Co-innovation of family farm systems in Uruguay: the role of farm modeling

Ecole Chercheurs Traits fonctionnels et conception de systèmes de culture multiespèces

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How quantitative simulation models and in particular explorative land use simulation at farm level contributed to co-innovation of family farm systems in South-Uruguay?
The unsustainability cycle

- Decreasing vegetables prices
  - Increasing prices of inputs
  - Increasing crop yields
  - Increasing production costs
  - Decreasing soil quality

- Decreasing Family Income
  - Intensify and specialize the farm system

- Increasing use of irrigation and inputs
Soil quality deterioration and impact on production costs and yield levels
The ‘innovation system’ in vegetable production in Uruguay

✓ Problem identification and solution design by system components, isolated from their interactions and emergent properties.

✓ Economic context and Policy instruments promoted specialization, production scale increase and concentration of production and markets.

✓ Lack of adoption by farmers was seen as caused by both, weakness of the extension service and by a general lack of willingness to change by farmers.
First explorative study: aim

✔ Explore strategic options for sustainable development:
   “Is specialization and soil use intensification the best way to increase farmer’s family income, improve soil fertility and reduce impact on the environment?”
   “Is it possible for farmers to make their living without deteriorating soil fertility with their current resource availability?”

✔ Contribute to a better informed discussion among stakeholders to improve innovation system and policy making regarding family agriculture
First explorative study: the modeling approach

Designing of Production Activities
FIELD LEVEL

Design of Farm Systems
FARM LEVEL

CROPS

ROTM Model

CROP ROTATIONS

CROP MANAGEMENT SYSTEMS

PRODUCTION ACTIVITIES Input-output tables

IMGLP Model Allocation of rotations to different farm fields

Classification of farms based on RESOURCE AVAILABILITY

Farm field evaluation: soil quality and area

Constraints related to farm resources: Labour, Capital, Water and Market

ANIMAL PRODUCTION

INTER CROP Management Practices

Physical Environment

Objective functions Parameters to quantify stakeholders views

Stakeholders Views Relevant objectives and priorities

Promising FARM SYSTEM
First explorative study: the modeling approach

- Mechanisation
- Crop protection
- Irrigation

Crop management

Crop Rotations

Production Activities 336,000

Inter - crop periods management

- Fallow
- Fallow + animal manure
- Green manure crops
- Forage crops

Soil type 2
- Pasture4
- OnionSD
- OnionLD
- SwPotatoE
- SwPotato
- SwMaize
- SwMaizeL
- SwPepper
- Squash
- Wheat
First explorative study: quantify Input-Output relations

Production activities

Economic performance:
- gross margin
- capital requirement

Resource requirements:
- labour
- external inputs
- irrigation

Impact on the environment:
- soil erosion
- SOM change
- N surplus
- EEP soil, water, air

Feed production:
- Metabolisable energy
- Metabolisable protein

Input - output tables
First explorative study: farm level optimization

Production activities
Input - output tables
Animal production

Farm resource endowment
(area, labour, machinery, irrigation, etc.)

MILP model

Farmer’s objectives and strategy

Farm X nearly - optimal system
Farm X optimal system
Farm X nearly - optimal system
First explorative study: farm level optimization

### Maximise or minimise:

<table>
<thead>
<tr>
<th>Objective functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max gross margin</td>
</tr>
<tr>
<td>Max family income</td>
</tr>
<tr>
<td>Min capital requirements</td>
</tr>
<tr>
<td>Min soil erosion</td>
</tr>
<tr>
<td>Max rate of change of SOM</td>
</tr>
<tr>
<td>Min N surplus</td>
</tr>
<tr>
<td>Min EEP</td>
</tr>
</tbody>
</table>

### Subject to:

#### Environmental constraints
- Max erosion per soil type
- Min SOM rate per soil type

#### Farm resource constraints
- Area per soil type
- Total labour
- Labour distribution (1/2 month per.)
- Irrigated area

#### Farm system complexity constraints
- Max number of production activities
- Max number of different crops
- Min plot area
- Max area of each crop
- Min area of each crop

### Model outputs:

#### Farm economic results
- Farm gross margin
- Family income
- Production costs

#### Farm resource requirements
- Capital requirements
- Area under irrigation
- Labour requirements
- Labour distribution

#### Farm externalities
- EEP soil
- EEP air
- EEP water
- N surplus
- Erosion in each soil type
- SOM rate in each soil type

#### Farm system design
- Cultivated area in each soil type
- Production activity in each soil type
- Total area of each crop
- Number of animals grown
First explorative study: some results

