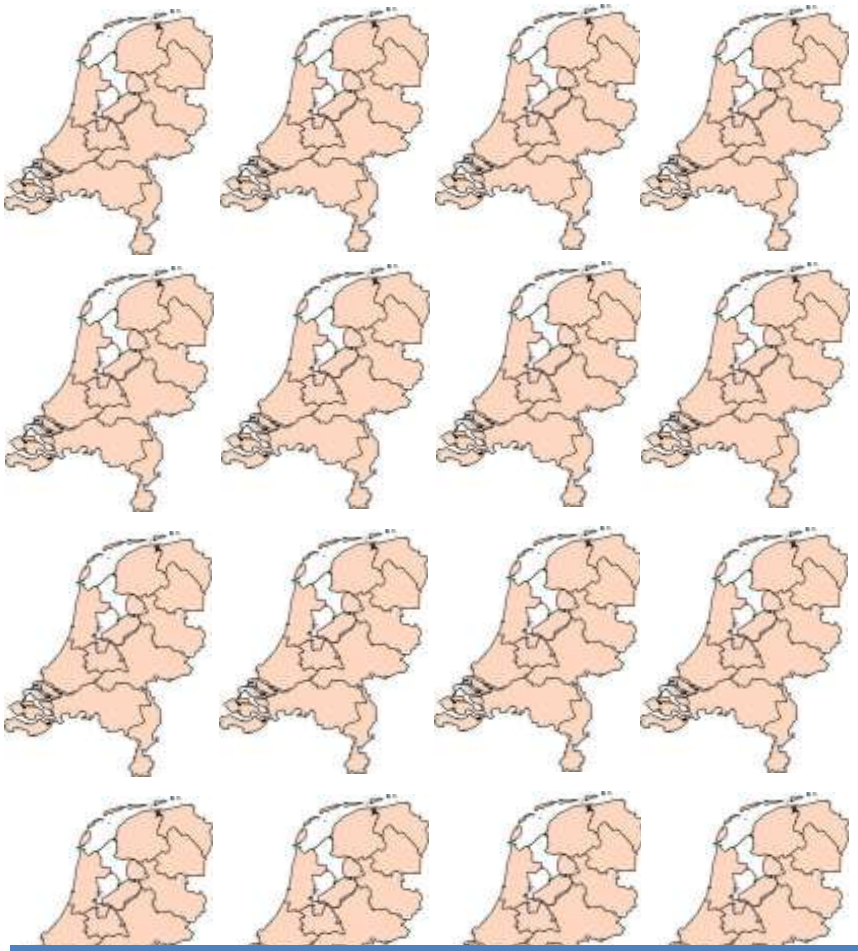
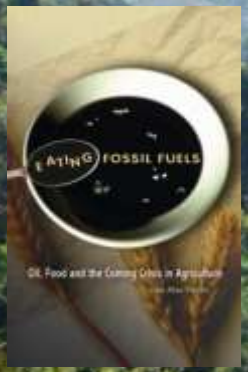
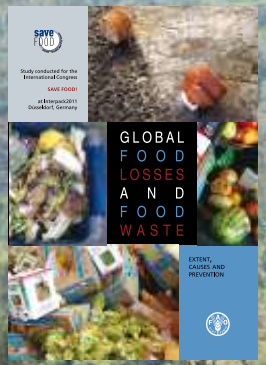


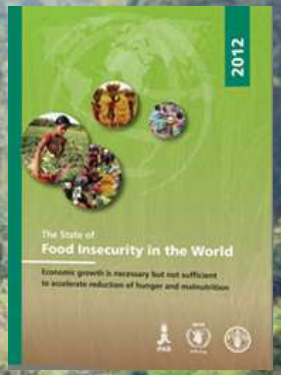
It is estimated that 30 to 50% of all food produced (or 1.2 to 2 billion tonnes) never reaches the human stomach (Gustavsson et al., 2011; FAO)

Ecological intensification

Change is much needed…



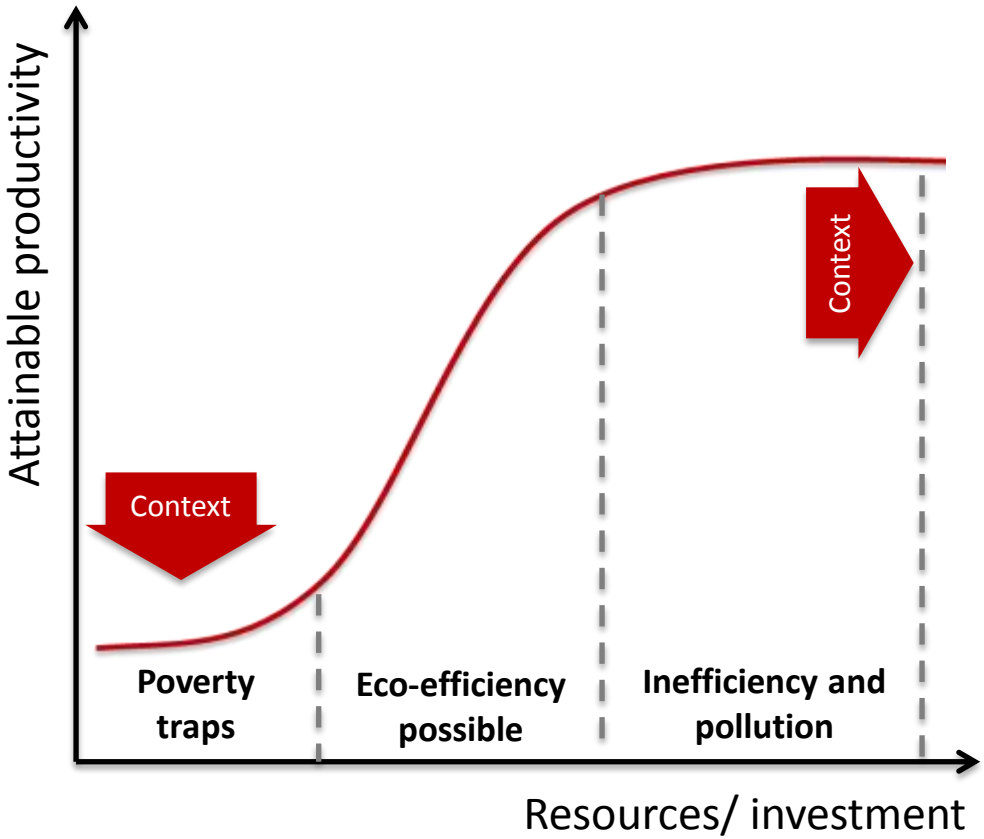




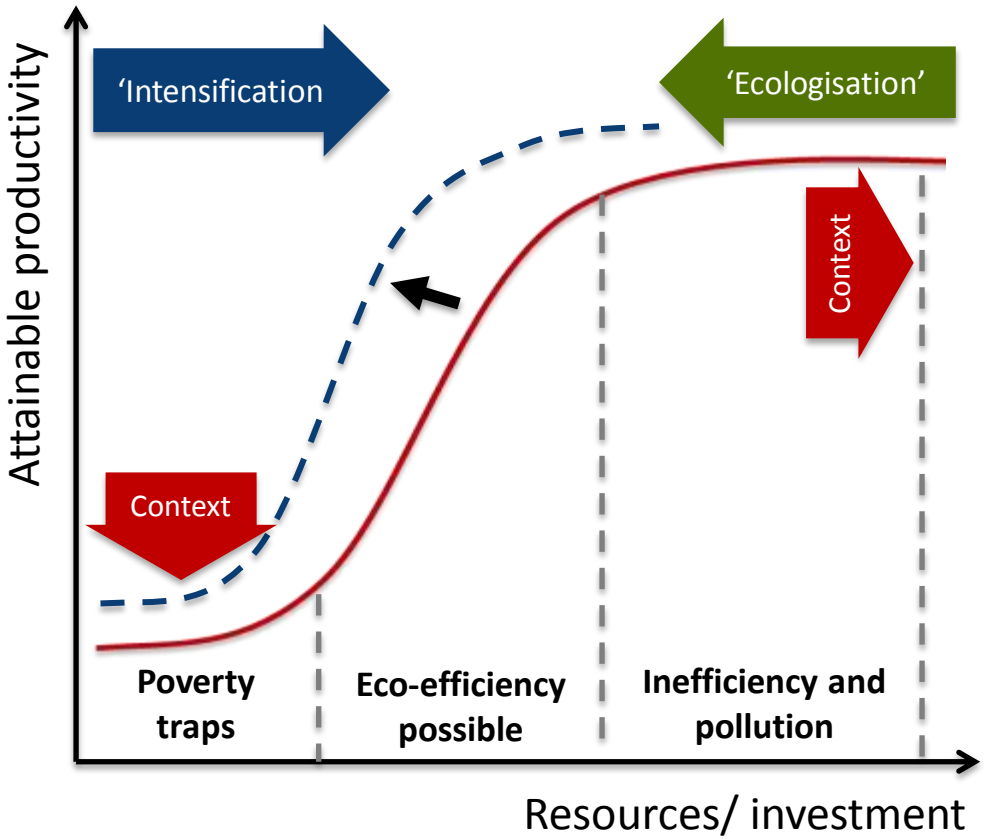
1. Worldwide, food is not produced where it is most needed
2. Agricultural inputs not affordable to all farmers
3. Current diets not compatible with sustainable resource use
4. Ineffective market, storage and distribution chains

2. Intensify in the South, extensify in the North, detoxify everywhere…

Intensify, extensify, detoxify…



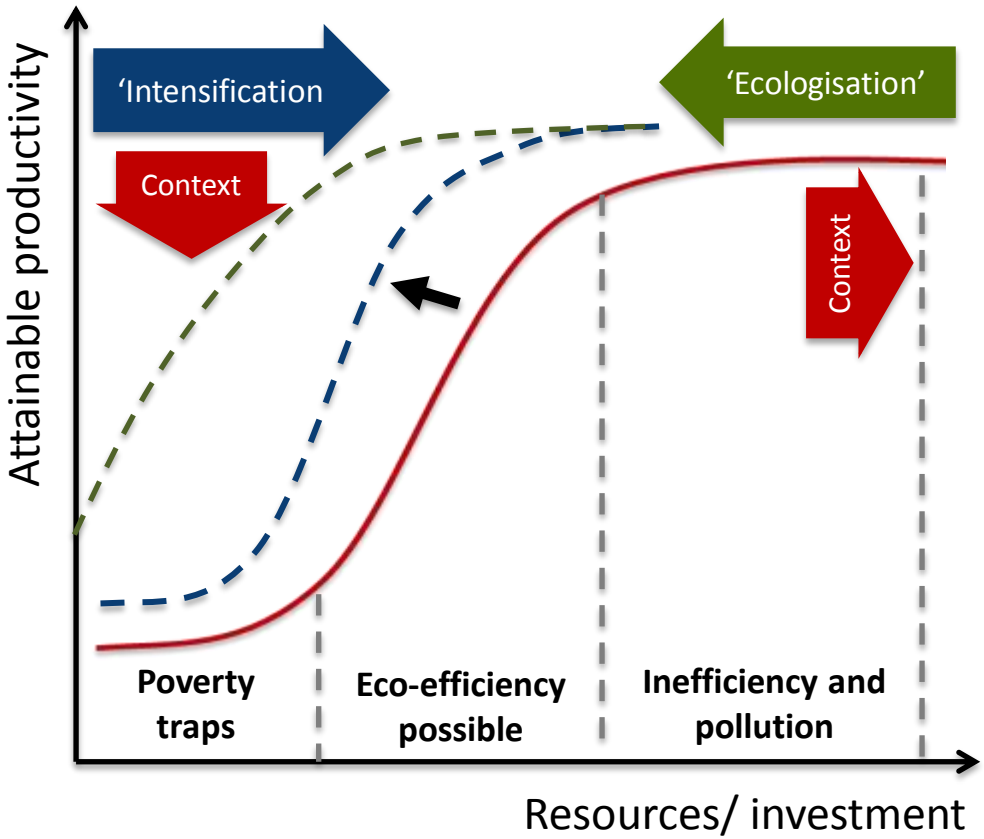
Intensify, extensify, detoxify…



'Ecologisation':
How to maintain productivity while reducing fossil fuel inputs?

'Intensification':
How to increase productivity in a sustainable, affordable way?

Intensify, extensify, detoxify…



'Ecologisation':
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Organic vs. conventional yields

Contents lists available at SciVerse ScienceDirect

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journal homepage: www.elsevier.com/locate/agsy

The crop yield gap between organic and conventional agriculture

Tomek de Ponti, Bert Rijk, Martin K. van Ittersum *

Plant Production Systems, Wageningen University, PO Box 430, 6700 AK Wageningen, The Netherlands

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ABSTRACT

A key issue in the debate on the contribution of organic agriculture to the future of world agriculture is whether organic agriculture can produce sufficient food to feed the world. Comparisons of organic and conventional yields play a central role in this debate. We therefore compiled and analyzed a meta-dataset of 362 published organic–conventional comparative crop yields. Our results show that organic yields of individual crops are on average 80% of conventional yields, but variation is substantial (standard deviation 21%). In our dataset, the organic yield gap significantly differed between crop groups and regions. The analysis gave some support to our hypothesis that the organic–conventional yield gap increases as conventional yields increase, but this relationship was only rather weak. The rationale behind this hypothesis is that when conventional yields are high and relatively close to the potential or water-limited level, nutrient stress must, as per definition of the potential or water-limited yield levels, be low and pests and diseases well controlled, which are conditions more difficult to attain in organic agriculture.

We discuss our findings in the context of the literature on this subject and address the issue of upscaling our results to higher system levels. Our analysis was at field and crop level. We hypothesize that due to challenges in the maintenance of nutrient availability in organic systems at crop rotation, farm and regional level, the average yield gap between conventional and organic systems may be larger than 20% at higher system levels. This relates in particular to the role of legumes in the rotation and the farming system, and to the availability of (organic) manure at the farm and regional levels. Future research should therefore focus on assessing the relative performance of both types of agriculture at higher system levels, i.e. the farm, regional and global system levels, and should in that context pay particular attention to nutrient availability in both organic and conventional agriculture.

Organic vs. conventional yields

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LETTER

doi:10.1038/nature11069

Comparing the yields of organic and conventional agriculture

Verena Seufert[1], Navin Ramankutty[1] & Jonathan A. Foley[2]

Numerous reports have emphasized the need for major changes in the global food system: agriculture must meet the twin challenge of feeding a growing population, with rising demand for meat and

Sixty-six studies met these criteria, representing 62 study sites, and reporting 316 organic-to-conventional yield comparisons on 34 different crop species (Supplementary Table 4).

