

# Complexity and Uncertainty: Challenges for Sustainability Science

**Since 2003  
Course SD-I, but  
no UU-support for  
SD-I research**

*or: how to wake up Copernicus*

**Bert de Vries**

**2004: [Zelf]evaluatie: Cie  
Hafkamp emphasizes  
integration**

**2003: Topic 6:  
Integration: models,  
methods, and uncertainty**

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**Considerable interest (and resources) at  
MNP for genuine collaboration**

# Has sustainability science any legitimacy? If so, what is a meaningful definition and focus?

Founding statements:

- Sustainability Science is about understanding the dynamics of evolving, coupled **social-ecological systems** (SES)
- Sustainability Science is **problem-driven**: manage complex coupled social-ecological systems (SES) in order to have them deliver what people value

Sustainability Science is **transdisciplinary**: solutions to the problems have to acknowledge that the world is/becomes more integrated, more complex, more uncertain

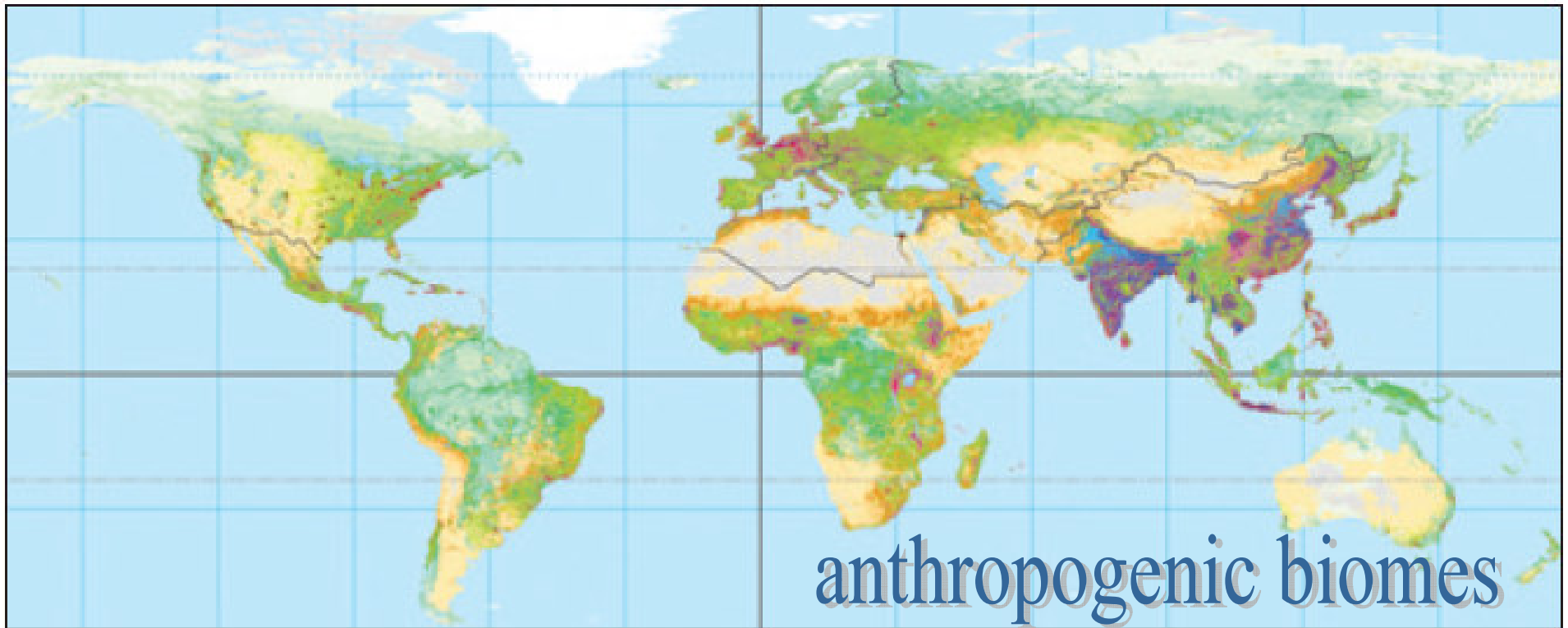
In particular, the focus of Sustainability Science is on the **interactions** between resource system (earth/life sciences), its users and the governance system (social sciences)

*(Kates et al. 2001, Clark and Dickson 2003, Perrings 2007...)*

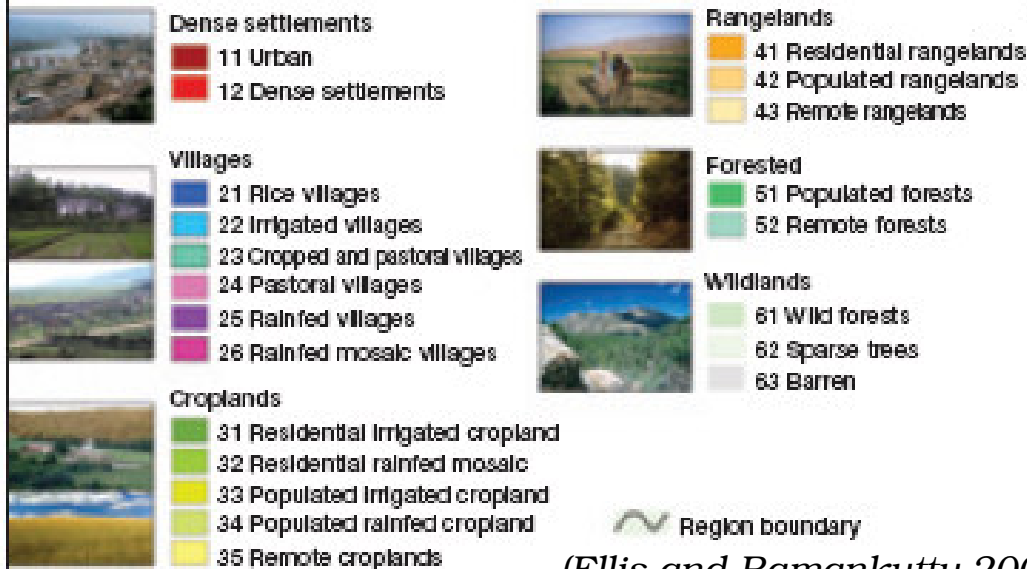
A shared vision should contain a framework on:

1. Social-ecological systems (SES): anthropogenic biomes (also called human-environment systems) and archetypical syndromes
2. Complex Systems Science (CSS): due to heterogeneity and interactions, SES are best considered as Complex Adaptive Systems (CAS)
3. Value pluralism and interpretative pluralism: consequence of [recognition of] [local] heterogeneity
4. Uncertainty: inherent in managing SES and, more specifically, Common pool Resources (CPR)
5. Integration: transdisciplinary as a consequence of complexity, pluralism and uncertainty, partly crystallising in [formal] models

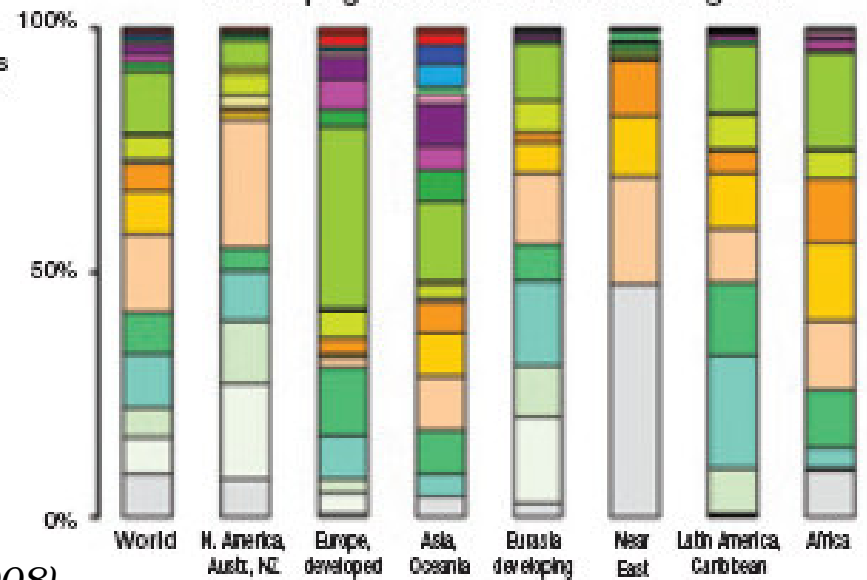
*This means: system behaviour over time is non-linear, cross-scale in time and space, multiple causes, evolutionary in character...*



**Anthropogenic biomes: legend**



**Anthropogenic biomes: % world regions**



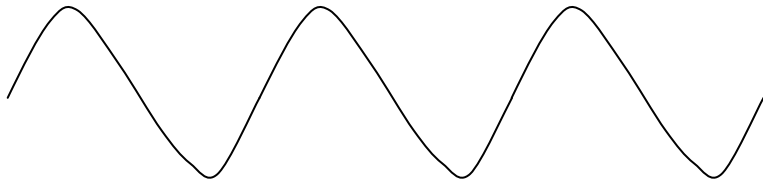
(Ellis and Ramankutty 2008)

## 2. CSS

Complexity: in the eye of the beholder?

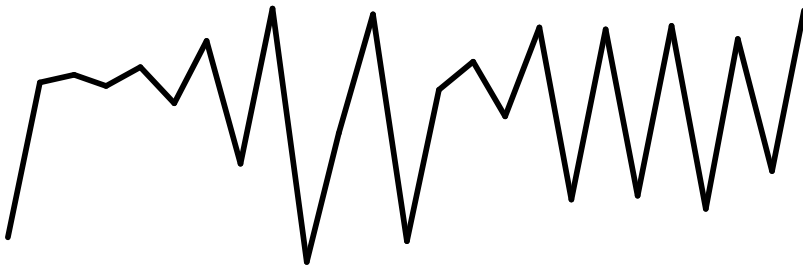


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Algorithmic simplicity & complexity



