Lume: a method for the economic-ecological analysis of agroecosystems

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Reclaiming
Diversity &
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Contents

Foreword

Lume: a strong instrument for promoting agroecology

Jan Douwe van der Ploeg

This book describes Lume, which provides a much needed instrument for critically monitoring, evaluating, comparing, supporting and strengthening the agroecological changes that are currently taking place in many parts of the world. This instrument is important in that it melds economic and ecological analyses and, especially, their interactions. This reflects the crucial point that, for those involved, agroecology represents an emancipatory movement aimed at radically improving their own situation.

The instrument is well rooted in critical theories, such as the social metabolism approach, the Chayanovian analysis of peasant agriculture and political economy. It shows an impressive capacity to translate these critical theories to the practicalities of rural life. In so doing it turns critical theory from an abstraction into a building block for effectively changing the world. In my opinion this instrument has the potential to help people to carve out even more pathways towards agroecological systems. Particularly refreshing is, in this respect, the inclusion of indicators that regard the time dedicated to household work, care and reproduction generally. This helps to specify, and fight, the gender-biased nature of the social division of labour created by, and through, patriarchy.

Lume brings aspects and dimensions to the fore that have been obscured by conventional analysis. It also enriches the rapidly growing body of agroecological literature. Whilst paying meticulous attention to the novel practices that can be seen at the interface of “nature and society” (as the authors write), its evaluation of agroecology and its potentials extend far beyond the technicalities involved. It addresses, in a well-articulated way, “the autonomy, responsiveness, social participation, gender equity and inclusion of young people” from family farms and the wider regional systems that these farms exist within.

This book and the instrument it proposes is the outcome of a rich and sturdy mix of study, debate, critique, application and testing. It reflects the strong involvement of the authors in both the international debate and in pioneering agroecological experiences in the Brazilian countryside. The authors’ descriptions of their experiences in the semi-arid area of North East Brazil are really outstanding. They describe the multifaceted and continuously evolving agroecological programme that provides a powerful and effective response to the drought that has struck the area for several years. The application of the Lume approach in this area and under such circumstances (which is well illustrated in this book) demonstrates its strength.

As method Lume is very much open-ended, which contributes to both its appeal and its strength. It is open-ended in the sense that it allows for different agroecological trajectories and, above all, different degrees. For agroecology is not a binary opposite to ‘conventional farming’: it is a movement that through ongoing searches and changes, constructs new realities that keep evolving. As such it is a transitional process that proceeds step by step and can be ‘measured’ in terms of degrees of being more or less agroecological. I think that Lume carries the potential to considerably contribute to people making such steps forward in the future: the more so since it allows for, and actively supports, participatory approaches.

As illustrated by the empirical case presented in this publication, one of the particular trajectories that might benefit much from Lume is the further unfolding of indigenous or ‘traditional’ styles of farming. Through a strengthening of the self-controlled resource base and by means of peasant-driven intensification such styles will become strongholds of agroecology.

The Lume instrument deserves widespread application and testing in different places, which would certainly contribute to its refinement.

The authors of this book have indeed created a strong method. Their book is a small monument that shows the strength of combining well-informed critical theory with involvement in social movements. At the same time the book reflects the many strengths and great richness of the agroecological movement in Brazil. The authors are to be lauded and congratulated for writing such a succinct, yet convincing, book that will allow these strengths and this richness 'travel' to other parts of the world

Foreword

Emma Siliprandi
FAO – Scaling up Agroecology Initiative

The need for new methodologies to characterize and assess the performance of agroecology in a holistic way is a reality and a challenge for all, due particularly to the multi-dimensional nature of agroecology. Built on critical economic and feminist perspectives, and focused on the concept of the autonomy of the farmers, the Lume method is a very important contribution to the discussion of agroecological performance, at a household or at a community scale.

One of its strong advantages is to analyse, in a very participatory way, the wider policy context in which family producers operate. Lume was developed to be an instrument for the self-assessment of farmers, allowing them to discuss their current situation and find ways to change it. Another important characteristic of Lume is the emphasis given to the centrality of labour in social reproduction, which allows consideration of the labour performed by women in the various spheres of economic life as a central element of the production of value and the social reproduction of families and communities. Giving visibility to and showing the importance of the so called “care work” done by women farmers is an important step in discussing the unequal power relationship between men and women that are behind the false neutrality of the prevailing economic analyses.

Since 2018, FAO has also been working with many diverse stakeholders on the creation of a global analytical framework called TAPE – Tool for Agroecology Performance Evaluation, and the Lume method was one of the instruments analysed by FAO for its elaboration.

The publication of the Lume method will enable a wide audience interested in agroecology - not only researchers, the academic sector, or public agents, but especially producers and practitioners – to have a robust instrument to generate evidence on the performance of agroecological experiences. This will contribute to the discussions on the benefits and the challenges agroecology faces to be recognized as a valid way to transform the current food system towards a more sustainable one.

Executive Summary

The dominant economic, sociological and agronomic theories underlying agricultural modernization largely contradict the empirical realities of farming and the rural world. Imposing the premises of neoclassical economics on agriculture means that agriculture has been studied and promoted solely as agribusiness. The technical-economic pattern of industrial-based farming is disconnecting the economy of the agroecosystems from the ecology of the ecosystems within which they are structured. Such pattern is intrinsically unsustainable: on the one hand, it appropriates nature as an endless source of resources; on the other, it discards residues and pollutants back into the natural environment, treating it as a limitless waste sink. It is also a socially unfair pattern that concentrates social wealth and destroys decent jobs.

This calls for the development of theoretical-conceptual and methodological approaches that enable the real-life situations of agroecosystems and agrifood systems to be analysed and understood.

The method

Despite the growing social and political-institutional recognition of family farming and agroecology, there is still a dearth of analytic tools for revealing the economic and ecological rationalities of family-managed agroecosystems as a superior approach to the entrepreneurial logic informing agrarian capitalism. The Lume method was developed as a contribution to fill this gap.

In the Lume method, the agroecosystem is viewed as a 'cultivated, socially managed ecosystem':

Community joint effort: labour mobilized by social reciprocity for silage production
Photo Credit: Túlio Martins/AS-PTA

- The agroecosystem is a social construct driven by the convergences and disputes between economic and sociopolitical agents in defined territorial settings. In this sense, the method dialogues with political economy.
- The agroecosystem is a material expression of the strategies adopted by families and communities to appropriate a landscape unit in order to reproduce their means and modes of life. In this sense, the method dialogues with ecological economics.

The method proposes analytic concepts and instruments capable of recognizing and increasing the visibility of the labour of the different people involved in the management of agroecosystems. To this end, it adopts an analytic approach consistent with feminist economics, expressing a critical view of the sexual division of labor and patriarchy, cultural and ideological elements that structure the economic relations dominant in the domestic and public spheres and mask the essential role of female farmers in generating social wealth.

In order to understand agroecosystems in the institutional context in which they exist, the method includes both qualitative and quantitative forms of evaluation for describing and analyzing the mechanisms of economic-ecological exchange.

Bean straw stored to feed animals in dry season
Photo Credit: Adriana Galvão Freire/AS-PTA

Practical applications

There are many practical applications of the Lume method. The method has been constantly improved by using it to assess the reality of family farming in different regions in Brazil and other latin-american countries, especially the territories where the non-government organisation Agricultura Familiar e Agroecologia (AS-PTA) is active, an institution to which all the authors are affiliated.

This paper explores its use in a study of the impact of water security public programme on the socioecological resilience of family farming in drought-affected region of Brazil. Variations in degrees of resilience, autonomy and intensity of agroecosystems were ascertained by comparing the agroecosystems immediately prior to the installation of water infrastructure and their situation some years later (seven on average). Data on the evolutionary dynamics of agroecosystems, as well as their current configurations, were collected through semi-structured interviews, systematized with the help of modelling instruments and analyzed both qualitatively and quantitatively.

The study found that by acting on the main ecological constraint of agroecosystems in the semi-arid region – water deficiency – the programmes help to expand farming families' room to manoeuvre to develop new technical-economic strategies through recombining locally available socio-material resources.

Setting out from the theoretical-conceptual foundations derived from these critical approaches to economics, the use of the method has helped reveal the growing contradictions between the scientific premises of agricultural modernization and the results of its practical applications in different socioenvironmental contexts. At the same time, it has proven extremely useful for supporting participatory processes of knowledge production concerning the positive multidimensional effects of agricultural development trajectories guided by the agroecological paradigm.

1 Introduction

Semi-structured interview
Photo Credit: Gustavo Ohara/ANA

Knowledge of reality is a light that always
casts a shadow in some nook or cranny
Gaston Bachelard (2002:25)

Over the course of the last century, and especially since the 1950s, economic thought concerning agriculture and the analysis of wealth flows in agrifood systems has experienced a paradigm shift. As well as reflecting the emergence of new trends in agricultural development, this change in the theoretical framework has also played an important role as a material force[1] propelling these same trends. This phenomenon forms part of the agricultural modernization paradigm, a theoretical construct consistently moulded on the synergistic combination of a technical-agronomic paradigm still under construction at that time and the orthodox economic theory.

Agricultural modernization consists of transplanting the technical-economic logic born during the Industrial Revolution, some two centuries ago, onto contemporary agriculture. Aided by new farming technologies, various strategies for increasing labour productivity typical of industrial Fordism began to be employed in agricultural fields: the substitution of endogenous production factors by exogenous inputs, progressive integration into vertical market chains, the social division of labour, productive specialisation and upscaling (Marsden 1992).

Analysed from the political economy perspective, this rapid transition from the predominance of organic metabolisms to industrial metabolisms in agrifood systems during the second half of the twentieth century (González de Molina & Toledo 2011; Petersen 2018) can be viewed as a political-institutional project designed to integrate the agricultural sector into broader processes of accumulation, whereby agricultural products, as well as the resources necessary for their production, become part of the capital cycle (Wanderley 2009).

The social legitimacy of this project has been actively promoted through powerful ideological mechanisms. Along with insisting on the need to transform so-called traditional farming – depicted as backward – this propaganda has disseminated a positive image of the business-oriented farmer as the only agent possessing any real economic rationality (Schultz 1983). With the propagation of this ideology, it became commonplace to take the modernization of agriculture to signify its integration with the upstream market, through the acquisition of inputs, equipment and services, and the downstream market, through the upscaling of commercial production. In

1 As Marx pointed out, like technologies, science should be comprehended as a productive force and conceptual language as a material force (Marx 1970 cited in Moore 2015). In his analysis of the historical process, Marx demonstrated how the production of knowledge plays a determinant role in the constant renewal of capitalism's strategies of accumulation.

essence, the aim was to transform agriculture into a branch of the chemical-mechanical industry.

This imposition of the premises of neoclassical economics on agriculture is the reason why agriculture has been studied and promoted solely as agribusiness ever since (Davis & Goldberg 1957). Agribusiness groups have assumed an increasingly hegemonic role in shaping agrifood systems (McMichael 2006), steadily increasing the commodification of production factors and foods (Magdoff 2012). This has been to the detriment of other ways of appropriating nature and social integration (Polanyi 2012) historically responsible for shaping the economic flows linking food production to food consumption. As a result, agriculture has been uprooted, losing its reference to the socioecological and cultural specificities of rural territories.

However, nature rebels against the practical application of theories that contravene its laws. In the name of the supposed economic superiority of agribusiness, the attempt to replace the cyclical and complex nature of ecological processes in agriculture with linear flows of matter and energy has generated environmental costs[2] (Kimbrell 2002) and social costs (Weis 2007) that have proved devastating for contemporary societies.

The overwhelming empirical evidence of the failure of productivist models has put the principle of sustainability on the agenda of academic debates, social movements and public policies. Two polarizing questions emerge from these debates: first, the role and place of family farming in reconfiguring the patterns of occupying and managing agrarian spaces; and second, whether agroecology as a scientific-technological approach can reconnect agriculture to the dynamics of ecosystems and reorganize agrifood systems so that they respond to the contemporary social aspirations and future demands for food in sufficient quantity, quality and diversity.

Despite the growing social and political-institutional recognition of family farming and agroecology, there is still a dearth of analytic tools for revealing the economic and ecological rationalities of family-managed agroecosystems as a superior approach to the entrepreneurial logic informing agrarian capitalism. The Lume method presented here seeks to help fill this lacuna by shedding light on economies hidden by the dominant economics theory.

2 Although these costs have been hidden by a dominant economic paradigm that deliberately ignores the biophysical materiality incorporated into the flows of commodities, the effects of global climate change have become apparent during the contemporary period as highly visible public symptoms of the limits of an institutional system that conceives nature as an inexhaustible source of resources and as a limitless dump for waste.

The paper contains six chapters. Following this introductory chapter, the second chapter presents recent thinking on agroecology and outlines why new methodological approaches to assessing the economics of agroecosystems are needed. The theoretical-conceptual foundations of the Lume method are outlined in Chapter 3, while Chapter 4 discusses the procedures for applying it. Chapter 5 illustrates its use as part of research in Brazil's semi-arid region. The final chapter lists a number of core conclusions.

2 An agroecological reading of the agrifood systems economy

Agroecology emerged in the 1980s in response to the deepening socio-environmental crisis caused by the global spread of industrial-based farming. Originally defined as the "application of ecological concepts and principles to the design and management of sustainable agroecosystems" (Gliessman 1998), agroecology resulted from the synthesis between agronomy and ecology – two sciences that have maintained a tense relationship with each other for much of the twentieth century (ibid). Furthermore, it incorporates an epistemological perspective that breaks with the positivism of conventional science (Norgaard 1987) by recognizing and integrating biocultural knowledge into its methodology for building knowledge on agroecosystems (Toledo & Barrera-Bassols 2015; Pimbert 2018).

Since the 1990s, agroecology has expanded its scope from local-level agroecosystems to agrifood systems (Wezel & Soldat 2009) – networks for producing, processing, distributing and consuming food from the local/territorial level to the global. Due to this broader perspective, agroecology is currently defined as "the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions" (Francis et al. 2003: 100). This much wider viewpoint has been a decisive factor in the establishment of strategic alliances between agroecologists and various social forces that are implicitly or explicitly resisting the globalized agrifood regime (Pimbert 2015), while also contributing to the local construction of concrete emancipatory alternatives to its imperial order (Ploeg 2008; Rosset & Martínez-Torres 2012).

As a result of this evolution, agroecology has come to be understood in three interconnected senses: as a science, as a practice, and as a social movement (Wezel et al. 2009). In essence, agroecology's development has involved the synergetic combination of these three forms of understanding, condensing its analytic focus, operational capacity and political advocacy into one seamless whole (Petersen 2013; Méndez et al. 2012).

By stimulating the synergetic interaction between social movements and academic research committed to achieving structural transformations to the dominant agrifood system (Levidow, Pimbert & Vanloqueren 2014), the agroecological field – to employ Bourdieu's sense of the term (2011) – is directly opposed to the technical, economic, sociological and cultural premises that underpin the 'long green revolution' (Patel 2013). This radical critical stance can be summarized as the defence of peasant farming as the sociocultural base of agroecology (Sevilla Guzmán & González de Molina 1993; Altieri & Nicholls 2010; Ploeg 2012; International Forum for Agroecology 2015).

Why is a new method needed?

Given its evolutionary trajectory, the frontiers of knowledge explicitly identified with agroecology have expanded as the ecological rationality of peasant production has become discernible (Toledo 1990) and its value clearly acknowledged in the design of sustainable agroecosystems (Altieri 2008). Identified through bibliometric analyses (Wezel & Soldat 2009), some authors have identified the limited scope of the founding principles of agroecology (Ikerd 2009), essentially linked to agroecosystem management strategies, while other authors have sought to clarify its socioeconomic principles (Dumont et al. 2016).

Whether because of the expansion of its object of study and its configuration as a science supported by an extended community of peers (Funtowicz & Ravetz 2000), or because of the risks associated with diluting its transformative critical perspective (Levidow, Pimbert & Vanloqueren 2014), this effort to consolidate agroecology's sociological and economic foundations has emerged today as a simultaneous intellectual and political challenge. The incorporation of key principles from the social sciences into the process of building agroecological knowledge should not be understood as a simple addition to the founding principles of agroecology. Given the coevolutionary nature of agroecosystems (Norgaard 2015), we need to transcend this kind of exercise in 'green arithmetic,' as Moore (2015) defines the dominant line of environmental thought that views nature and society as independent entities.

On this point, Garrido Peña et al. (2007) have developed a radical critique of the core notions that contributed to the crystallization of the 'human being/nature' binarism in the founding epistemology of the social sciences, and effectively concealed the physico-biological bases of social organizations.[3] Meeting this challenge requires the development of theoretical-conceptual and methodological approaches that enable the real-life situations of agroecosystems and agrifood systems to be analysed as the outcome of the co-production between nature and social organizations. Among other reasons, this is essential to ensure that the incorporation of social scientific principles into agroecological analysis does not become a mere exercise in idealism. Idealist perspectives hinder the understanding of the economic-ecological rationalities of peasant farming and undermine effective dialogue between different knowledges and skills in the construction of agroecological knowledge.

The development of the Lume method (Box 1) is founded precisely on observing the lack of tools for systemic analysis of the economic and ecological relations that singularize the peasant modes of production and life that have been hidden or disfigured by conventional economic theory. As a proposal for analyzing the processes involved in appropriating and converting ecological goods into economic goods for their later distribution within the social sphere, the method seeks to respond to two epistemological challenges:

1) overcoming the rigid boundary established between the social sciences and the biological sciences reflecting the human being/nature binarism that organizes modern science and its institutions;

2) revaluing and reintegrating non-academic knowledge into formal processes of knowledge production about agrifood systems, agrarian realities and rural development dynamics.

In order to understand agroecosystems in the institutional context in which they operate, the method includes both qualitative and quantitative forms of evaluation for describing and analyzing the mechanisms of economic-ecological exchange.

3 Through its 'human being/nature' binarism, economics has developed as a reductionist discipline (focused on the production, circulation and consumption of commodities) and a mechanistic discipline (focused on price balances in the markets), incapable of capturing the biophysical materiality and the social and political nature of economic flows, or the incommensurable values responsible for the organization of social life.

BOX 1 A brief history of the Lume method

The ideas presented here are the core elements of a proposal developed over the course of several years by the authors of this paper (Petersen et al. 2017). The method has been enhanced continuously by comparing it to the reality of family farming in different regions in Brazil and in other latin-american countries, especially the territories where the non-government organisation Agricultura Familiar e Agroecologia (AS-PTA) is active, an institution to which all the authors are affiliated. It has also benefitted from the input of organizations linked to the National Agroecology Alliance (Articulação Nacional de Agroecologia: ANA) and the Brazilian Semi-Arid Alliance (Articulação Semiárido Brasileiro: ASA) – national and regional-level networks, respectively, in which AS-PTA participates.

The method was originally conceived to contrast the economic performance of agroecosystems managed according to agroecological principles with the performance of traditional agroecosystems and/or those managed according to the technical precepts of modernization (Gomes de Almeida 2001; Gomes de Almeida & Fernandes 2005). However, its application over the years in partnership with various organizations has provided ready proof of its versatility and capacity to respond to a wide range of issues associated with family farming economics: the influence of public policies on the development of agroecosystems (Rede Ater-NE 2014); a description of the heterogeneity of family farming in rural territories (ANA 2017); an evaluation of the effects of the 'Brazil Without Poverty' Programme (implemented by the Brazilian Agricultural Research Corporation: EMBRAPA) and the One Million Cisterns (P1MC) and One Land Two Waters (P1+2) programmes (implemented by ASA) on the economic intensity and resilience of family farming in semi-arid regions.

For further information: A document (in Portuguese) with a more detailed presentation of the method can be found at http://aspta.org.br/2017/03/livro-metodo-de-analise-economico-ecologica-de-agroecossistemas/. In partnership with the EITA Cooperative (http://eita.org.br/), AS-PTA has recently been developing the "Lume platform" (https://app.lume.org.br) for processing agroecosystems economic-ecological data and information. The platform will soon be available in English and Spanish versions.

3 The theory behind the method: the dialogue between agroecology and critical economics

"Economics and larger economic and political systems cultivate their own version of truth. This last has no necessary relation to reality"
(Galbraith 2004, p. x).

The Lume method sets out from the observation that the economic, sociological and agronomic theories underlying agricultural modernization largely contradict the empirical realities of farming and the rural world. The failure of growth in the agribusiness economy (Delgado 2012) to improve indicators of other dimensions of development reveals the analytic and prescriptive weakness of agricultural modernization theory.

The method aims to capture dimensions of social life and work concealed by the dominant economic theory. Two theoretical frameworks are central: the Chayanovian approach to the analysis of peasant economies (Thorner, Kerblay & Smith 1966; van der Ploeg 2013); and the social metabolism approach to the analysis of agrifood systems (Toledo & González de Molina 2007).

Ironically, both these approaches have remained latent for decades in the scientific-academic world. As Sevilla Guzmán (2006) demonstrated clearly in his description of how liberal and orthodox Marxist frameworks came to dominate agrarian social thought, as well as producing 'versions of truth' that obscured important areas of reality, "wider economic and political systems" have obscured theories that contribute precisely to revealing these overshadowed areas. One of these hidden dimensions is the fact that the organization of economic systems is strongly conditioned by power relations in society rather than by the balancing of market prices, as postulated by neoclassical economists. From this observation derives the third perspective which underpins the method: political economy, i.e. the study of the power relations involved in the spheres of production, transformation and circulation of values, as well as the social distribution of the wealth generated by labour. These three perspectives are discussed in turn below.

