Agro-pastoral system sustainability: the social-ecological perspective

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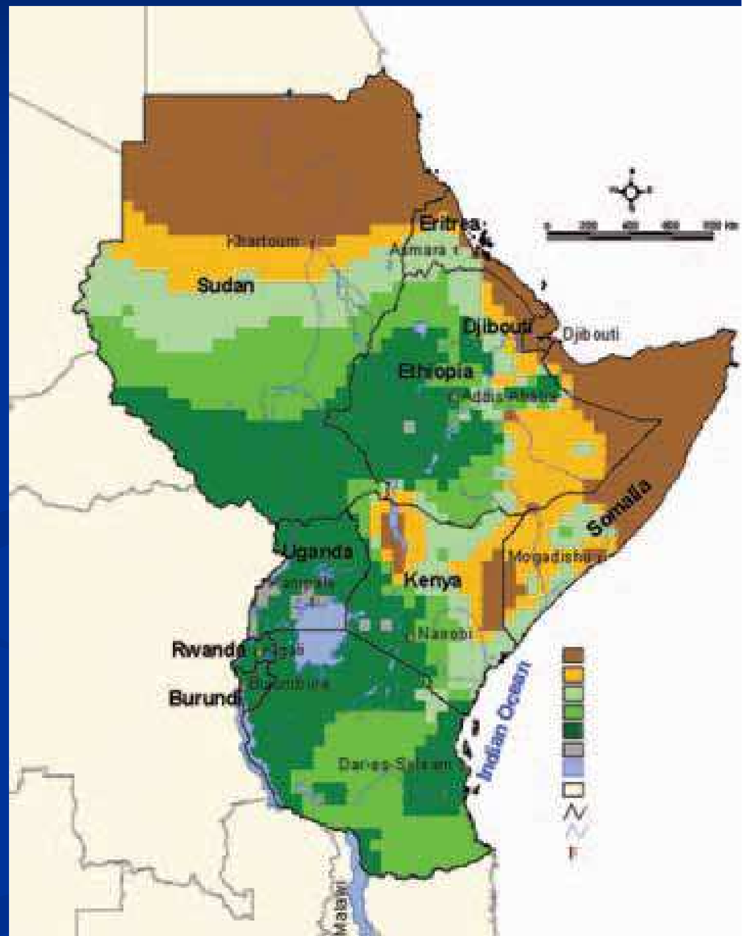
INTRODUCTION

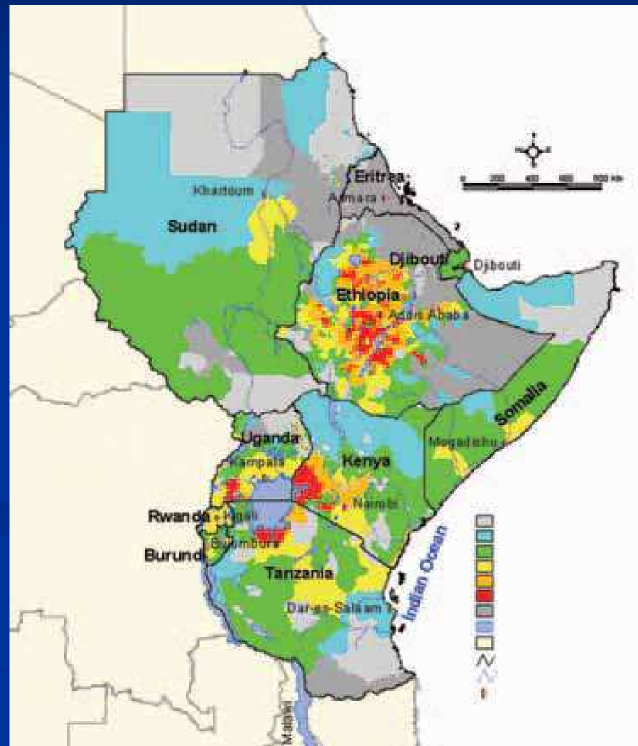
- Agro-pastoral systems in Eastern Africa
  - Economic, cultural and environmental importance
  - Socio-economic transition in traditional pastoral systems
  - Important stressors that constraint development and make this transition a challenging factor for multidimensional sustainability
- Objective
  - Present origin and motivation of an ongoing projects on sustainability of agro-pastoral systems in Ethiopia
  - Describe approach and tools for sustainability analysis of social-ecological systems
- Management: complexity and non linearity
  - Neither simple approaches nor silver bullet technologies
  - Rational management schemes are needed
  - Fundamental contribution of quantitative tools

1. Socio-ecological transition in agro-pastoralist systems

- Pastoral systems in Eastern Africa
  - Have developed over the last 4 thousand years
  - In an environment with an enormous variability in productive potential
    - Most in arid with less than 60 growing days to semi-arid with 60-120 growing days (P>PET)
  - Significant grassland cover Ethiopia
    - With highlands of considerable potential for crop-livestock production

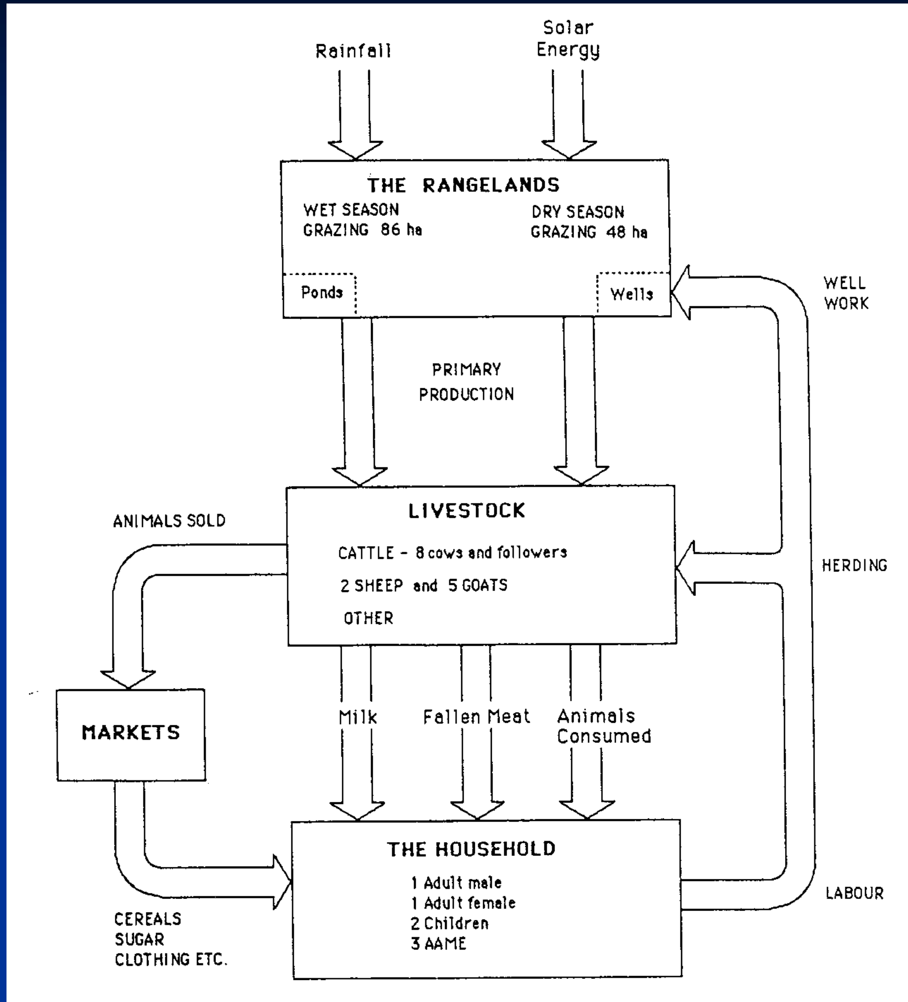


- Risk management in pastoral systems
  - Rainfall (>50 mm) represents the major constraint
  - Characterized by frequent droughts and high level of risk of production
  - Risk is managed mainly by moving livestock on a daily and seasonal basis following quality and quantity of pasture
- Enormous importance and potentiality
  - Economic
  - Cultural



