A conceptual model for multipoints of view analysis of complex systems. Application to the analysis of the carbon dynamics of village territories of the West African savanna

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Mercredi, 16 septembre 2009

Context

Introduction

- Complex system modelling

  - Cover multiple domains: sociology, ecosystem management,

  - Requires collaboration between different disciplines having not necessarily same point of view on the objects of the real system

  - Necessity to take into account these different points of view for a better understanding of complex system (CS)

Complex system modelling

- What is a complex system?
  - *"a set of entities with non-linear behaviour, interacting with each other and evolving at least three scales of time and space and (2) such that the behaviour at the global scale cannot be reduced to the composition of the local behaviours*". (Müller, 2004)

- To deal with the complexity of CS, the representation of a CS requires (Müller, 2004):
  - the need of multi-scale descriptions,
  - the multiplicity of view points
  - the articulations between the local and global behaviour
  - the emergence of the whole organisation

Complex system modelling (4)

- **Questions:**

  - **how to deal with multi-point of view description both at the global (macro) level and local (micro) level while integrating environment?**

  - **how to deal with the articulations between the global level and local level?**

Objectives

- Proposition of a conceptual framework allowing multi points of view description of complex systems at micro and macro levels while integrating the environment
- Definition of a methodology and a language
- Validation of the proposed framework by a generic model to simulate and analyse the C dynamics from plot to village level in West-Africa Savanna.

Contributions (1)

Organisation-Role-Entity - Aspect (OREA) model

Carbon of Territory Multi-Agent Simulator (CaTMAS)

- Based on multi-agent system paradigm
- An extension of Agent-Group-Role (AGR) (Ferber and Gutknecht, 1998)
- Decomposition of CS from different point of view:
  - At global level: reification of a point of view as an organisation made of roles
  - At local level: decomposition of entities in a set of aspects
- Separation of the organisation behaviour and the entities local behaviour
- Integration of the environment objects in organisation

Contributions (2)

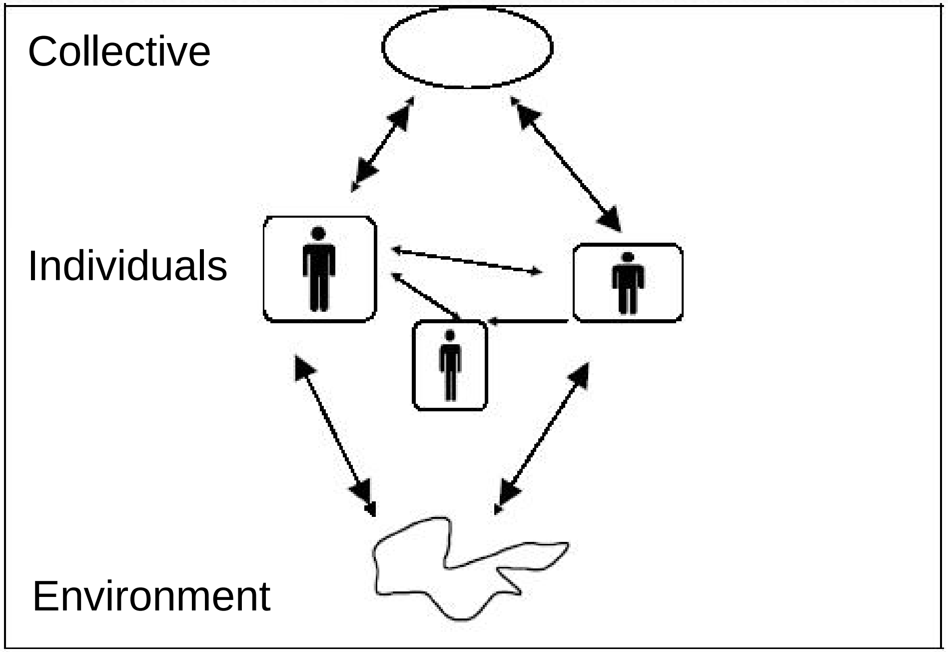
Organisation Role Entity Role (OREA) model

Carbon of Territory Multi-Agent Simulator (CaTMAS) model

- Application of the OREA model
- An integrated model for the C dynamics from plot to territory level in West-African Savanna
- Taking into account the socio-economic and bio-physical dimensions
- Based on the MAS approach and the coupling with the Century model and a geographical information system (GIS)

Review

Multi-Agents Systems



Two approaches in specification of MAS structure:

(1) Agent-Centered Multi-Agents Systems (ACMAS) approach

(2)Organisation-Centered Multi-Agents Systems (OCMAS) approach

Organisation of a MAS model (Bousquet, 2001) (Modified)

Multi-Agents Systems: OCMAS approach

- Three main concepts: organisation, role and agent
- Two levels of description: organisation level (macro-level) and agent level (micro-level)
- Makes easy the description of CS for many reasons:
  - Heterogeneity of language
  - Multiple applications and architectures.
  - the security control
  - The modularity in MAS building
- Examples of OCMAS models: AGR (Ferber and Gutknecht, 1998), GAIA (Wooldrigde et al.,2000), ISLANDER ()

Multi-Agents Systems: OCMAS approach

- No explicit representation of the organisation structure: Gaia (Wooldridge et al.)

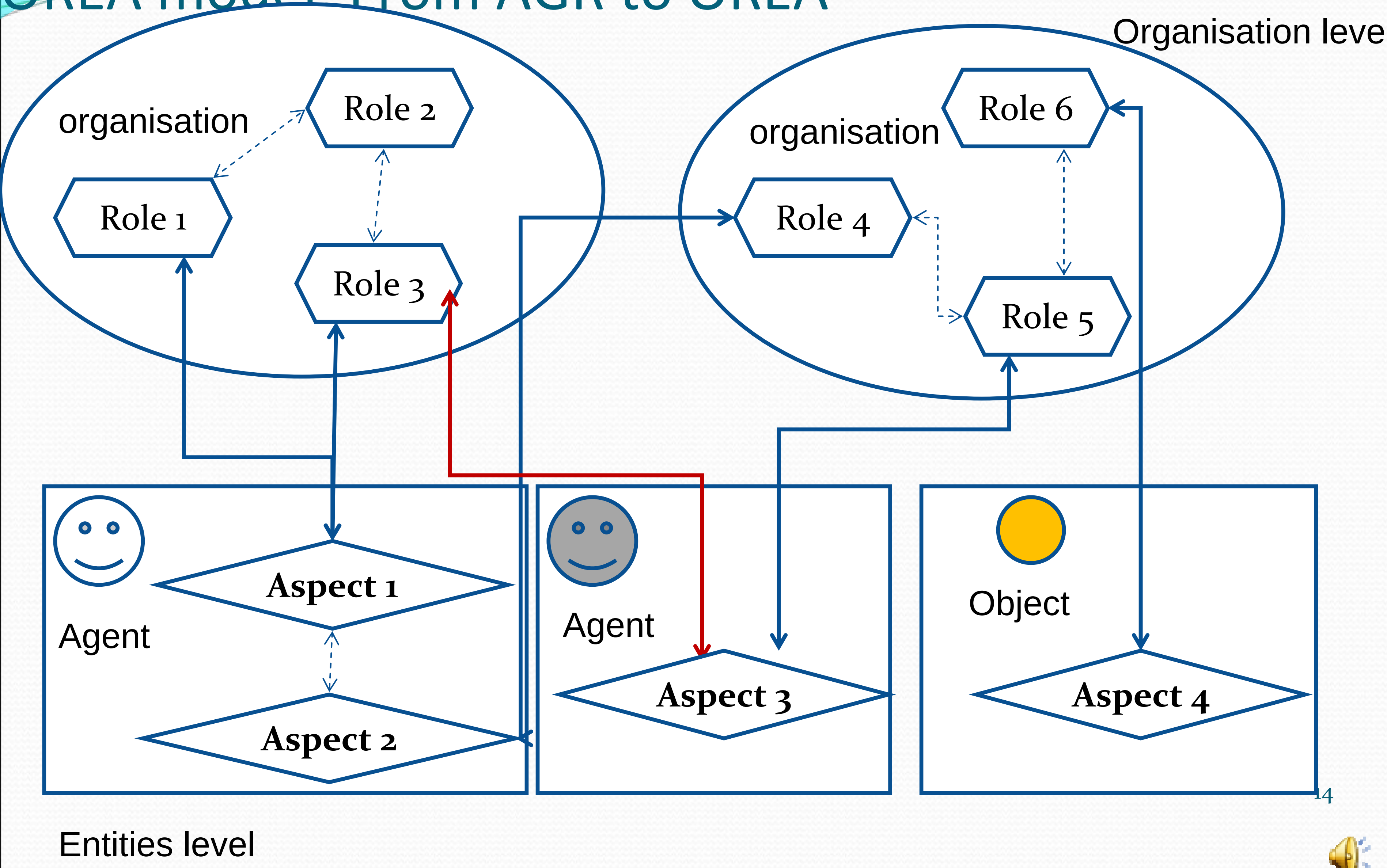
- Dependency of the organisational structure of the agent structure: RIO (Hilaire, 2000), MOCA (Amiguet et al.,2003) , Parunak and O'dell (2002).

- The roles as both the organisational status and the behaviour of the agents
- Impossibility to play in different way the same role

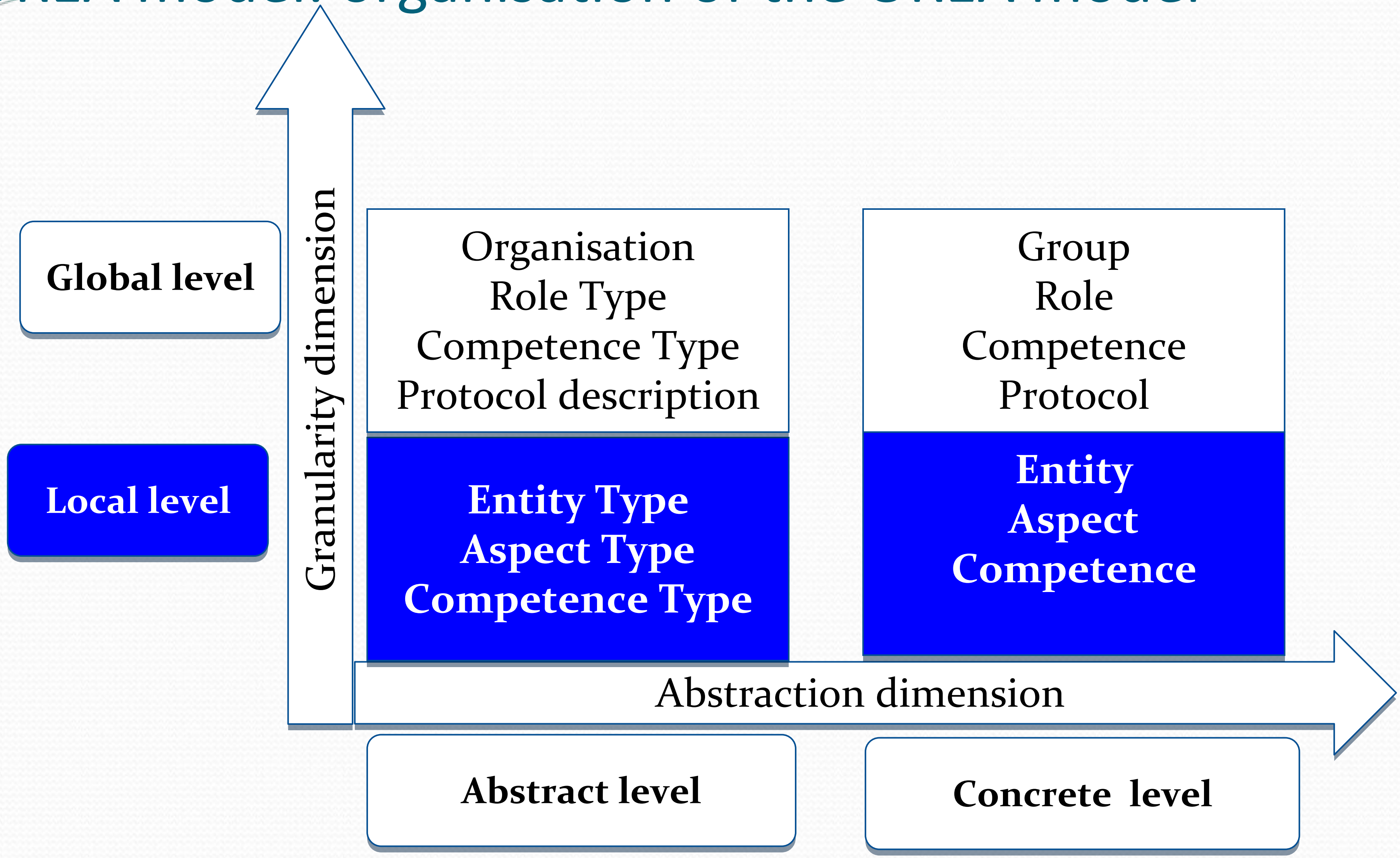
- No integration of the environment objects in the organisational structure: AGRE, Mascaret, Parunak and Odell model
  - Impossibility to specify the perception of the agents according to the roles they play in the system.