AHVIIRBTLDOEBYDDROHN

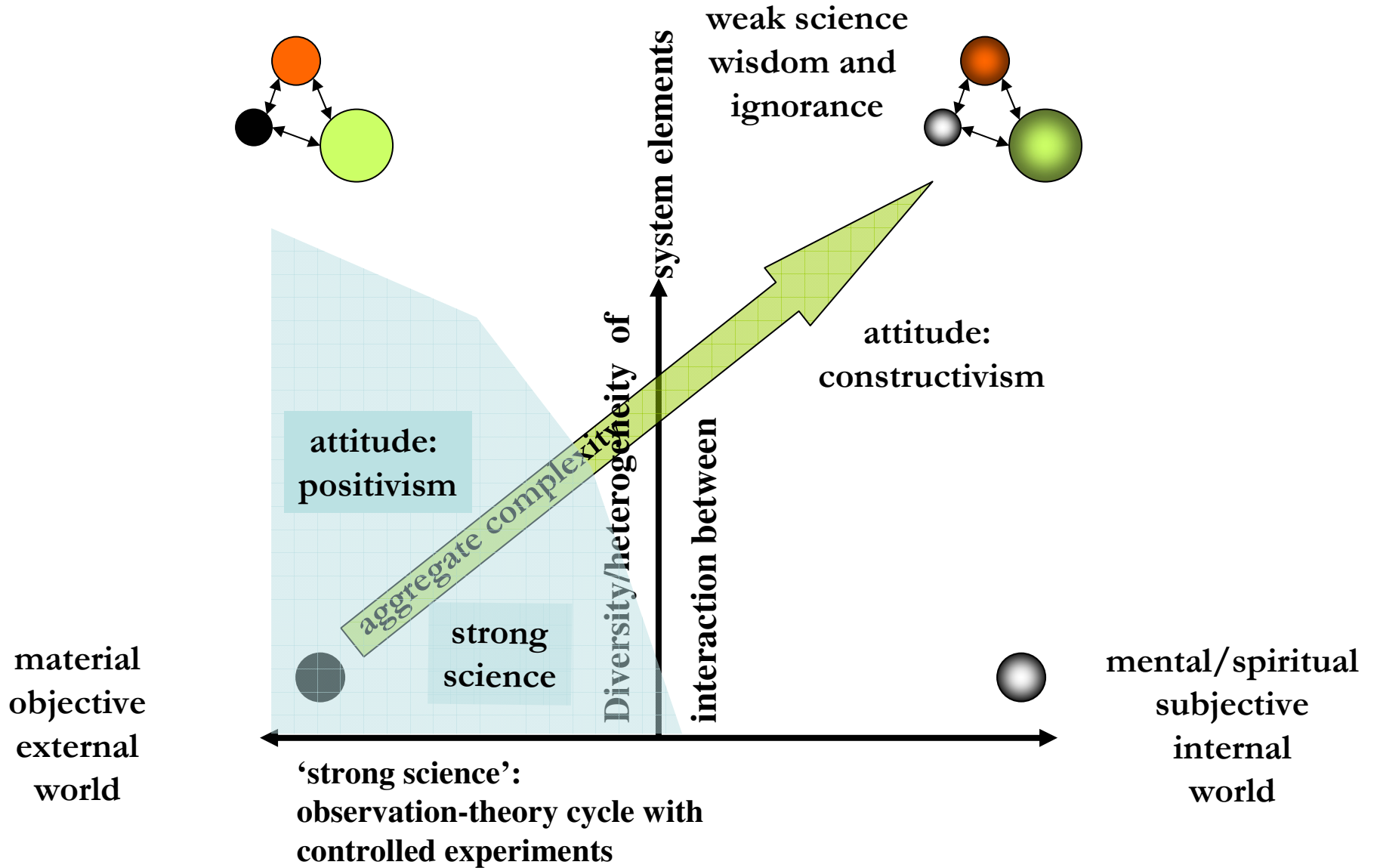
Chaos from the simple  
logistic map

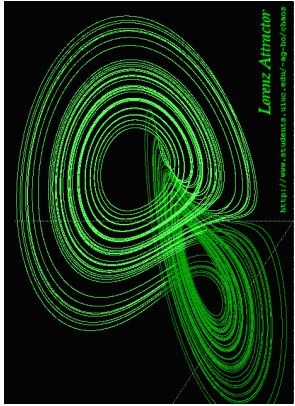
$$X_{n+1} = X_n \left[ 1 + \alpha \left( 1 - \frac{X_n}{K} \right) \right]$$



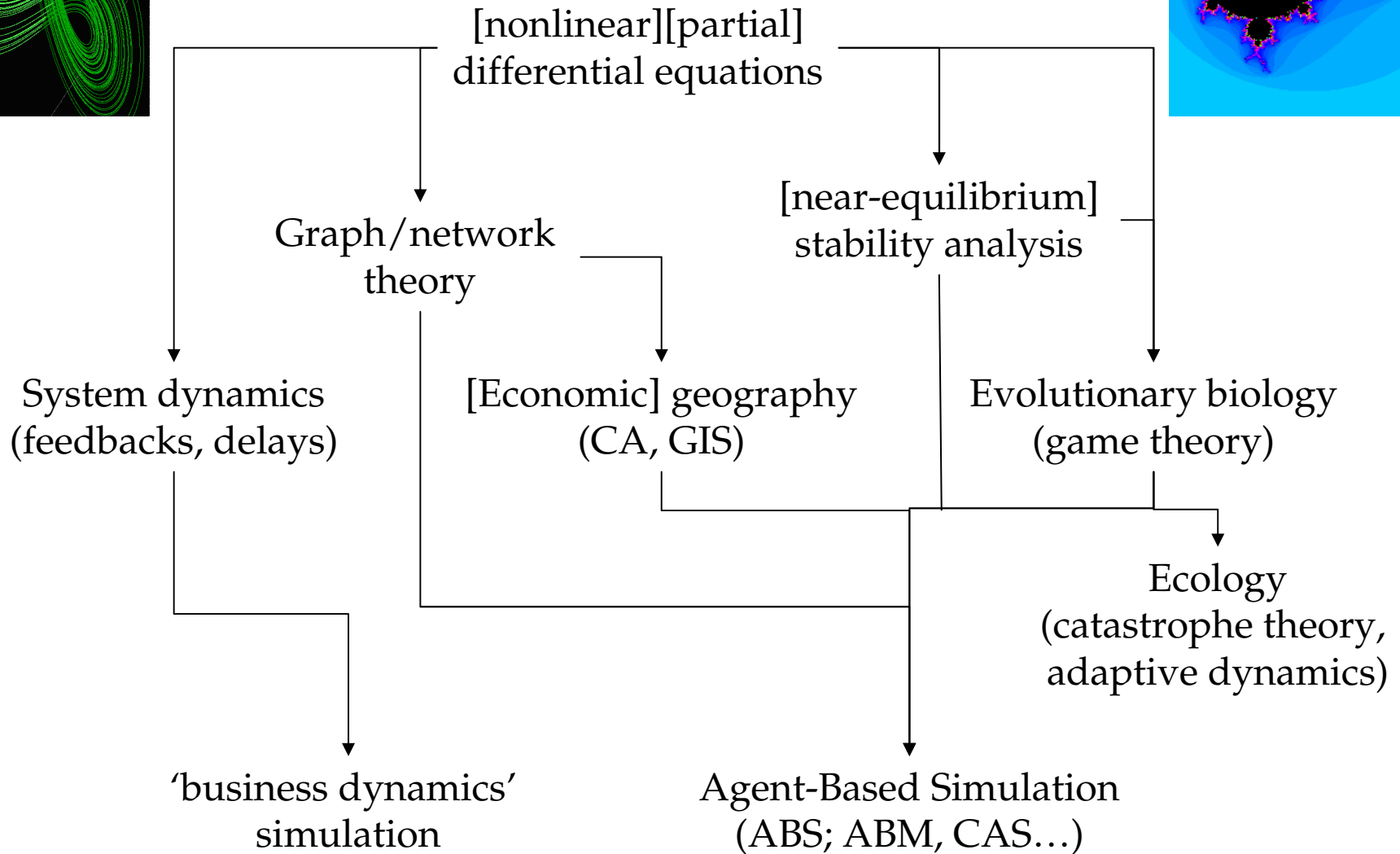
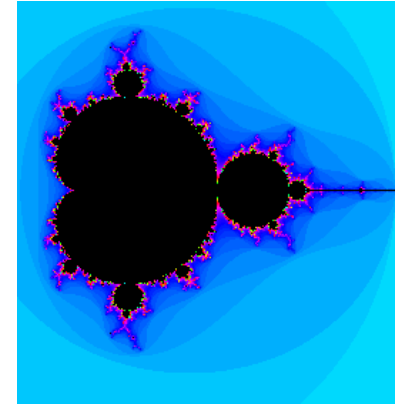
L'AMOUR GUÉRITTOU