Cattle density
(From: Thornton et al., 2002)

- Adaptability in traditional systems
  - Strategies of resource use (efficiency in water and rangelands exploitation)
  - System of trade and exchange between households and groups
  - The case of the Borana (typical of many East African communities)
    - Well known ethnic group in Southern Ethiopia
    - Recently investigated for options for improvement



The household economy in the traditional Borana system (From Cossins and Upton, 1987)

- Traditionally livestock are used as a social “safety net”
  - Exchange cementing <u>mutual obligation</u>
  - <u>Cattle are symbol</u> of wealth and prestige
  - Herds are managed in a way that <u>minimizes sales</u> (other than income generation)
- Transition toward a mixed systems
  - Pastoralist to agro-pastoralist

- Drivers of change
  - Demand of dairy products (a relatively new phenomenon)
  - Change in traditional land use rights and access to land
    - At the basis of sustainability
    - Change in land use (e.g. conservation areas) and land tenure systems
  - Access to water
  - Governments are reducing support to pastoral peoples who are often marginalized
    - Promotion of sedentarization
  - Origin of mixed systems

- Integration of grassland into smallholder farming systems
  - Sedentarization and settlement improve income-earning capacity
  - Expansion of cropping in areas where agriculture is feasible
  - Herders attempt to better manage risk and respond to drought
  - Cultivated forages have received less attention from breeders that other crops
  - Increasing the cut-and-carry zero grazing system
  - New agro-pastoralists compete with traditional pastoralists pushing them onto more marginal lands for grazing

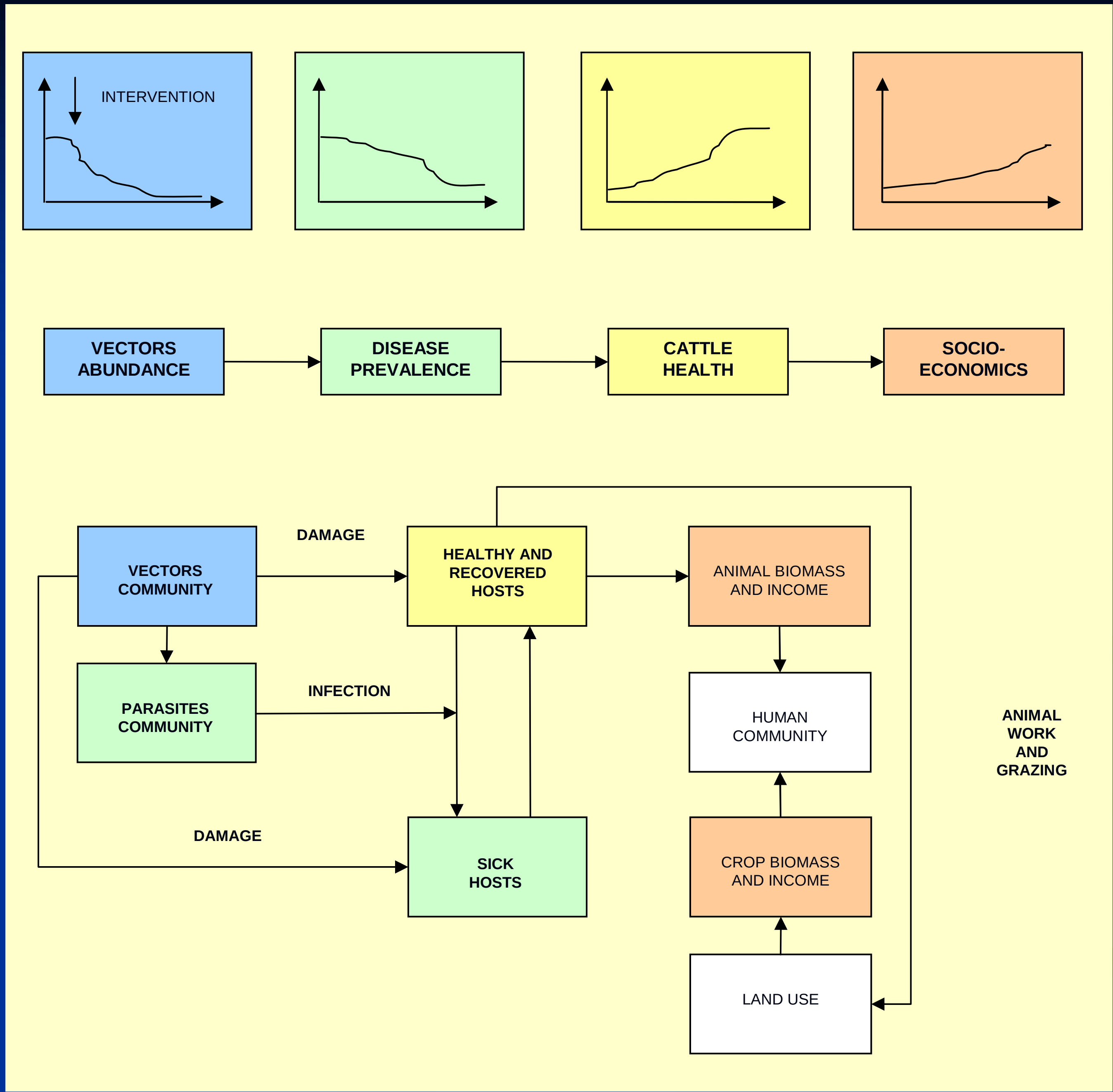
2. A case study of the evolution of an agro- pastoral system. Implication for sustainable development of tsetse- trypanosomiasis control

- Tsetse and trypanosomiasis control at Luke (Gurage, Ethiopia)

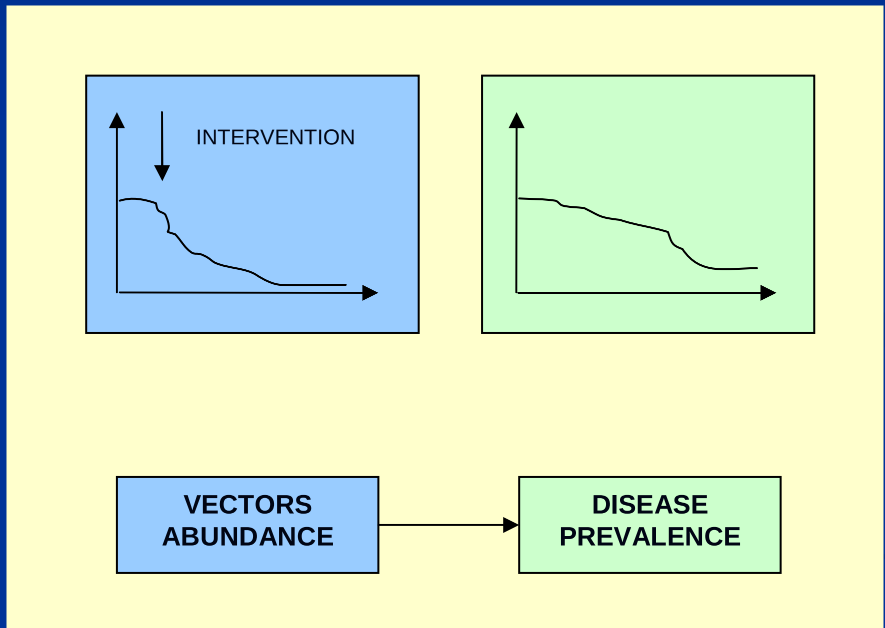
- Implications for epidemiological systems management
- Implications for project interventions aiming at poverty alleviation and development
- Implication for sustainability

