Modelling complexity in LFS to address trade-offs and synergies

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Outline

- Complexity in livestock farming systems
- Reasons for considering complexity
- Consequences for research
- Promising research methods
    - Functional farm typologies
    - Design-oriented quantitative system models
- Implications

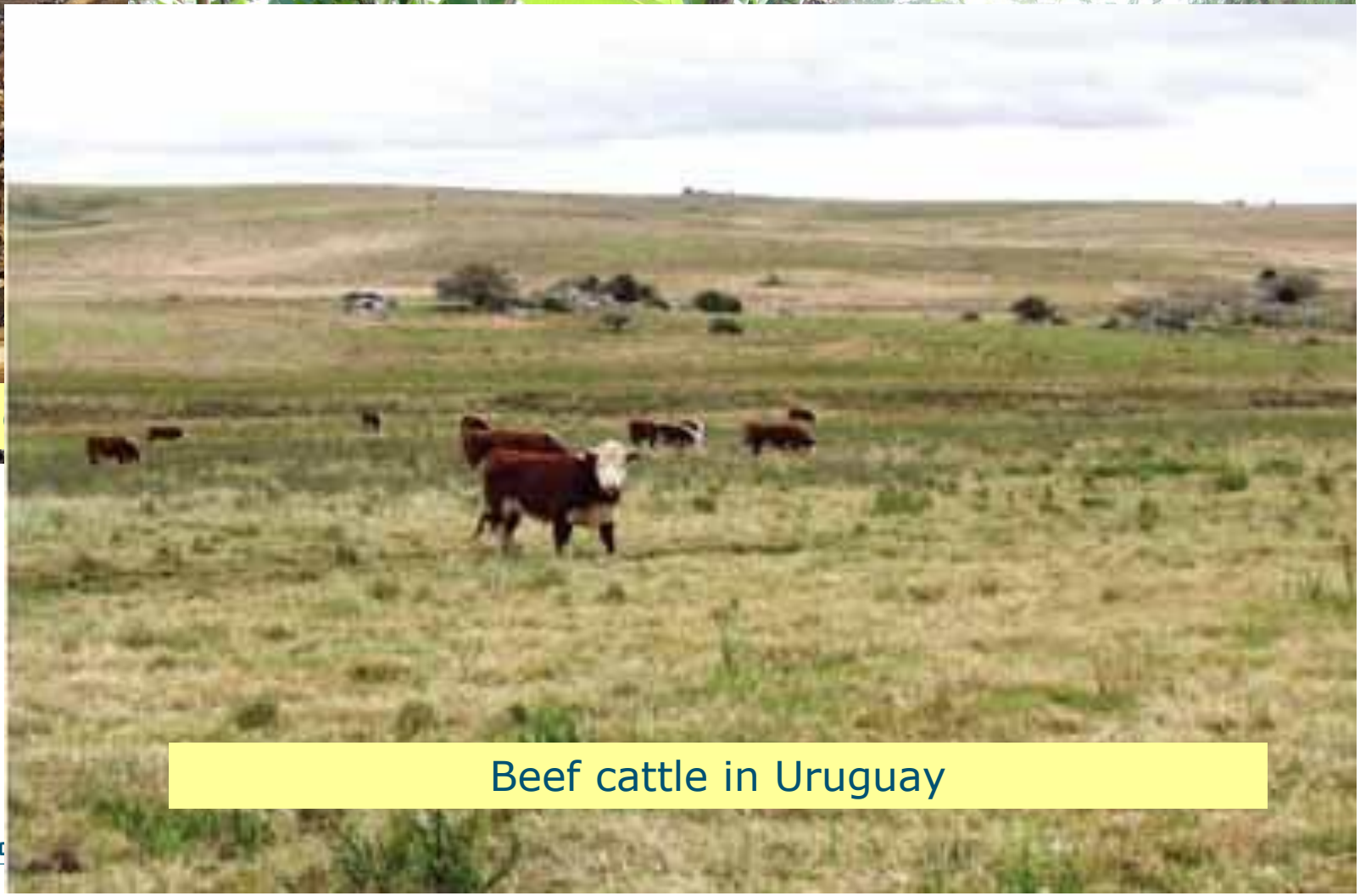
Throughout: examples from the South and the North, biased to cattle-based and mixed systems

Complexity in livestock farming systems

- Complexity due to diversity in system phenotypes
- Complexity due to number and type of system components
- Complexity due to interaction of social and bio-physical systems

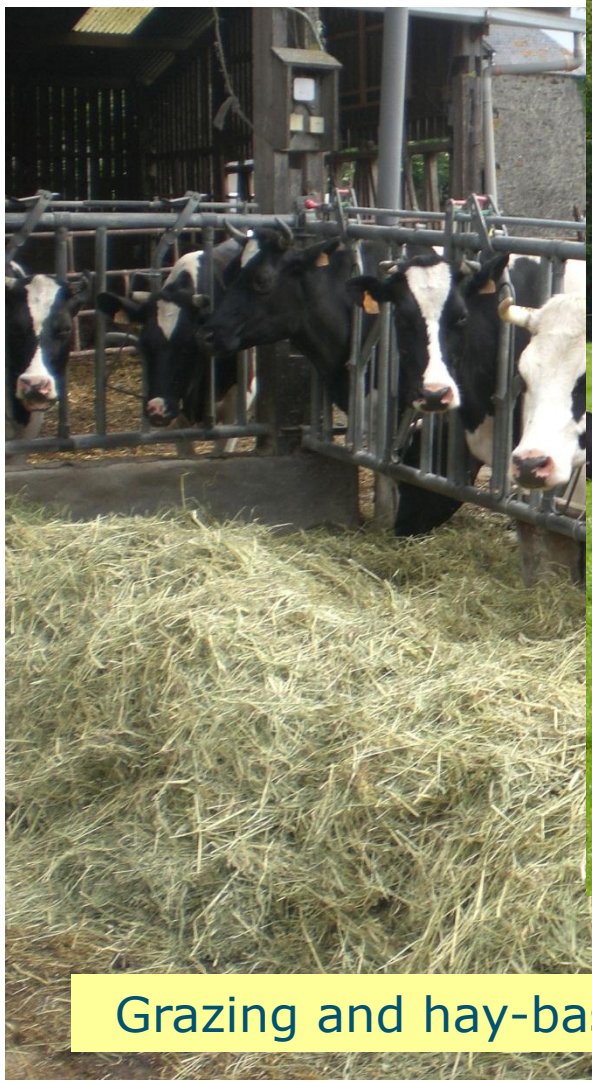
Complexity - 1: System phenotypes

Fe



Beef cattle in Uruguay

Complexity – 1: System phenotypes

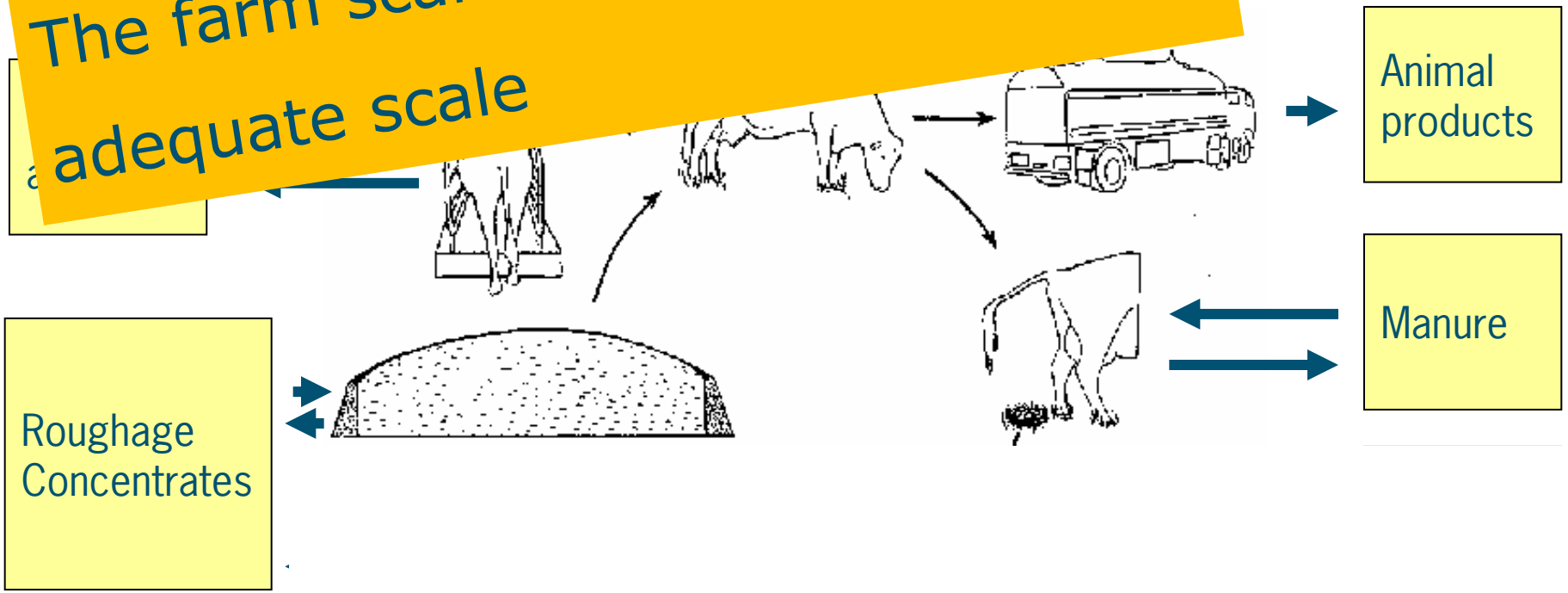


Grazing and concentrates, The Netherlands

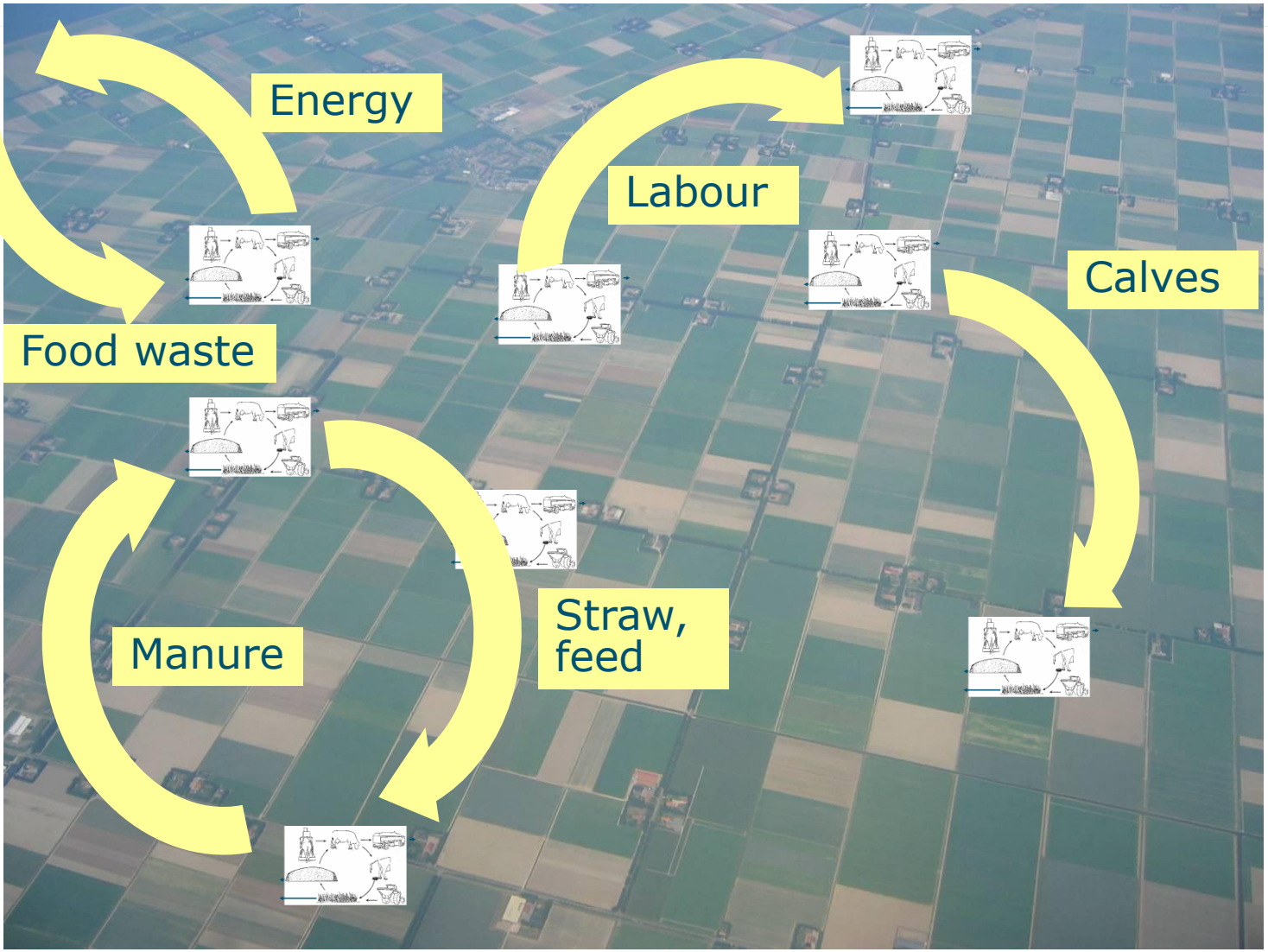
Grazing and hay-based cheese production, France