# Complexity: an epistemological bridge?

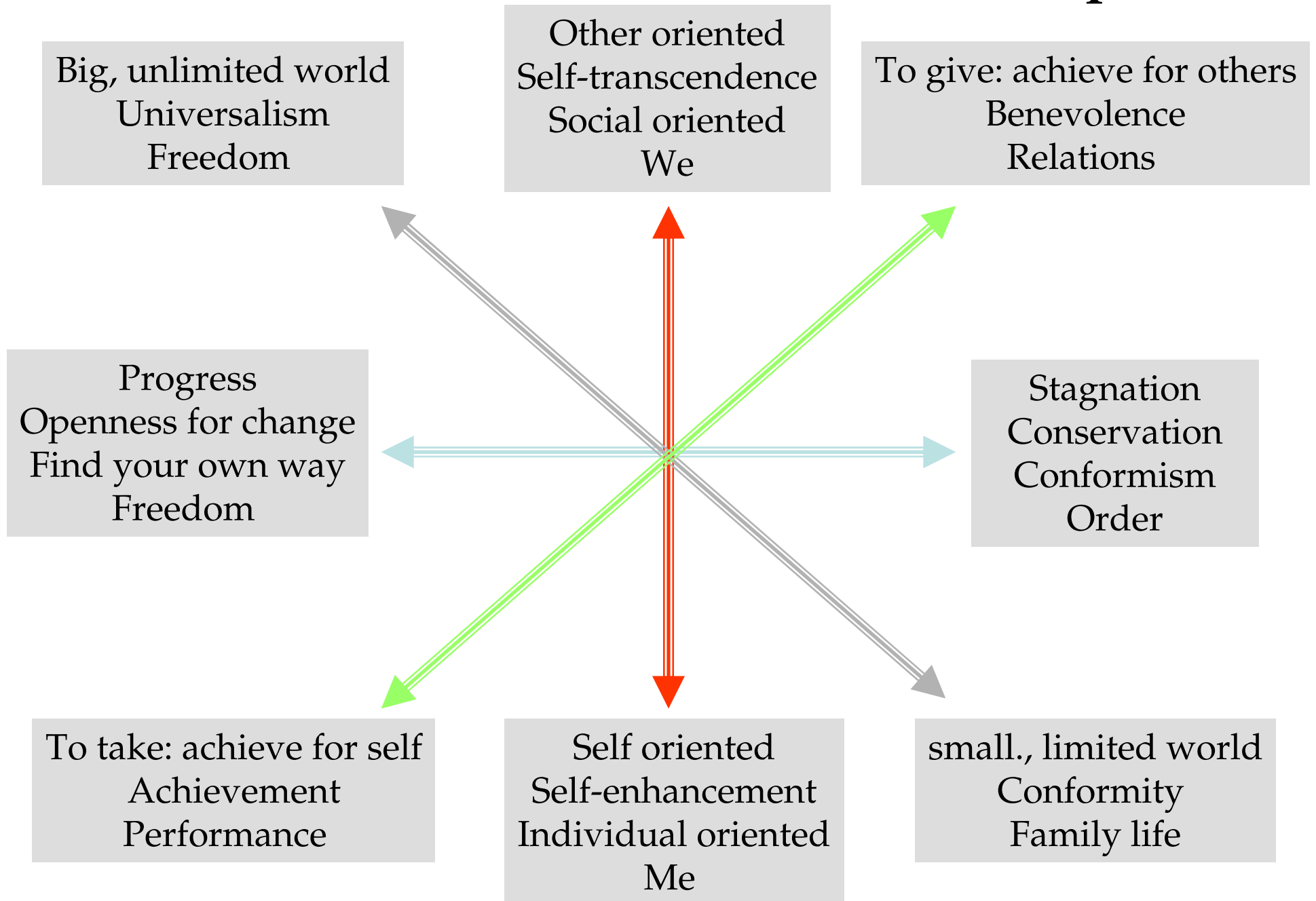




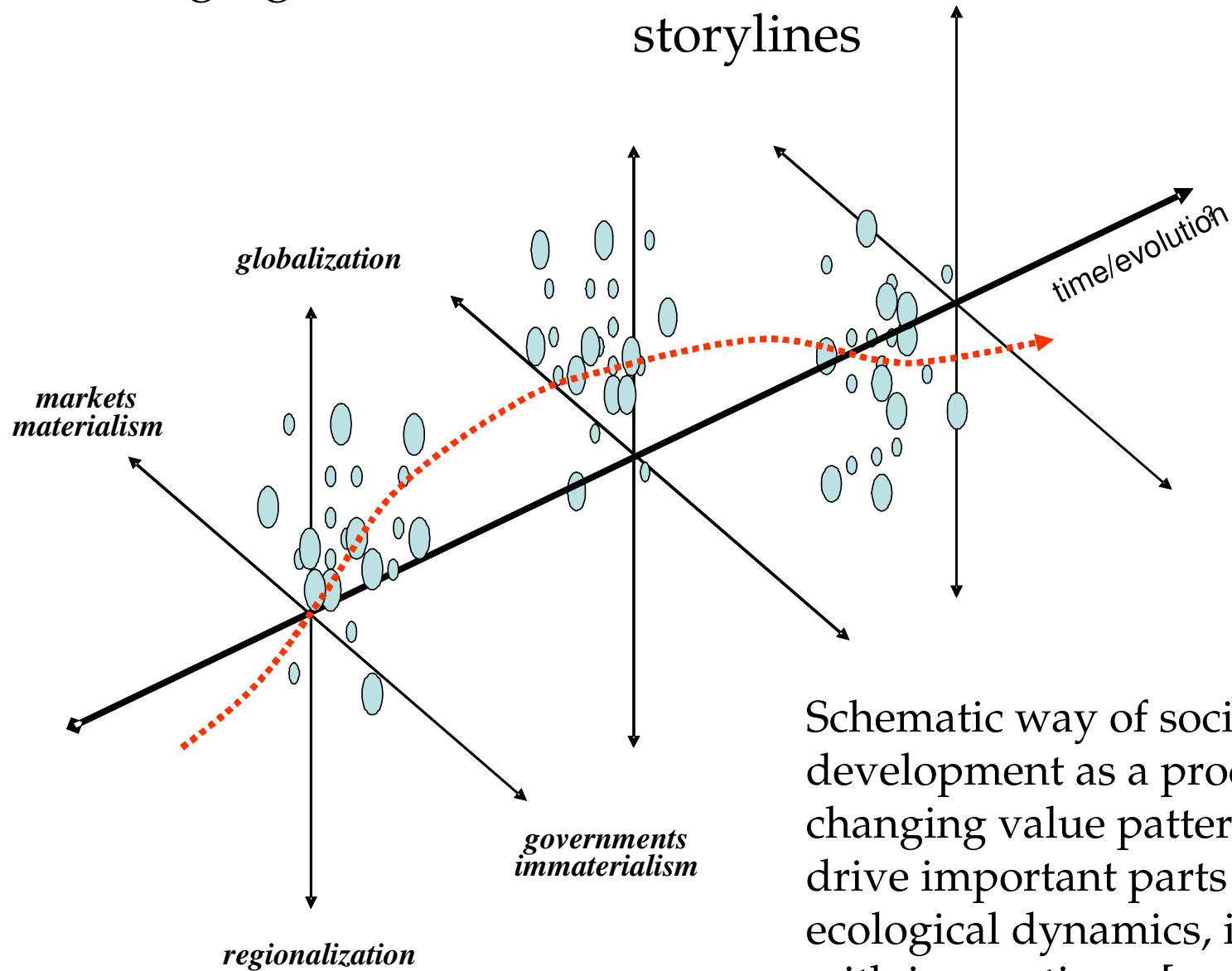
# An incomplete 'complex systems science tools' genealogy



### 3. Pluralism in values and mental maps



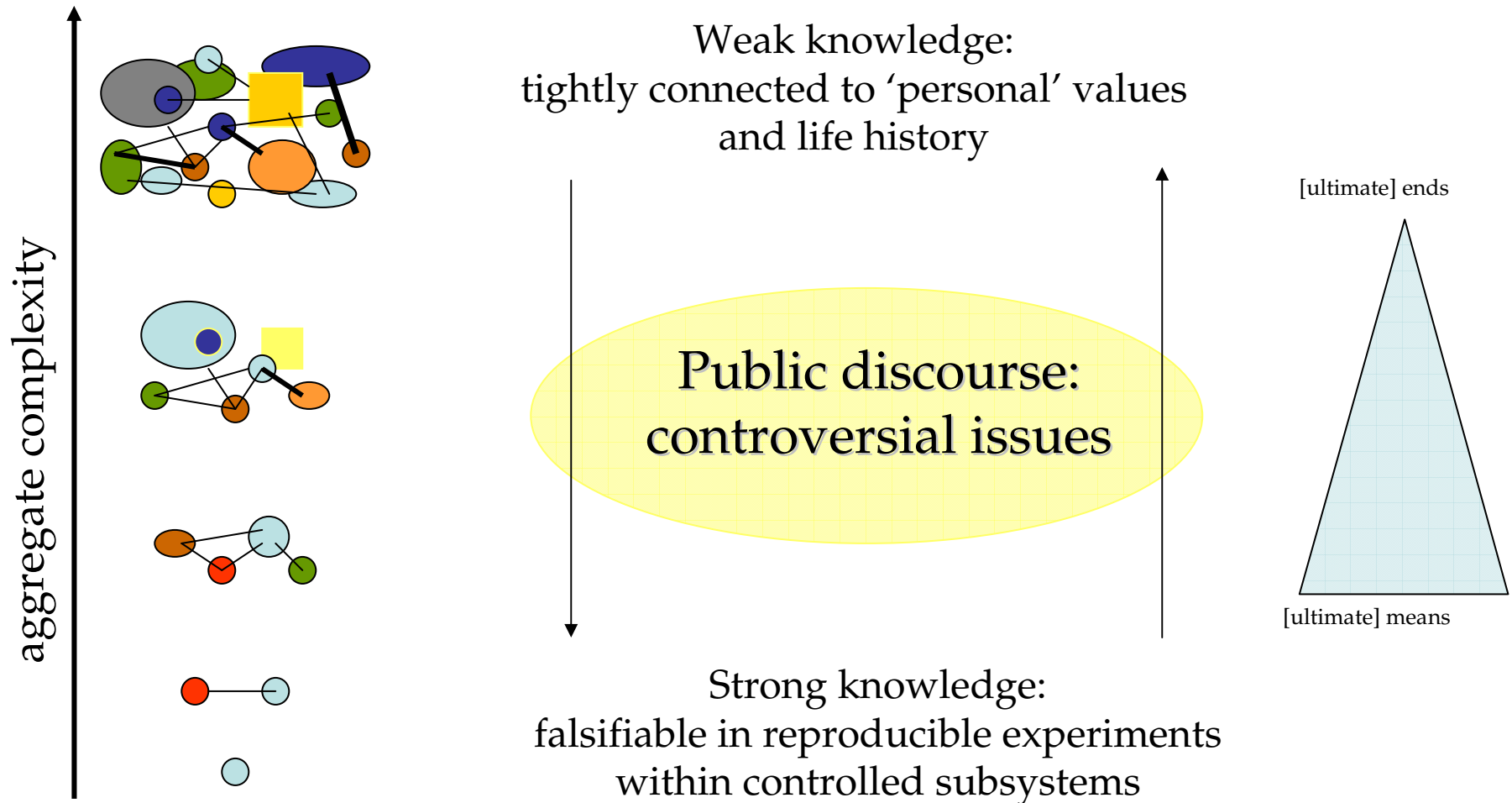
# Changing [individual] worldviews as elements in scenario storylines



Schematic way of societal development as a process of changing value patterns which drive important parts of the social-ecological dynamics, in interaction with innovations, [resource] conflicts...

# 4. Uncertainty

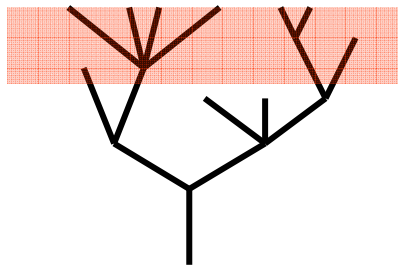
Complexity and uncertainty :  
the public discourse between strong and weak knowledge



# 5. [Model-based] Integration

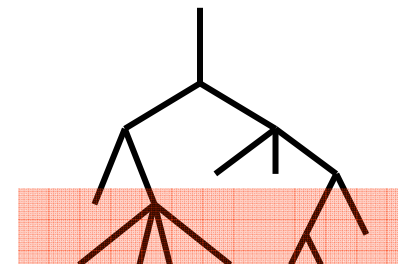
Scientific disciplines  
(fragmentation, view from below)

- Philosophy, ethics...
- Social science/anthropology
- Economic science
- Psychology
- Medical science
- Biology/ecology
- Geology
- Physics/chemistry

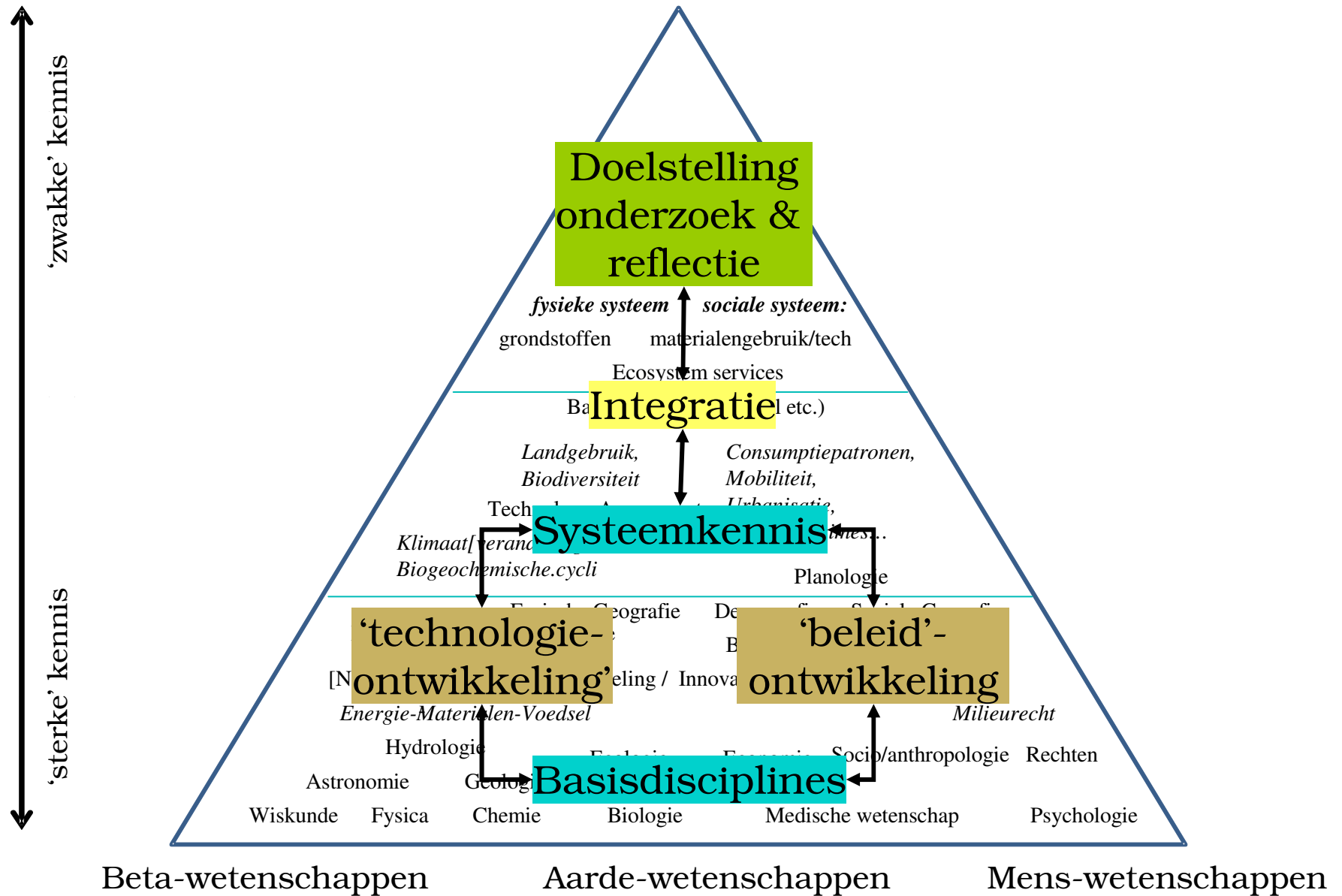


Sustainability science  
(decomposition, view from above)

- Conceptual partitioning
- Separating subsystems
- ‘sum is more than parts’
- Avoiding disciplinary myopia



# Integration and the organization of knowledge acquisition



# What does this mean for a research agenda?

Within the Copernicus Institute, the focus has to anchor in existing positions, in particular:

- Energy demand and supply systems
- Ecosystems and land use / biodiversity
- Innovation dynamics and management
- Governance in social-ecological systems

In this presentation I will briefly work out three directions for (future) research:

- a) Simulating the social-ecological dynamics in anthropogenic biomes
- b) Managing common pool resources, in casu: climate (but also: fisheries, forest...)
- c) LETSGO: decentralized energy in Nederland 2020

I indicate tentative ideas, possible concepts and theories from various disciplines, and relevant expertise.