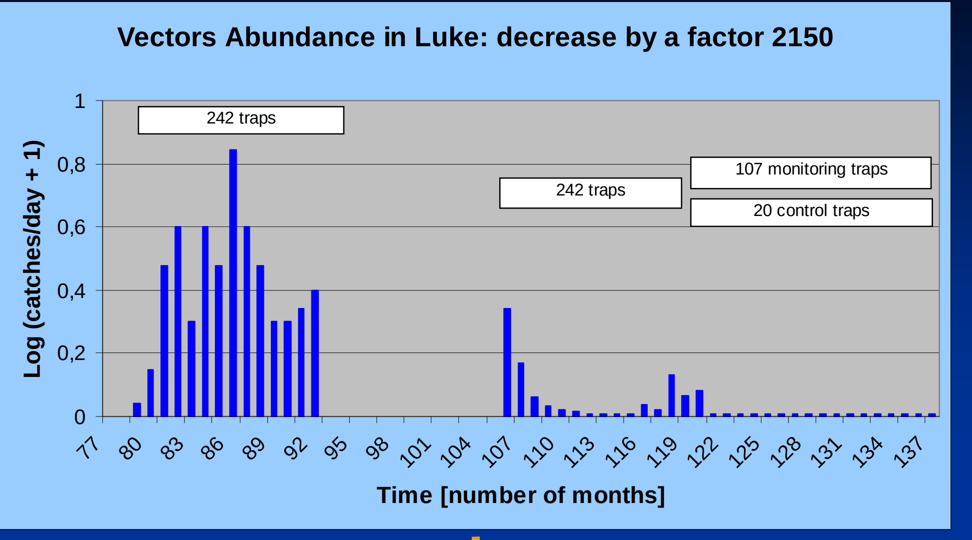
- Common presumptions in many traditional management schemes
  - Exists a linear chain causes-effects
  - Consider necessary and sufficient intervention on a single level (often relying on a single technology)
  - Complexity of interaction between social and ecological sub-systems and between these and management are often disregarded
- The (implicit) epidemiological thinking

VECTORS ABUNDANCE → **DISEASE PREVALENCE** → **HOST HEALTH** → **SOCIO-ECONOMICS**


INTERVENTION
VECTORS ABUNDANCE
DISEASE PREVALENCE
CATTLE HEALTH
SOCIO-ECONOMICS
DAMAGE
VECTORS COMMUNITY
HEALTHY AND RECOVERED HOSTS
ANIMAL BIOMASS AND INCOME
PARASITES COMMUNITY
INFECTION
HUMAN COMMUNITY
ANIMAL WORK AND GRAZING
DAMAGE
SICK HOSTS
CROP BIOMASS AND INCOME
LAND USE

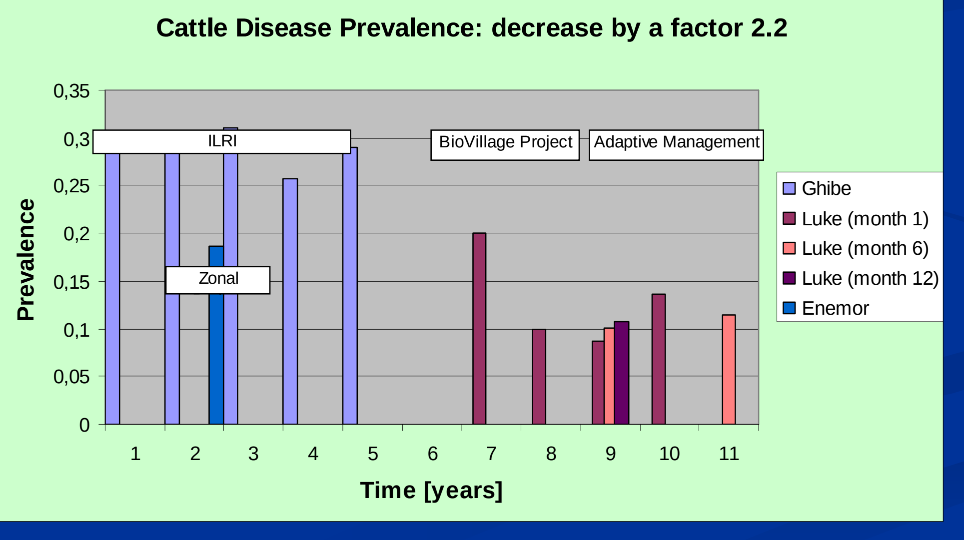
- Step 1 (from intervention to prevalence): the expectations





Vectors Abundance in Luke: decrease by a factor 2150
242 traps
242 traps
107 monitoring traps
20 control traps
Log (catches/day + 1)
Time [number of months]

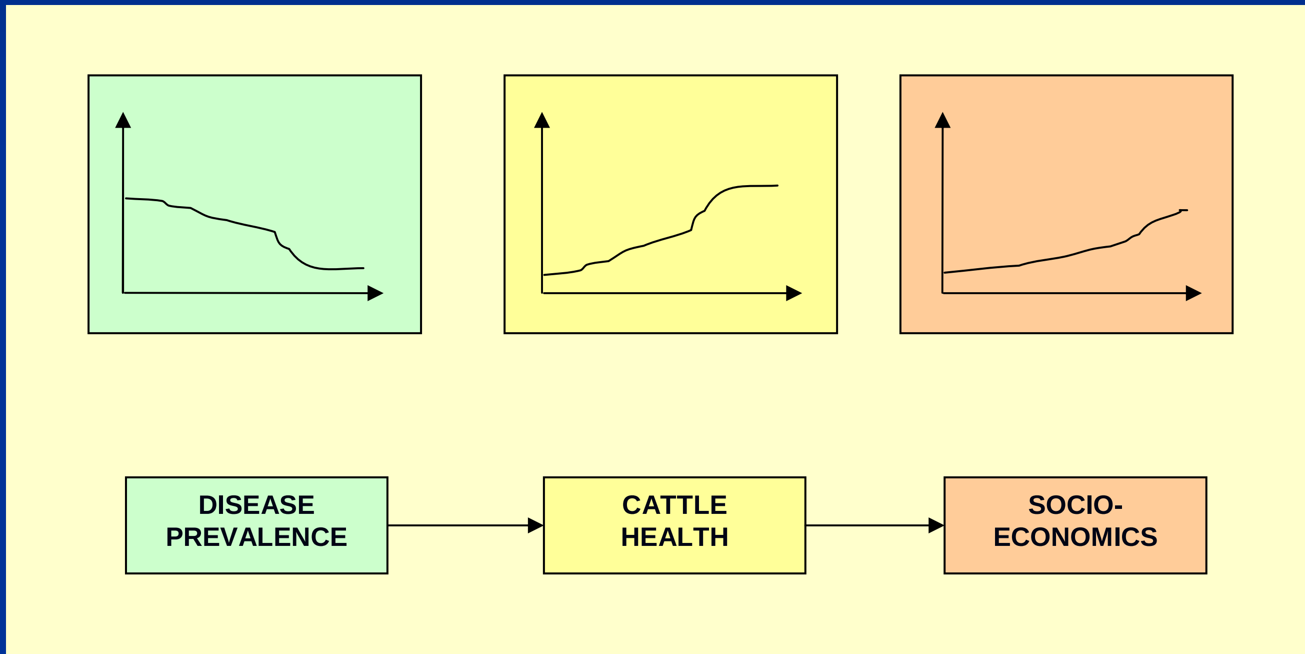
A

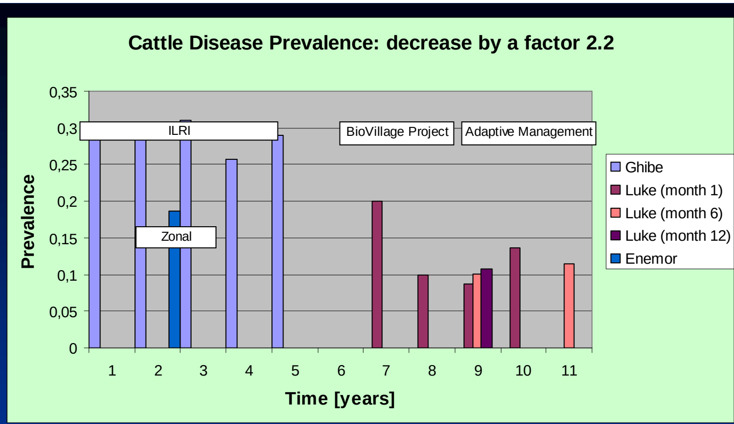


Cattle Disease Prevalence: decrease by a factor 2.2
ILRI
Zonal
BioVillage Project
Adaptive Management
Ghibe
Luke (month 1)
Luke (month 6)
Luke (month 12)
Enemor
Prevalence
Time [years]

B = *f* (A) ?