The Chayanovian approach

The seminal contribution of Russian economist Alexander Chayanov to our discernment of the singularities of the peasant economy is one of the mainstays of the method's theoretical frameworks. By describing a set of principles that controls the economic functioning of family farming units and differentiates them from the capitalist mode of production, Chayanov (1966) was able to explain why family farms are not directly governed by market rules despite being conditioned and influenced by the capitalist context in which they operate.

The essential aspect distinguishing peasant economic organization from its institutional surroundings is that labour is provided by the family itself. This means that the production unit is not structured around the aim of generating profit. Furthermore, since they are simultaneously the owners of the means of production and the workers, peasant nuclei (families and communities) depend on the preservation – and, where possible, the expansion – of productive assets. Both factors (use of their own labour and ownership of the means of production) imply a specific rational management of resources that allows farming families a degree of autonomy from the service and input markets. Therefore, the technical-economic rationality of peasant farming cannot be understood through analysis developed for capitalist entrepreneurial units – i.e., cost-benefit equations, technological standards, the availability of productive land, and the like.

Instead of the mechanistic outlook that controls the economic organization of capitalist agriculture, governed by market laws, Chayanov conceives peasant farming as an art: "We can affirm that the art of farming is rooted in the most appropriate use of the many particularities that are entailed in his farm" (Chayanov 1924: 6; van der Ploeg 2014). In this idea, Chayanov summarizes the essence of his theory: the economic organization of the family farming unit results from the constant search for an adequate balance between the diverse variables involved in the reproduction of their means and ways of life. The balance between "labour and consume" and "drudgery and utility" were the two main focus areas explored in his microeconomic analysis of thousands of peasant production units in Russia at the start of the twentieth century.[4]

In summary, Chayanov convincingly showed that the peasant production unit is the material expression of strategic decisions taken by the families themselves over the course of their lives. "We will fully understand the basis and nature of the peasant farm only when in our constructs we turn it from an object of observation to a subject creating its own existence, and attempt to make clear to ourselves the internal considerations and causes by which it forms its organizational production plan and carries it into effect" (Chayanov 1966 [1925]: 118).

The social metabolism approach

The idea of social metabolism originally derives from Karl Marx (Foster 2000). In his conception, metabolism corresponds to the labour process through which human society transforms external nature and, in so doing, transforms its own inner nature. The effects of the labour process on inner nature condition the social relations of production. Marx postulates that "labour is first of all, a process between man and nature, a process by which man, through his own actions, mediates, regulates and controls the metabolism between himself and nature" (Marx 1983 [1867]: 149).

4 For decades after the establishment of the Provincial Administration System in Russia (Zemstra) detailed surveys were undertaken of the peasantry, making up more than 4,000 volumes in total. Based on this material, a school of agricultural economics emerged and flourished that exerted a huge influence in the country until 1920. Kossinsky and Bructus were the two theorists from this school responsible for formulating a pioneering analysis of the fundamental distinctions between peasant farming and capitalist farming. However, it was Chayanov who expanded and deepened this work (Kerblay 1971).

Fodder production: ensuring autonomy from the input markets
Photo Credit: Adriana Galvão Freire/AS-PTA

Despite the seminal character of this concept, adapted from the natural sciences to the analysis of economic systems, it remained in the shadows for many years.[5] This fertile intuition has been developed over recent decades by ecological economists, especially in the wake of Georgescu-Roegen's (1971) formulations concerning the entropic nature of conventional economic systems. According to the social metabolism approach, the relations of coproduction between society and the rest of nature are closely integrated, forming an economic-ecological system. These relations can be analyzed by identifying five basic metabolic processes: appropriation, transformation, circulation, consumption and excretion (disposal). In any socioecological

5 It is curious that not even Marxist economists took up Marx's fertile insight. Fischer-Kowalski (1997) traces the origin and evolution of the idea of social metabolism, presenting it as a stellar concept for undertaking economic-ecological analyses. Since then the concept has been applied to various objects of study, among which we can highlight economic development, collective health, environmental justice, agricultural sustainability and so on. Applied to the analysis of agrifood systems (González de Molina & Guzmán Casado 2006), the social metabolism perspective functions as a theoretical-methodological tool for supporting the planned transition of such systems towards more sustainable patterns of production and consumption. Given its versatility, it can be employed at various scales of analysis, spanning from a single crop area to the global agrifood system.

system, including agroecosystems, the flows that interconnect these five processes vary over time in response to changes in ecological conditions and/or the social organization of production.

The social metabolism approach has revealed new methodological possibilities for combining the natural sciences and the social sciences (González de Molina & Toledo 2011). It has also demonstrated the strong correlation between ecological unsustainability and social inequality in the mainstream models of development (Martinez-Alier 2009).

In order for this mutual influence between the natural and the social to be understood, the metabolic processes are explored through the convergence of their tangible and intangible dimensions, i.e. the biophysical materiality of flows of matter and energy, and the rules of social organization. This means that metabolic patterns are regulated by a combination of hardware and software. While the hardware operates as the material and tangible anchor point, the software corresponds to the operational programming of the metabolism, or in other words to the social configurations that shape the syntax of the economic-ecological flows (González de Molina & Toledo 2011). The social metabolism is thus decisively conditioned by institutionally-regulated mechanisms of social integration.

Defined as the rules of the game in a society (North 1990), institutions are the intangible dimension of social metabolism. For this reason, economic-ecological analysis requires the adoption of an institutionalist approach to economic activity. Polanyi (2012), one of the classic authors of institutional economics, identified three predominant mechanisms in the organization of economic systems:[6] reciprocity, redistribution and market exchange:

- Reciprocity is the mechanism by which economic flows are established between symmetrical individuals and/or groups. It amounts to an economic system rooted in networks of proximity[7] that establish their own mechanisms for regulating flows of exchange.
- Redistribution implies that economic flows travel from the actors embedded in the economic system to a central nucleus before then returning to the actors according to rules implemented by the central nucleus. The tax system is the main organizer of the flows centralizing a portion of social wealth, which is subsequently channelled by redistributive flows enabled by the mediation of public policies.
- Market exchange is the mechanism by which economic flows are freely established between social actors according to their own interests. In this case, the functioning of the economic system depends on the presence of an institution regulating exchange through the use of measures of equivalence of value universally recognized and accepted by the social actors integrated in this system. The institution is the price-setting market, while the measure of equivalence is the currency.

6 This organization corresponds to the co-ordination of the movements of goods and services within society, aiming to overcome the effect of differentials of time, space and occupation. In the author's words, "thus, for example, regional differences within a territory, the time span between sowing and harvesting, or the specialization of labor is overcome by whatever movements of the respective crops, manufactures, and labour make their distribution more effective" (Polanyi 1977: 35).

7 Proximity in the sociological rather than physical-geographic sense.

Central to Polanyi's analysis is the fact that the combined functioning of these three forms of social integration depends on the presence of well-established institutional structures. From this perspective, economies can be classified according to the dominant forms of social integration (Polanyi 2001).[8] As we shall see later on, this approach is central to the theoretical grounding of the analysis of the 'degrees of commoditization' of agroecosystems proposed by the Lume method.

Political economy and the centrality of labour in social reproduction

According to Marx (1983), the scientific discovery that the products of labour, like value, express the human labour consumed in their production marked a revolutionary turning point in the history of economic thought and the development of humankind. He emphasized, however, that this discovery did not dispel the alienation process responsible for assimilating the social character of labour and the value generated by it with the intrinsic nature of things, as though commodities have their own existence independent of human labour.

This bias was enshrined in the neoclassical school of economics at the end of the nineteenth century in a historical context marked by the expansion of

8 In his main work, The Great Transformation, Polanyi (2001) interprets the historical rise of capitalism as the dominant economic system from the moment in which land and labour come to be conceived as commodities. Since then, the relative importance of the markets in the organization of social life has depended on the more or less liberal economic policies adopted by nation states.

Participatory mapping: delimiting agroecosystem spaces
Photo Credit: Luciano Silveira/AS-PTA

capitalism. It was in this environment that neo-classicists contested the labour theory of value and formulated an alternative theory of utility value as the basis of the economic system. This strand of economic thought sees the economy as a system of commodity exchanges, whose value depends not on labour but on individual interests expressed in the relations of sale and purchase in the market place. As a consequence, markets assume the central role in the economic system as an aggregate of the individual choices of economic agents who seek to meet their different needs through them. In sum, for neo-classicists, only utility generates value, expressed in the commodities that take on life as autonomous entities without origin and without history.

By concealing the central place of labour in economic processes, the logical exercise of neoclassical economics, framed by a strong mathematical apparatus, performs the role of legitimizing the power relations and distributive systems that sustain capitalism and the market relations in which socially generated value is transformed into money.

This commodity fetishism, which conceals the social relations responsible for the production of value in things, also hides the relations established with nature during the labour process. In the same way that human labour is exploited and concealed in the inert and objectified form of the commodity, nature too is subjected to a process of objectification and uncontrolled exploitation by an economic system whose physical centre of production and distribution is controlled by an intangible, abstract and infinite form of embodying value: capital.

The more distant and less transparent the relations between human labour, nature and the goods and services produced become, the more pronounced and more effective is the concealment of labour's value in social relations.

With the advent and dissemination of the technological packages of agricultural modernization and the gradual configuration of agrifood systems into the format of vertical chains, this concealment effect has slowly but insidiously penetrated the universe of family farming. At least three approaches to representing the economy of agroecosystems have contributed to this process of alienation: a) economic analyses focused on products or production chains, which mask the complex and diversified labour process involved in optimising added value through productive diversification and cost-reduction strategies; b) economic evaluations which view agricultural products as natural goods, ignoring the fact that they contain value generated by farmers' labour; and c) economic evaluations which limit the concept of added value to the alteration of products through processing, ignoring the fact that it is additional investments of labour that add value to the primary product.

The end result of these forms of representation is that the economic operation of the agricultural production unit is conceived to be the outcome of the same laws governing the market economy, combined with the biological, chemical and physical laws involved in converting inputs into outputs. Under such conditions, markets and technologies become the factors that define how, how much and in what form value is generated and distributed.

Another critical effect of the neoclassical representation of family farming is that it conceals one of the central elements of the production of value and the social reproduction of families and communities: the labour performed by women in the various spheres of family economic life. As well as devoting considerable time to generating monetary income and for the family's own consumption, domestic food production is a central activity in women's everyday lives. In addition to this work, women are also predominantly responsible for so-called 'care work,' which involves a complex interweaving of family relations in a context of invaluable affectionate and emotional relations (Castaño 1999; Carrasco 2003).

By removing the sexual division of labour from the analysis, contemporary mainstream economic thought generates a profound 'conceptual silence' over the meaning and economic value of women's work and its connection to domestic wealth generation and within society as a whole (Carrasco 1999). These prevailing analytical models – focused exclusively on market production and the conversion of values of exchange and money in markets – explicitly or implicitly locate domestic work outside the economic sphere, failing to attribute this activity any significant role and place in the production of material wealth (ibid: 18).

It is important to emphasize that this patriarchal culture of labour also plays a decisive role in obscuring the connections and interdependencies between mercantile labour, domestic labour and care labour, favouring the preservation of male power as the sole wealth generator, provider, and administrator of family needs.

By emphasizing the equivalent economic status of domestic and care labour, and the labour directed towards market commercialization and family self-consumption, feminist economics has broken away from many of the conceptual and interpretative models central to hegemonic economic thought. It has also worked to counteract the effects spread by the latter at the levels of economic organization, socio-political relations and the ideological assumptions dominant in our societies.

The social participation of family members is another important sphere of labour and economic relations that is overlooked and categorized as non-work. Social participation involves the social involvement of farmers in regional networks and institutions through which relations of reciprocity are established, enabling resources unavailable in local agroecosystems to be accessed through a basis of 'common goods' (Ostrom 2015). This basis creates and maintains the social connections essential to the technical-economic structures of agroecosystems and to realizing the potential for optimizing added value through family labour.

In sum, the Lume method refutes the market and the utility value of commodities as the central axis of economic activity and restores the centrality of labour in the social processes of production and reproduction. It also breaks with the dichotomy established between the so-called spheres of productive and reproductive work,[9] since it sees both spheres of labour as being structural elements in generating value. Finally, by highlighting the equivalent economic status of the various spheres of work in agroecosystems, it underlines how added value reflects the set of activities contributing to it. In line with the interpretation advanced by Sen in 2001, this focus on evaluating the dynamics of wealth production and distribution in agroecosystems recognizes farming families and their communities as centres of co-operation and conflict in managing, organizing and caring.

The agroecosystem as the expression of a social reproduction strategy

In the Lume method, the agroecosystem is viewed as a 'cultivated, socially managed ecosystem'. It embodies the physical anchorage of matter and energy exchanges between the natural and social spheres. According to the social metabolism perspective (see above), we can also define it as a 'social unit for appropriating and converting ecological goods into economic goods.' Its physical boundary is delimited by the environmental space appropriated by a 'social nucleus of agroecosystem management' (SNAM). In family farming, the SNAM tends to be the family itself. In this case, the physical limits of agroecosystems reflect the boundaries of the farm – irrespective of the land tenure regime involved.

Areas of community use accessed for economic purposes by the SNAM - as community lots in rural settlements or collective forests, rivers, lakes - are also considered structural elements of the agroecosystem. In other words, the appropriated ecological goods originates from an environmental space whose use is institutionally regulated within the community as 'commons'.

9 According to feminist economics the division between productive and reproductive labour specifies that while the former results in goods or services that have monetary value and for which the producers are thus compensated in the form of a monetary payment, the latter is associated with the private sphere and involves anything that people have to do for themselves that is not for the purposes of receiving monetary compensation.

Map of family production unit
Photo Credit: Luciano Silveira/AS-PTA

When the SNAM comprises a community nucleus (a set of families), as is frequently the case among indigenous peoples and traditional communities, the boundary of the agroecosystem coincides with the community's territory. In these instances, the appropriation of environmental resources by the families making up the community is regulated by local rules for governing and managing commons.

Consistent with the Chayanovian approach and contrary to the theoretical perspective adopted by agricultural modernization, the SNAM is not seen as a passive recipient of changes planned by external actors – e.g. technological diffusion – or as a reproducer of immutable technical-economic routines established by traditional norms and conventions. Instead the SNAM is considered a social actor who defines objectives and implements management strategies based on a variety of cosmovisions, material interests, evaluation criteria, previous experiences, perspectives and opportunities.

By employing an 'actor-oriented perspective' (Long 2001), the agroecosystem can be interpreted as a management unit comprised of a cognitive nucleus with the capacity to read and interpret the conditions of the context in which it operates in order to shape its development trajectories in accordance with its own strategic objectives.

At the same time, the approach proposed here recognizes that the SNAM is not a homogenous nucleus free from conflicts or contradictions among its various members. Instead the approach is sensitive to gender and generational social relations, and takes into account the influence of power relations within the SNAM on the overall configuration of the agroecosystem.

From this viewpoint, the agroecosystem is understood as the expression of a conscious strategy adopted by the SNAM to attain its economic and social objectives. Different strategies correspond to different styles of economic-ecological management and in practice are expressed through different ways of organizing agroecosystems.

Styles of economic-ecological management of agroecosystems

The method proposed here seeks to capture the socio-material reality of family farming by focusing on its labour processes. To do so, it adopts the concept of 'farming styles' as formulated and developed by Ploeg (1990, 2003, 2010).

The farming styles approach (ways of practising agriculture) views agroecosystems as expressions of strategies[10] of social reproduction actively constructed and implemented over farming families' life cycles. In this sense, farming styles can be understood as particular ways of structuring SNAMs' labour processes. Distinct farming styles emerge from the different responses of farmers living and working in the same territorial context to changes in the local political-institutional, economic and ecological environment. These

10 The notion of 'strategy' occupies a central position in the comprehension and analysis of agroecosystems and their development trajectories. Each strategy is closely associated with a specific logic of reproduction (Ploeg 2003) identified in terms of a 'calculus,' that is, a conceptual structure with which the farmer reads and interprets empirical reality. The author explains: "a calculus is the backbone of a particular strategy. It is the 'grammar' of the decision-making process. It entails the way in which farmers evaluate pros and cons" (ibid: 137).

responses are strongly influenced by moral economies (Scott 1976) that condition how farmers perceive, interpret and respond to real-life situations

Hence, the analysis involves three complementary points of focus:

1) An anthropological perspective: this seeks to understand the perceptions, representations and cultural values that connect social life and the labour process under the specific material conditions in which family farmers and their communities live and produce. By adopting this approach, the analysis takes into account the fact that the organization of agroecosystems in family farming is based on biocultural memories and repertoires (Toledo & Barrera-Bassols 2015). Consistent with the epistemological bases of agroecology (Norgaard 1987), local knowledge and values are key elements structuring the agricultural labour process.

2) A structural analysis of how the SNAMs interrelate with the institutional environment, in particular the balance between non-commodity economic relations (involving reciprocity) and commodity relations. This analysis allows us to identify the effects of these relations on the economic-ecological functioning of agroecosystems, and to evaluate how and why these equilibria change over time. It differs from conventional structural analysis, which overvalues the influence of external factors to the detriment of the concrete practices of the actors involved (Long 1986). An 'actor-oriented' analysis helps us to understand how farmers – men and women, individually and collectively – put into practice strategies that guarantee and, where possible, increase their autonomy from the agroindustrial and financial sectors and from the prescriptive power of modernization policies (Long & Ploeg 1991). Maintaining, improving and protecting non-commodity relations are the core strategies used to guarantee some degree of autonomy (or strategic distancing) from markets.

3) An analysis of the agricultural labour process, which seeks to explore the complexity involved in SNAMs' labour organization strategies. According to Karl Marx (1983), three basic elements are involved in the labour process: the workforce; the objects of labour; and instruments of labour. The peculiarity of the labour process in farming is that most of its 'objects of labour' come from living nature (animals, plants, soil, water and so on) (Ploeg 1993). As a consequence, as well as generating use and exchange values - channelled to workforce reproduction, agricultural labour is actively oriented towards regenerating the objects and instruments of work. For this reason, production and reproduction form a coherent and analytically indivisible whole in the agricultural labour process.

By conceiving of the agroecosystem as a unit of production and reproduction, the analysis encompasses the diverse activities undertaken in the various spheres of work as a whole. It also includes the domain of 'social participation,' that is activities involving direct interaction with external institutional environments (markets, the community, political-organizational spaces, and so on). From this perspective, the analysis brings to the fore cultural, ecological, institutional and political dimensions concealed in conventional studies of agricultural development trajectories. In particular, it allows us to underline the decisive role of farmers in shaping these trajectories, confirming Chayanov's affirmation that peasants are subjects who create their own existence (Chayanov 1966b). In this sense, contrary to structuralist interpretations of social change, the practices of the SNAMs at a micro level are not taken to be simple reactions to the development projects formulated and executed from the macro level down (Hebinck & Ploeg 1997).

One decisive aspect in the analytic distinction between different styles is the 'degree of commoditization' of agroecosystems, which reflects the balance between the resources mobilized in the markets and the resources reproduced in the agroecosystem itself and/or mobilized in the community through relations of reciprocity. In the approach adopted here, a specific style of economic-ecological management of agroecosystems translates into a particular equilibrium in the relations established between the agroecosystem, on one hand, and the community, markets and the state on the other. Instead of using binary logic to categorize agroecosystems, the approach makes use of a diffuse logic mapping varying degrees of commoditization.

This analytic framework has proven extremely useful for describing the diversity of family farming (Niederle 2006). On the one hand, it helps us move beyond the generalizations of conventional appraisals and official statistics, which conceal the specific reproduction strategies of rural families and communities. On the other, it avoids particularist analytic approaches that ultimately identify each individual agroecosystem as the expression of a specific logic of production.

The typology of agroecosystems established by local actors according to the farming styles framework is not designed to pigeonhole rural establishments into watertight categories, unlike the official schemas adopted to guide the allocation of public resources. The empirical reality of agroecosystems is much more complex than the binary representations used in these institutional classifications. Although the styles are expressed materially through technical and social practices, the same practices may be employed in agroecosystems managed according to distinct styles. Hence what defines a style of management is not the adoption of a specific practice, or a defined set of practices, in the labour process, but how they are interconnected in space and time and driven by the SNAM's strategic approach.

Degrees of peasantness

Agricultural modernization promotes styles of economic-ecological management that entail the continuous externalization of reproduction-related activities in agroecosystems. An increasing number of activities are thus effectively separated from the labour process, performed by outside economic agents instead.