Organic vs. Conventional crop yields

ELSEVIER

The crop yield gap

Tomek de Ponti, Bert Ri

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Comparin
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Verena Seufert[1], Navin

Numerous reports have
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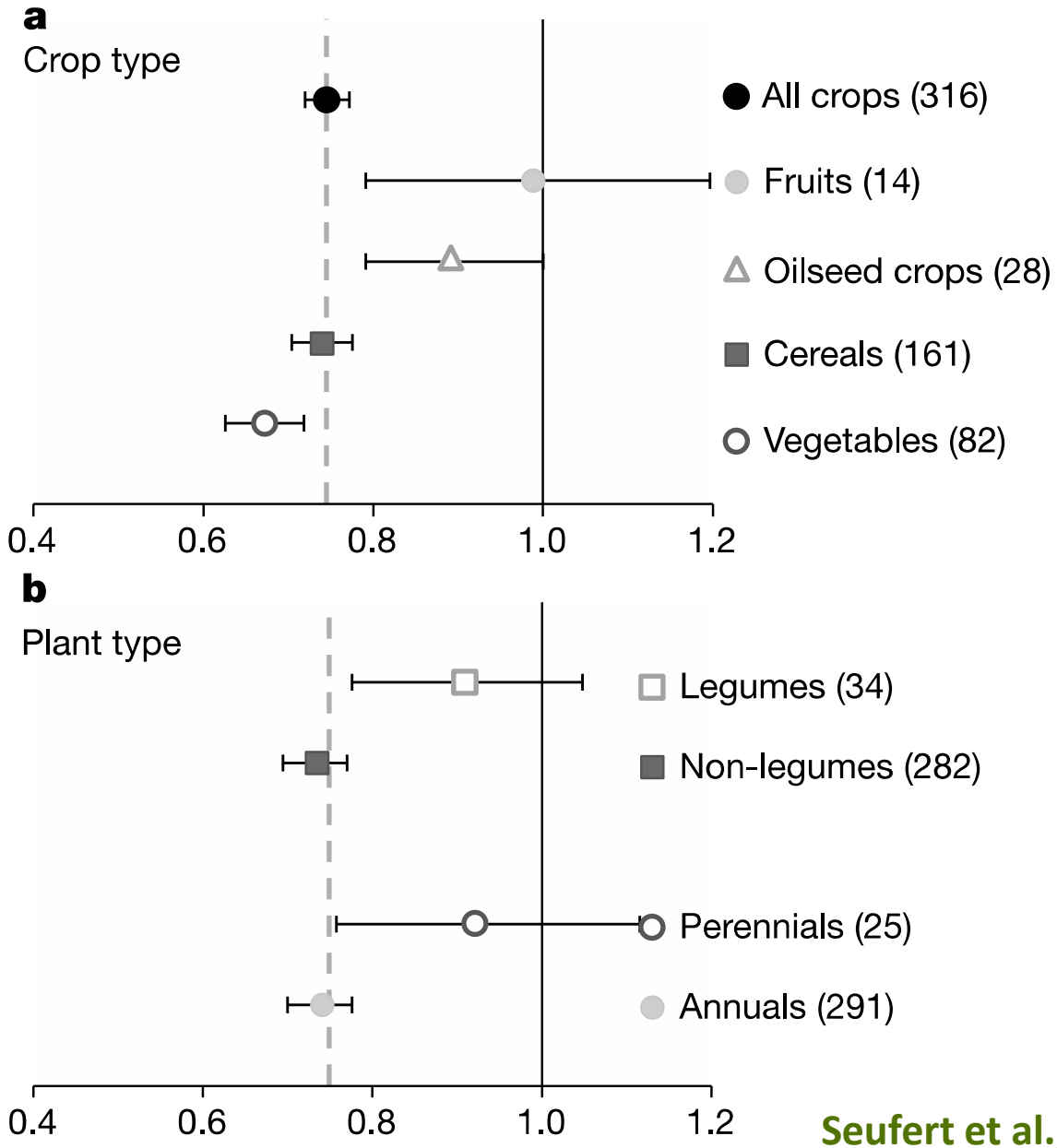
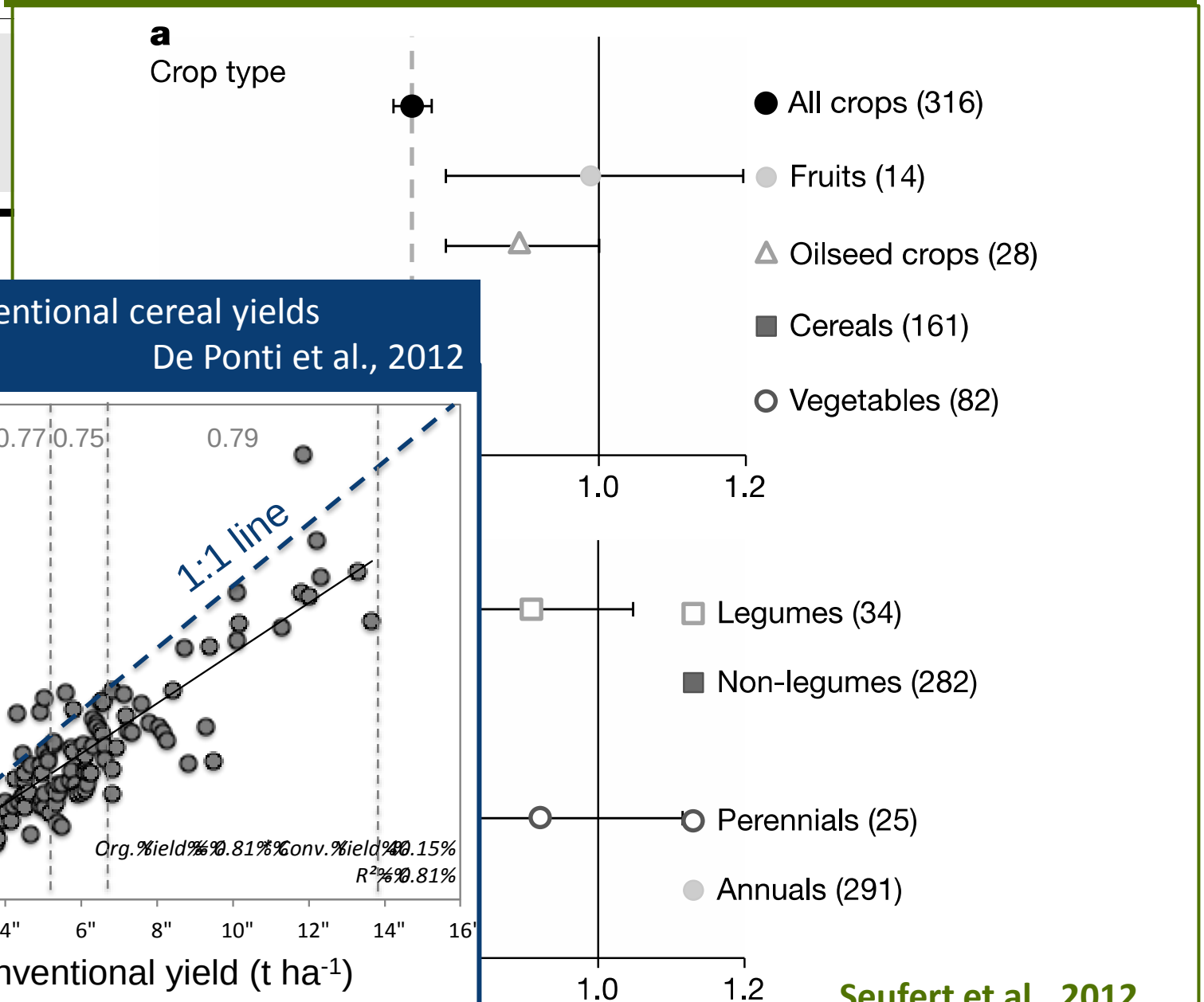


Seufert et al., 2012

Organic vs.

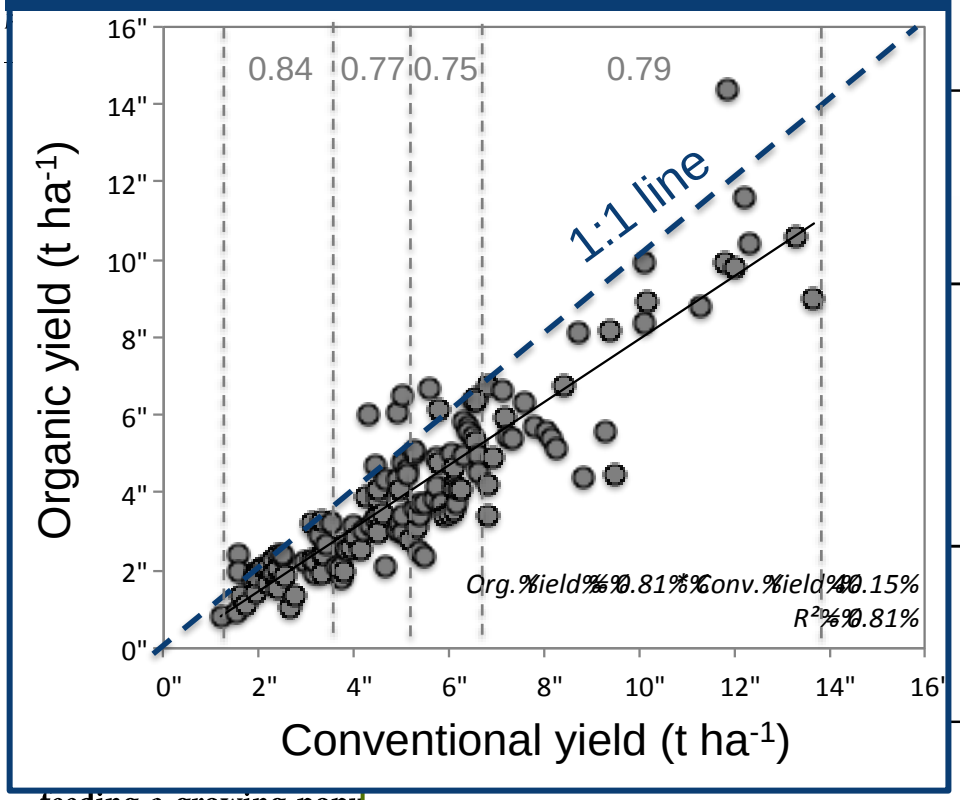
Organic vs. Conventional crop yields



Seufert et al., 2012

Organic vs. conventional cereal yields

De Ponti et al., 2012



feeding a growing population, with rising demand for meat and ... different crop species (Supplemental Table 1).

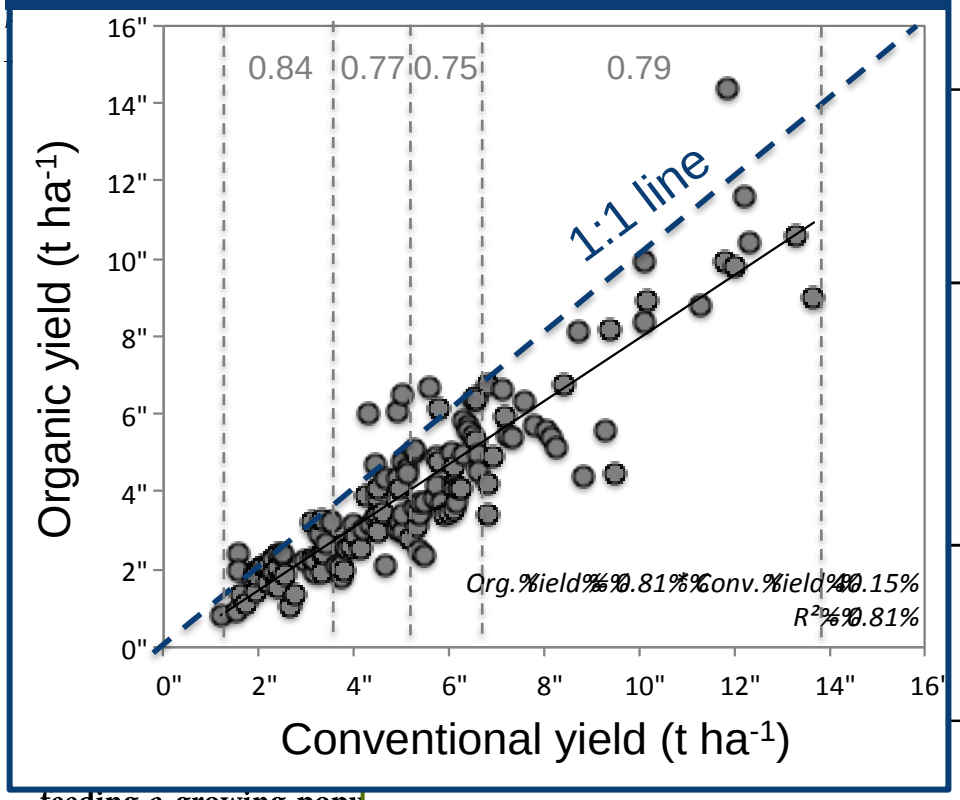
Research investment gap between organic and conventional agriculture?

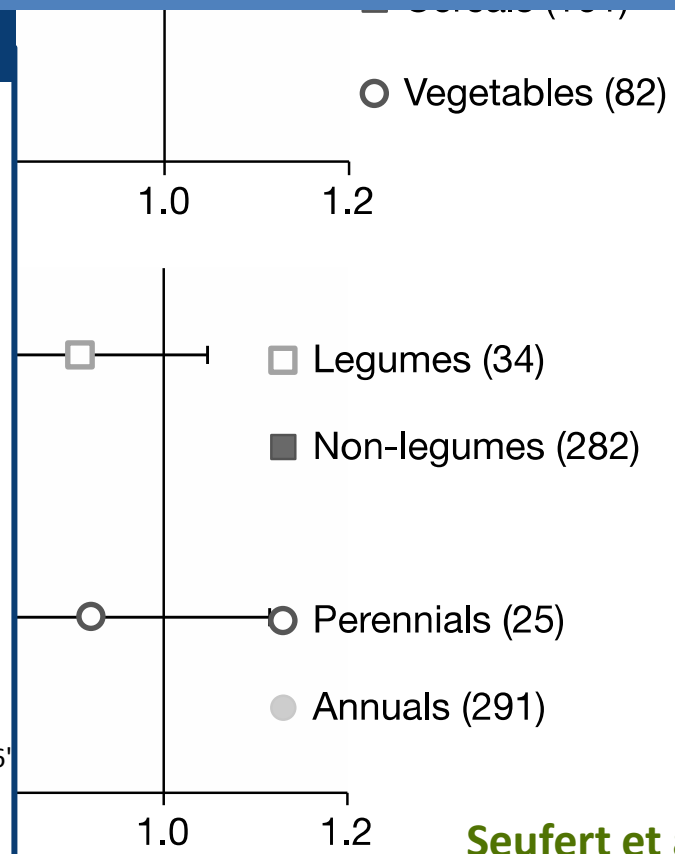
e.g.,

Dutch government = 4 million euro/year

Monsanto = 980 million dollars/year (www.monsanto.com/investors)