The OREA model

OREA model: From AGR to OREA



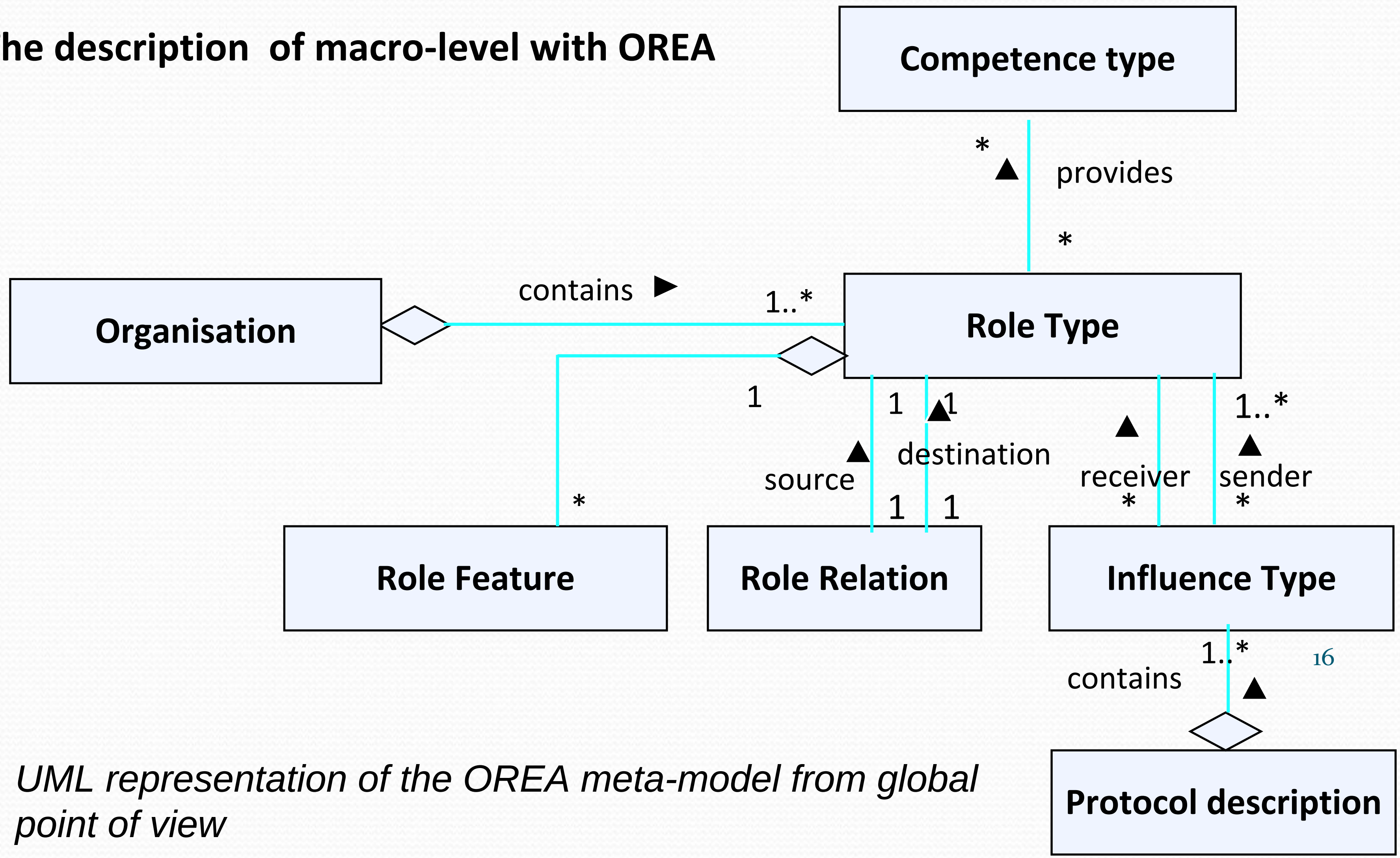
OREA model: organisation of the OREA model



The concepts of OREA for the description of CS at the macro level and micro level

Meta-model of OREA: Abstract level

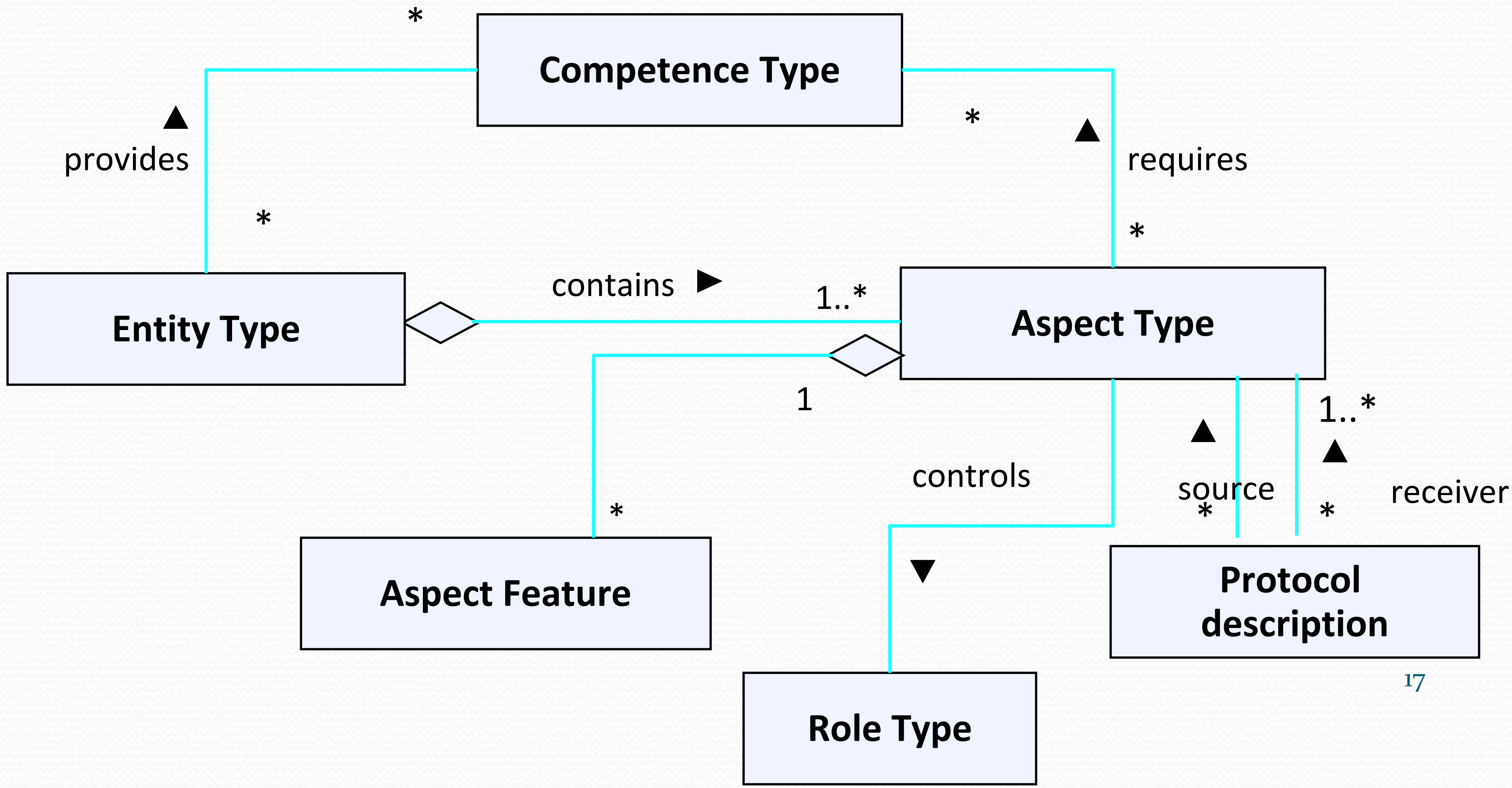
The description of macro-level with OREA



UML representation of the OREA meta-model from global point of view

Meta-model of OREA: Abstract level

The description of micro-level with OREA



UML representation of the OREA meta-model from local point of view

OREA model

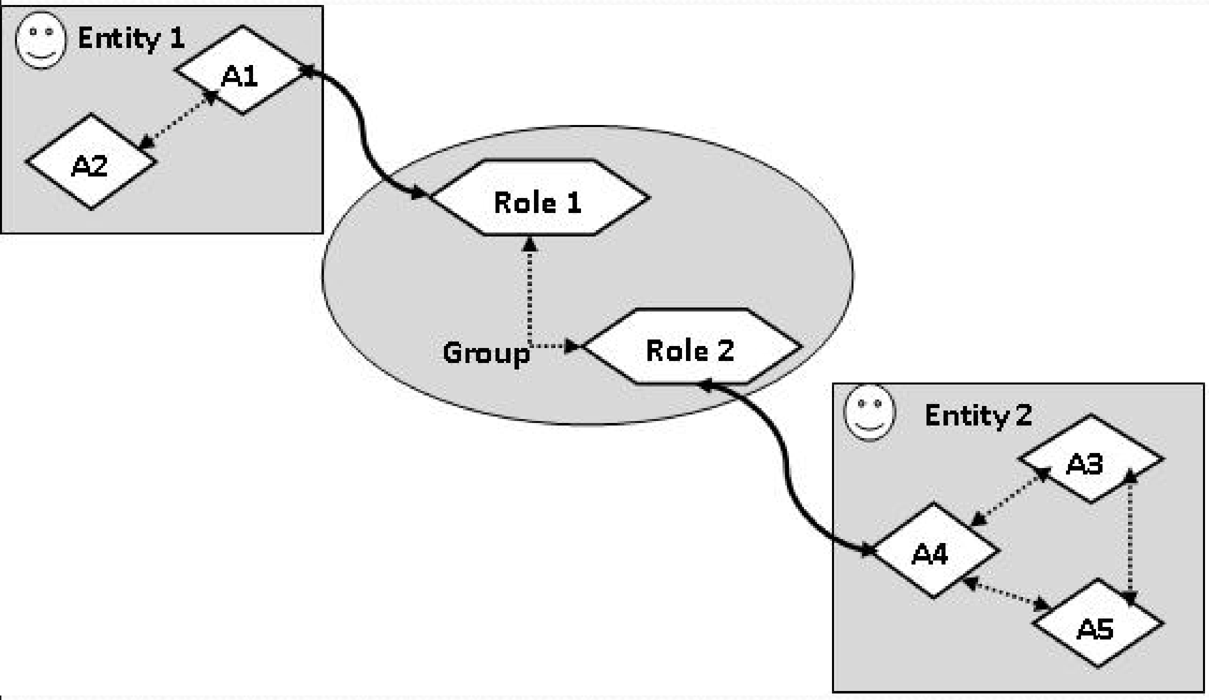
- Different ways to play differently the same role type by the entities
- An explicit separation between the organisational behaviour from the local behaviour:
  - Roles:
    - observable behaviour of entities
    - Allows to entities to be in relation and interact between them
  - Aspects:
    - internal behaviour of entities, represent the entities activities and how they reason about the social organisation.
    - Define how the roles are played
    - Implement the autonomy of the entities

→ Separation between the *mind* (defined by the aspects) and the *body* (defined by the roles)

→ Coherency of a system both at the global and local level

Dynamics

Dynamic of entities (1)



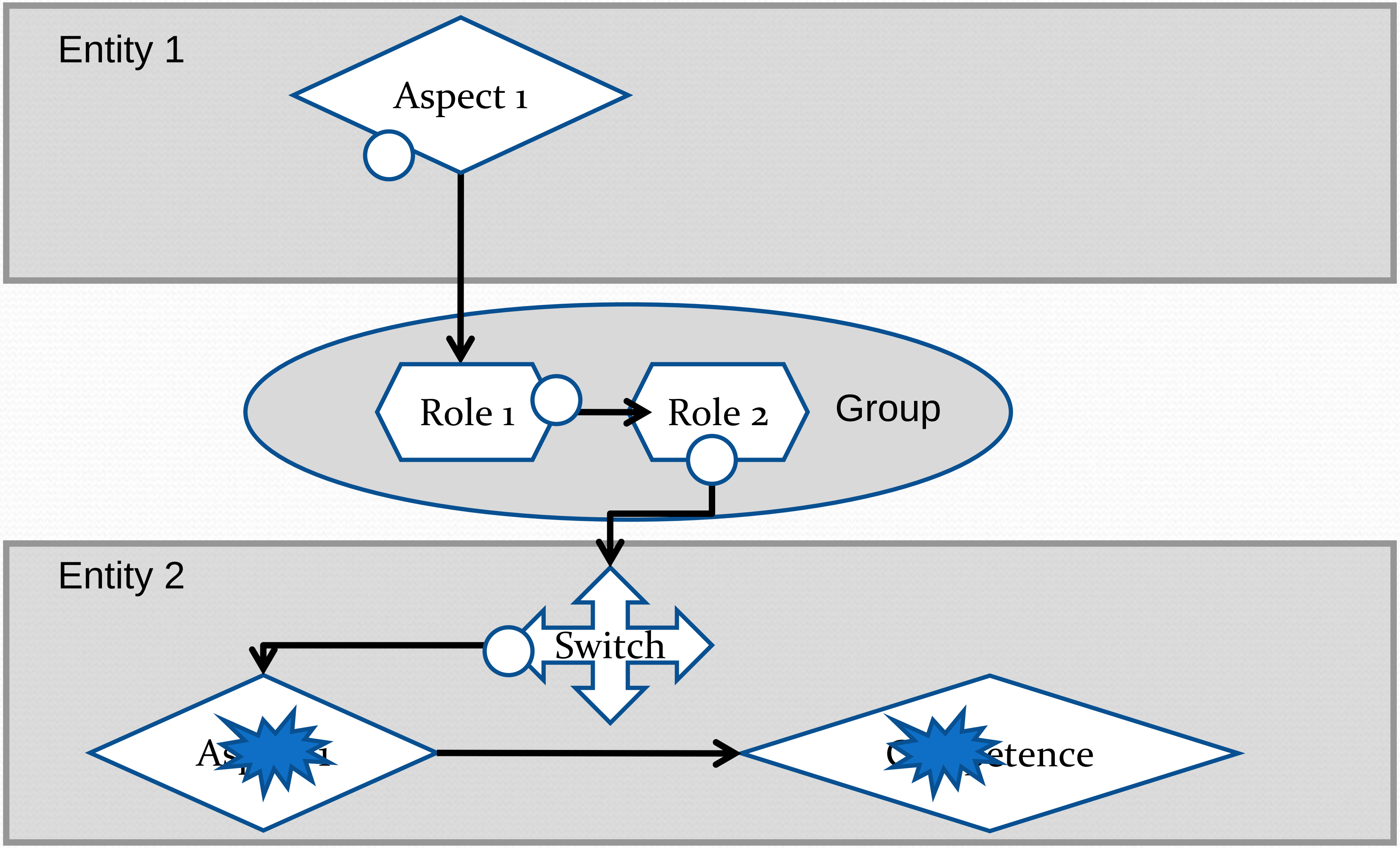
- external behaviour: Interactions between entities through the roles within the groups.

