Linking landscape patterns and farm trajectories: a prerequisite to design eco-efficient landscapes in agricultural frontiers of Brazilian Eastern Amazon

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1 Introduction

The Amazon plays an important role in providing global ecosystem services such as carbon sequestration, biodiversity conservation, water cycle regulation, etc. In agricultural frontiers of the Brazilian Eastern Amazon, the colonisation process by extensive cattle ranching led to landscape changes with a conversion of native forest to pastureland. Recently, legislation became more restrictive prohibiting deforestation and in this context making extensive cattle ranching unsuitable. In response, cattle farmers went into intensification movement and land use diversification. An agrarian transition process has been occurring but until today, it has poorly succeeded in leading to large scale innovative cattle systems, while promoting ecological services at landscape level.

Considering the isolation and the potential of this region, an increased efficiency of natural resources use through new farming practices and spatial reorganisation is relevant. In order to design such eco-efficient farming systems, we need to understand the mutual relationship between farmers' decisions (which lead to farming practices and farm spatial organisation) and landscapes. Therefore, this contribution presents the concepts and methodological framework to analyse the links between farmer's decision systems and landscape patterns in an agrarian transition process. Our hypothesis is that farmer decisions dealing with spatial organisation and natural resources use have changed leading to different landscape trajectories.

We refer to a bottom-up approach (Overmars *et al.*, 2007) focused on farmer and farm. In a first step this approach consists to understand farmer decision-making processes (systemic approach) which led to landscape patterns. In a second step, farmer's decisions are modelled in order to be able to predict landscape patterns (spatial modelling).

The present work corresponds to the first step. To link farmer's decisions and landscape patterns, we borrowed concepts from farming systemic approach (agronomy) and spatial modelling (geography).

2 A systemic approach to understand farmer's decisions

The conceptual representation of farmer's decision process is based on a systemic approach which distinguishes a "production system" (or biotechnical system) made up of interacting crop, animal and soil compartments from a "decisional system" which guides and manage this production system to achieve management purposes. These two systems are connected through a cybernetic relationship: feedback from the production system may lead to a decision that influences future management action and changes, in turn, the production system (Bonneviale *et al.*, 1989 ; Keating & McCown, 2001). The conceptual model defines internal (*e.g.*: characteristics of the farm household) and external (socio-economic, politic or regulation context, pedoclimatic conditions) determinants that can influence farmer's decision which therefore changes farmer's projects.

To understand farmer's decisions, it is important to note that farmers are not rational profit maximizers (Edwards-Jones, 2006). It was particularly true in the frontier of the Brazilian Amazon, where, migrants opted for cattle production not only for the profitability but also for land appropriation, work productivity, social promotion, security, etc. (Vaz *et al.*, 2012).

To test our hypothesis and to embrace the heterogeneity of farming strategies, we established a typology based on expert knowledge. Two variables, considered as relevant indicators of the situation of farmer in the agrarian transition process, were chosen: the level of intensification and/or diversification and the respect or not of the Brazilian environmental legislation. From these variables, three types of farm were defined: (i) farms which have extensive farming systems (similar to migrant's strategies), (ii) farms which began changing some practices, (iii) farms which have been intensifying or diversifying. We also distinguished family farming and cattle ranching.

Semi-open interviews have been conducted aiming at understanding the current global functioning of the farm and spatial organization and at building farm trajectories. We based on three complementary approaches: farm global functioning approach (Bonneviale*, et al.*, 1989), spatial organization approach (Naïtlho *et al.*, 2003) and retrospective surveys (Moulin *et al.*, 2008). The survey is conducted to both collect information about (i) specific facts (farm history and characteristics, livestock and crop system, spatial organization, farm projects) and (ii) farmer outlook. This data collection method, proposed by Girard (2006), aims at understanding the choice of practices of the farmers, adjustments made, and how they justify their choices.

Quantitative and qualitative data are transcribed and analysed to build farmer decision rules and a conceptual model to illustrate the decision making process. These individual decisions are discussed and compared with another sample of farms.

3 Choremes: the use of graphic representation to design landscape patterns

Graphic representations have been used to represent the concept of landscape patterns. Choremes have already showed their ability to represent spatial and functioning organization of farms (Lardon & Capitaine, 2008). They are a relevant support to link farmer decision (the reasoning) and landscape (the result of farmer's action). Chorematic alphabets already exist to design generic graphic representations from structure and process (Piveteau & Lardon, 2002).
As we want to show how farmer's decisions and practices have had impacts on the landscape, we represent landscape spatiotemporal dynamic at relevant intervals. To do that, we use data from surveys and satellites from year 2000. We focus graphic representations on landscape composition (land-use and some landscape elements as riparian forests and trees on pasture) and configuration (spatial arrangement) which are both related at eco-efficiency level. We design the evolution of landscape on two levels: large individual farmer and smallholders community. The results of these retrospective evolutions are showed to farmers and leaders of the community. They are discussed which helps us to explicit farmer's decisions. Cross-analysis of results from systemic approach and graphic representations allow us to build conceptual decision model.

4 Application of the framework

We implemented this framework on two contrasted territories of Pará state (Eastern Amazon), Paragominas and Redenção. In these two municipalities, the process of land occupation by cattle ranching from the 1960s led to a predominance of agropastoral landscapes and livestock extensive farming systems. But, since the last years, the agrarian dynamic have become different. Paragominas is involved in an intensification process. Farmers experiment other options to extensive grazing and stakeholders got involved to get out government's blacklist municipalities with high deforestation rates. This municipality became the first Green Municipality of Pará state. In Redenção, innovation process is more tempered. Farmers didn't necessarily experiment alternatives to extensive grazing, which was a strength of livestock production in this region (Vaz*, et al.*, 2012). The choice of these two heterogeneous situations allows us to outline the lever and impediments to design eco-efficient farming systems at farm and territorial scales.

5 Conclusions and perspectives

Designing eco-efficient farming systems requires understanding farmer's decision making process, in order to be able to promote practices or spatial organization suitable to farmers while improving landscape eco-efficiency.
In the agricultural frontiers of Brazilian Amazon, farmer's decisions were poorly studied in a cattle ranching intensification perspective. The global framework presented in this work will allow understanding and characterizing the links between innovation and landscape dynamics. The results will provide map support and knowledge to monitor an agrarian transition process towards efficient systems at territorial scale.

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