Complexity – 2: System components

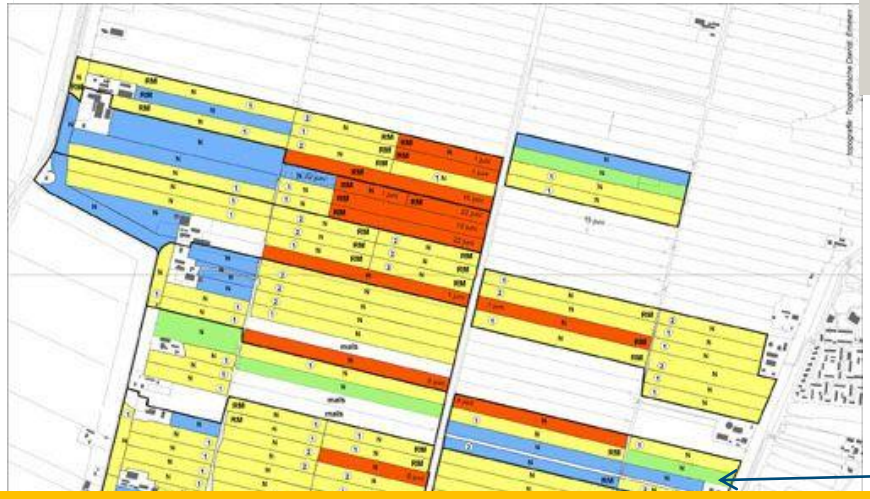
The farm scale may not be the adequate scale



Complexity – 2: System components



Complexity – 2: System components

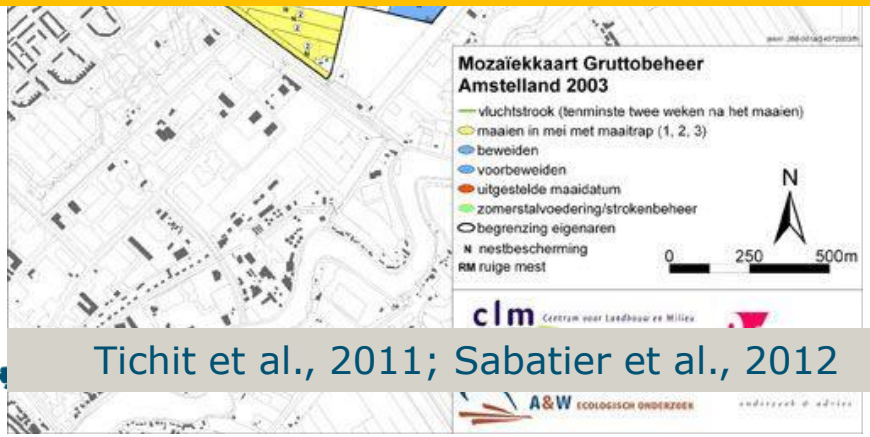


Black-tailed godwit
Limosa limosa

Zero grazing and

Number of system components increases due to variation in management and variation in space

Bird rescue strip (+2 wk)