*a) Simulating social-ecological systems:  
humans in the anthropogenic biomes*

# Research on complex ecosystem behaviour

## Catastrophic change in (lake) ecosystems change in slow variables

*Scheffer et al, 2001*

## Food web complexity and stability interaction patterns with weak links in long loops

*De Ruiter et al.2006*

## Micro-scale infiltration ↔ large-scale precipitation spatial patterns, regime change, theory vs. measurements

*Dekker, Rietkerk en Bierkens 2006.*

# Evolutionary biology: adaptation dynamics

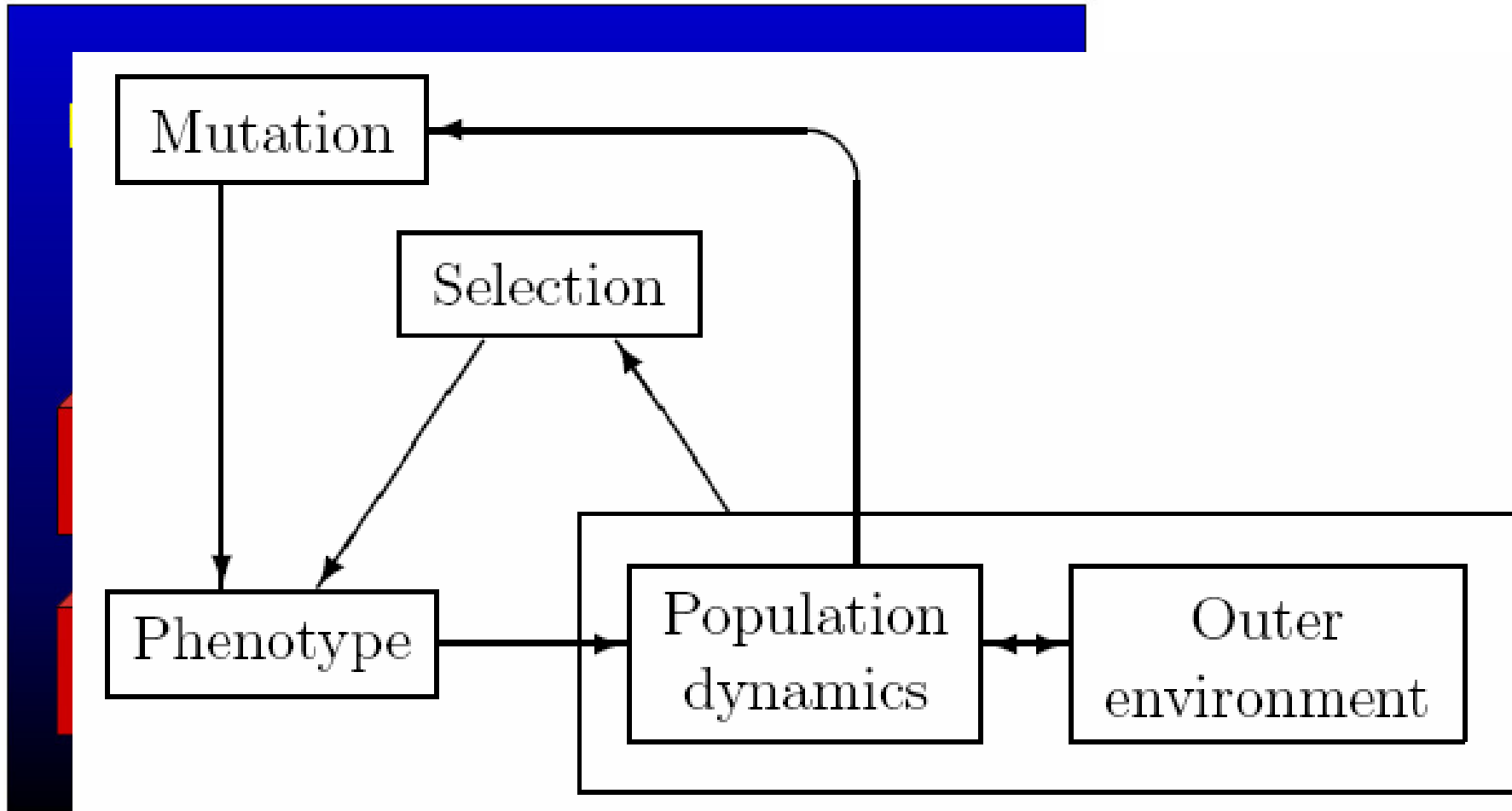


FIG. I.2 – *Modelling principle of adaptive dynamics.*

(Dieckmann 2002, Champagnat 2004)

*Integrating climate proxies and the human dimension in the past in a novel modeling framework*

## **Holocene climate fluctuations and their potential impact on cultural development**



Universiteit Utrecht



**cultural development**

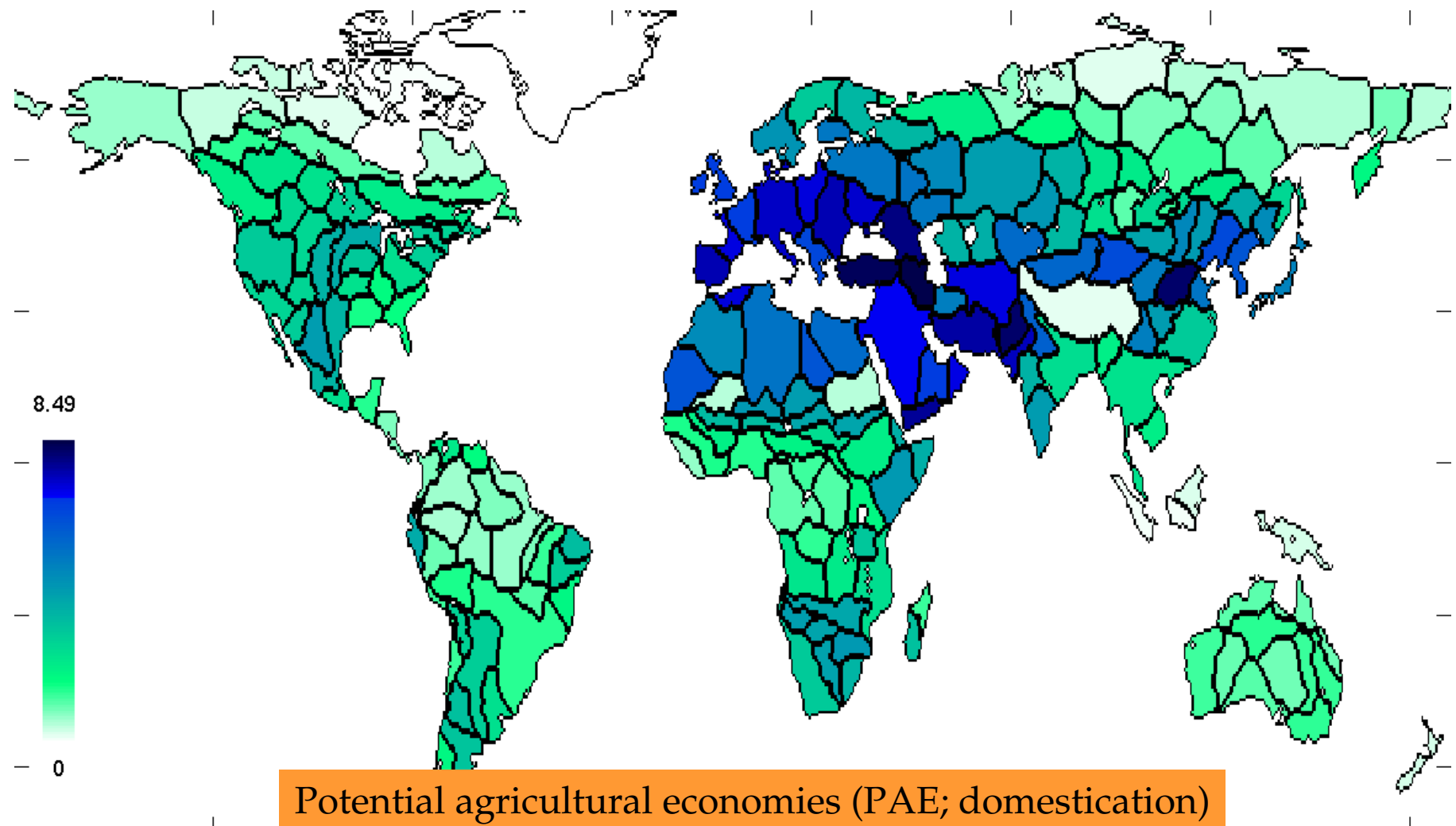


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Carl-von-Ossietzky Universität Oldenburg, Germany

