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Agroecology, Public Policies and Labor-Driven Intensification: Alternative Development Trajectories in the Brazilian Semi-Arid Region

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Abstract: The institutional recognition obtained by family farming in Brazil over recent decades has translated into the launching of a broad and diverse set of public policies specifically aimed towards this sociopolitical category. However, the design of these policies was heavily influenced by the productivist bias derived from the agricultural modernization paradigm, making the sector increasingly dependent on input and capital markets. In this same movement of institutional evolution, policies consistent with the agroecological approach created new margins for maneuvering for development trajectories founded on the use of local resources self-controlled by rural families and communities. Taking as a reference the recent trajectory of rural development in Brazil's semi-arid region, the article analyses the role of the agroecological perspective in the strategic combination between territorially endogenous rural resources and public resources redistributed by the State. Based on the analysis of the economy of agroecosystems linked to two sociotechnical networks structured by contrasting logics of productive intensification, the study demonstrates agroecology's potential as a scientific-technological approach for the combined attainment of various Sustainable Development Goals, starting with the economic and political emancipation of the socially most vulnerable portions of the rural population.

Keywords: rural development; agroecology; agricultural intensification; public policies; sociopolitical innovation

1. Introduction

The quarter century spanning from the beginning of Brazil's return to democracy, especially following the proclamation of the 1988 Constitution, and the abrupt end of the Dilma Rousseff government in 2016 marked a period of innovation in the institutions linked to rural development in the country. One decisive element in this process was the inclusion of the family farming in the 'social pact', which authorized the launch of public administration policies and instruments targeted specifically at this sociopolitical category, previously pushed to the margins of the Brazilian State's interests.

These institutional advances, which brought Brazil widespread recognition during the International Year of Family Farming in 2014, should be understood as the end result of a long historical trajectory of struggles and demands pursued by rural social organizations and movements [1]. The core point of this struggle for social recognition and legitimization is the affirmation of the specificities and potentialities of the modes of production and ways of life of this extremely diverse social universe as part of resolving an interconnected set of polarizing questions about the national public agenda: the rise in unemployment rates; the continuing rural exodus and the growth in unplanned urbanization; increasing levels of urban violence and rural conflicts; the rapid degradation of ecosystems; the crises

in the food supply and, as a consequence, the elevation in inflation rates and in the population's levels of food and nutritional insecurity.

The launch of the National Program for Strengthening Family Farming (*Programa Nacional de Fortalecimento da Agricultura Familiar: PRONAF*) in 1995 was a landmark for the official legitimization of family farming. However, it was only from 2003 onward, with the political priority given by the Lula government to eradicate hunger in the country, that a broad and diverse set of official initiatives created an institutional environment more favorable to development and to the public expression of the family farming's contribution to society as a whole.

In the course of this instituting process, the launch of the Zero Hunger Program, the inclusion of the Human Right to Adequate Food (HRAF) in the Federal Constitution, and the approval of food and nutritional security plans (PLANSAN) and plans for sustainable and solidary rural development (PNDRSS) contributed to strengthening the conceptual and political connection between the official initiatives aimed at strengthening family farming and the strategies for overcoming rural poverty and promoting food and nutritional security in the country. New institutional arrangements created during this period generated synergetic effects between social welfare initiatives and economic development programs, two spheres of intervention historically autarchic within the State's functional structure.

According to the multilevel perspective approach [2,3], these advances that were made can be understood as *niches of institutional innovation* in a political-ideological environment dominated by a narrative that asserts the supposedly inherent incapacity of impoverished small farmers to adapt to the technological and financial treadmill of modern farming [4].

Rooted in earlier theoretical approaches that questioned the economic propensity and social reproductive capacity of the poorest contingent of the rural population [5,6], this dominant narrative continues to assert homogenization of the rural world as an inexorable process. For theorists linked to this approach, most of the family farming sector, branded as *peripheral*, is destined to vanish. Family farming policies should therefore focus exclusively on those sectors identified as *consolidated* and *in transition* [7], perceived as the legitimate agents of social and economic progress in the rural world.

According to this prevailing narrative, rural development is driven by the economic growth of farming establishments, envisaged as independent business units. This growth, in turn, is viewed to be an outcome of trajectories of productive intensification promoted by the use of modern technologies. Through this rhetorical construct, rural development was equated with agricultural development and the latter with the modernization of the technological base of agroecosystems. Consequently the very concept of intensification became unduly assimilated as a synonym of technological modernization. As a corollary, alternative trajectories of economic intensification, built using the multifunctional potential of family farming, were excluded from the horizon of possibilities propagated and legitimized by the dominant narrative. Consequently the interpretative schemes based on the modernization paradigm used to interpret the agrarian world, and which strongly influence the design of agricultural and agrarian policies, are incapable of recognizing, describing, and analyzing rural development trajectories that are essentially driven by family farming labor.

The State initiatives consistent with the agroecological paradigm should be understood and evaluated within this political-ideological and institutional context. Exploiting the limited institutional spaces achieved with governments more permeable to democratic debate, organizations from the agroecological field were able to take the lessons learned from decades of decentralized construction of agroecology among rural communities, transforming this social experience into innovative public policy proposals. The evolution of this process culminated in 2012 with the creation of the National Policy for Agroecology and Organic Production (PNAPO), put into operation in 2013 by the First National Plan for Agroecology and Organic Production (I PLANAPO), which was updated and revised in 2016 in Plan II [8].

The growing participation of grassroots movements seeking to establish themselves in the public spaces in which government policies are formulated and monitored [9] created conditions favorable to rural development dynamics consistent with the agroecological approach. Previously driven almost

exclusively by territorial-level civil society networks, these dynamics began to receive substantial support from government funding. Contrary to the direction taken by agricultural modernization policies and programs, the public funds invested in these trajectories helped increase social capital and ecological capital in rural territories, stimulating the expansion and diversification of these sociotechnical networks through an endogenous development approach [10]. Two interrelated ideas are central to the concept of endogenous development: local resources and local control. In this sense, the endogeneity of development is determined by the degree to which rural economies are: (a) constructed on the basis of local resources; (b) organized in accordance with local models of combining resources, which also implies control of the use of these resources; (c) strengthened through the distribution and local reinvestment of locally produced wealth [11]).

In economic terms, these endogenous trajectories are guided by a model of *labor-driven intensification* [12]. This signifies that instead of the intensive support of market-supplied factors of production, a characteristic typical of conventional trajectories of agricultural intensification, the agroecological approach is based on the use of skilled labor [13] to promote ecological processes at the level of the landscape, simultaneously ensuring the continuous regeneration of ecosystem services [14] and the conversion of natural goods into a diverse range of economic goods.