<table>
<thead>
<tr>
<th>Farm nr.</th>
<th>Suitable area (ha)</th>
<th>Labour area (ha)</th>
<th>Irrigated area (ha)</th>
<th>Labour per ha (h ha^-1)</th>
<th>Mechanisation level</th>
<th>Fixed costs (10^3 US$)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Low</td>
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<td>1.0</td>
<td>3.6</td>
<td>High</td>
<td>177</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Model settings:
- Objective function = maximise family income
- Max. erosion soil type 1 (Mg ha^{-1} yr^{-1}) = 7
- Max. erosion soil type 2 = 5
- Max. erosion soil type 3 = 5
- Rate of change of SOM (Mg ha^-1 yr^-1) > 0
- Minimum plot area (ha) = 0.5
- Maximum number of crops = 6
- Max. erosion soil type 1 (Mg ha^{-1} yr^{-1}) = 7
First explorative study: some results

<table>
<thead>
<tr>
<th>Farm number</th>
<th>Family income (10^3 US$ yr^-1)</th>
<th>Average soil erosion per cropped area (Mg ha^-1 yr^-1)</th>
<th>Average rate of change of SOM (Mg ha^-1 yr^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Current situation</td>
<td>Improved system</td>
<td>Current situation</td>
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<tr>
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<td>11.7</td>
<td>27.1</td>
<td>13.3</td>
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</tbody>
</table>
First explorative study: some results

**Farm 1**
- Current system
- Proposed system

**Area (ha)**
- Grass & legume pasture
- Squash
- Sweet pepper
- Sweet maize
- Sweet potato

**Number of beef cattle animals**

<table>
<thead>
<tr>
<th>Farm no.</th>
<th>Current</th>
<th>Proposed</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>7</td>
<td>36</td>
<td>25</td>
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</tbody>
</table>

**Farm 6**
- Current system
- Proposed system

**Area (ha)**
- Grass & legume pasture
- Sudan grass
- Wheat
- Squash
- Sweet maize
- Sweet potato
- Potato
- Onion
- Garlic
An alternative development strategy

For a large proportion of vegetable farms might be possible to significantly increase family income and at the same time reduce soil erosion by a factor 2-4 and reverse soil organic matter decline, by:

- Reducing the area of vegetable crops
- Matching labor availability and demand through the year by diversifying crop choice and varieties
- Introducing long rotations with pastures, forage and cereal crops
- Introducing cover crops and animal manure applications during the inter-crop periods
- Introducing beef-cattle production into the farm system
A co-innovation approach to more sustainable farm systems

- Selection of pilot farms
- Diagnosis of current Farm Systems
- Re-design of Farm Systems
- ‘ex-ante’ evaluation of innovative alternatives
- Implementation of selected innovations
- Monitoring and evaluation of interventions
A co-innovation approach to more sustainable farm systems

<table>
<thead>
<tr>
<th>Implementation support and monitoring</th>
<th>Negotiation and agreement at strategic level</th>
<th>Process monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visits to each farm twice a month</td>
<td>Agreement on diagnosis results</td>
<td>Records and analysis of the interaction process between farmers and scientists</td>
</tr>
<tr>
<td>RE-DESIGN</td>
<td>Agreement on re-design: Working plan</td>
<td>PIPA workshop</td>
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<tr>
<td>RE-DESIGN</td>
<td>Feedback of results to farmers</td>
<td>Reflection workshop</td>
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<tr>
<td>RE-DESIGN</td>
<td>Adjustment of the working plan</td>
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MSC

MSC
## Results of co-innovation in pilot farms

<table>
<thead>
<tr>
<th>Planned improvements</th>
<th>% adoption</th>
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<tbody>
<tr>
<td>Drainage and erosion control</td>
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<tr>
<td>Green manures</td>
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<tr>
<td>Chicken manure</td>
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<tr>
<td>Crop Rotation</td>
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<td>Rotation with pastures</td>
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<td>Area of Crops</td>
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<td>Crop manag</td>
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<td>Strategic weed control</td>
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<td>Record sheets</td>
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<table>
<thead>
<tr>
<th>Farm</th>
<th>% adoption</th>
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<tr>
<td>16</td>
<td>75</td>
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</tbody>
</table>
Results of co-innovation in pilot farms

- Family Income per capita/ Average income in rural areas
- Income per hour of family labor
- Relationship with groups and local networks
- Actual main crops yield/ Attainable Yield
- Participation in training activities
- Direct Costs/ Gross Product
- Distribution of area among crops (gini index)
- Costs in cash/ Total Costs
- Distribution of Income over production activities (gini index)
- Free time and leisure
- Family labor/ Vegetable crops area
- Health problems
- Family Labor/ Total labor
- Irrigated Area/ Vegetable crops Area
- SOC actual/ SOC mineralizable

Initial Average vs Final Average
Second explorative study: perspectives for improvement