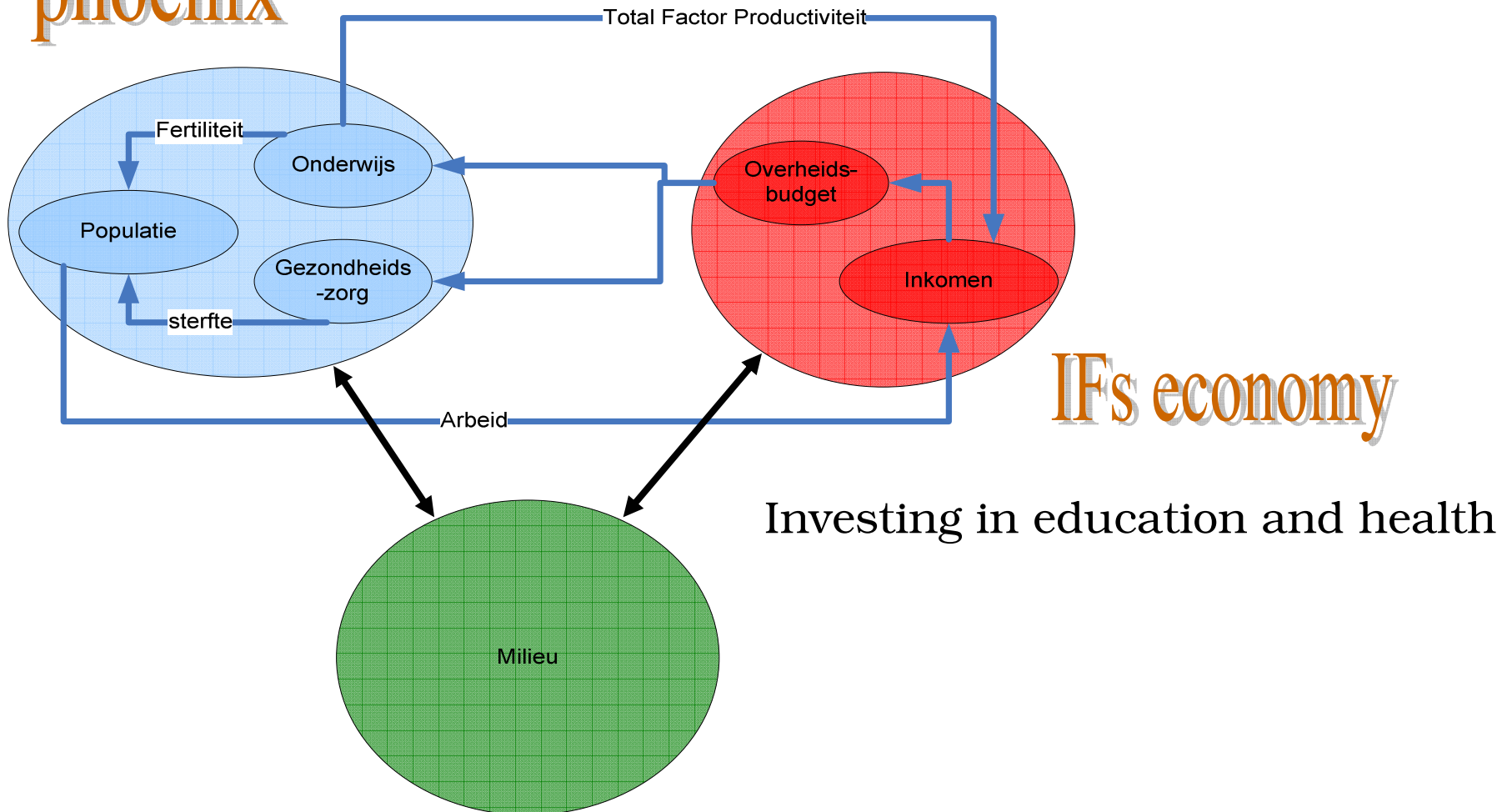


# Global Integrated Sustainability Model (GISMO)

an integrated framework for Global Change research

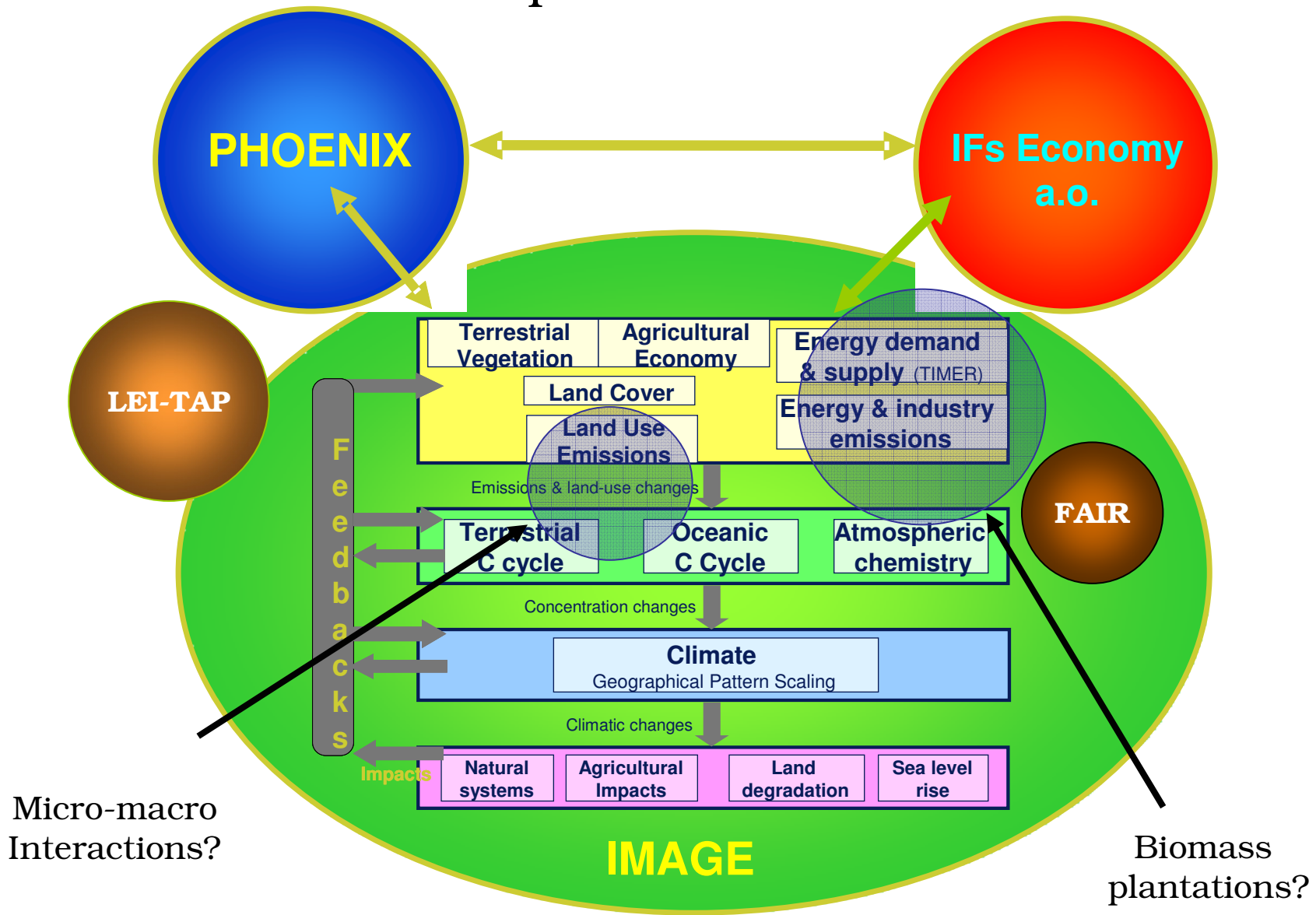
Developed at/ linked to  
IMAGE/TIMER/FAIR framework at MNP

phoenix



Investing in education and health

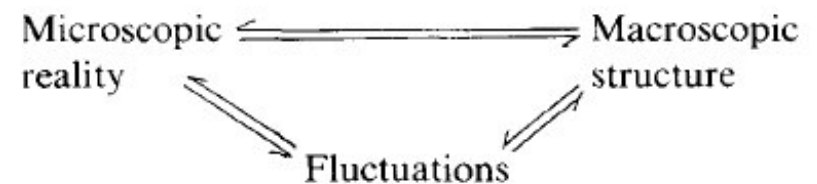
# Can a GISMO framework be an integrating platform at Copernicus Institute?



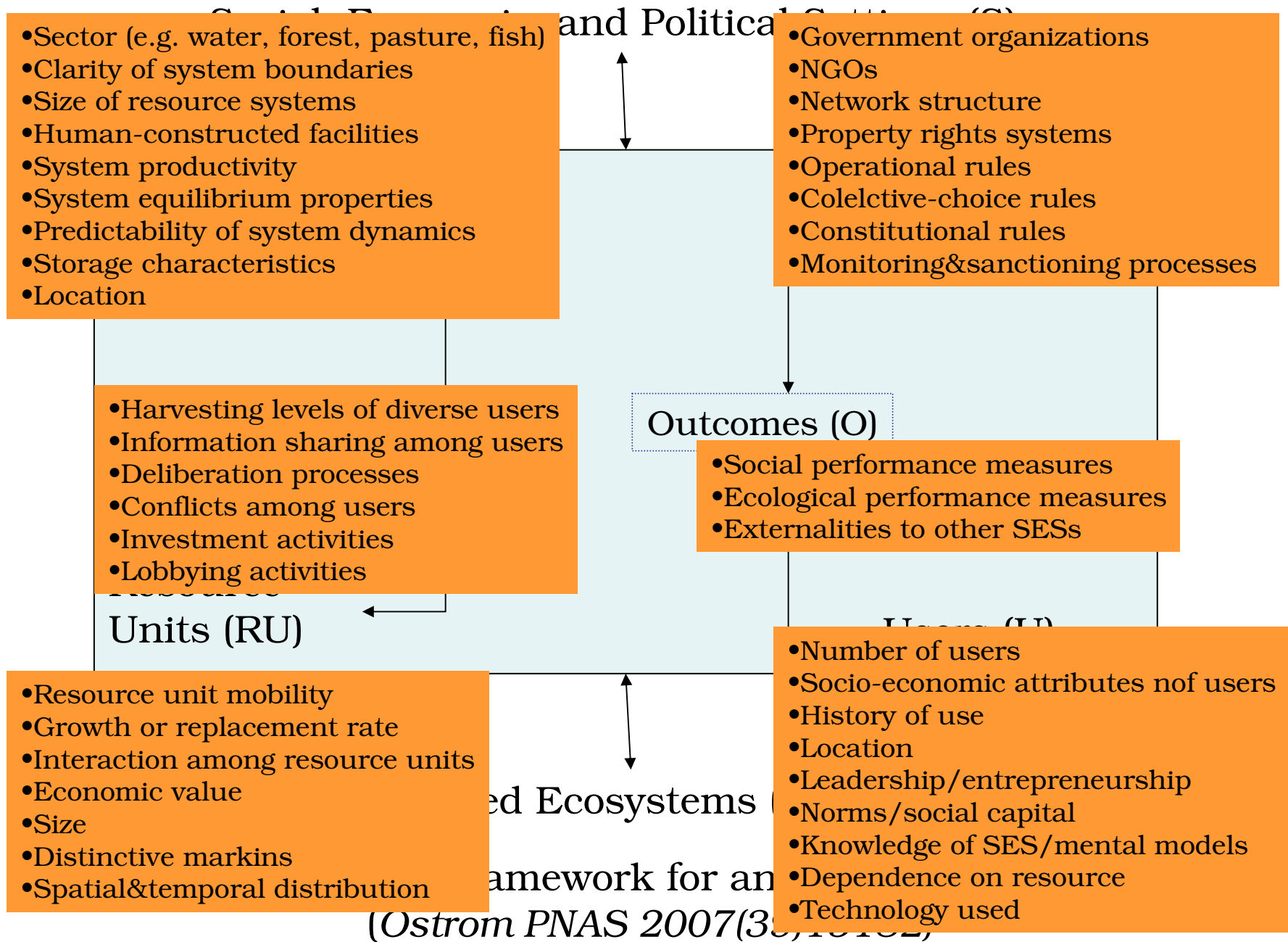
## b) Common Pool Resource (CPR) management

*“The Tragedy of the Commons” and ways out of it*

*Onder ‘global commons’ worden die natuurlijke hulpbronnen en ecosystemen verstaan, waarvan zowel het nut voor de mens als de benodigde beheersinspanning de landsgrenzen (verre) overstijgen. **De atmosfeer en de oceanen** zijn bekende voorbeelden van global commons. (VROMRaad 2003)*



There are two extremes - '**stochasts**' and '**cartesians**'. But, as we have seen for our fishing example **both behaviours are necessary** to the system. We must avoid both the total *dispersion* of randomness, and the complete enslavement by *information*. It is however the discoveries made by these risk taking 'stochasts' which nourish society in the long run, and allow its expansion and greater sustenance, but of course the efficient and directed behaviour of the 'cartesians' constitutes the *consensus*, and gives stability and form to society (Allen and McGlade 1987:166)