Taking as a reference point the recent dynamics of rural development in the Brazilian semi-arid region, a process promoted by a new generation of public policies, this article seeks to show how the strategic combination of resources endogenous to rural territories and public resources redistributed by the State has favoured the unfolding of agricultural intensification trajectories that organically articulate economic production with ecological reproduction. In this sense, these trajectories differ fundamentally from the controversial notion of sustainable intensification [15] that became integrated into the new official rhetoric in international debates about the future of farming and food, without challenging the technicist and productivist bias inherited from the narrative of agricultural modernization. As González de Molina and Gúzman Casado emphasize, and as formulated and disseminated, this notion amounts to a contradiction since it lacks any thermodynamic basis concerning the sustainability perspectives of agroecosystems [16].

The study also looks to show how public support for these trajectories of *economic intensification without ecological simplification* [17] can help overcome the structural poverty in which the majority of the rural population is trapped, as well as engaging poor family farming as dynamizing agents of rural development capable of generating wider benefits for society, contributing to the combined attainment of various Sustainable Development Goals (SDGs) [18].

2. Material and Methods

2.1. Context of the Study

Measured in territorial or demographic terms, the Brazilian semi-arid region is one of the largest such regions on the planet. Covering a geographic area of 982,000 km², concentrated in states in Brazil's Northeast, the region is home to a population of 22.5 million—12% of the national population—with 44% living in the rural area, making it the least urbanized region of the country [19].

Also concentrating 35% of the country's family farming establishments (1.5 million) [20] and more than half of the country's poorest population [19], the Brazilian semi-arid region is considered a problem region in some intellectual and political circles [21]. This kind of interpretation reflects a determinist bias that associates, as though two sides of the same coin, the low social indicators with the recurrent droughts typical of the biome's semi-arid conditions. The narratives historically produced through this bias imposed themselves on the national collective and political imagery, generating an environment of tacit acceptance of a supposed historical predestination of the region to poverty and backwardness compared to other regions of the country. For decades the dissemination of this fatalistic view of the historical process in the semi-arid region exerted a strong influence on the legitimization of the system of power responsible for maintaining the extremely concentrated agrarian structure

inherited from Brazil's colonial era [22]. Because of these structural conditions, family farming emerged and developed in the region on the margins of the large estates dedicated to extensive cattle ranching.

The long history of territorial dispute with big landowners and the increasing constraints on land, an outcome of the fragmentation of family establishments caused by intergenerational processes of dividing up inheritances, left traditional strategies for managing the fertility of agroecosystems increasingly out of step and vulnerable. The high levels of migration away from rural areas, especially among young people, highlight the significant limitations posed to the social and economic reproduction of family farming in the region.

In parallel with the demographic exodus, however, family farmers, individually or collectively, sought to develop technical-economic and political responses to the agrarian issue in the region. These responses combine two simultaneous movements: on one hand, the fight for land; on the other, the innovation in agroecosystem management practices designed to intensify the use of agricultural land [23]. Though largely invisible, this second movement corresponds to a recurring process of change to the technological base of peasant agriculture when faced with limited access to natural resources, beginning with the land [24]. One of the main conclusions of Boserup's work is that there is no agrarian ceiling or natural support capacity in any particular region. The levels of productivity obtained depend not only on ecological capital but also on the social and human capital capable of continuously improving technical systems through local investment in experimentation [24].

Founded on the contemporary paradigm of living with the semi-arid region [25,26] in contrast to the established notion of fighting the droughts, this decentralized movement of peasant innovation has been responsible for the development of an extensive stock of technologies and management processes relating to production and social organization, adapted to the very specific edaphoclimatic and agrarian conditions of the semi-arid region. For a long time, though, this innovation remained largely unnoticed and/or shunned by public programs aimed at regional development.

It was only from the 1980s onwards with the return to democracy in Brazil that civil society institutions became structured to provide systematic advice to peasant organizations [27], looking to associate the critique of the historical pattern of agrarian occupation in Brazil and of the conservative modernization project [28] with the building of alternative styles of rural development.

Identified today with the agroecological field, these civil organizations work in an integrated fashion with the decentralized dynamics of rural development in the region. At the end of the 1990s, after almost two decades of accumulating practical experiences, the organizations united in the Brazilian Semi-Arid Alliance (*Articulação Semiárido Brasileiro: ASA*). Today ASA comprises a network formed by more than a thousand organizations present in the eleven federal states covered by the semi-arid region, (see www.asabrasil.org.br) drafted and advocated for public programs for improving water security in rural communities. ASA was responsible for designing, negotiating, and executing two programs for improving water security: the Program for Training and Mobilizing to Live with the Semi-Arid Region—A Million Rural Cisterns (P1MC), designed to ensure quality water for human consumption; and the One Land and Two Waters Program (P1 + 2), aiming to install local infrastructures for catching and storing rainwater for food production. Fifteen years after the launch of ASA's programs, more than one million and two hundred thousand cisterns for human consumption (first water) and more than 160,000 infrastructures for storing water for production (second water) have been implanted [29].

The infrastructures implanted by the public programs run by ASA allow the capture and storage of rainwater, reducing a critical ecological factor in the region's agroecosystems. Consequently they play a decisive role in expanding the margins for maneuvering for the development of trajectories of local innovation rooted in the recombination of other elements from the resource base self-controlled by rural families and communities, whether such elements are material (land, biodiversity, infrastructure, etc.) or social (labor, knowhow, cooperation practices, etc.).

Analytically, ASA's programs reproduce practices and perspectives consistent with the notion of endogenous rural development, a pattern of development founded on the deployment and

redynamization of resources locally available in rural territories [10]. Among other characteristics, this pattern reactivates ecological capital and expands social capital through trajectories of technical and socio-organizational innovation driven by territorial-level sociotechnical networks.

As social constructs, these agroecology sociotechnical networks vary from place to place in terms of the levels of governance that they exert on rural development dynamics. On one hand, this governance is related to the capacity of actors linked to the network to combine the public resources mobilized through different policies in line with a specific strategy focused on the quantitative and qualitative expansion of the self-controlled resource base. On the other hand, it entails the capacity to involve, commit, and mobilize the participation and political support of growing sectors of the rural and urban population, seeking to amplify the room for maneuvering so that the network can spread horizontally and increase in density within the territory.