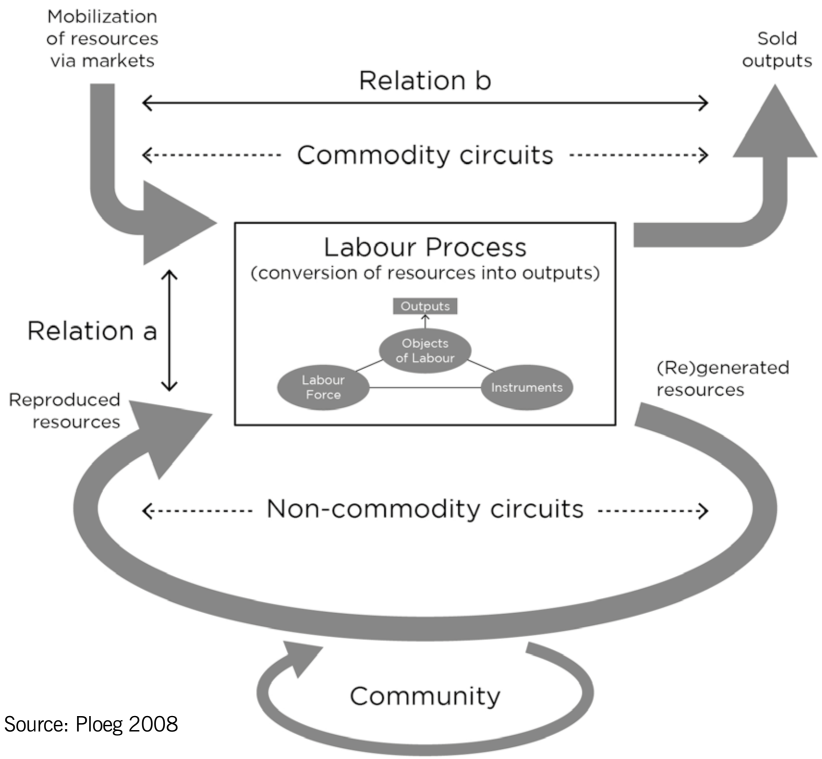
The configuration of agroecosystems according to contrasting styles can lead to two polar patterns of reproduction: "relatively autonomous, historically guaranteed reproduction" and "market-dependent reproduction" (Ploeg 1993). The former corresponds to the peasant mode of production and the latter to the entrepreneurial mode of production (Ploeg 2009).[11] However, the major contribution of the farming styles analytic framework is to reveal that in real life, these two modes of production cannot be classified into a static dualist frame between 'peasants and entrepreneurs'[12].Instead, agroecosystems should be analyzed according to their 'degrees of peasantness' (as proposed by Woortmann in 1990 from an anthropological perspective and Toledo in 1999 from the perspective of ecological economics).

Different degrees of peasantness correspond to distinct metabolic patterns shaped by the agricultural labour process. Figure 1 shows two central relations in the regulation of metabolic flows in agroecosystems. Relation (a) corresponds to the balance between the productive resources (inputs, workforce) mobilized via the markets and the productive resources reproduced by the labour process itself. The former are introduced into the agroecosystem as commodities and the latter are used without the need for market intermediation (e.g. local seeds, manure, labour etc). Relation (b) reflects the economic-financial balance between the products sold and productive resources purchased. The closer this balance is to 1, the more

11 Mode of production in the sense formulated by Karl Marx (1983[1867]), i.e. as the set of relations between the agents of production, and between them and nature.

12 The term 'peasant' is not used here to mean a social class or a political category. It refers to a modus operandi in which the labour process reproduces patterns of socioecological metabolism that take advantage of flows of coproduction with nature, as well as relations of reciprocity in economic exchanges.

FIGURE 1 Economic-ecological flows in the agroecosystem



Source: Ploeg 2008

oppressive the relationship between market agents and the SNAM (see the section on quantitative analysis in Chapter 4 for an explanation of the calculations involved).

Management strategies involving higher degrees of peasantness combine practices that give the SNAM greater control over the agroecosystem's economic-ecological flows. These practices affect all stages of the metabolism (from appropriation to excretion/disposal) and continually construct, enhance and regenerate a 'self-controlled resource base'.

This resource base is composed of elements from the natural and social spheres. Within the natural sphere, the SNAM seeks to quantitatively expand and qualitatively improve the management of ecological assets mobilized in the labour process (land, water and genetic resources). Within the social sphere, the SNAM seeks to ensure the control, improvement and reproduction of collective action devices that allow for the development of the workforce in quantitative and qualitative terms (mutual aid schemes, collective management of productive resources, farmer-to-farmer knowledge exchanges, etc.). The co-ordination between the natural and social spheres is founded on technical and social interactions centred on the valuation and continual expansion of ecological and social capital.[13] These strategies require a large investment in reproductive labour able to undertake multiple operational tasks in time and space.

In technical-economic strategies more closely focused on commodity exchanges (i.e. lower degrees of peasantness), financial capital assumes a central role in shaping economic-ecological flows. In order to render these strategies viable, production is primarily oriented towards generating products with an exchange value, which are converted into money in the market. Under such conditions, reproductive work loses some of its relevance, leading the agroecosystem's operational tasks to become increasingly externalized and inducing the operational simplification of the labour process.

13 The meaning of the term capital has gradually broadened in the social sciences in an attempt to explain differences between regions that, in principle, had the same amount of capital when measured in a conventional form. With this conceptual expansion, capital has come to assume various forms: human, social, economic, cultural, symbolic and natural (Bourdieu 2011). This extension in meaning is also applied to the microeconomic analysis undertaken in the context of agroecosystems. In this sense, capital is not limited to the classic meaning of Marxist thought. Capital in an agroecosystem is composed of stocks of resources, both tangible and intangible, mobilized by labour. Land, equipment, infrastructure, livestock, knowledge and specific skills, networks of social relations and other resources form and shape the SNAM's tangible and intangible assets, i.e. its self-controlled resource base.

Understanding agroecosystems' development trajectories

The analysis of agroecosystems from an actor-oriented perspective emphasizes the need to contextualize the system within an historical trajectory shaped by the strategic decisions defined and redefined by the SNAM over time. Consequently, the configuration of the agroecosystem at any particular moment can be seen to correspond to a contingent point in a development trajectory that materially expresses the interface between the accumulation of strategic decisions taken in the past and the actions of the present, informed by prospects for the future.

Considering that the economic-ecological reproduction style adopted by an SNAM guides the course of its actions over time, the development trajectories of agroecosystems subject to the same structural conditions can differ significantly.

From a strictly economic point of view, the development trajectories of agroecosystems can be interpreted from two analytic perspectives: as variations in 'scale' and as variations in 'intensity.' Scale corresponds to the number of objects of labour per workforce unit employed in the conversion of these objects into products (i.e. into use and exchange values). The number of hectares, animals or fruit trees managed per worker (or by hours worked) are indicators of the scale of production. In this sense, the objective of any increase in scale is to boost labour productivity, i.e. the coefficient of the "income/number of workers" ratio in the agroecosystem concerned.

Intensity refers to the production (or the value of the production) obtained per object of labour. In farming, intensification signifies an increase in technical efficiency in the work of converting ecological goods into economic goods. Production per cultivated hectare, per head of cattle bred, and per fruit tree managed are all indicators of intensity.

Patterns of development based on increases in scale and intensity are not mutually exclusive in either time or space. They can succeed each other at different moments in the agroecosystem's trajectory or may be simultaneously combined in the logic of managing the subsystems forming the agroecosystem. Alternation in these patterns over time basically stems from transformations in the circumstantial conditions faced by the SNAMs during their life cycles

Self-controlled resources: a condition for building autonomous economies
Photo Credit: Adriana Galvão Freire/AS-PTA

as they seek to achieve their economic objectives.

The availability of land (and other ecological goods) and labour at different moments define the development perspectives adopted by the SNAMs. These variables are central in the self-controlled resource base and can alter significantly over farming families' life cycles. As Chayanov observed, the equilibrium between hands able to do the work and mouths that are to be fed is one of the determinant factors in the economic organization of peasant farming (Chayanov 1966b).

The history of world agriculture can be interpreted as a history of productive intensification (Mazoyer & Roudart 2009). Boserup (1981) described this phenomenon through the study of the historical trajectories of the technological changes in farming practised in different regions of the planet. One of the central points of her analysis is the trigger-effect played by demographic growth in local dynamics of technical and socio-institutional innovation. The innovations generated through this process provide incremental rises in the levels of physical productivity of crops and livestock herds, meeting the food demands of growing populations. One of the main conclusions of her study is that there is no agrarian ceiling or precise limits to natural support capacity in any determined region. The levels of productivity obtained depend not only on ecological capital, but also on the social and human capital necessary for the continuous improvement of sociotechnical systems through local investment in experimentation and innovation.

The same phenomenon identified at macro scale by Boserup was described and analyzed by Chayanov (1966a) at micro scale, i.e. at the level of peasants' agroecosystems. In this case, the increases in levels of consumption of family farmers during their demographic cycles can also trigger agricultural intensification.

The conclusions of both authors essentially highlight the relevance of family farmers' initiatives to increasing the efficiency of the process of converting locally available factors of production into value. In other words, they refer to "endogenous development processes" (Oostindie et al. 2008).

From the mid-twentieth century, following the imposition of the neoclassical economic perspective on the analysis and prescription of the economic operation of agroecosystems, the notion of intensification acquired new meaning, becoming associated with the use of modern technologies to boost yields. Contrary to the approach employed in classical agronomy (Argemí 2002), intensification began to be understood and represented thereafter as an exogenous development processes – dependent on continuous inputs of external resources obtained from markets.

This introduced a significant incongruence between the currently enshrined notion of land productivity and the formal meaning of intensity as a reference to technical-economic efficiency.[14]

From the conceptual viewpoint, the intensity of an agroecosystem reflects the technical efficiency of the conversion of resources into products. This conversion occurs through the labour process, more specifically through the synergetic co-ordination between 'human work' and 'work of other elements

14 An eloquent demonstration of this incongruence relates to the controversial notion of 'sustainable intensification' that became part of the mainstream discourse in international debates on the future of agriculture and food (TRS 2009). Failing to question the technicist and productivist bias inherited from agricultural modernization, this notion reveals itself as a contradiction in terms, given that it possesses no biophysical basis in the sustainability of agroecosystems (González de Molina & Guzmán Casado 2017).

of nature'. However, the conventional evaluation of land productivity hides the fact that a significant proportion of the productive resources used in industrial agriculture derives from other agroecosystems external to the system being studied (seeds, forage, etc) and other environmental spaces (chemical fertilizers, fuels, etc). As a result, it masks the fact that maintaining the high levels of productivity obtained in conventional productive systems depends structurally on exogenous resources, some of which are finite and whose widescale use is responsible for a substantial percentage of atmospheric greenhouse gas emissions.[15] In this sense, when we focus on the biophysical materiality of the economic-ecological flows of agroecosystems from the social metabolism perspective, the purely rhetorical character of the new narratives legitimizing industrial farming – associated with notions of 'sustainable intensification' and 'climate smart farming' (FAO 2010) – becomes clearly evident.

Labour-driven intensification

'Labour-driven intensification' is basically founded on the continuous enhancement of the ecological, social and human capital mobilized in the labour process, seeking to improve the technical-economic efficiency of agroecosystems. Contrary to the logic of 'capital-driven intensification', this is an endogenous approach to development, anchored in the valorization and continual expansion of the self-controlled resource base.

The term intensification can refer both to the increase in the level of intensity of the agroecosystem (or a particular subsystem) and to the process through which this increase is obtained. Contrasting styles of economic-ecological management lead to equally contrasting processes of intensification. Management styles that essentially depend on the mobilization of production factors derived from the self-controlled resource base guides labour-driven intensification trajectories. These farming styles tend to reflect higher degrees of peasantness. More entrepreneurial styles on the other hand – whose reproduction of the agroecosystem is market-dependent – shape intensification trajectories based on the systematic (and increasing) use of financial capital.

15 In order to correct this distortion, the economic accounting of agroecosystems should include the 'virtual hectares' needed for the production/extraction of the resources mobilized through the markets. As will be shown later in this paper, this method proposes using a correction factor called an 'index of endogeneity' to amend this distortion.

Ploeg (2008) argues that, despite the existence of striking historical evidence concerning the success of labour-driven intensification, this peasant-like development trajectory has seldom been explored at a theoretical level, and likewise remains absent from most current debates on development. This neglect is mainly due to the dominance of the modernization paradigm on scientific and political institutions, meaning that they have effectively been rendered incapable of identifying, describing and analyzing the possibilities of labour-driven intensification.

In Ploeg's view, these development trajectories have been obscured by three types of mystifications surrounding the peasant mode of production. The first relates to the supposed existence of an agrarian ceiling – that is, a carrying capacity inherent to the ecological qualities of particular ecosystems. According to this viewpoint, irrespective of the means at its disposal and whatever its creativity or resilience, peasant farming is also subject to economic development limits. As a result, it is condemned to subsistence production and poverty (Schultz 1983).

The second mystification relates to the misapplication of the law of diminishing returns, as formulated by neoclassical economics, in predicting the economic behaviour of peasant farming. According to this viewpoint, above a determined level of labour investment in the agroecosystem, each additional hour worked represents a smaller increase in production, and may eventually even become counterproductive and anti-economic. In real-world situations, though, this Cartesian operation of agroecosystems proves to be the exception rather than the rule. Returns do not diminish, precisely because family-run agroecosystems are dynamic, in constant evolution, with the capacity to generate adaptive responses to the internal and external transformations taking place over time.[16] Contrary to the canonical assertions about the conservative traditionalism of the peasantry found in the classic texts of agricultural modernization, longitudinal analyses of traditional communities show that creativity and innovation are key elements of peasant worlds.

16 On this point, it is interesting to note that Lenin claimed that the law of diminishing returns is an empty abstraction that ignores the levels of technological development and the states of productive forces. "Consequently, instead of a universal law, we have an extremely relative 'law' – so relative, indeed, that it cannot be called a 'law', or even a cardinal specific feature of agriculture" (Lenin 1961: 109 apud Ploeg 2013: 107). Another remark made by the author on this theme is highly significant for the purposes of the analysis proposed in the Lume method: "this explains why neither Marx nor the Marxists speak of this 'law', and only representatives of bourgeois Science ... make so much noise about it" (Lenin 1961: 110 apud Ploeg 2013: 107).

Finally, the third mystification, directly related to the first, concerns the abundant empirical examples of stagnation and poverty among peasant communities worldwide. Through a simplistic and awkward application of the inductive method, these empirical situations of material vulnerability are presented as incontestable examples of the supposed backwardness intrinsic to peasant farming. Ploeg, however, calls attention to the fact that no complete studies exist of the specific causes of such stagnation. Furthermore, those indications already studied – which make no connection to the alleged incapacity for development inherent in peasant farming – are systematically ignored in academic and political circles. Faced by this scenario, the author argues that the "misery entailed in practice is turned into poverty of theory" (Ploeg 2008: 47).

Ploeg (2014) identifies five main mechanisms that enable labour-driven intensification. These may occur in isolation or in different combinations:

- Higher investment in the labour force and in instruments of labour, allowing greater attention and care to be paid to each object of labour and, consequently, greater efficiency in the conversion of ecological goods into economic goods. Examples of this mechanism include more frequent and careful weeding, greater attention paid to animal health, and higher investment in labour to produce seeds, high-quality fodder, organic fertilizers and so on.
- Fine-tuning of management practices. This is related to the SNAM's capacity to adapt its labour process to the local ecological context. Contrasting with the reductionist technical strategies of industrial farming and designed to limit the depressive effects of critical ecological factors, fine-tuning is done through the use of multifunctional practices capable of regulating ecological processes at landscape scale. For example, fences created with a variety of tree species can perform various economic-ecological functions in the agroecosystem: nutrient cycling, windbreaks, animal feed and firewood production, shelter for natural enemies, etc. In other words, the aim is to develop systemic solutions to systemic problems.[17] Fine-tuning is done directly by members of the

17 A typical example of this contrast concerns strategies for dealing with nitrogen depletion in cultivated soils. The practical solution to this agronomic limitation provided by the reductionist approach is the use of soluble nitrogenous fertilizers. For the systemic approach, on the other hand, the solution involves management of the biomass, including the introduction into the agroecosystem of species that fix atmospheric nitrogen. In the reductionist approach, although the limiting factor is reduced, undesired ecological effects can be generated (such as acidification of the soil, an increased vulnerability of crops to pest insects and pathogens, contamination of the water table,

Territorial markets favors the development of economies of scope in agroecosystems
Photo Credit: Luciano Silveira/AS-PTA

SNAM based on cycles of observation, interpretation, reorganization and evaluation, very often making use of local experimentation. These fine-tuning practices are highly dependent on contextualized knowledge that can be expanded and enriched continuously through the participation of the SNAM in territorial-level sociotechnical networks where experimental knowledge circulates freely as a common good (Hess & Ostrom 2007).

- The continuous enhancement of resources used in the production process, especially objects of labour. Generally speaking, these enhancements occur slowly through a careful balance between productive and reproductive work in the agroecosystem. Typical examples of this mechanism include improvement of soil quality (with organic fertilizer, erosion control measures,

etc.). In the systemic approach, the limiting factor is balanced along with other growth factors, promoting healthy environments for crop development. The reductionist practices depend little on the context in which they will be employed. Employing the systemic approach, however, demands fine-tuning since the practices should be adapted in situ as they are site specific.

irrigation, drainage, and so on), the genetic improvement of crop varieties and animal breeds, and the installation of new infrastructure.

- Local innovation, i.e. the introduction of new technologies and processes that increase the efficiency with which resources are converted into products.
- The form in which SNAMs perceive, calculate, plan and organize the labour process. This fifth mechanism is decisive for the economic output of the agroecosystem, and is related to what Ploeg calls a 'calculus'. It highlights the contrast between the economic rationalities of capitalist and family farming. The former is interested in obtaining the maximum return on the capital invested (profit) while the latter on optimizing remuneration for its labour (added value). Although the production of added value is the central objective of the family farming economy, different strategies can be adopted to achieve this objective. Economic-ecological management styles more closely in tune with an entrepreneurial logic (market-dependent reproduction) emphasize economies of scale, while styles with higher degrees of peasantness (relatively autonomous and historically guaranteed reproduction) seek to enhance intensity. In practical terms, the crucial difference between the two strategies resides in the fact that the latter emphasize improving the physical outputs of their production and reducing production costs, while the former seek to increase the unit rentability of commercialized products (the price-cost margin) and expand the operational size of their productive activity.

Added value: labour-generated wealth

By placing labour as the main element in the production of wealth, the Lume method uses added value as the central indicator in the economic-ecological analysis of agroecosystems. In this sense, the economic output of the agroecosystem is presented from a different perspective to the approach taken by official statistics and their focus on gross value of production (GVP). As a monetary expression of the sum of all the goods produced in a one-year period, GVP masks the wealth effectively produced by the labour process, since it is calculated by combining the value of the final products with the sum of the commercial inputs used in their production. Added value is calculated as the difference between the monetary value of the goods produced – whether sold, self-consumed and/or given – and the input costs incurred during production. It therefore expresses the value of production without the 'double counting' effect, providing a substantive representation of the agroecosystem's economy.

The concept of added value and the interpretative models associated with it allow us to identify, categorise and analyze SNAMs' organization and labour processes, and their links to wealth generation. They also enable us to determine how this wealth is shared among the various SNAM members (men, women and young people) and the other socioeconomic agents directly or indirectly involved in the production process (day labourers, land-lessors, banks, etc.).

Applying the concept of added value also reveals the relationships of interest and power present in the territories in which the agroecosystems are located. It is in this circulation stage that the portion of wealth created through SNAM's market-directed work acquires a monetary value. It is in the markets that power relationships determine the appropriation of added value produced through agricultural labour. The outcome of these relationships depends on the capacity of SNAM members and their integration with autonomous economic and political organizational processes in the territories. By incorporating these mechanisms of social participation into the analysis of agroecosystems, the SNAM ceases to be conceived as individual producers in open competition on the market – as posited by liberal strands of economics. Instead, they are understood as socioeconomic and political actors who co-operate with other actors (mainly within the territory) in shaping sociotechnical networks to defend the highest monetary measure for the goods produced by their own labour.

From this point of view, by focusing on the wealth generated through labour, the Lume method proposes a double analytical approach, focusing on the labour processes that drive the agroecosystems' economy, and on the nature of the individual and/or collective mediators (unions, associations, cooperatives, seed banks, etc.) and commercial circuits that support the SNAM's strategies for optimizing added value.

Agroecology and the embedded economy of agroecosystems

Following the analytic approach proposed in the previous sections, agroecosystems are understood as socioecological constructions: that is, as the result of the continuous interaction and mutual transformation between social and natural processes. The technical-economic pattern of industrial-based farming develops through the systematic attempt to disconnect the economy of agroecosystems from the ecology of the ecosystems on which they are structured. In such cases, the organic unity between economic production and ecological reproduction responsible for the evolution of farming practices for thousands of years is dismantled to give way to the development of industrial metabolisms shaped by linear and increasingly globalized flows of matter and energy. These metabolisms are intrinsically unsustainable: on one hand, they appropriate nature as an endless source of resources; on the other, they discard residues and pollutants back into the natural environment, treating it as a limitless waste sink.

As a scientific approach to the development of sustainable food systems (Gliessman 2015), agroecology's concepts and methods focus on improving and/or restoring organic metabolisms capable of promoting economic intensification while avoiding the ecological simplification of agroecosystems (Petersen, Silveira and Galvão Freire 2012; Petersen 2018). It involves rebuilding the circular nature of the economic processes in agrifood systems by mimicking the key principles of ecological processes (Jones, Pimbert & Jiggins 2011; Riechmann 2006). Its goal is to combine the various social functions of farming in order to produce and distribute diverse and high-quality food in the quantity required for a rising global population. It aims to achieve this in the context of unstoppable climate change and impending scarcity source of fossil fuel energy.