Tichit et al., 2011; Sabatier et al., 2012

Complexity – 3: Socio-ecological systems

Innovation context

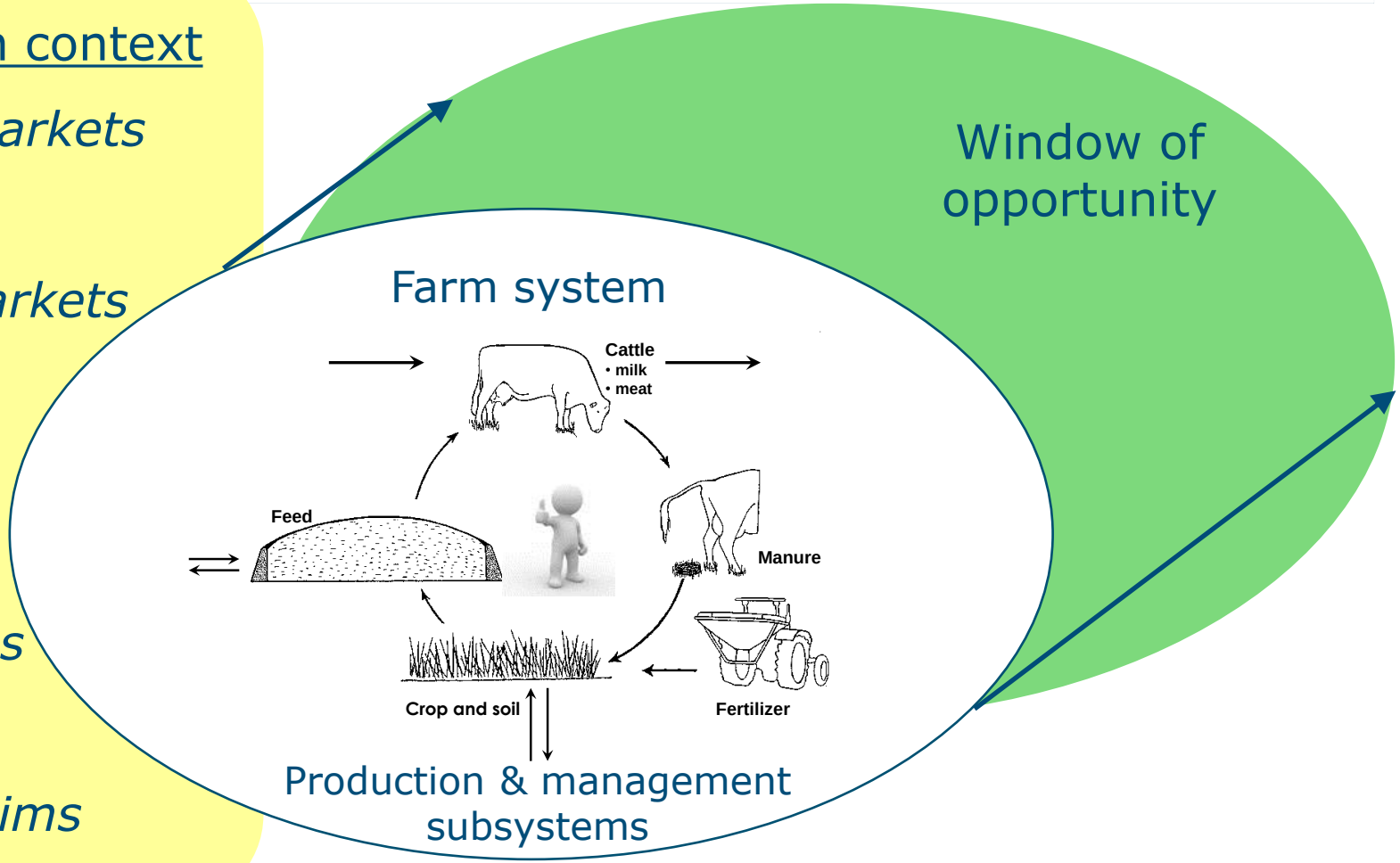
Product markets

Labour markets

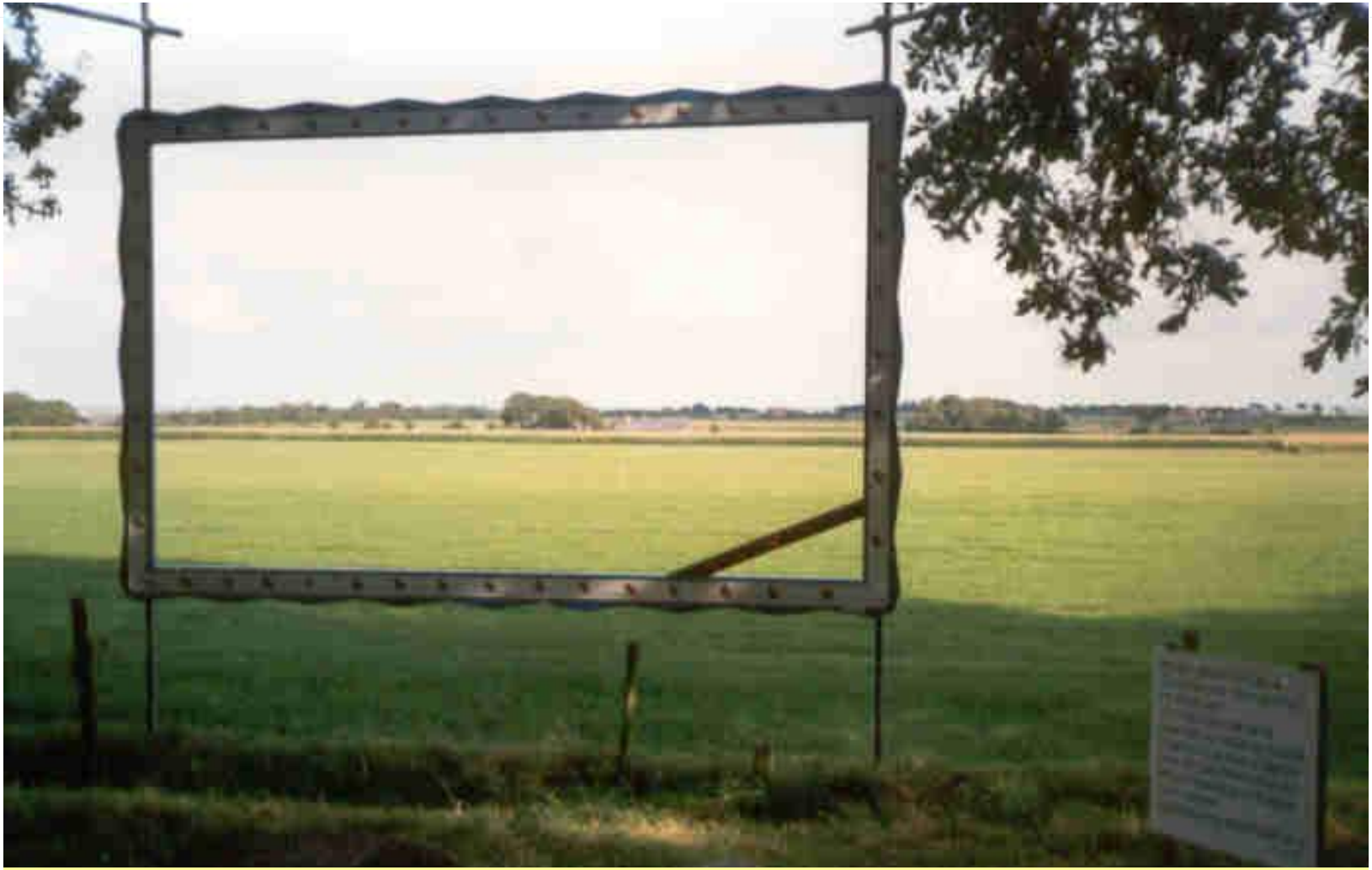
Prices

Institutions

Citizen claims



Complexity – 3: Socio-ecological systems



Response to citizens' claims for landscape quality

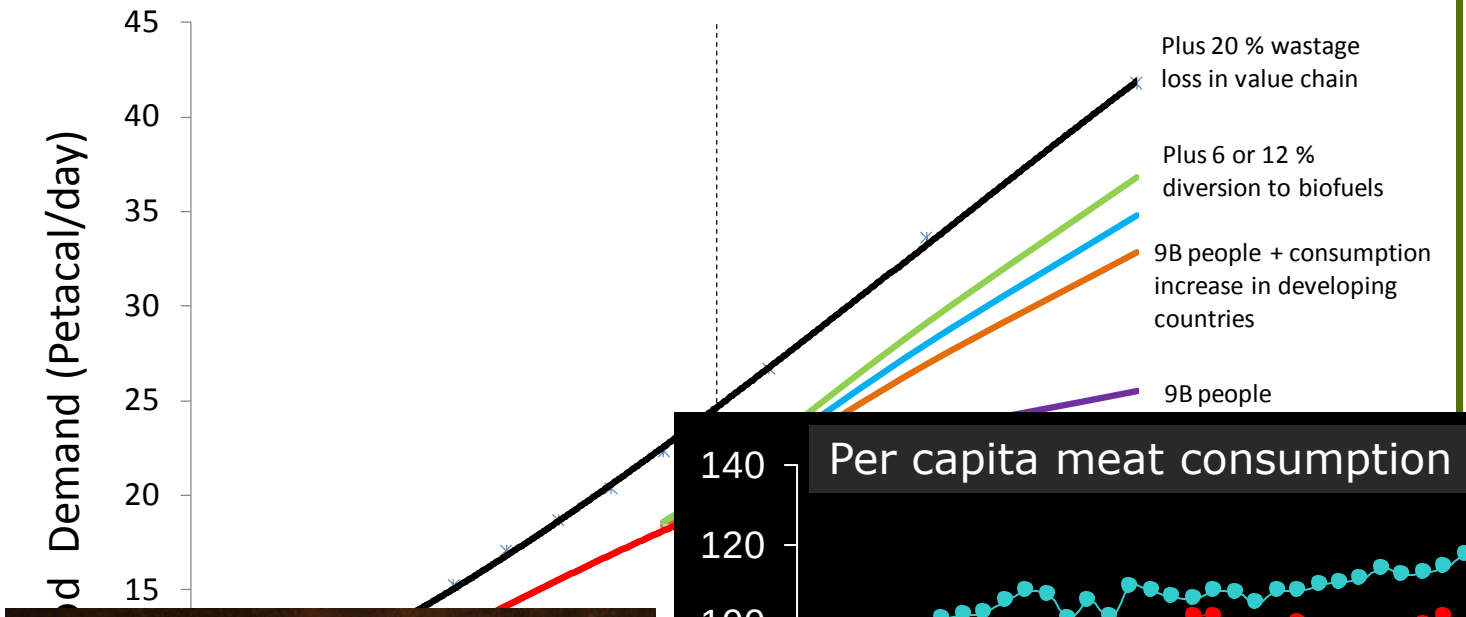
Complexity – 3: Socio-ecological systems

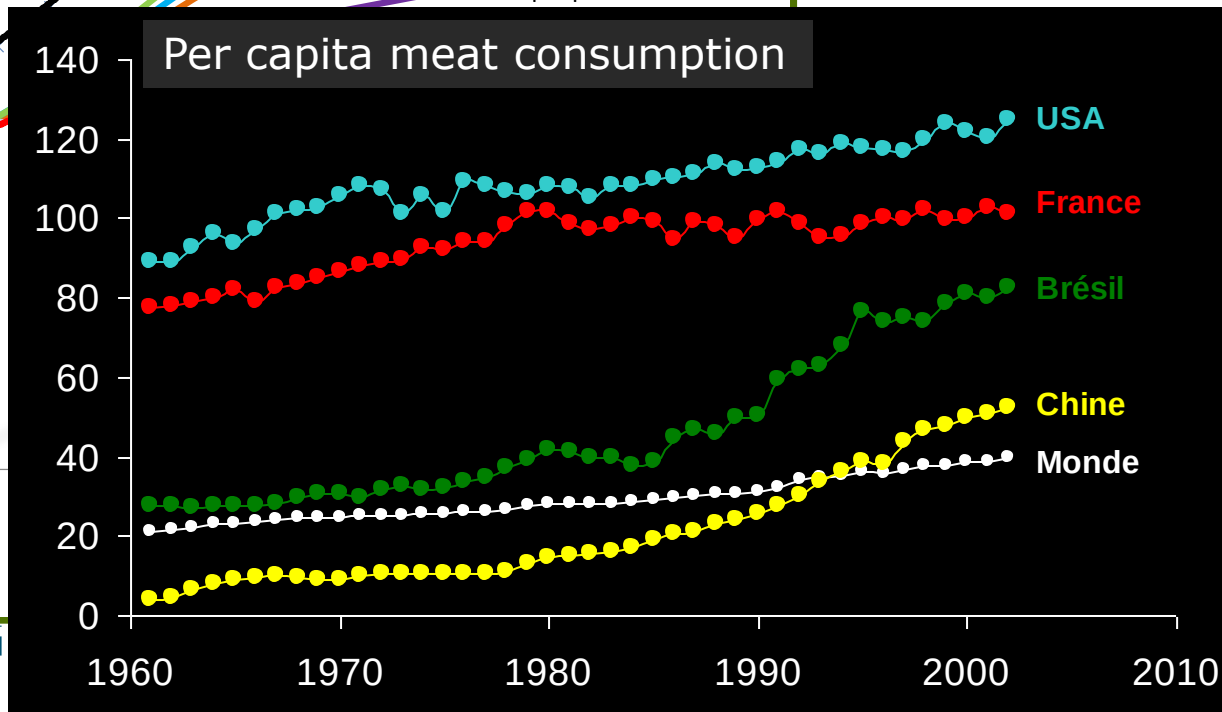
Complexity in livestock farming systems

- Complexity due to diversity in system phenotypes
  - Systems are contextual
- Complexity due to number and type of production system components
  - Determined by outlook
- Complexity due to interaction of social and bio-physical systems
  - Non-linear relations and feedbacks: emergent behaviour

Why the interest in complexity?

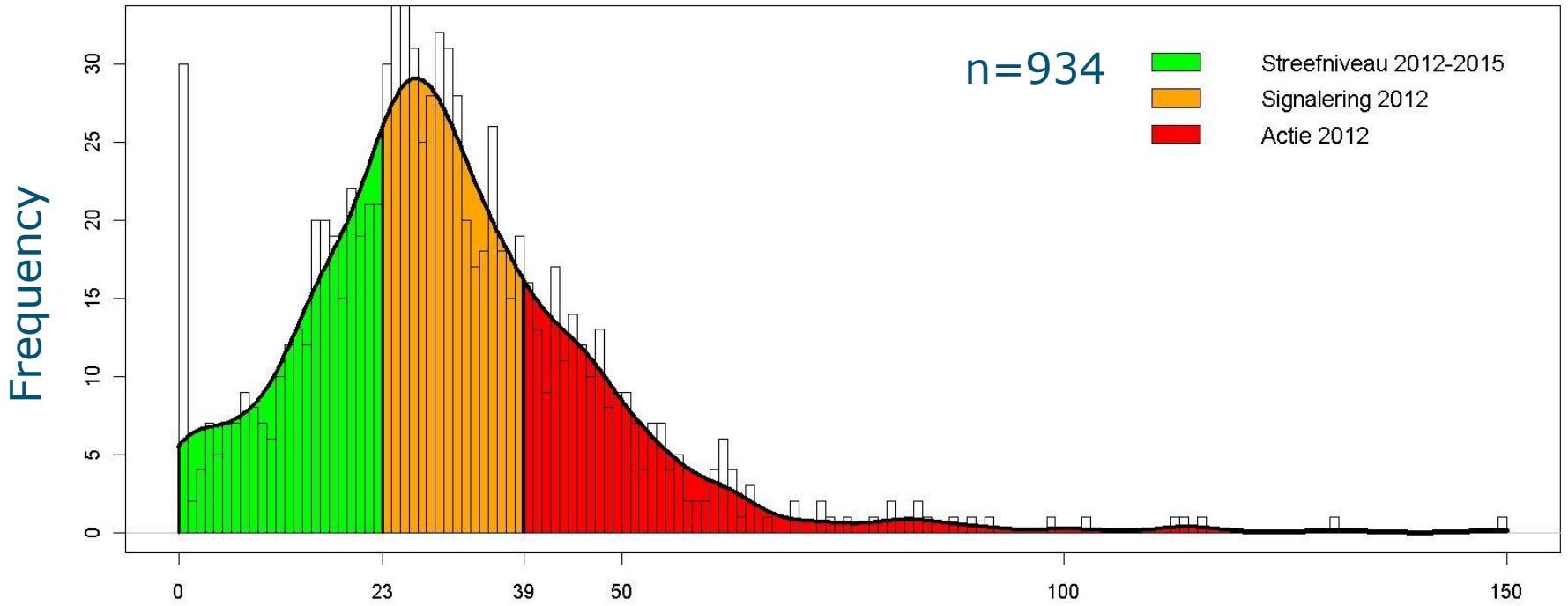
Food demand to 2050





Produce more, but produce differently

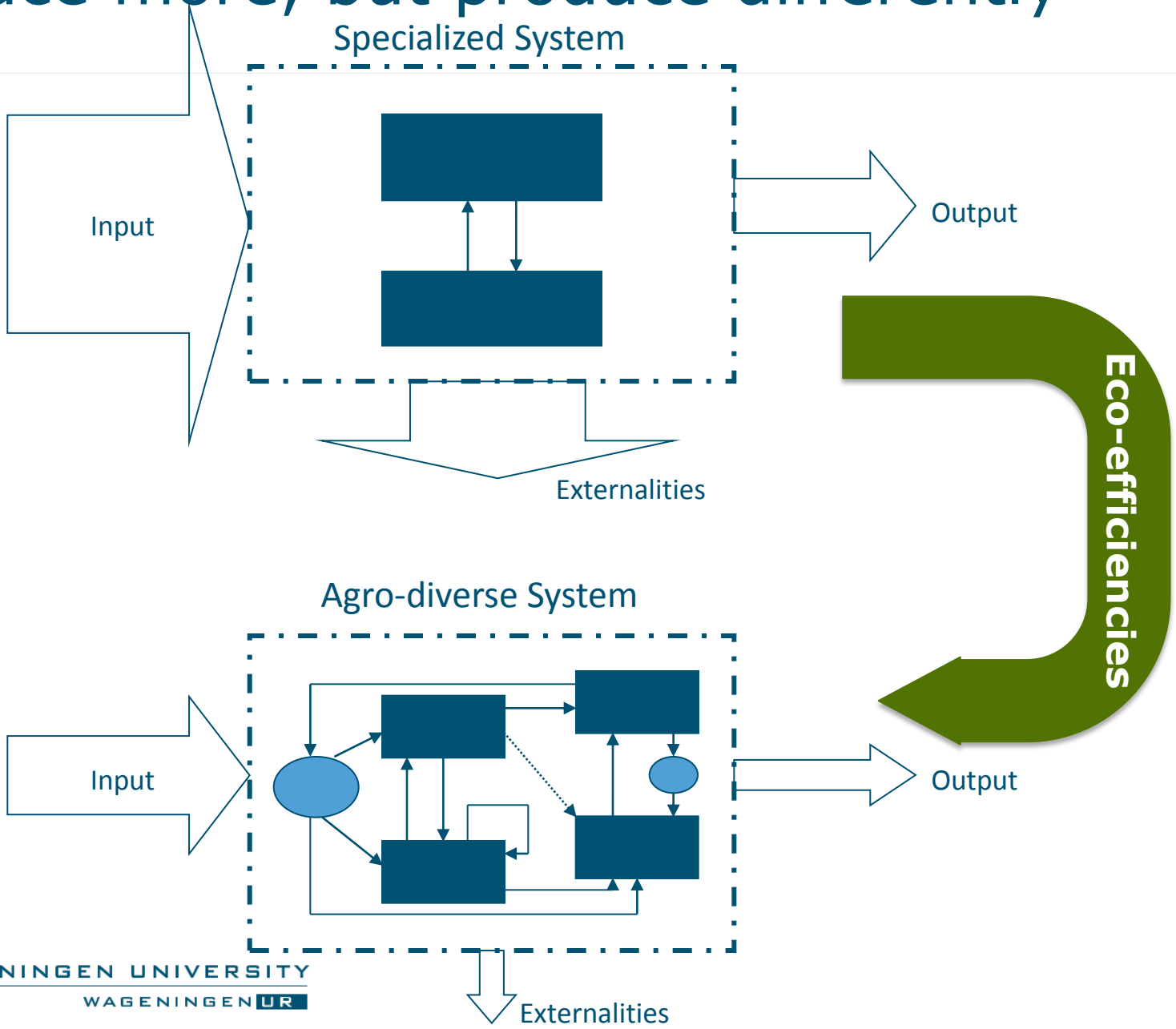
Antibiotics use in calf fattening in The Netherlands