- Internal behaviour: defined by the dynamics of aspects and their interactions.

- Relations between external behaviour and local behaviour through the interactions between roles and aspects

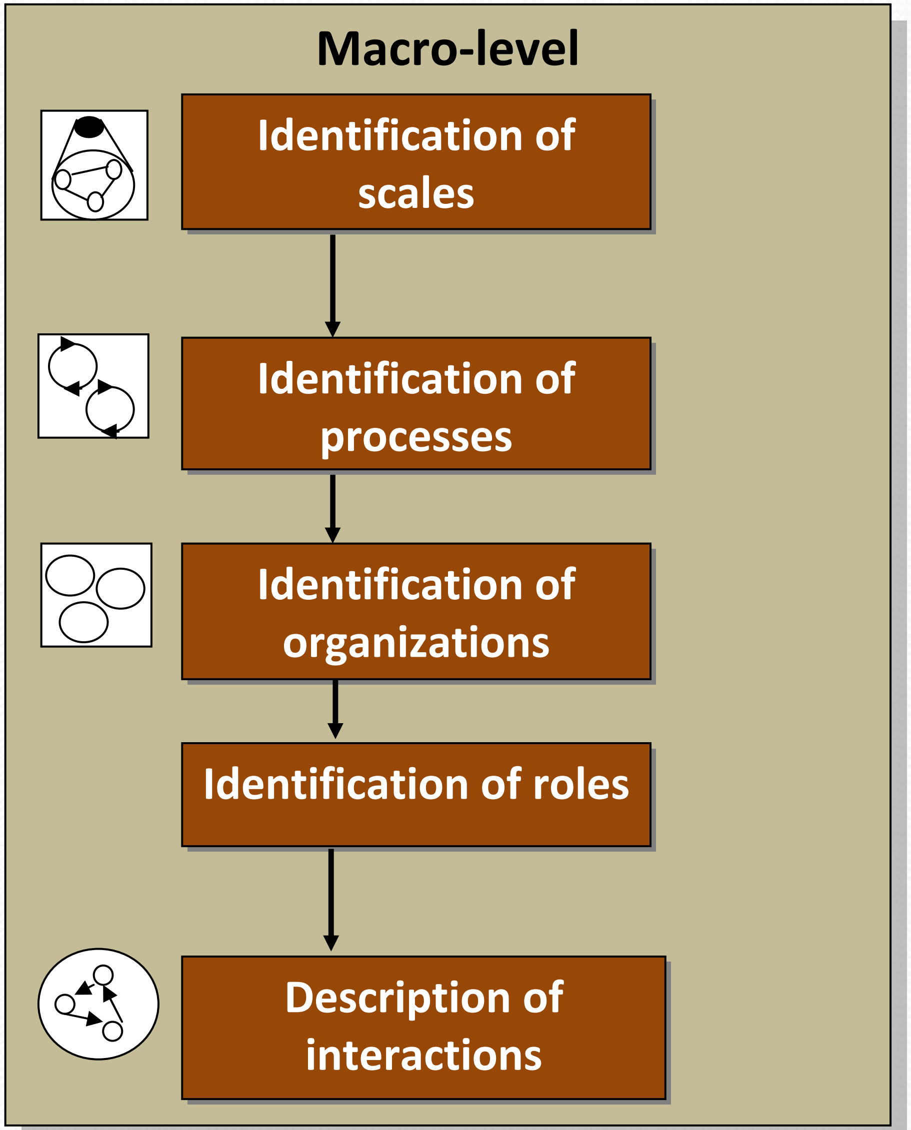
Separation of the organisational behaviour and the local behaviour of the entities

Dynamics of entities (2)



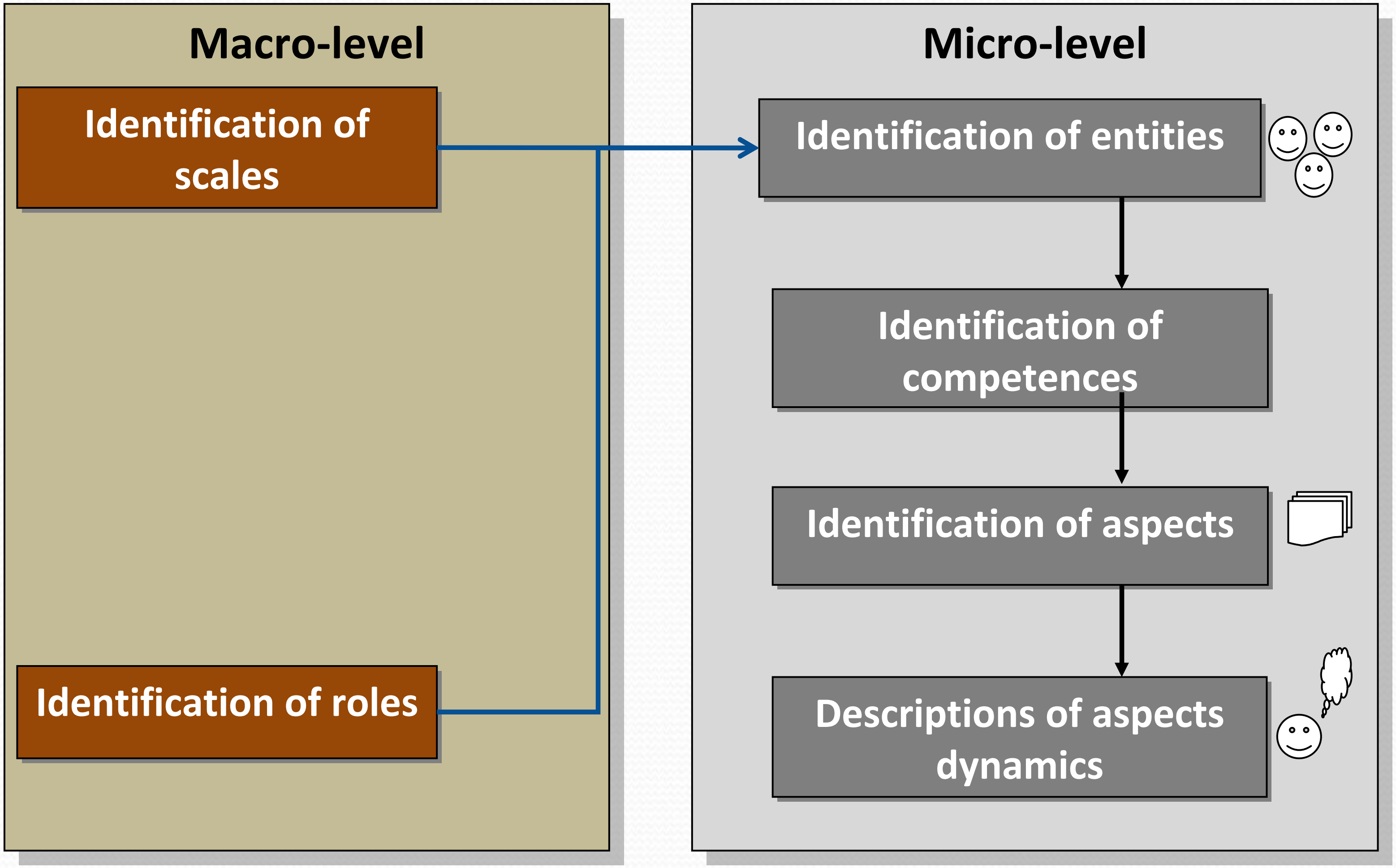
Interaction between two entities through their roles

Methodology of OREA (1)



Description of the macro-level by following the OREA methodology

Methodology of OREA (2)



Description of the micro-level by following the OREA methodology

Application of the OREA model: Conceptual model of the CaTMAS model

Issues of carbon dynamics

- Carbon resources : condition of viability of farming system in sub-Saharan Africa. It is a:
  - Economical good: human consumption, wood, fodder.
  - A means of production: control of fertility of tropical soil, maintain animal.

Problem: The carbon is declining in West African savannas (Ker, 1995)

- The carbon controls the global climatic change

➔ crucial to improve the carbon resource management from local agroecological and global environmental points of view

Carbon dynamics, a complex system

- Carbon resources : renewable resources

- Their management involves to apprehend the interactions between biological and social dynamics

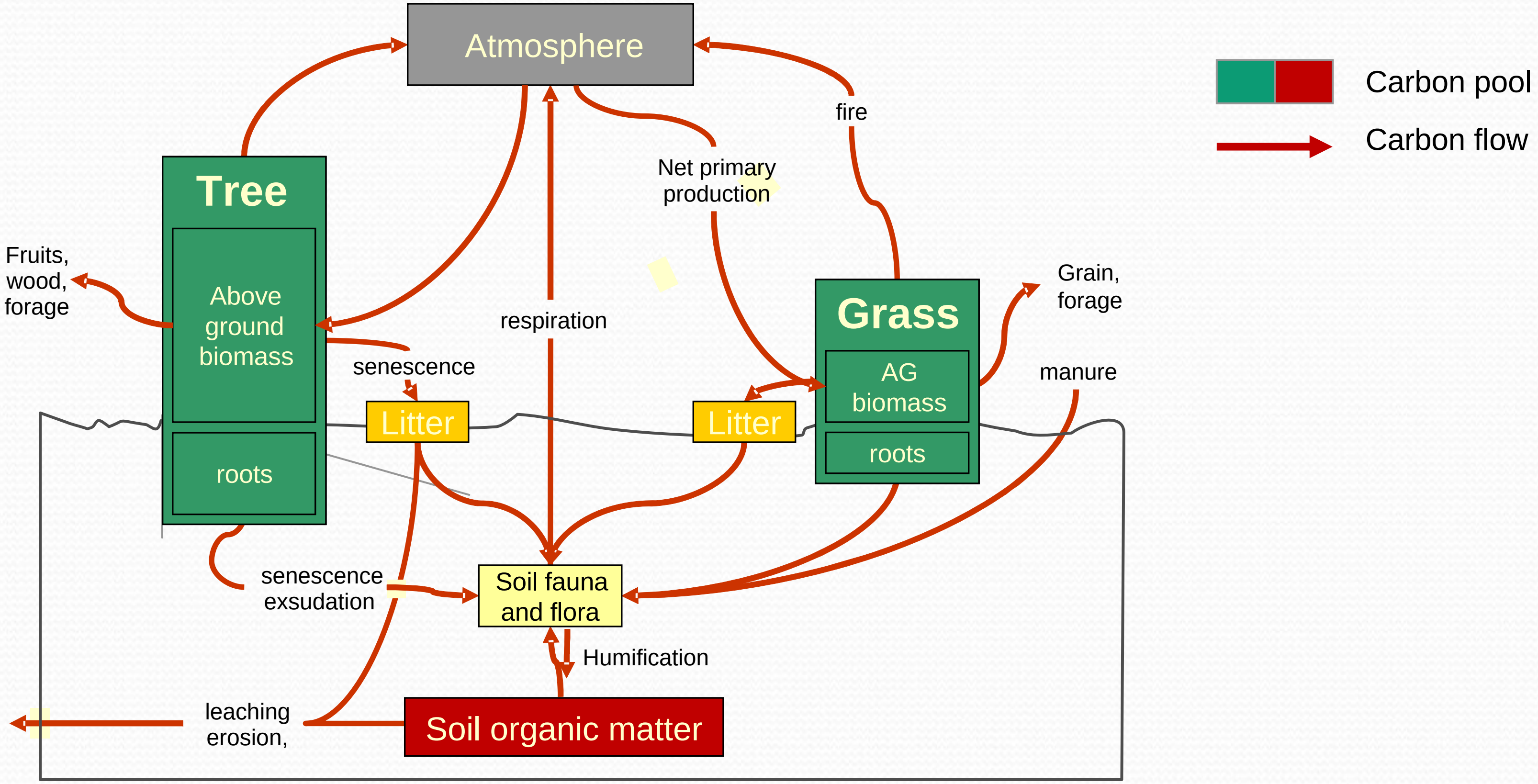
- The understanding of carbon dynamics requires considering five major factors: biological, social, physical, economical factors.

