Bio-economic modeling: State-of-the-art and key priorities

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1- Introduction

It is possible to consider three "families" of bio-economic models (*)

1. Models that are essentially a representation of biological processes, with an economic analysis added component.
2. Economic optimization models including bio-physical components.
3. Models integrating in an interactive manner biophysical and economic models.
4. The first category are essentially management models for fisheries or forestry where agro-ecological or biological processes can be quite sophisticated. However, most of them only account for net returns from possible activities and do not simulate production decisions. Others, apply management rules to optimize decisions in a normative manner.
5. We take into account the second and third category

(*) Classification made by Brown D.R. (2000). A review of bio-economic models. Cornell African Food Security and Natural Resource Management (CAFSNRM) Program, vol. 102

2 - Some Conceptual Issues

- Models, for what?
- To analyze the relations between intensification with land, energy, water and the environment
- Need to describe explicitly the relationships between factors of production and products in physical quantities.
- Models based on a dual approach are not able to properly analyze relationships between intensification and the environment.
- All the models we include in our review are based, at least partially, on engineering production functions.

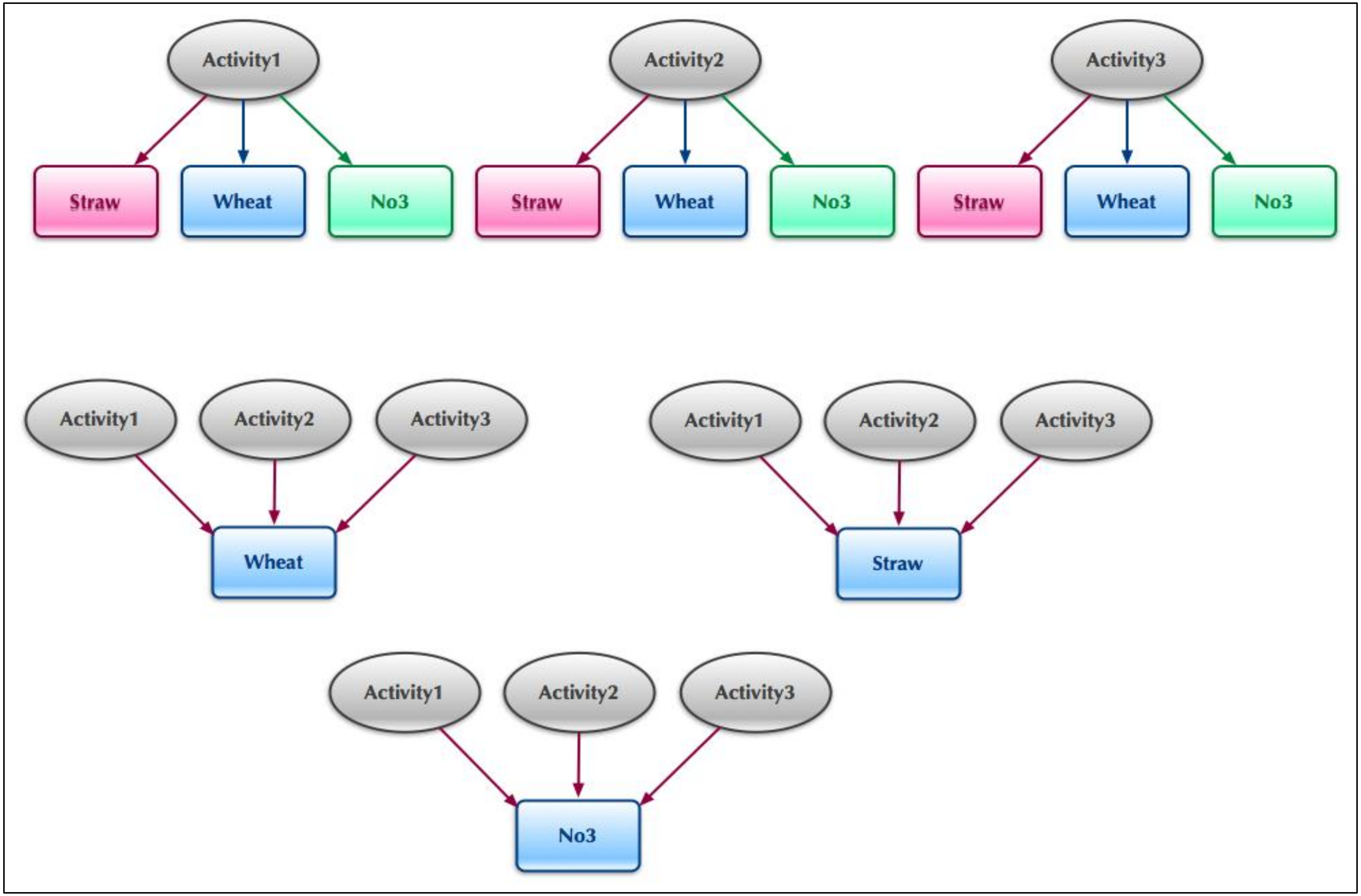
Some Conceptual Issues

- To describe relationships between production factors and products, it is necessary to use - as basic unit of information - the production processes, and not the products.
- In other words, to have an approach based on production activities, in the sense of Koopmans (1951).
- We use here the term “products”, not only to name agricultural goods,
- But also to name all the other outputs appearing as a consequence of a specific production process

These are also products

- soil erosion,
- chemical pollution,
- gas emissions,
- loss or gain of organic matter,
- change in bio-diversity,
- change in labor use
- change in water use (i.e. depletion of water tables)

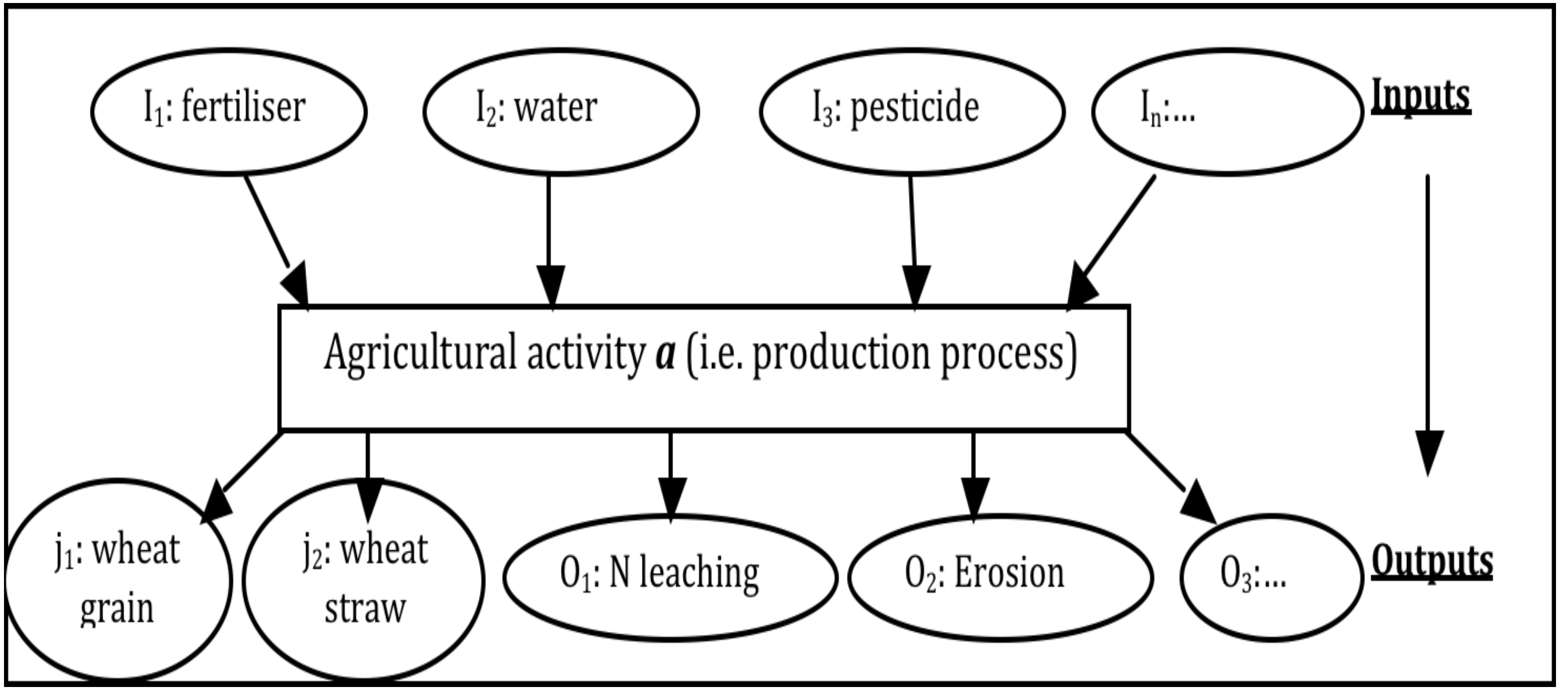
Activities and Products



Activities and Products

- The diagram shows the causal relationships implied in this type of model.
- "Products" (wheat, straw, NO3) are outputs of the activities.
  - One activity (or production process) has several outputs – joint production
  - One product can be produced by several activities
- This representation allows taking into account the positive and negative jointness (Baumgärtner et al., 2001) associated to the production process
- It allows assessing in an integrated manner policies linked as well to products as to production processes.

