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How farms trajectories and pathways are analyzed? from the farm to a territorial dynamic representation, a systematic literature review

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Abstract. In the Amazonian pioneer fronts, the processes of change towards sustainable agricultural practices is a complex issue regarding environmental and social specificities. Studies on farm trajectories and pathways analyze the spatial-temporal evolution of agricultural dynamics. There is a diversity of methodologies used for the study of agricultural trajectories ranging from farm to regional scales. The purpose of this study is to analyze the literature on farms trajectories and pathways in order to describe the main approaches, their conceptualization, how they address agroecology, family organization and the role of women. Using a systematic review of the literature adapted from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, it was found that studies on trajectories are mostly retrospective analyses while studies on pathways are prospective, however there is no consensus on the use of these trajectory and pathway concepts. Four main methodological approaches of retrospective farm trajectory were classified, i) territorial approach, ii) in-depth approach at farm scale associated with territorial output, iii) landscape and farmer dynamics approach and iv) comprehensive approach of the process of change at farm scale. For prospective analyses, most of them use simulation tools for the creation of future scenarios. There is no real articulation between retrospective approaches (trajectories) and prospective approaches (pathways), nor an integration of the agroecological transition in the methodologies analyzed. The role of women and family organization are not priority questions in studies on agricultural trajectories. We propose an analytical framework that focuses on the family organization and the principles of agroecology to better describe agricultural dynamics in a pioneer front context. We focus on farmers' decisions that affect the spatial organization of the farms, highlighting territorial factors and public policies.

Keywords: agricultural trajectories, farm pathways, work group organization, pioneer fronts, Amazon.

Classification JEL: Q01, Q12, Q23

1. Introduction

Farmers worldwide need to adapt to changing environmental conditions such as climate change, loss of biodiversity but also pressing demand of societies for more sustainable practices and products (IPBES., 2019, Shukla et al., 2022).

This is particularly the case in pioneer fronts of tropical forest, characterized by a process of colonization of landless people to settle in sparsely populated lands, a great diversity of migrant populations, generally leading to advanced deforestation (Arnauld de Sartre, 2006; Théry, 2014; Thalês et al., 2021).

In pioneer fronts farmers manage extreme tensions between economic development and environmental protection leading to more or less rapid rate of forest deforestation (Curtis et al., 2018). Farm trajectories are linked to the evolution of pioneer fronts and deforestation. Most of the time in the first stage of the pioneer front, deforestation is done by hand driven familiar working group (Cialdella et Navegantes Alves, 2014).

Analyzing farm trajectories over time help understanding the link between changes in household work group organization (Hostiou et Dedieu, 2012). Women role is recognized as essential for agroecological practices implementation at the farm level, but still often remains invisible in agronomical studies (Centrone et al., 2018).

Agroecology can be defined as a science, a set of practices, and a social movement, which aims to promote ecological thinking to the whole food system and is increasingly presented as one of the best alternatives to achieve sustainable development goals (Wezel et al., 2020). Many authors analyzed agroecological transitions (Duru et al., 2015), however one challenge is to analyze to what extent the transitions at stake in pioneers' fronts are related to agroecological principles over time.

This paper aims to review the existing literature on agricultural trajectories in order to i) describe the type of methodologies that are used on farms trajectories analysis ii) identify if agroecology is integrated into the analysis of farms trajectories. iii) understand the complementarities or divergences between trajectory and pathway concepts, iv) identify the factors that influence the change of agricultural practices, particularly in pioneer fronts, v) and how the family organization and the role of women in the trajectories are analyzed.

After a description of the methodology of the systematic review of farm trajectories and pathways, we present the results on concepts and methodologies used. We then discuss the main limitations and strengths of the methods used, especially on pioneering fronts, and propose an

analytical framework to better describe trajectories in pioneer fronts. This work is part of a research project aiming to analyze the trajectories and determinants towards sustainable Amazonian territories.

2. Method

A systematic literature review (SLR) based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) process was built to have an exhaustive understanding on how agricultural changes at the farm level are analyzed in agrarian sciences (Page et al., 2021). We then focus on papers that used methodologies based on practices and farm pathways or trajectories.