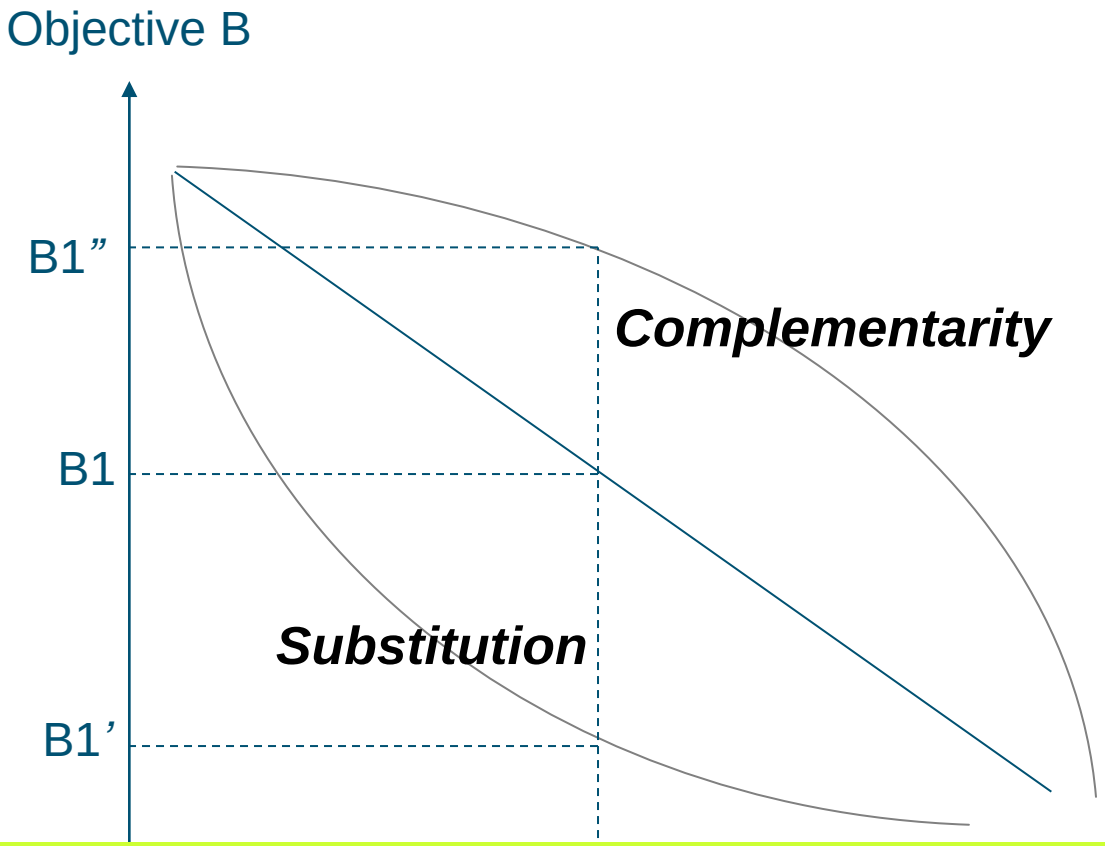
SDA, 2012

1977	283	7.07	40.0
2005	484	26.21	18.5
% change	71%	271%	-54%

Produce more, but produce differently



Trade-offs among multiple objectives



Implications

- A single decision may affect two or more objectives at the same time
- Choices are limited: e.g., by resources, by time, by cultural aspects, etc.
- Role for science: elucidate relations among objectives and find complementarities

Consequences for research

- Analysis and re-design of entire production systems
  - Multi-scale: field, farm, landscape/region
  - Multi-objective: economic, ecological, social
  - Multi-stakeholder: licence to research
- Modelling to make sense of existing and future complexity
  - Understanding existing patterns
  - Synthesizing mechanistic knowledge on components at the system level
- Maximize use of ecological knowledge during re-design
  - Ecology, agronomy; anthropology, innovation science

Outline

- Complexity in livestock farming systems
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    - Functional farm typologies
    - Design-oriented quantitative system models
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Farm typologies

- Aim to categorize farm diversity
- Purpose: policy (monitoring and evaluation), research
- Often used to extrapolate (scaling up or out)
- Range of methods: statistical clustering, participatory ranking, expert knowledge

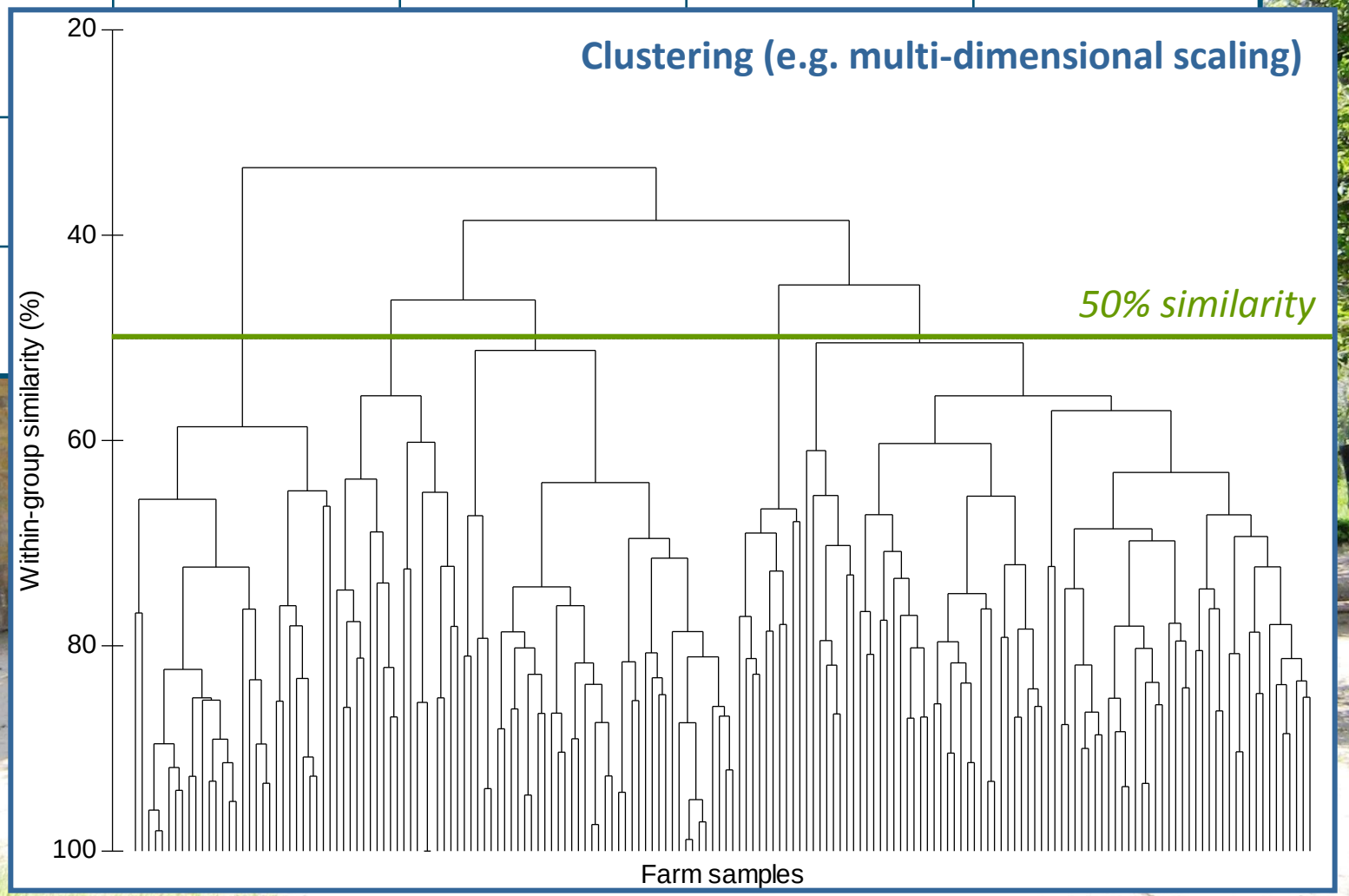
Structural → Based on resources and asset levels

Functional → Livelihood strategies and household dynamics

Structural typologies

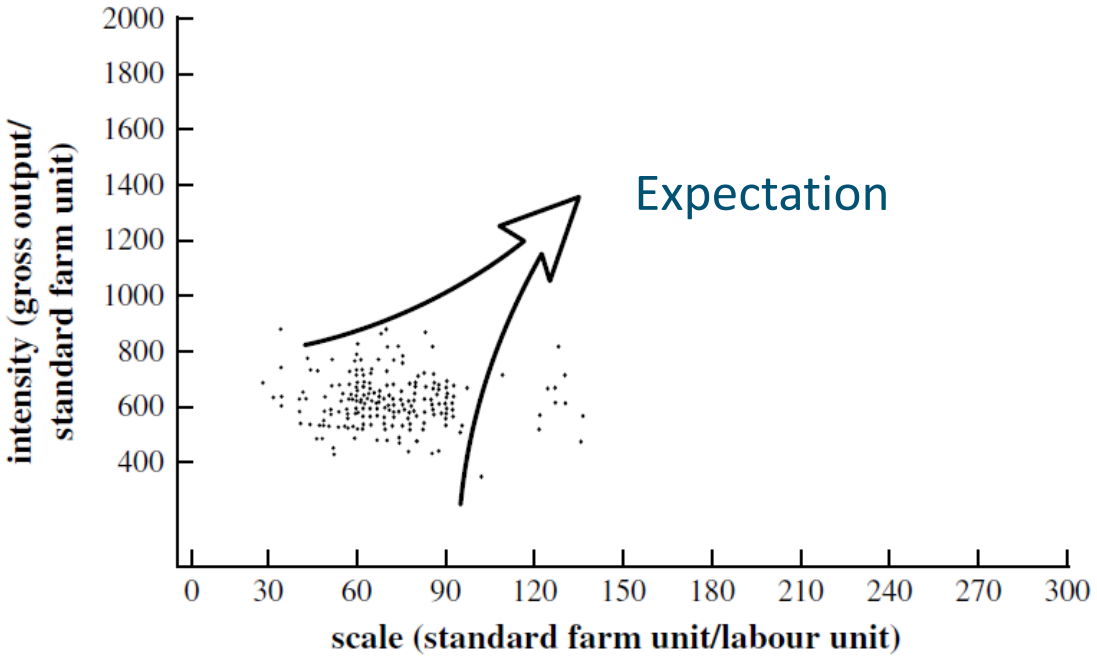
Smallholder households in NE Zimbabwe

Farm type	Farm size (ha)	# Livestock	# Scotch carts	Maize yield (t ha^{-1})
Poor				
Medium				
Rich				



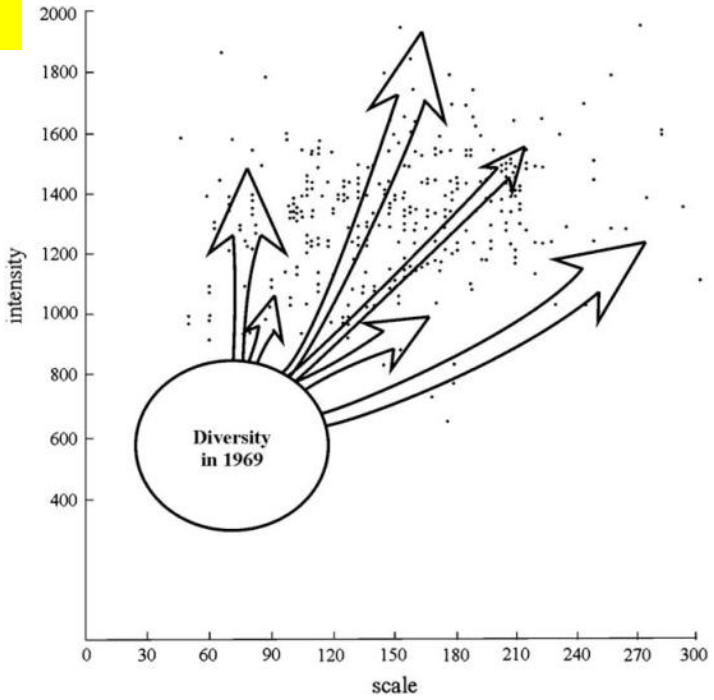
Structural typologies: Dairy farms in NL

1969



Expectation

1981



Van der Ploeg et at. 2009, JEM

Extrapolation capability of structural typologies is limited: farm development does not only revolve around resources and assets

Functional typologies

- Resource endowment (allocation pattern)
- Production orientation (subsistence, markets)
- Livelihood strategy (e.g., access to non-/ off-farm income)
- Household structure (position in farm development cycle)
- Household dynamics (where do they come from/ go?)