- Step 2 (from prevalence to socio-economics): the expectations

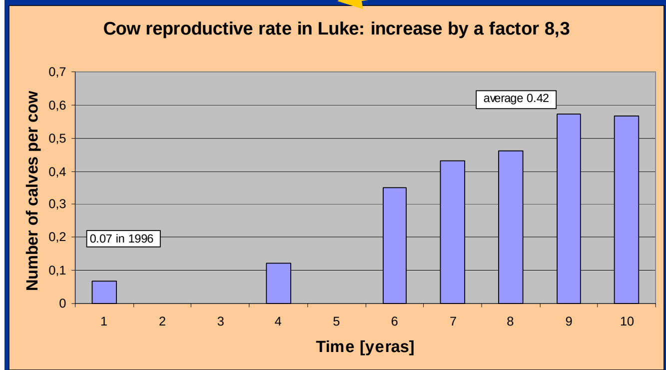


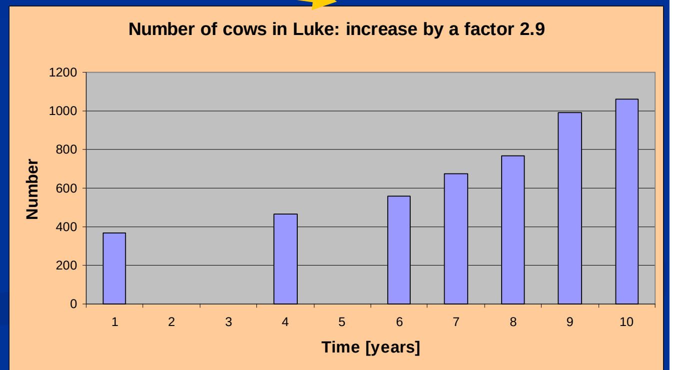


B

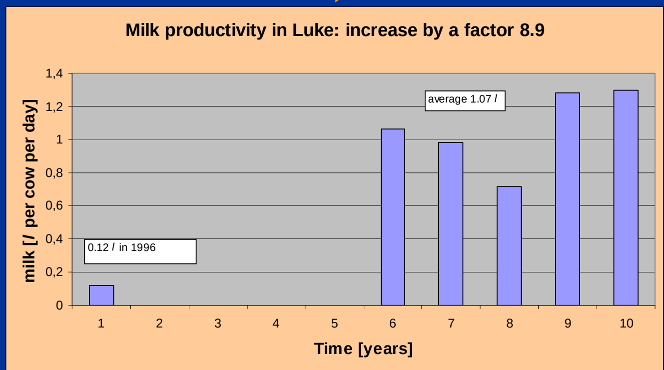
C = *g* (B) ?

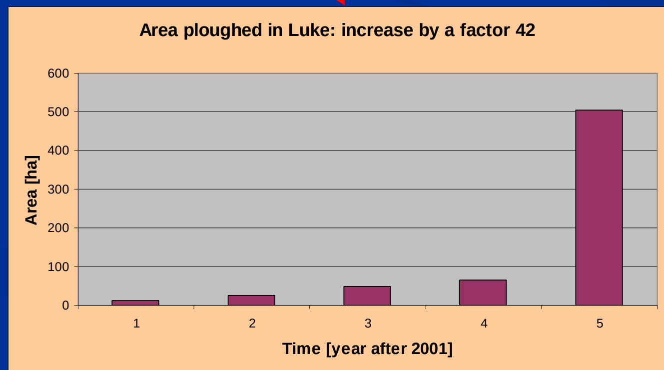
D = *h* (C)



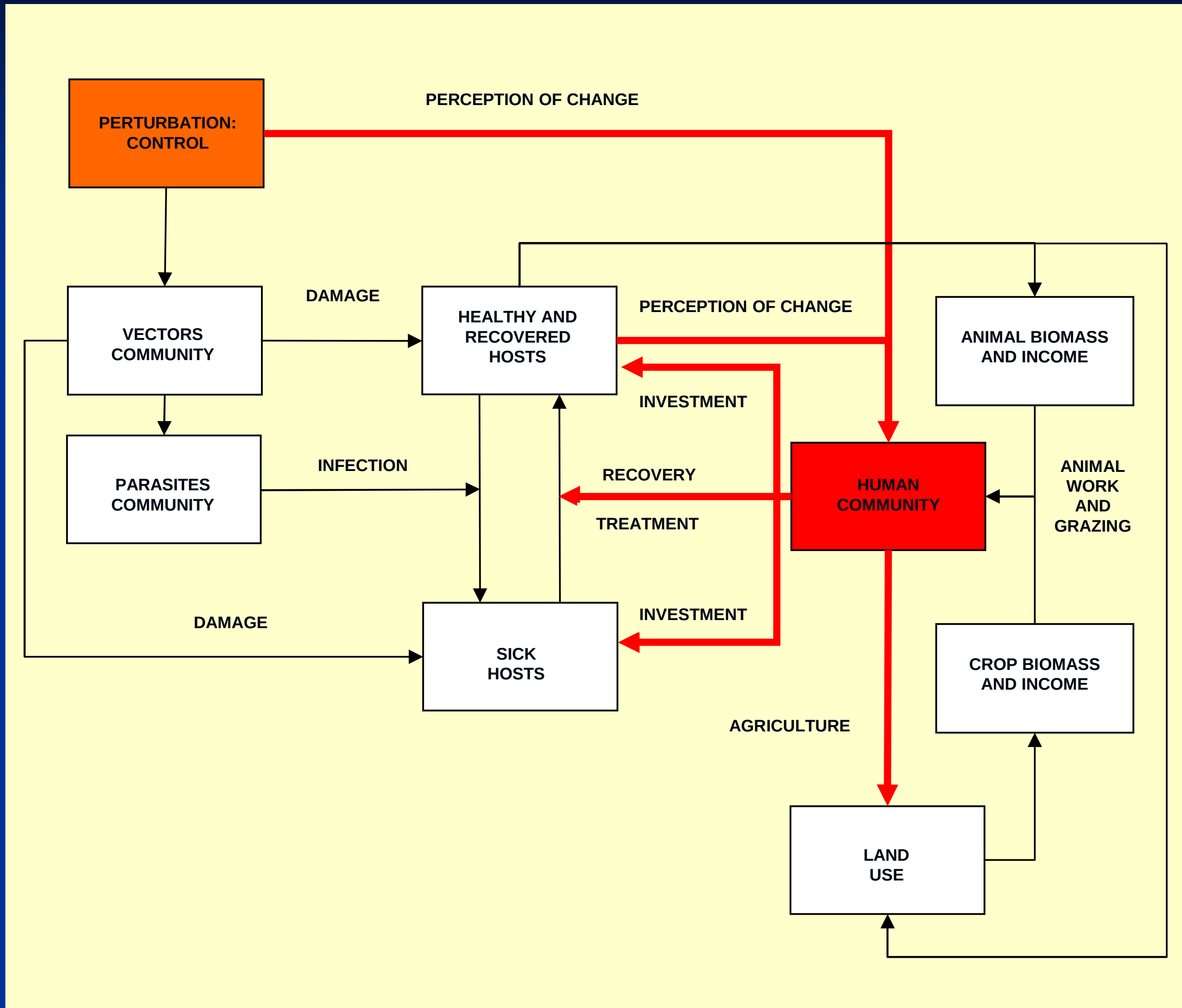


E = *k* (B) ?