From this point of view, the issue is one of reorganizing 'economies of scope' in agrifood systems, rather than the current trend for global expansion through economies of scale. In the latter the goal is to reduce unit costs via the productive specialization of agroecosystems and rural territories, and through the successive expansion of production scales. In contrast, economies of scope (or synergy) seek to reduce total costs by finding synergies between diverse productive activities co-ordinated through a single management process. Economies of scope benefit from the circularity of economic-ecological flows at the territorial level. They reproduce a basic principle in the functioning of natural systems: the residues of one species are used as food for another, or are converted into the necessary elements for the reproduction of other economic-ecological processes.

The management of agrifood systems through an economies of scope logic involves two complementary strategies: a) the use of the same factor of production in different productive processes, especially those over which families possess ownership and managerial autonomy, such as family labour, land and other ecological goods; and b) the construction and maintenance of collective action devices (local markets, local seed banks, mutual aid mechanisms, etc.) at the territorial level that enable families to mobilize factors of production from a resource base socially regulated within the communities (common goods) and to benefit economically from their production, both marketable and non-marketable, through local outlets.

Both strategies combine to reduce the level of commoditization of agroecosystems and, consequently, to increase the levels of governance possessed by local actors over their labour processes. On the other hand, relations of reciprocity take on greater importance in the structure of governance of the metabolism of agrifood systems. Hence, the development and dissemination of economies of scope in the management of agroecosystems depends on the existence of institutional contexts favourable to the creation and stabilization of metabolic functions mediated by mechanisms of reciprocity, whether in the exchanges with nature (appropriation and excretion) or in the social sphere (transformation, circulation and consumption).

In this sense, the enhancement of the mechanisms of 'ecological reciprocity' and 'social reciprocity' is a decisive element for a more "embedded economy" (Polanyi 2001) –agroecosystems embedded within institutional frameworks controlled by local actors themselves, whether these are farmers, processors, merchants or consumers.

4 Methodological procedures

Based on the theoretical-conceptual foundations presented above, in this chapter we explore how the Lume method combines a set of procedures for obtaining and analyzing information and data on agroecosystems, and relating them to the critical economical approaches presented in the previous chapter. In the next chapter we use the example of research in Brazil to demonstrate the very practical applications of the method.

A key element of the process is to develop models[18] to represent the structure and functioning of agroecosystems. This simplified representation is achieved by selecting particular components and processes, making it possible to transform a generic and dispersed set of information collected in the field into a conceptual structure in which the information is condensed and coherently organized.

Partial and simplifying in nature, models are open to continual improvement and refinement. The degree of involvement is so subjective and the method so empirical that the provisional nature of the analyses made through this kind of approach is never in doubt. Adopting an approximative approach to knowledge building,[19] the method is based on the principle of optimal ignorance, i.e. focused on the objective of collecting the information necessary and sufficient to acquire increasing levels of comprehension of the dynamics of the analyzed agroecosystems.

By creating a common basis for dialogue, the modelling tools proposed here enable the perceptions and interpretations of different actors involved in the process – especially those of farmers (women and men, young people and adults) – to be recognized and incorporated into the analysis. The production and critical reflection on these representations in collaboration with farming families and, wherever possible, specialists in different areas, allow for intercultural dialogue and transdisciplinarity, overcoming the diffusionist and reductionist perspectives that still dominate the methodological conceptions employed in rural and agricultural research and extension.

Modelling agroecosystems

The models for representing agroecosystems are developed from information collected in the field via semi-structured interviews.[20] Guided by a basic script of questions spanning the environmental, social, technical, cultural and institutional variables involved in the configuration of the agroecosystem, the interview takes the form of a dialogue in which interviewers and interviewees have ample freedom to add aspects that they judge relevant.

The information collected relates to the structure and economic-ecological operation of the agroecosystem at the time of the interview, as well as in the past. Two instruments are used to systemize and present this information coherently (described below): a timeline for organizing historical information; and a flow diagram for representing the agroecosystem's structure and functional dynamics. With the help of these instruments, the analysis of the agroecosystem is contextualized in time as a contingent point within a development trajectory, and in space as a singular operational unit linked to the social and institutional surroundings through flows of economic-ecological exchange.

18 In our building of models, we create an idealized representation of reality in order to demonstrate some of its properties (Santos 2002). As conscious products of a distancing in relation to reality, models allow us to return to the real world with indefinitely renewable questions and inquiries (Bourdieu, Chamboderon & Passeron 1999).

19 The approximative approach corresponds to an incomplete objectification of reality as, indeed, good scientific practice always preaches (Bachelard 2004). Self-contained knowledge-building processes, which leave no space for doubt and ambiguities, produce fragile truths that quickly reveal a failure to match the objective world. The rejection and systematic doubting of previously produced knowledge comprises one of the basic principles of the advance of knowledge itself. In adopting this epistemological perspective, the method is founded on a process of knowledge building aware of its own insufficiencies and virtues.

20 The semi-structured interview has the characteristics of an open conversation (dialogue), focused on particular topic. It is different to a formal interview, based on a closed questionnaire that limits the dialogical interactivity between interviewers and interviewees. While the closed questionnaire has the advantage of gathering precise data and information capable of being tabulated and compared, it has the disadvantage of narrowing the scope of the interview, preventing important aspects for understanding the agroecosystem from being identified and recorded. The semi-structured interview is conducted using an interview guide that can be adapted to circumstances. Although some closed questions can be included in the guide, the methodology emphasizes dialogue steered by open questions.

The agroecosystem timeline

Creating a chronological record of the main events allows us to analyze the historical trajectory of agroecosystem in a coherent sequence, rather than just a list of facts disconnected from one another. The timeline is essential for discerning the underlying strategies informing the evolution of the agroecosystem, including the role of farmers as lead actors in their own development. The timeline is a social construct resulting from the interface between the accumulation of technical-economic decisions taken in the past and the strategic objectives for the future.

While agrarian research based on the theory of agricultural modernization takes rural development to be a linear process driven by a supposedly superior and universal economic rationality, this analytic perspective views the agroecosystem as the result of historical processes shaped by strategic choices made at specific moments in the SNAM's lifetime. In essence, this involves a dialectic relation between the possible and the real (Kosík 2002).[21]

In understanding the agroecosystem as a sociotechnical system shaped by the SNAM's reproduction strategy, the approach focuses on the patterns of congruence between the technical-economic practices adopted over its evolutionary trajectory. These patterns simultaneously define the internal organization of the agroecosystem and the external relations established by the SNAM – that is, the different levels of integration with and/or strategic distancing from sociotechnical networks structured in the territory. These

21 In this sense, the Lume method adopts a historical-dialectical materialism approach (Marx 1983). It takes as a reference point the concrete social practices (praxis) related to the reproduction of social life, giving central significance to labour in the processes of transforming nature and mediating social relations. By adopting this analytic perspective, it becomes possible to observe how the practices adopted over time by the SNAM mutually interact to shape a particular socio-technical system, while also being coherently linked to socio-technical networks structured at wider geographical scales.

FIGURE 2 Matrix for recording information on agroecosystem timeline

AGROECOSYSTEM TIMELINE																						
		Family:					Area:			Community:				Municipality:								
Agroecosystem	Others																					
	Fixed Capital (land and equipments)																					
	Livestock production																					
	Crop production																					
	Peridomestic system																					
	Family lifecycle																					
		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Territory/markets	Participation in the management of common goods																					
	Integration with political-organizational institutions																					
	Access to markets																					
	Access to public policies																					
	Others																					
		0 Years	1 Years	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years	11 Years	12 Years	13 Years	14 Years	15 Years	16 Years	17 Years	18 Years	19 Years	20 Years

patterns of congruence are actively constructed by the SNAM based on the selection of practices over time in response to both positive and negative events inside and outside the agroecosystem.

The essential information on the agroecosystem's trajectory is recorded in a pre-formulated matrix (Figure 2). Presenting it as a matrix makes it easier to understand interactions between the recorded events, and to communicate findings.

The information recorded on the timeline can be interpreted in two complementary directions:

1) Longitudinally: by interpreting the information over time, changes can be identified in the trajectory. Generally speaking, agroecosystems evolve through subtle changes – the outcome of a gradual incorporation of economic, socio-organizational and technical innovations. Over time, these changes significantly alter the structure and functioning of agroecosystems. In certain situations, trajectories can be observed to undergo abrupt changes (positive or negative) at specific moments, leading to a rapid reorganization of the SNAM's labour process. These critical moments of change usually occur when the SNAM increases its access to land (through purchase or distribution policies), gains access to new markets, begins a new economic activity, or loses a family member (through death or migration), suffers drastic changes in the environment and/or markets, and so on.

2) Transversally: this reveals the influences among the various variables recorded on the timeline and trends in the agroecosystem. This helps to highlight how the SNAMs combine the elements of the labour process (objects of labour, workforce and instruments) and respond to changes in the political-institutional surroundings. Two key elements can be identified in this exercise: a) the influence of the SNAM's social integration into the community and markets on the labour process (including production and processing techniques, commercialization, access to knowledge and common goods); and b) the influence of public policies on the processes of transforming the agroecosystem's structure and functioning.

BOX 2 The Systemic Perspective

Any system is an abstraction. Its delimitation aims to organize and process the knowledge relating to the set of co-ordinated elements from the real-life context that function as a structure organized in relatively autonomous form, but dependent on its surroundings to reproduce itself. In this sense, the system is a unit that reproduces itself in space and time through the dynamic balance established between the internal processes of self-organization and the ties of dependence on the external context. The system only exists due to its double condition of openness and closure to the outside. Hence it should be simultaneously conceived as a unit belonging to the context and as a difference in relation to this context. In order to exist as part of the context, the system differs in relation to the context (Morin 2008). As a product of particular contexts, the systems establish hierarchical levels between themselves. They are structurally subordinated in more wide-ranging systems and are composed by others located at a smaller scale. From the conceptual viewpoint, it is situated at a hierarchical level between the subsystems and suprasystems. As well as contextual, the systemic approach is processual. This means that systems are continuously transformed through adaptive processes triggered by changes to this context. Considering its double condition of openness and closure to the context in which it is embedded, the agroecosystem should be conceived as a self-governing unit, insofar as it establishes its own limits through operations of exclusion effected within its boundaries through dynamics shaped over time as an outcome of transformations to the external and internal contexts (Maturana 1975). This pattern of systemic organization takes the form of a metabolic web. The function of each subsystem in this web is to contribute to the production and transformation of other subsystems and, at the same time, help maintain the self-organizational dynamic of the whole. Additionally, the system selects the exchanges of matter, energy and information that it makes with the exterior in order to conserve and continuously renew its structure and functioning.

The agroecosystem flow diagram

The Lume method explores the economy of agroecosystems through a substantive evaluation of the economic process (Polanyi 2012),[22] seeking to analyze how economic-ecological flows are structured and integrated in real-life situations. To this end, a spatial representation using flow diagrams can reveal the metabolic processes described in Chapter 3. This tool borrows two core notions from systemic theory (box 2) in order to a) delimit the agroecosystem; and b) define the structure and function of the agroecosystem.

The modelling involves three phases: representing the structure of the agroecosystem; representing the agroecosystem's functioning (definition of flows); and quantifying flows.

Representing the agroecosystem's structure

The modelling instrument proposed by Lume method establishes a conceptual standardization to represent the structural elements of the agroecosystem, as well as the economic-ecological flows that link them systemically. The following structural units are represented by flow diagrams:

- Agroecosystem: the ecological infrastructure (natural or artificial) used by the SNAM in its labour process.
- Subsystems: the basic economic-ecological management units of an agroecosystem. They can comprise a single economic production (an orange orchard for example) or an integrated set of productions (a field with annual crops, a backyard, and so on).
- Fertility mediators: structural elements that form part of the ecological infrastructure of the agroecosystem. In the proposed methodology, only the artificial elements of the ecological infrastructure are represented, i.e. the equipment and facilities used to capture, store, transport and process the abiotic resources (water, nutrients and energy) mobilized by the agroecosystem's labour process.

22 According to Polanyi (2012), economy can be understood in two senses: the substantive and the formal. "The latter derives from logic, the former from fact" (ibid: 294). "The substantive meaning of economic derives from man's dependence for his living upon nature and his fellows. It refers to interchange with his natural and social environment, in so far as this results in supplying him with the means of material want satisfaction… The formal meaning implies a set of rules referring to choice between the alternative uses of insufficiency resources" (ibid: 293 and 294).

- Suprasystems: the SNAM establishes relations with three kinds of suprasystem (Box 3): the community, the markets and the state, corresponding to the social integration mechanisms identified by Polanyi (2001).

BOX 3 The three suprasystems

1. Community: for the purposes of this analysis, 'community' is defined as the social universe in which the SNAM engages in economic transactions mediated by relations of reciprocity (non-monetarized exchanges).
2. Markets: are institutions in which the products and services generated by the SNAM's labour are converted into money or, in the opposite direction, where the SNAM's financial capital is exchanged for material goods and/or services. They are represented in two distinct categories corresponding to different levels of regulation carried out by local actors: "territorial markets" and "conventional markets". With this distinction it becomes possible to discern different degrees of control exerted by the SNAM over the market transactions in which it engages.

   The territorial markets (FAO/CMS 2019) can be understood as hybrid institutions, since they combine reciprocity with commercial exchanges (Sabourin 2011; Polman et al. 2010). Unlike the conventional/capitalist market, structured by abstract conventions and impersonal relations shaped by hegemonic power relations, territorial markets, also called 'nested markets' (Hebinck, van der Ploeg and Schneider 2015; Ploeg 2015), are structured by the direct interaction between the economic agents involved. Through them are realized particular market transactions involving price formation, relations of trust and fidelity established with consumers, the quality and diversity of products and, finally, the percentage of added value retained in the territory.

   The conventional market corresponds to an institution whose operational rules are controlled by outside economic agents (for instance: suppliers of industrial inputs and equipment, commercial banks, etc.). The market transactions established in the conventional market (upstream and downstream of the agroecosystem) frequently involve the outflow of a significant part of the wealth produced by the SNAM's labour process to agents outside the territory.

   State: the economic flows between the agroecosystems and the state move in two directions: the inflows correspond to the resources mobilized through official public policies; the outflows represent tax payments.

Representing the economic-ecological functioning of the agroecosystem

The economic-ecological functioning of the agroecosystem is represented by the flows amongst its structural elements described above. The tool proposes developing three specific flow diagrams to organize the information collected in the field: inputs and outputs (Figures 3 and 4); monetary and non-monetary income (Figure 5); and the social division of labour within the SNAM (no image)

In Figure 3, inputs are represented as inflows (black arrows) into the systems (the agroecosystems or subsystems). The origin of the consumed inputs is essential information for the analysis. They may derive from the agroecosystem itself, either as subproducts of production processes (e.g. the use of crop residue as animal fodder or dung as organic fertilizer) or as material specifically produced for a particular subsystem (e.g. the fodder grown in grass fields). They may also come from suprasystems, whether through market flows or through relations of reciprocity established with other actors from the community.

FIGURE 3 Input Flows

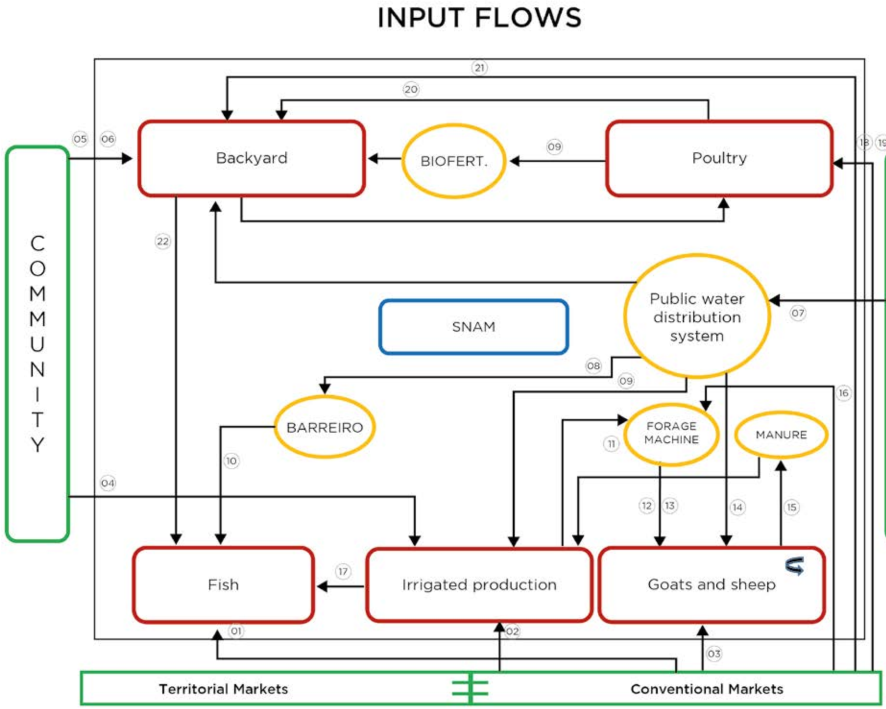


FIGURE 4 Output Flows

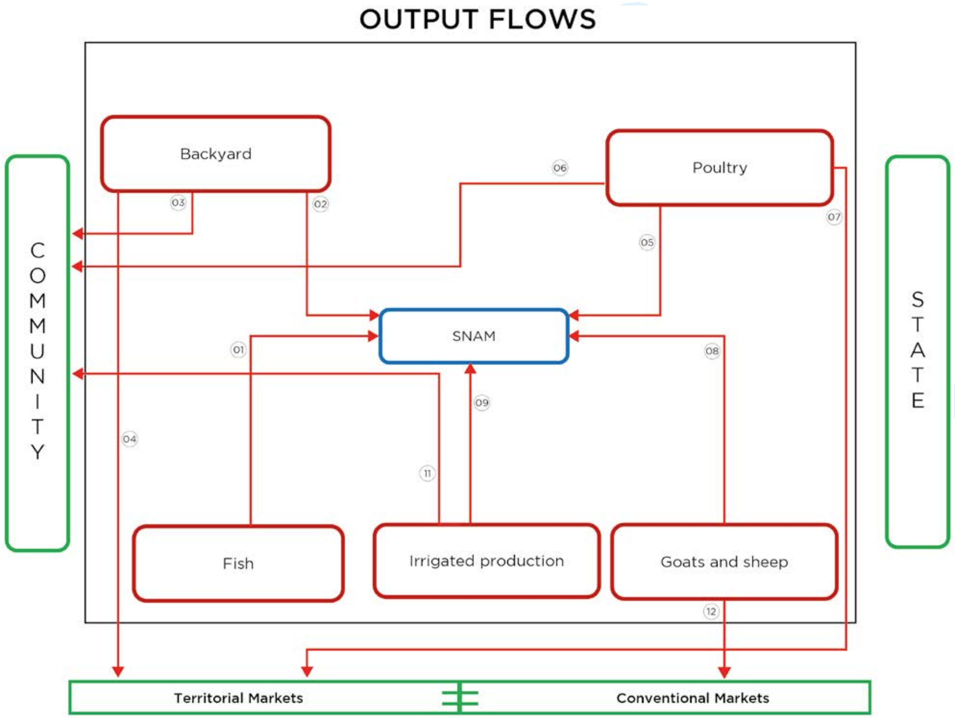
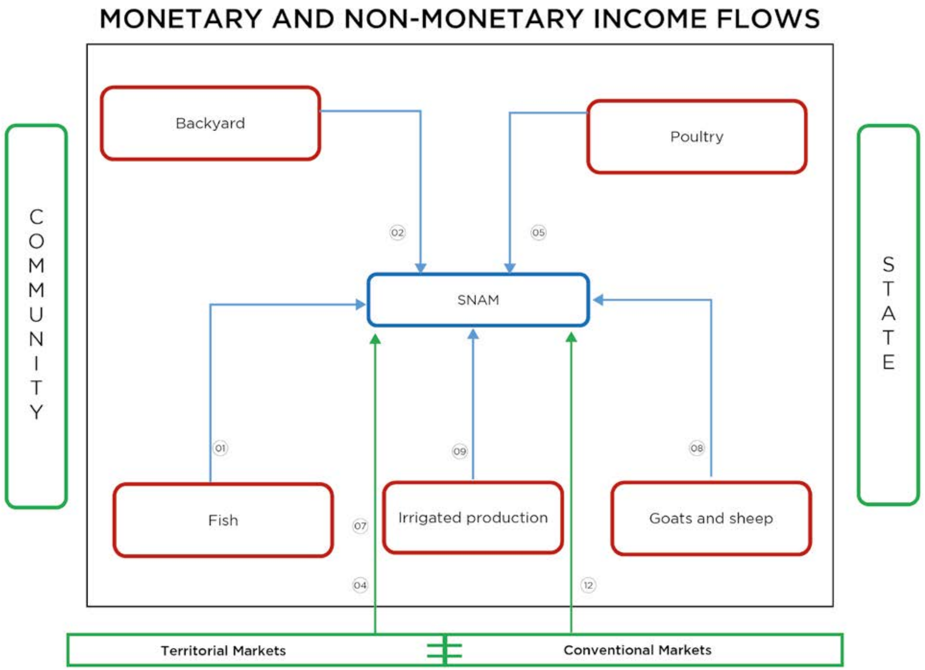


FIGURE 5 Monetary and non-monetary income flows



In Figure 4, outputs (red arrows) are defined as every ecological good converted into economic good (income), whether monetary (exchange value) or non-monetary (use value). In the diagram, outputs are shown flowing directly to the SNAM (representing outputs converted into non-monetary incomes) and to the suprasystems (market, converting into monetary income; or community, converting into non-monetary income).