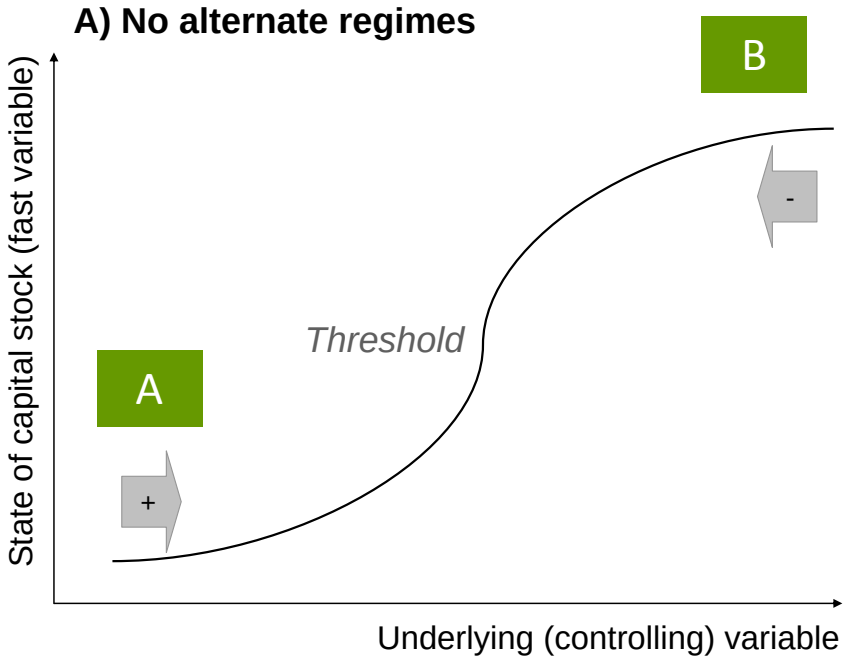
Hypothesis (Tittonell, 2011):

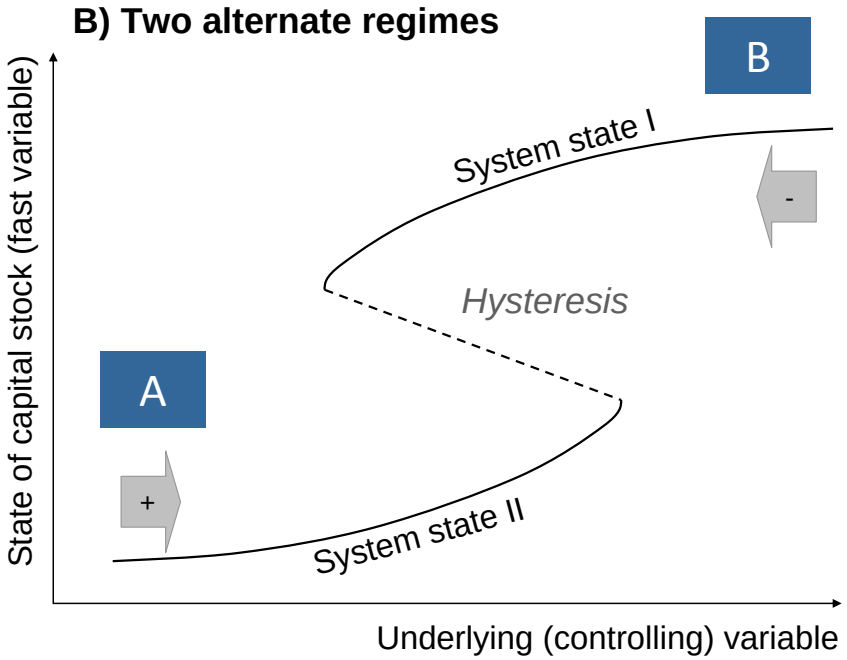
Different household types may be seen as alternate states of the same system (in this case, the smallholder rural livelihood system)

This may allow:

- Understanding the nature and resilience of poverty traps
- Analysing possible shifts between household types in response to e.g. poverty alleviation measures, market or climatic scenarios, etc.

Assumptions underlying typologies





Assumptions structural typologies:

Policies and development interventions impacting on the right driving variables will gradually move systems from A to B

A threshold may be there…

Assumptions functional typologies:

Moving from A to B may not be so easy; these are two alternative system regimes; interventions need to provoke a 'jump' (hysteresis)

Discontinuity, irreversibility…

Scheffer et al., 1993; TREE; other Resilience thinkers

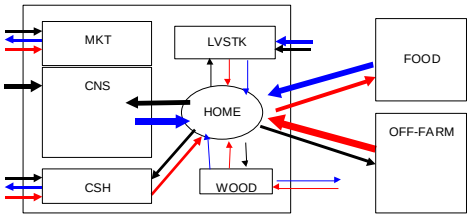
Western Kenya

A functional typology for East African highland systems

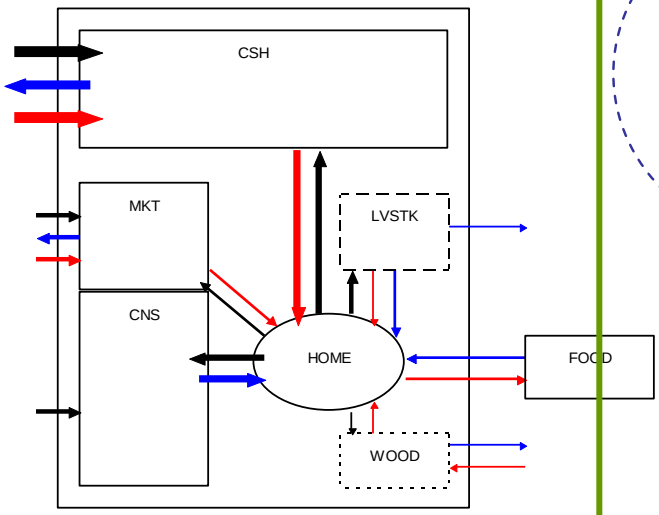
Wealthier households

Mid-class to poor households

Type 1

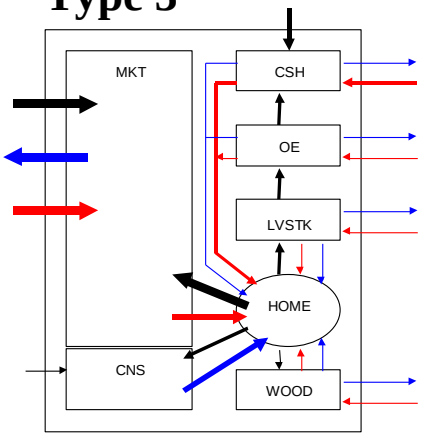


Type 2

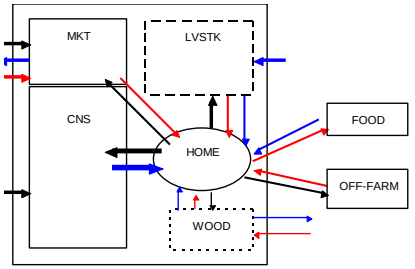


Resource allocation strategies

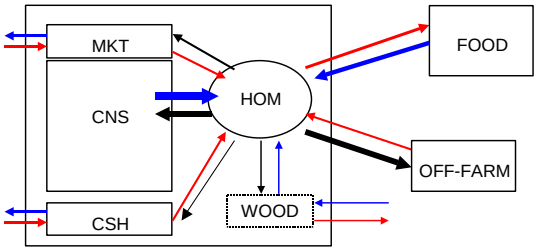
Type 3



Type 4



Type 5



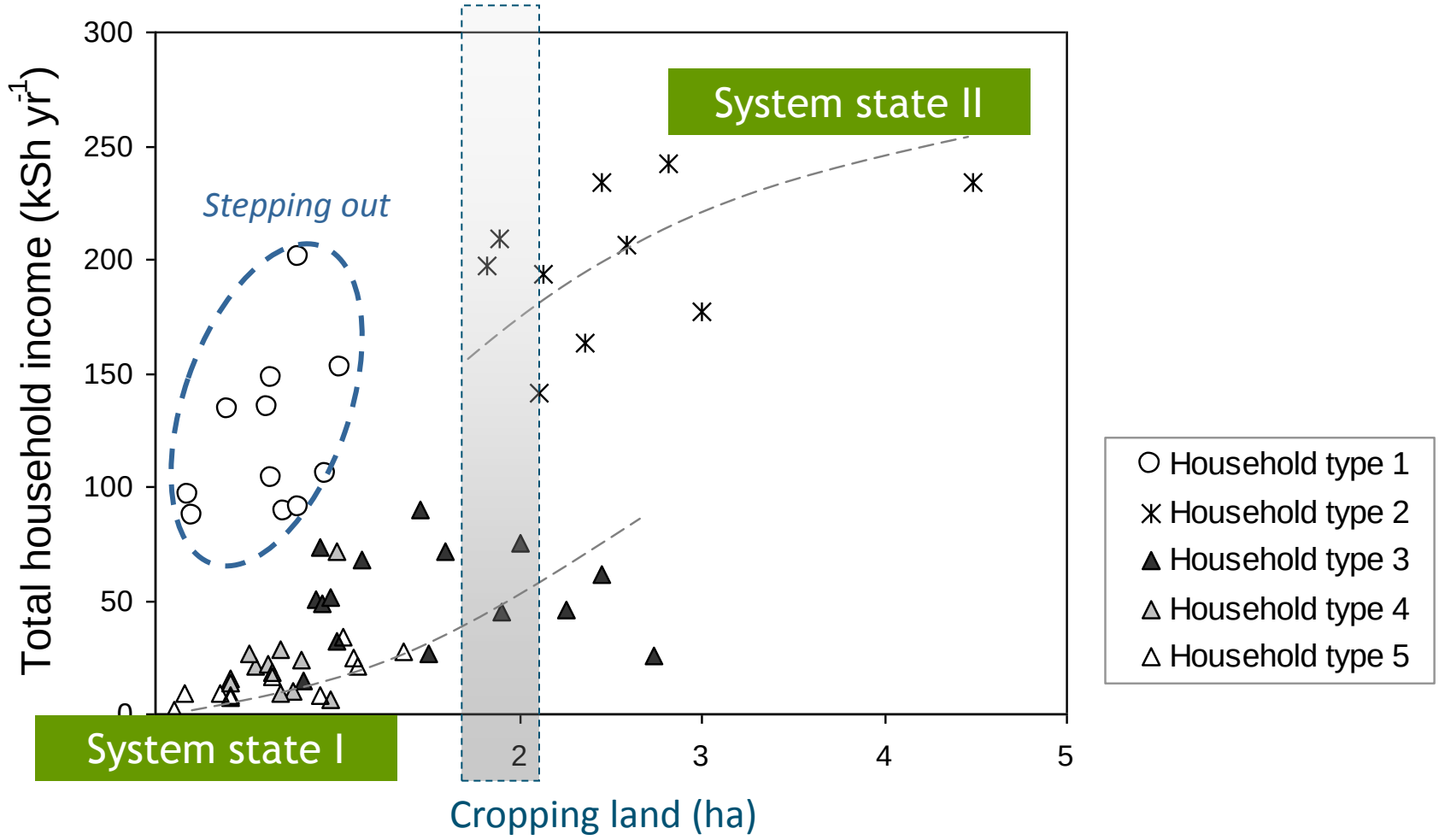
Cash

Labour

Nutrients

Tittonell et al., AGEE 2005a,b

Indicators of ‘resources’ and ‘performance’