F = *l* (B) ?



PERTURBATION: CONTROL
PERCEPTION OF CHANGE
VECTORS COMMUNITY
DAMAGE
HEALTHY AND RECOVERED HOSTS
PERCEPTION OF CHANGE
ANIMAL BIOMASS AND INCOME
INVESTMENT
PARASITES COMMUNITY
INFECTION
RECOVERY
HUMAN COMMUNITY
ANIMAL WORK AND GRAZING
TREATMENT
DAMAGE
INVESTMENT
SICK HOSTS
CROP BIOMASS AND INCOME
AGRICULTURE
LAND USE

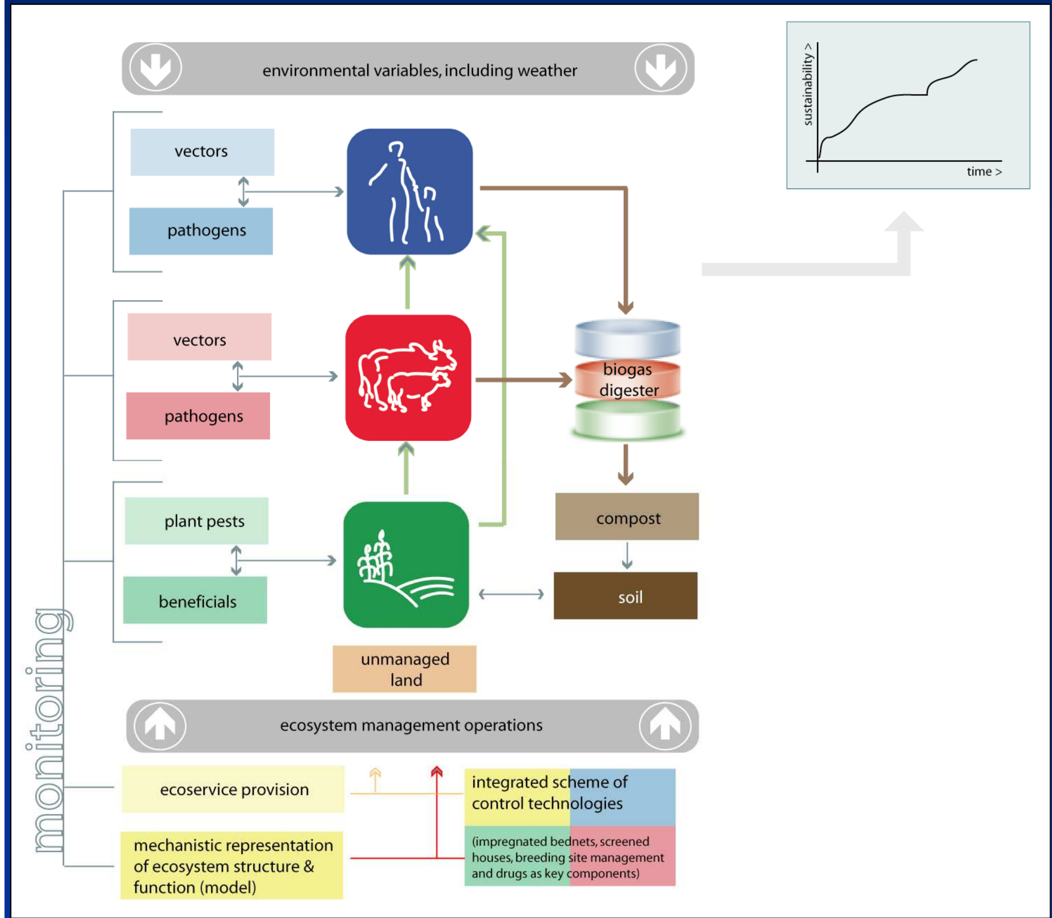
- Lesson learnt
  - Compartments are connected by complex (non liner) relations
  - Logic of linear causality is replaced by a circular logic (network)
  - Human community is no more seen as passive and final component
  - That plays a central role to promote and sustain system change
  - Important relation between animal health and abundance and the impact on a fragile ecosystem (resulting in overgrazing and soil erosion)
- To summarize
  - A project success is a factor than can trigger an ecological disaster
  - Need for and utility of conceptual models to serve as a basis for developing policy for sustainable agro-pastoral resource management in sub-Saharan Africa

3. System analysis and sustainability

- Traditional approach
  - Analysis of resource management strategies
  - Based on
    - Resource extraction strategies
    - Balance between stocking and grazing rate and grassland productivity
  - Objective: stabilize nutrient and energy flow to livestock and thus productivity throughout the seasons
  - Based on growth-consumption rate model

- Reasons for an extension of the traditional approach
  - Complexity of the object
    - Pastoral → agro-pastoral system
    - Social-ecological system
  - Complexity of sustainability analysis
    - Beyond the traditional growth-consumption rate model
    - Multi-dimensional analysis
  - Implication of considering humans as part of the system
    - New concept, approach, tool → new models
    - Explore potentiality of bio-economic analysis

Sustainability analysis based on Ecosystem Services



Supply (from natural capital)

$$\Delta S(\Delta t) = P(\Delta t) - C(\Delta t)$$

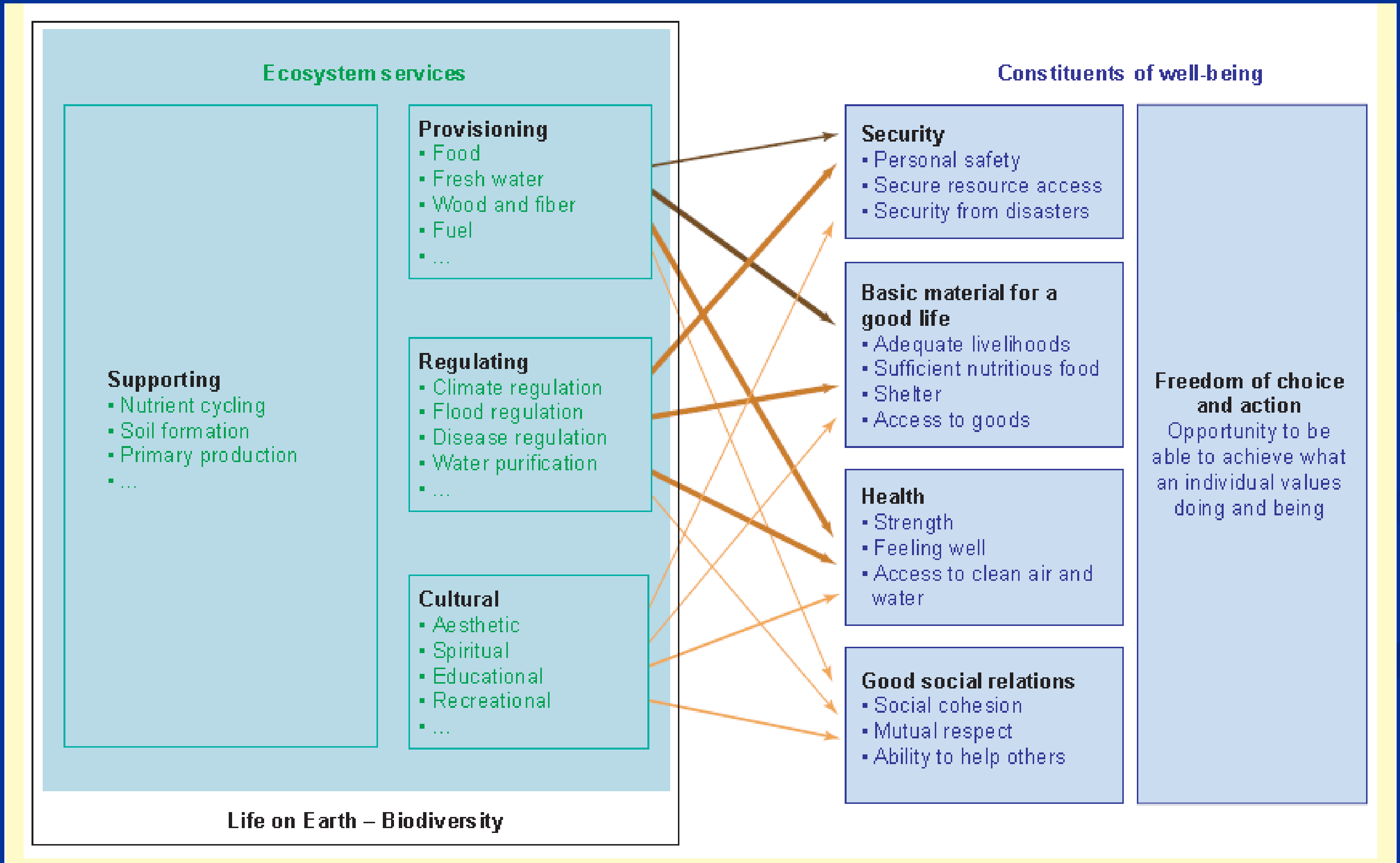
Demand (human or natural consumers)