Monetary and non-monetary income flows are represented in Figure 5. In this case, the sold products are represented by monetary flows from the markets to the SNAMs (green arrows). Non-monetary income (blue arrows) flows from the subsystems to the SNAM (production for self-consumption) and the community (exchanges by reciprocity).

The third diagram represents the social division of labour and seeks to identify the activities performed in four social spheres: generation of agricultural income (sale, self-consumption, exchange and donations); domestic and care labour; social participation; generation of non-agricultural income (or pluriactivity).

The work carried out in the sphere of agricultural income production is represented by flows from the SNAM to the subsystems. In the domestic sphere and care work, labour is represented by circular flows within the SNAM. The work related to the sphere of social participation is represented by flows from the SNAM to the community. Finally, the work in the sphere of non-agricultural income production (pluriactivity) is represented by flows towards the markets – even where the work is public, i.e. remunerated by the state.

As well as identifying the distribution of labour among the different spheres of occupation, this diagram represents the sexual and generational division of labour within the SNAM. This discrimination makes it possible to measure the proportional contribution of men, women, adults and young people from the SNAM to the generation of wealth produced in the agroecosystem.

Quantifying economic-ecological flows in the agroecosystem

Taking these flow diagrams as a reference point, the next stage of the modelling involves quantifying each of the flows represented (inputs and outputs, monetary and non-monetary incomes, and labour time dedicated to different activities). The analysis period is one agricultural year to allow for at least one cycle of conversion of resources into products. It also comprises the period of reference for the SNAMs' economic accounts.

Both monetary and non-monetary income flows are calculated by quantifying the input and output flows using the data obtained during the semi-structured interviews described earlier. This exercise enables us to evaluate the relevance of those economic-ecological flows masked by conventional economic analyses, which is limited to the sphere of market circulation. Non-monetary income is measured by determining the equivalent monetary value of products that are self-consumed and/or exchanged in the community.

The quantification of labour dedicated to distinct spheres of economic occupation allows us to calculate the share of each social segment of the SNAM (men, women, youth, adults) in the joint production of the added value or the total income of the agroecosystem. Measuring labour time is a form of economic analysis that has been increasingly and productively adopted by feminist economics authors (Durán Heras 2010). Among other positive effects, it helps to generate information that can support the feminist struggle against gender inequality.

Using the information and data collected in the field and presented in the two models described above, the economic-ecological analysis of the agroecosystem is undertaken from two complementary perspectives: one qualitative, the other quantitative.

Qualitative analysis of the agroecosystem

Analysis of information collected in the field tends to be a weak point in participatory rural appraisals, undermining the results and the aims of these exercises in collective knowledge building. Generally speaking, this shortcoming stems from the absence of adequate theoretical-methodological benchmarks for analysing the complex set of variables relating to different dimensions and scales involved in the dynamics of the economic-ecological functioning of agroecosystems.

This proposal for qualitative analysis was conceived precisely to help fill this lacuna. Inspired by the concepts and instruments developed in the Framework for Evaluating Management Systems Incorporating Sustainability Indicators (Masera, Astier & López-Ridaura 2000),[23] it adopts a conceptual framework based on systemic theory applied to agroecology, helping guide participatory processes of critical reflection on different systemic attributes of agroecosystems.

Despite its qualitative nature and the presence of a subjective component to its evaluations, the method uses a coherent logic for organizing and translating the information and data collected in the semi-structured interviews into synthetic indices of interconnected parameters, reflecting different systemic qualities.

23 The Framework for Evaluating Management Systems Incorporating Sustainability Indicators (the MESMIS Framework, following its Spanish acronym) is a methodology developed by four Mexican institutions in the 1990s: Interdisciplinary Group for Appropriate Rural Technology (GIRA following its Spanish acronym), the Centre for Ecosystem Research at the National Autonomous University of Mexico, the Southern Frontier College and the Centre for Research in Farming Sciences at the Morelos State Autonomous University. MESMIS is an interdisciplinary methodology based on theoretical contributions related to complex and adaptive systems, systemic self-organization processes and agroecology. To these theoretical frameworks, the authors added elements from the then emerging academic debate on attributes of sustainability in agriculture (Astier et al. 2008).

Systemic attributes: the focal points of the qualitative analysis

The functional organization of socioecological systems, including agroecosystems, stems from the complex dynamics among ecological, economic, social, political, technical and cultural variables. According to systems theory, these interactions generate emergent qualities (or emergent properties) which singularize the system in relation to the context in which it is embedded.

As discussed earlier, the agroecosystem's patterns of organization are the result of strategies of economic-ecological reproduction (or management styles) adopted by the SNAMs.

The Lume method guides analytic reasoning by translating the objective information collected in the field into synthetic judgements on specific qualities of the agroecosystem, understood here as 'systemic attributes'. The following attributes are examined in the analysis and described in turn below: a) autonomy; b) responsiveness; c) the SNAM's social participation; d) gender equity/women's empowerment; and 5) young people's empowerment. Annex A contains tables for each of these attributes, containing the parameters and criteria used for assessing them.[24]

Autonomy

The autonomy of the agroecosystem will always be partial – varying according to the restrictions and opportunities encountered in the external context and the strategic options adopted internally by the SNAMs.

Furthermore, autonomy does not remain static over time. It varies as a result of circumstantial or permanent transformations in the political-institutional, economic and ecological environment in which the agroecosystem operates and as an outcome of the strategic decisions taken by the SNAM itself. Consequently, the level of autonomy always depends on the dynamic balances established between the external determinants and internal capacities for response.

As an attribute resulting from the balance between the conditions inside and outside the agroecosystem, autonomy should be evaluated from a double perspective:

24 The systemic attributes should be understood solely as guides for orienting the analysis and not as characteristics inherent to the agroecosystems analyzed. Although attributes can be analyzed individually, they influence each other. Hence the option to guide the analysis according to attributes specified by objective parameters and criteria should not give way to the use of reductionist and mechanistic interpretations of agroecosystem's qualities.

- As the SNAM's room for manoeuvre (or margin of freedom) in implementing reproduction strategies consistent with their economic perspectives and life projects. In this case, the attribute refers to the internal conditions and should be described as 'autonomy to ...'
- As a power relationship established between the SNAM and the social and political universe constituted by agents and institutions that determine and regulate the rules for appropriating natural goods and the economic-ecological flows within agrifood systems. In this case, the attribute refers to the relations with external actors and should be described as 'autonomy from...'

Autonomy can only be fully understood when observed from both sides. For the first perspective (autonomy to...), autonomy is increased with the expansion of the 'self-controlled resource base' through which the SNAM mobilizes production factors without the need to resort to market purchases. On the other hand, a resource base that is limited and under pressure implies lower levels of autonomy.

This analytic perspective is congruent with the notion of 'development as freedom', as formulated by Sen (2001). According to his approach, development occurs when individuals and collectivities control the 'means' by which they can achieve their desired 'ends'. In the author's words, "[...] development consists of the removal of various types of unfreedoms that leave people with little choice and little opportunity of exercising their reasoned agency" (ibid: xii). For this actor-oriented perspective, the results of development are reflected not only in improvements to material life, but also in the capacities of farmers (individually and collectively) to define and put into practice their reproduction strategies.

Adopting Sen's analytic approach, these capacities are conditioned by three elementary factors: the 'stock of resources' accessed by the labour process; the 'possibilities for production' linked to the technological pattern and the mastery of knowledge; and the 'exchange conditions' related to the power exerted over market transactions.

Economic-ecological management strategies founded on the construction, maintenance and, where possible, continuous expansion of a self-controlled resource base ("entitlements" as defines Sen) are characterized by high levels of investment in qualified reproductive work, designed to integrate the multiple tasks undertaken in the SNAM's various spheres of work.

Meanwhile the second analytic approach to autonomy (autonomy from...) indicates that this attribute is higher when the 'level of externalization' of the operations linked to the SNAM's labour process is lower – i.e. there is a lower transfer of control over productive resources to outside actors (banks, companies, co-operatives, technical specialists and industries). An increase in degrees of externalization implies a larger proportion of resources entering the production process in the form of commodities. This progressively destructures the agroecosystem's organic unity between production and reproduction, making the SNAM more structurally dependent on market relations and the technical and administrative requirements associated with them (Ploeg 1990).[25] In this sense, this second focus to evaluating autonomy is directly associated with the agroecosystem's 'degree of commoditization'.

In more autonomous agroecosystems, markets are used mainly as routes for selling production. In less autonomous (or more dependent) agroecosystems, markets act as an organizing principle of the labour process. Adopting this perspective, the resulting gradation can be associated with the agroecosystem's degrees of peasantness, the most autonomous being those identified with the peasant mode of production, and the least autonomous more closely identified with the entrepreneurial mode of production.

By highlighting the central role of the SNAM's labour process, analysis of the autonomy of the agroecosystem focuses attention on the decisive element in the economic-ecological reproduction strategies of farming families: namely, the production and appropriation of the highest added value possible vis-à-vis the agroecosystem's objective internal circumstances (autonomy to...) and external circumstances (autonomy from...).

A set of objectively verifiable parameters is associated with the SNAM's capacity to economically optimize its workforce, whether to amplify added

25 The Technological and Administrative Task Environment (TATE) is a concept developed by Benvenuti (cited in Ploeg 1990) "to describe the network of market-agencies and associated institutions to which farmers are tied both economically and technically (agricultural industries, banks, trade consortia, extension services, etc.)... It is from TATE that the farmer obtains those elements which are necessary but which he cannot independently ot fully develop himself. TATE therefore forms the embryo of a specific division of labor between head and hand (i.e., TATE expresses the separation of what in craftsmanship, to large extent, still forms a unified whole)" (idem:107).

value, or to limit transfer of this value to external agents. Mirroring the two approaches to analyzing autonomy, this set of parameters is subdivided into two groups. The first is related to the use of marketable productive resources and corresponds to autonomy from the inputs and services markets. The second group is related to the self-controlled resource base (see Table A1 in Annex A for the parameters and criteria used in the assessment).

Responsiveness

Responsiveness relates to the capacity to respond to changes in the social, economic and environmental surroundings of the agroecosystem. These changes may be positive or negative – in other words, they may restrict or create new opportunities for the development of agroecosystems.

Increasing responsiveness involves the continuous investment by the SNAM over the years in order to enhance internal mechanisms for systemic self-regulation, providing greater certainty that it can achieve its economic and social objectives. Hence, the development of responsiveness results from the adoption of conscious strategies by the SNAM to counter its perceptions of risk. In this sense, responsiveness is actively built through the combination of strategic preventive decisions and tactical adaptive actions. For this reason, agroecosystems managed with the objective of maximizing short-term economic gains tend to be less responsive.

Responsiveness can be analyzed from four complementary perspectives, each of which corresponds to a type of response to changes in the socioecological context involving different levels of intensity and predictability (see Table A2 in Annex A for more details):

- Stability: the agroecosystem's capacity to maintain or raise production levels in response to recurrent and predictable fluctuations in the surrounding context. Such responses do not require structural alterations in the agroecosystem since it possesses internal compensation mechanisms capable of dealing with such fluctuations.
- Flexibility: the agroecosystem's capacity to adapt to unforeseen and permanent changes to the context. These require structural transformations in the agroecosystem to adapt to the new context. More flexible agroecosystems adapt to changes in context more quickly and at lower cost.
- Resistance: the agroecosystem's capacity to maintain its dynamic equilibrium when faced with intense unforeseen and episodic (transient) changes to the context in which it operates. More resistant agroecosystems remain active during periods of disturbance, thanks to the presence of internal compensation mechanisms and a stock of resources available on which to draw.
- Resilience: the agroecosystem's capacity to recover its dynamic equilibrium after reducing its activity in response to intense unforeseen and episodic changes to the context in which it operates. The quicker and more autonomous this capacity for recovery, the higher the agroecosystem's resilience.

Social participation

Social participation is the set of non-commoditized relations established by the SNAM within the socio-institutional environment in which it lives and produces. Although important in evaluating the agroecosystem's autonomy and responsiveness, it is analyzed separately in order to increase the visibility of the economic exchanges based on reciprocity, a mechanism of social integration characteristic of peasant family farming (Sabourin 2011).

The active participation of members of the SNAM in community life is indispensable for common goods to be created, accessed and mobilized for the labour process and the economic-ecological reproduction of the agroecosystem. This is the reason why this method counts the time involved in social participation as reproductive work.

Access to resources redistributed by the state is also strongly influenced by the SNAM's practices of social participation, in particular participation in spaces of collective deliberation and influence over public policies (unions, associations, cooperatives, etc.). Table A3 in Annex A lists the parameters and criteria used in the assessment of social participation.

Gender equity/women's empowerment

This attribute helps shed light on gender-based social relations in the SNAM, making visible various forms of oppression against women that are frequently overlooked in conventional analyses of family farming economies. The information produced can lend support to women's struggle against patriarchy, in particular challenging traditional practices surrounding the sexual division of labour and other asymmetries in the power relations between men and women. It is evaluated using the parameters and criteria listed in Table A4 in Annex A.

Generation equity/young people's empowerment

Expanding the range of possibilities for young people from the SNAM to work, acquire professional training and realize their life projects (inside or outside farming) is a key objective for transforming family farming. Recognizing rural youth as people with rights and increasing their access to alternative forms of work, income, educational spaces and leisure in the rural world are essential for overcoming the intergenerational asymmetries and conflicts related to agroecosystem management, frequently controlled by the father as head of the family. These culturally-rooted asymmetries tend to be accentuated by the domination of short-term productivist perspectives in the logic of economic management of agroecosystems. By analyzing the intergenerational relations in the SNAM (using the parameters and criteria listed in Table A5 in Annex A), the method seeks to increase the visibility of this central dimension for the continuity of family farming.

Evaluating the systemic attributes

Evaluating the systemic attributes involves interpreting all the information collected in the field and systemized with the help of the models designed to represent the agroecosystem, as presented earlier.

Each attribute[26] involves the integration of a narrow set of objective parameters that, in turn, are specified by associated criteria (listed in Annex A). Consequently, the method makes use of a logical framework composed of criteria, parameters and attributes that guide analytic reasoning, allowing the information relating to the complex of variables involved in the economic-ecological functioning of the agroecosystem to be processed coherently.

In this logical process, the criteria operate as conceptual devices for selecting and interpreting the relevant information concerning each of the evaluated parameters. The criteria for each of the parameters are scored on

26 Although it is not essential to evaluate all the proposed systemic attributes, the analysis of the whole provides a broader vision of the current dynamic functioning of the agroecosystem and its prospects for sustainability. In addition, other attributes can always be included, enabling specific aspects to be explored that do not form part of this methodological proposal.

TABLE 1 Scores for evaluating the parameters

Score	Significance
1	Very low
2	Low
3	Middle
4	High
5	Very High

a scale of 1 to 5 (Table 1). The scores attributed to each of the parameters condense objective information on particular characteristics of the analyzed agroecosystem.

After the qualitative evaluation of each of the parameters specifying the systemic attributes, the scores are entered into a spreadsheet designed to generate combined indices (on a scale of zero to one) which express the qualitative evaluation of each of the systemic attributes, as well as the agroecosystem as a whole. As the scores are entered, the spreadsheet simultaneously produces spider graphs that visually display the qualitative evaluation of each of the systemic attributes (see Figures 9, 10 and 11 in Chapter 5 for examples).[27]

Although they are averages of the scores, these combined indices provide an approximate view of the operational dynamic of the agroecosystem in relation to its surroundings. They are not sensitive enough to capture differences between agroecosystems managed through the same style of economic-ecological reproduction. On the other hand, significant contrasts can be identified when the comparative evaluation is made between agroecosystems managed according to different styles. As well as allowing for different agroecosystems to be compared, the method also enables the same agroecosystem to be contrasted at different moments of its development trajectory.

27 The spreadsheets are available at www.aspta.org.br/2015/05/metodo/ (in Portuguese).

Quantitative analysis

The quantitative analysis of the economic performance of the agroecosystem is inspired by the 'Diagnostic Analysis of Agrarian Systems' methodology, formulated by Dufumier (2009) and used in an United Nations Food and Agriculture Organization (FAO) technical co-operation project for producing knowledge on the family farming economy in Brazil (Garcia Filho 1999). The Lume method proposes a framework of indicators that express the economic-ecological output of the agroecosystem from different perspectives. This is done by recording data on the economic-ecological flows identified when modelling the agroecosystem in a spreadsheet designed to present the various indicators in a numerical and graphic format. Once the raw data has been added to the spreadsheet, the indicators are presented at different levels of aggregation, generating a detailed representation of the economy of the agroecosystems broken down into different analytic areas: subsystem, sphere of work (commercial and self-consumption, domestic and care work, social participation and pluriactivity), sphere of economic circulation (commercial exchanges or reciprocity), gender and generation.

By diversifying the perspectives beyond those of conventional economic analysis, the indicators reveal labour and power relations concealed in the official statistics on agriculture and agrifood systems. The indicators include:

- Gross Product (GP): the sum of all sold, self-consumed, donated and stored produce. This means that it includes both monetary and non-monetary values.
- Gross Income (GI): equivalent to the gross product minus the stored produce.
- Added Value (AV): equivalent to the gross income minus the market-purchased inputs that are entirely consumed in the production process - the costs related to intermediate consumption or (IC). This indicator expresses the wealth effectively generated by the labour process.
- Agricultural Income (AI): equivalent to the added value minus the monetary amounts spent on outsourced services.
- Monetary Agricultural Income (MAI): the portion of agricultural income resulting from the sale of produce.
- Territorial Added Value (TAV): the portion of wealth (AV) generated in the agroecosystem that remains in the territory, generating multiplying effects for the regional economy. It is calculated by identifying the destination of the monetary resources used to purchase production inputs: whether local actors (from the territorial markets) or companies based outside (conventional markets).
- Rentability Index (RI = MAI/PC): the Monetary Agricultural Income recovered per unit of monetary cost invested in production. Obs. Production Costs (PC) correspond to the inputs and services purchased.
- Endogeneity Index (EI = AV/GP): the portion of gross income generated by the work involved in managing the agroecosystem. It indicates the proportion of total income generated by converting ecological goods from the SNAM-controlled resource base into economic goods. It is used as a corrective factor for conventional indices of intensity (GP/hectare) (Figueiredo e Côrrea 2006) that mask the use of exogenous ecological goods in the labour process of agroecosystems.
- Intensity Level (IL): the wealth obtained per unit area – it expresses the level of technical-economic efficiency in the conversion of ecological goods from the SNAM-controlled resource base into economic goods. It can be expressed in two forms: a) added value per unit area (AV/ha), which expresses the efficiency level obtained through the activities of the labour force as a whole allocated to production activities; or b) agricultural income per area unit (AI/ha), which expresses the efficiency level obtained by the labour force for generating part of the AV directly appropriated by the SNAM.
- The Commoditization Index (CI): where CI = PC/TPC, where PC (production costs) is the costs of the resources (inputs and services) that enter the production process as commodities and TPC (total production costs) is the sum of the cost of the marketable productive resources and the productive resources reproduced by the labour process itself (including the inputs produced within the agroecosystem or obtained by reciprocity relations at community). It indicates the agroecosystem's degree of dependence on the inputs and services markets.
- Labour Productivity: this is indicated by three indicators: added value per hour worked (AV/HW); agricultural income per hour worked (AI/HW); and added value per unit of family labour (AV/UFL).

- The share of the added value created by different economic occupations, gender groups and generations within the SNAM. It indicates the proportional contribution of the different segments of the SNAM and of the labour performed in the different spheres of economic occupations to the wealth generated in the agroecosystem over a one-year period.