De Ponti et al., 2012





Seufert et al., 2012

feeding a growing population, with rising demand for meat and

Biological N2 fixation

Maize-Pigeon pea intercrops in Southern Africa

No interference

Relaying effect

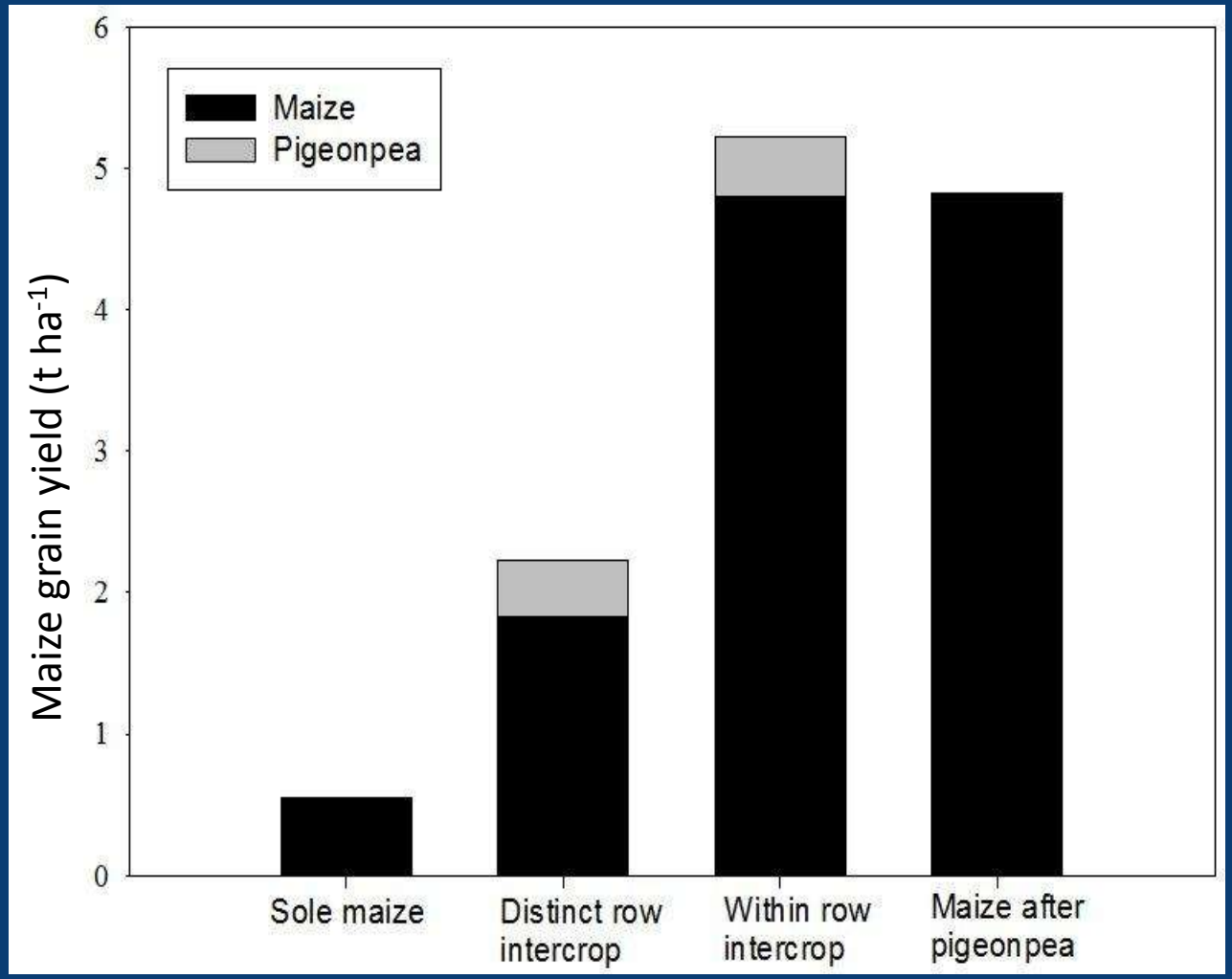
Nutrient cycling

Biological N2 fixation

Maize-Pigeon pea intercrops in Southern Africa

No interference

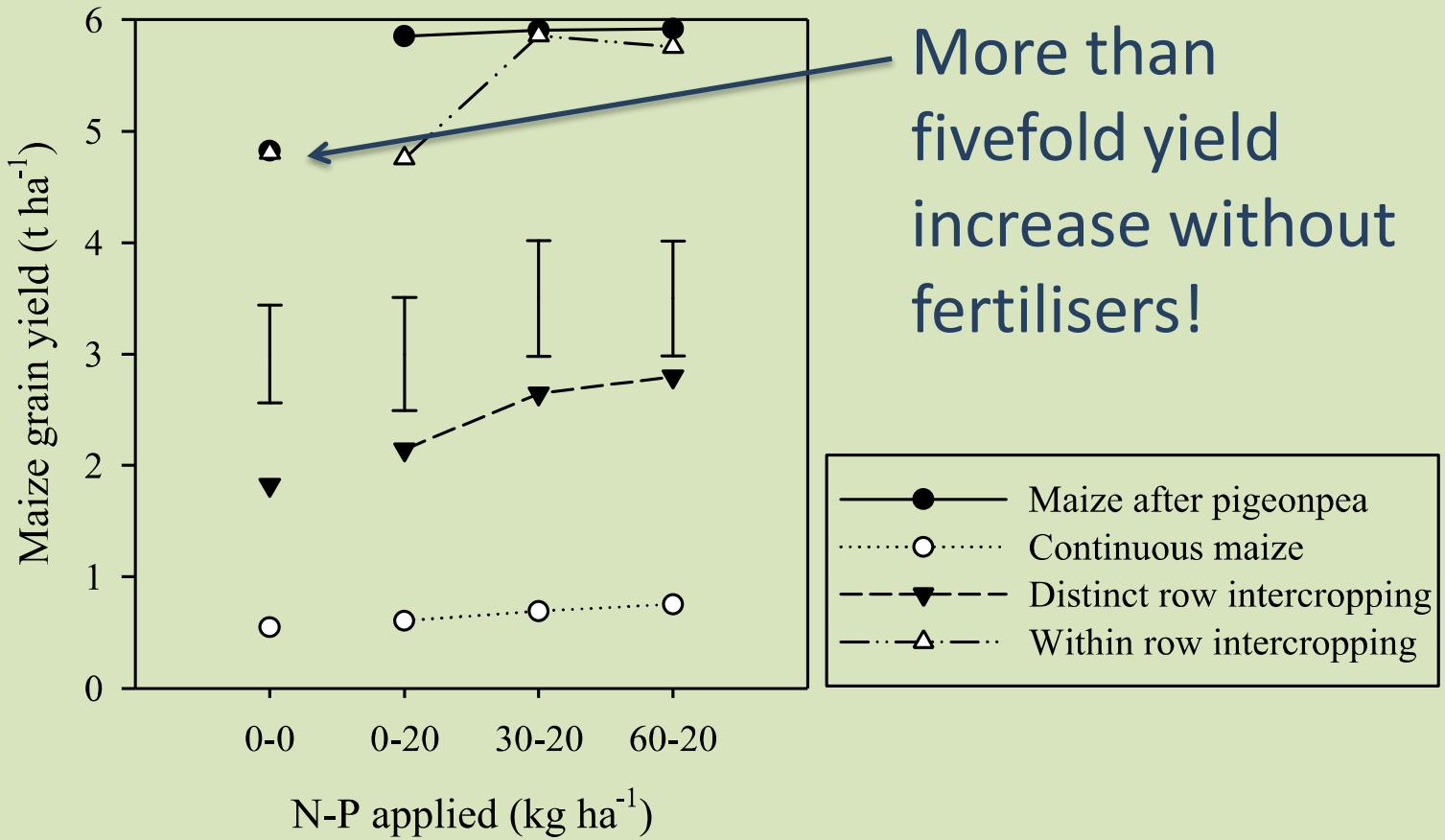
Residual effects on maize



Ruzinamhodzi et al., 2012

Biological N2 fixation

Maize-Pigeon pea intercrops in Southern Africa



More than fivefold yield increase without fertilisers!

Fig. 3. Effect of intercropping, rotation, and N and P fertilisation on maize–grain yield in Ruaca in the third (2010/2011) season.

Ruzinamhodzi et al., 2012

Designing agricultural systems by mimicking nature

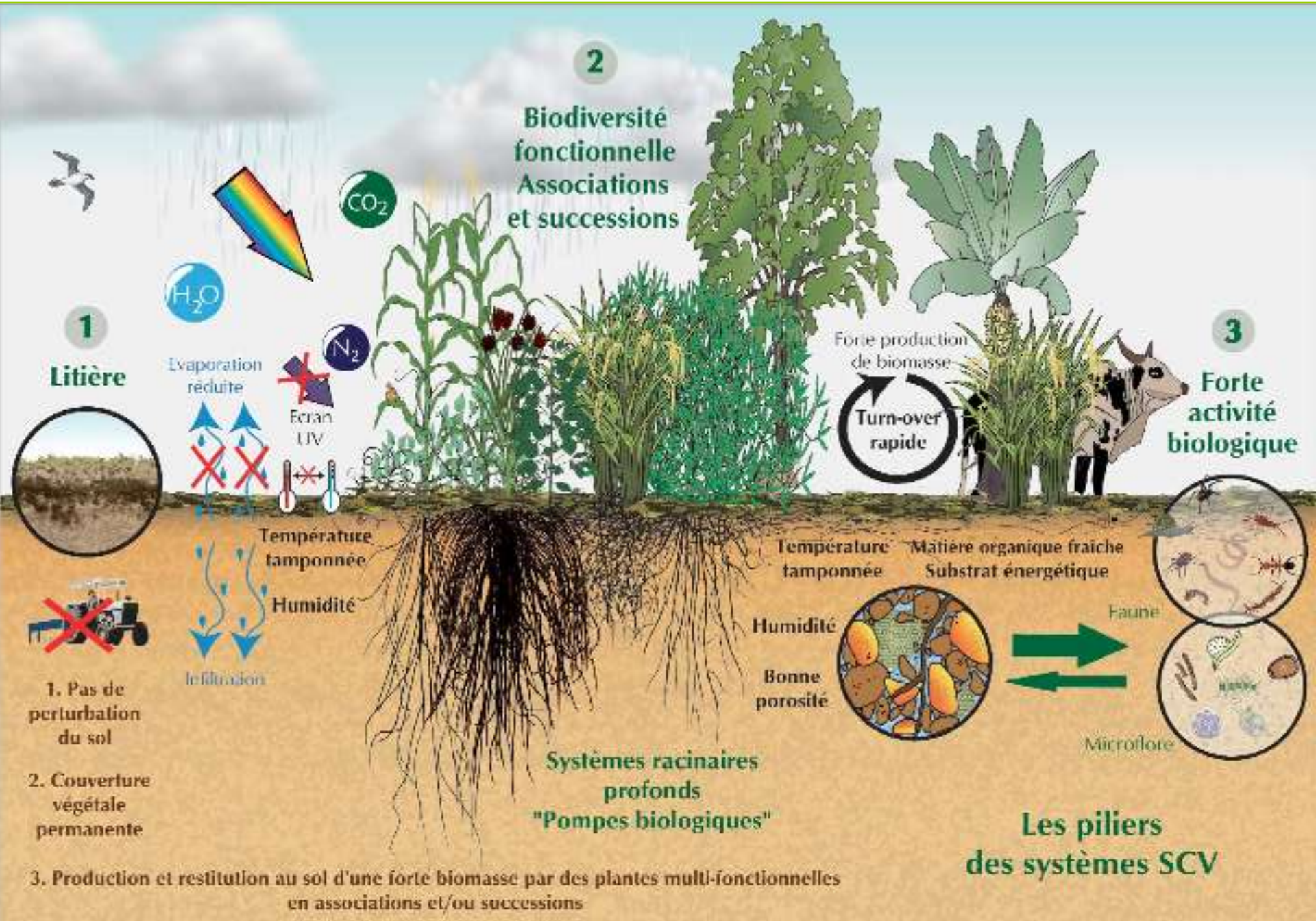
Agricultural field (millet/cowpea)

Net primary productivity = 1 to 2 t/ha/year

Savannah vegetation (under use)

Net primary productivity = 10 to 20 t/ha/year

Designing agricultural systems by mimicking nature



Simplistic approaches will not work…

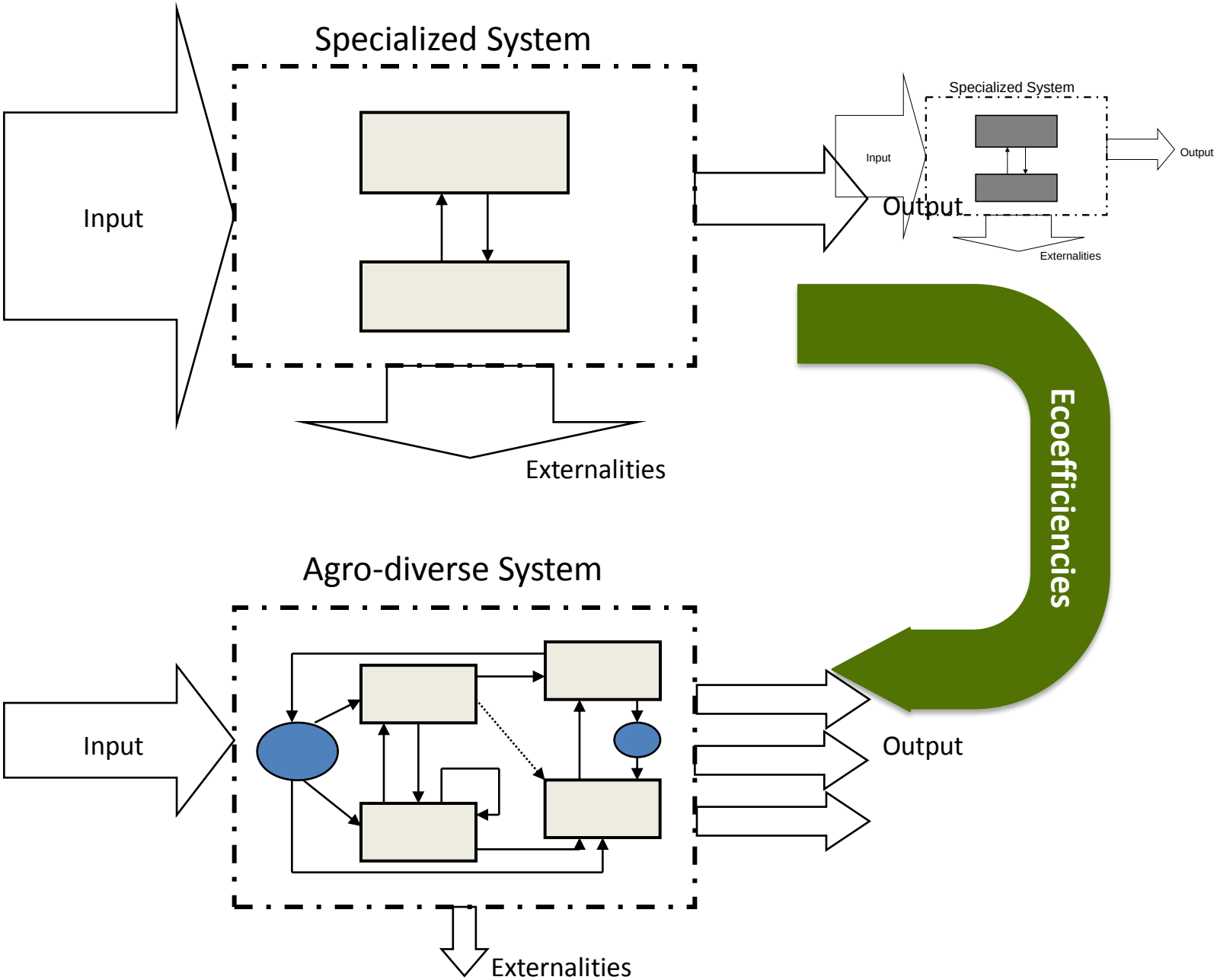
3. Farming systems ecology: systems, landscapes and actors

Simplistic approaches will not work…

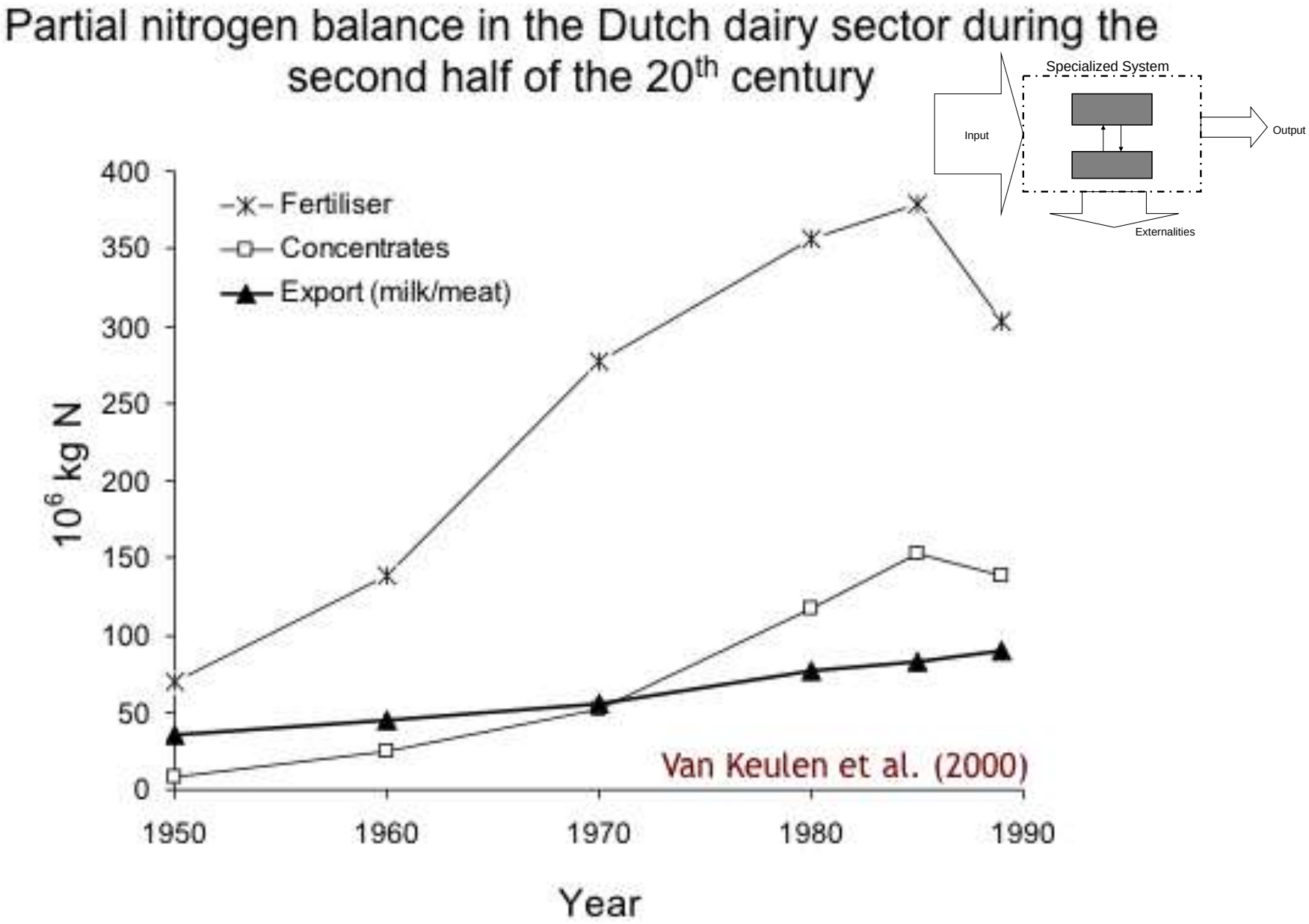
1. The yield gap between organic and conventional agriculture is to large extent a research investment gap
2. Great potential to intensify symbiotic N fixation; yet nutrient management is a bottleneck for up-scaling ecological farming
3. Green revolution technologies do not work on degraded or fragile soils: need to draw inspiration from nature
4. We need systems approaches that embrace landscape-level processes and the communities that manage and/or live on them