This second aspect is essential, especially when we consider that agroecology networks are not formed in territories free of disputes over endogenous resources and the allocation of public resources. Sociotechnical networks structured by technical-economic approaches informed by the modernization paradigm also channel public resources to the territories, very often by means of the same policies, but establish distinct and frequently conflicting forms of appropriating ecological assets and organizing the agricultural labor process.

By employing public resources redistributed by the State predominantly to the expansion of the self-controlled resource base at the level of the agroecosystems and rural communities, the agroecology networks help strengthen the territorial economies through investment in qualified labor informed by contextualized knowledge [13]. In summary, the issue is one of catalyzing development trajectories rooted in distribution and local reinvestment of socially produced wealth, contrasting with the conventional dynamics of economic growth, founded on the systematic (and growing) influx of capital and exogenous technologies.

The recent experience in the Brazilian semi-arid region exemplifies the importance of the agroecological perspective in the establishment of mechanisms of synergetic coordination between public policies, in order for their resources to be channeled coherently in endogenous development trajectories.

In order to assess the potential impacts of this emergent process in the semi-arid region, the study focused on the Borborema territory, a region in the state of Paraíba densely occupied by family farmers producing staple foods and an area where a vigorous sociotechnical network inspired by the agroecological paradigm has been developing for more than twenty years. Supported by the non-governmental organization AS-PTA (www.aspta.org.br), this network is dynamized by the *Polo Sindical e das Organizações da Agricultura Familiar da Borborema* (Pole)—a collective actor that currently connects 14 municipal-level rural workers unions, 150 community-level grassroots organizations, and a regional association of agroecological farmers, Ecoborborema [30,31].

The network expanded and spread further afield with the decisive input of public funds mobilized through a broad and diverse set of government policies. Today it mobilizes a social base of around five thousand farming families, corresponding to roughly 30% of the family farming universe in the territory's 14 municipalities. Organically integrated with the network, a movement of women farmers has grown in strength, participating actively in the local dynamics of agroecological innovation and in the fight against gender inequalities.

2.2. Characterization of the Heterogeneity of Family Farming in the Territory

At the outset of its work in the region in 1993, the AS-PTA established a partnership with family farming organizations in two municipalities. To produce an overview of the local situation and guide its advisory work, it proposed the implementation of a participatory appraisal of agroecosystems to its local partners. Some years later, between 2001 and 2003, an updated survey of knowledge concerning the situation of family farming in the region was conducted, this time encompassing the social universe of 14 municipalities covered in the Pole's work. On this occasion, the territory was stratified into

environmental zones by means of a participatory appraisal. Twenty-three years after the emergence of the agroecology network in the territory, a new update was carried out, this time seeking to focus more specifically on identifying the influence of public policies on the recent development trajectories in the family farming in the territory (all these activities included the participation of the authors and this paper presents partial results from the last update).

Although this second update considered the territory as a whole, a more in-depth analysis was undertaken in the municipalities covered by the environmental zone locally identified as Agreste do Roçado (Figure 1). As well as including a substantial portion of the farming families and organizations linked to the Pole, this portion of the territory is the setting for the development of sociotechnical networks that foment contrasting trajectories of agroecosystem intensification.

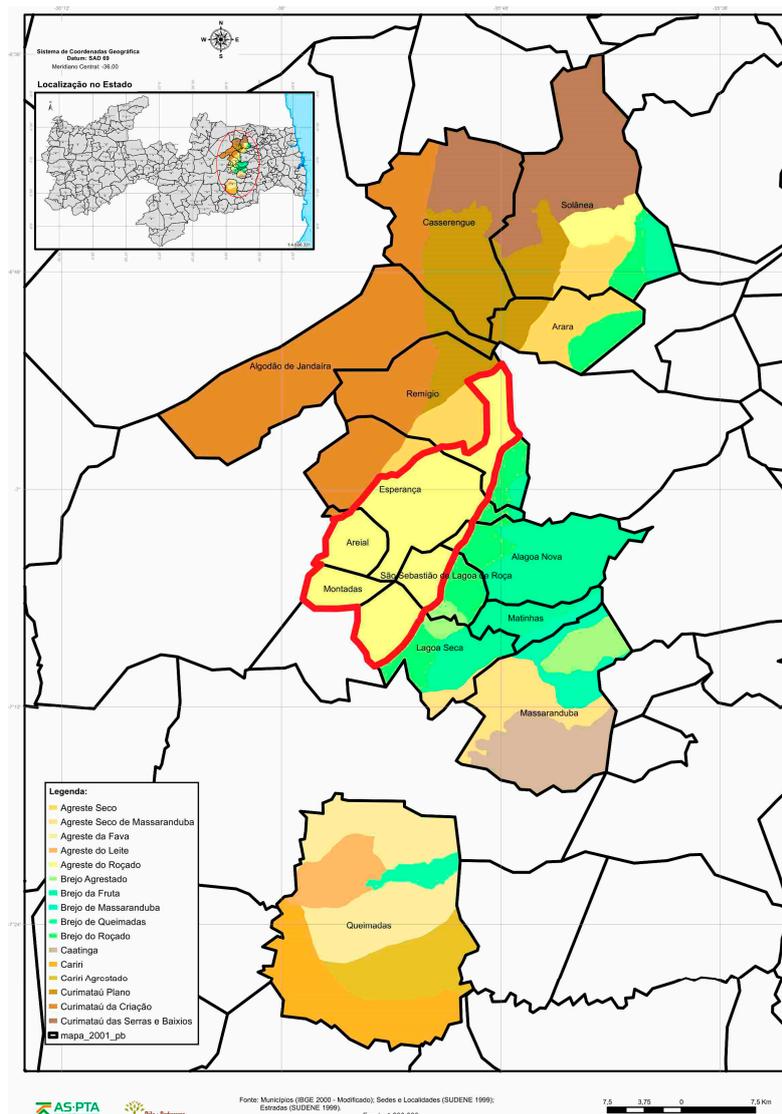


Figure 1. Environmental zoning of the Borborema Territory (*Agreste do Roçado* outlined in red).

As an initial stage of the appraisal, a two-day seminar was held in the first half of 2015, attended by 60 family farming leaders, men and women, from the Agreste do Roçado region, with the objective of describing and analyzing the transformation to the family-based agroecosystems in the region. This analytic exercise, systemized in the form of a time line, enabled the group to discern the influence of public policies on the emergence and development of sociotechnical networks organized

according to contrasting economic approaches. On one hand, networks were identified that drive intensification trajectories in line with the technical-economic paradigm of agricultural modernization. The tendency to generate a growing dependence of farming families on input and service markets was presented as a recurrent feature of these trajectories, which lead agroecosystems to different levels of technical-economic embedding in production chains of specific crops, such as potatoes, fennel, and tobacco in the past, and free-range chickens (*caipirão*) and intensive olericulture presently.