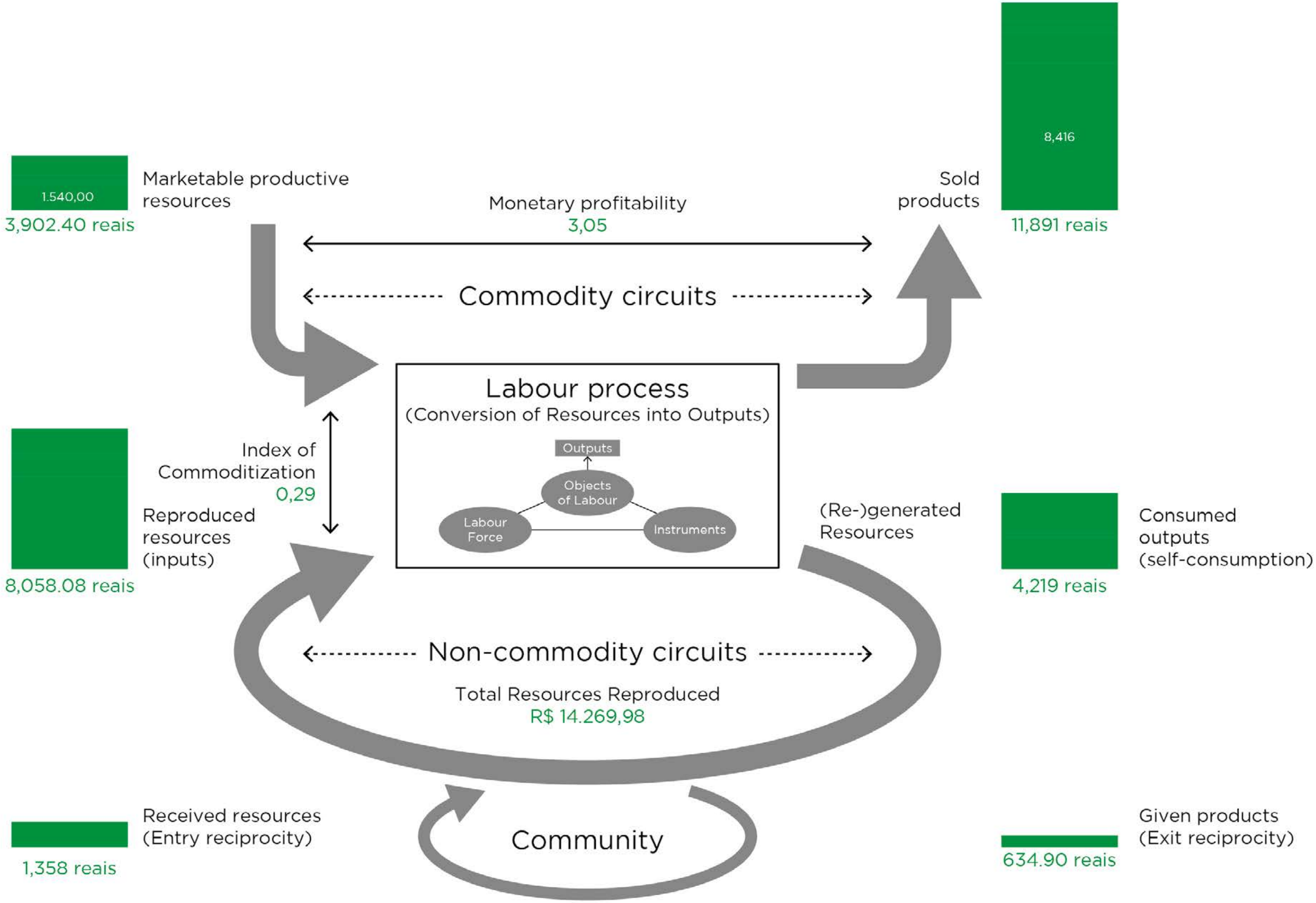
As well as presenting a set of tables and graphics with the economic indicators listed above, the spreadsheet make up automatically an overview diagram of the monetary equivalents for the economic-ecological flows involved in the process of converting resources into products (Figure 6).

Two economic relationships shown in the diagram express the agroecosystem's patterns of economic-ecological reproduction. The first is the balance between the revenue generated by the sold produce and the expenses incurred in mobilising production factors (inputs and services) from the markets (marketable production resources). This balance, the monetary agricultural income (MAI), varies according to the quantity and cost of the marketable resources consumed, the technical efficiency in converting resources into products, and the price of the marketed products. The rentability index – i.e. the percentage of remuneration from the money invested in production (MAI/PC) – is an indicator directly derived from this balance. Although this indicator has considerable importance in defining SNAMs' reproduction strategies, it assumes a central role in those agroecosystems employing entrepreneurial styles of management, since their economic-ecological flows are essentially governed by the 'market logic'.

The second relationship is the balance between marketable production resources (inputs and services) and the resources reproduced through the labour process in the agroecosystem and/or received from third parties through relations of reciprocity. In management styles with a higher degree of peasantness, a relatively higher percentage of resources mobilized for the labour process is reproduced by labour performed in previous production cycles, implying a higher degree of autonomy from the inputs and services markets. The relative degree of autonomy from (or dependency on) production factor markets is indicated by the commoditization index (described above).

When combined, these two relationships reveal striking differences between the styles of economic-ecological management of agroecosystems. In market-dependent styles (more business-oriented), commoditization indices are higher (closer to 1), while in relatively autonomous and historically guaranteed styles (higher degrees of peasantness) commoditization indices tend to be smaller (closer to 0).

FIGURE 6 Overview of the agroecosystem's economic-ecological flows



5 Implementing the method in Brazil

There are many practical applications of this method. This chapter explores how it was used during the study on "Family farming systems resilient to extreme environmental events in the context of the Brazilian semi-arid region: alternatives for confronting desertification processes and climate changes", which was conducted from 2014 and 2017.[28] Executed in partnership between the Brazilian Semi-Arid Alliance (Articulação Semiárido Brasileiro: ASA)[29] and the National Semi-Arid Institute (Instituto Nacional do Semiárido: INSA/MCTI), the aim of the research was to evaluate the impacts of public programmes to promote water security in rural communities on the socioecological resilience of family farming in the region.

Conceived and executed by civil society organizations from the beginning of the 2000s, the programmes are designed to install small-scale infrastructure in rural establishments and communities in the semi-arid region in order to catch and store rainwater for human consumption (P1MC Programme) and food production (P1+2 Programme).[30] The programmes offer innovative technological proposals for supplying water to the rural population, breaking with the tradition of public intervention focused exclusively on constructing large-scale infrastructure (reservoirs, dams, water ducts). They also offer a new approach to public action, centred on a partnership between civil society organizations and the state, aiming to promote endogenous rural development.[31] These innovations represent a paradigm shift insofar as they are guided by the notion of 'living with the semi-arid', in clear contrast to the 'fighting the drought' approach that has informed state initiatives in the region historically (Silva 2006; Conti & Pontel 2013).

More than 15 years after the start of the programmes, more than 1.2 million cisterns ('first water') have been constructed, mostly through the P1MC Programme, and more than 100,000 hydraulic infrastructures ('second water') by the P1+2 Programme (MDSA 2016). Despite empirical evidence of the positive impacts of the programmes on the livelihoods of the region's rural families and communities,[32] a systematic study encompassing different socioenvironmental contexts had never been undertaken.

The INSA-ASA research study sought to fill this lacuna by gathering useful lessons for improving public policies both for adapting to climate change and for combating desertification in the Brazilian semi-arid region. It was conducted amid a lengthy period of drought which tested the socioecological responsiveness of the agroecosystems in the region.[33] Setting out from the understanding that resilience results from the dynamic interaction between social and ecological variables, the study sought to describe and analyze the effects of the structural and functional transformations occurring in agroecosystems located in 10 semi-arid territories following their involvement in ASA's programmes. As well as incorporating water infrastructure as 'fertility mediators' in the metabolism of the agroecosystems (see Chapter 4), this involvement included participating in farmer-to-farmer exchanges and training courses organized by the programmes. Figure 7 identifies the locations where the research was conducted. The sample size of the study was around 45 family units, although the entire method (qualitative plus quantitative analysis) was only applied in 10 units, one from each territory.

28 The project was financed through Tender MCT/CNPq/CT-Hidro No. 36/2013, particularly the thematic line "Water and soil management on areas undergoing desertification."

29 The Brazilian Semi-Arid Alliance (ASA) is a network of more than 3,000 civil society organizations working on policies for "living with the semi-arid" environment.

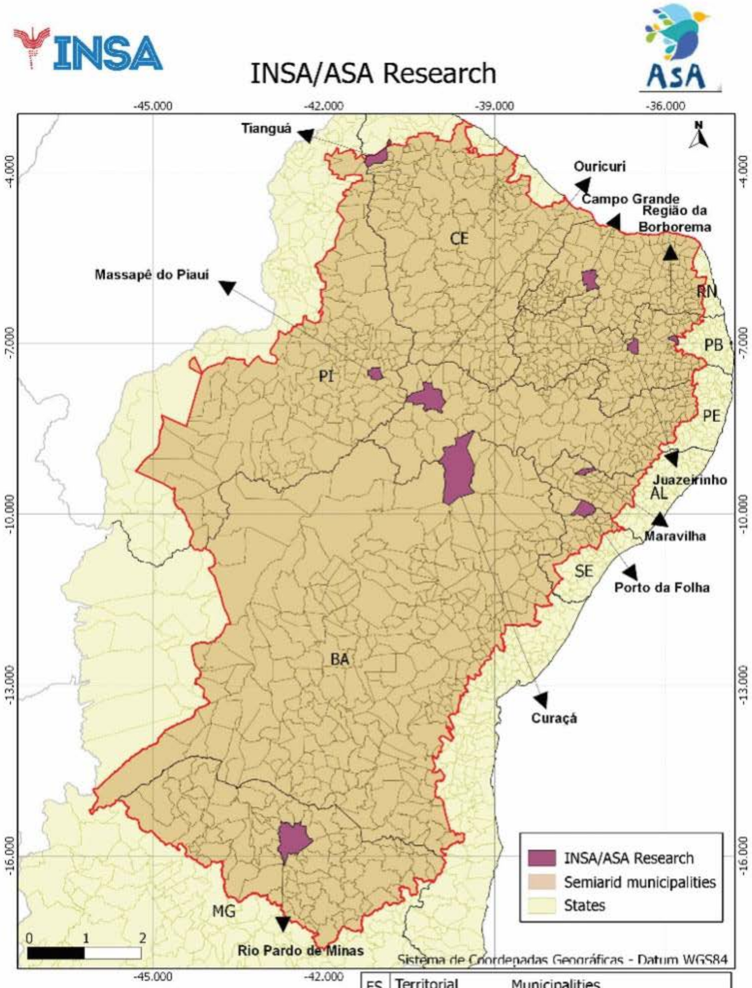
30 The "Training and Mobilization Program for Living with the Semi-Arid Region – A Million Rural Cisterns" (P1MC) aims to construct cisterns to catch and store water for human consumption. The "One Land and Two Waters Program" (P1+2) aims to install technologies to manage rainwater for the purpose of food production. For more information on the programs, see www.asabrasil.org.br (in Portuguese).

31 P1MC and P1+2 reproduce practices and perspectives consistent with the notion of endogenous rural development, a development pattern based on the mobilization and redynamizing of resources available locally in the rural territories.

32 Among the richest and most complete empirical evidence on the effects of these programmes on the lives of rural families and communities are 'O Candeeiro' ('The Lamp'), a collection of more than 2,200 information bulletins produced by ASA's organizations which document life histories (see www.asabrasil.org.br/acervo/o-candeeiro).

33 Taking into account total rainfall amounts, this period has been identified as 'the biggest drought' in the last 100 years (Silva 2017). Despite the severity of the phenomenon, there is a general conviction that its negative social effects were significantly lower than previous droughts (Osava 2017).

FIGURE 7 Location of the 10 case-study territories



FS	Territorial Management Units (UGT)	Municipalities
PE	CHAPADA	OURICURI
PI	CARITAS - PI	MASSAPÊ DO PIAUÍ
SE	CDJBC	PORTO DA FOLHA
PB	AS-PTA/PATAC	BOBOREMA/JUAZEIRINHO
RN	SERTÃO VERDE	CAMPO GRANDE
AL	CDECMA	MARAVILHA
BA	IRPAA	CURAÇA
MG	CAA	RIO PARDO DE MINAS
CE	ESPAF	TIANGUÁ

Sampling was not random – the idea was to analyse those units that began to innovate following the installation of water infrastructure.

The hypothesis tested was that the ASA programmes exert a 'trigger-effect' on the sociotechnical innovation trajectories in family farming in the semi-arid region. This means that by developing mechanisms for compensating for the effects of drought, they simultaneously increase socioecological resilience, while also increasing economic intensity and technical autonomy through greater efficiency in converting production factors from the self-controlled resource base into income. In other words, by acting on the main ecological constraint of agroecosystems in the semi-arid region – water deficiency – ASA's programmes help to expand farming families' room to manoeuvre to develop new technical-economic strategies through recombining locally available socio-material resources.

To verify this hypothesis, the research was carried out using the Lume method. Data on the evolutionary dynamics of agroecosystems, as well as their current configurations, were collected through semi-structured interviews, systematized with the help of modelling instruments and analyzed both qualitatively and quantitatively.

Variations in levels of resilience, autonomy and intensity of agroecosystems were ascertained by comparing two moments in the agroecosystems' trajectories: immediately prior to the installation of the water infrastructure by the ASA programmes (dates varying according to the agroecosystem) and the year when the interviews were conducted (between 2014 and 2016). On average, the period between these two evaluation moments was seven years.

Mapping agroecosystem trajectories and innovation

The analysis of the agroecosystems trajectories was key for evaluating any increase in responsiveness levels. It involved interpreting the information recorded on the agroecosystem timelines so as to view the continuous processes of structuring 'webs of innovations', in which SNAMs' initial innovations create the conditions for the emergence of subsequent innovations and so on (see Figure 8 for an example).

The timelines also revealed that the sequencing of innovations in time and space depends on local socio-material realities and evolves in response to families' opportunities, constraints and strategic objectives. Many of the studies revealed that part of the water stored in the new reservoirs was systemically allocated to intensifying the production of domestic yards. This option meant that these spaces acquired greater importance in the economy of the agroecosystems, either by producing a significant portion of the food consumed by the families, or by generating large volumes of products sold locally, either processed or not.

Livestock production was another important area for innovation in the agroecosystems. As well as providing larger reserves for watering livestock, the new water infrastructure helped to increase the volumes of fodder biomass produced. New fodder species were introduced by the SNAMs, including native species, and new spaces for fodder production were created. In many situations, the increase in livestock boosted family income, as well as the volumes of manure produced. Given the heightened demand to restore fertility in new spaces of the systems (such as yards), organic fertilizer began to play an essential role in technical reproduction, ceasing to be sold in some of the studied situations. In order to improve the quality of the fertilizer used, other innovations were introduced, such as manure storage tanks and wormeries. In some cases manure has become valued as a source of energy through the installation of biodigesters.

Other areas of innovation, such as the management of agrobiodiversity, replanting with multifunctional species, and local processing of produce, also saw the SNAMs' web of innovations expand in various directions and work domains. The flow diagrams helped to visualize changes in the metabolism of the agroecosystems, along with the increasing density of economic-ecological flows. Similar to the ecological processes in ecosystems, cycles of matter and energy are produced at an agricultural landscape scale, allowing the same factor of production to be used in subsequent processes of converting ecological goods into economic goods.

This increase in 'connective density' among the components and subsystems makes the agroecosystem more autonomous and flexible. These are particularly important systemic qualities given the climate instability in the region, as they help to expand the range of alternatives for the allocation of locally available productive resources. Additionally, some fertility mediators

(such as silage and other forage storage strategies, forage species, manure stocks and seed banks) function as structures for storing productive resources during dry periods of the year or prolonged droughts, when they are not naturally available to the labour process.

One aspect that stands out in the analysis is that these trajectories never evolve through isolated initiatives by farming families. It is families' active participation in various associations and local co-operation mechanisms that is key for such changes to take place. From this perspective, the agroecosystems should be understood as structural elements within territorial sociotechnical networks.

Another key factor in the evolution of these networks is the influx of public resources. As well as the programmes executed by the ASA, other government policies and programmes add exogenous financial and material resources to the dynamics of local development. These resources are combined with endogenous resources in driving sociotechnical innovation.

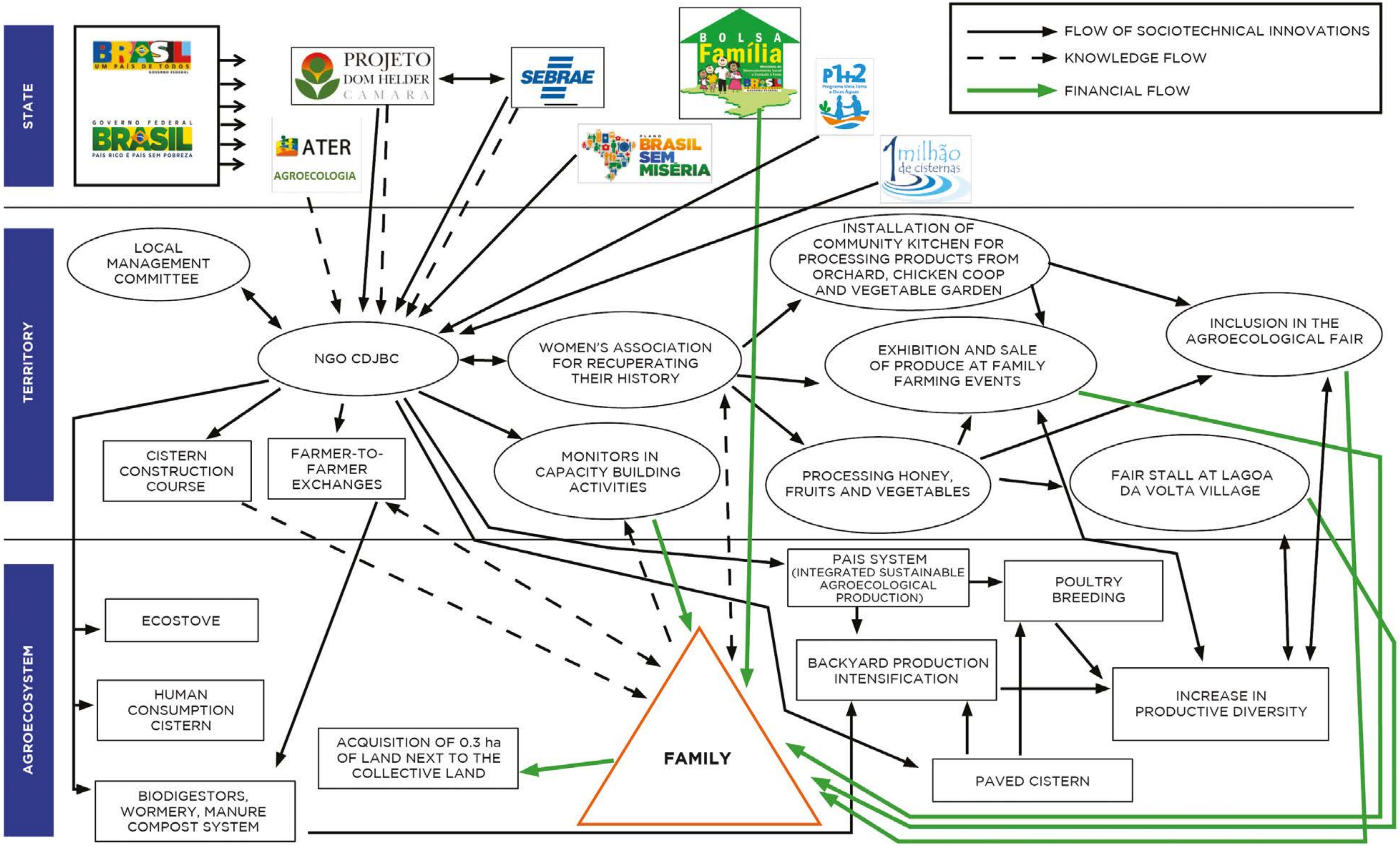
For these reasons, the webs of innovation should be analyzed at three levels: the agroecosystem, the territory and the state. Figure 8 shows this multi-level perspective for the web of innovations in one agroecosystem in the state of Sergipe following the introduction of infrastructure through ASA's programmes.

This schematic representation helps identify the dense webs established between the innovations triggered by the installation of the water infrastructure. The ability to store water allowed for new economic activities and/or the productive intensification of existing ones. Thereafter innovations unfolded in various directions, especially the processing and commercial sale of produce, and the production and processing of inputs used in agricultural and livestock production.

The diagram also shows that the web of innovations evolved following acquisition of knowledge on management practices (mainly through farmer-to-farmer exchanges) and with the intensification of families' participation in co-operative activities at the territorial level. Finally, it highlights the contributions of public policies and programmes to innovation.

It should be stressed, however, that different development trajectories are frequently observed among agroecosystems in a given territory, despite

FIGURE 8 Multi-level web of innovations in the state of Sergipe following ASA's interventions



receiving support from the same public policies. These reflect farming families' different economic-ecological management styles (strategies). In some cases, the agroecosystem becomes linked to sociotechnical networks in the form of vertical chains of specialized production. Applying the method outlined here, we have shown in another study how these contrasting trajectories generate equally contrasting impacts on the dynamics of rural development (Petersen & Silveira 2017).