Activities and Products



The above diagram represents an input-output linear vector concerning one single production activity.

Externalities as joint products

- We do not approach the external effects as direct consequences of wheat production
- It is a production activity that generates this cost to other agents.
- For calculating the externality as a cost, we need first to have some knowledge about it as a physical product, and measure it in physical terms (tons of soil erosion, kg of NO3 pollution, etc.).
- Fortunately, we have had access for about 20 years to dynamic biophysical models that simulate the different outputs related with an agricultural activity (in our case, grain, straw, pollution) within an integrated framework
- In many cases what is necessary is to get information on the joint product (positive or negative) in physical terms.
    - Health issues
    - Resources depletion

3 - Survey of selected bio-economic models

- Modeling the relations between agriculture, natural resources and environment needs to mobilize different types of models and knowledge. For describing the models we use the following typology:
    - Farm models
        - Static
        - Dynamic
    - Landscape models
    - Regional and National Models
        - Static
        - Dynamic

Survey of selected bio-economic models

PRINCIPAL CHARACTERISTICS OF SELECTED BIO-ECONOMIC MODELS					
	LEVEL	KEY STRENGTH	KEY WEAKNESS	REGIONS OF APPLICATION	TREATMENT OF AGENTS BEAHAVIOUR
MODAM	FARM	Modular structure	Lack of farm interactions on resources and fixed livestock	North-Central European Regions	Risk neutral. Positive approach+goal-oriented normative
ILM	FARM-LANDSCAPE	Spatial specification, treatment of several environmental issues	Lack of farm interactions	Central Europe (Austria)	Positive approach. No risk analysis
FARM DESIGN	FARM	Treatment of trade-offs between economic and environmental objectives - Genericity	Yields are fixed as targets, do not depend on management options	The Netherlands, Mexico, Uruguay,Nepal,India	Positive approach. No risk analysis
FSSIM-MP FSSIM-DEV	FARM FARM-REGION	Modular structure. Genericity. Linkage with a DB	Complexity. Need of "ad hoc" linkage with bio-physical model	FSSIM-MP several European Region FSSIM-DEV Sierra Leone	Positive approach. Considers risk. Allows different calibration methods
CEBALAT	FARM	Feed-back between biophysical and	Complexity Fixed livestock	Tunisian region	Positive approach. Stochastic resolution

Survey of selected bio-economic models

PRINCIPAL CHARACTERISTICS OF SELECTED BIO-ECONOMIC MODELS				
	AGRICULTURAL ISSUES	ENVIRON-MENTAL ISSUES	FOOD ISSUES	TREATMENT OF TIME
MODAM	Arable crops, livestock	Erosion	NO	Static (claiming a possible dynamic use, not applied)
ILM	Arable crops, livestock: includes interactions	Carbon emissions, biodiversity	NO	Static (bio-physical model dynamic)
FARM DESIGN	Arable crops, livestock: includes interactions	Organic matter, Nitrate emissions	NO	Static
FSSIM-MP FSSIM-DEV	Arable crops, livestock, permanent crops: includes interactions	Potentially all issues dealt with the coupled biophysical model	YES	Static (bio-physical model dynamic)
CEBALAT	Arable crops, livestock	Salinity	NO	Dynamic-Recursive-Stochastic

Positive and normative approach

- The described models use optimization methods
- In principle these are normative models, the purpose is to help agents' decision making
- But in reality, most of them are used in a positive manner, trying to reproduce the way a system works, in order to be able to simulate "ex-ante" the impact of different type of shocks related with:
    - Policy
    - Environmental
    - Macroeconomic
    - Or complex combinations of these and other changes.