3. Farming systems ecology: systems, landscapes and actors

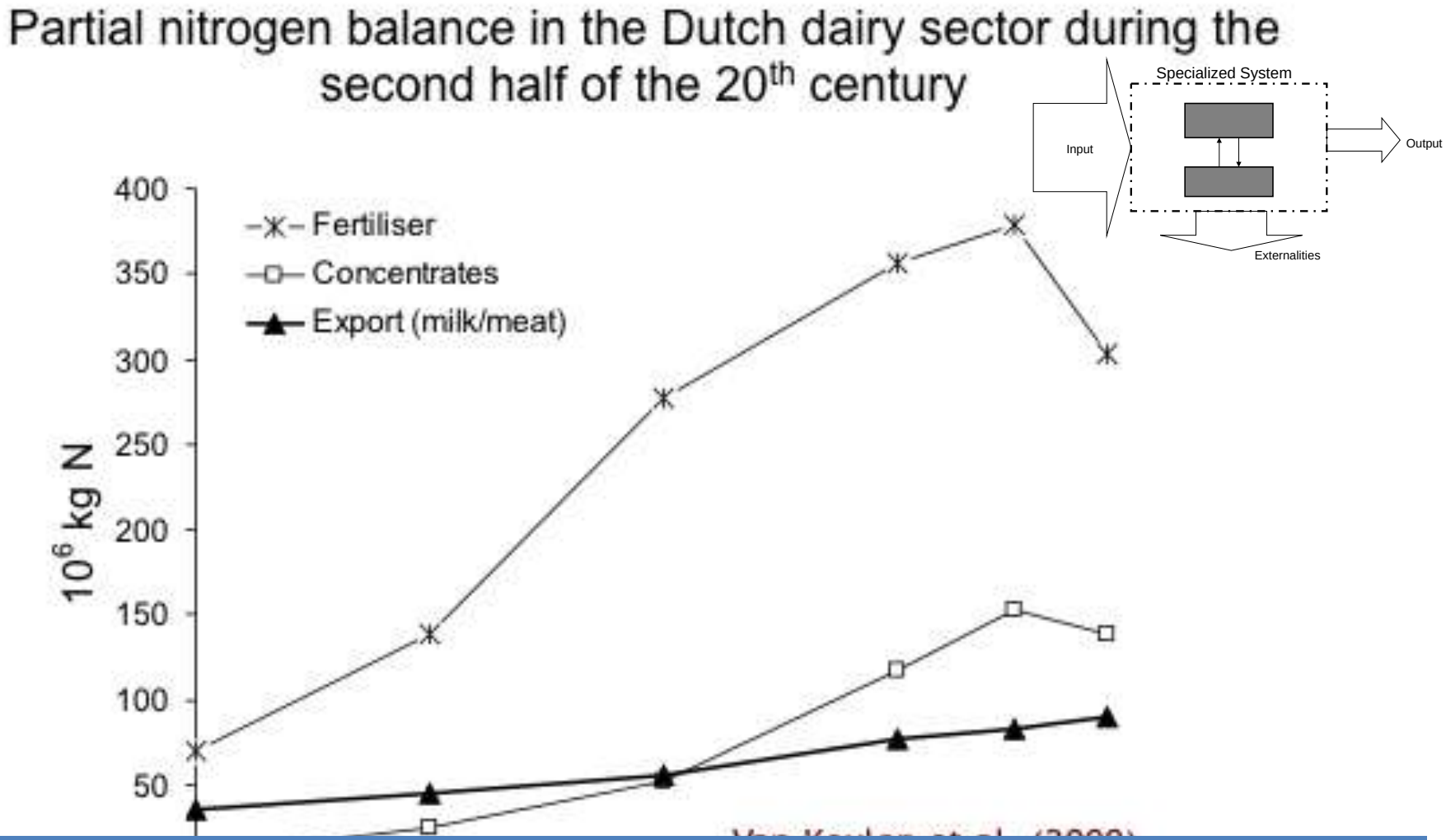
Produce more, but produce differently…



Produce more, but produce differently…

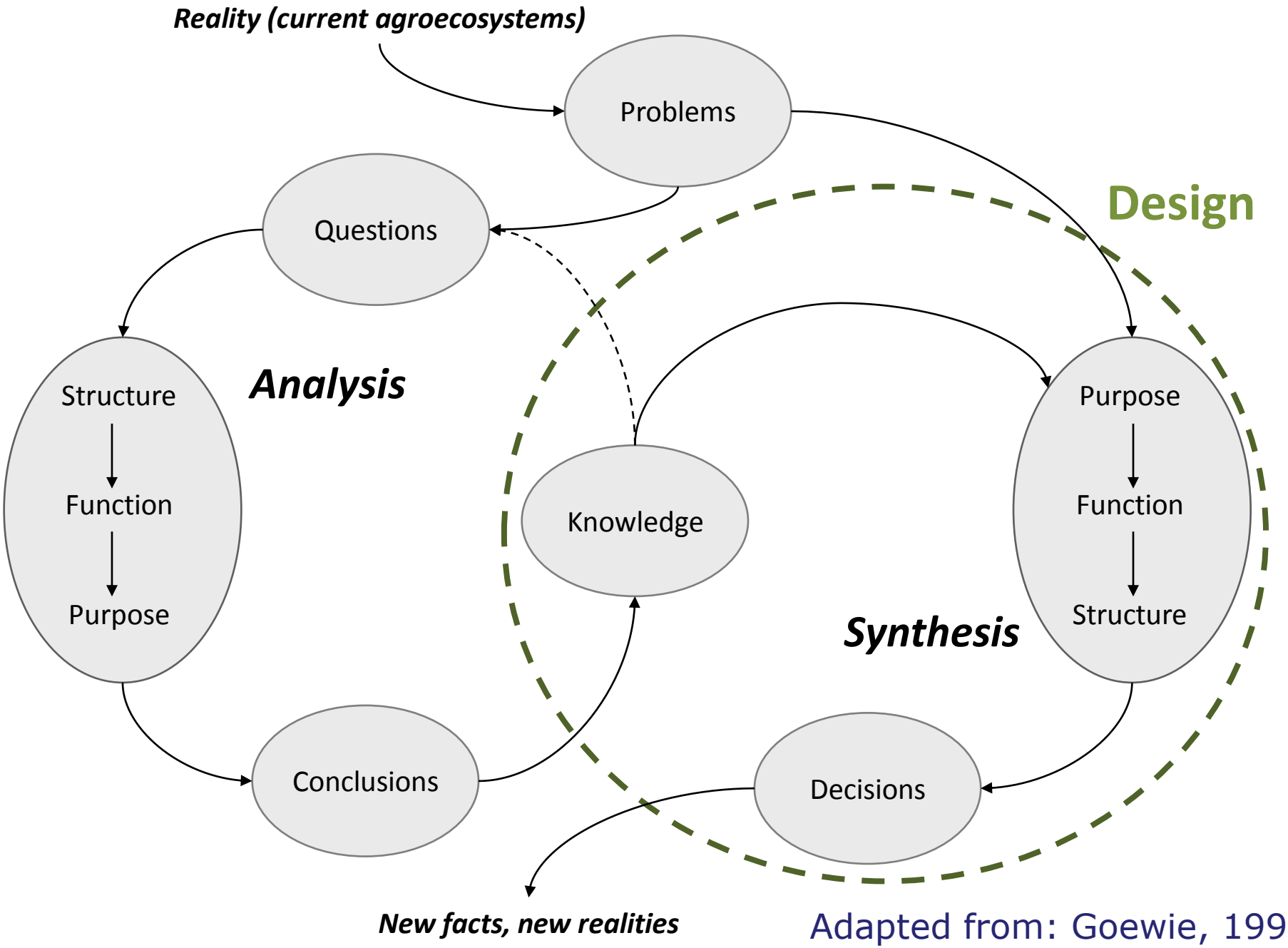


Produce more, but produce differently…



Pursuing narrowly-defined efficiency reduces systems resilience (Walker et al., 2009)

Ecological intensification requires systems re-design



Adapted from: Goewie, 1993

Building upon local agroecological knowledge

Rice-ducks-fish-azolla - Indonesia

Khumairoh et al., 2012

Building upon local agroecological knowledge

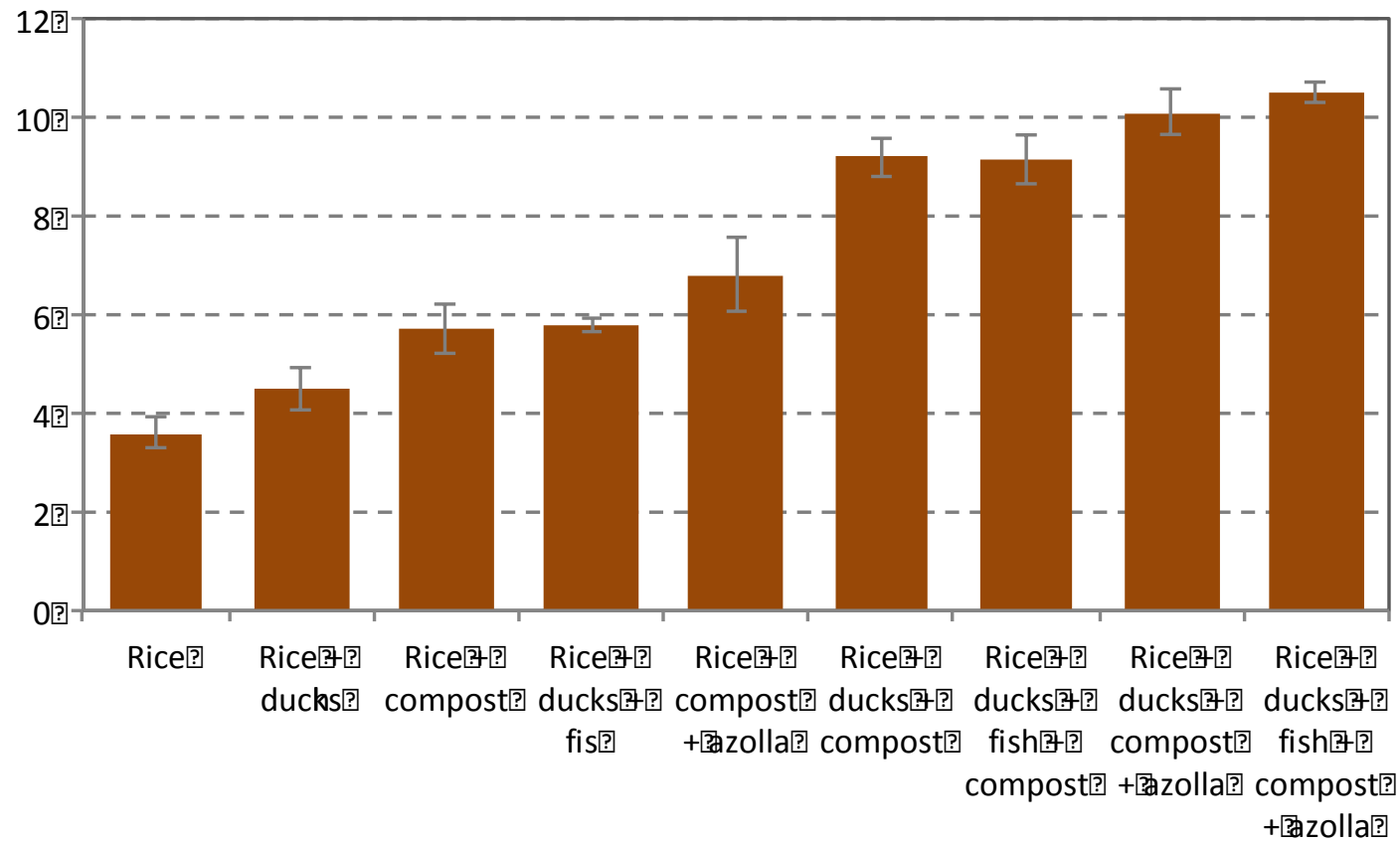
Rice-ducks-fish-azolla - Indonesia

Khumairoh et al., 2012

Building upon local agroecological knowledge

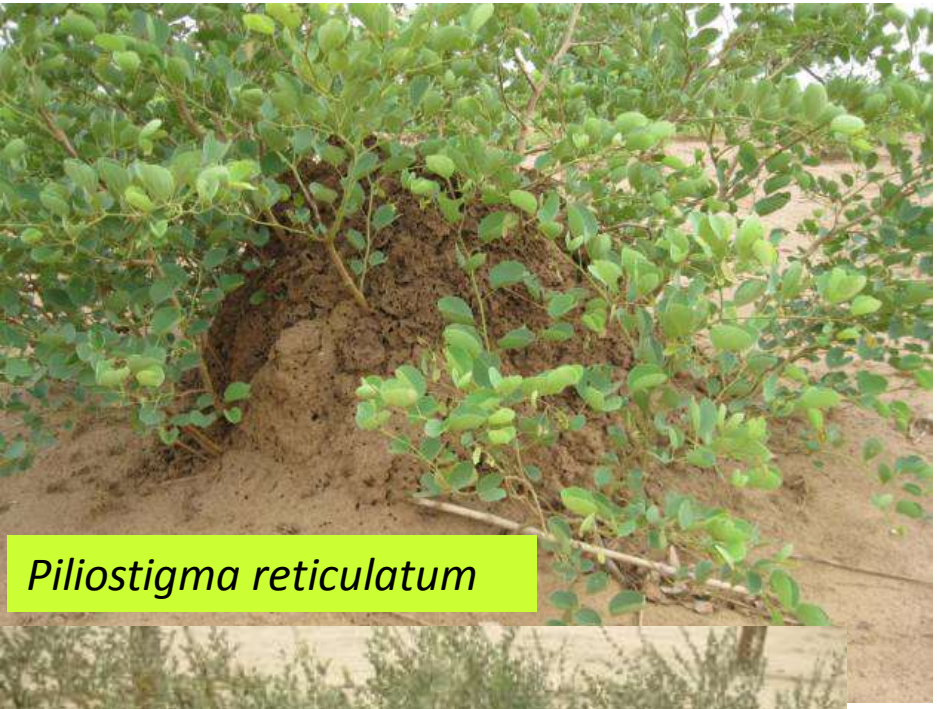
Rice-ducks-fish-azolla - Indonesia

Rice yield (t ha^{-1}) at increasing levels of complexity



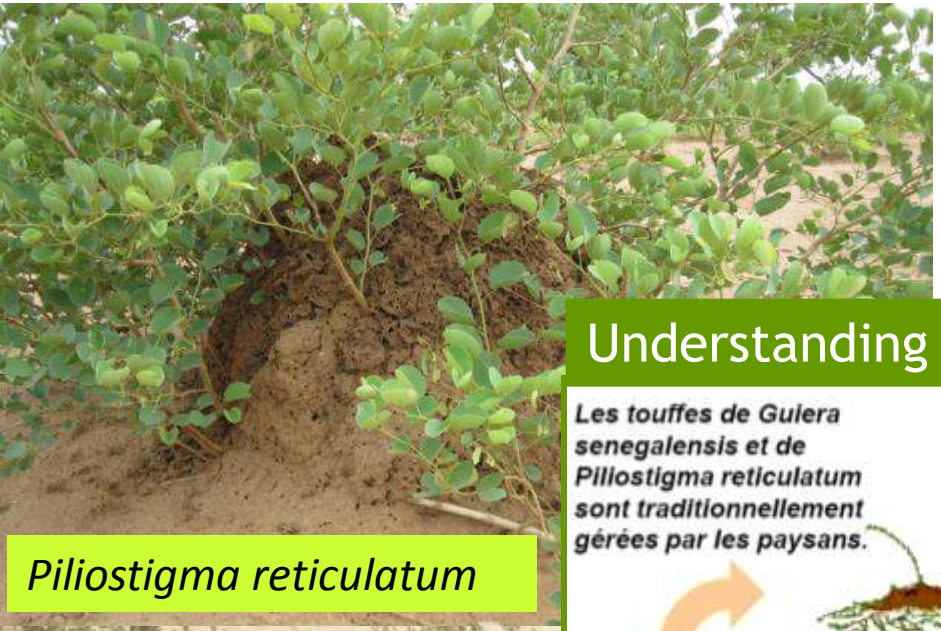
Khumairoh et al., 2012

Native resources and local knowledge in the Sahel



Facilitation of crop production through association with native woody species (Lahmar et al., 2012)