Measuring impacts on autonomy and socioecological responsiveness

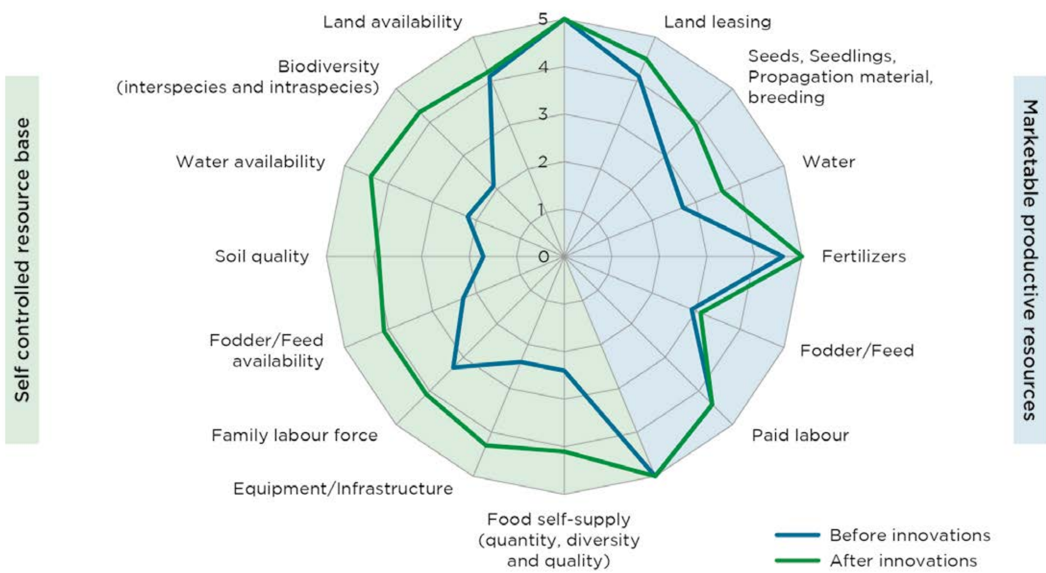
Figures 9, 10 and 11 display the effect of the webs of innovation on the autonomy and responsiveness of the agroecosystems.

Figure 9 compares autonomy from two complementary perspectives: a) the input and service markets (the blue half of the graph); and b) the investment of labour force according to families' strategic projects (the green half of the graph). The first perspective is analyzed using parameters associated with levels of autonomy/dependence in relation to 'marketable productive resources'. The second is analyzed through parameters associated with different elements from the 'self-controlled resource base'.

Aggregating the parameters in the two sections indicates that the average index of autonomy of the agroecosystems rose from 0.60 to 0.83 (for details of the method see the section in Chapter 4 called "Evaluating the systemic attributes"). Although the variation between the blue curves (before the innovations) and green curves (after the innovations) indicates the increase in autonomy in the two sections of the graph, it is notable that the most pronounced changes occurred in the half corresponding to the self-controlled resource base. This is explained by the relative status of the parameters at the 'starting points' of the trajectories. While the levels of autonomy from markets were already relatively high, the parameters related to the self-controlled resource base were initially lower.[34]

34 The ten case study agroecosystems represent what the literature conventionally calls 'traditional farming,' i.e., a mode of production that makes use of local resources and makes little use of production factors acquired in the markets (Schultz 1983). Generally speaking, the low use of commercial inputs results from families' limited financial capacity. It thus involves autonomy derived from restrictions and not necessarily from choice. For this reason, subsidized rural credit is considered one of the main public policy instruments for shifting traditional farming towards an entrepreneurial mode of production.

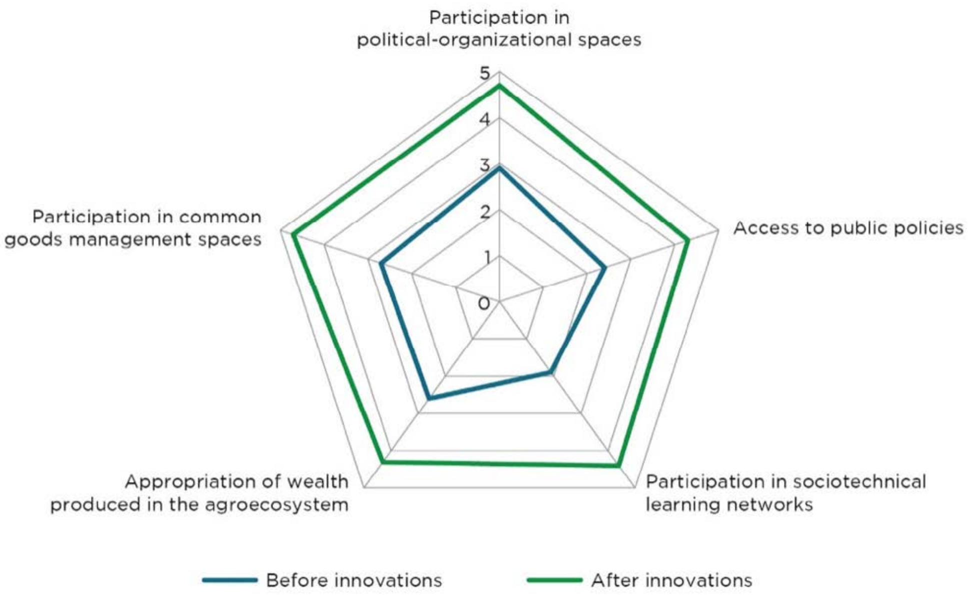
FIGURE 9 The autonomy of the ten agroecosystems before and after intervention



Unlike conventional technical-economic approaches, always focused on maximizing short-term financial incomes at the cost of autonomy from the input and service markets, the strategies adopted in the evaluated agroecosystems aim to meet the immediate economic needs of farming families while gradually constructing family capital through the systematic investment of labour inside and outside the family production units. This strategy explains the large improvement identified in the local self-controlled resource bases, a multifaceted variation that involves tangible and intangible elements of the labour process, as explained below.

From the tangible viewpoint, families strove to acquire a small patch of land, using this to constitute a secure base for other transformations (construction of houses, water infrastructure, fences, chicken coops and pigsties, biodigesters, manure storage tanks, irrigation systems, and so on). In this sense, permanent and secure access to land emerges as an indispensable

FIGURE 10 The social participation of ten SNAMs before and after intervention

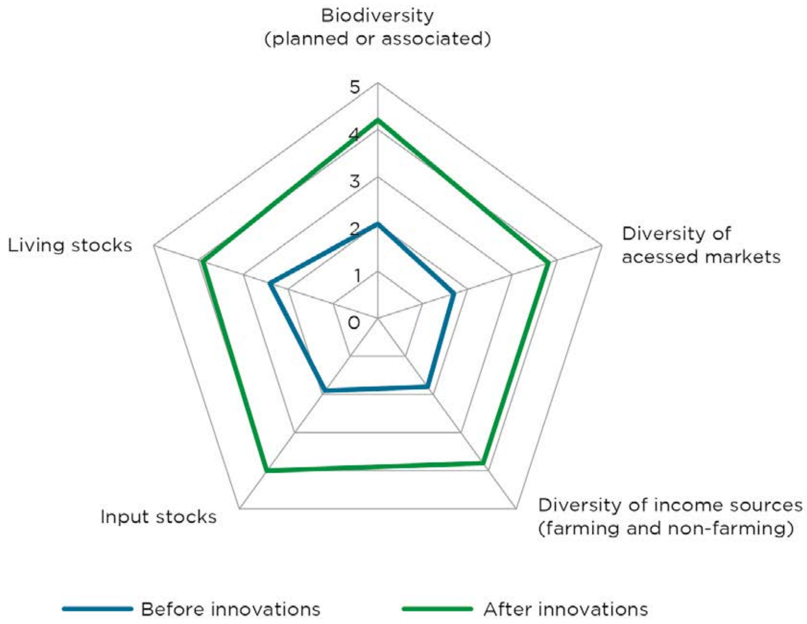


condition for new material investments to be made, configuring a gradual expansion of the 'agrarian capital' of the agroecosystems.

By performing the function of 'fertility mediators', as described earlier, the new infrastructure helps to qualify the labour process in the agroecosystem, particularly in activities for the reproduction and continuous expansion of its 'ecological capital' (soil quality, agrobiodiversity, production and qualitative transformation of biomass, stocking productive resources, etc.).

From the intangible viewpoint, the self-controlled resource base is improved by increasing local knowledge about the labour process (human capital) and by the quality and stability of relations of co-operation and mutual help established at the territorial level (social capital). Through participation in associations, unions, informal groups, seedbanks, revolving solidarity funds,

FIGURE 11 The responsiveness of ten agroecosystems before and after intervention



local fairs and other local organisations, families acquire new knowledge and access to new material resources, whether they are common goods whose management is socially regulated in the community (seeds and other elements of biodiversity, community labour), or public goods, redistributed by government policies.

The variables associated with the construction of human and social capital are closely linked to the level of social participation by SNAM members in territorially-embedded sociotechnical networks. The parameters associated with this aspect were also evaluated in the research and indicate an average rise in the 'social participation index' from 0.5 to 0.9. These variations are broken down in Figure 10.

As well as influencing the levels of autonomy of the agroecosystems, the SNAMs' social participation is directly related to the levels of 'connectivity' between the agroecosystem and its socioecological surroundings, a key principle of systemic resilience (Biggs et al. 2012).[35]

The Lume method indirectly evaluates the impacts of innovations on agroecosystem responsiveness by analysing a narrow set of parameters objectively verifiable through the semi-structured interviews. The development of systemic qualities associated with these parameters over the trajectory of the agroecosystems contributes to the creation and maintenance of the ‘diversity of responses’, ‘redundancy of functionalities’[36] and ‘reserves of productive resources’ – three key principles for the resilience of socioecological systems (Walker et al. 2006).

The research identified a significant improvement in the average indicator of responsiveness of the ten evaluated agroecosystems: from 0.39 to 0.79 (Figure 11).

Measuring impacts on the intensity of agroecosystems

The development trajectories of the ten case study agroecosystems can be characterized as ‘labour-driven intensification’ processes. The increases in levels of intensity were identified through an economic analysis which compared the moments before and after the introduction of the water infrastructures. In order to realize this operation, the data related to the economic-ecological flows described when modelling the agroecosystems was quantified and processed in order to generate various economic performance indicators. Next, in collaboration with the farming family members, the economic analysis was reworked by subtracting the data on the flows created following the introduction of the innovations.

35 Connectivity favors the material and information exchanges necessary for the operation of socioecological systems. The connections between the systems in the ecological and/or social landscape are essential for the mobilization of (tangible and intangible) resources necessary for recuperation of the ecosystem after a disturbance.

36 Diversity of responses and functional redundancy are two key qualities for confronting disturbances of environmental and/or social origin. Both qualities are provided by the diversity of elements in the system’s structure, a characteristic associated with three interrelated components: variety (number of different elements); equilibrium (number of units of each element); and disparity (level of differentiation between some elements and others). Redundancy is a quality that provides a higher level of security to the system since it functions as an internal compensation mechanism in response to the deactivation of one or more of its functional elements (Biggs et al. 2012).

FIGURE 12 Percentage increase in Gross Product (GP) for ten agroecosystems before and after intervention

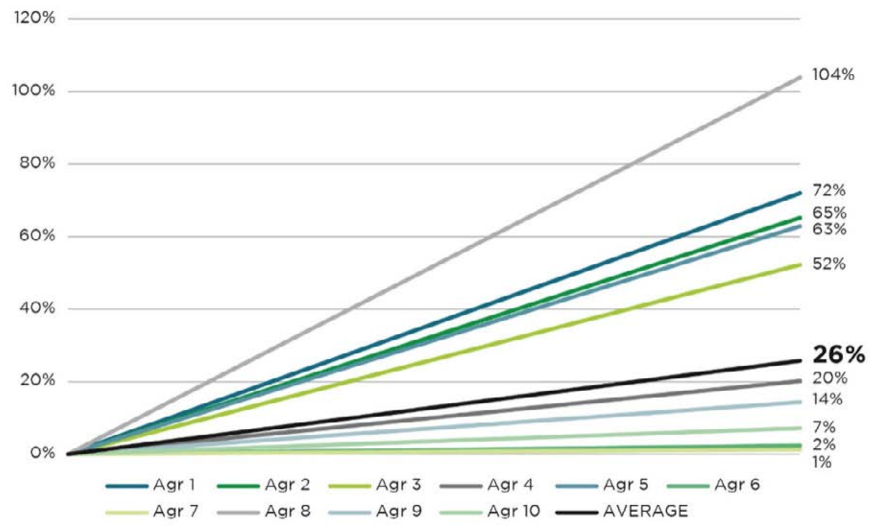
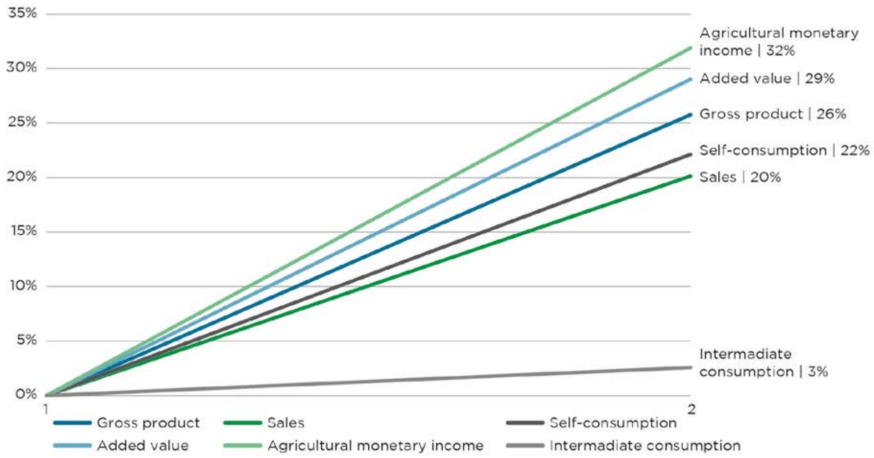


Figure 12 compares the Gross Product (GP) between the two moments of the trajectory for each of the ten analyzed agroecosystems. Although the graph indicates a large variation in the percentage increase in GP (ranging between 1% and 104%), the general trend is one of growth – with an average increase of 26%.

Unlike development trajectories based on productive specialization and economies of scale, the intensification trends did not affect agroecosystems’ levels of autonomy from the input and service markets observed previously (Figure 9). This means that growth in GP results from an increase in added value (29% on average, see Figure 13), that is, new wealth produced through families’ labour. This aspect can be seen in Figure 13, along with the changes in other economic indicators for each agroecosystem.

The average increase of 26% in GP alongside an average increase of just 3% in the value of intermediate consumption (i.e. the market-purchased inputs that are entirely consumed in the production process) reflects an endogenous

FIGURE 13 Average improvement in various economic indicators in 10 agroecosystems before and after intervention



pattern of economic growth. This signifies a logic rooted in the expansion of the local and self-controlled resource base by rural families and communities. The evidence for this expansion in numerical terms confirms the qualitative analysis in Figure 9. It reflects the systematic investment of farmers' labour in restructuring agroecosystems and in configuring the new relations within the socio-institutional environment.

The continuous growth of the self-controlled resource base can be understood as an increase in the capital with which families sustain their economies. However, 'capital' is used here in the Chayanovian sense, not in the classic sense defined by Karl Marx. Capital here refers to the family 'patrimony', i.e. the means of production created and controlled by the family over the course of its life cycle. The values involved in this 'family capital' are not limited to exchange values. Stocks of water, fodder, seeds and manure, for example, possess a use value since they are employed in the reproduction of the agroecosystem itself. Through the labour process, these values are converted into fertile soils, nurseries and healthy crops. This increase in ecological capital is also converted, through farmers' labour, into higher production values. All these conversions essentially depend on an investment of labour rather than financial capital.

In this approach to organizing labour in the agroecosystem, economic production and ecological reproduction are organically interconnected in a single process in which human labour and nature are synergistically integrated. In economic terms, the increase in 'added value' (or 'product of labour') over the course of the analyzed trajectories reflects the improvement of these processes of co-production. In other words, it reflects 'labour-driven intensification.'

A large investment in labour is also made to create, strengthen and reproduce collective action devices in the communities and territories in which the families live and produce (community seed banks, community pastures, agroecological fairs, farmer-to-farmer exchanges, solidarity funds, collective processing activities etc...). On the one hand, this 'social participation' allows access to ecological assets from a base of common goods, thereby reducing input costs. On the other hand, this investment in co-operative activities is recompensed by mobilising third-party labour through relations of reciprocity, helping farming families to increase their added value. This aspect is reflected economically in the significant average increase in the agricultural incomes in agroecosystems (Figure 13). These incomes, which correspond to the 'clear part' of the gross value of production (Zhao and Ploeg 2014), may or may not be converted in the markets. In the case-study agroecosystems, the share converted into currency (monetary agricultural incomes) increased by 32% on average, while the portion consumed directly by families (non-monetary incomes or self-consumption) increased by 22% on average.

Understanding the economy of agroecosystems

Unlike conventional approaches to economic analysis, the Lume method's use of different analytic frames to explore the origin of income and the allocation of labour allows us to increase the visibility of social and political relations. This is of considerable relevance to the contemporary debates on family farming's contributions to rural development and food security (HLPE 2013; FAO 2014), and, in a broader sense, to attaining the UN Sustainable Development Goals (SDGs), since transforming the agrifood systems economy is a core challenge for most of the 17 SDGs (UN 2015; Petersen and Arbenz 2018).

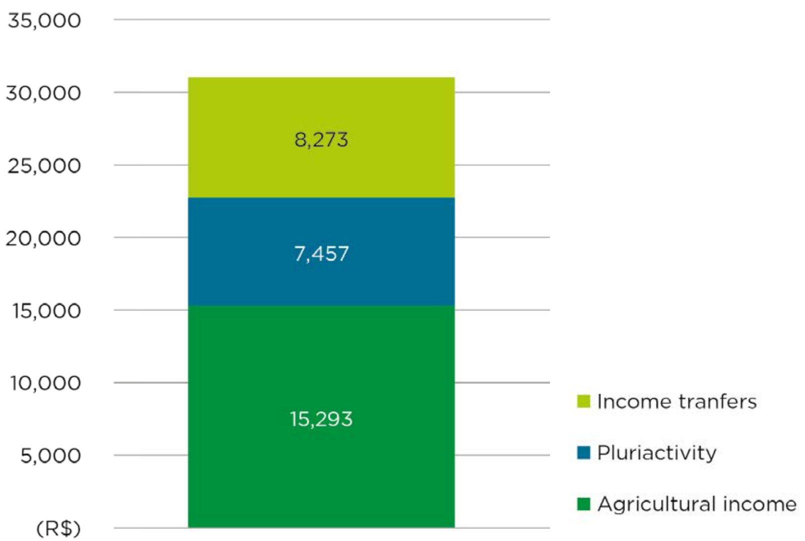
Here we highlight three important insights revealed by combining different aspects of the data generated by the ASA-INSA research:

1) The income sources of the ten interviewed families.
2) Men and women's differing contributions to the SNAMs' production of wealth.
3) The economic output of each of the subsystems.

Income sources

Figure 14 presents the families' total average annual income broken down into agricultural income, non-agricultural income (pluriactivity) and income transfers (public programs or remittances from relatives).

FIGURE 14 Share of total average income of the 10 families interviewed



Three conclusions can be drawn from the data:

a) Half of the families' total income came from agricultural labour. Given that the data were collected in drought years when agricultural labour productivity tends to decline abruptly, we can presume that in normal years the contribution (both proportional and absolute) made by agricultural income is significantly higher.

b) Pluriactivity generated 23% of the families' income, confirming that investing in labour for generating non-agricultural income is an extremely important strategy for the material reproduction of family farming, as well as for integration into contemporary society (Carneiro 1998; Schneider 2001). Far from signalling a tendency to abandon farming and the rural world, as some authors already suggested (Graziano da Silva 2002), it expresses a strategy of resistance and projection into the future through diversifying livelihoods (Niederle and Grisa 2008).

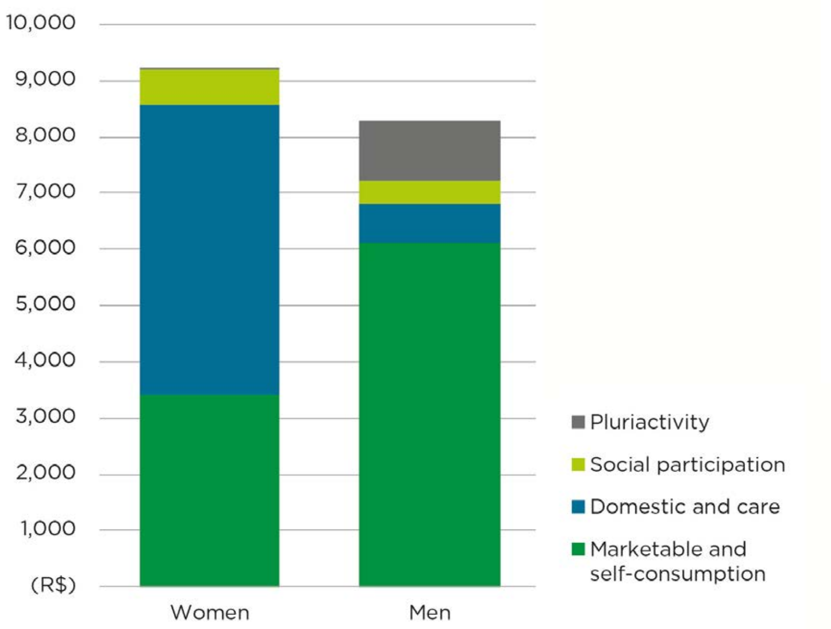
c) Income transfer (state support, e.g. social security and agricultural insurance policies) contributed 27% of the total average income of the families interviewed. Although this proportion may vary from year to year depending on the performance of agriculture, these resources play a wealth of functions in the economies of agroecosystems. By reducing the social vulnerability of the poorest rural families, they substantially increase their room for manoeuvre to invest their labour in the continual expansion of their own resource base. As well as meeting their most pressing material needs, therefore, the regular influx of financial resources contributes to structural improvements in agroecosystems. Hence, when combined with multiple strategies for economic and political emancipation, these transfers have a multiplying effects on the development of family farming.