The search strategy consisted of consulting the Web of Science Core Collection (WoS), Scopus, Springer (databases) and Cairn (provider). Our query ranges from 1975 to February 2022 for WoS, from 1960 to February 2022 for Scopus, from 1973 to February 2022 for CAB Abstracts and 1946 to February 2022 for Cairn. The search was conducted under three key concepts: trajectory, pathway and farmers. The following search equation was constructed to search results in titles, abstracts and key words.

• TITLE-ABS-KEY (("farm* trajec*" OR "farm* pathway*" OR "agric* trajector*" OR "agric* pathway*" OR "pathway* for agriculture"))

The cairn provider was considered in order to include social sciences journals and to ensure French speaking indexation journals. For the cairn search tool, i) we focused the research equation on the whole document, ii) a specific equation was made in French.

 «trajectoires des exploitations agricoles» OU «parcours des exploitations agricoles» OU «trajectoires de l'agriculture»

This allowed us to find papers that are based on in-depth studies of family organization in pioneer fronts (eg., Cialdella et Navegantes, 2014).

Using these equations and after removing duplicates, 209 documents were found. The first selection process screening was done on the Rayyan platform¹, a web application for systematic reviews, that allowed to perform the initial screening and inclusion of documents on titles and abstracts in a structured and organized way. The documents that met the following criteria were included:

¹ Rayyan is an AI assisted collaboration tool to conduct systematic literature reviews https://www.rayyan.ai/

- 1. The core of the study is trajectories/pathways.
- 2. The main subject of the study is farmers.
- 3. The trajectories are studied at the farm scale.
- 4. Peer reviewed articles.

At this stage, 66 articles matched these selection criteria and were included. In addition, we included 7 IFSA (International Farming Systems Association) conference papers, because we consider them to be at the heart of our farm trajectory/pathway topic. Finally, we had 73 documents (list in Annex 1) for a full-text qualitative and quantitative analysis. 108 papers that did not meet the criteria, 13 papers that are not peer-reviewed articles and 8 that are not open access were excluded.). For each document we then analyzed: i) the conceptual definition used of farm trajectories and farm pathways, ii) the method used to describe farm trajectories/pathways; iii) details on trajectories changes; iv) the focus made or not on pioneer fronts, v) the consideration of working group and role of women.

The figure 1 summarizes the selection scheme of the all articles.





Figure 1 PRISMA Diagram

Furthermore, for the articles selected, we classified the main methodologies used to describe the farms trajectories and pathways (figure 3) in types. The analyses were divided into retrospective (trajectories) and prospective (pathways) analyses. Regarding the retrospective analyses, when they were territorially explicit and produced a territorial output (representation of agricultural and livestock production systems in a given territory), they were classified in TYPE R1. Studies with a territorial output and that included the dynamics of the landscape or the territory in the farm trajectories (e.g., public policies, demographic factors or markets accessibility) were classified as TYPE R2. Studies that were territorially explicit but not producing any territorial output and mostly based on an in-deep approach (family farmers interviews) were classified as TYPE R3. The ones that were not territorially explicit but based on comprehensive approach of farm/family history at the farm scale, were classified as TYPE RC. On the other hand, prospective analyses that used models have been classified in type P1, and mixed models (modelling + workshops) in type P2.

3. Results

Farm trajectories and pathways: some retrospective and prospective conceptualization

Only 4 out of the 73 documents shared an explicit definition of the concept of farms trajectory. Rueff et al., (2010) defined it as "a succession of chronological steps characterized by structural and/or organizational changes in the farm and farming system" that joined the definition made by (Mawois et al., 2019; Revoyron et al., 2018) that "identifies successive phases separated by transition periods. Chantre et Cardona., (2014) defined farms trajectory as a concept to analyze the processes of change in farming practices. Moreover, 6 of 73 documents had an explicit definition of farm pathways. Mawois et al., (2019) defined it as "the identification of mechanisms adoption of practices for farmers that can be used towards change", this definition was close to the one made by Quénon et al., (2020) "combinations of changes in farmers' herd management practices". As well, Pearson et Dare.,(2021) defined pathways as "potential routes of to realize desired goals" and (Madelrieux et al., 2014) as "the evolution of the family's on-farm and non-farm activities, production systems, retail outlets and labor arrangements . Additionally, (Antle et al., 2014; Valdivia et al., 2017) used the concept of "Representative agricultural pathways" that are plausible qualitative narratives and quantitative trends in economic, social and technical aspects in agriculture to generate and translate them into a model (i.e. scenarios) for climate impact assessment.