Native resources and local knowledge in the Sahel



Piliostigma reticulatum

Guiera sene

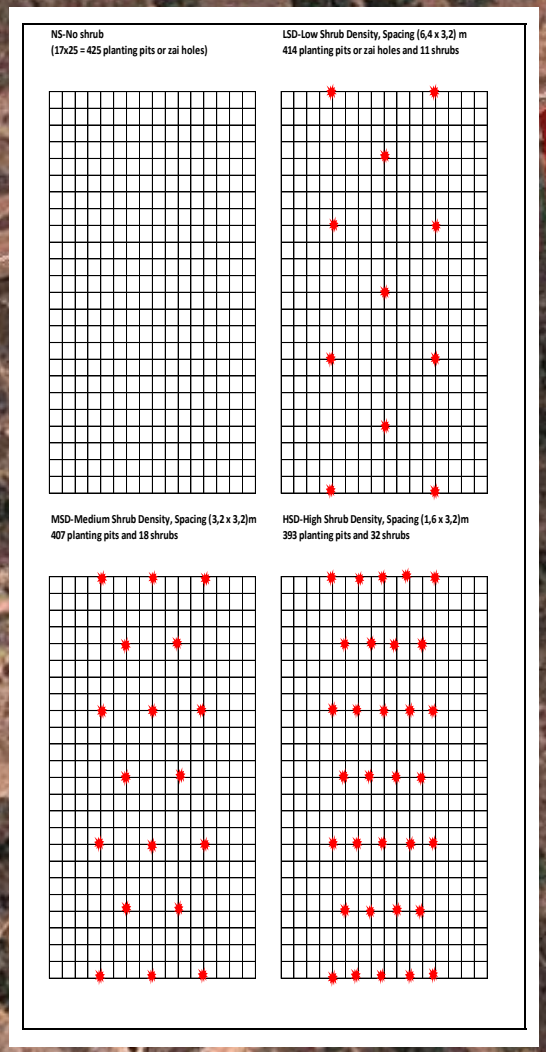
Facilitation of crop production through association with native woody species (Lahmar et al., 2012)

Understanding traditional soil fertility management

Understanding/optimising local practices

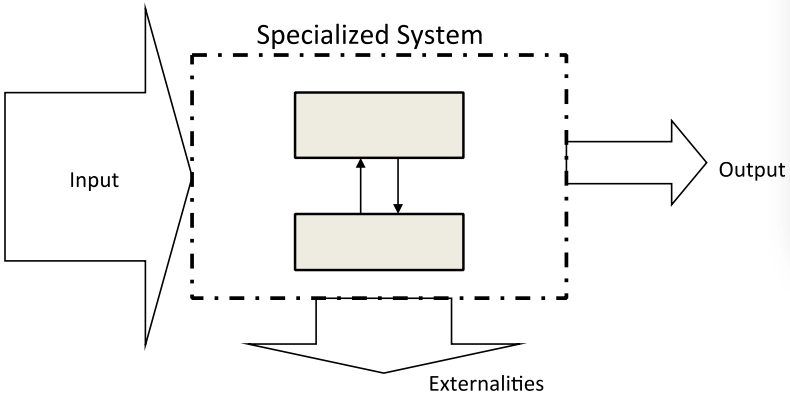
Thesis: Georges Félix, FSE

Understanding/optimising local practices



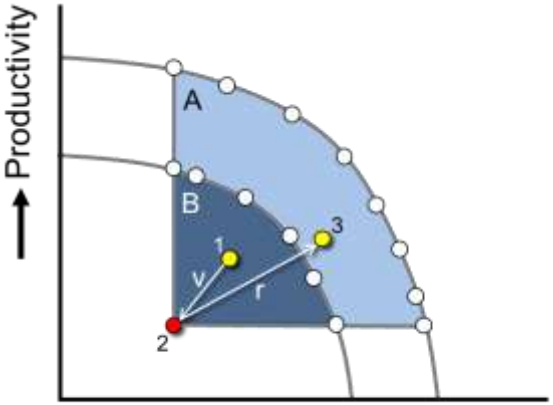
Thesis: Georges Félix, FSE

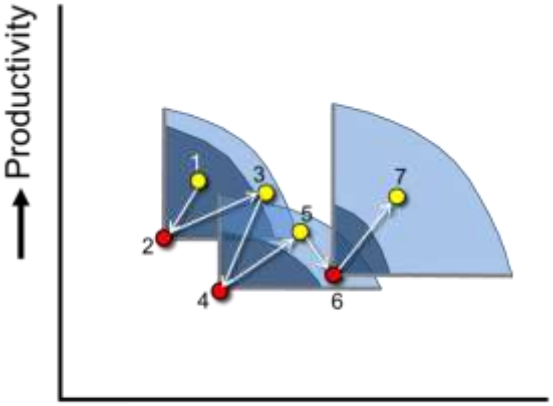
Sustainable intensification pathways



Cortez-Arriola et al. (2013)