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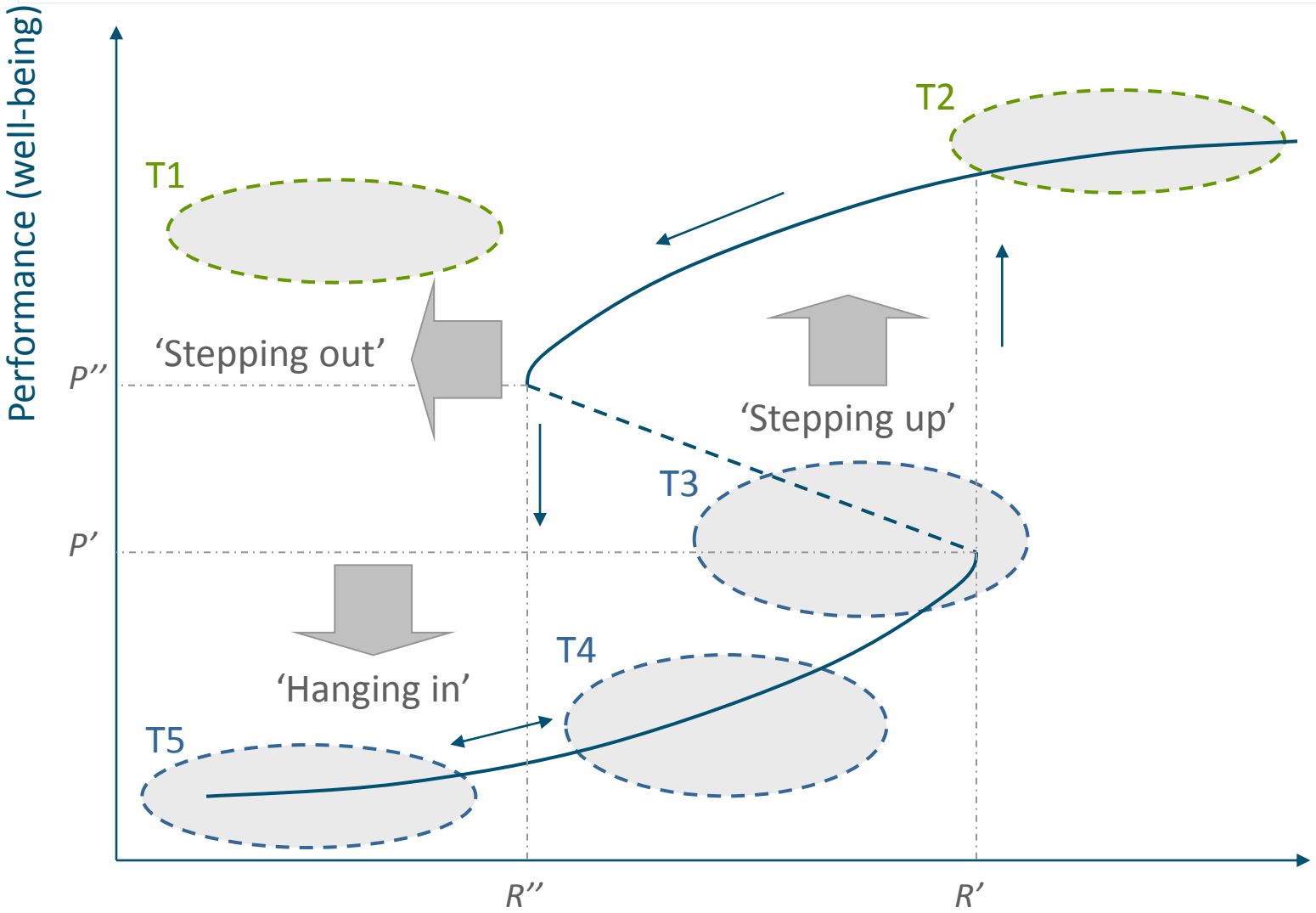
More on this work in

Tittonell et al., 2010 & in prep; AgSys

Functional farm types and system state



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Dorward (2009)

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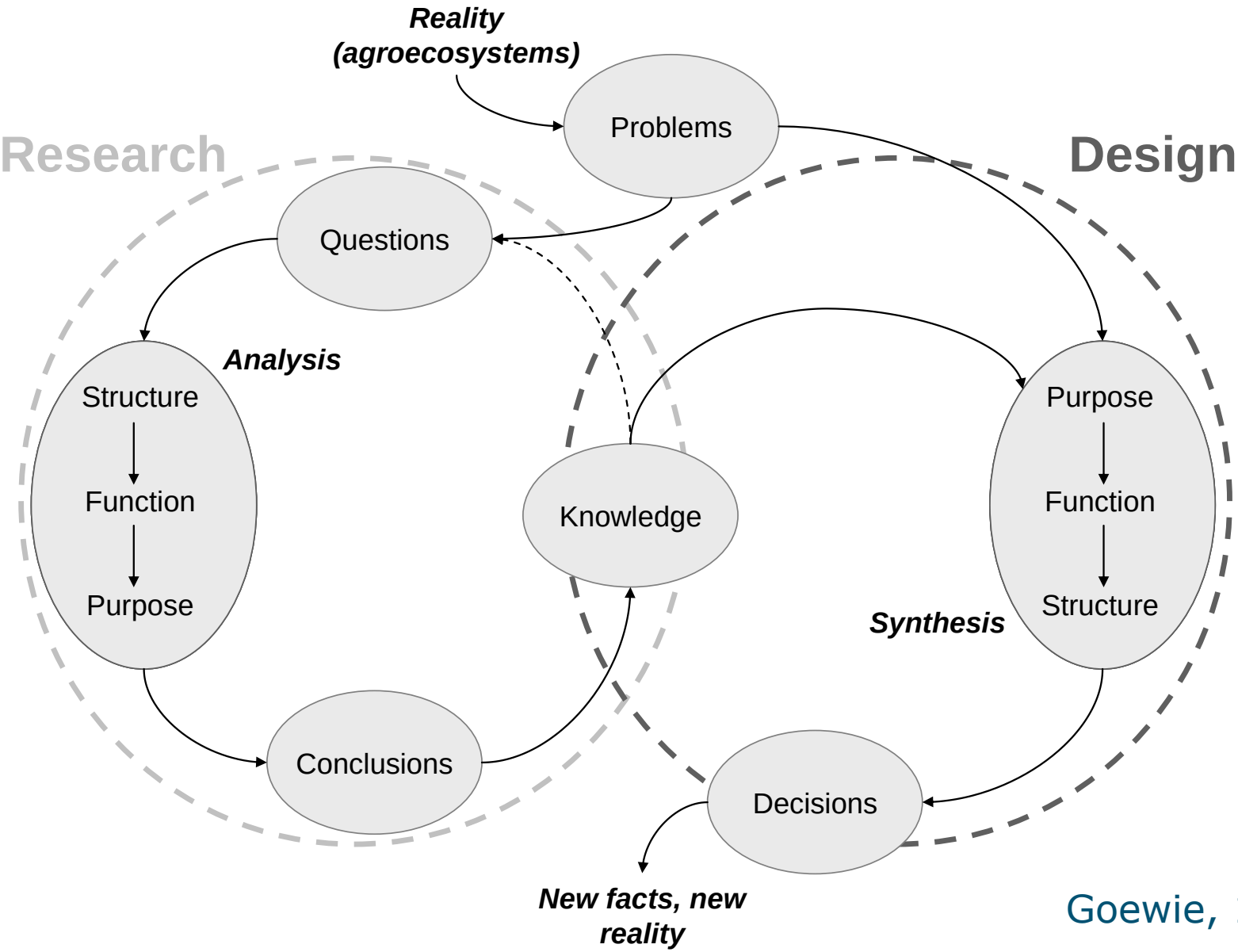
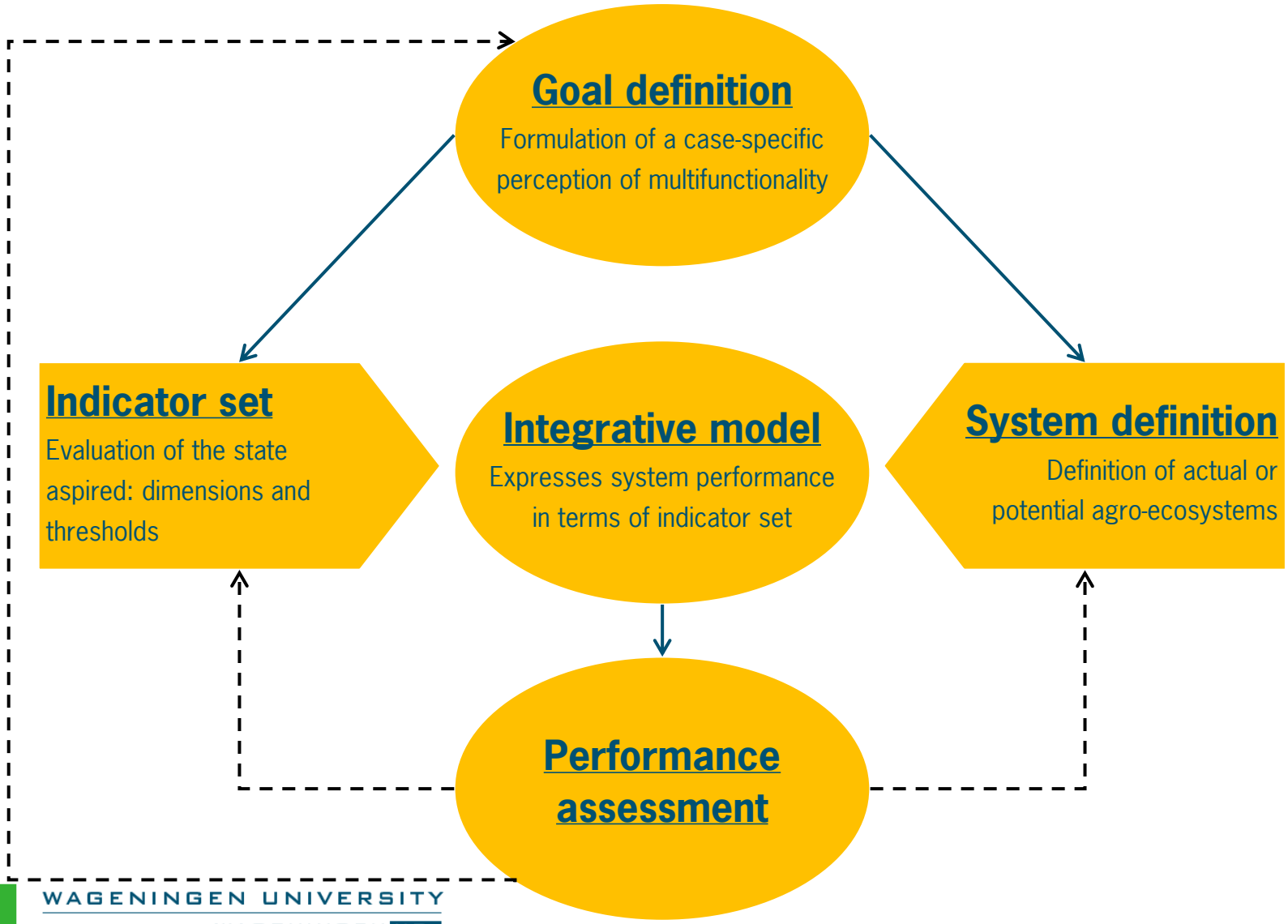
‘Research’ versus ‘Design’



Goewie, 1993

Design-oriented systems modelling



Multi-objective redesign of dairy landscapes

Landschapsbeheer Friesland

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Landscape case

grey = field borders
green = existing hedgerows
red = planned new hedgerows

500 m.

case study 870 ha

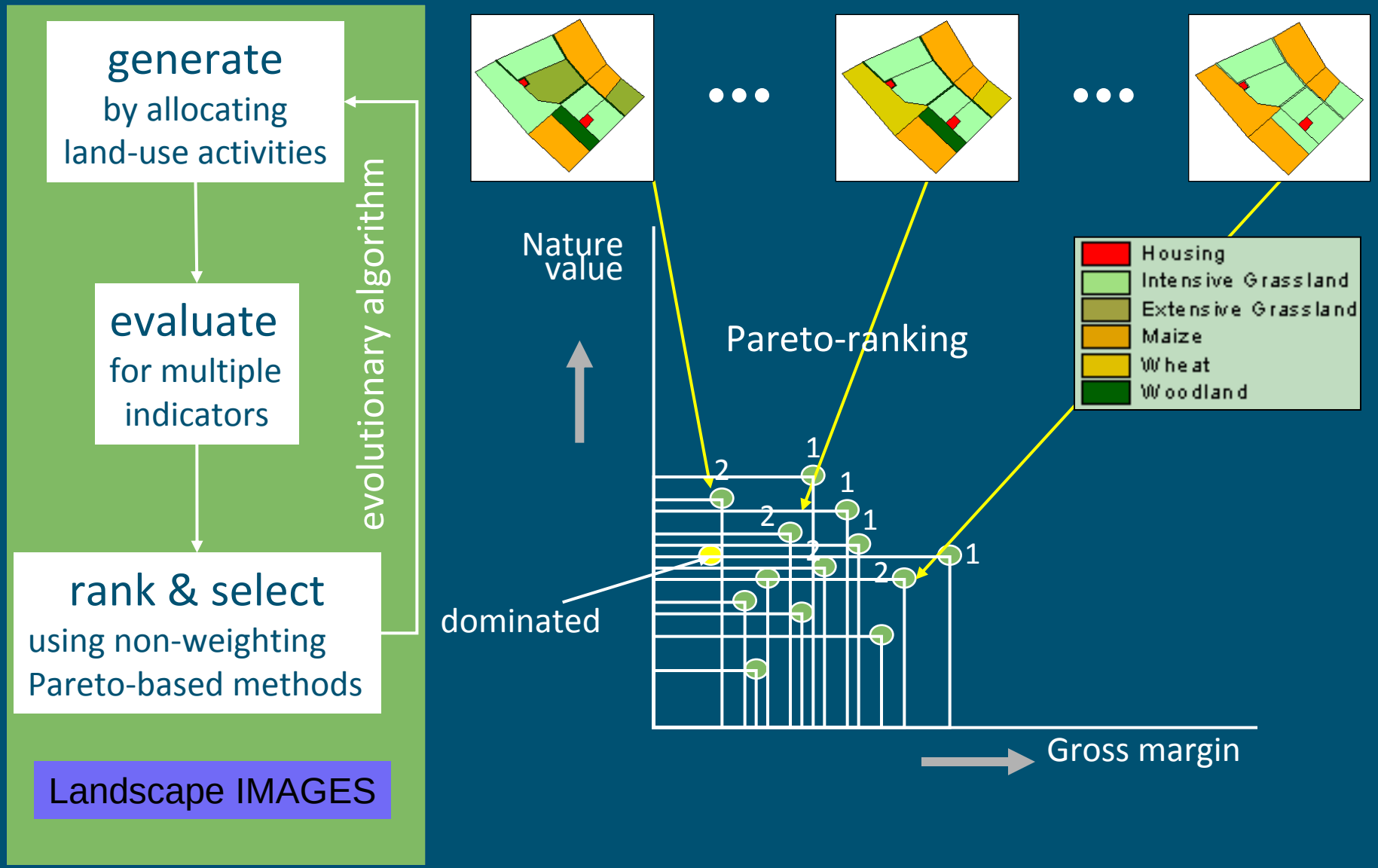
Indicator set (↑ maximize, ↓ minimize)