18 of the studies used both concepts. 10 of them used the two as synonyms : 8 studies used both terms to refer to retrospective analyses (Rueff et al., 2010; Moreno-Perez et al., 2011; Madelrieux et al., 2014; Terrier et al., 2012; Alavoine-Mornas et al., 2014; Gonzáleza et al., 2014; Kong et al., 2019; Rissing et al., 2021) , and 2 papers referred to prospective analyses (Cradock-Henry et al., 2020; Maccarthy et al., 2021). 8 of the 18 studies made the difference between trajectories and pathways: for 5 studies, pathways are the regrouping of individual trajectories (Ryschawy et al., 2014; Chantre et al., 2015; Mawois et al., 2019; Huttunen, 2019; Revoyron et al., 2018) whereas 3 additional ones referred to pathways as an alternative way to existing trajectories (Navegantes-Alves et al., 2012; Vall et al., 2017; Bruce, 2019). 84% of the papers had a retrospective approach, generally associated to the trajectory concept, while 16% of the papers used a prospective analysis mostly associated to the pathway concept.

Only 10 papers used the concept of trajectory also consider the concept of agroecology, 4 of them integrated agroecology into the analysis, among them all used the efficiency-substitution-redesign (ESR) framework used to analyze the transition of agricultural systems toward systems that includes the principles of agroecology (Revoyron et al., 2018; Mawois et al., 2019; Merot et al., 2019; Bakker et al., 2021).

In all the studies, there was no articulation between retrospective and prospective analyses, and the use of the concepts of trajectories and pathways was sometimes confused.

Main trajectory and pathways characteristics and methods

The authors used different tools for analyzing trajectories and pathways (figure 2). The most used ones were qualitative analyses to describe trajectories and pathways from a narrative approach using for example semi-directed interviews (62%). Most of the authors also used exploratory quantitative analyses (59%) based on statistical tools such as cluster and principal component analyses (PCA). Simulation tools, inferential analyses and cartography were also used, but less frequently. It should be noted that these tools are not mutually exclusive and that, in most cases, they are complementary.



Figure 2: Methodological tools used in farm trajectories and pathways (%)

Figure 2 Methodological tools used in farm trajectories and pathways

Four main types can be distinguished from the methodological retrospective analyses classification (Figure 3), Type R1 studies that have a territorial approach, focused on the land use and the exhaustiveness of production systems in a territory with samples ranging from 40 to 3200 observations. A good example is the study conducted by Perrot et al., (1995), that proposed to analyze how the farmers stay or change of type between two key dates (Figure 4). In R2 category, the use of simulation tools stands out. The integration of landscape and farm scale dynamics in their analysis is a characteristic in their approach. Plassin et al., (2015), studied the spatio-temporal process of intensification strategies at the farm scale in the Brazilian Amazon, highlighting the interactions between farmers' decision systems and natural resources, located in a landscape.

Type R3 then uses the farm scale to draw conclusions on a territorial scale. For example, Navegantes-Alves et al., (2012) analyzed the factors of grassland degradation in eastern Amazonia between 2003 and 2008. The authors classified stable and changing farms, one of their main results showed that under the same management practice, the invasion of undesirable plants was lower in the stable farms. Most of the time, this type was based on medium-sized samples (from 24 up to 130).



Figure 3 Main farms trajectory and pathways methodologies

Figure 3 Farms trajectory and pathways methodologies

Type RC with a comprehensive approach (family farm history, life cycles), at the farm and family scale, were not spatially explicit, except in the studies in which a cross-case analysis of various case studies was done (Dedieu, 2009; Cialdella et Navegantes Alves, 2014). These papers emphasized the study of the process of change and in-depth family history. Most of them did not analyze more than one production system. The production systems analyzed were mostly livestock, dairy cattle, wheat and maize systems. Samples generally range from 7 to 50 farmers.