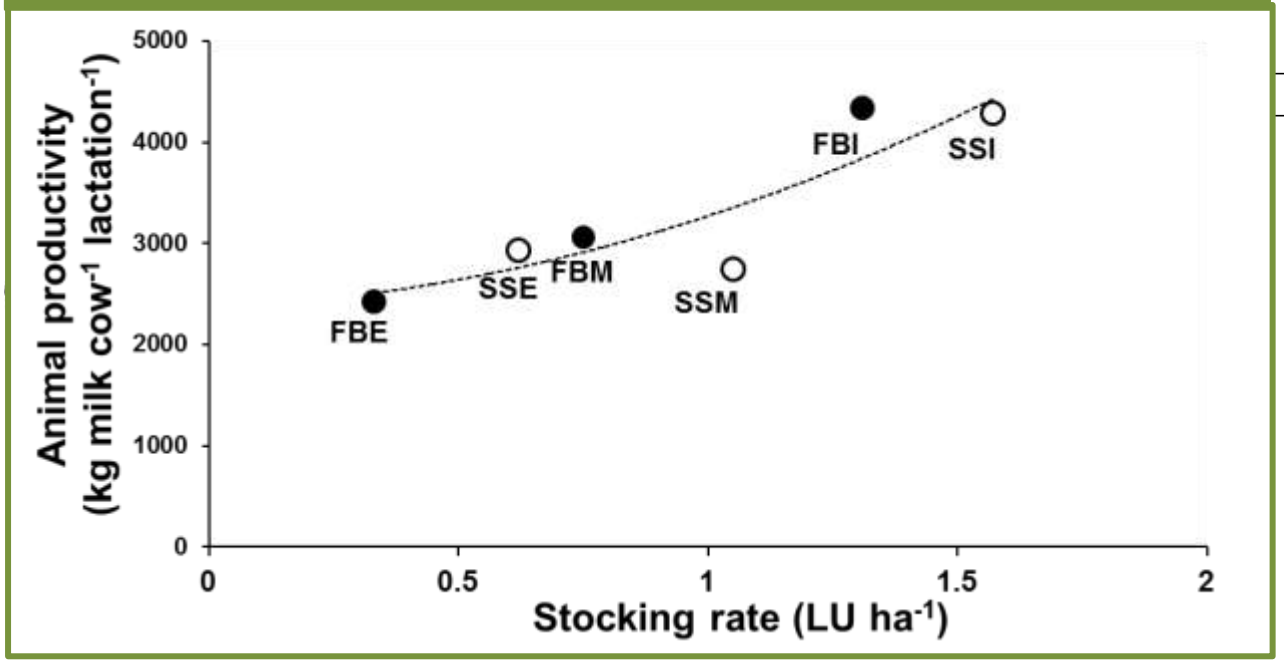
Farm productivity gap





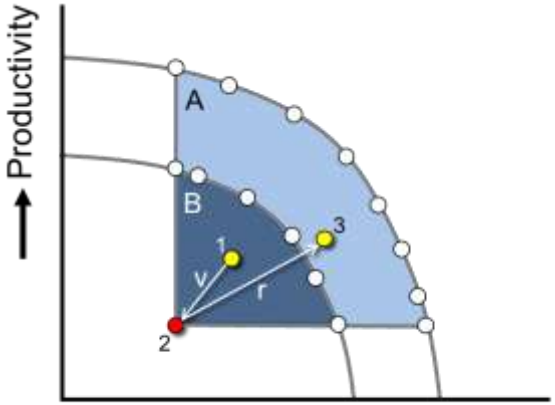
Sustainable intensification pathways

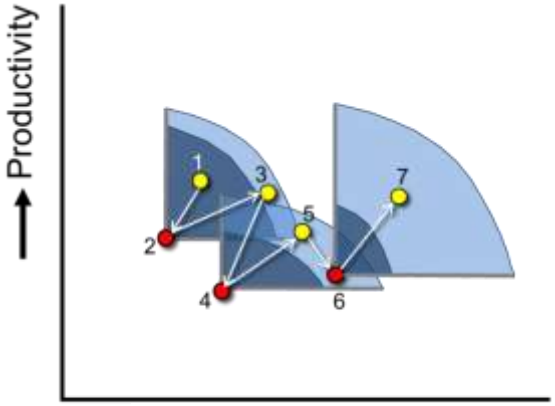
Productivity per animal



Output

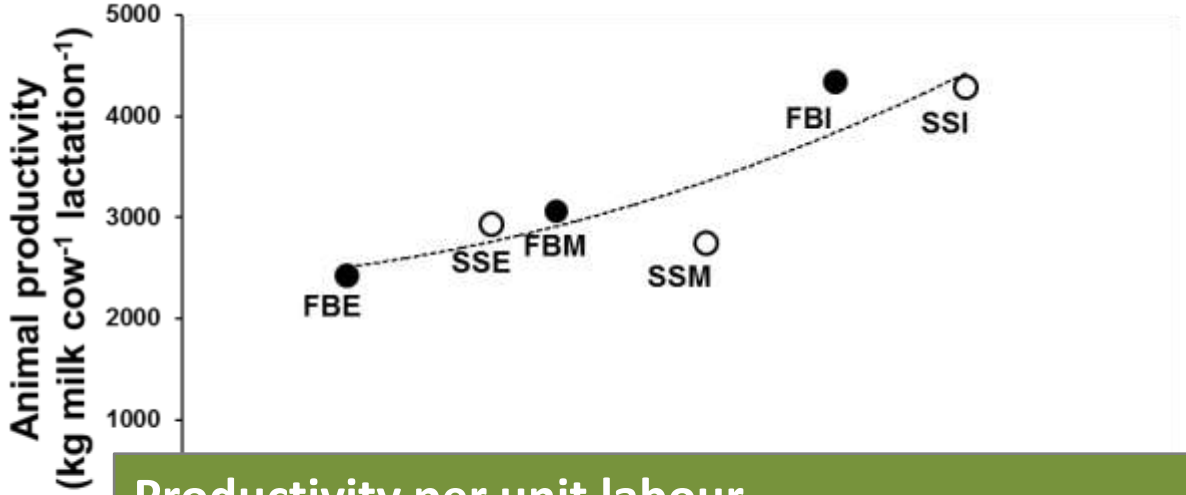
Farm productivity gap





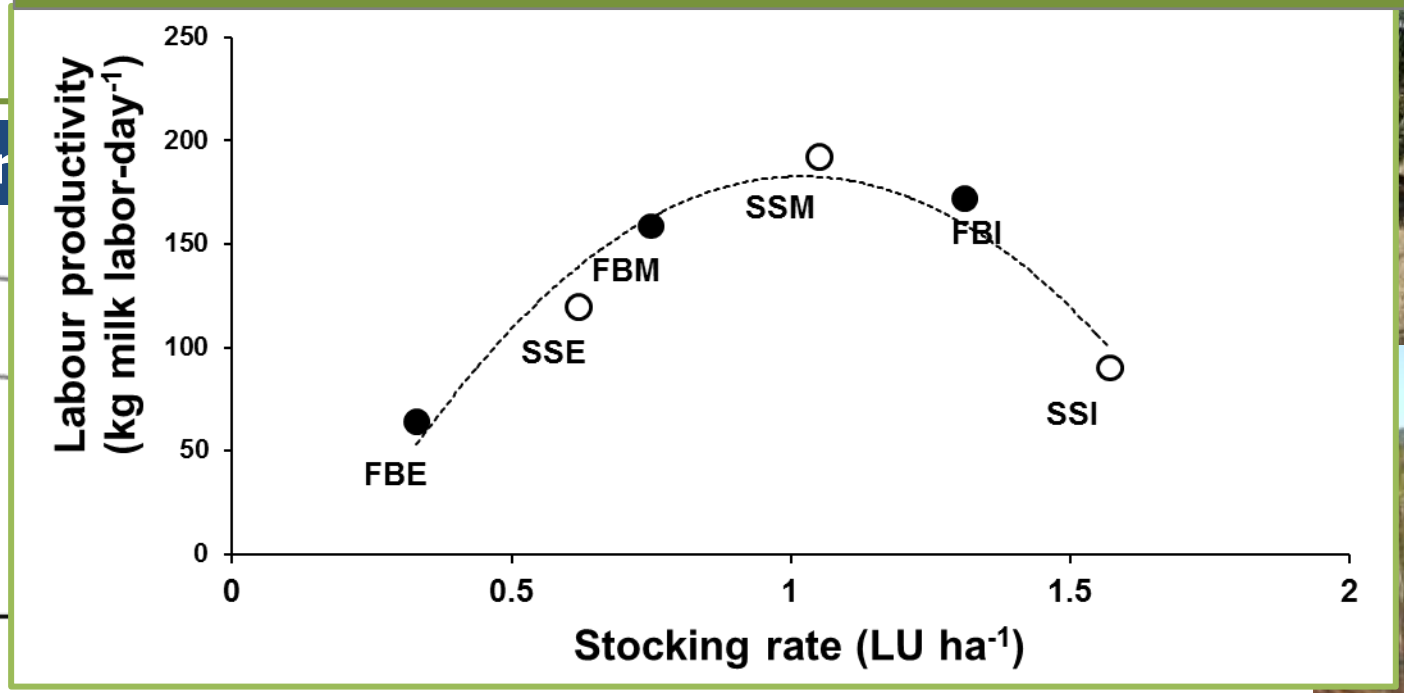
Sustainable intensification pathways

Productivity per animal



Output

Productivity per unit labour

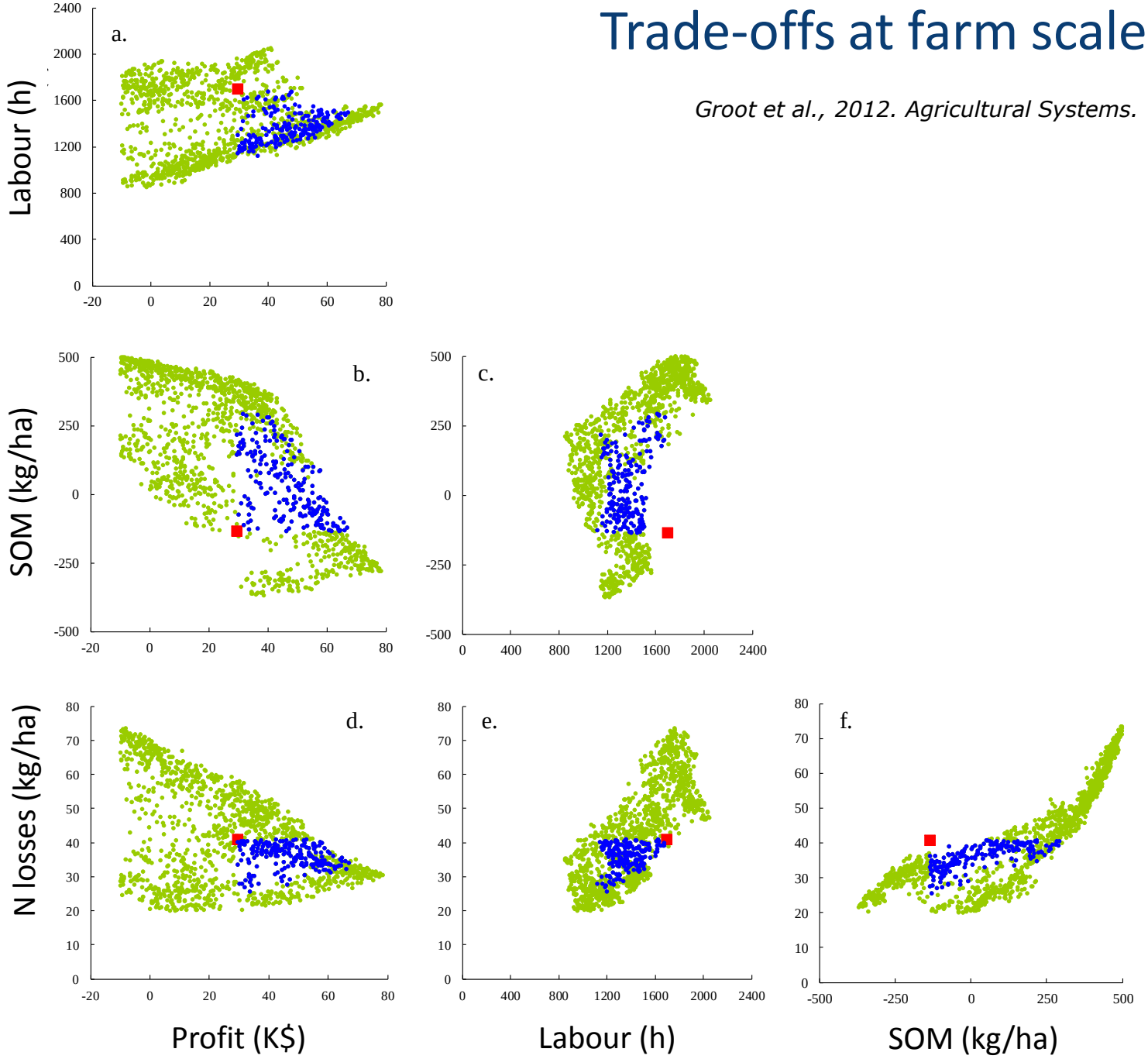


Far

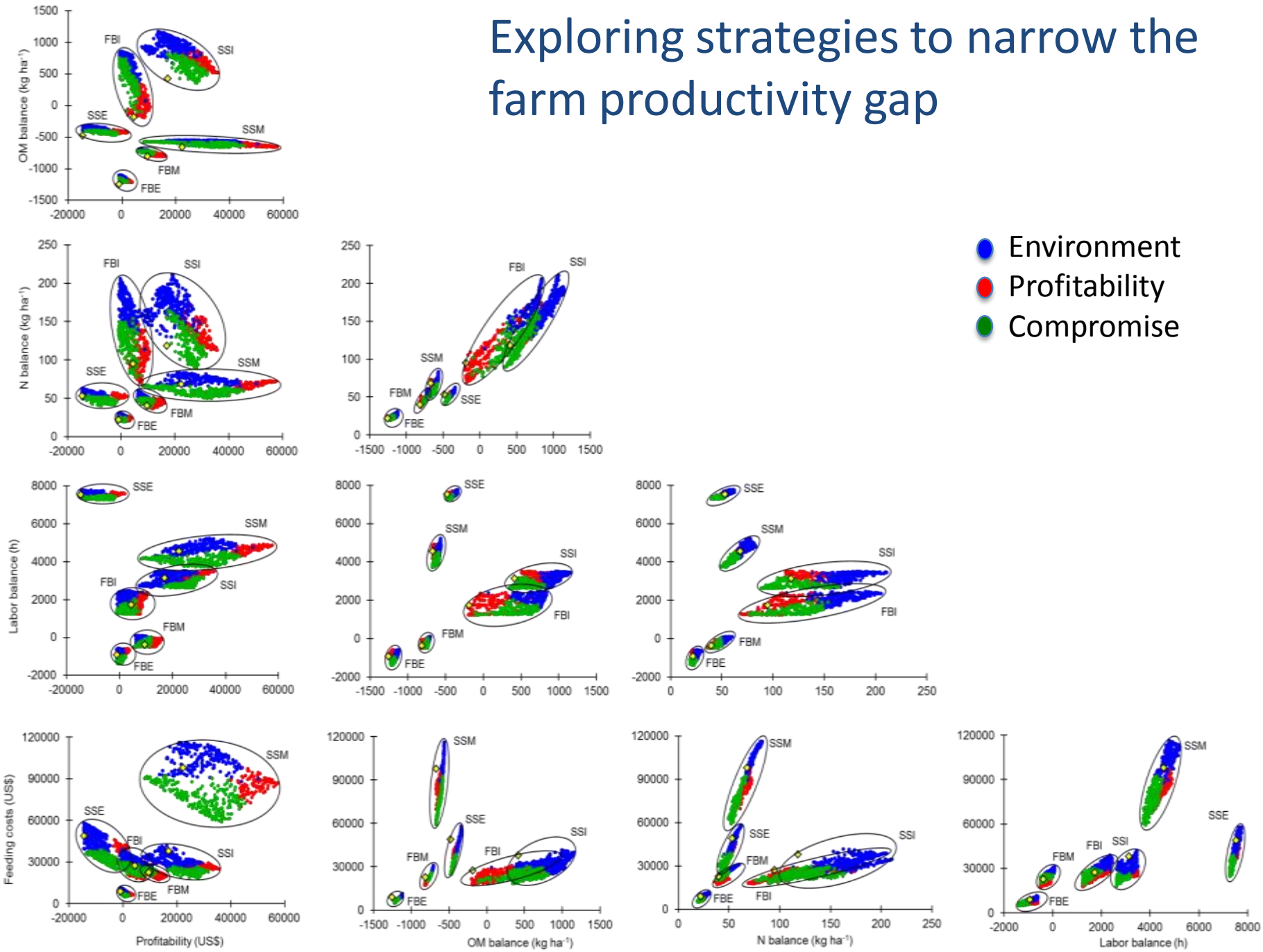
Productivity

Trade-offs at farm scale

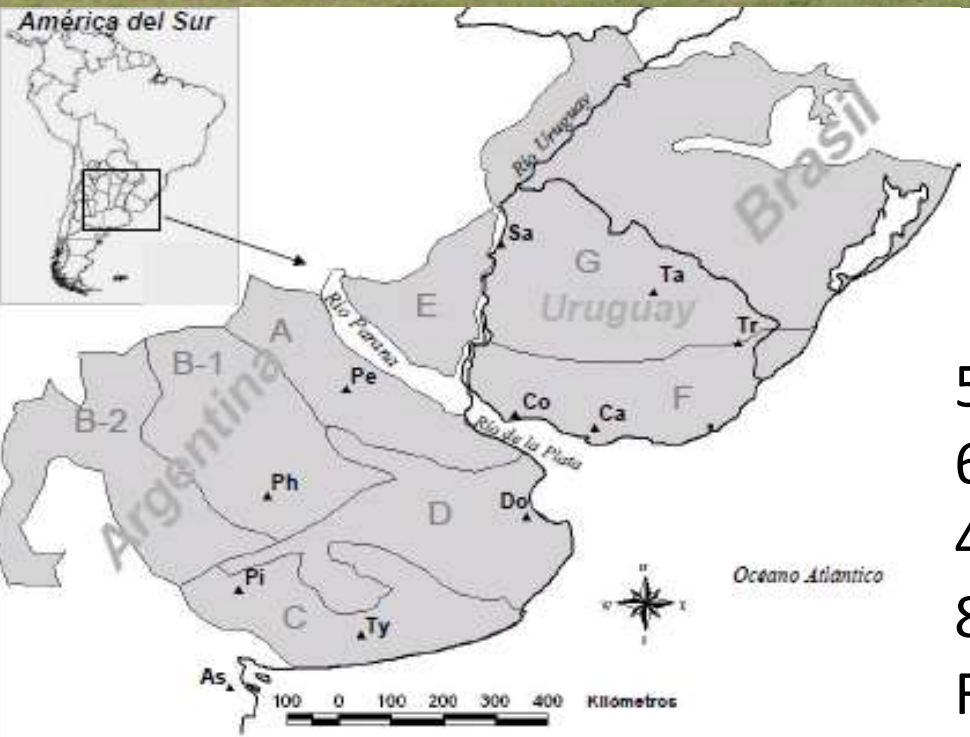
Groot et al., 2012. Agricultural Systems.



Exploring strategies to narrow the farm productivity gap



Ecological intensification of grazing systems



Theses:

Andrea Ruggia (INIA)

Pablo Modernel (UR)

500,000 km^2

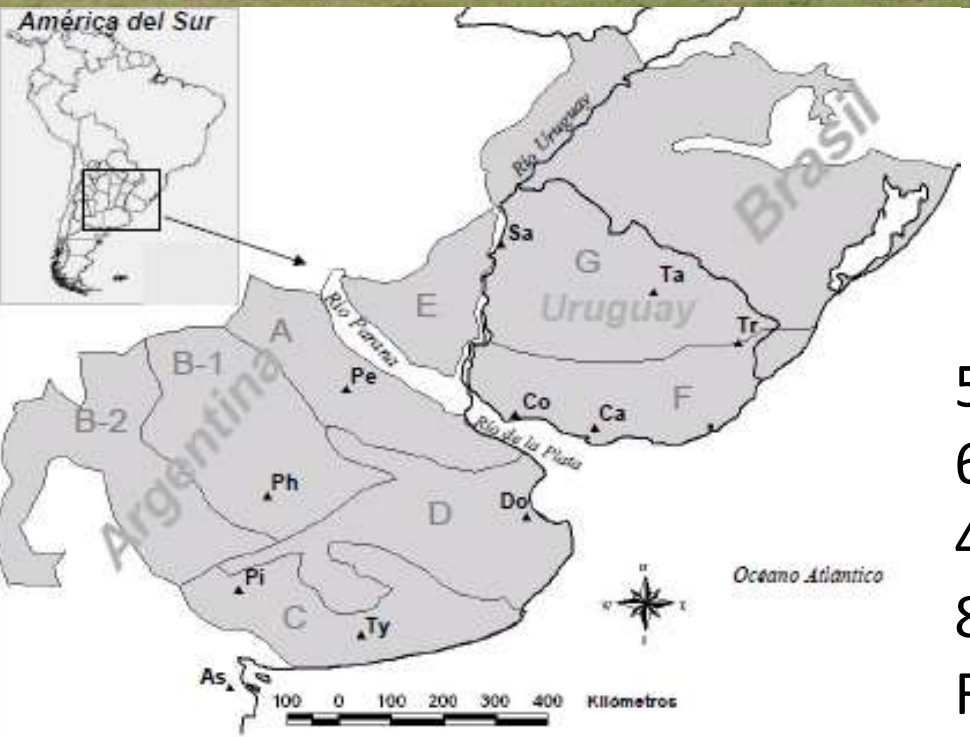
65 million heads of cattle

430,000 farms

800 grasses and 200 legumes species

Regional economic relevance

Ecological intensification of grazing systems



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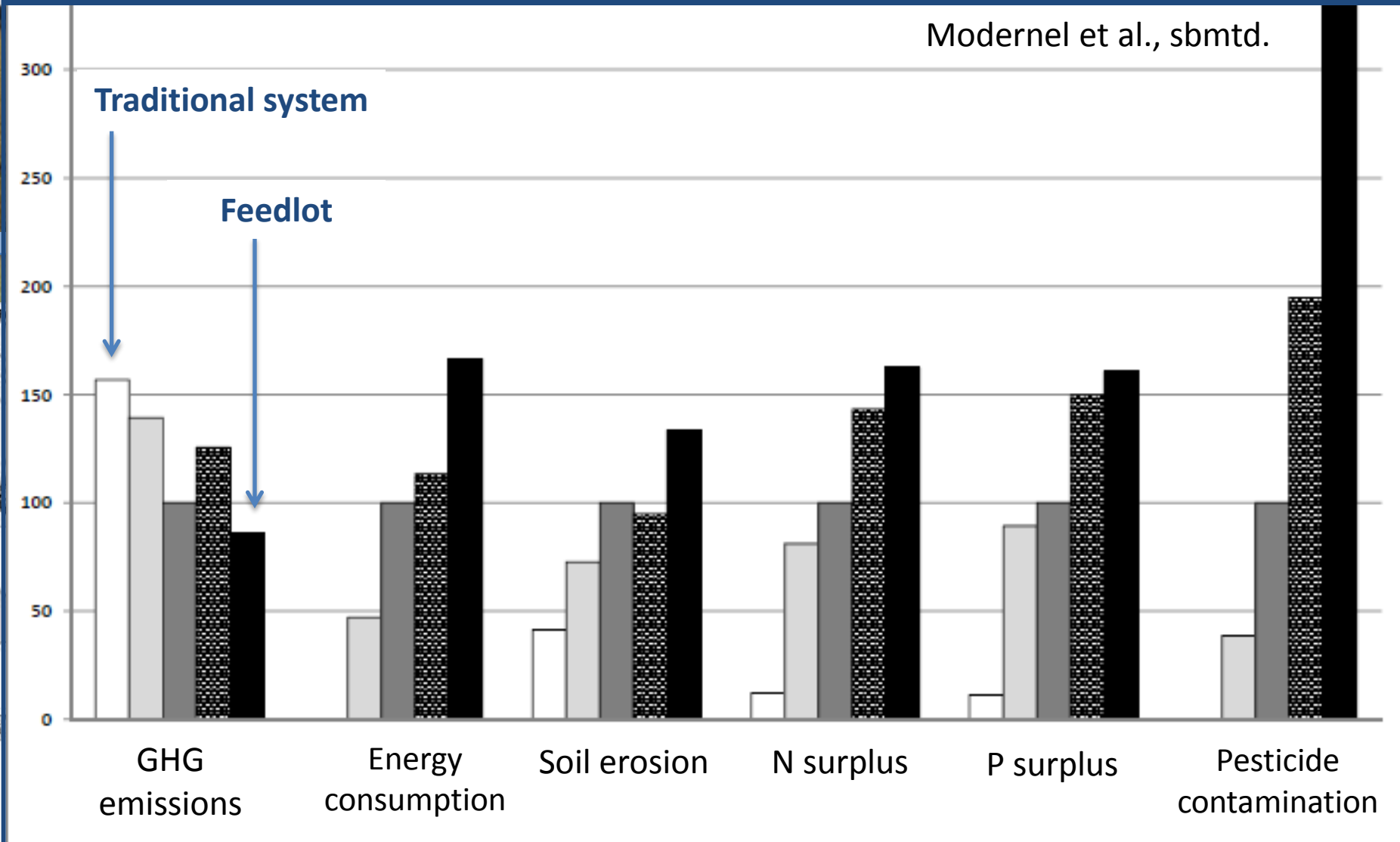
Environmental impact of different intensification pathways