  - The analysis of carbon dynamics a multidisciplinary issue

- Carbon dynamics, a multilevel system: Plot, farm and territory levels

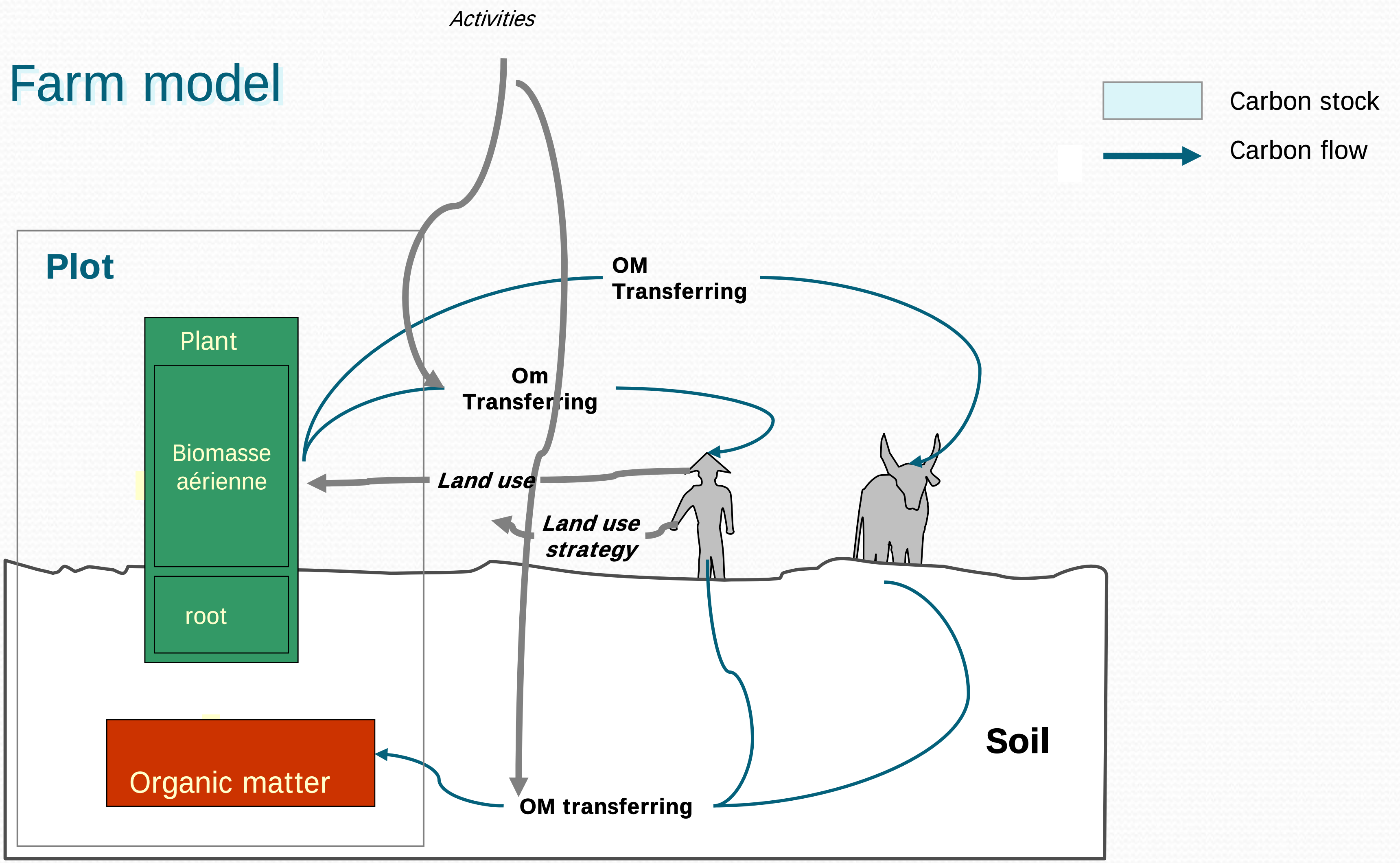
Carbon dynamics, a complex system

- Carbon dynamics at the plot level



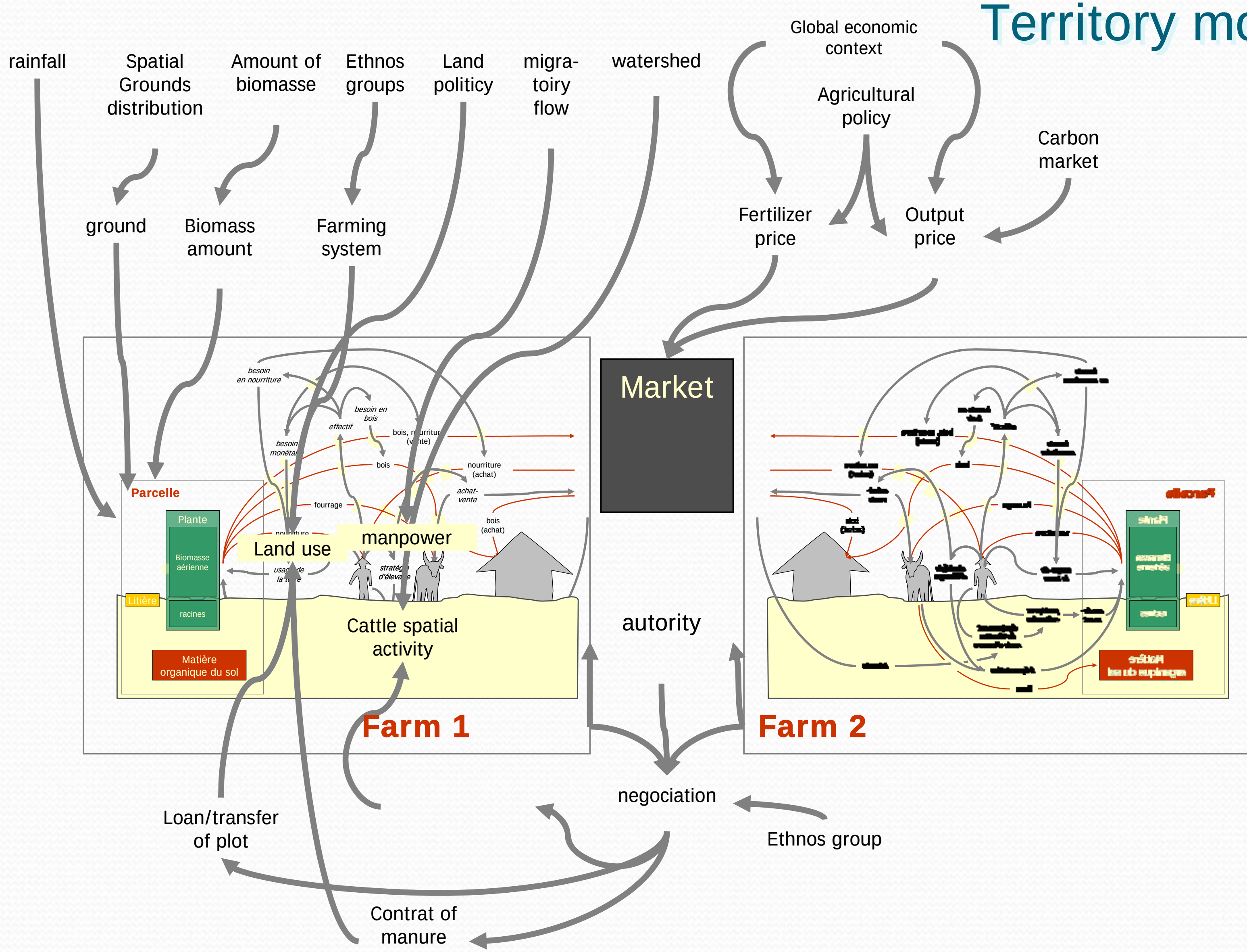
Carbon dynamics, a complex system

Farm model



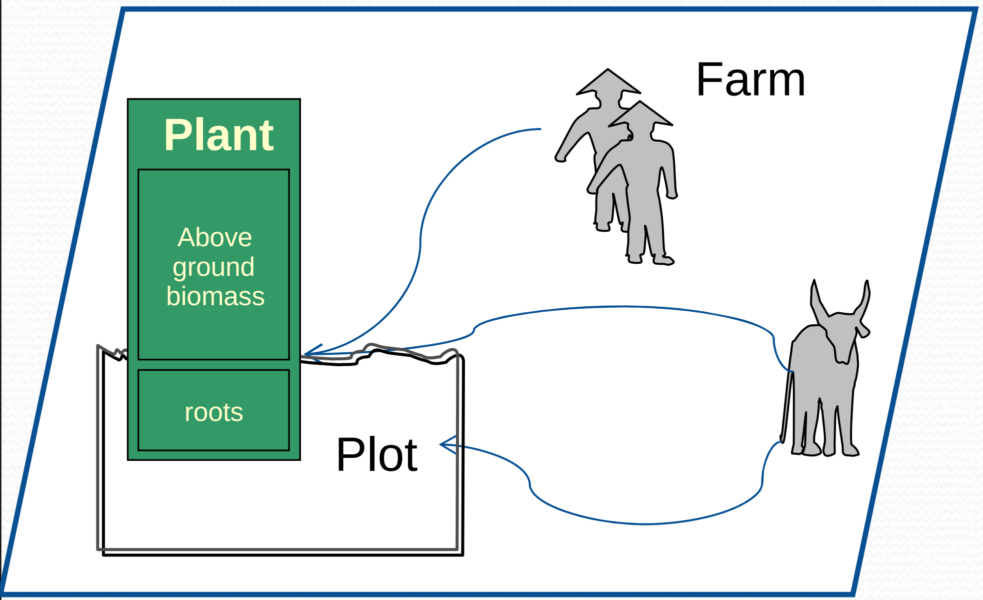
Carbon dynamics, a complex system

Territory model



Modelling carbon dynamics using OREA

The identification of the scales and processes



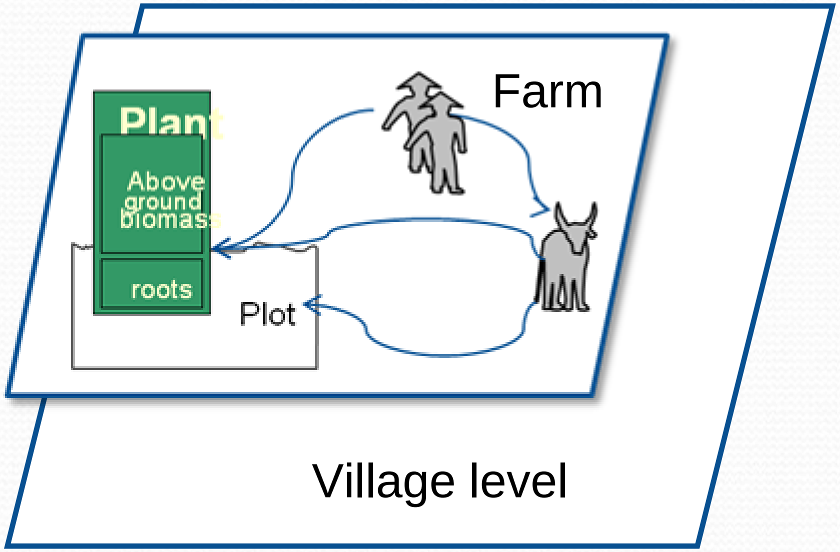
- plant production
- organic matter production
- organic matter exchange
- water exchange
- organic matter decomposition

- land-use change rules
- fertility management

The processes at plot scale

Modelling carbon dynamics using OREA

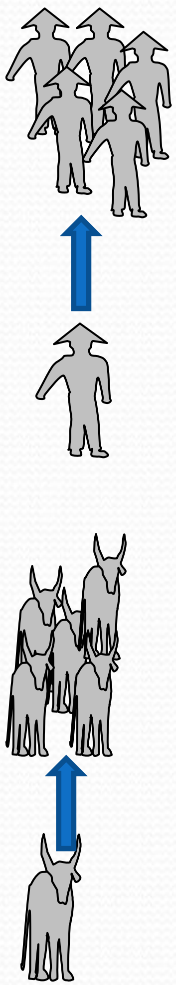
The identification of the scales and processes



- organic matter market
- labour force exchange, land exchange (plot allocation, purchase, hiring)
- climate change
- global economy change

Modelling carbon dynamics using OREA

The identification of the scales and processes



Family

- economy of households
- animals production
- cropping system

Person

- ageing, birth, death, migration

Social scales

Herd

- pasture dynamics
- Ingestion
- Excretion

Animal

- cycle of production (ageing, birth, death, growing, selling, purchase)

Modelling carbon dynamics using OREA

Identification of organisations

- Land allocation

Land tenure

- plant production
- land-use change rules
- fertility management
- cropping system

Crop production

Production

- Pastoral dynamics
- Ingestion
- Excretion
- animal cycle of production (ageing, birth, death, growing, selling)

Animal production

- organic matter decomposition
- organic matter production

OM transformation

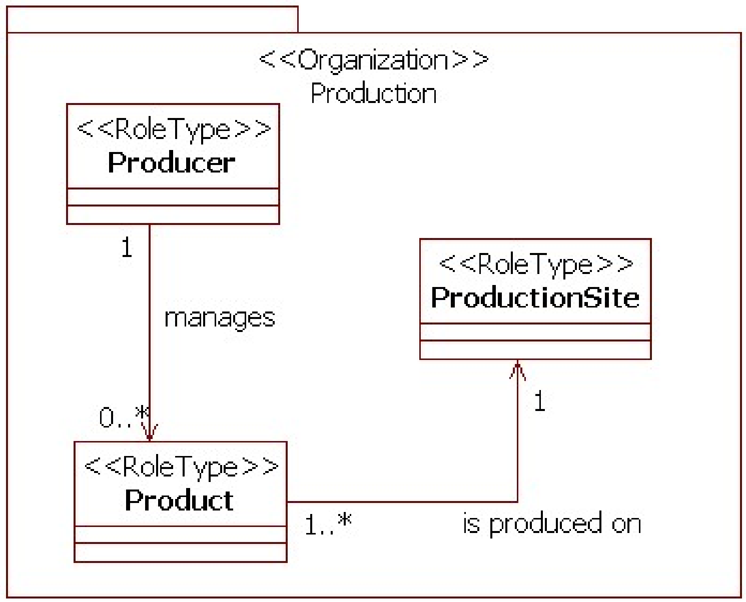
- organic matter market
- Goods exchange