Figure 4. Adapted from Perrot et al., (1995) Relative frequency in % by type of initial functioning, of farms having disappeared, type changed or kept the same type of functioning



Figure 4 Example of type A1

In the analyses of the trajectories, the time scale was important. The time step, which is the division of the time scale into periods where the changes to be studied take place is also relevant. Type R3 and RC studies that were based on interviews tended to use time steps from 6 to 10 years. However, not all studies used a single time step in the analysis, e.g. for Chantre et al., (2015), argues that each trajectory has different phases which in turn have a different step time.

The prospective studies (12 papers) using a pathway approach mainly used models for their analysis. The ones that used exclusively simulation tools were classified as type P1. In this group, 9 of the studies used Representative Agricultural Pathways (RAP), this models project biophysical and socio-economic data in order to provide regional agriculture information, generally for adaptation to climate change (Rosenzweig et al., 2013; Antle et al., 2014; Mulwa et al., 2016; Mu et al., 2019; Naqvi et al., 2019; Ahmad et al., 2020; Maccarthy et al., 2021; Tui et al., 2021; Valdivia et al., 2017). 1 study used the AgFutures model that explores sustainable agriculture futures using land-use evolution and impact assessment on environmental and socio-economic systems (Sharma et al., 2006). 2 papers used Adaptation

pathways approaches; these studies were classified into type P2. Based on mixed methods, including, modelling, workshops and interviews with farmers, financial services and central governments, they aimed to establish a multiple perspective on climate change adaptation. (Kenny, 2011; Cradock-Henry et al., 2020).

Analysis of factors influencing changes at farm scale

Changes in farm trajectories can be the result of a set of factors that may be endogenous to the agricultural activity (family organization, agricultural practices) or exogenous (agricultural development policies, markets, migration dynamics). 15% of the studies did not analyze the reasons for changes or are methodological proposals rather than case studies (Antle et al., 2014; Stark et al., 2016).

Of the total number of papers addressing the issue of trajectory changes (85%), 31% of the papers linked changes through variations in farmers' capital, which refers to farm size, number of heads, land ownership and economic performance and markets (Benoit & Laignel, 2011; Moreno-Perez et al., 2011; Malaquin et al., 2012; Huttunen, 2019; Veysset et al., 2015).

25 % of the studies linked these changes to practices, for example, changes towardsspecialization, diversification or intensification (Iraizoz et al., 2007; Cots-Folch et al., 2009,p.; Bernard et al., 2014; Navegantes-Alves et al., 2012; Vall et al., 2017).

9% of studies associated these changes to family farm organization (Terrier et al., 2012; Alavoine-Mornas et al., 2014; Madelrieux et al., 2014; Carvalho et al., 2015; Kongmanee & Ahmed, 2019). 8% of the papers analyzed the effects of public policies such as the common agricultural policy, agrarian reforms, agri-environmental measures (AEM) and transport development policies (David et al., 2014; Ryschawy et al., 2013; Vall et al., 2017).

Few of the studies, (6% of papers), that looked at the reasons for these changes state that they are due to drivers of land use change such as population growth and biophysical characteristics of the land (Sharma et al., 2006; Mellisse et al., 2018; Kong et al., 2019). Only 6% of the studies analyzed bifurcations (in general terms bifurcations are important breaks or moments of redefinition of the trajectory in a short time (Grossetti, 2006). The authors mentioned that the cause of bifurcation may be lack of successor, illness, professional identity changes, financial difficulties or public policies focused on credit (Lamine, 2011; Bredart et Stassart, 2017).

Family organization and women role

Although family is a fundamental pillar in in the dynamics of agricultural systems, when studying farm's trajectories and pathways only 19 % of the papers have included it in their analysis. They are type R3 and RC. Most of them analyzed the family organization from the process of land inheritance (Valbuena et al., 2010) or the will to continue with the activity (Malaquin et al., 2012), illness of family members (Carvalho et al., 2015) or family engagement to new practices (Alavoine-Mornas et al., 2014). Madelrieux et al., (2014) proposed a methodology based on the family farm organization: the description of structure of the work group, the on-farm activities by family members, pluriactivity of farmers and non-farm activities of spouses. In addition, Rissing et al.,(2021) highlighted that the specific needs of women farmers are often not met by official agricultural education and technical assistance . Only one study proposed an in-depth analysis of the co-evolution of farm, family organization and gender issues (Terrier et al., 2012), this study integrated 5 factors:

- i) <u>The process of inheritance on the farm and the role of the previous generation in the farm</u> <u>activity;</u>
- ii) The professional career of the spouses
- iii) The division of work by gender on and off-farm
- iv) Balances of power by gender and generations
- v) Time and space (at farm level) management

Specificity of the trajectory's analysis in pioneer front

Only 10% of the selected were studies in pioneer fronts. It is possible to identify major stages or patterns in the agricultural trajectories: i) Settlement of colonist with a deforestation of about 5 hectares (ha) on land that can range from 50 to 100 ha: the deforestation process is done practically by hand, using machetes, ii) Planting of self-consumption crops, mainly plantains, cassava and maize, iii) Initiation of pastures to prevent the forest from returning, iv) Pastures are used for cattle breeding. Cross-analysis of the evolution of farms over time, combined with semi-structured interviews were used to analyze these pioneer front dynamics (Carvalho et al., 2015; Cialdella et Navegantes Alves, 2014). It should be noted that most of these studies were conducted in Brazil. Other studies combined the results of retrospective interviews to characterize the coherence of the farmer (reasoning) and the landscape (result of the farmer's actions) (Plassin et al., 2015). External factors played an important role in the farm trajectories on the pioneer fronts, Kong et al., (2019) analyze land use/cover changes

(LUCC) with a conceptual framework based on i) proximate causes: infrastructure development(routes), agriculture, resources exploitation and ii) underlying factors, such as demographic, economic, technological, environmental and political factors in Cambodia pioneer fronts. The authors stated that "LUCC is not a simple linear relationship related to agricultural expansion. There are complex dynamic relationships between different proximate causes and underlying factors interacting at different temporal and spatial scales."

4 Discussion

Strengths and weaknesses of existing path analysis methods

Our analysis of existing literature highlighted that there is no real articulation between the concepts of trajectories and agroecology. Articulating these two concepts could allow for better qualification of progressive changes or bifurcations in trajectories. In other terms, it could be interesting to characterize the trajectories favoring the biophysical (diversification, synergies, recycling, etc.) and socio-technical principles of agroecology (participatory governance, co-creation of knowledge). This combination should allow for a better characterization of sustainable trajectories over time, i.e., an improvement in the traceability of these sustainable practices.

The choice of methodological approach may depend on (i) the degree of specificity of the change to be analyzed in the trajectory, (ii) the limitations of the data, and (iii) the context of the agricultural dynamics: generally, if state capacity is limited in the territory under study, changes in farms emerge with a higher frequency.

Type R1 studies generally have a good representation of the diversity of farmers in the studied territory (Perrot et al., 1995). This methodological approach assumed independence in the evolution of farms. However, they did not really analyze the links that may exist between farm types, for example the role of collective action on both the farmers' practices and the territory. In addition, the process of design of farm typologies could leave residual farms that do not belong to any type but could be the ones that innovate and set a new trajectory. In type RC works, which includes retrospective interviews, the interviewee merely recreates the history and evolution of the trajectory based on the memory of the farmers. Some authors attempted to corroborate the qualitative data collected during the interviews with events at the territorial level, but when these events occur at the farm level (son becoming independent, local illness, separation from a marriage) they are harder to be corroborated.

Studies type R3 allow to overcome the limit of static variables that characterizes the type R1 approach and to have primary data on the evolution of farms. However, analyzing the effects of exogenous factors at territorial scale (such as roads, or markets) on farm perspective trajectories is a challenge when trying to integrate different cropping and livestock systems, due to i) the lack of data at the farm level ii) the heterogeneity of the variables of each production system, iii) the creation of a causal link between the effects of the territory and what happens on the farms.

Furthermore, although some studies mentioned the role of women in agricultural trajectories, none of them analyze it. Interviews were generally conducted only with heads of household, which can create a bias and underestimate the work or role of women when she is not the head.