On the other hand, the agroecology network dynamized by the organizations linked to the Pole drives production intensification trajectories that ensure the maintenance of high levels of autonomy of agroecosystems vis-à-vis the markets for factors of production (inputs, land, labor). This autonomy is also evinced by the fact that a considerable portion of the food consumed by farming families is produced by themselves. Furthermore, the gradual increase in the self-controlled resource base mobilized in the process of farm work was presented as a recurrent characteristic of these intensification trajectories guided by an agroecological approach.

In the second stage of the diagnostic survey, semistructured interviews were held with 201 farming families with the aim of characterizing in detail the evolving dynamics of family farming in the region and comparatively assessing the effects of different development trajectories on various criteria related to the technical-economic reproduction of agroecosystems.

The interviews used a script of open questions designed to identify transformations in the sociotechnical organization of agroecosystems, especially over the course of the last decade and a half, as well as various characteristics of their current configurations (a self-controlled resource base, the production of monetary and non-monetary and agricultural and non-agricultural income, relations with input and product markets, access to public policies, and so on).

Taking as a reference point the information obtained in the interviews, the agroecosystems were classified in three main categories: Type 1: traditional systems, i.e., those with a limited connection to sociotechnical innovation networks (87 interviews—43%); Type 2: systems linked to the agroecology sociotechnical network (102 interviews—51%); Type 3: systems linked to sociotechnical networks structured as specialized production chains (12 interviews—6%).

The diagram below schematically represents the transformations occurring in the region's agroecosystems over the recent decades (Figure 2). The two polar trajectories of agroecosystem intensification are illustrated by the dotted arrows. The trajectories linked to the agroecology network basically correspond to the processes of the transformation of Type 1 (traditional) agroecosystems into Type 2, i.e., those managed via *relatively autonomous and historically guaranteed* strategies of technical-economic reproduction [32]. As well as maintaining high levels of autonomy vis-à-vis input and service markets, other characteristics also detected in the Type 1 agroecosystems, these trajectories are distinguished by the gradual incorporation of technical and socio-organizational innovations that assure the continuous reproduction and enable the gradual quantitative and qualitative expansion of the self-controlled resource base mobilized in the labor process of farming families. In this sense, they typically comprise labor-driven intensification trajectories.

The trajectories of technical-economic innovation linked to the specialized production chain correspond to the development of Type 3 agroecosystems whose reproduction strategy structurally depends on the mobilization of the factors of production in the markets. In this sense, they figure as conventional trajectories of production intensification (or capital-driven intensification).

One aspect to be emphasized in the model shown in the diagram is that the intensification trajectories illustrated by the dotted arrows correspond to an ideal type—in Max Weber's sense [33]—of the development dynamics of family farming in the region. However, the interviews conducted with the farming families revealed a more complex empirical reality insofar as they showed the existence of various combinations between these patterns of technical-economic organization of agroecosystems. This means that, in many situations, the processes of innovation observed in the region's family farming establishments are guided by hybrid strategies that mix practices that are typical of two or more sociotechnical networks.

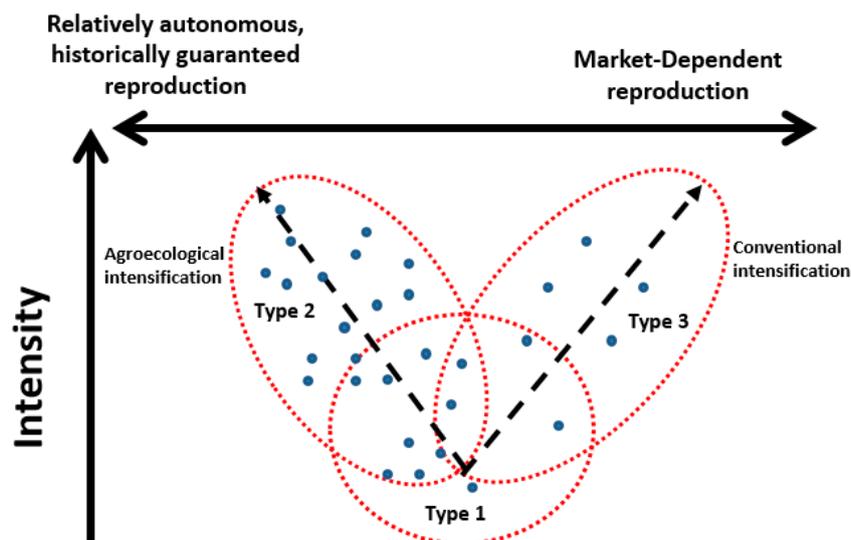


Figure 2. Contrasting intensification trajectories and resulting types of agroecosystems in Agreste do Roçado.

The outcome of the adoption of these multiple strategic possibilities in the organization of the labor process by the region's family farmers is the forming of a significant heterogeneity among agroecosystems in terms of the levels of intensity and autonomy in relation to markets, or in other words, to the *degrees of commoditization* [32]. The degree of commoditization reflects the relative importance of market relations in the organization of the labor process in the agroecosystem. Analytically it corresponds to the ratio between the resources mobilized in the markets and those reproduced in the agroecosystem itself and/or mobilized in the community through relations of reciprocity. In the diagram, this heterogeneity is represented by the positioning of agroecosystems around these two main axes, forming three clusters that correspond to the predominant types of family farming.

According to the theoretical-methodological approach adopted to represent the diversity of family farming in the region, the agroecosystems may be located at the intersection of two or more clusters. This positioning that is *halfway* between two or more categories differs from the dualist classificatory schemas frequently adopted to represent the diversity of agriculture and to inform the design of public policies. The adoption of binary categories easily identifiable through simple and objective criteria, such as property size, income level, technical system adopted, and so on, tends to produce images of the agrarian world incongruent with the strategies of technical-economic reproduction adopted by family farming. The decision to pursue this perspective to representation, inspired by the farming styles approach proposed by Ploeg [34], is founded on the understanding that agroecosystems correspond to the expression of technical-economic strategies adopted by farming families. Consequently they are not understood as sociotechnical configurations hermetically sealed in space or immutable in time, but as the sociomaterial outcome of the solutions actively constructed by farmers in response to the contexts of objective opportunities and constraints faced in the process of reproducing their means and ways of life.