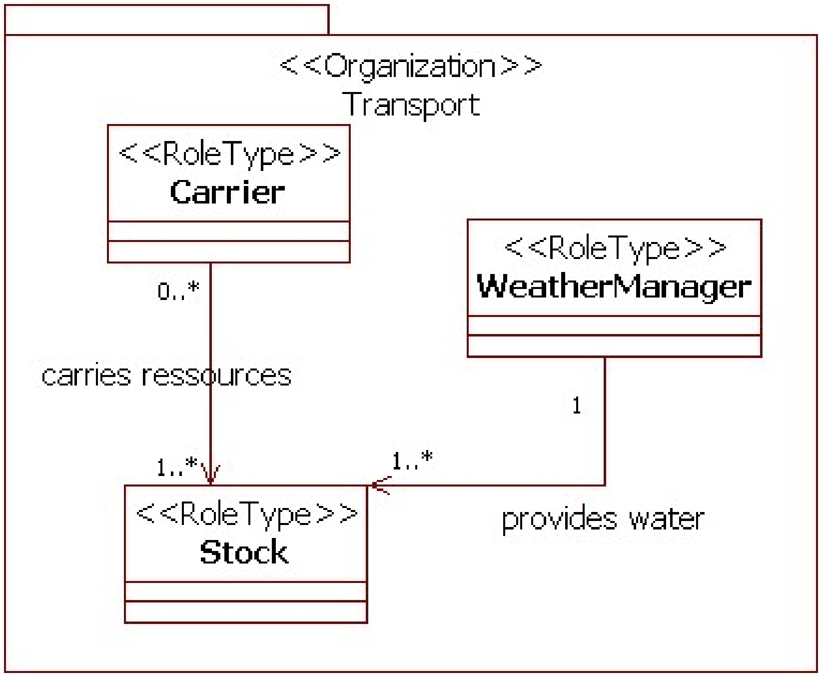
Market

Modelling C dynamics using OREA

Description of organisations

Description of the animal and plant production



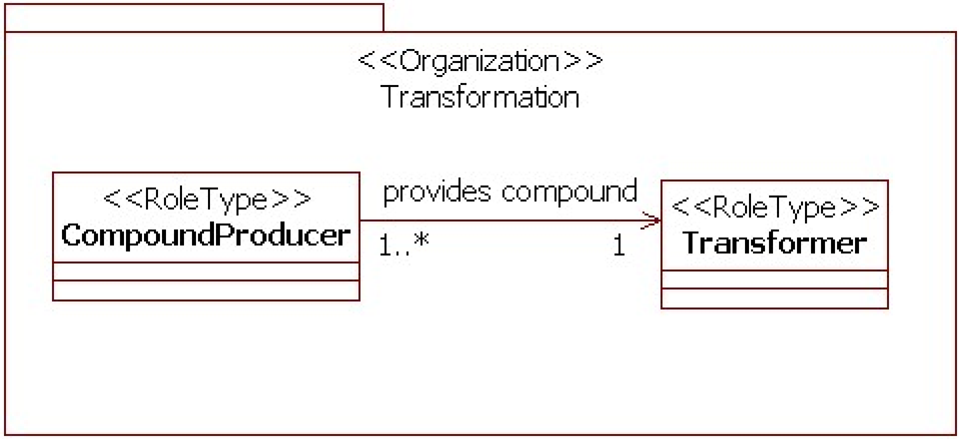


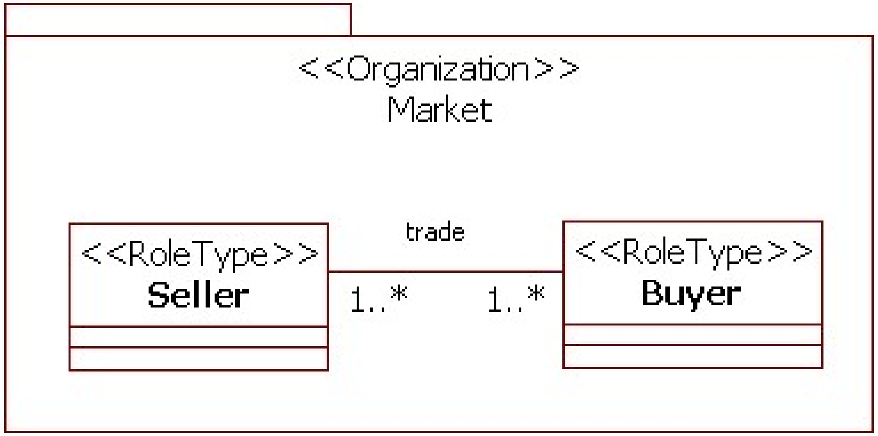
Description of the C flows (storage and transport of resources) between entities

Modelling carbon dynamics using OREA

Description of organisations

Description of the organic matter transformation through the interactions between ***CompoundProducer*** and ***Transformer*** roles