Proposal for an analytical framework in a pioneer front context

A minority of the papers analyzed pioneer fronts and deforestation. Analyzing agricultural trajectories in pioneer fronts requires an evolution of existing methods. In addition to the factors for analyzing pioneer fronts that emerged from this literature review (routes, policies, markets, etc.), pioneer fronts literature highlighted the importance of the evolution of the stages of pioneer fronts. These stages refer to i) the beginning of pioneer fronts, characterized by land ownership conflicts with scarce infrastructure and services. ii) the active pioneer front, when a major organization of land ownership emerges, but roads and services are still precarious. iii) the post pioneer fronts characterized by an expansion of production systems based on a model of intensification or diversification (Poccard-Chapuis et al., 2020; Thalês et al., 2021). The stages of pioneer fronts and their relationship to agricultural trajectories at farm scale remain unexplored.

In order to understand farmers' decisions over time and how they are reflected in the spatial organization of the farms we propose an analytical framework based on a bottom-up approach focusing on household and farm changes (figure 5). This approach first allows us to understand the characteristics of the farms based on the description of: i) the typical practices used in the pioneer front such as intensification, specialization and diversification, that may change from a pioneer front stage another based on the general objectives, (economic or environmental factors) principles of action, (how to manage diverse environmental conditions) and rules of crop management (Chantre et al., 2015), ii) the evolution overtime of agroecological principles that are applied at farm scale in order to identify sustainable

trajectories, such as the ones that favor the synergy between elements of the agroecosystem (animals, crops, trees and water) (Wezel et al., 2020), iii) the collective organization of farms, such as producer associations and inter-farm relationships; iv) the collective or family work, using the family configurations approach (Terrier et al., 2012).

Public policies are important factors considered in this framework. Semi-directed interviews with farmers can help identifying the main public policies that, in one way or another, have affected agricultural individual trajectories. They can be complemented and cross checked with surveys of public institutions to identify the main policies aimed at developing the agricultural sector at territorial scale. The main difference between the analytical framework we propose and those already used on the pioneer fronts is this emphasis on stage of pioneer fronts on farm trajectories.

Our approach proposes considering territorial factors such as migration dynamics, access to land, markets and road construction as recurrent variables that have a significative effect on pioneer fronts. The specific role of each factor on farm trajectories may depend on the stage of pioneer front.

Selecting the correct time step to report patterns of change in farm trajectories remains a major challenge (Cialdella et al., 2009; Rueff et al., 2012), especially in the context of the pioneer fronts where changes may occur more frequently. In this conceptual framework we propose to test a step time of 10 years in the territorial scale, in first instance. As suggested by Chantre et al. (2015), time scale needs to be flexible, in order to perceive the elements that cause changes, without defined fixed time steps, these could emerge from the interviews. For example, separations of the couple, or illnesses of family members do not have a definite step time but have an important repercussion on trajectory.

We propose to link retrospective and prospective analyses, assuming that past farmer trajectories are the basis for constructing future analyses (Ryschawy et al., 2014). For the prospective analyses, as done in the P2 pathways group, we suggest using focus groups and interviews for the creation of participatory pathways (Cradock-Henry et al., 2020). In the last 10 years, there were few works on trajectories in pioneer fronts and these were specifically anchored to the retrospective Brazilian dynamics. However, these studies and the related databased could be used for the construction of pathways (prospective) scenarios.



Figure 5 Analytical framework in a pioneer front context

Figure 5 Analytical framework in a pioneer front context.

5. Conclusion

The systematic review allowed us to have an overview of the types of methodologies used for describing farm trajectories and pathways. Two clear trends emerged in the results, a retrospective approach for trajectories and a prospective approach for pathways. They have their own strengths and drawbacks for the study of farm trajectories and low linkage with the concept of agroecological transition. The diversity in methodologies highlighted some gaps, i) the articulation between retrospective and prospective analyses has not been explored at farm scale, ii) the tradeoff between conducting a general study with a large database and a diversity of variables, or studying in depth the evolution of a few trajectories based on family and farm history iii) the role of the family in agricultural trajectories is scarcely studied, especially the role of women. Moreover, few authors analyzed exogenous effects at territorial scale on

trajectories. We proposed a methodological framework useful for future studies that would analyze these linkages. Consideration should be given to develop studies on different contexts, especially active and consolidated pioneer fronts, where agricultural trajectories must aim at preservation and forest restoration.

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