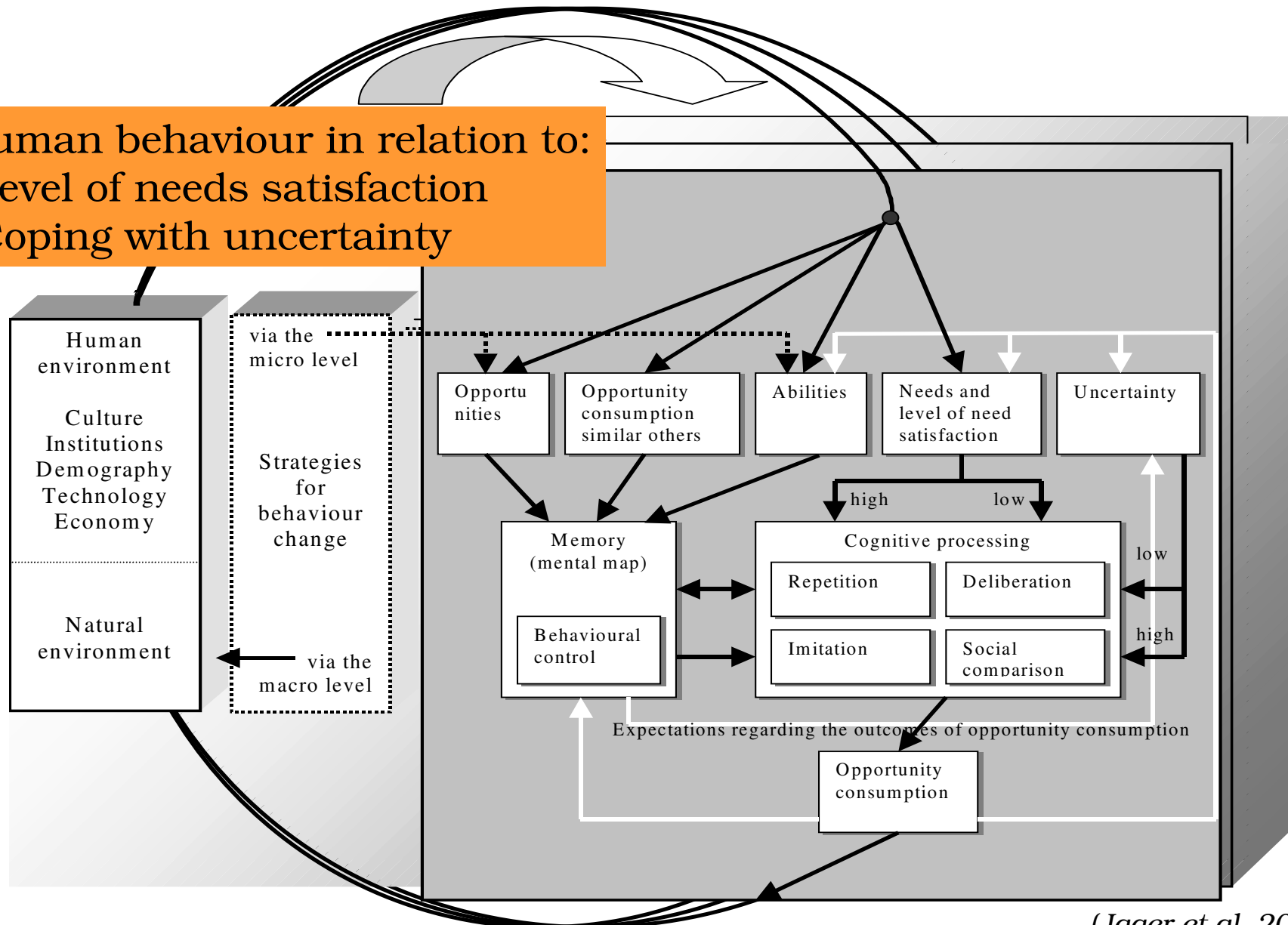


# A set-up for multi-agent simulation (MAS)

## insights from environmental psychology

Human behaviour in relation to:

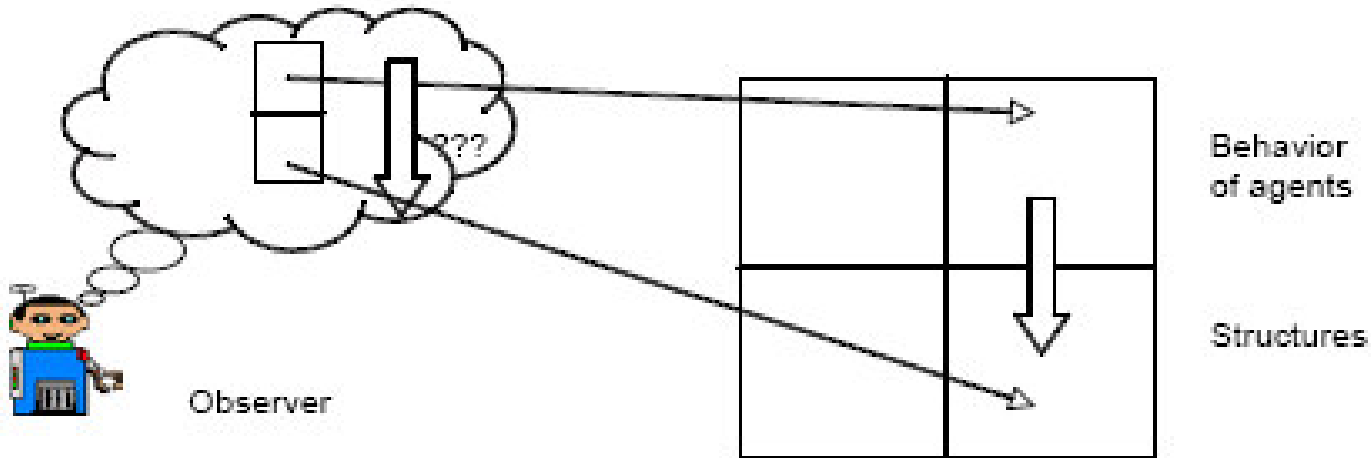
- Level of needs satisfaction
- Coping with uncertainty



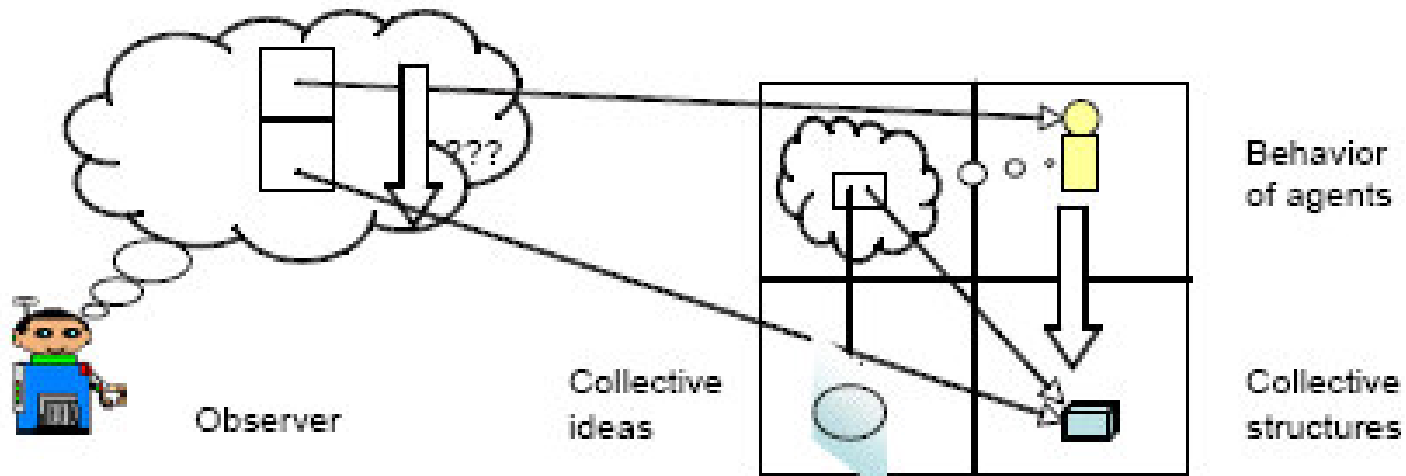
(Jager et al. 2000)

# Complexity: emergence and immergence

**Figure 5: Weak emergence (emergence of structure)**  
seen from an (external) observer point of view

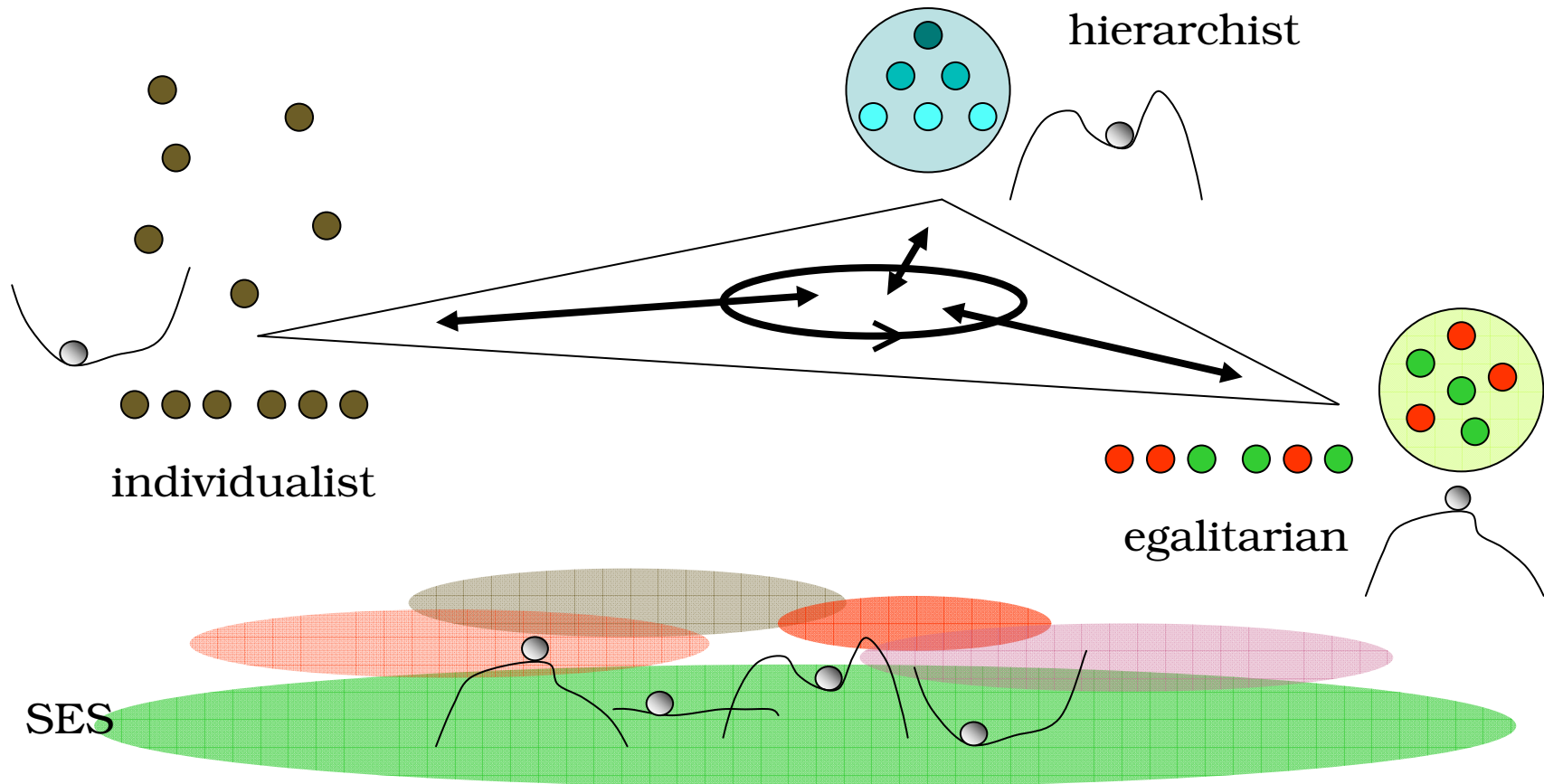


**Figure 8: M-Strong emergence (emergence of structure)**  
seen from both an agent and an (external) observer point of view