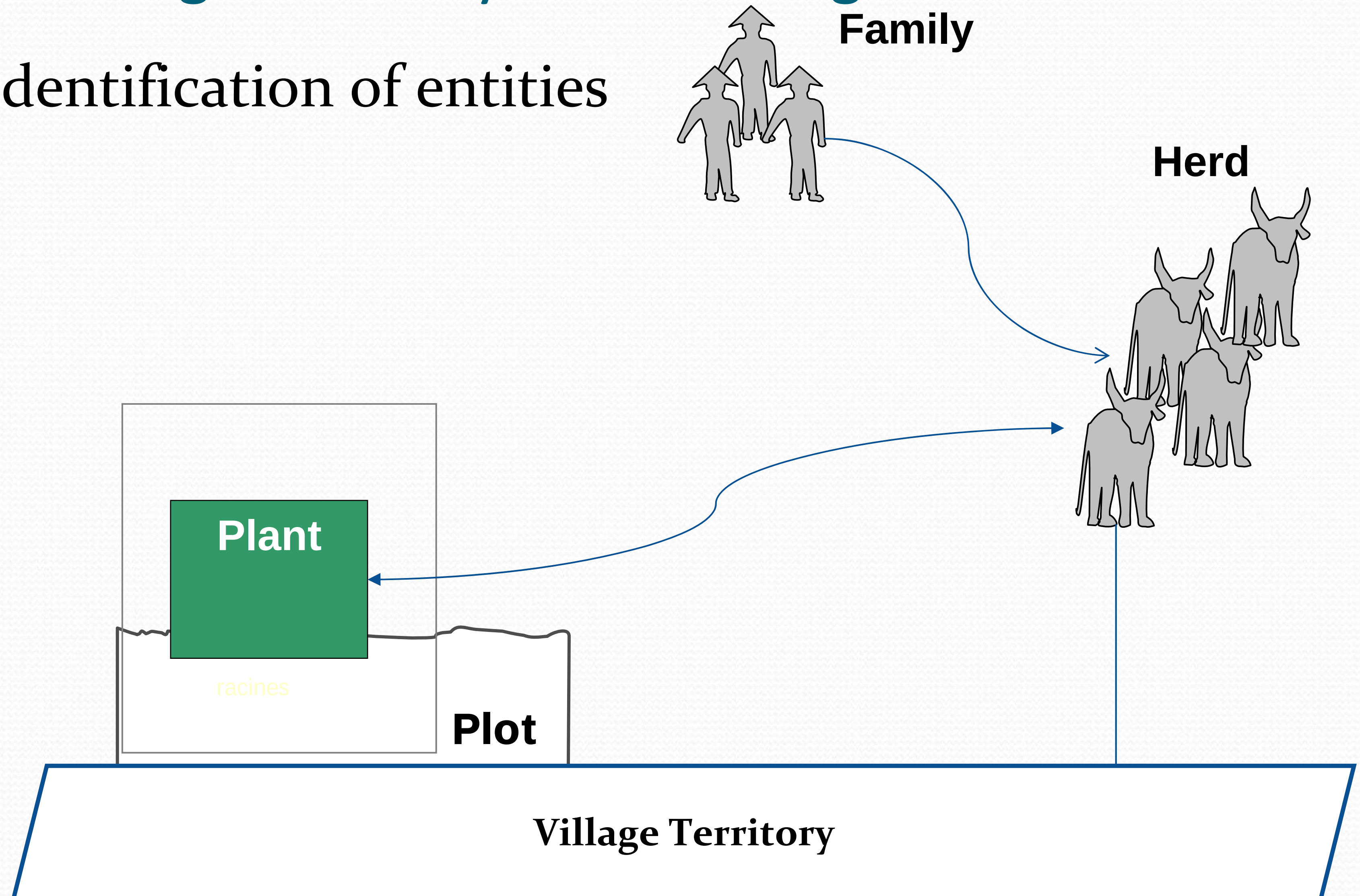




Description for the organic matter exchange

Modelling carbon dynamics using OREA

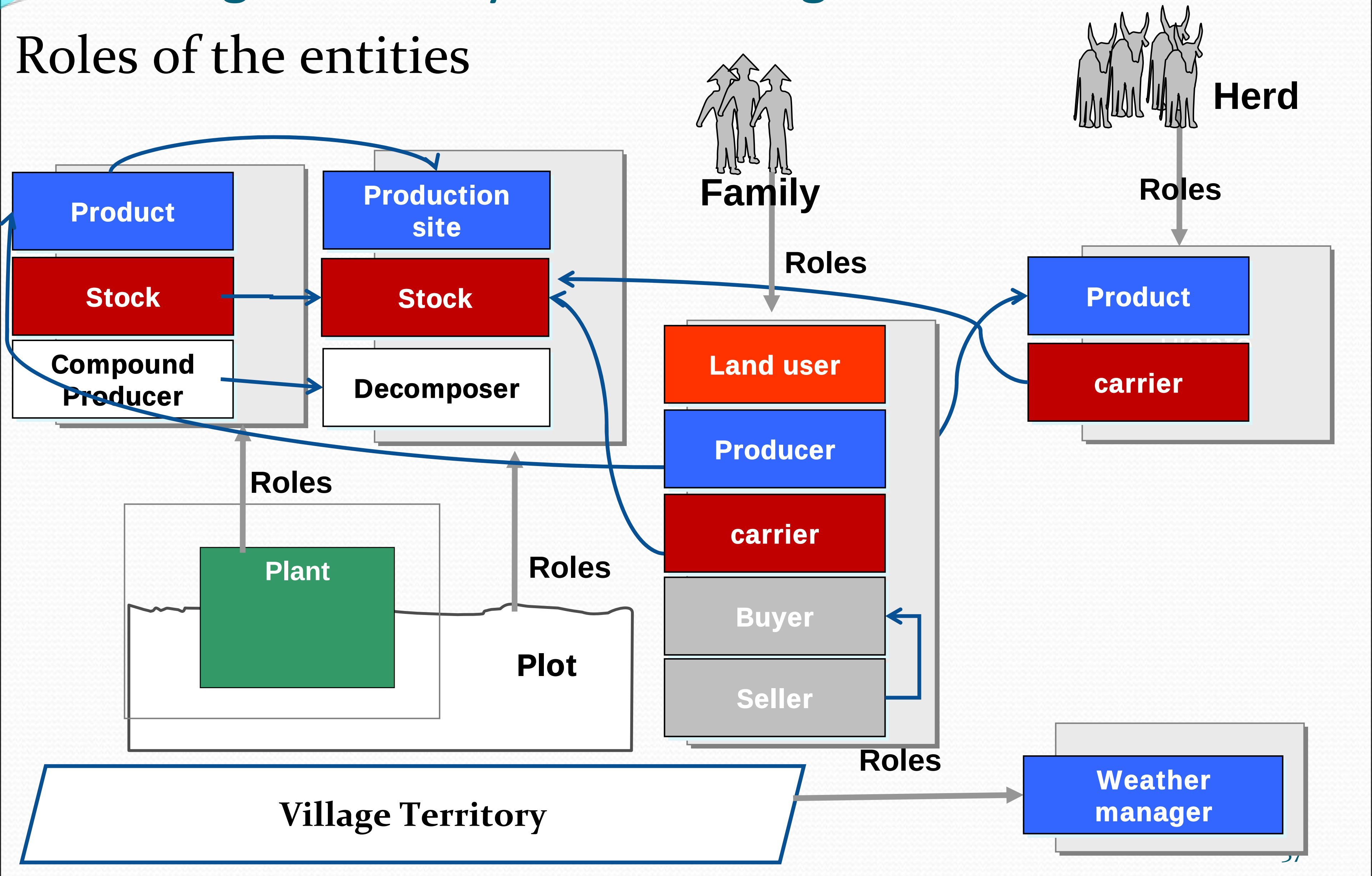
Identification of entities



The identification of the entities

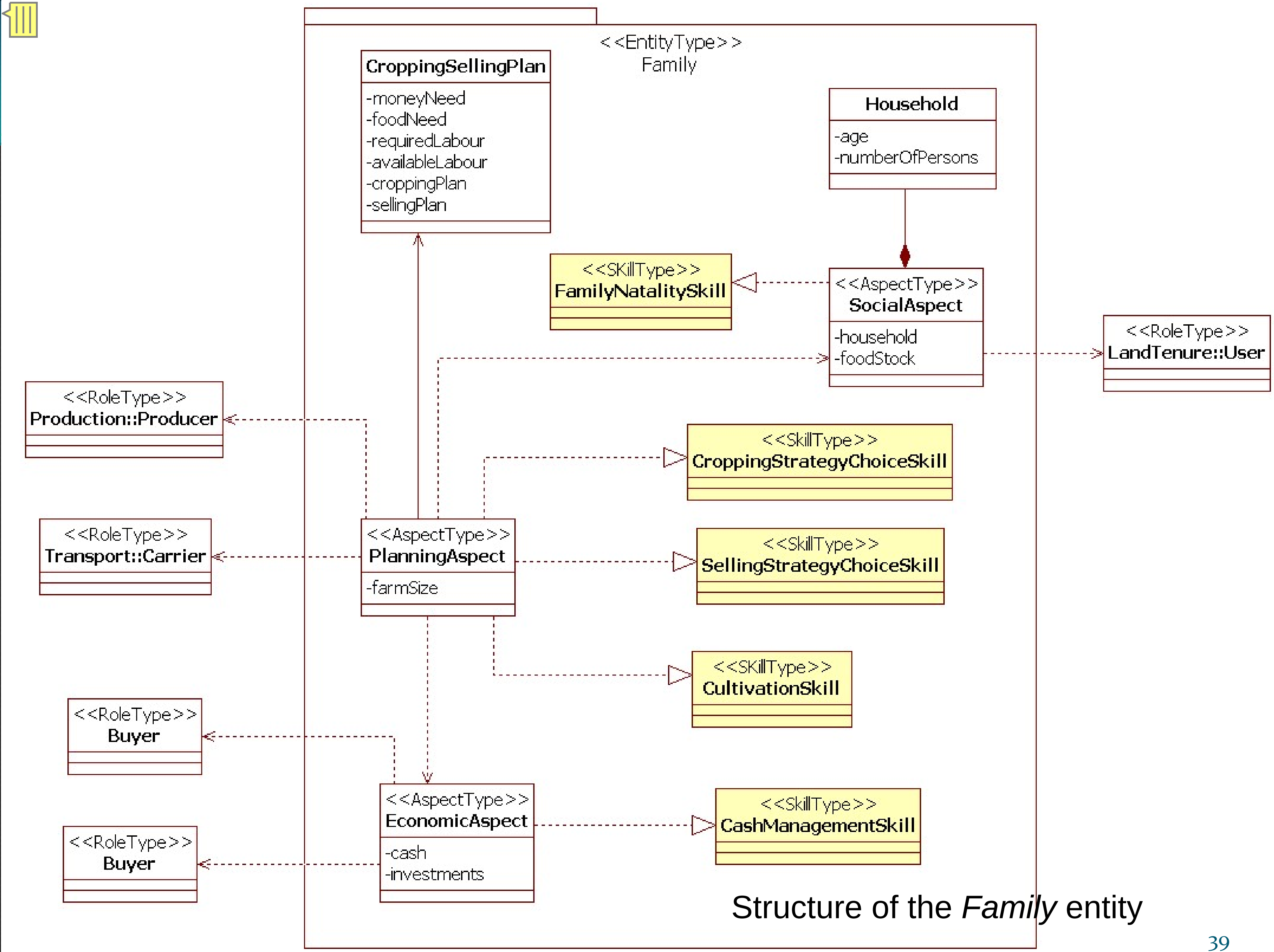
Modelling carbon dynamics using OREA

Roles of the entities



Modelling carbon dynamics using OREA

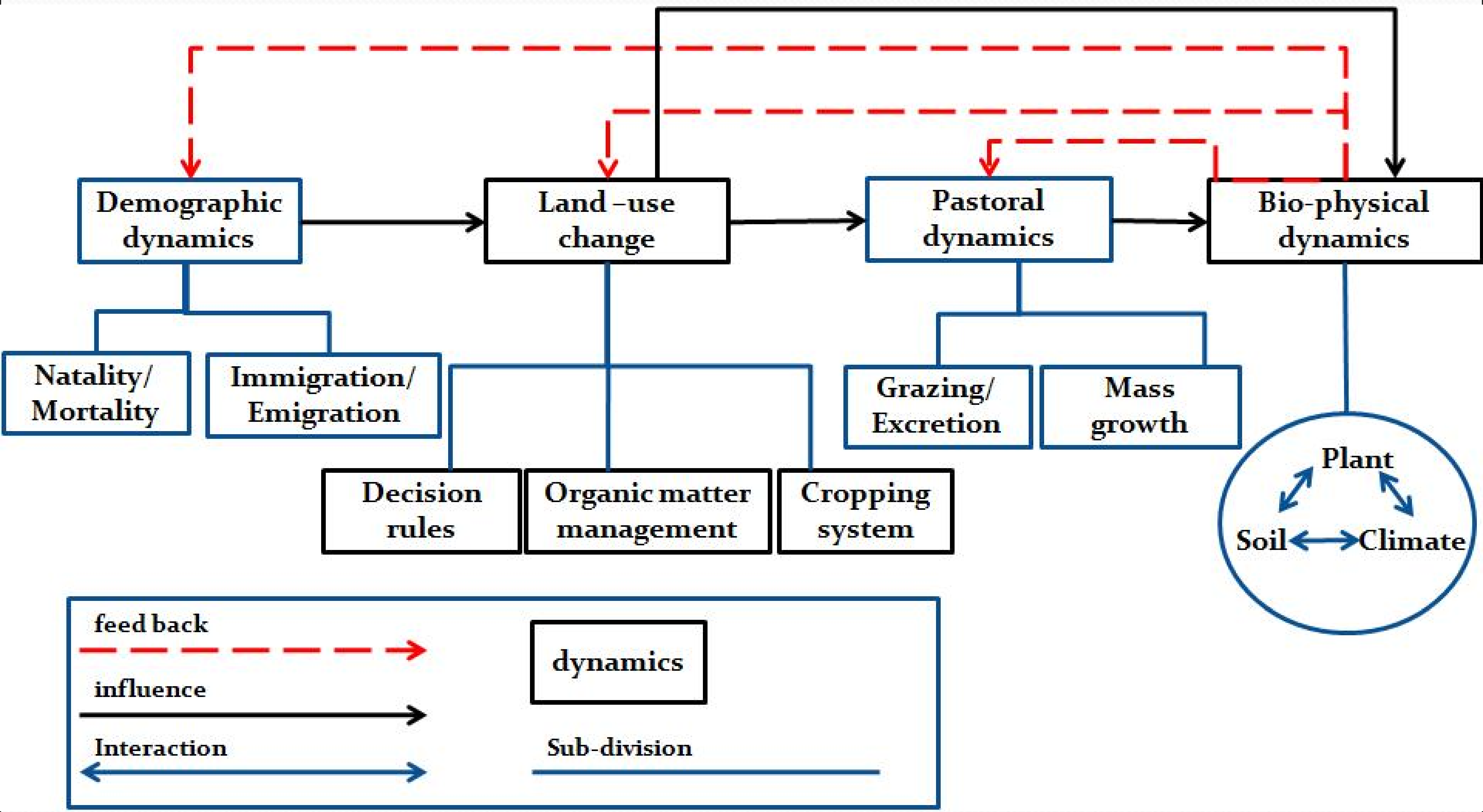
Description of the entities from internal and external point of view



Structure of the *Family* entity

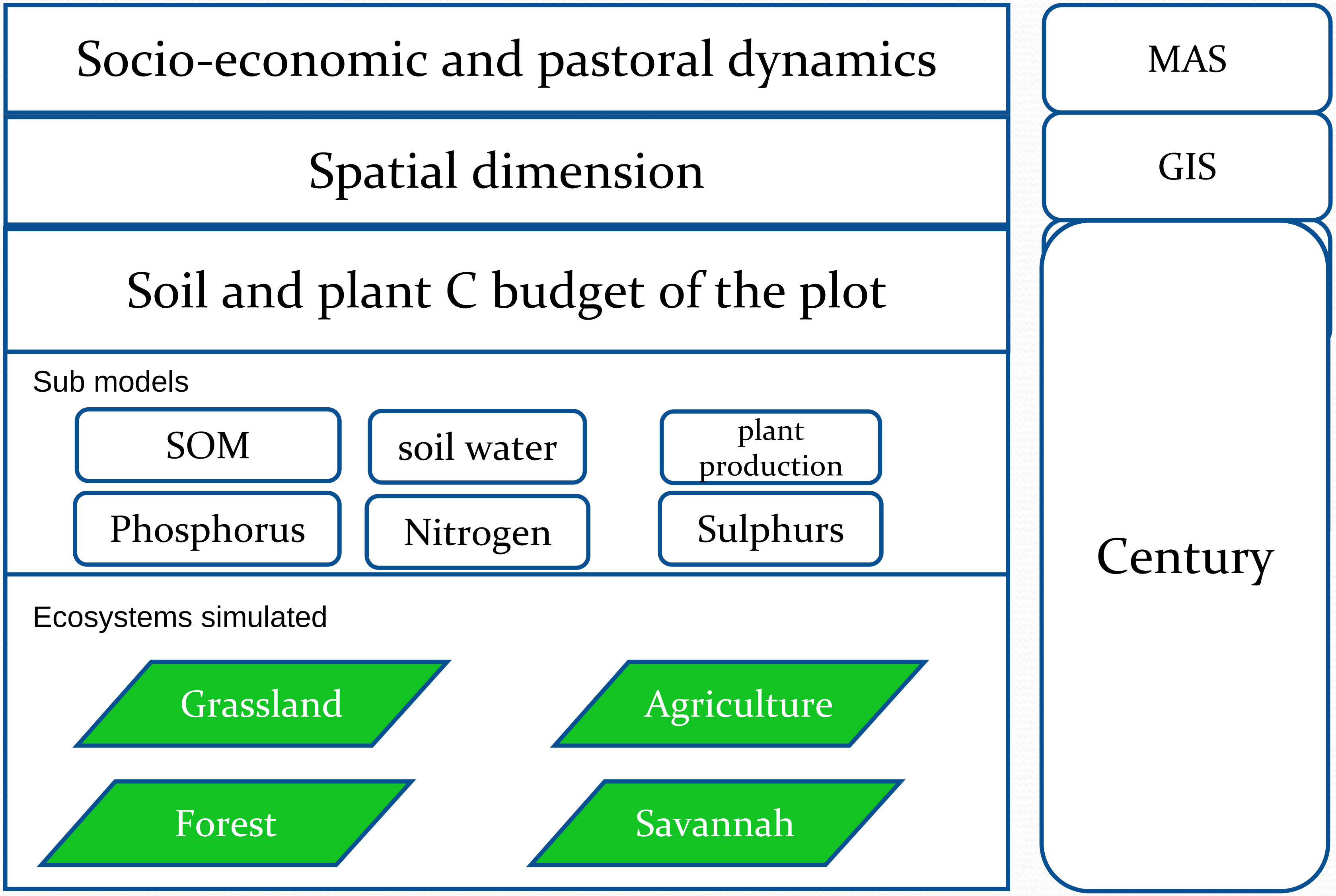
Implementation of the CaTMAS model

An integrated model



Dynamics of the CaTMAS model

An integrated model: Coupling with Century and GIS



Coupling CaTMAS with the Century model and GIS

Experimentations

- Case study based on a virtual village

- Comparison of two contrasted cropping system and the impact of the climate change on the C dynamics

Experimentations: simulated cropping systems

Semi-continuous system (SCS)

1	2	3	4	5
Yam	**Maize**	**Sorghum**	**Sorghum**	**Sorghum**

Continuous system (CS)

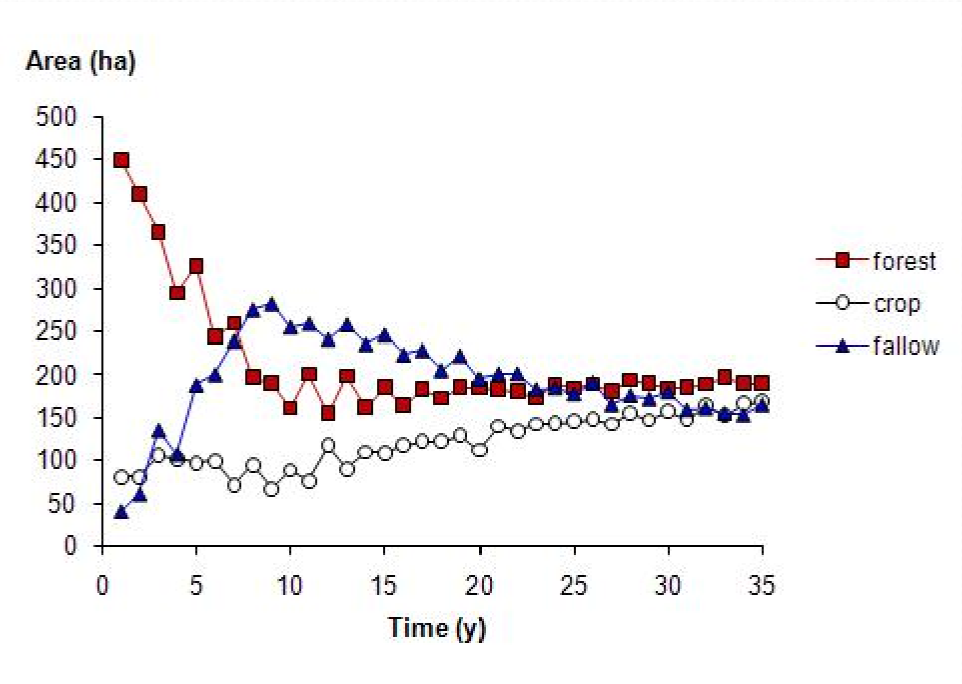
1	2	3	4	5	6
Maïs	**Coton**	**Maize**	**Sorghum**	**Sorghum**	**Sorghu m**

Experimentations: Three climate scenarios

- C_0: the present precipitation and temperature.
- C_+: is a 1.5° C increase in mean monthly temperature and a 25 mm decline in annual precipitation
- C_{++}: is a 3° C increase in mean monthly temperature and a 50 mm decline in annual precipitation
-

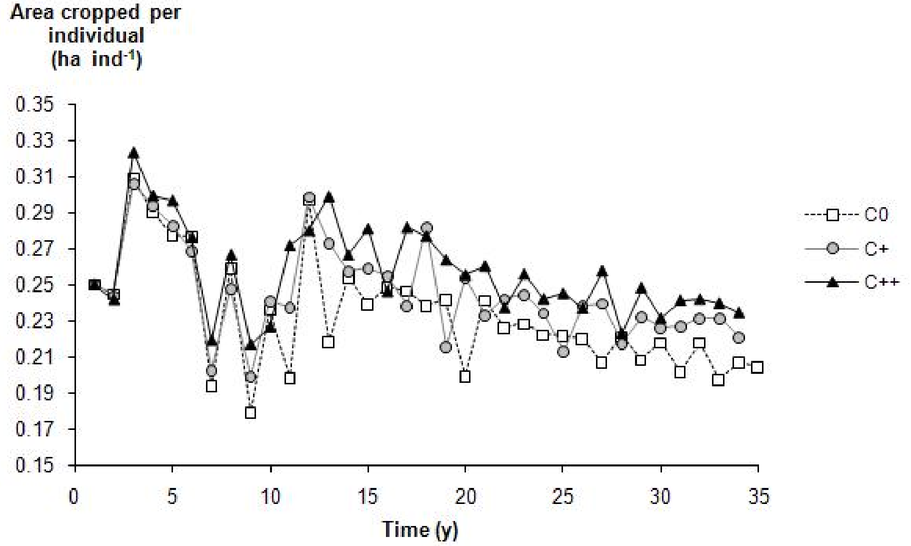
Results

Results: Impact of population on land-use change



Simulated land-use change in scenario C_0

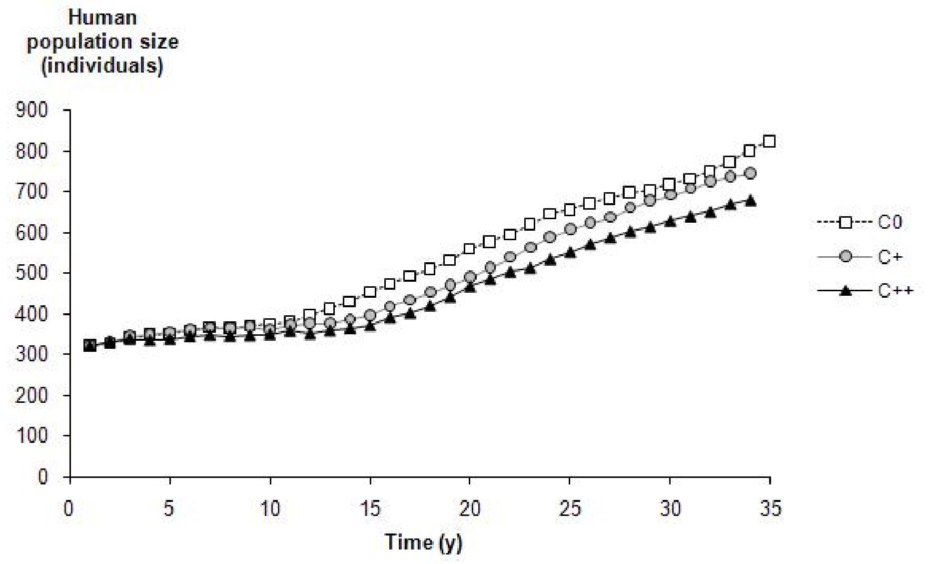
Results: Impact of population on land-use change



