Participatory design of agroecological systems

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Outline

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- Biophysical system modeling
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Agroecology and ecosystem services

Agroecology is the science and practice of applying ecological principles and knowledge to the design and management of sustainable agroecosystems

Basic principle = promote practices that:

- enhance regulation and provisioning ecosystem services
- drastically reduce external inputs (synthetic chemical pesticides and fertilizer, and fossil fuel)
- develop agroecosystem resilience

Motivation

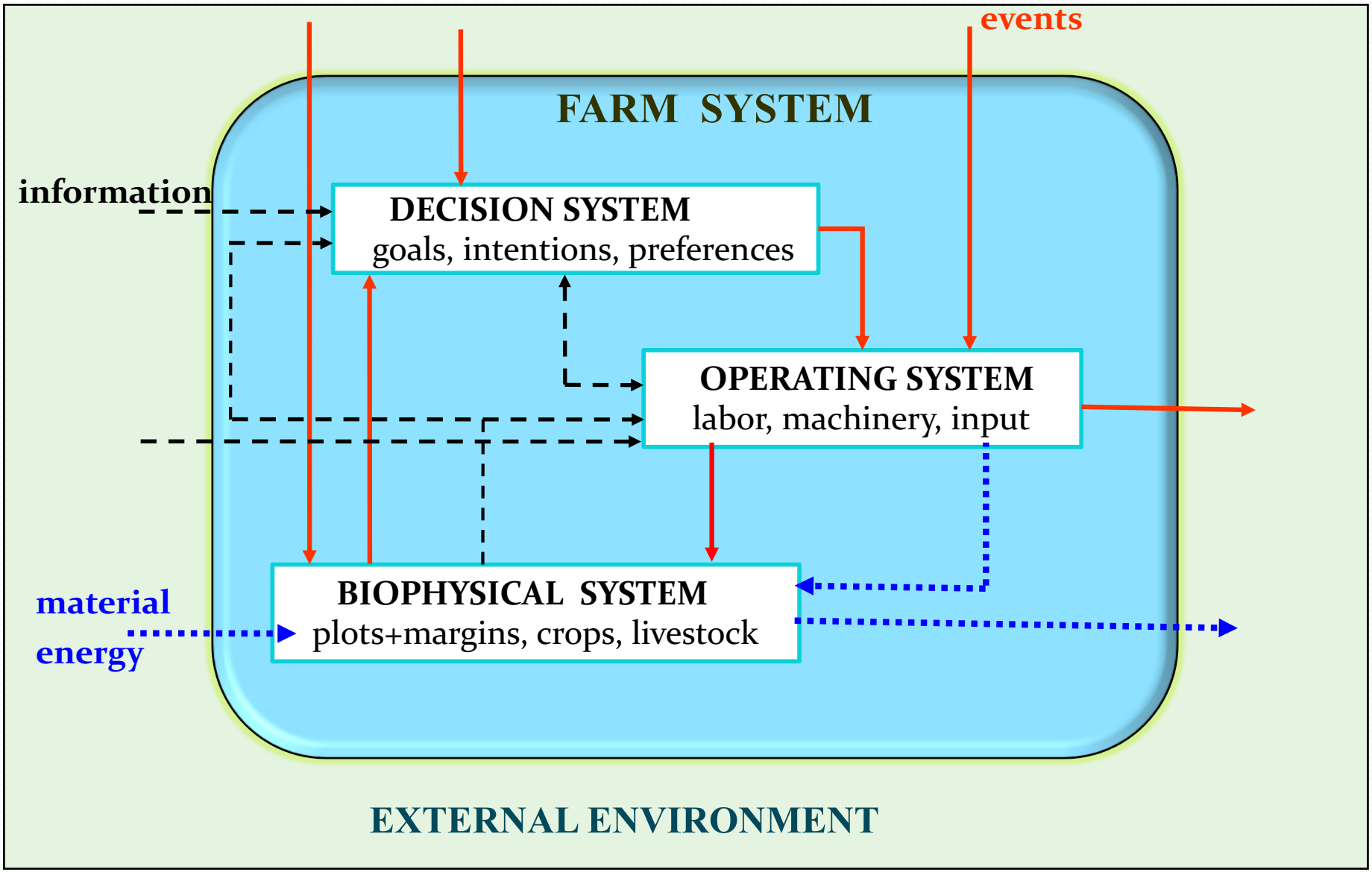
Agroecology is a very attractive approach, but the transition from conventional agriculture to agroecology is difficult: it requires knowledge-intensive active learning

The learning process can be boosted by modeling and simulation tools

Research needed because models are specific models to support understanding and design of agroecological systems:

=> Towards simulation-based experimentation as basis of participatory learning and design workshops

Global view


events
FARM SYSTEM
information
DECISION SYSTEM
goals, intentions, preferences
OPERATING SYSTEM
labor, machinery, input
material
energy
BIOPHYSICAL SYSTEM
plots+margins, crops, livestock
EXTERNAL ENVIRONMENT

Challenging management aspects

A difficult problem of control of a dynamic complex system:

- Many highly connected variables, spatially structured
- Influenced by external factors (weather, pests)
- Knowledge intensive but many gaps
- Most actions have context-dependent effects, often delayed
- Most variables are not directly observable
- Requires anticipatory (goal-based, plan based) behavior
- Some interventions require coordination between farmers (e.g. landscape matrix management)