- Ecology
  - ↑ spatial cohesion
  - ↑ local species diversity
- Landscape quality
  - ↑ variation in sight lines
  - ↓ 'porosity' (road to road view)
  - ↑ length/width ratio hedges
- Implementation costs
  - ↓ addition of new hedges
  - ↓ removal of existing hedgerows
  - ↓ total length of hedgerows

- Farm economics
  - ↑ gross margin, incl. AES subsidies
- Environmental impact
  - ↓ nitrogen surplus

Groot et al., 2007; AGEE
Groot et al., 2010; EJA

System model: Landscape IMAGES



System model: Landscape IMAGES

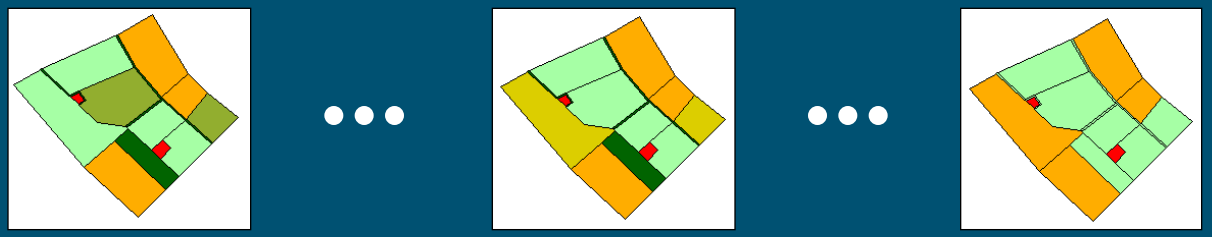
generate
by allocating
land-use activities