2.3. Comparative Analysis of Contrasting Trajectories of Intensification

In order to comparatively assess the effects of contrasting development trajectories in family farming in the region, two typical cases were chosen from the universe of agroecosystems described above that express polar opposite situations. The first agroecosystem is strongly linked to the agroecology network dynamized by the Pole, while the trajectory of the second is linked to the sociotechnical network shaped by the production chain of free range chickens (*caipirão*) structured in

the territory since the start of the 2000s. Both networks receive support from public funds, either for the implantation of infrastructures and processes of collective action (such as cooperatives, chicken processing units, projects for selling to institutional markets, etc.), or for financing and direct support for the farming families linked to it. As well as expressing contrasting strategies for technical-economic reproduction, the two agroecosystems were selected since they possess similar sized territories (around 15 hectares) and equivalent workforces (2 Family Labor Units).

In order to identify the contributions made by both the agroecosystems and the sociotechnical networks to which they are connected toward rural development, an economic-ecological method of agroecosystem analysis was employed. The method was proposed by AS-PTA with the aim of highlighting the economic, ecological, and political relations that set apart the modes of production and ways of life of family farming, but which have been systematically eclipsed or distorted by conventional economic theory [35].

To carry out the present study, the method was put into practice in two subsequent stages. In the first phase, semistructured interviews were conducted with the families in order to collect the information needed to describe and analyze the evolving trajectories of the agroecosystems and to develop representative models of the structure and economic-ecological functioning of the agroecosystems in the year of the study (2015). The information on the trajectories taken by the agroecosystems was systemized in the form of time lines, which allowed mapping of the significant changes inside and outside of the farms. This methodological approach made it possible to identify the logics involved in mobilizing the recourses of public policies aimed at farming families in order to promote the structural and functional transformations in agroecosystems. The models, elaborated in the form of flow diagrams, are schematic representations that enable the identification of the circulation of inputs and products, monetary and non-monetary incomes, and the social division of labor between family members and between the family and outside economic agents.

In the second phase, through a new interview, the economic-ecological flows represented in the models were quantified and the data obtained was fed into an electronic spreadsheet specifically designed to generate a wide-ranging set of economic indicators. The comparative analyses are quali-quantitative in nature and are grounded in the information and data collected via in-depth interviews with the families managing the two agroecosystems.

3. Results

3.1. A Trajectory of Agroecological Intensification

The family of Paulo and Josefa resides in the Oziel Pereira rural settlement in the municipality of Remígio (PB). For 21 years, since their marriage in 1978, they have been a landless family. The couple obtained income by working the land owned by other people, either as tenant farmers, or as sharecroppers, or with the right to plant fields for a two-year period in exchange for clearing land for pasture. One of the areas where Paulo worked in the past was precisely where the family was settled, in 1999, after years of activism in the Landless Rural Workers Movement (MST). When they took possession of their plot of land, Paulo and Josefa discovered they had been given a heavily degraded area, “completely treeless”, a situation reverted over the years through organic fertilization of the soil and reforestation of the area with multifunctional tree species.

Through their participation in the community association, the family became an active member of the agroecology sociotechnical network dynamized by the Pole with the local Rural Workers Union functioning as a channel of dialogue between the community and territorial spheres. It is also worth emphasizing the Pole’s integration in sociotechnical networks organized at higher geographical levels, such as the Paraíba Semi-Arid Alliance (ASA-PB), the Brazilian Semi-Arid Alliance (ASA), and the National Agroecology Alliance (ANA). Based on this multilevel social participation, the agroecosystem’s development was heavily shaped by the processes of learning and experimentation generated in the networks of farmer-experimenters assisted by the Pole and AS-PTA, as well as by the

political capacity of the Pole and its organizations in mobilizing and channeling public resources to enable transformations in the territory in line with the agroecological approach.

In addition to the already mentioned reforestation of the lot, favored by the existence of a territorial network of community nurseries, over the years the family incorporated a set of management practices closely connected to processes organized by the Pole. Among them, we can highlight: the use of adapted seeds, seasonally-timed access that is ensured through participation in the community seed bank and in trials of local maize varieties organized by the Paraíba Semi-Arid Alliance (ASA-PB) in partnership with the Brazilian Agricultural Research Corporation (EMBRAPA); implantation of cisterns for collecting rainwater for human consumption and for production with resources obtained from public programs implemented by the Brazilian Semi-Arid Alliance (ASA); restructuring and intensifying house yard production with resources mobilized in a community revolving fund; an increase in the volume of forage produced and stored, making use of a forage machine managed by the Remígio Rural Workers Union and obtained through the Citizenship Territories program from the Agrarian Development Ministry; participation in the municipal agroecological fair and the sale of produce to the National School Meals Program (*Programa Nacional de Alimentação Escolar*: PNAE).

The gradual incorporation of technical and organizational innovations in the agroecosystem, made possible by material investments associated with learning processes and local experimentation, helped broaden the family's self-controlled resource base and simultaneously enhance the process of converting these resources into a diverse range of products for market sale and self-consumption. As well as the access to land through the land reform program, the family was able to combine the resources mobilized through different public policies—including income transfer programs—to build a multiproduct unit with low technological dependence, which provides them with a high level of food security and enables them to sell their produce via diverse local markets. The changes introduced to the family's house yard under Josefa's leadership assumed a prominent role in the reorganization of their work and in the economic results of the agroecosystem as a whole (an aspect to be examined later).

3.2. Effects on Rural Development

The trajectory through which the agroecosystem run by Paulo and Josefa's family became constituted cannot be assumed to be a generalizable empirical expression of the agroecosystems connected to the Agroecology network in the territory. A complex set of material and immaterial factors, both internal and external to the rural establishments, influence the strategic decisions taken by families and, consequently, the development trajectories taken by agroecosystems. Ultimately, each agroecosystem then possesses a unique configuration that expresses the contingent result of the accumulation of strategic decisions taken over the years. However the analyses undertaken through concrete reference to this agroecosystem are valid in terms of extrapolating the potential effects at the territorial level, allowing the identification of a variety of contributions to the agroecosystems linked to the agroecology sociotechnical network for rural development.