Designing pest suppressive landscapes

Hawassa, Ethiopia

Thesis: Yodit Kabede

Designing pest suppressive landscapes

Spatio-temporal variation

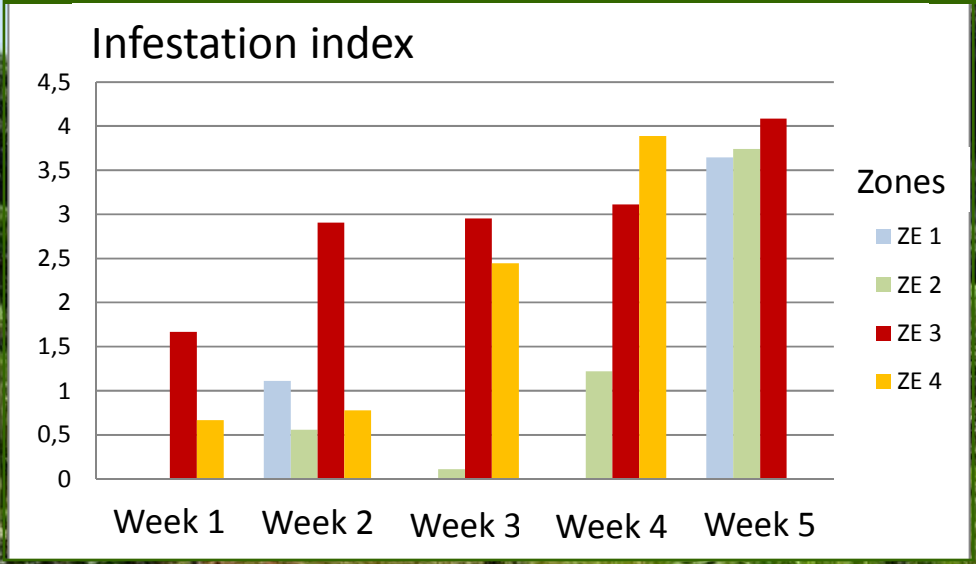
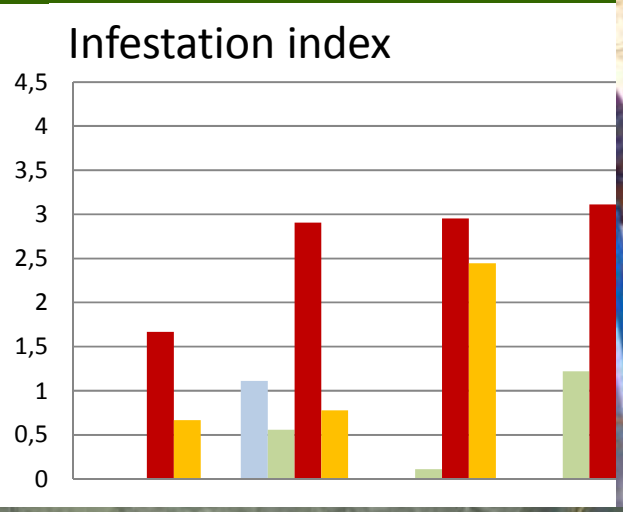


Table 2: Effect of presence and species composition of hedgerows on levels of aphid infestation and predator abundance in beans and cowpea fields in western Kenya (André, 2011)

	Plant infestation index	Nr of predators per field
Fields with hedgerows	2.2±0.6	3.7±0.5
Fields without hedgerows	3.4±0.7	6.5±2.0
Dominant hedgerow species		
Euphorbia	0.6±0.3	2.1±1.1
Lantana	2.4±0.9	4.0±0.9
Eucalyptus	1.5±1.0	3.2±1.4

Designing pest suppr

Spatio-temporal variation



Hawassa, Ethiopia

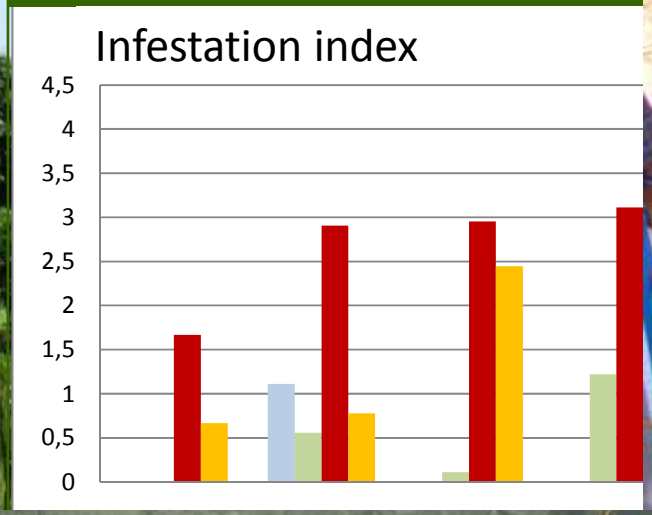
Thesis: Yodit Kabede

n levels of aphid infestation and predator
1)

Nr of predators per field
3.7±0.5
6.5±2.0
2.1±1.1
4.0±0.9
3.2±1.4

Designing pest suppr

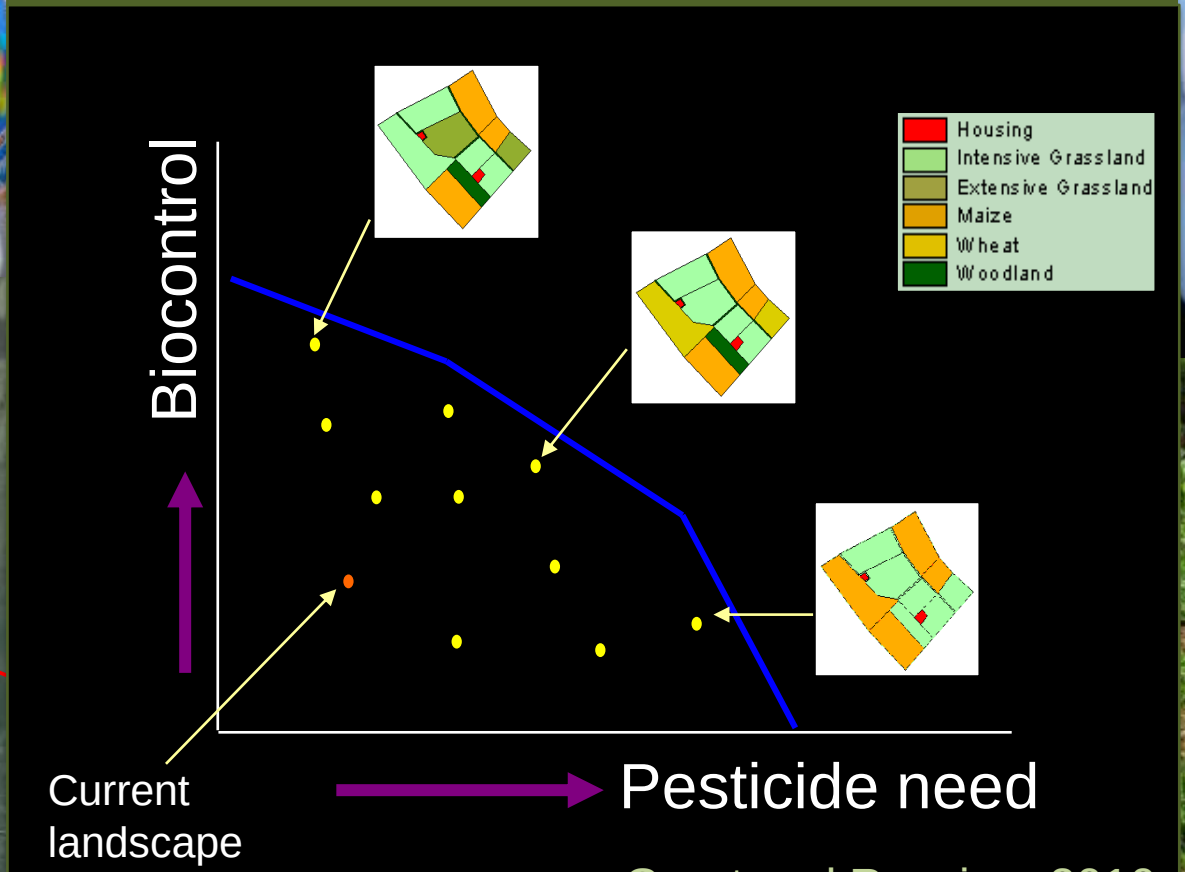
Spatio-temporal variation



Hawassa, Ethiopia

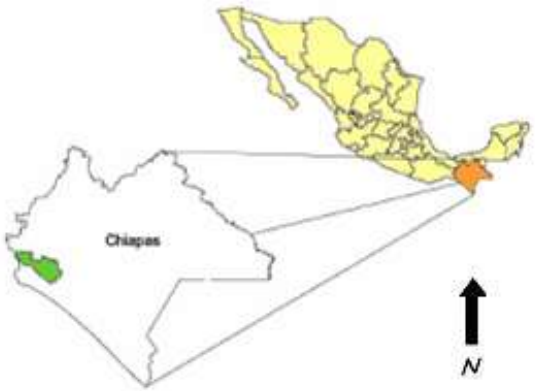
Thesis: Yodit Kabede

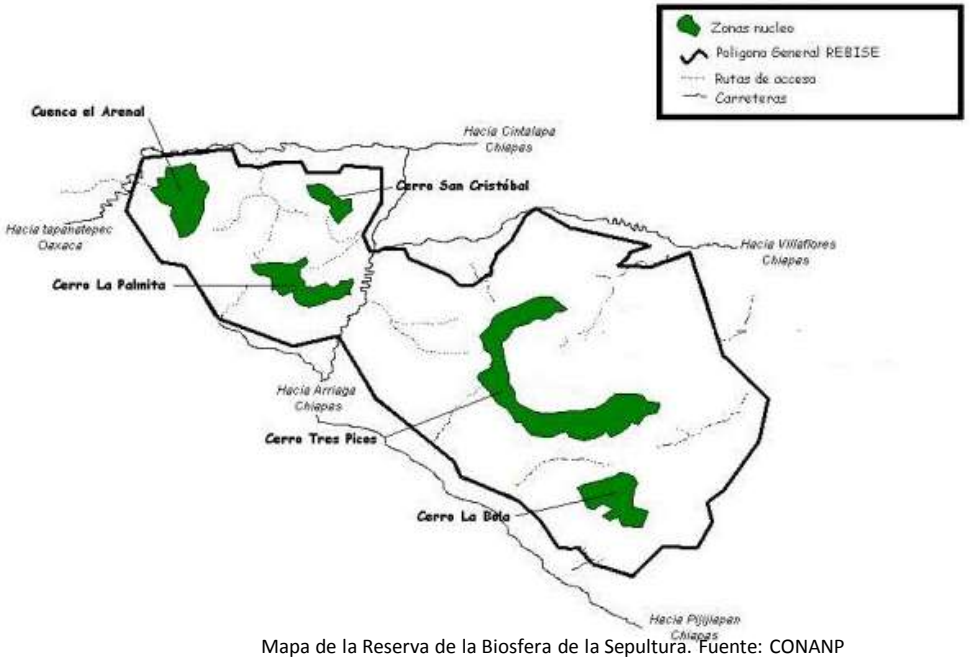
Exploration of alternative landscape structures



Groot and Rossing, 2010

Collective decision making on natural resources





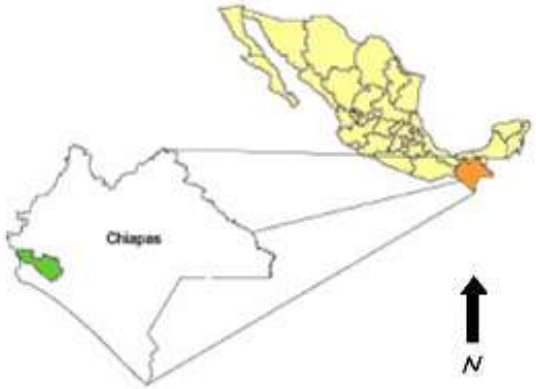
Mapa de la Reserva de la Biosfera de la Sepultura. Fuente: CONANP

Simulation and gaming for improving local adaptive capacity;