Simulation-based constructivist approach (1)

Modeling/simulation framework:

- Incremental modeling of both scientific knowledge and farmers mental models of biophysical causality
- Virtual experimentation of interaction between biophysical, decision and operating systems
- To be used in a collective setting for critical discussions and cross fertilization of viewpoints and experience

Simulation as an intellectual partner to help exploration and support design

Simulation-based constructivist approach (2)

To be used in a sequence of participatory workshops

- 3-6 farmers + scientist facilitator
- study of a concrete farm case with an initial management strategy
- 1- mental model + strategy (implementation), 2- testing and analysis, 3- innovative strategies

Adequacy criterion = ability to effectively contribute to

- better understanding of local biophysical reality
- exploration of management variants in line with farmer's goals, values and constraints
- fruitful discussions and capitalization of knowledge

Research issues: biophysical system

Develop representation framework of farmer's mental model of causality in the biophysical system:

- in terms of factors that enable to compare options
- responsive to events and actions
- rather simple: few parameters and driving variables
- rough representation (qualitative rate of change and landmarks)
- both fast and slow processes
- integrated with existing scientific knowledge

Enable frequent revision and fast development => modularity requirement

Enable participatory evaluation through comparison with typical cases => intelligibility requirement

Develop method to elicit knowledge (belief) from farmers

Research issues: decision system (1)

Cognitive structures and processes for representing cognitive structures and farm management process:

- beliefs (informational state coming from mental state or observation)
- goals (state-based or abstract desire, achievement or maintenance)
- intentions (plans chosen to realise the goals, possibly collective)
- Preferences and values (internal criteria for evaluation of alternative goals, plans, actions)

Affiliated processes

monitoring, prediction, goal formation, plan adjustment, action scheduling…=> need of an integrative reasoning mechanism

Research issues: decision system (2)

Organizing work in activities and linking them with goals

Activity as the primitive unit of work:
an operation, on a spatial entity, with some resources

Aggregated activities built with organizational constructs
- sequencing, concurrency, synchronization, delay
- iteration
- optional execution
-alternative choices and wrapping

The state of any activity (*waiting, open, closed, cancelled*) changes according to temporal windows and/or predicates

Research issues: decision system (3)

Organizing work in activities and linking them with goals

Aggregated activities are linked to set of goals

Plan = top level aggregated activity

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                  iterate (deplacementLaitieres)),
      iterate (optional (fauche)),
      before (rentréeLaitieres,
                  iterate (alimentationConservée)))
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Plans can be revised if circumstances require it

Research issues: operating system

The link between decision and change made on the biophysical system

Resources (labor, equipment, inputs) and their role in management process

- Execution is resource-dependent (availability required, determine speed and quality of realization)
- Operation can be interrupted (resources no longer available, feasibility conditions no longer satisfied)
- Resource allocation and scheduling of operations

Preference representation and processing

Conclusion

Toward a simulation-based methodology of participatory design and collective learning

Future works

- Develop framework for farmer's mental models of biophysical causality
- Develop model of cognitive structure and processes that handle reasoning about actions in agroecosystems
- Improve collective knowledge elicitation methodology
- Apply the approach as proof of concept for supporting the development and dissemination of agroecology

?

Research issues: decision system

Activity as the fundamental structural unit in work organization (which operation, on what, with what kinds of resource)

Pertinence of execution of activity defined by temporal window and state-dependent conditions

Activities are aggregated using procedural and temporal constraints

Each aggregation of activity can be linked to a concrete goal

Plans (top level aggregation) are flexible specification of what should be done

Plans are revised if circumstances require it

Management:
an activity-centered conceptualization

Primitive activity = incomplete specification of what to do, on what, by whom

< Cutting, ungrazed fields, one driver>

- opening and closing intervals
- opening and closing predicates
- status (sleeping, waiting, open, closed, cancelled)

Operation

Operation = intentional transformation of biophysical state
= the "what to do" in a primitive activity
< Cutting, ungrazed fields, one driver>

- effect on the biophysical system
- speed
- enabling conditions
- specific resources needed

Organizing activities in a plan

Aggregated activities built with temporal and programming constructs (*before, meet, co-start, iterate, optional, or, and, …)*

- sequencing, concurrency, synchronization, delay
- iteration
- optional execution
- alternative choices and wrapping

before (iterate (Pruning1), iterate (optional (Pruning2)))

Plan = top level aggregated activity

Plan flexibility

- Temporal interval of opening & closing
- State-dependent opening & closing
- Patterns of optional execution, branching between alternative activities, adjustable iteration of activities
- Abstract specification of entities to be processes by an operation
- Discriminating functions to decide between sets of activities
- Contingent adjustment of plan

Management strategy

An envelope of courses of action built for an objective

- Flexible plan (procedure) of activities
- Plan adjustment conditional to events
- Indicators and perception scheme
- Constraints on use of resources and between activities
- Preferences for tactical arbitration between activities

Example of scheduling problem in agriculture

In the autumn, 3 tasks compete for machinery and labor resources: harvest potatoes, harvest sugar beet and sow winter wheat

Can neither run both harvest simultaneously nor harvest one crop while tilling and sowing wheat

=> Alternate activities in compliance with

- context dependent ordering constraints
- time range for each activity
- arbitration between crops, wheat fields, activities, resources (labor, inputs, tools, tractors)