Simulated cultivated area per capita

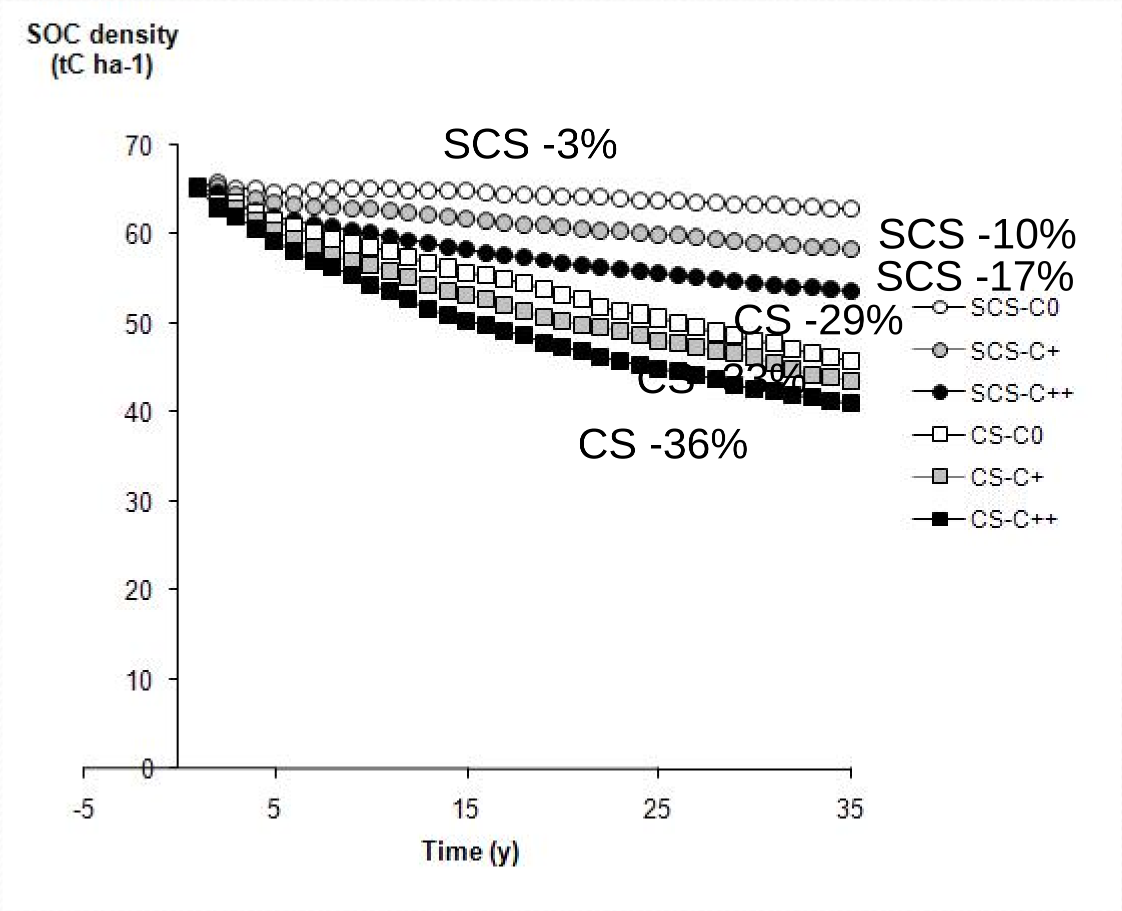
Higher cultivated area per capita in C_{++} than in C_+ and C_0 despite a lower level of population.

➢Increase of the cultivated area with the low crop yields.



Simulated population evolution

Results: Impact of climate change on C sequestration



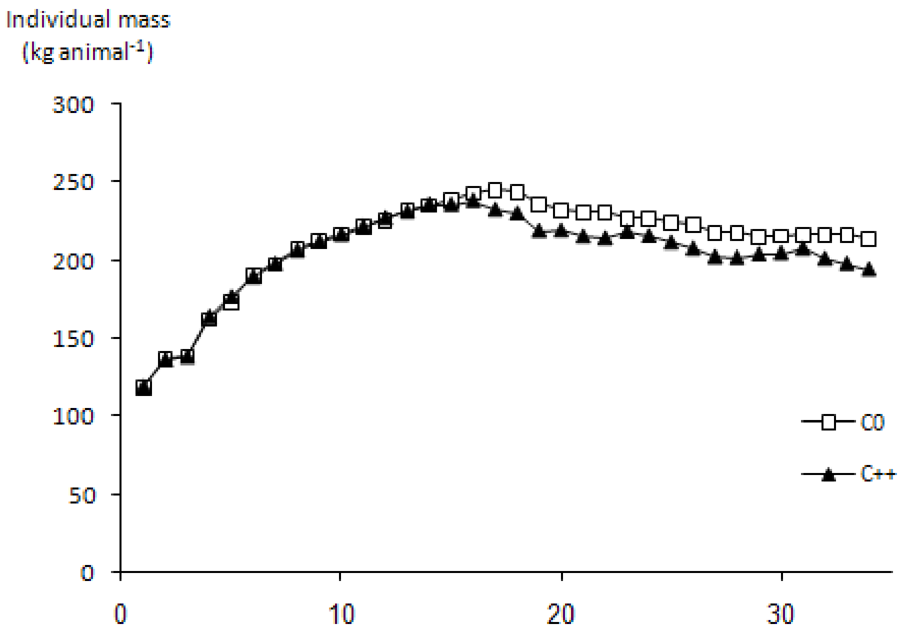
Higher SOC density in SCS systems than in CS

Important impact of climate change on the C sequestration

Vulnerability of the SCS to the climate change

SOC density in SCS and SC in the scenarios C1, C2 and C3

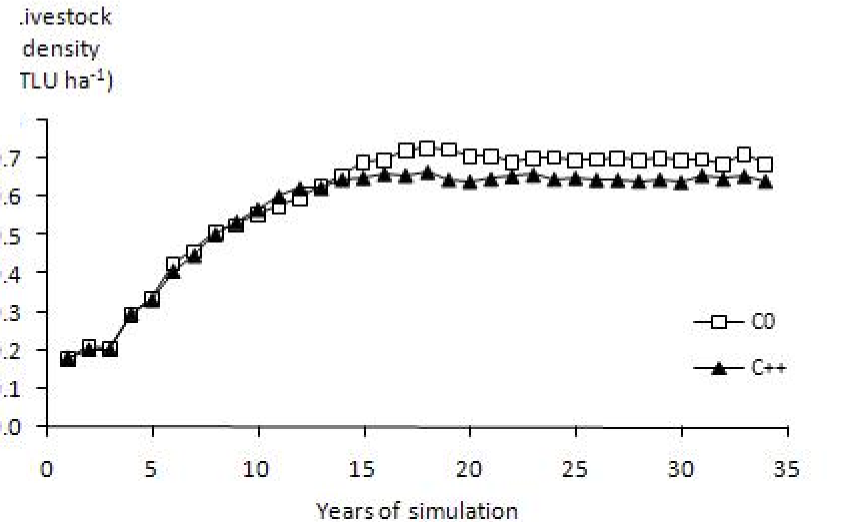
Results: Impact of climate change on pastoral dynamics



Low individual mass and animal density in C_{++} in comparison with C_0.

Decrease and settling down of the animal mass and density after 15 years of simulation

The response of animal mass evolution to the climate change



The evolution of the livestock in the response to the climate change

Conclusion and perspectives

- OREA model
  - separation between macro-level and micro-level
  - Guarantying the coherence from the local and global point of view
  - Representation of environment
- Perspectives:
  - the hierarchical representation
  - Relations *micro to macro* and *macro to micro*
  - the role dependencies and incompatibilities

Conclusion and perspectives

- CatMAS model
  - Provides a realistic representation of the C dynamics
  - Simulates the relationships between population and resources based on Malthus approach
  - Takes into account the C production, storage and transformation
  - Applicable to different cases study
- Perspectives:
  - Application of the model at a large scale (region, country)
  - taking into account the economic returns of the C sequestration.
  - Implementation of user interface
  - Simulation of a real system

A CONCEPTUAL MODEL FOR MULTIPOINTS OF VIEW ANALYSIS OF COMPLEX SYSTEMS. APPLICATION TO THE ANALYSIS OF THE CARBON DYNAMICS OF VILLAGE TERRITORIES OF THE WEST AFRICAN SAVANNA

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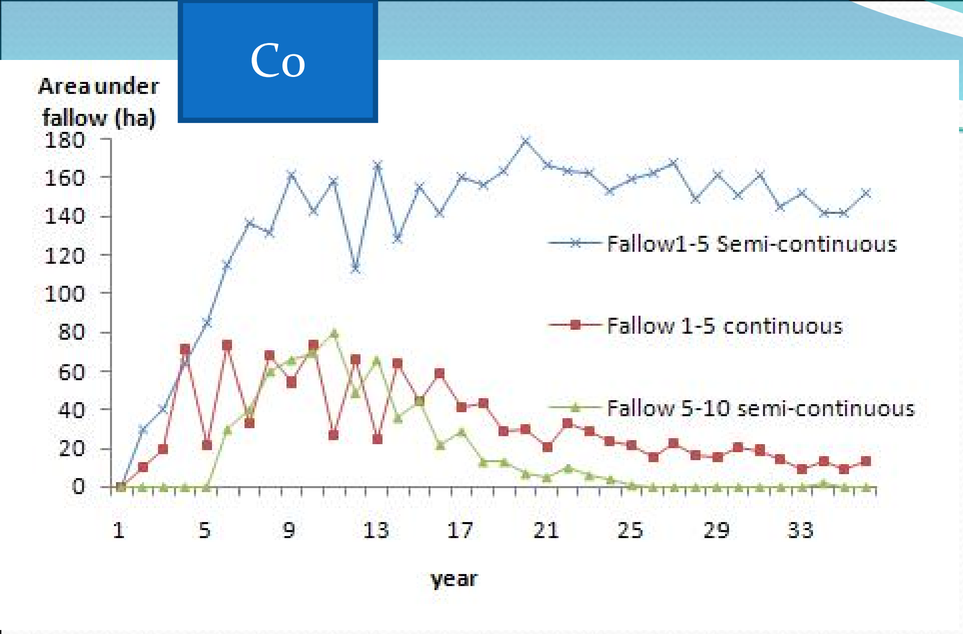
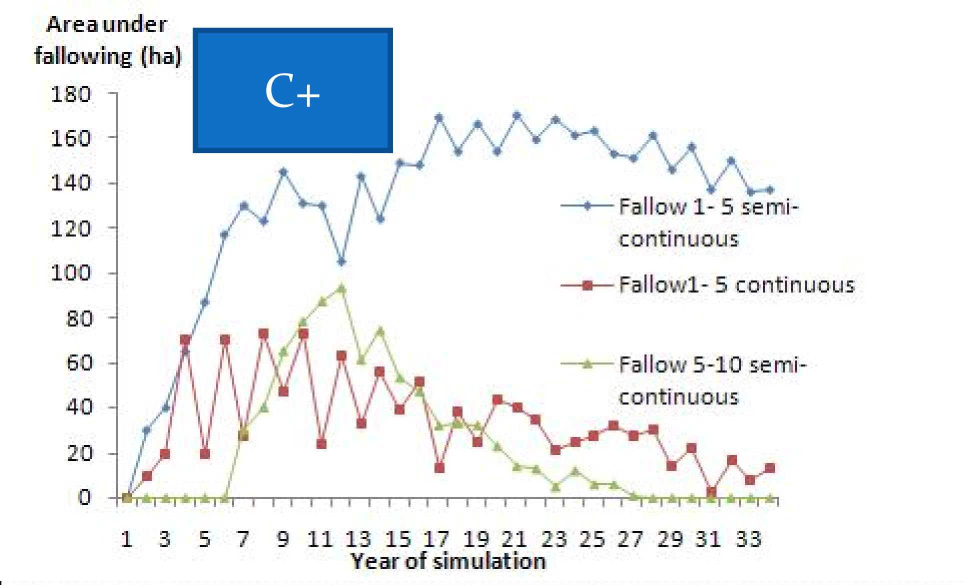


