Abstract Title:

FARMING, BIODIVERSITY AND ECOSSYSTEMS CONSERVATION: TRADE-OFF OR WIN-WIN? A QUALITATIVE MODEL APPROACH

Abstract

With a huge decline in global biodiversity and millions of people suffering from hunger, one of the greatest challenges of modern science is to find a balance between agricultural production and biodiversity conservation. Recently, this debate has divided experts in two groups. Defenders of the so called Land Sparing approach argue that there is a tradeoff between agricultural production and conservation of biodiversity. Therefore the maximum production should be achieved in already farmed areas (intensification), saving more land for conservation purposes. Biodiversity Friendly Farming defenders point out that agricultural intensification has negative impacts on biodiversity and human development. They suggest that non-intensive farming practices such as agroforestry may produce large quantities of high quality food (food security) and still keep biodiversity. Education is, of course, a key element to move forward in this debate.

This work presents a qualitative simulation model that compares the impacts on both farmed and natural areas of these two approaches to agriculture management, with respect to productivity, water resources, soil properties, greenhouse gases emission (C and N) and biodiversity. The model was built with Qualitative Reasoning techniques (see the special issue of *AI Magazine*, 24(4), 2003), an approach has been successfully used to model ecological systems (see the special issue of *Ecological Informatics*, 4(5-6): 261-412, 2009), and implemented in the Garp3 workbench (www.garp3.org).

In qualitative models, continuous properties of *entities* are modeled as *quantities*. Relations between quantities include causal dependencies of two types: *direct influences* (I+ and I-) and *qualitative proportionalities* (P+ and P-). Direct influences represent processes and are the initial cause of change in the system. For example, I+(SV,R) reads as that the rate R is added to the derivative of the state variable SV after a certain period of time. The effects of processes are propagated via proportionalities to the rest of the system. For example, P+(AV, SV) means that the derivative of the auxiliary variable AV will take the same value of the derivative of SV, that is, if SV is changing, then AV changes in the same direction. Combined, these primitives build up causal chains: R → SV → AV. Simulations start with initial scenarios that describe the structure of the system and the initial values of some quantities. A space state containing all the possible outcomes of the initial situation is then produced. For each possible state Garp3 automatically generates a *causal model* that shows how causality flows in the system during that time period (Figures 1 and 2).

Intensive Agriculture is treated in the model as a combination of simultaneous processes financed by an external *Investor* agent. *Intensification rate* positively influences *Mechanization, Irrigation, Fertilizer*, *Pesticide*, and negatively influences *Spatial heterogeneity*. Feedback loops operating via P- or P+ may

stabilize parts or the whole intensification process. The effects of the process in turn propagate to quantities both in farmed and natural areas (Figure 1).

Agroforestry management is characterized as a cultivated system containing significantly amount of arboreal component with a forest-like biodiversity (Figure2). *Agroforestation rate* influences *Carbon fixing plants*, *Nitrogen fixing plants*, *Water holding plats* and human *Labor*. These quantities in turn negatively influence *Agroforestation rate* creating feedback loops. Some of these quantities influence (P+) the agricultural soil and the *Species variation rate.* Although not shown here, environmental education, traditional ecological knowledge and product certification also influence the system.

Concerning biodiversity protection, the Land Sparing approach shows (Figure 1) that *Species variation rate* in both farmed and natural areas is negatively affected by *Pesticides*. In the Biodiversity Friendly approach *Species variation rate* receives positive influences from different types of plants. *Species richness* increases spatial heterogeneity, eventually leading to a positive feedback loop towards the agroforestry management. Concerning agricultural production, simulations starting with the agroforestry scenario lead to an increase of *Total production*, due to control of *Pest outbreak* and increase in *Pollination* and *Light incidence*. The same result is found in intensive agriculture simulations, but not in all possible behavior trajectories predicted by the model. In fact, some of the paths show decline in *Total production* due to the effects of *Pesticide* that reduces (via the rate) *Species richness*, causing an increase in *Pest outbreak* and a decrease in *Pollination*, or the reduction in *Agricultural intensification rate* due to lack of *Financial investment*.