This latter point is particularly important for farming women, for whom direct access to financial resources is a powerful instrument of emancipation in the context of a structurally unequal and culturally patriarchal society.

Men and women's contributions to wealth production

This second aspect is directly related to the gender inequalities culturally rooted in family farming's economic organization. The method allows us to ascertain

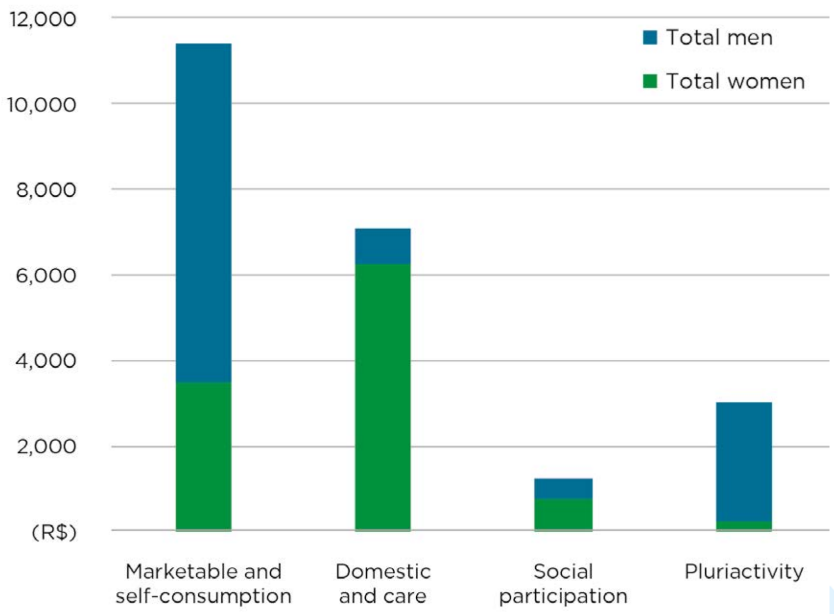
FIGURE 15 Average annual contribution to added value of male and female household heads' labour



the proportional contributions of men and women to the SNAMs' production of wealth. Based on average data from the economy of the 10 agroecosystems, Figures 15, 16 and 17 present this share of the added value from different analytic viewpoints. Figure 15 compares the contribution of male and female household heads' labour to added value. Two main aspects can be identified in the graph: a) in absolute terms, women's contribution to the generation of added value is 11% higher than that of their male partners; b) there is a large contrast between genders in the time allocated to the different spheres of occupation. While the bulk of women's time is dedicated to activities related to 'domestic labour and care labour' (55%), most of men's time (73%) is directed towards activities of 'marketable production and self-consumption.'

These differences in the allocation of labour time between men and women is also shown in Figure 16, this time for all men and women in the 10

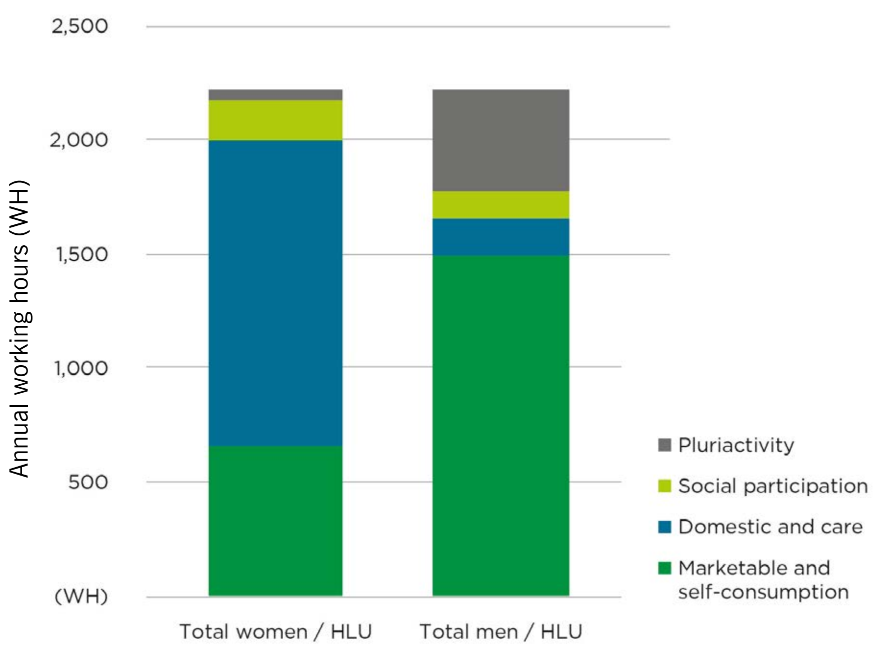
FIGURE 16 Average annual contribution to added value of all household members' labour



SNAMs, not just the household heads. Two important aspects emerge from the graph: a) 37% of SNAMs' labour time is allocated to activities typically considered to be reproductive (domestic labour, care labour and social participation), revealing the importance of this work in the agroecosystems' economy; and b) women assume 82% of the workload in the spheres of reproductive labour (rising to 86% when the focus is specifically the sphere of domestic and care labour).

Figure 17 provides a more precise comparison of men and women's tasks in managing the agroecosystems. In this case, the shares of time dedicated to distinct spheres of labour were measured by translating them into an equivalent 'hired labour unit' (HLU), that is, a period of 2,105 hours per year, based on an 8-hour working day in line with labour legislation in Brazil.

FIGURE 17 Men and women's time allocation to the various spheres of work in 10 agroecosystems



The analytical focal points proposed here help shed light on the key role of women in all spheres of work in the agroecosystem. This is overlooked in conventional economic analyses, despite being fundamental to the social reproduction of family farming. By revealing women's heavy burden of work and the indissociable links between the so-called spheres of productive and reproductive labour, the method produces consistent evidence to challenge culturally-entrenched ideas that relegate domestic and care activities to the category of non-work and reduce women's labour in the various spheres of marketable production to the category of help. By calling attention to these aspects, recognizing and valuing women's varied forms of economic inclusion, the method helps uncover latent paths and potentials for connecting the analysis of the material life of family farming to the feminist struggle for the political and economic emancipation of women.

The economic output of each of the subsystems

The third aspect revealed by the data is the economic output of each of the subsystems. This calls attention to two features of particular importance to the family farming economy. Firstly, it shows the contributions made by each subsystem to the dynamic functioning of the agroecosystem as a whole. These contributions can be measured in exchange values (sold production) and use values (the produce consumed directly by families and the inputs consumed in subsequent production processes). Since the conventional analytic approach takes monetary rentability as the principal indicator of technical-economic efficiency, subsystems' contributions to socioecological reproduction are seen as not relevant. Secondly, this breakdown of the economy of the agroecosystem according to subunits of agricultural labour management allows us to discern variations in intensity levels across subsystems.

Both aspects were revealed in the analysis of the 10 agroecosystems. This showed that in the years in which the economic data were collected, domestic yards produced on average 34% of the added value generated through families' agricultural labour, despite occupying a tiny share of agroecosystems' areas. Slightly over half of this value (51%) was converted into monetary income in the market – the remainder was consumed by the families themselves.

As well as underlining the importance of women's work in the economic output of the agroecosystems as a whole, these data show the significance of backyards for building the resilience of agroecosystems, since they kept on producing despite consecutive years of drought, in contrast to other subsystems which were temporarily deactivated or saw production heavily reduced.

Core conclusions from the research

By describing and analyzing the development trajectories of agroecosystems, the research showed how the public resources redistributed by the state through different policies and programs were decisive for increasing the economic intensity, technical autonomy and socioecological resilience of family farming. At the same time, it showed how these public resources were channelled by territorially-based sociotechnical networks in order to be combined synergetically with (ecological and social) endogenous resources, contributing to gradual expansion of the local and self-controlled resource base of rural families and communities.

Through its qualitative and quantitative assessments, the study confirms the positive impacts of the public programmes co-managed by ASA on the resilience of family farming in Brazil's semi-arid region. Furthermore, it demonstrates that these programmes are helping to promote rural development trajectories that reconcile the intensification of economic production with ecological reproduction. This has enabled them to reverse desertification processes underway in the region and, simultaneously, promote economic emancipation for a portion of the socially most vulnerable population.

6 Final considerations

The Lume method proposes new approaches to the analysis of agroecosystems managed by family farming. By viewing agroecosystems as economic-ecological management units situated in specific territories, it helps shed light on the social and power relations that condition the labour processes in family farming, but which are overlooked or distorted by the prevailing theories that inform the design of public programs and policies for agriculture and for food systems. It draws on critical theories of economics formulated precisely to reveal dimensions of social life and work hidden by orthodox economic thought.

Applying the method has helped reveal the growing contradictions between the scientific premises of agricultural modernization and the results of its practical applications in different socio-environmental contexts. At the same time, it has proven extremely useful for supporting participatory research into the positive multidimensional effects of agricultural development guided by the agroecological paradigm.

Applied to the analysis of agrarian realities in specific territories, the method has helped to overcome the normative dualist delimitations that seek to represent the complexity of family farming in watertight categories, such as 'large and small producers,' 'entrepreneurial and peasants,' 'consolidated and peripheral,' or 'agroecological and non-agroecological.' The proposed approach seeks to locate agroecosystems along the vast spectrum of different degrees of peasantness in the economic-ecological reproduction strategies of family farming.[37]

37 Long and Ploeg (1991) point out that the classifications conventionally used to analyse real-life farming act as guidelines for redistributing public resources to the various production units. In this sense, they involve a considerable exercise of power since they are used to legitimize some political-economic projects to the detriment to others. Hence the agroecological perspective adopts approaches which capture the heterogeneity of family farming and which reflect the economic rationalities adopted in the management of agroecosystems.

The method has also proven to be extremely useful for evaluating public policies and revealing rural development dynamics and how transformations in agroecosystems are strongly driven by the responses of local actors (individuals and/or collectives) to the constraints and opportunities posed by the political-institutional and ecological contexts in which they live and produce. This was a key feature of the research into the effects of public programs executed by ASA on the development trajectories of family farming in ten territories in Brazil's semi-arid region.

Contrasting with conventional approaches to the analysis of public policies, usually centred on ascertaining the scope of support activities,[38] the method focuses on evaluating the finalistic objectives associated with strengthening family farming's means and modes of life and the various positive effects of agroecology for society as a whole (promotion of food and nutritional sovereignty and security, conservation of agrobiodiversity, building socioecological resilience, generation of work and income - opening new horizons for rural youth, empowering women, etc.).

In summary, the Lume method helps to overcome the bias of economistic productivism that prevails in conventional analyses of rural and agricultural development trajectories. Instead of the mechanistic and positivist approaches to the study of agricultural economics, the Lume approach understands farming as the art of co-production between human beings and the rest of nature. Consequently, the subjective dimension and the approximate quality of the analyses are directly linked to the understanding that the agroecosystem corresponds to a "cultivated, socially managed ecosystem."

The current configuration of the method is the outcome of a collective construction, gradually shaped over time by applying it to the study of the various dimensions of the socioeconomic reproduction of family farming. Like all knowledge, one of the main ambitions of the method is for continual improvement through confrontation with different realities and with other methodological approaches equally motivated by the aim of comprehending and contributing to the enhancement of the economic-ecological functioning of family farming-managed agroecosystems.

38 Evaluations of public policies are very often limited to assessing rural development support in terms of the volume of financial resources used, the number of items of equipment sold, infrastructure built, the number of families assisted through capacity-building activities, and so on. One of the most eloquent and ironic examples of this limitation in the policy evaluation processes was the adoption of the indicator "number of tractors sold" as one of the main means of verifying the success of a public programme whose objective could not be more explicit: the Pronaf 'More Food' programme. Not surprisingly, in many situations, the increase in the number of tractors meant a drop in food production.

Annex

Parameters and criteria for systemic attributes assessment

Table A1 – Parameters and criteria adopted for autonomy assessment

	Parameter	Criteria
Mercantile Productive Resources	Third party land	Autonomy in relation to land use under renting, leasing, and other payment schemes for the right to use the land
	Seeds, seedlings, propagative material, offspring	Autonomy in relation to the acquisition of genetic resources used in agroecosystem
	Water	Autonomy in relation to the acquisition of water for different consumptions in the agroecosystem (human, domestic, agricultural, livestock)
	Fertilizers	Autonomy from market-sourced inputs for soil fertility regeneration
	Fodder / Animal Feed	Autonomy from market-sourced animal feed sources
	Third party work	Autonomy in relation to the hiring of third party services to perform activities related to agroecosystem management (in all spheres of work - mercantile and self-consumption; domestic and care; social participation)
Self-Controlled Resource Base	Food self-sufficiency	SNAM food supply level (in quantity, quality and diversity) from production generated in the agroecosystem itself and / or production donated by community members through reciprocal relationships
	Equipment / Infrastructure	Agroecosystem fixed capital, ie, level of structuring of agroecosystem. Note: the assessment of fixed capital seeks to identify any restrictions on the economic agroecosystem's performance and the quality of life of the SNAM due to (inadequate) infrastructure (housing, fences, corrals, electrification, etc.) and equipment. (forage machines, cars, tractors, tanks, dumpers, etc.)
	Workforce	Quantitative and qualitative availability of the SNAM workforce effectively allocated to agroecosystem management. Note: This assessment allows identifying possible restrictions on the agroecosystem's economic performance due to the insufficient available workforce. The amount of work is associated with the number of people and the time they devote to agroecosystem management tasks (across all spheres of work). The quality of work is linked to the level of knowledge associated with activities performed in the agroecosystem. It is assumed that the greater the domain of knowledge related to the work done on the agroecosystem, the greater the quality and efficiency of the work. In this sense, investing time to participate in training activities and exchange of experiences contributes to increase the knowledge base associated with the work.

	Parameter	Criteria
Self-Controlled Resource Base	Forage / Animal Feed Availability	Forage biomass produced in the agroecosystem or freely appropriated on communal lands. Note: This evaluation allows to identify the existence of quantitative or qualitative deficiencies in the feeding supply for the animals during the year.
	Soil fertility	Chemical, physical and biological qualities of soils worked by SNAM. Note: As these qualities may be increased or degraded over time depending on the management practices adopted, this judgment helps to identify qualitative change processes as well as positive or negative aspects in the technical strategies adopted for reproducing soil fertility.
	Water availability	Water availability to meet different consumption demands in the agroecosystem (human, livestock and agricultural). Aspects to consider when analyzing this criterion: 1) volume and stability of the natural supply (rainfall, rivers, water table, groundwater etc). 2) infrastructure for water collection, storage and distribution for different consumption.
	Biodiversity	It covers both planned biodiversity (diversity of plant and animal managed species, considering both intraspecific variability and interspecific diversity), as well as associated biodiversity (spontaneous / wild species diversity). Note: A decisive factor in this assessment refers to the local adaptability of genotypes to ecological and management conditions, as well as the adjustment to cultural preferences. Another aspect to be considered concerns the ecological services provided by biodiversity at the agricultural landscape scale (nutrient cycling, promotion of favorable microclimates, water economy, regulation of insect pest populations and pathogenic organisms, etc.).
	Land availability	Territorial extension of the agroecosystem, that is, the environmental space in which the SNAM appropriates ecological goods to convert them into economic goods. Note: In addition to considering the physical extent of the land directly explored, this assessment should take into account SNAM's degree of mastery over the management of this space. If the lands are their own, the SNAM has complete governance over space management. In contrast, the SNAM has limited governance over appropriate third-party land management through regimes that do not ensure stability of access and freedom to use the resource. Increased land availability and / or increased security of access to and use of this factor of production implies the expansion of SNAM's self-controlled resource base. This judgment is of great relevance for understanding the economic strategies of family farming for two reasons. First, it helps to identify potential bottlenecks in the agroecosystem's economic performance related to the limitation of access to this resource. Secondly, because it helps to identify strategies adopted by the SNAM over the years to expand the territorial base that exploits and controls

Table A2: Parameters and criteria for responsiveness assessment

Parameter	Criteria
Biodiversity (planned or associated)	Diversity, adaptability and ecological functions of plant and animal genetic resources maintained in the agroecosystem. Higher levels of diversity and adaptability of genetic resources provide better conditions for managing the risks associated with seasonality effects and unforeseen environmental and / or economic disturbances. In addition, the ecological functions generated by biodiversity contribute to improved nutrient cycling, the water economy and the regulation of insect pest populations and pathogenic organisms. Variations in biodiversity interfere positively or negatively with system responsiveness
Diversity of Accessed Markets	Variety of commercial circuits used to flow the agroecosystem production. This assessment considers markets at different levels of formalization. For example: neighborhood, middlemen, fairs, supermarkets, businesses, institutional markets, etc.
Income diversity (agricultural and non-agricultural)	Items that make up agricultural income (monetary and non-monetary) and incomes generated by non-agricultural labor. Rents obtained regularly through transfers by the state or relatives are also considered.
Input stocks	Productive resources stored in the agroecosystem to be used in subsequent production cycles. They are usually stocked in agroecosystem infrastructure (fertility mediators). Examples: water, seeds, fodder, organic fertilizers. They can also be mobilized from community stocks (seed banks, water reservoirs, nurseries, etc.) The judgment of this criterion is related to the effects (positive and negative) of the evolution of these stocks on agroecosystem stability.
Living stock	“Standing stocks” present in the agroecosystem. They function as a saving of strategic resources mobilized in critical moments of economic, ecological and / or climatic disturbance or for structural investments in the system. Examples: herds formed / reserved for this purpose, fodder production fields, forest resources, etc.

Table A3 - Parameters and criteria for the SNAM social integration assessment

Parameter	Criteria
Participation in political-organizational spaces	Level of interaction of one or more SNAM members in political-organizational spaces. Participation in trade unions, cooperatives, community associations in women’s and youth groups and other organizations related to the access and defense of social and political rights stand out in this evaluation.
Access to public policies	Degree of access to resources redistributed by the state through public policies. These resources can be accessed directly from official bodies or brokered by civil society organizations. This assessment considers the diversity of policies accessed, as well as the regularity of access by one or more members of the SNAM. The public resources accessed can be invested directly in the agroecosystem or not. The evaluation includes agricultural (credit, extension services etc), social (income transfers, social security, etc.), infrastructure (light, maintenance of public roads etc), health and education policies.
Participation in socio-technical learning networks	Interaction of one or more SNAM members in learning processes directly related to the qualification of the work done in agroecosystem management. This assessment should consider continuing learning processes, whether formal or informal. This implies systematic participation in capacity building activities, exchanges, participatory research, seminars, workshops and others. Formal education processes provided by the state should be considered in the parameter “access to public policies”.
Participation in community spaces dedicated to the common goods governance	Interaction of one or more SNAM members in collective actions aimed at the governance of common goods at community or territorial level. This interaction corresponds to the time devoted to the management of community facilities (seed banks, agroindustry, machinery, cars, etc.), natural resources of collective appropriation (pastures, farmland, seeds, animals, water reserves , etc.), local markets (fairs), cooperative work systems (working groups, day exchanges, etc.), community savings, etc. Note: Local knowledge-building processes are assessed separately through the parameter “participation in socio-technical learning networks”.

Table A4 - Parameters and criteria for the gender equity / women's empowerment assessment

Parameter	Criteria
Sexual division of housework and care (adults)	Level of symmetry in the division of domestic and care tasks between adult men and women in the SNAM. More symmetrical divisions indicate greater equity in gender relations within the SNAM
Sexual division of housework and care (youth)	Level of symmetry in the division of domestic and care tasks between young men and women in the SNAM. More symmetrical divisions indicate greater equity in gender relations within the SNAM.
Participation in agroecosystem management decisions	Level of symmetry between men and women in decision-making power related to agroecosystem structuring and management strategies, as well as marketing activities
Participation in socio-organizational spaces	Level of symmetry between men and women in the participation in organizations (formal and informal), social networks and movements.
Appropriation of wealth generated in agroecosystem	Degree of equity between men and women related to the appropriation of the income generated by the work of the SNAM
Access to public policies	Equality between men and women in autonomous access and / or decision-making power over redistributed resources through public policies

Table A5 - Parameters and criteria for youth empowerment assessment

Parameter	Criteria
Participation in learning spaces	Degree of involvement of SNAM youth in spaces (formal and/or informal) of education and professional training. Consider participating in exchange activities, youth groups, training courses, and other educational and training spaces
Participation in agroecosystem management decisions	Degree of involvement of SNAM youth in strategic decisions related to the structuring and management of agroecosystem and production marketing processes
Participation in socio-organizational spaces	Degree of involvement of SNAM youth in organizations (formal and informal), networks and social movements
Access to public policies	Level of autonomous access and / or participation in decision-making on the use of resources redistributed by the state through public policies by SNAM youth
Financial autonomy	Autonomy degree of SNAM youth in the management of productive activities, as well as the level of appropriation of the monetary income generated by their work

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