High followling lenght in SCS system than in CS system

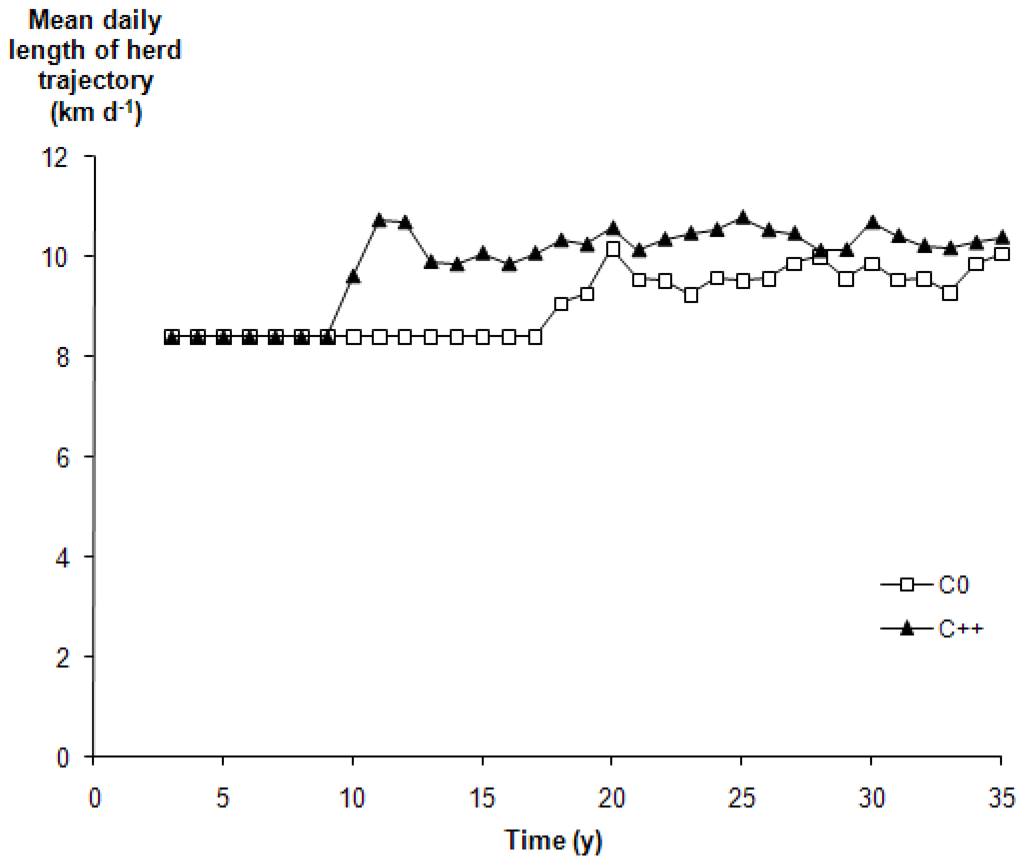
Emergence of two new cropping systems

Simulated following length in SCS and CS system in scenario C0



Simulated following length in SCS and CS system in scenario C+

Results: Impact of climate on pastoral activities



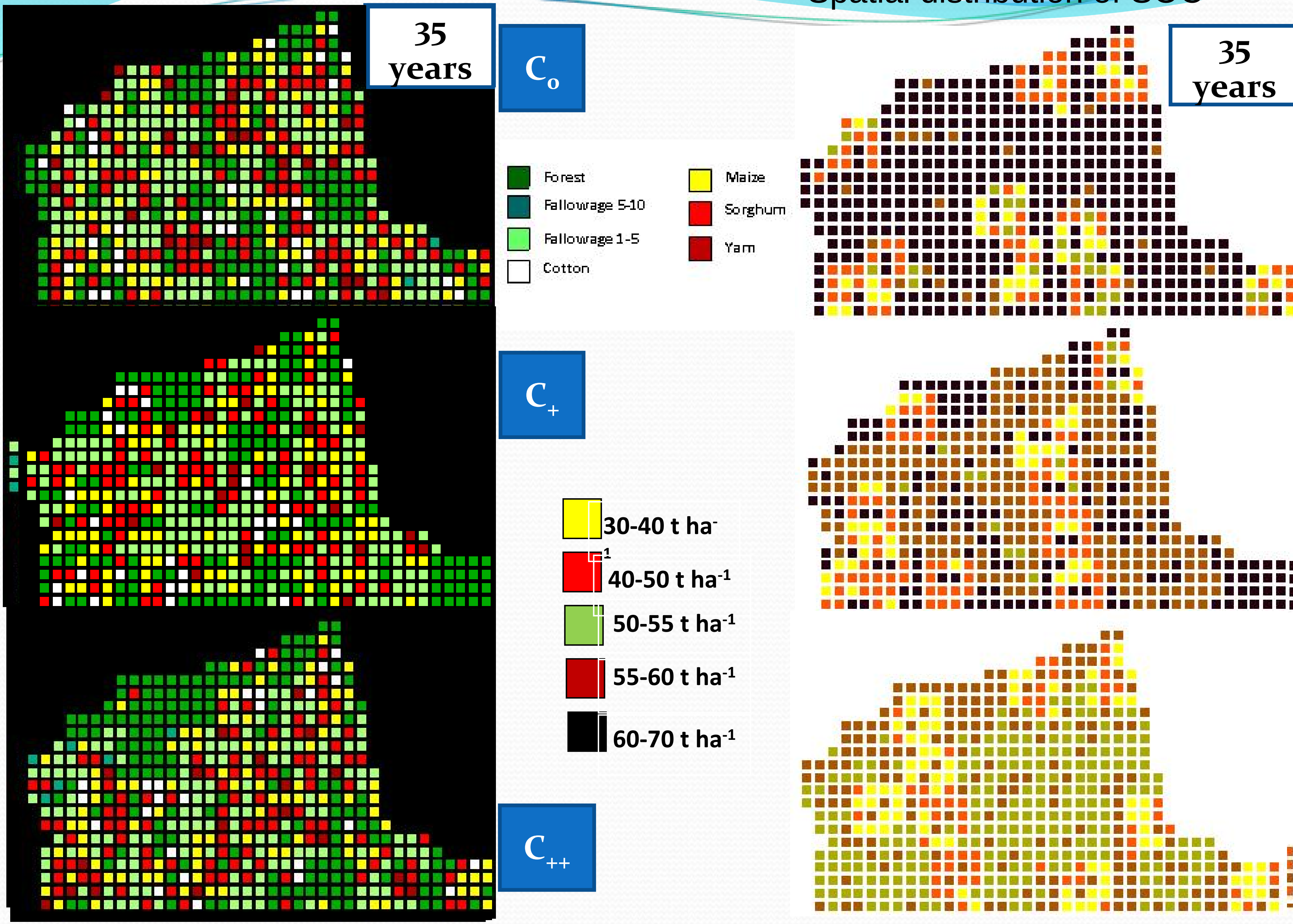
High pastural length in C++

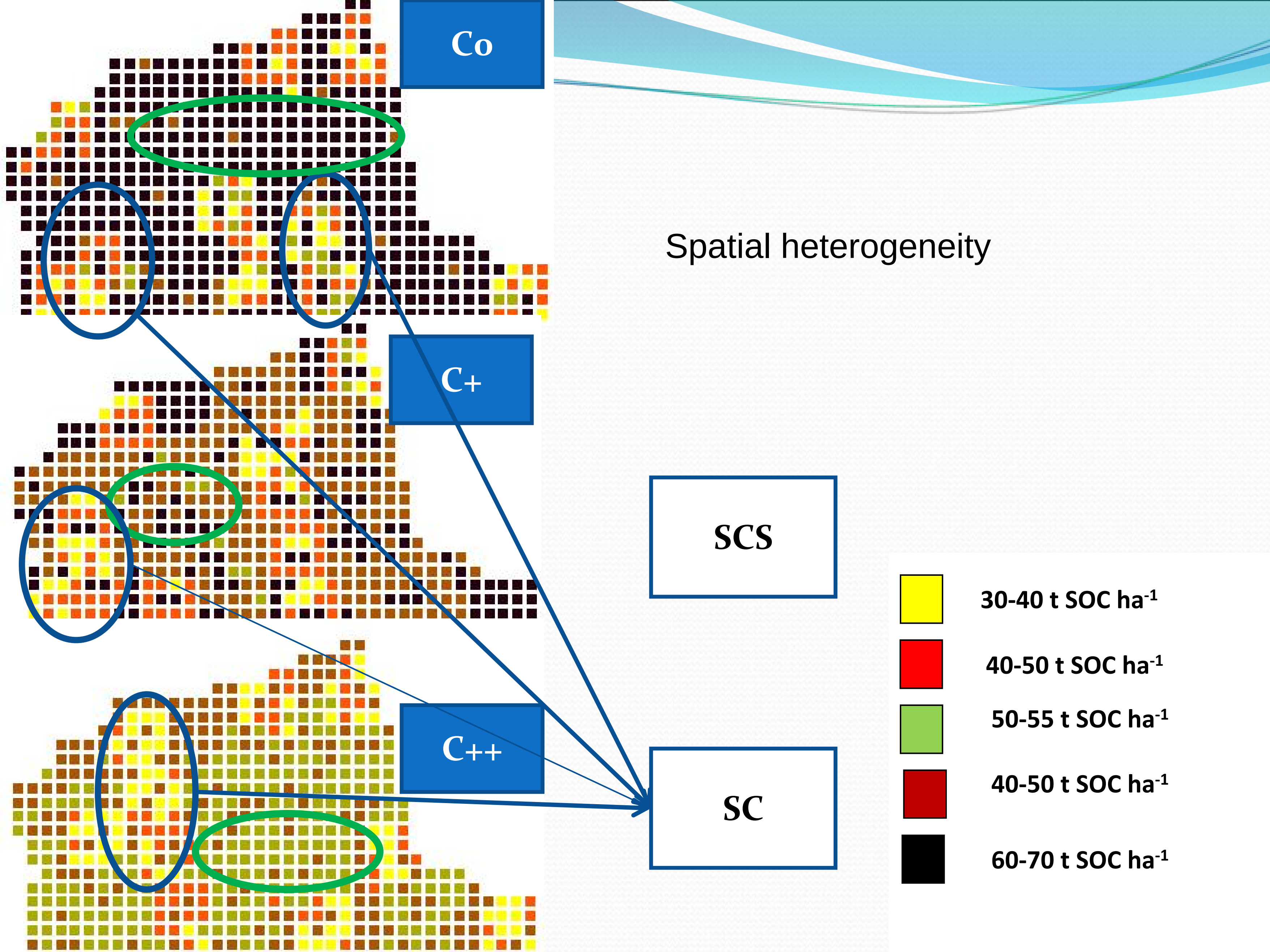
- ➢Decrease in the biomass production .
- ➢Increase in the cultivated area

Evolution of pastoral length under two climate scenarios: C0 and C++

Land occupation

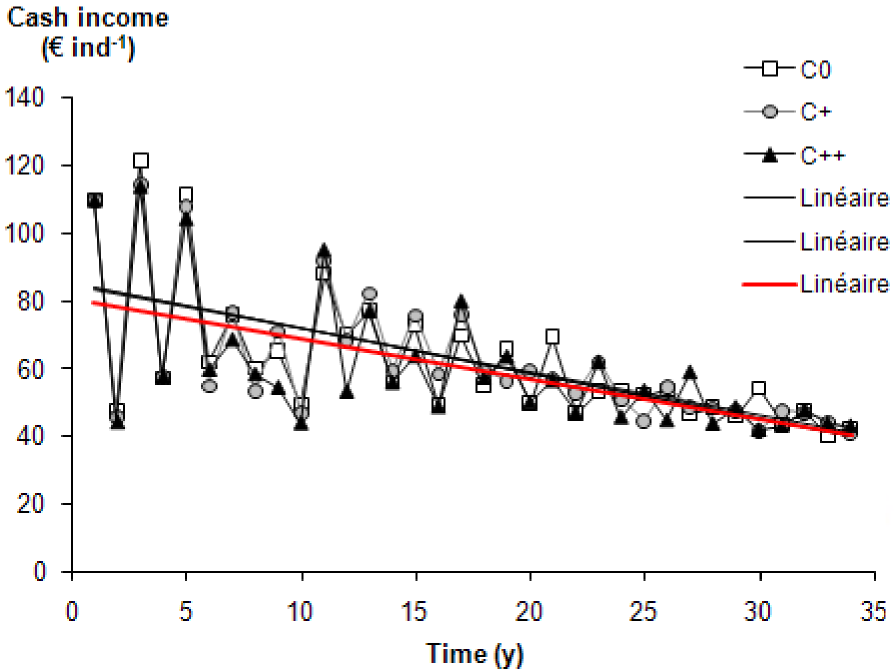
Spatial distribution of SOC



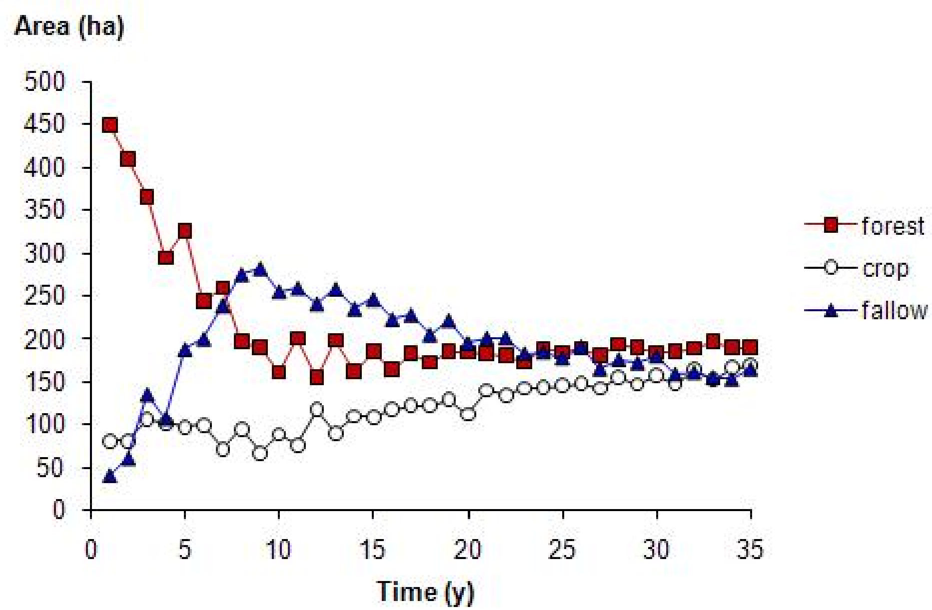


Spatial analysis of the cropping system and climate impacts on C sequestration

Results: impacts of climate change on cash income



Cash income per capita in three climate scenarios



Simulated land-use change in scenario C_0