These results can be effectively communicated to learners, as shown in previous studies about using qualitative models in science education. The diagrammatic approach, the explicit representation of causality and the possibility of inspecting all the possible behaviours improve learners' understanding of the system. Having compared the effects of Land Sparing and Biodiversity Friendly paradigms on agricultural production and biodiversity, we are confident that qualitative models have a role to play in finding out the urgently needed balance between production and conservation.
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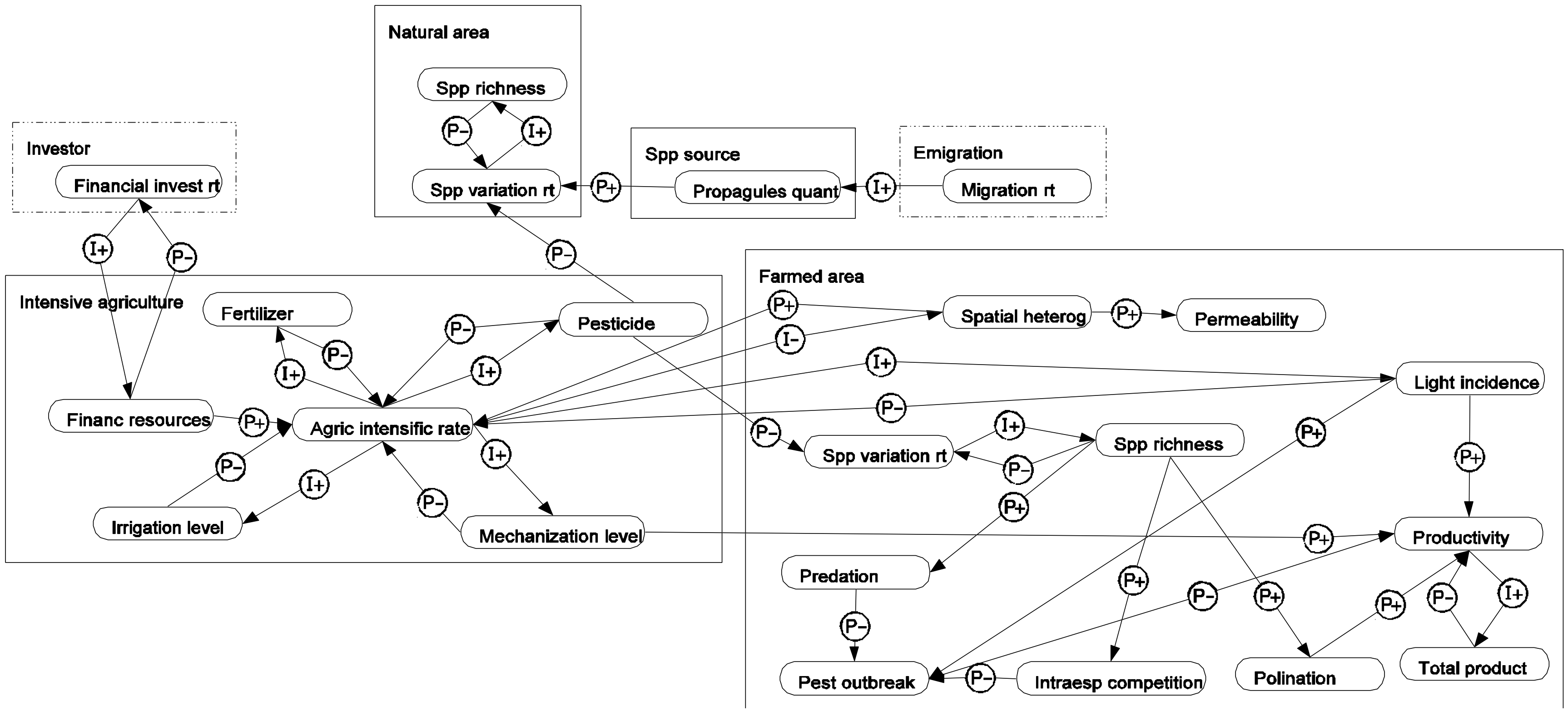

Figure 1: Causal model automatically generated by Garp3 in a state of one simulation showing the causal relations involving Investors, Intensive agriculture, Farmed area, and Natural area.