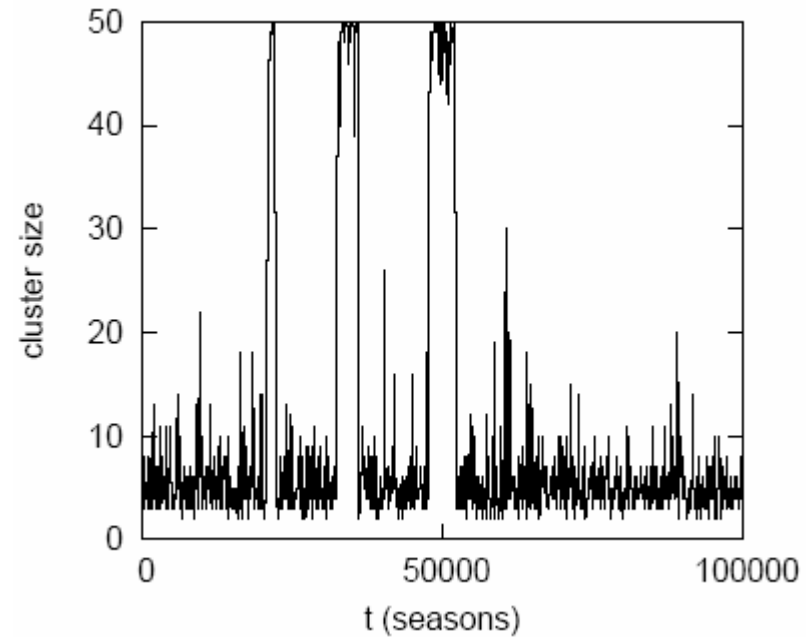
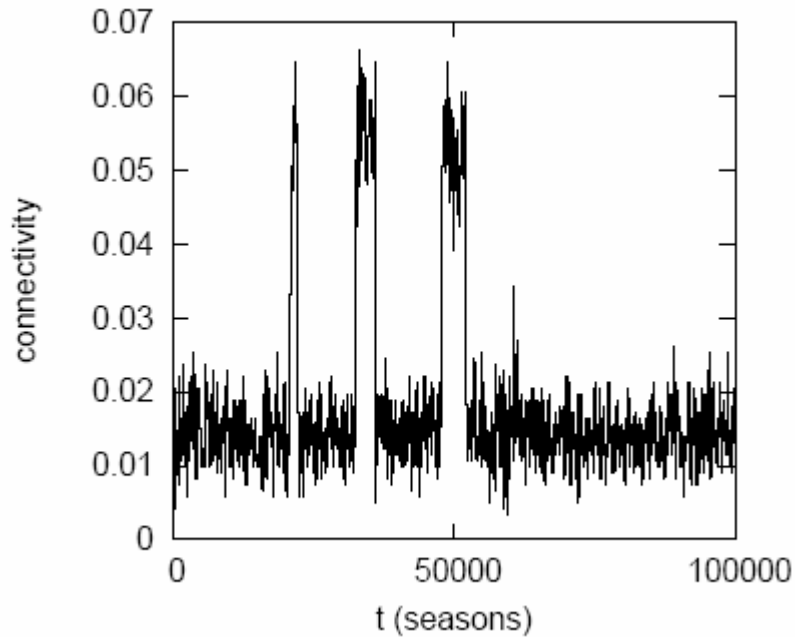
# Understanding social dynamics

Interaction between worldviews triggered by events

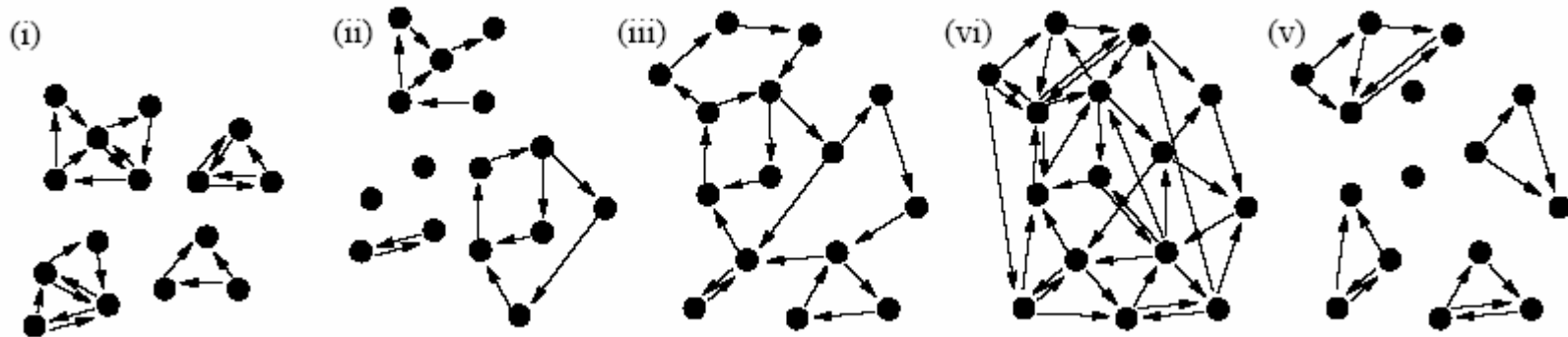


Example: the Battle of Perspectives (Janssen and De Vries 1999)

# Dynamic network formation in a cost-benefit setting in certain parameter domains endogenous cycles



## Typical Growth-Decline Cycle

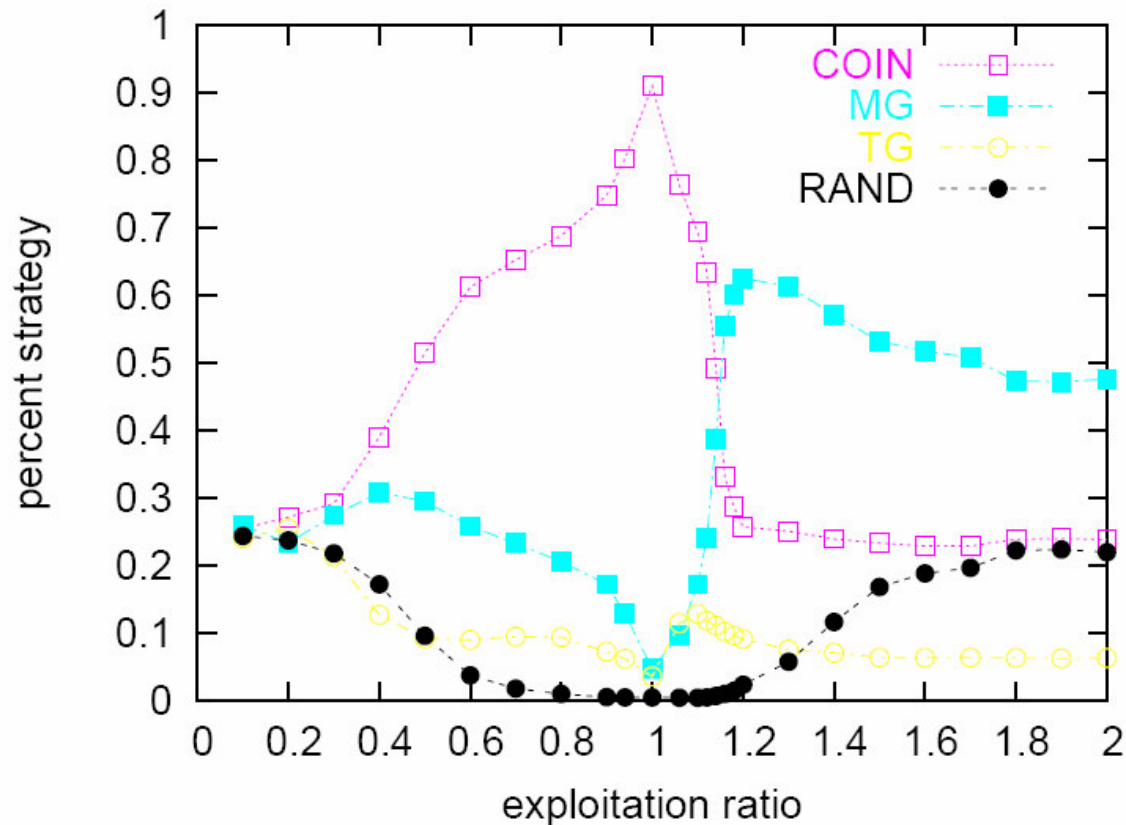


# Exploiting a renewable resource: fisheries

the 'optimal' i.e. most effective strategy depends on exploitation depth

Dependence on the exploitation ratio

$$r = \frac{NC_{\max}}{\sum_i Z_i}$$



COIN COLlective INTelligence  
MG Minority Game  
TG Team Game  
RAND Random

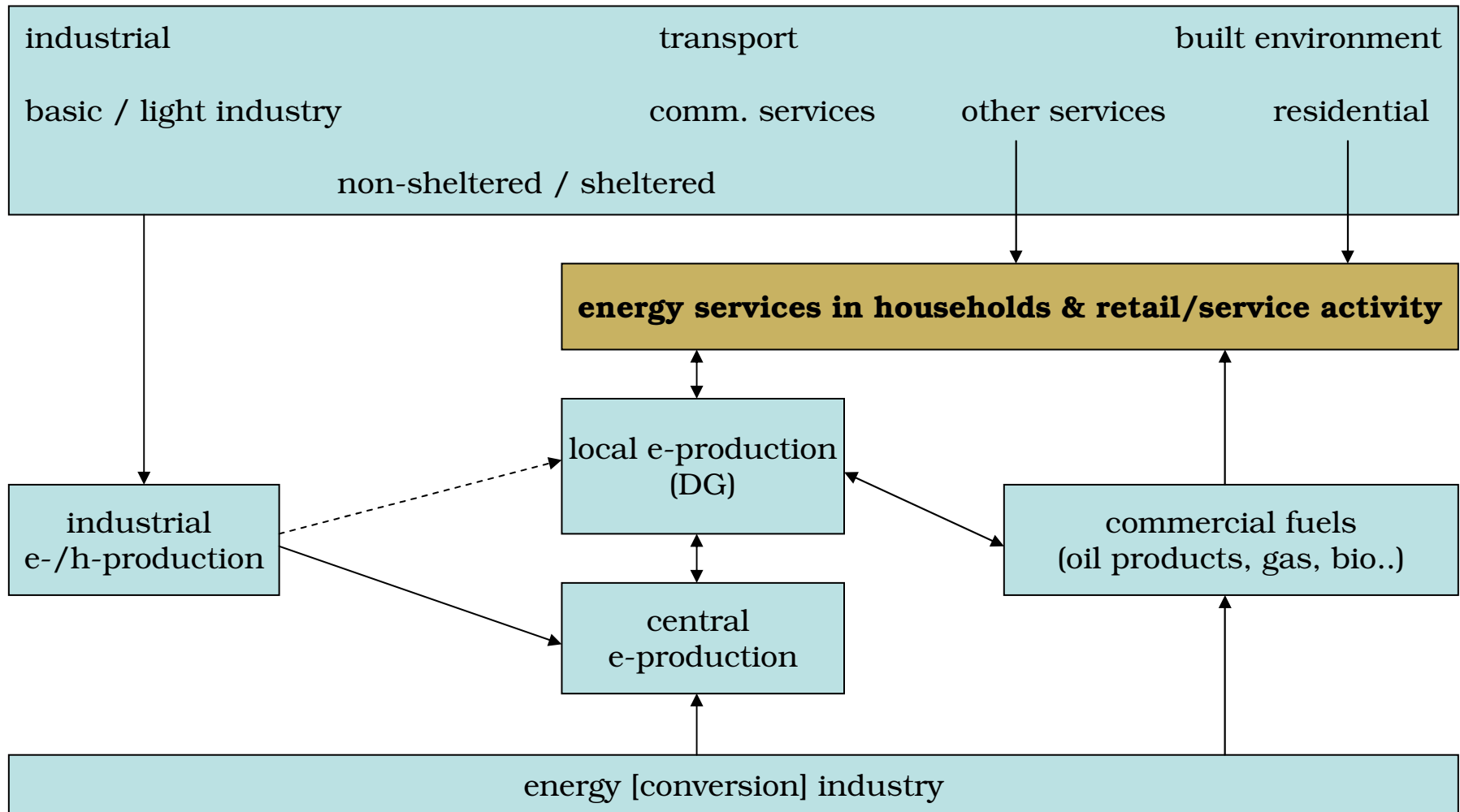
← under-exploited

→ over-exploited

(Brede and De Vries 2007)