Availability of selected models

	LEVEL	KEY STRENGTH	KEY WEAKNESS	FOOD	AVAILABILITY
MODAM	FARM	Modular structure	Lack of farm interactions on resources and fixed livestock	NO	ZALF. Leibniz Centre for Agricultural Landscape Research
ILM	FARM-LANDSCAPE	Spatial specification, treatment of several environmental issues	Lack of farm interactions	NO	Institute for Sustainable Economic Development. University of Natural Resources and Applied Life Sciences, Vienna
FARM DESIGN	FARM	Treatment of trade-offs between economic and environmental objectives - Genericity	Yields are fixed as targets, do not depend on management options	NO	Farming Systems Ecology group (FSE) of Wageningen University
FSSIM-MP FSSIM-DEV	FARM	Modular structure. Genericity. Linkage with a DB	Complexity. Need of "ad hoc" linkage with bio-physical model	NO	Seamless Association. Wageningen University
	FARM-REGION			YES	Joint Research Center, European Commission and CIHEAM-IAMM
CEBALAT	FARM	Feed-back between biophysical and economic	Complexity Fixed livestock	NO	CIHEAM-IAMM

3 - Challenges: what is not (completely) done

Calibration issues

- 1 - The basic information is related to a production activity
- 2 – This information is consistent with “engineering data”.
- 3 – Each activity can be represented by a linear vector defining per unit of land the technical coefficients of the activity.
- 4 – Following previous assumptions,

  average costs = marginal costs

Calibration issues

The PMP standard approach (R.Howitt 1995)**, under certain conditions, can be appropriate for bio-economic models**

- The basic PMP initial idea is to "reveal" the "real" costs farmers are facing, using available information (it can be the cost, the yield or other variable).
- The standard version of PMP consists in revealing these costs by imposing in a first step a set of constraints to the LP model in order to reproduce the observed situation in terms, i.e. of cropping pattern.
- The dual values of these constraints will provide a revealed additional cost associated with the activity.
- Standard economic theory, assumes that costs are not linear, average costs are different from marginal costs (correct for products, not for activities)

- **Different methods are proposed to specify the cost functions, always assuming that MC are different from AC but we assume MC = AC**

Calibration issues

- An “almost linear” specification for the revealed cost that emerges from the dual values of the constrained activities in the first phase of standard PMP could be a good choice
- The assumption is that MC are only slightly different from AC, in order to be able to obtain a calibrated solution to the model.
- An important advantage of this approach concerns the cost specification of the activities that are not observed in the base year and also for the marginal observed activity: it is not needed to use information not corresponding to those specific activities
- A consistent methodological approach is respected, avoiding "black boxes" made out from functional forms – usually adopted for their mathematical qualities – and/or empirical estimations emerging from information not consistent with the conditions of what is going to be analyzed.

The issue of « available data »

- We consider that data do not grow on wild forests
- Data are a deliberate construction.
- If we have a clear conceptualization on how the data are going to be used, we can “build” them in the appropriate manner.
- The information needed to build vectors, mathematical expressions of the production activities, is never directly available,
- It is absolutely necessary to develop a Data Base (DB) structure consistent with the models that are going to use this data.
- This DB should have an open structure, allowing a constant development,.

- As one of the objectives of BioSight is precisely the construction of data, it should be possible to build the DB in the required format in order to be used by bio-economic models.

The issue of « available data »

- Existing data are not adapted to the needs of BEM as we have defined them
- Most of the structured information is based on products, not on production activities
- Information on production activities exists, but is not homogeneous, not consistent even inside countries.
- A good example is the case of the European Union : a huge DB with data of a representative sample of farms exists but
  - It has been built following accountancy principles
  - It even lacks of data concerning cost allocation per crop in a farm
  - Since many years, good researchers spend enormous amounts of resources developing methods to estimate this information
- For administrative reasons it seems impossible for the EC to directly collect the necessary information

Indicators for big regions, nations or global level

- Bio-economic models - as we understand them - can be elaborated at the level of a farm and/or a small region,
- How develop linkages with models working at a national, continental or global level
- A meta-modeling approach can be applied, calculating indicators from the results obtained by the bio-economic models.

  - A sample of representative regions (taking into account as well ecological and socio-economic characteristics) should be constructed
  - Statistical procedures can be applied to expand this indicators to the rest of the regions
  - This idea was developed for the SEAMLESS European Project , but not applied

4 - The "ideal" model …

- Modular structure, allowing the choice of modules to be applied in specific applications.
- This idea was inspired by what is being done for bio-physical models.
- Dynamic model, natural resources issues are always dynamic. Even if it is possible to use inputs from dynamic bio-physical models, it is frequently necessary to allow for feedbacks between the two models and this makes necessary a dynamic structure
    - Recursive integration of the impacts of natural resources on production choices
    - Impacts of production choices on the state of natural resources
    - a meta-modeling approach is the simplest way for implementing this procedure

The "ideal" model …

- From the survey of models, the "ideal" model does not exist, but the know-how for producing one exists and combining characteristics of presented models can make it possible. Let us be optimistic.

- Applying the methods used in ILM, FSSIM-DEV and CEBALAT, we are close to our "ideal model".

Thanks for your attention!