From the environmental viewpoint, the style of economic management of the agroecosystem contributed simultaneously to: (a) a continual renewal of the fertility of the cultivated lands through intensive production cycles and the restoration of biomass to the soil, a significant aspect in a region subject to processes of desertification (contributing to the reach of SDG 15); (b) the conservation and enrichment of agrobiodiversity, based on the adoption of a diverse set of valued practices linked to economic and ecological functions of the local genetic resources—i.e., local plant varieties and native livestock breeds, replanting with species with multiple purposes, etc. (SDG 15); (c) completely dispensing with the employment of pesticides and other contaminating inputs (SDG 3 and 12).

When considered together with the diverse range of economic options available to the family, these environmental management practices confer greater resilience to the agroecosystem, a fact verified in the most recent period of sustained drought, which has already lasted for five years. Furthermore, this pattern of managing the farm landscape, based on geobiochemical cycles propelled by photosynthesis, contributes to a reduction in the levels of greenhouse gas emissions (SDG 13). These results demonstrate

the possibility of reconciling practices of agricultural intensification and strategies for mitigating and adapting to climate changes. In other words, it means that the challenge of intensifying farming does not necessarily imply the appropriation of natural assets through predatory practices. On the contrary, the experience reveals the possibility of attaining the objectives of intensifying farm production while restoring degraded landscapes (SDG 8).

These processes of protecting and expanding ecological capital at the levels of the agroecosystem and the territory cannot be comprehended separately from a strengthening of social capital—that is, the improvement of the collective action mechanisms used to build, defend, and continuously replenish common goods. To boost these processes, the Pole and AS-PTA have fostered an intense social dynamic aimed at producing and sharing knowledge and involving activities related to participatory appraisals, local experimentation, exchange, and research in partnership with official scientific-academic institutions. As a common good, knowledge circulates freely in the sociotechnical network, helping boost human capital and, consequently, the quality and efficiency of labor (SDG 4).

Still on the question of the expansion in social capital, it needs to be emphasized that the creation and strengthening of tools for managing common goods in the region's communities occur in association with a deliberate strategy of the Pole and AS-PTA to overcome the patriarchal culture and the various forms of violence against women, creating better environments for critical reflection on gender inequalities. These in turn helped foment a regional movement in support of the political and economic emancipation of women in private and public spaces (SDG 5). In Josefa's case, for example, her active involvement in community revolving funds allowed her to obtain wire mesh to fence off her yard and animals in order to expand and improve the quality of her poultry livestock. Furthermore, Josefa's integration in this community-level space facilitated her entry into the women's movement at the territorial level, participating in various exchange visits and six annual editions of the Women's March for Life and Agroecology, co-organized by the Pole and AS-PTA.

The horizontal spread of the network through the region's municipalities, engaging an ever increasing number of family farmers, is anchored in and contributes to the strengthening of territorially rooted institutions based on relations of reciprocity (SDG 16). The creation of 65 community seed banks and eight community nurseries, the setting up of 140 community revolving funds, the collective management of twenty motorized silage machines for processing and storing forage, the swapping of knowledge and genetic material in exchange activities, as well as the various forms of cooperative work (work rallies, day swaps, local fairs), are more or less formalized expressions of the strengthening of institutional capital, a decisive condition for individual capacities to be mobilized in support of actions of the collective interest without the need for the intermediation of commodified relations.

One important practical implication of the amplification and management of common goods for rural development is the increase in the quality of the labor processes and products in agroecosystems. Among the various expressions of this improvement, we can highlight the quality of the food produce, whether destined for self-consumption or for market sale. Given the rise in health issues associated with the consumption of processed foods and/or with residues of pesticides and other contaminants, this is undoubtedly an especially important positive effect (SDG 3 and 12).

The creation of the Borborema Territory Association of Agroecological Farmers (Ecoborborema) in April 2005, set up to stimulate the commercial outlet for diversified and differentiated food production, was one of the key moments in the evolution and densification of the network run by the Pole. Responsible for coordinating a set of 12 agroecological fairs and managing projects for the sale of produce in institutional markets, Ecoborborema has played an essential role in broadening and diversifying the actors belonging to the sociotechnical network, especially by establishing connections with growing portions of the urban population in the region's municipalities. This valorization of local production in ever broader social circles within the territory is a key element in strengthening its symbolic capital, i.e., in the increased public recognition of the benefits generated by the family farming mode of production linked to the Pole.

3.3. Impacts on Family Economies

As well as helping to strengthen the agroecology sociotechnical network, the public policies for family farming implemented in the territory over recent decades have supported the development of production chains for specific food produce such as potatoes and tobacco in the past, and free range chickens (*caipirão*) and intensive vegetable cultivation in the present. The logic of economic intensification of agroecosystems linked to these chains tends to generate processes of ecological simplification and increased dependence on commercial inputs. At the same time, the higher level of productive specialization makes these agroecosystems more dependent on commercial relations over which the families themselves have little or no control.

Contradicting the central argument propagated by advocates of agricultural modernization, comparative economic analyses conducted in the region have systematically demonstrated that increases in the value of the production of the agroecosystems linked to these chains do not necessarily yield agricultural incomes any higher than those obtained by families who do not make use of modern technologies.

This fact became apparent when the economic yield of the agroecosystem managed by Paulo and Josefa was contrasted with an agroecosystem of analogous size (around 15 hectares) and labor capacity (two adults), but which followed a conventional intensification trajectory, today managed with the intensive use of external inputs following an economic logic based on intensive capital inputs. In this case, the agroecosystem employed as a comparative reference, identified here as AE1, is linked to the productive chain of free range chickens, a sociotechnical network that first emerged in the region at the start of the 2000s. This network is strongly polarized by a regional cooperative of poultry breeders and has been able to mobilize resources from public policies for credit, material support, and rural extension services. The free range system of poultry breeding has been actively promoted as a labor and income alternative for the region's family farmers, including the mobilization of resources from social policies like the Misery-Free Brazil Program (*Programa Brasil Sem Miséria*), an initiative launched by the Brazilian government in 2011, with the objective of drastically reducing the poverty indices in the country through the social and productive inclusion of the section of the population considered to be living in extreme poverty. However, the logic of technical-economic management of the activity leads families to establish ties of structural dependence with the input and service markets (purchase of feed, chicks, and other production inputs, hiring outside labor).

In technical terms, while the AE1 management style follows the logic of an economy of scale, seeking to reduce unit costs through specialization and through the continual increase in the operational dimension of the production processes, the agroecosystem run by Paulo and Josefa's family, AE2, is based on the logic of an economy of scope, seeking to reduce total costs through a synergy between the productive activities. Specialization and scale, on one hand, diversity and synergy, on the other, are keywords for defining what distinguishes the two management styles.