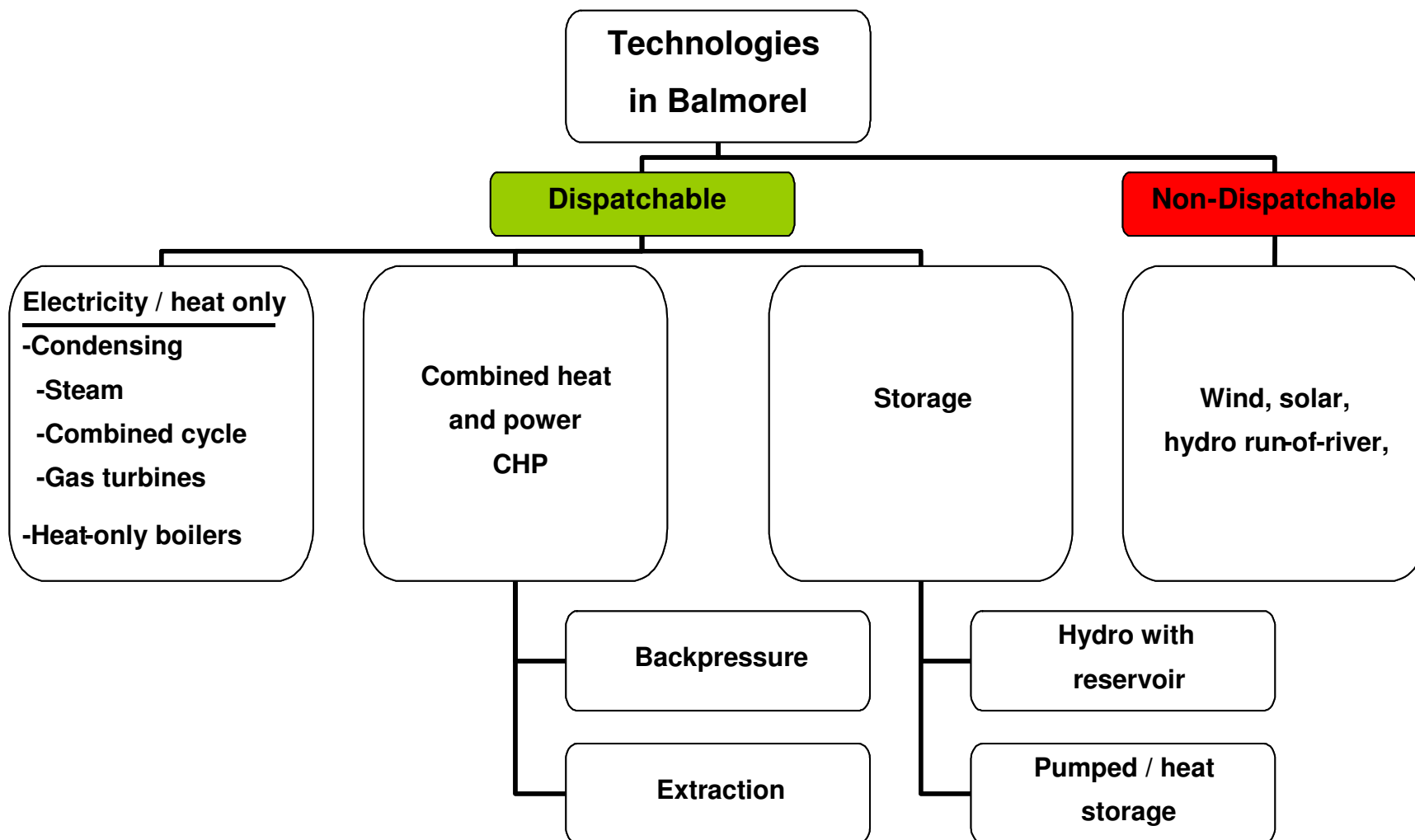
# c) *Locale E-TranSitie in de Gebouw Omgeving (LETSGO): Nederland 2020*

the issue: energy transition [management]

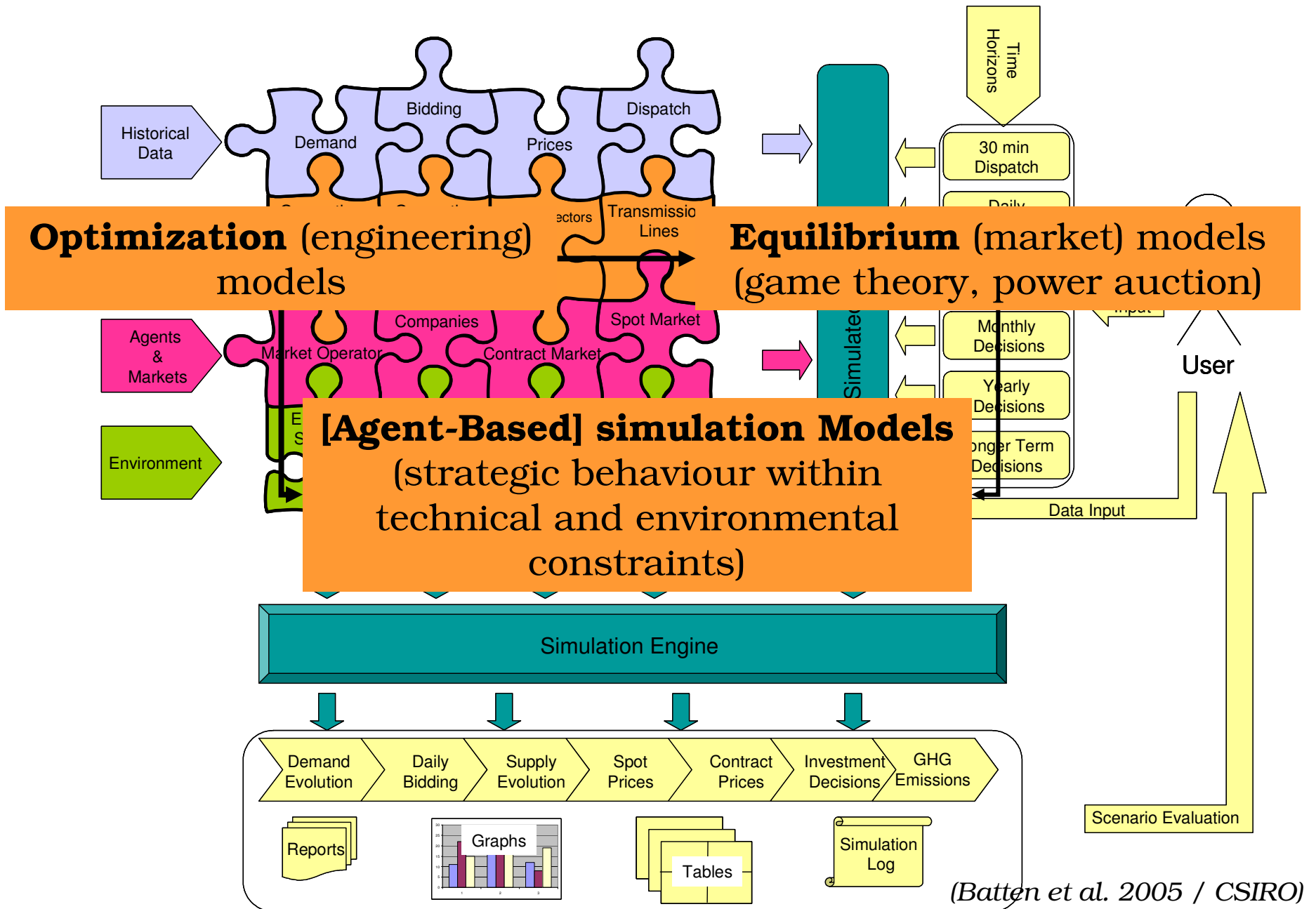


# Technologies in Balmorel

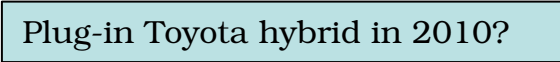


## (Baltic Model of Regional Electricity Liberalisation)



# NEMSIM (National Electricity Market) Overview



# LETSGO: some suggestions

- assessment of **future energy use**: intermediate variables (floor space, appliance stock, electric car, domotica etc.)  

- **weather model and data**: role of future climate change (air-conditioning, heating...)
- options, opportunities and risks of **distributed generation technologies**: innovation dynamics  

- **'smart meters' & ICT**: tariff differentiation (time, source; [carbon] tax), interactive info/control, community level dispatch
- [Cournot] **market model** for power contracts and exchanges in Europe, emission trading (APX, EMELIE-model)
- **agent's behaviour**: using value surveys, spatial consumer info at MNP (Duurzaamheidsverkenning), simulation gaming
- **scenario** investigations – plant cost & environment performance, new power plants, blackouts, new rule  


# Using spatial information in an institutional dynamic frame the Environment Explorer (LOV): three spatial levels

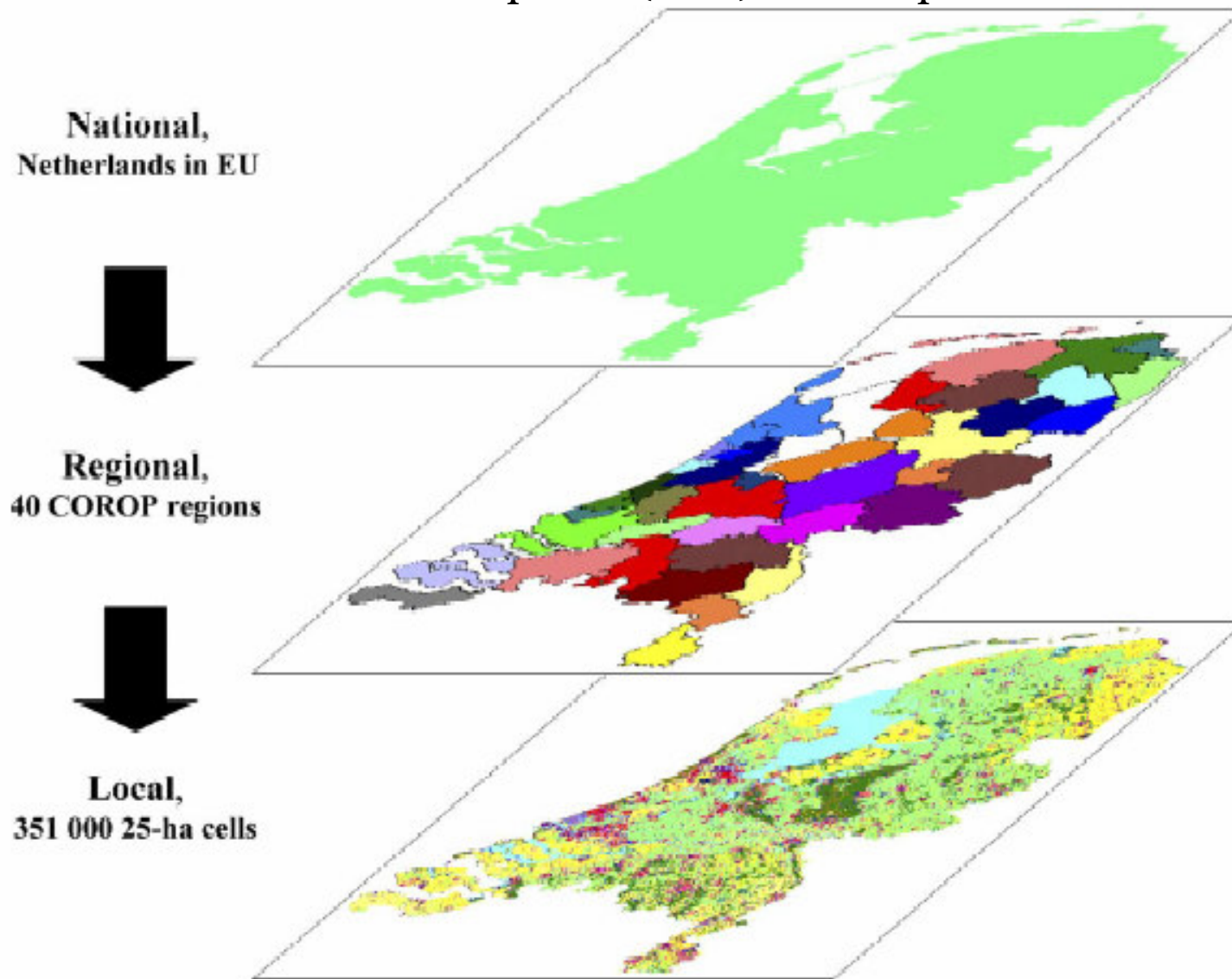


Fig. 2. The three spatial levels, national, regional and local, represented in the Environment Explorer.

*Dank voor uw aandacht*