For each ES a <u>balance between production and consumption</u> defines a sustainability index $S(t)$ for that ES

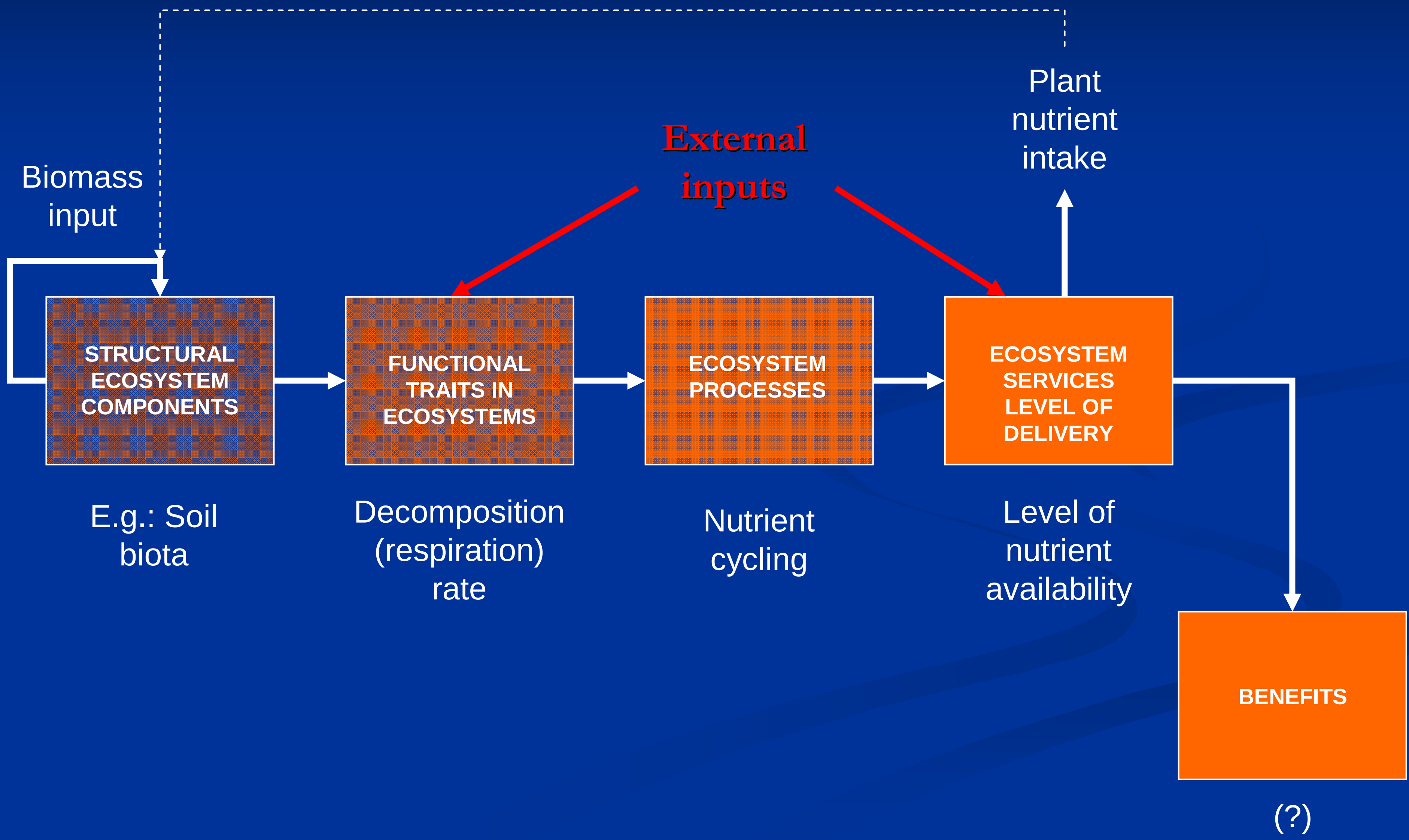
$$P(\Delta t) > C(\Delta t) \qquad \Delta S(\Delta t) > 0$$

Evaluated in a system of <u>interacting compartments</u> maximizing growth functions

- Type of ESs
  - Provisioning services such as food and water
  - Regulating services such as regulation of floods, drought, land degradation, and disease
  - Supporting services such as soil formation and nutrient cycling
  - Cultural services such as recreational, spiritual, religious and other nonmaterial benefits" (MA, 2005).



- Ecosystem basis (SPU) of sustainability and the importance of quantitative assessment