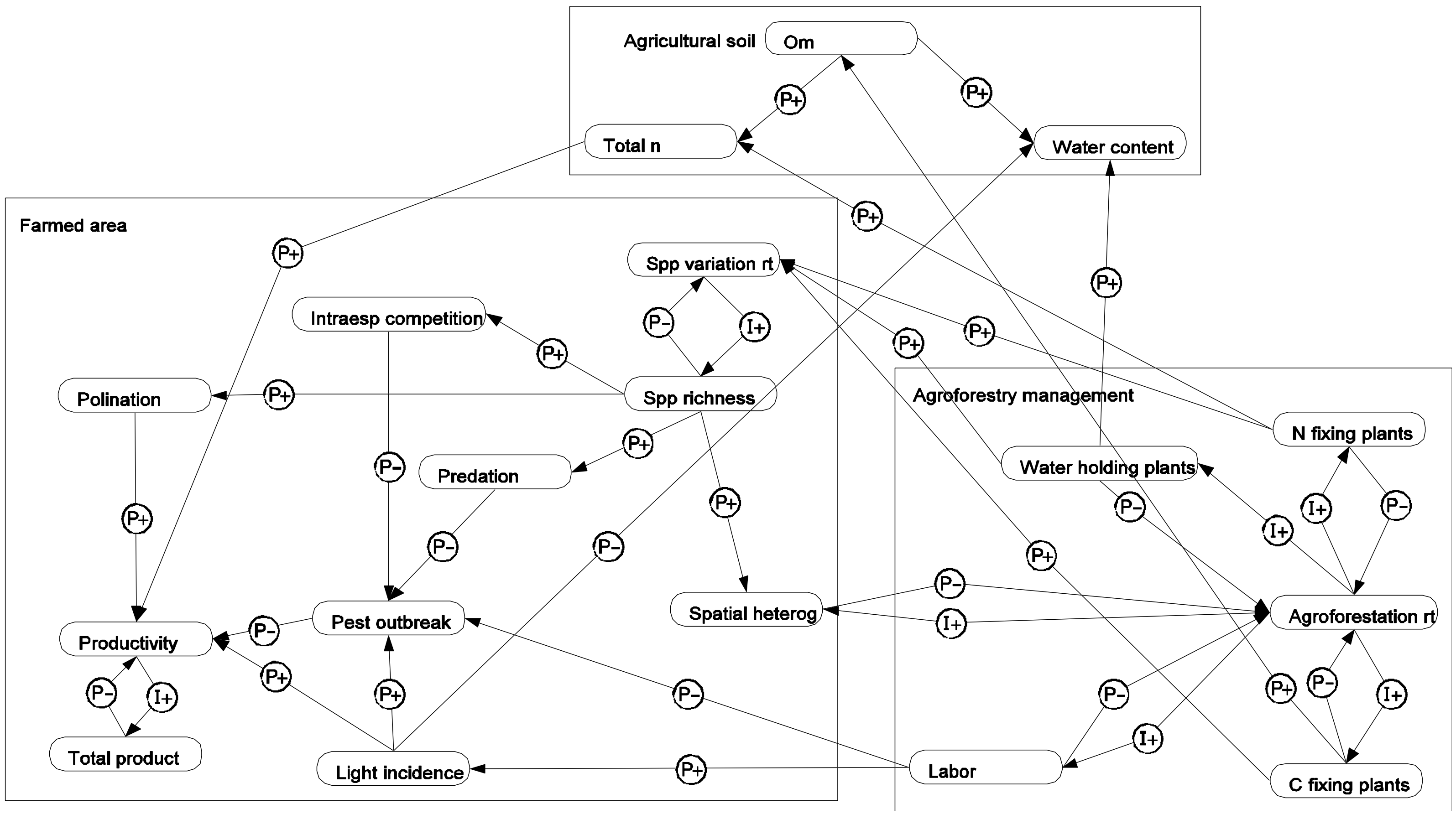

Figure 2: Causal model automatically generated by Garp3 in a state of one simulation showing the causal relations involving Agroforestry management, Farmed area and Agricultural soil.

Student presentation: Yes

Mentoring program: Yes

Topic area:

1) Sustainable agriculture
2) Indigenous knowledge and conservation
3) Conservation modeling

Alternate presentation format:

1) Poster

Comments:

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Student Award Candidate: Yes

Extended student award candidate abstract: uploaded