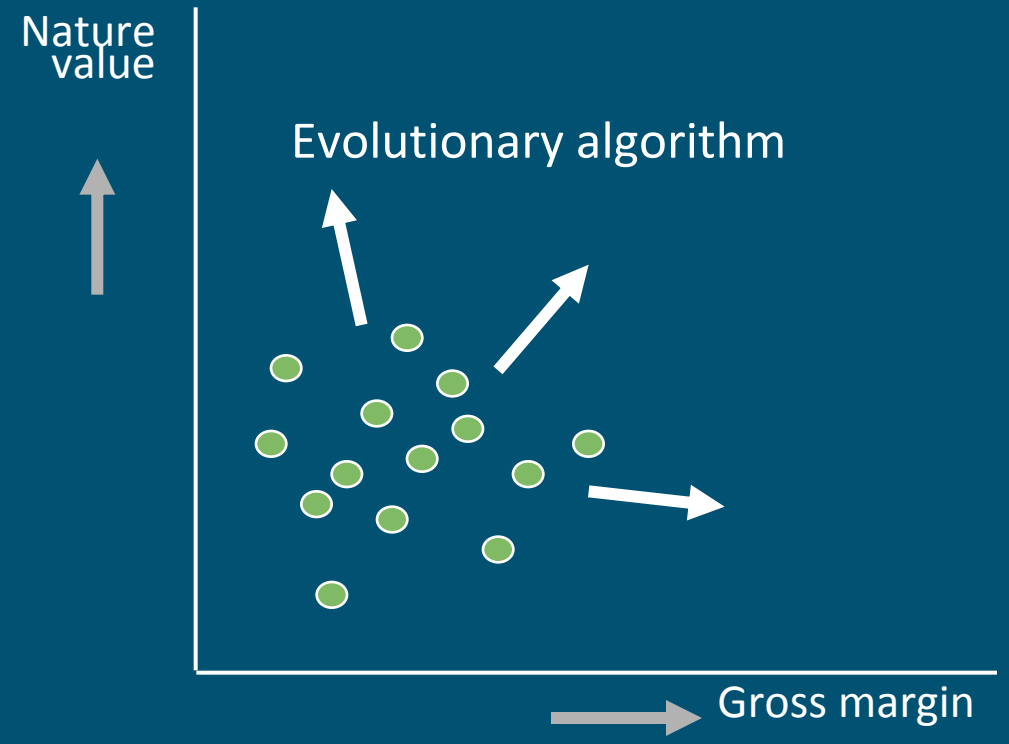
evaluate
for multiple
indicators

rank & select
using non-weighting
Pareto-based methods

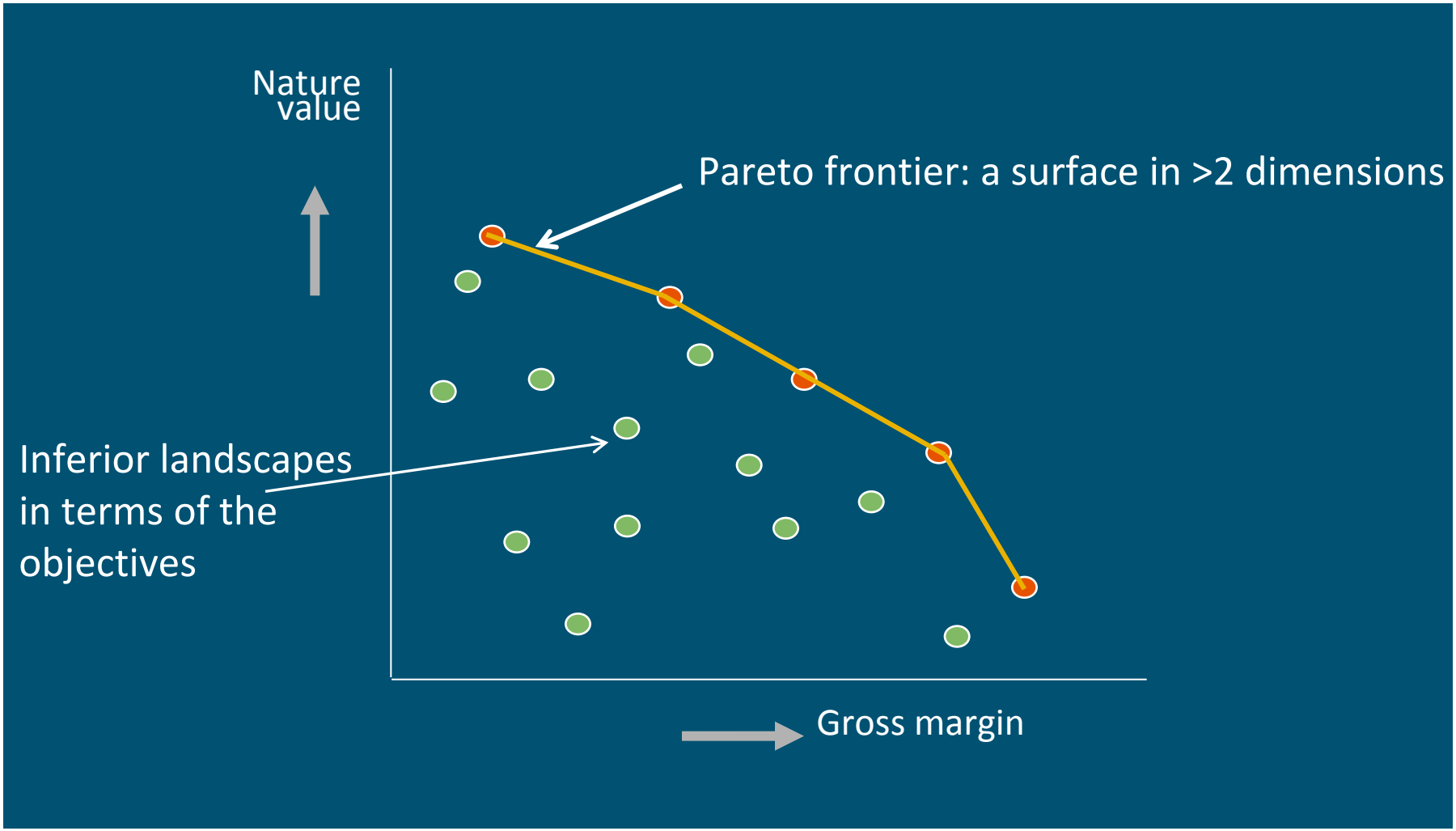
evolutionary algorithm

Landscape IMAGES

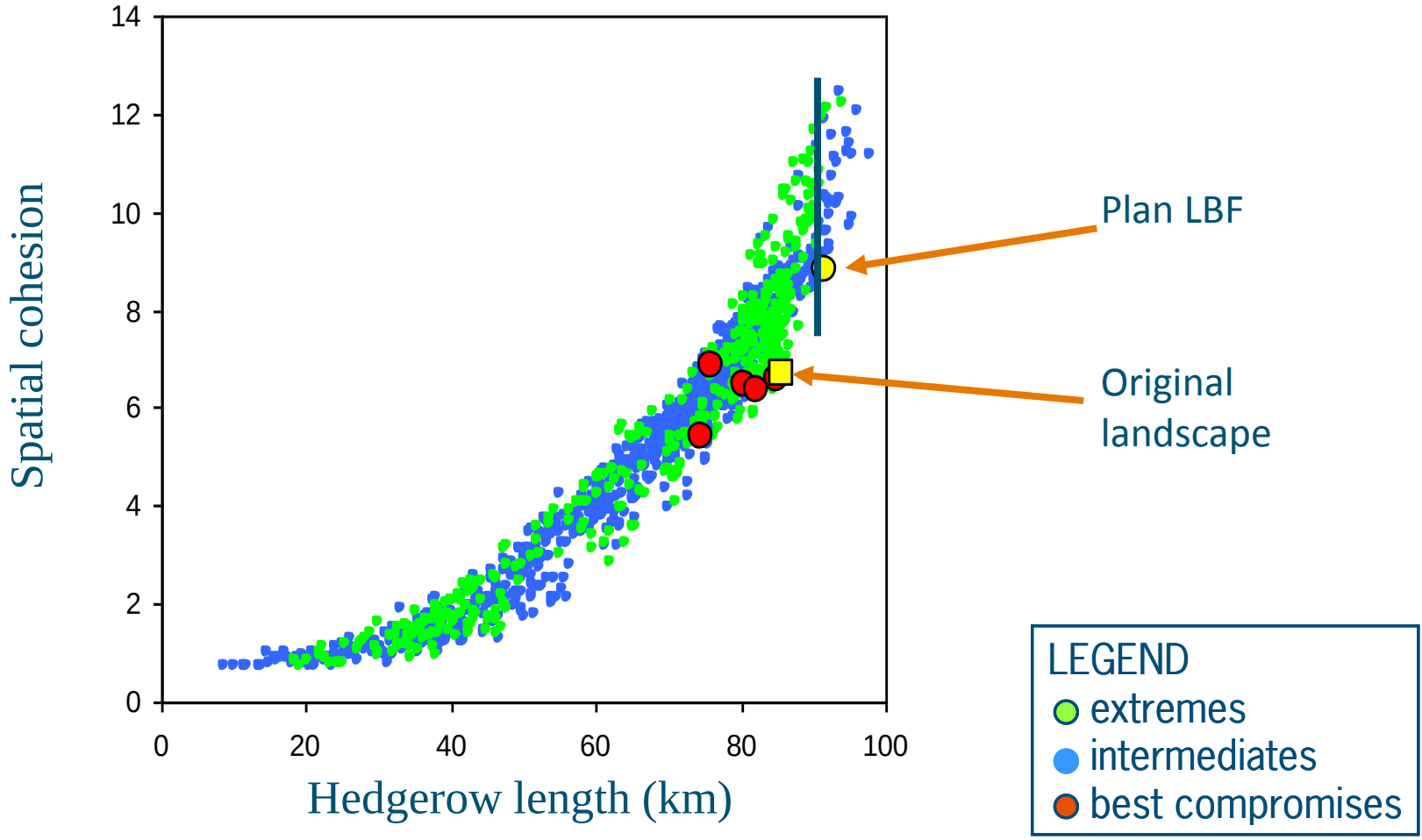




Result of procedure: trade-off frontier

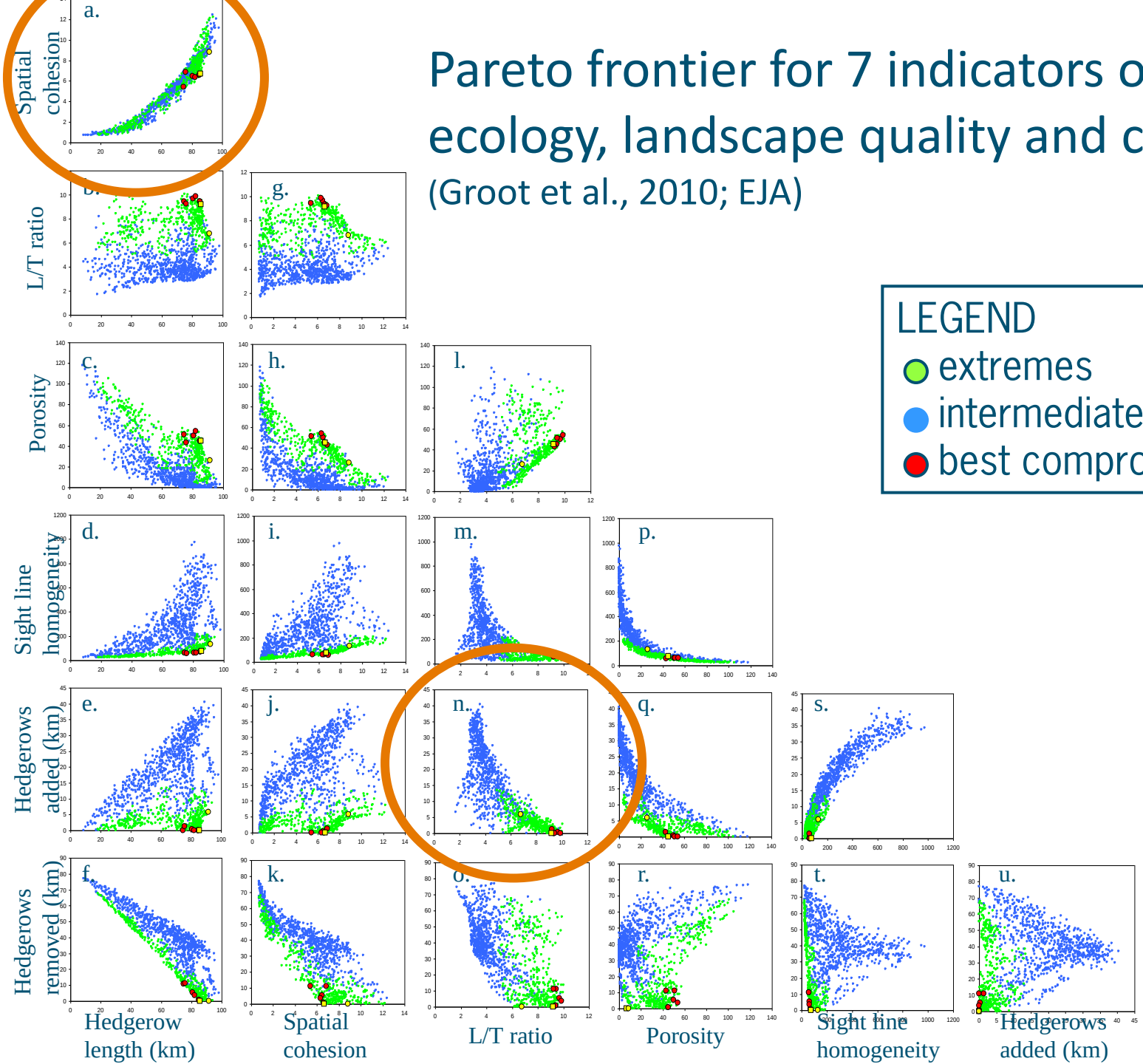


Calculated trade-offs and reality



Pareto frontier for 7 indicators of ecology, landscape quality and cost

(Groot et al., 2010; EJA)

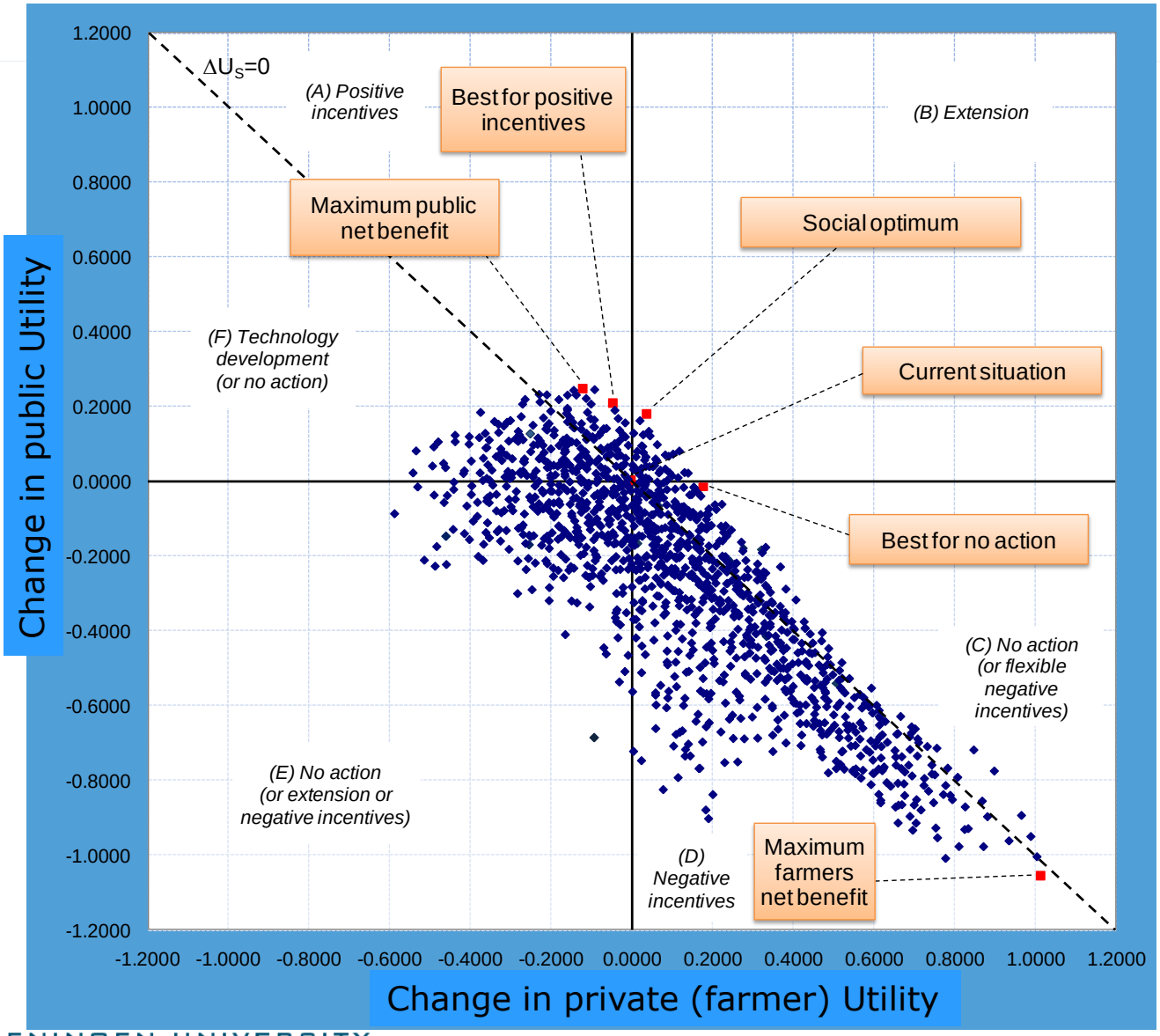


LEGEND

- extremes
- intermediates
- best compromises

grey = field borders
green = existing hedgerows
red = planned new hedgerows

From indicators to societal preferences



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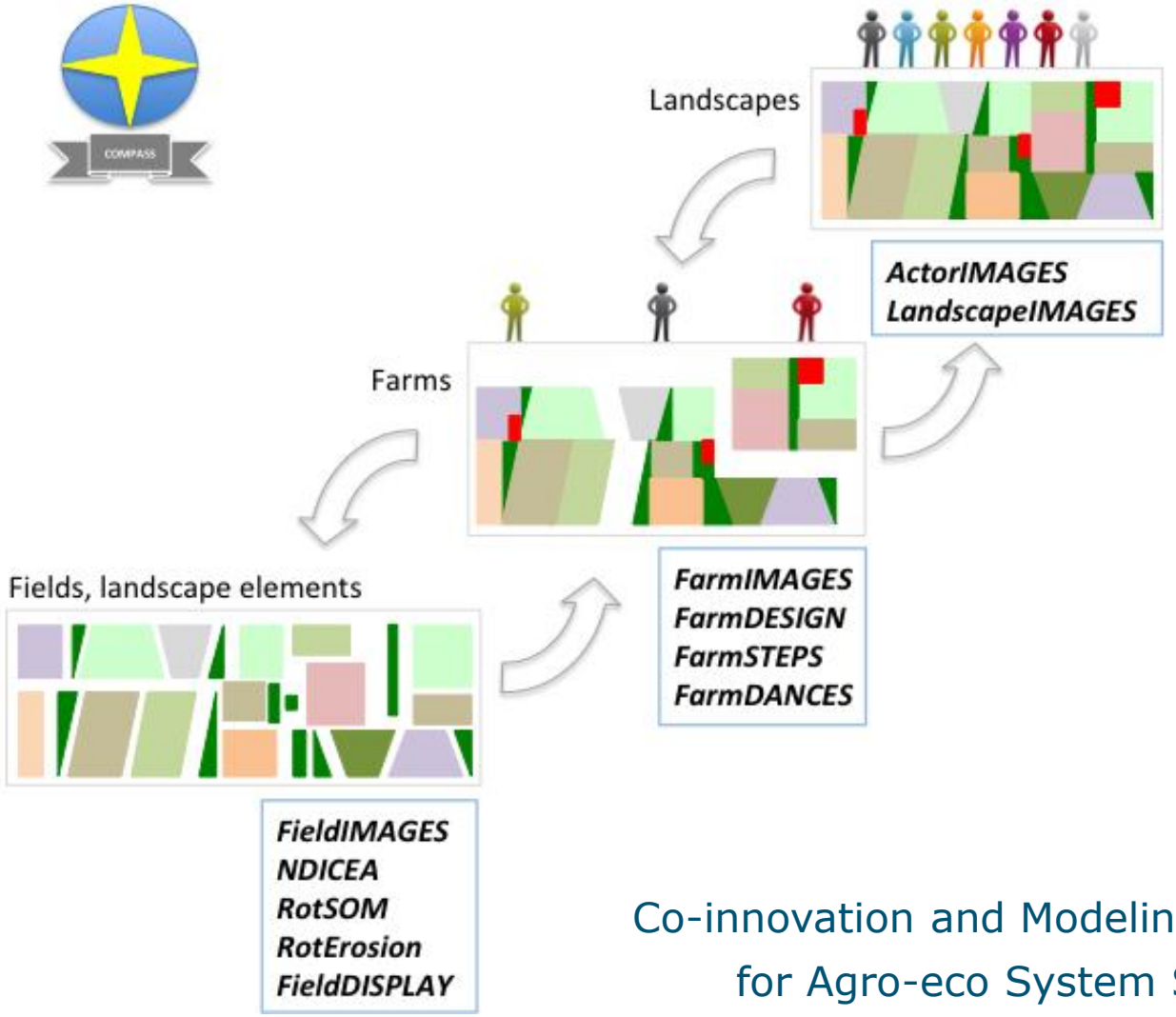
Parra et al., 2009; Land Use Pol.

Modeling: COMPASS



Co-innovation and Modeling Platform for Agro-eco System Simulation

Rounding up

- Producing differently requires system approaches
- Different research perspectives are possible and needed:
  - Functional farm typologies: alternate states hypothesis provides new research direction
  - Design-oriented modelling: new way to interface research and innovation
- New options for combining disciplines: e.g. landscape ecology, rural sociology, landscape architecture
- New directions for the disciplines : robustness of animals, management of species-diverse pastures, etc.
- From complexity as a liability to complexity as an asset: in search of useful patterns of agro-diverse systems

Thank you for your attention

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