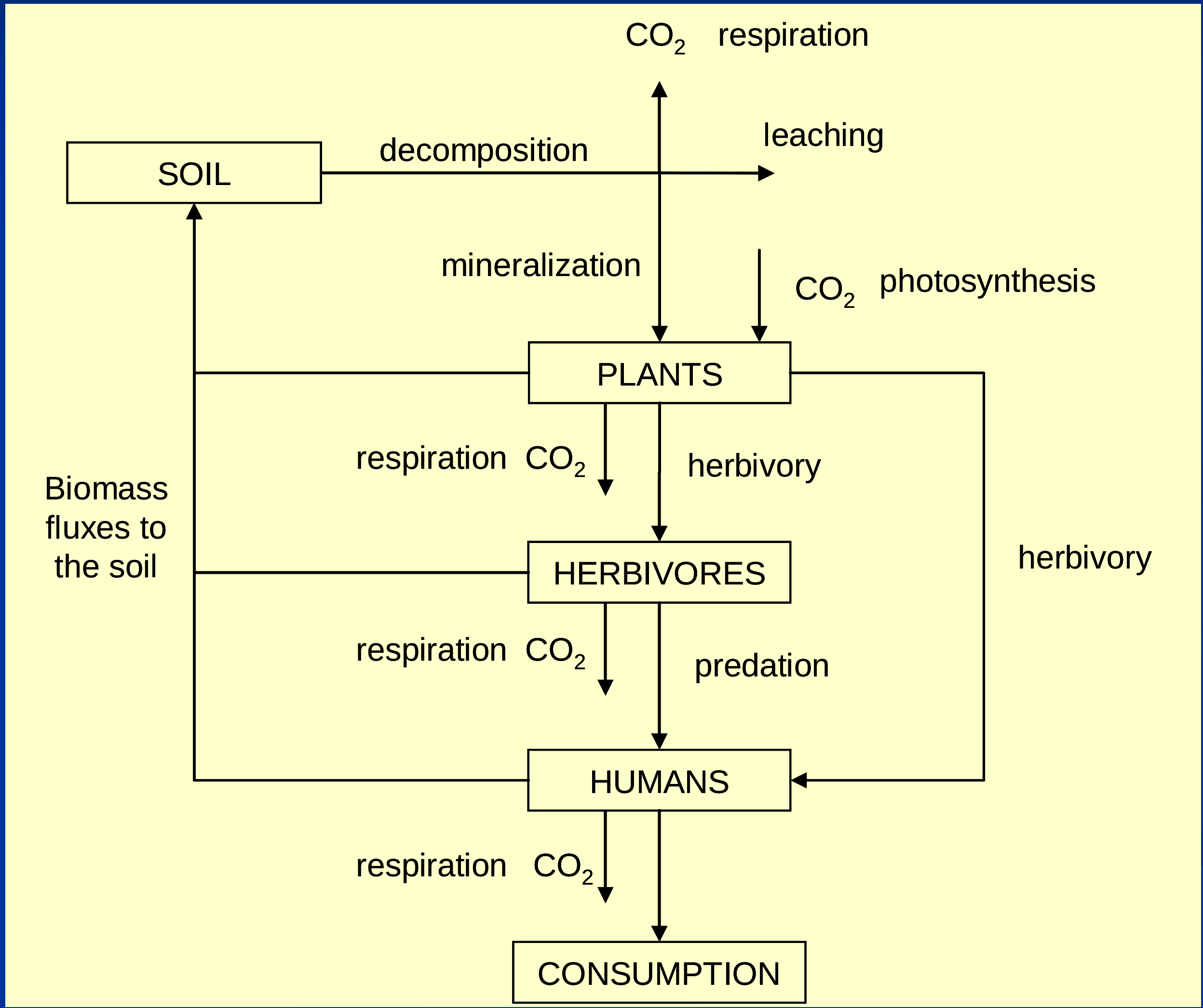
4. Modelling approaches

- Modelling of pastoral systems reflect differences between Western system and nomadic systems (e.g. in East Africa)
  - Western approach
    - Grazing plans and stocking rates
    - Cut-and-carry zero grazing system
  - Pastoralist strategies
    - Tracking grazing strategies

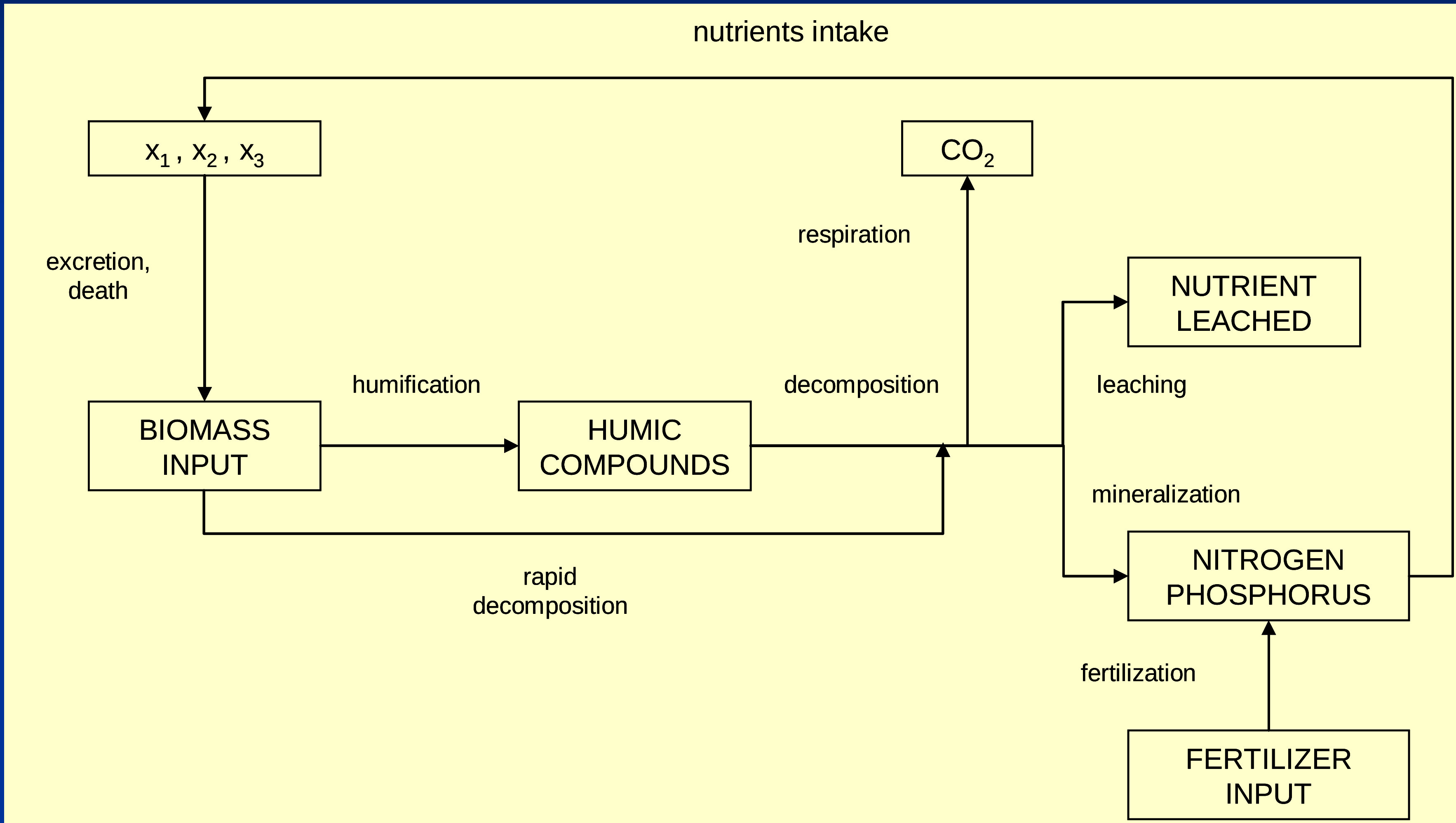
- Two approaches for agro-pastoral system in East Africa
  - Traditional → non-equilibrium analysis
    - Rainfall variability
    - Soil fertility gradient
    - Other constraints and/or rules
  - Mixed/sedentary → equilibrium analysis
    - Contribution of horticultural and crop production

- To evaluate sustainability of agro-pastoral systems we developed a composite modelling approach (4 levels)
  - Non-autonomous models
    - Spatially explicit
    - Dependent on environmental forcing variables
    - For both equilibrium and non-equilibrium
  - Autonomous models
    - Equilibrium-based approach
    - Lumped parameters
  - Non-equilibrium approach
    - Lumped parameter stochastic models
  - Bioeconomic analysis
    - Considering the role of the perception of risk