An eloquent numerical expression of this contrast is given by the diversity of items produced in the two agroecosystems. While AE1 produces two items in two subsystems (poultry and cattle), AE2 produces 23 items in 4 subsystems (crops, fruits, cattle, and poultry). Through a complex of synergistic relations between the different activities performed, AE2 comprises a dense web of economic-ecological flows strategically organized in space and time to attain an integrated set of family objectives.

When we turn to consider monetary and non-monetary economic flows, the comparative analysis of the annual economic yields of the two agroecosystems reveals aspects usually hidden in conventional accounting, though they are central to understanding the economic operation of family farming. Focusing narrowly on Gross Value of Production (GVP), the main economic indicator used in official agricultural statistics, AE1 presents an annual performance 2.6 times higher than AE2 (R\$107,500 versus R\$40,200). However, when our focus of comparison shifts to the clean part (net yield) of economic production—the agricultural income—a superior performance of AE2 is observed (R\$26,000 versus R\$31,700).

A panorama even more divergent from conventional economic approaches is revealed when we turn our comparative analysis to land productivity. Observing that the two agroecosystems generate similar agricultural incomes per hectare (R\$1547 versus R\$1717), a conventional analysis would conclude that they possess an equal level of efficiency in terms of allocating this factor of production. However, when we analyze the situation from the viewpoint of the ecological economy, it becomes clear how many virtual hectares are needed for the production/extraction of the resources obtained from the markets—with costs reaching R\$73,000—to activate the productive processes of AE1. This means that the labor process in the management of AE1 consumes resources appropriated in a much larger environmental space than the space directly exploited by the agroecosystem (principally the inputs for making feed, produced in large transgenic monocrop plantations in the Cerrado region of Brazil), revealing a low level of endogeneity of AE1 (0.29) compared to AE2 (0.79), whose production costs (intermediary consumption) were just R\$8000 (obs.: A representation of the endogeneity of the agroecosystem through a synthetic index is obtained through the ratio between Added Value and Gross Income). Applying these indices to the adjustment of the land productivity indicators, we can conclude that AE2 is 302% more intensive than AE1 (R\$448/ha versus R\$1356/ha). In this analysis it should be noted that AE1's main income generating activity, poultry breeding, makes virtually no use of the ecological resources provided by the agroecosystem itself. Hence conventional analyses tend to generate a somewhat distorted picture of the degree of technical efficiency of modernized establishments insofar as the income generated by them does not effectively express the technical efficiency in the use of local environmental resources.

This analysis of land productivity through non-conventional lenses reveals the essential difference between the logics of intensification adopted by the two families. While the management of AE1 is associated with an intensive and constant application of capital, AE2, run by Paulo and Josefa's family, makes use of most of the factors of production from a self-controlled resources base, built up slowly over the years and continually regenerated by investing the labor of the family itself, including towards the maintenance and expansion of relations of reciprocity established at the territorial level.

4. Discussion

Although the two agroecosystems taken here as benchmarks do not represent the significant heterogeneity of family farming in the Borborema Territory, the analyses derived from them enable a number of comments to be elaborated on concerning the effects of public policies on rural development dynamics. This is because they illustrate two practically opposite trajectories of agricultural intensification. Between these two polar situations, the reality on the ground contains a varied mixture of technical-economic management rationales. In this sense, the resulting heterogeneity of agroecosystems may be interpreted as the expression of hybrid strategies that combine investment in labor and capital in different proportions.

It is important to stress that the strategies adopted by the families reflect legitimate options for continuing to reproduce themselves as family farmers in response to the structural conditions encountered by them in the territory. Hence the focus of analysis should be on the institutional environment in which these decisions are taken in the private sphere, in particular on the influence of State action on the creation of the conditions for developing and consolidating the multifunctional potential of family farming, including those sectors historically considered marginal, peripheral, or non-viable.

Firstly, we need to focus on the role of the State in working to resolve a decisive factor in the political economy of agriculture, namely the agrarian question. The experience of Paulo and Josefa's family is emblematic of the relevance of land reform to compliance with the constitutional provisions related to the social and environmental functions of the land. In little more than a decade, the settled family and community have transformed the landscape from a large economically unproductive and environmentally predatory farm into a space generating hundreds of decent jobs and steady sources of income to meet their economic needs, by diversifying the production of the agroecosystems. It

is worth emphasizing that Paulo and Josefa's children also obtained plots of land through the land reform program, demonstrating the role of this policy in the intergenerational reproduction of family farming. In addition to the direct benefits for settled families, and in an effective contribution to the structural overcoming of poverty (SDG 1) and food insecurity (SDG 2), this State intervention was decisive in terms of stimulating the territorial economy (SDG 8), the ecological restoration of degraded areas, and the increase in the production of quality food produce to supply local and regional markets (SDG 12).

The family's experience also emphasizes that, beside land redistribution, other public initiatives are essential for making space for the expression of the multifunctional potentialities of family farming. The resources redistributed by different public policies were channeled by the family towards strengthening typically peasant strategies of economic reproduction, i.e., driving trajectories of intensification rooted in the management and continual expansion of the self-controlled resource base [12].

The presence of a social environment favorable to the production of contextual knowledge and the generation of local innovations proved to be an indispensable condition for self-controlled endogenous resources to be identified, valorized, and amplified. Here we can stress the decisive role played by AS-PTA's advice in the use of an agroecological perspective to comprehend the socioenvironmental peculiarities of the territory and the agroecosystems operating within it. This perspective is directly opposed to the focus on technological diffusionism that has historically influenced the organization of the extension service and agricultural research institutions.

The public programs for implanting decentralized infrastructures for catching and storing rainwater (P1MC and P1 + 2) have performed an essential role in this trajectory by functioning as the triggers of processes of sociotechnical innovation, contributing to the reorganization of the labor processes in the agroecosystems and rural communities. On one hand, they helped to substantially reduce the time dedicated to obtaining water for human consumption, generating a series of positive effects for families, particularly for those individuals previously involved in this activity, traditionally women and children. Here we can also highlight the significant improvement in the quality of the water consumed with positive impacts on collective health (SDG 6). On the other hand, they enabled an increase in the water reserves directed towards production, contributing to a rise in the efficiency of land use and labor.