The case of a buffer-zone community in Mexico

E.N. Speelman

Collective decision makin



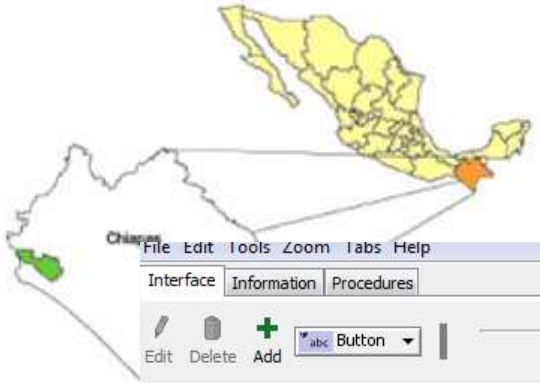
de la Reserva de la Biosfera de la Sepu

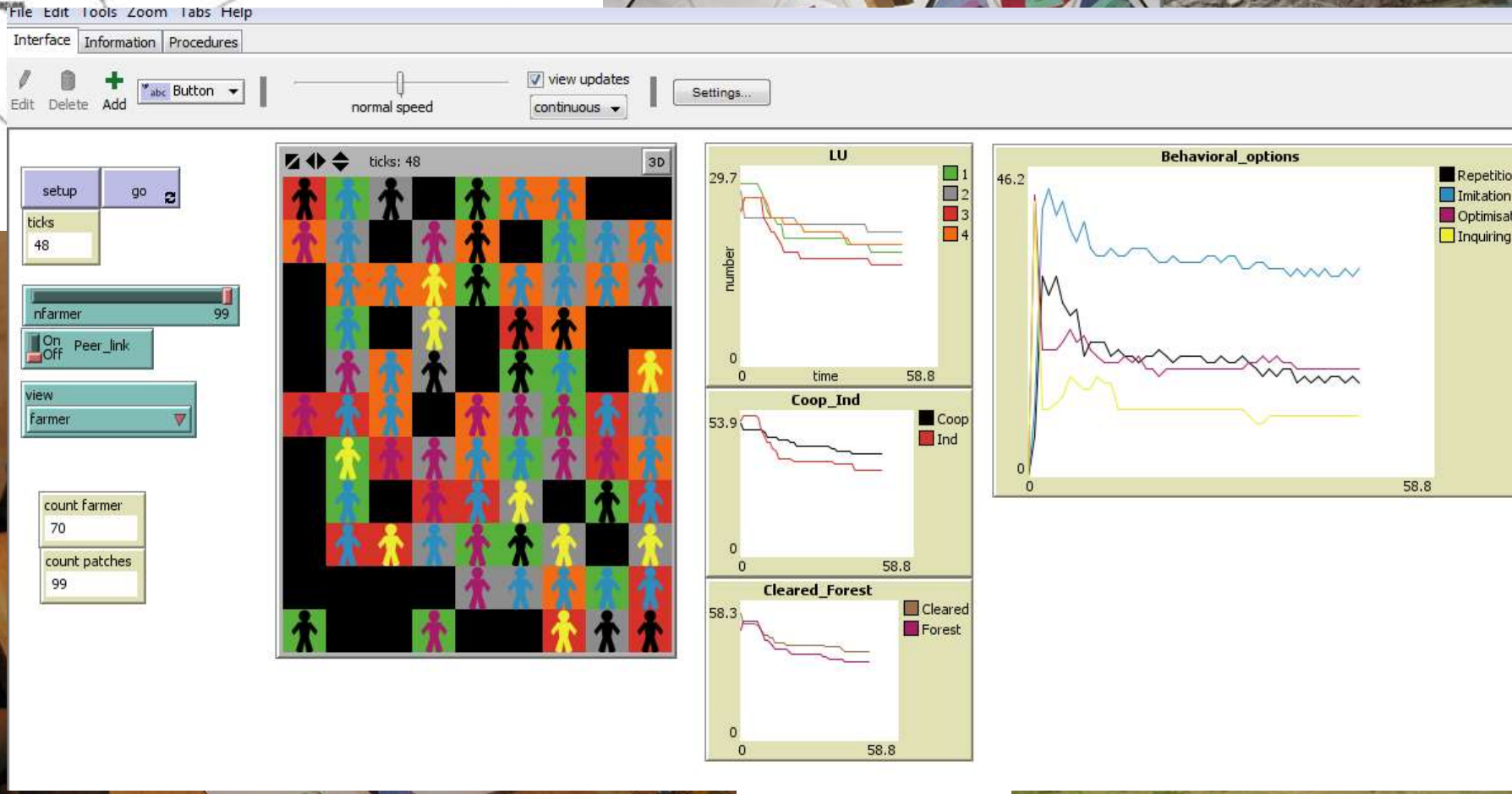
ng local ada

Mexico

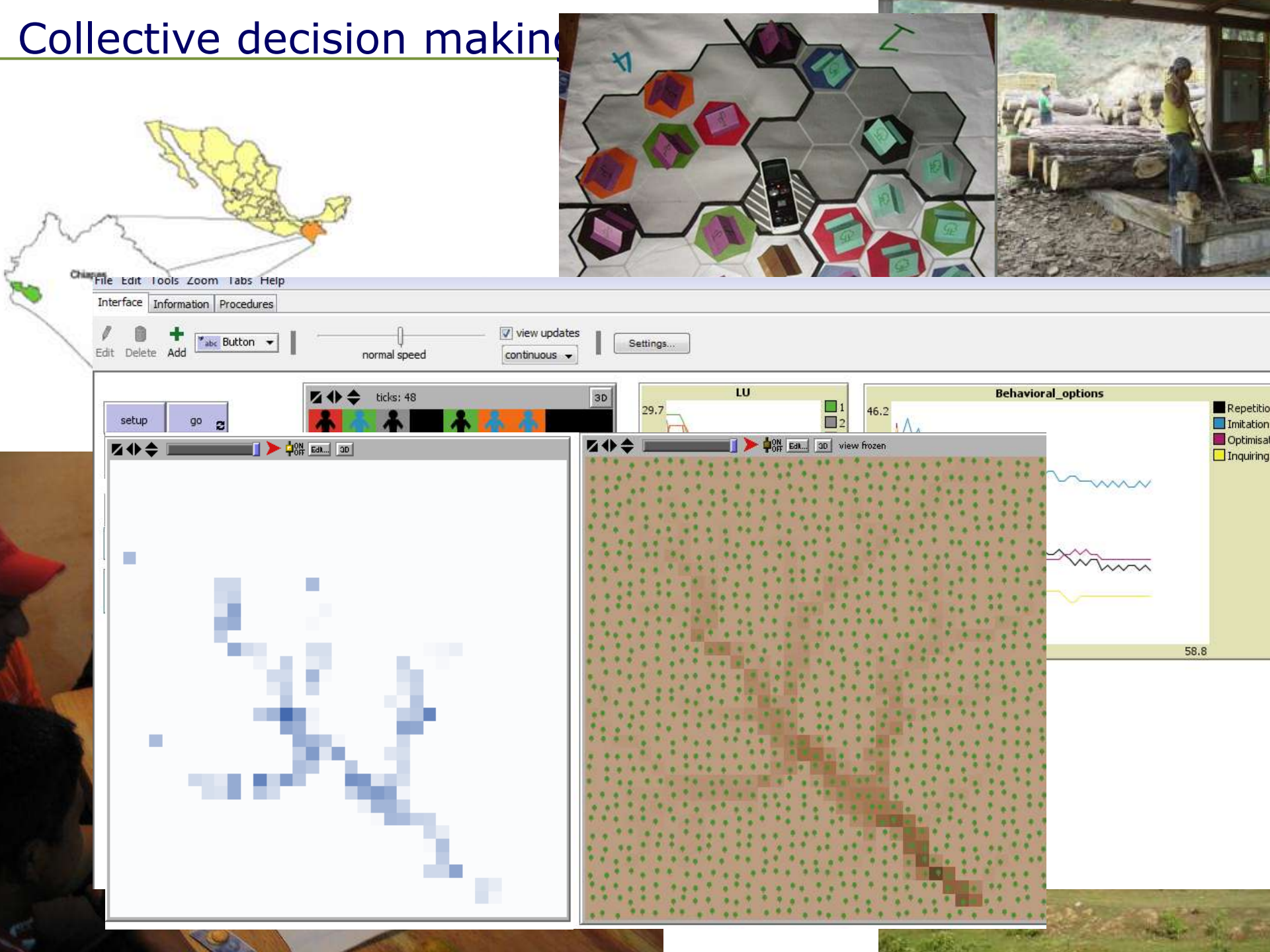
Speelman

Collective decision making





Collective decision makin

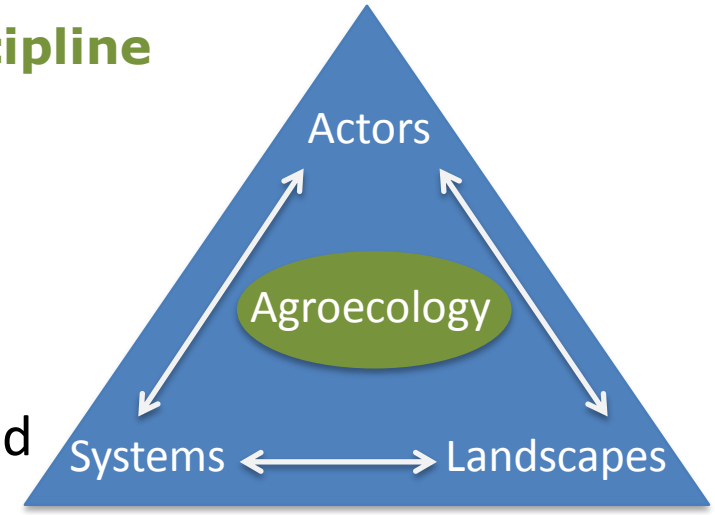


Farming Systems Ecology (FSE) research strategy

Guiding principles

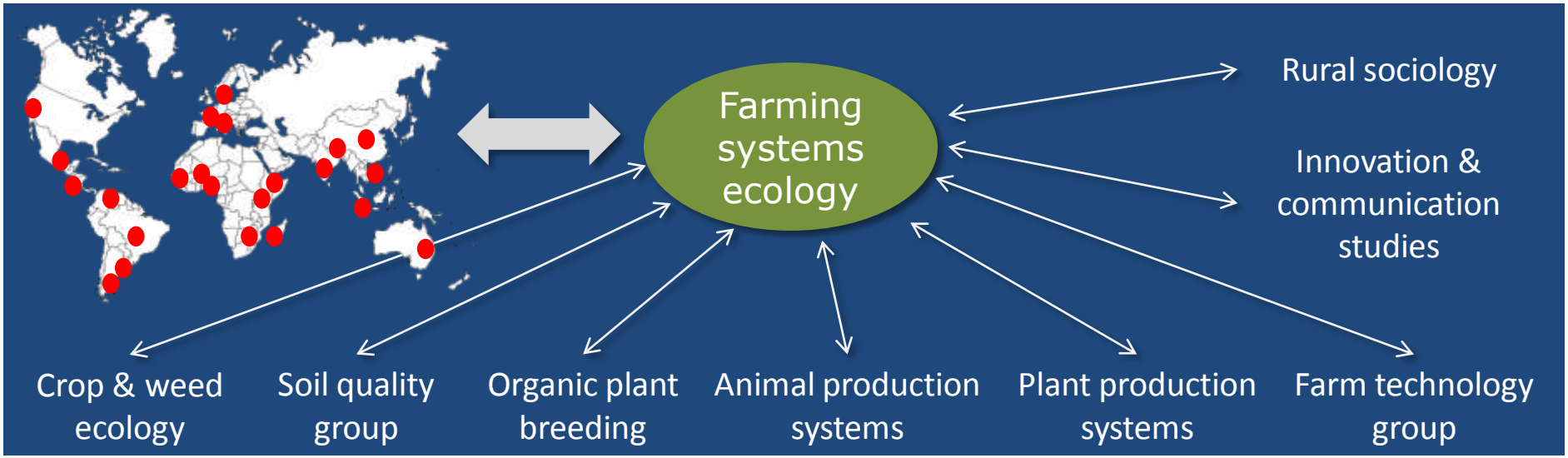
- Ecological intensification
- Systems design as core business
- Interface between ecology and society
- Parallel strategies for the North (Europe) and the South (Tropics)

Discipline

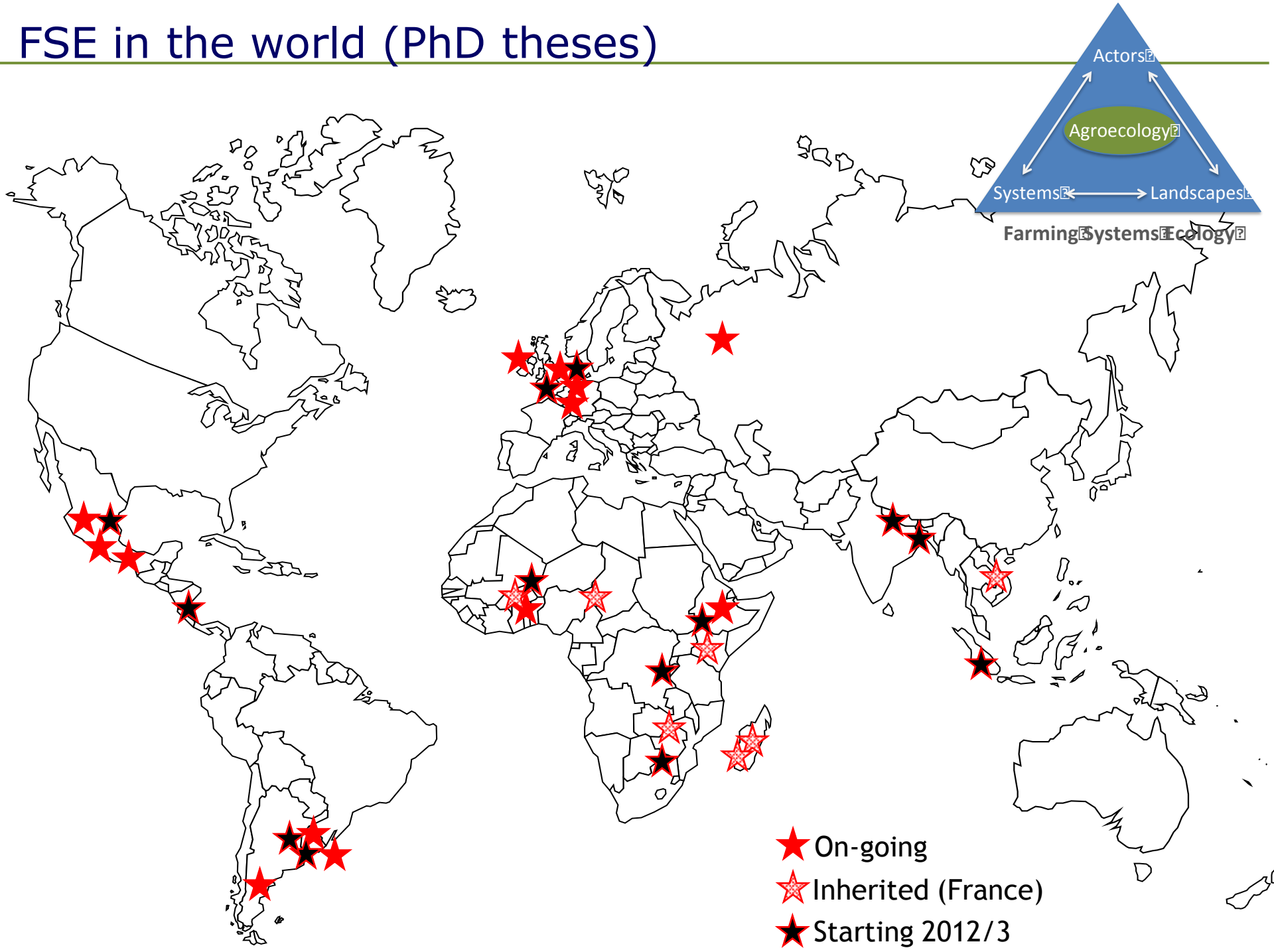


Farming Systems Ecology

Collaboration



FSE in the world (PhD theses)



Communication and image

Communication and image

A conventional farmer purchasing pesticides

An agroecological farmer inspecting his intercrop

Estancia Laguna Blanca, Entre Rios, Argentina
Ecological farming on 3000 ha

Be inspired

PSG employees share social media success stories

2
April

Social media is all the rage, but how can you best use social media for your research group or to promote your research? Pablo Tittonell, chair holder of the Farming Systems Ecology Group, and Daniël de Jong, scientist at Applied Plant Research (PPO), will share their experiences with social media on 2 April.

'Like it or not – First experiences in communicating research through social media'

Prof. Dr Pablo Tittonell
Farming Systems Ecology Group,
Wageningen University

**'Social Media again!
The value of social networking'**

Ir. Daniël de Jong
Arable Farming, Multifunctional Agriculture and Field Production of Vegetables,
Applied Plant Research (PPO)

Location Radix W1-W3
Time 15:30 – 17:00 + Drinks

PSG-employees from outside Wageningen will be able to view the seminar on the web:

http://wurtv.wur.nl/presentations/radix

WAGENINGEN UR
For quality of life

aguna Blanca, Entre Rios, Argentina
Ecological farming on 3000 ha

aguna Blanca, Entre Rios, Argentina
Ecological farming on 3000 ha

Be inspired

natuur

Landbouw die optimaal gebruikmaakt van de plaatselijke ecosystemen, met waar nodig een snufje hightech, wordt de toekomst. Het huidige systeem dat vooral draait op olie en chemie, heeft zijn langste tijd gehad, zegt de Argentijn Pablo Tittonell.

Kees de Vos

Wie is Pablo Tittonell?

Pablo Tittonell werd in 1971 geboren in de Argentijnse hoofdstad Buenos Aires. Hij studeerde er landbouwkunde. Na een jaar bedrijfsleven besloot hij verder te studeren, onder meer in Wageningen. Hij promoveerde daar ook – in 2007 – en ontwierp er zijn eerste. Tittonell werkte voor zijn promotie voor TSBF, een instituut voor bodembiologie en bodemvruchtbaarheid dat is gevestigd in de Keniaase hoofdstad Nairobi. Nadat hij zijn doctorstitel behaalde werkte de Argentijn jaren voor CIRAD, het Centre de coopération Internationale en Recherche Agronomique pour le Développement. Vanuit dit gouvernementele instituut in het Zuid-Franse Montpellier deed hij onderzoek naar kleinschalige landbouw in zuid-Afrika en westelijk Afrika, Brazilië en Vietnam. In 2012 werd hij benoemd tot hoogleraar landbouwkundige in Wageningen. Vandaag opnieuw bij er zijn hoogstpersoonlijk zelf uit.

Een vrouw geeft sorghum in een diep

deVerdieping 9

duurzaamheid & natuur

Landbouw moet intensiever, maar dan wel ecologisch

In Burkina Faso. Met kennis van het plaatselijke ecosysteem kan er op sommige gronden beter worden geteelt.

Concluding remarks

Ecologically intensive farming is more than just conventional farming without inputs

It requires:

- ecological engineering at farm and landscape level
- ability to engage with local actors and learn from them
- systems approaches that embrace the complexity of social-ecological interactions

It needs:

- Serious public funding that compensates for the investment gaps

Intensify in the South, extensify in the North, detoxify everywhere…