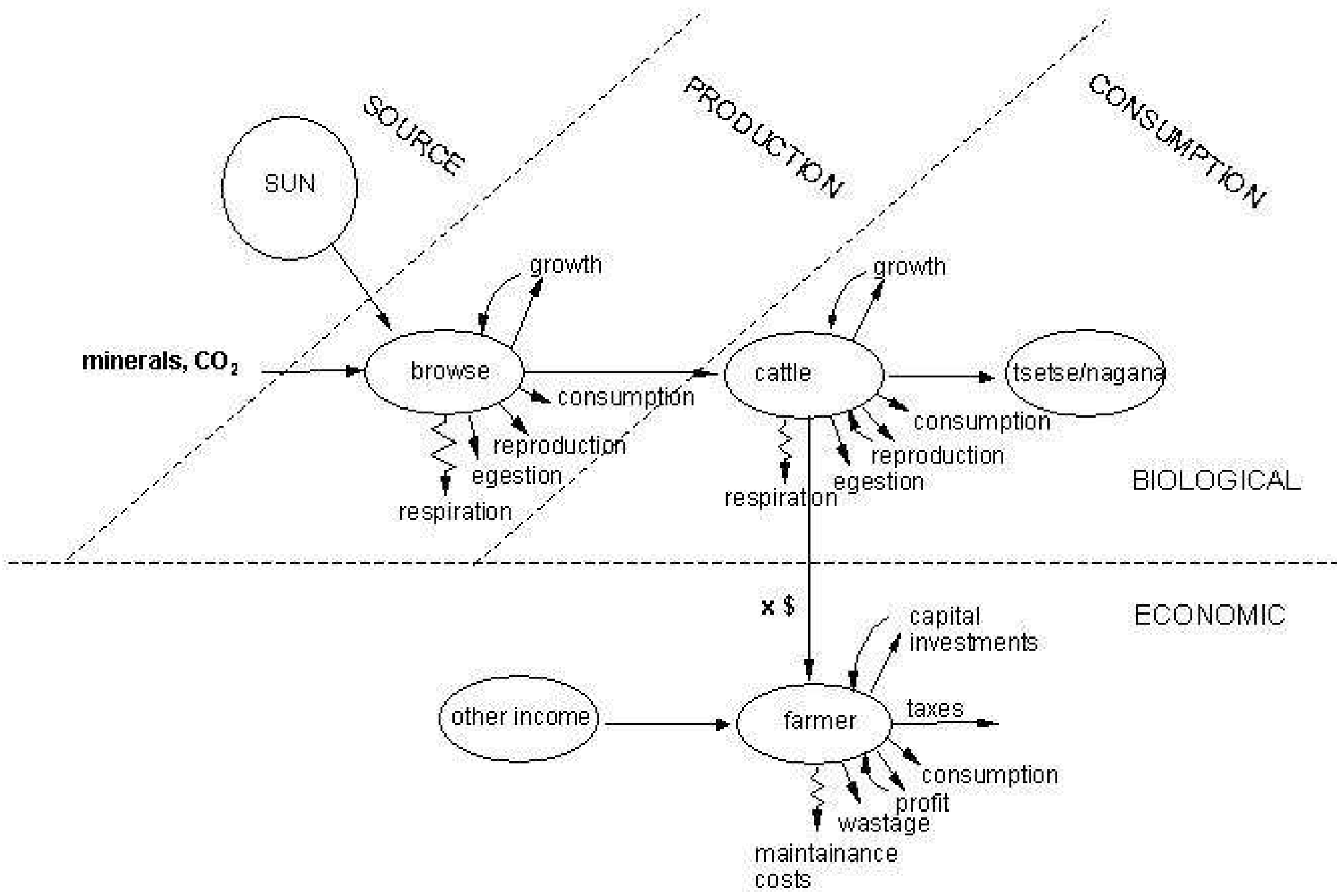
- Modelling approach based on
  - Biomass fluxes in ecosystem
  - Allocation of resources to consumption

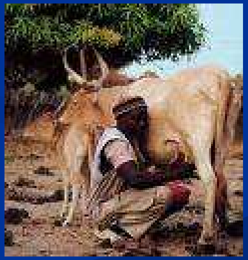


Modelling the soil compartment



■ Physiologically-based approach





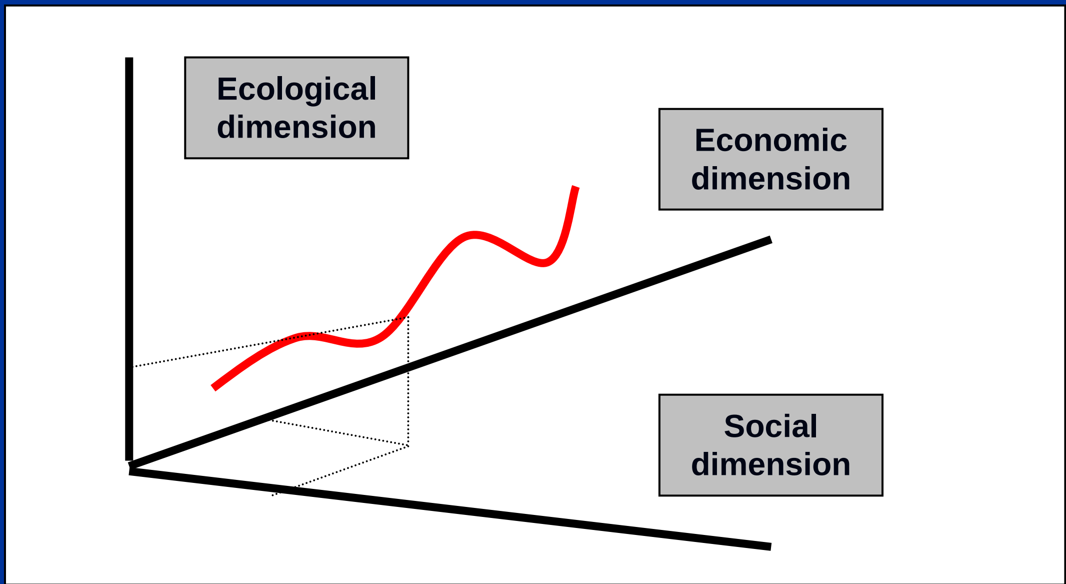
Epidemiological

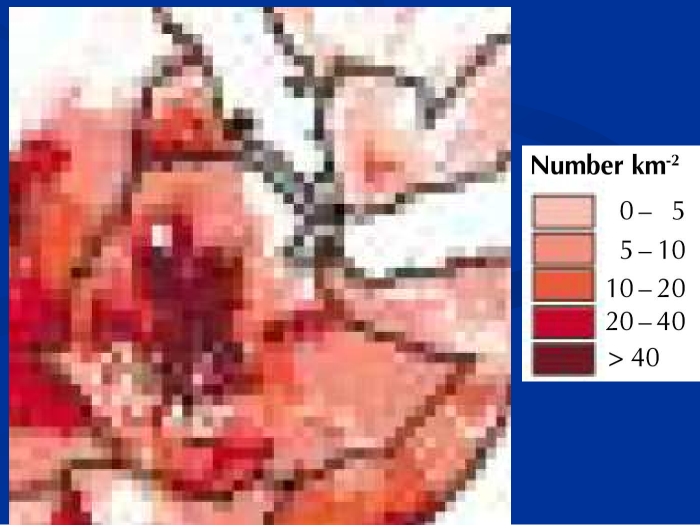
- Ongoing research and communications
  - Simulation of a <u>grazed grassland productivity</u> in Ethiopian highlands
    - Provide spatially explicit estimation of resource availability for cattle
  - Overview of the <u>multi-trophic system analysis</u>
    - Summarize results of eequilibrium-based approach
  - Qualitative analysis of a <u>three-trophic system</u>
    - <u>Application</u> of equilibrium approach to a system composed by crop-pasture, cattle and humans
    - System has been <u>parameterized with data</u> from literature and field work at the project site

- Future research steps and objectives
  - To develop a complete ecosystem model
    - Including soil, cattle, and human components
    - Already developed and parameterize, calibration stage
    - Explore the role of environmental driving forces
  - Simulation on a grid (lattice model) covering the entire Ethiopia
    - Derive lumped parameter for the composite models
    - Spatial variability in the qualitative behaviour of the model
  - Include the bio-economic analysis

- Provide a set of tools for strategy and policy evaluation
  - Decision support (e.g. land use planning)
  - Scenario evaluation (e.g. social, economic change)
  - Sustainability analysis (multidimensional)

MULTIDIMENSIONAL EVALUATION





5. Some concluding remarks

- Very challenging task
  - Time and resource constraints
  - Consistent advances in the methodological basis for system analysis and choice of adequate quantitative methods
  - Preliminary results
- Role of system analysis and quantitative approach
  - Effects of multiple factors (biological, environmental, treatments, etc.) on agro-pastoral system dynamics
  - Solid basis for sustainability analysis based on data and scenarios
- Requirements
  - Data
  - Resources
  - Collaboration


Thank you!