The intensification in house yard production, with substantial impacts on the income generation and food security of local families (SDG 2), was one of the most significant outcomes of the installation of water infrastructures. The relative economic importance of these spaces is illustrated by the agroecosystem managed by Paulo and Josefa. Despite occupying just 0.5% of the agroecosystem's total area, the house yard, a space primarily managed by Josefa, was responsible for generating 24% of the family's agricultural income in the year when the study was conducted, a drought year. Another notable effect of the programs is the greater stabilization of livestock herds and flocks during the dry periods of the year, another hugely important contribution to the resilience of the agroecosystems.

However the innovations brought about by these programs are not limited to the technical dimension. Both programs were conceived and successfully introduced by ASA after lengthy negotiations with a series of federal government administrations. Along with obtaining the funds needed to implement the infrastructures, ASA negotiated an innovative mode of partnership with the State that enabled joint execution and public oversight of the programs. Through this innovative framework, the Borborema Pole, along with hundreds of other organizations linked to ASA, was able to optimize its role as a collective actor in the promotion of territorial development dynamics. By strengthening the capacities of civil society organizations to execute and oversee the use of public resources, the partnership between governmental and non-governmental public entities has helped shift beyond a political culture congenitally linked to clientelist practices responsible for reproducing the political and economic subordination of the most impoverished sectors of the rural population within oligarchical local power structures.

Instead of submitting the most vulnerable farming families to clientelist relations and those able to make a modest living through dependency on the agribusiness sector, this style of joint public policy management has helped to strengthen political citizenship and to activate and dynamize social mechanisms of reciprocity, amplifying social capital in the territory, a decisive element in terms of the generation of common goods managed by the organizations and families linked to the Pole.

The development of a variety of collective action devices in the territory has also depended on the crucial support of resources redistributed by government policies. Among these we can highlight the short circuits to commercialization (institutional markets and agroecological fairs), community seed banks and nurseries, solidary revolving funds, machinery for making screens and fencing, and the silage machines for collective use. These and other initiatives created and consolidated through the sociotechnical network coordinated by the Pole are important expressions of rural development dynamics unleashed through the coproduction of public action involving the State and territorially-based civil society organizations. They also express the capacity of territorial-level sociotechnical networks to mobilize and provide coherence to public resources derived from different government policies, including those not directly identified with rural development.

Here we can emphasize the pronounced influence on the trajectory of the network exerted by income transfer policies, especially rural pensions and the Family Allowance Program (*Programa Bolsa Família*), a federal government direct income transfer program, targeted at families living in poverty and extreme poverty in rural and urban areas. Firstly, regular access to these resources among the most impoverished families (rural and urban) has contributed to an increase in the overall demand for food produce. In this sense, income transfer policies perform polyvalent functions in the territory, not only by reducing levels of poverty and food insecurity but also by dynamizing the regional economy through the valorization of the work of family farming. Moreover, it should also be observed that access to these resources by farming families significantly expands the margins of freedom for them to improve their economic reproduction strategies, not only by responding to more pressing needs, but also by assuring the regular influx of financial resources that are partly invested in structural improvements to the agroecosystems. This aspect is particularly important for women farmers, since their direct access to financial resources comprises a powerful tool of emancipation from the double condition of subalternity to which they have traditionally been submitted: by being poor in a structurally unequal society; and by being women in a culturally patriarchal society. Hence, whenever this is combined with multiple strategies for economic and political emancipation, the income transfers effected by social policies generate multiplying effects on territorial development.

Although the higher rates of decline in extreme poverty in Brazil over recent years have occurred precisely in the semi-arid region [36], revealing the universal effect of income transfer policies, they do not necessarily imply the inauguration of development trajectories capable of overcoming the structural conditions responsible for the pronounced social inequality experienced in the region. The effects of these social policies on the improvement of the welfare conditions of the poorest families and, in some cases, on the stimulation of local markets are not enough by themselves to transform the productive bases of the rural territories since their resources are primarily used to purchase essential goods not produced locally (a substantial portion of food items, medicines, clothing, household appliances, furniture, building materials, and school materials) [37]. On the other hand, the experience of the most socially vulnerable family farmers linked to the sociotechnical network coordinated by the Pole demonstrates that the alleviation of severe hardship through regular access to social policy resources comprises an essential condition for them to obtain enough room for maneuvering to be able to join trajectories of material accumulation based on labor-driven intensification processes.

The substantial improvement in the public service provision in the areas of education, health, and infrastructure (rural power supply, communications, road systems, etc.) in the territory have also contributed to expanding the freedom of the poorest farming families to invest their labor in self-emancipation processes. As the Indian economist Amartya Sen [38] (p. 66) made clear: "The quality of life can be vastly raised, despite low incomes, through an adequate program of social

services". This observation led the author to challenge the idea of trickle-down economics used to justify keeping large swathes of the population in poverty as a necessary sacrifice for national economies to grow and create the structural conditions for 'sharing the cake' later.

The empirical evidence observed in the Borborema Territory over recent decades corroborate this challenge to orthodoxy by the winner of the Nobel Prize for Economics. The Agroecology sociotechnical network coordinated by the Pole combined resources endogenous to the territory with resources redistributed by the State to drive a robust dynamic led by regionally interconnected collective actors working to build and defend their own project for rural development amid a social universe conventionally labelled marginal and unproductive. This dynamic unfolded through autonomous strategies of economic reproduction based on processes of coproduction with nature, on the expansion of the practices of reciprocity in the management of common goods, and on the local production of technical and organizational innovations. The process thus promotes the creation of a new political and institutional culture that gives a new meaning to public action, contributing to the decentralization of State action and to strengthening the ties between the dynamics of territorial development and the deepening of participatory democracy.

5. Conclusions

In adequate political-institutional conditions, the most impoverished portions of family farming can become the leading agents of rural development dynamics, contributing to the combined attainment of various SDGs. In this sense, the evidence presented here directly contradicts influential arguments that downplay the economic vocation and innovative capacities of this largest section of the rural population. These conditions should favor the emergence and development of territorially-based sociotechnical networks capable of mobilizing and synergically combining public resources redistributed by the State and endogenous social-material resources.

The agroecological paradigm offers the conceptual grounding and adequate methodological tools for the identification, recombination, and continuous improvement of the resource base self-controlled by rural families and communities in order for it to be valorized in productive intensification trajectories. From this viewpoint of sociotechnical innovation alone, the trajectories of productive intensification can be considered sustainable since they do not place demands on the systematic importation of material and energy. However, in order for the agroecological intensification approach to be put into practice at ever wider social and geographic levels, it becomes necessary to strengthen the institutions of participatory democracy in order for public policies to be continuously improved, allowing critical and active citizenship to exert a leading role in the governance of agri-food systems.

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