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# Beyond the shade: Family farmers' perceptions of silvopastoral systems in the Amazon

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## Abstract

This exploratory study examines the efforts of family farmers in the Brazilian Amazon to establish silvopastoral systems that integrate trees, pasture, and cattle in the same area. These systems offer an alternative to conventional livestock rearing practices that remain the primary source of income for many impoverished families, and yet are also major drivers of ecological degradation, with far-reaching regional and global climate impacts. Using a qualitative case study approach, we conducted in-depth interviews with 17 smallholder families living in zones of rapid soybean expansion to identify the factors that support and constrain the adoption of silvopastoral systems. Our analysis highlights six issues that emerged from farmers' accounts: the cultural dominance of monoculture agriculture; experiences of ecological problems associated with conventional agriculture; community-based alternatives to dominant agricultural practices; relationships between farmers and technicians involved in silvopastoral implementation; emerging farmer insights

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on ecological dynamics and biodiverse livestock systems; and the material limits of these innovations. Taken together, these findings advance four key arguments relevant to efforts to build alternatives to environmentally damaging food-production regimes. First, historical settlement patterns, long-standing socio-economic exclusion, and the cultural dominance of conventional agriculture continue to bind many smallholders to conventional livestock systems despite their declining ecological and economic viability. Second, community networks and non-governmental organizational (NGO) initiatives grounded in Freirean participatory pedagogy can create openings for cooperation, dialogical learning, and the production of situated silvopastoral knowledge. Third, these socio-technical relations foster new practices through which farmers revalue biodiversity as both an ecological and economic asset. Fourth, the adoption of silvopastoral systems remains limited by labor demands, knowledge and skill requirements, and initial environmental conditions that slow system establishment.

**Keywords**
agroforestry, deforestation, Brazil, participatory rural development, sustainable food production, Amazon

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The authors disclose that there are no financial or other relevant interests that could be construed as resulting in an actual, potential or apparent conflict.



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## Introduction

Dominant rural development models follow a productivist paradigm that privileges large-scale monocultures, often at great cost to communities, ecosystems, and the global climate (Elouattassi et al., 2023; Thompson, 2017; 2020; Weihs et al., 2017). However, such agricultural methods are not the only way of producing abundant food (Ikendi, 2022). Archeological evidence suggests that large pre-Hispanic Amazonian populations fed themselves growing native trees and crops on the same land (Furquim et al., 2023; Miller & Nair, 2006). Much of this knowledge was lost with the demographic collapse following the conquest of the Americas and development efforts that, starting in the 1960s, have promoted monoculture expansion over native forests and agrobiodiverse spaces maintained by Indigenous peoples (de Assis, 2005; Montgomery, 2012; Thompson, 2017; Urzedo & Chatterjee, 2022).

Our research examines how non-Indigenous family farmers in contemporary Amazonia advance similar agricultural practices growing native trees and domesticated animals on the same land with beneficial social and ecological outcomes. Although our interlocutors, like most Brazilians, have Indigenous and African heritage, they grew up in non-Indigenous families and territories. Moreover, they were often born outside the Amazon region, arriving there as workers in state-directed development efforts that framed Indigenous and traditional practices as "backwards" (Ramos, 1998). We explore how implementing biodiverse agricultural approaches requires landholders to reconsider these dominant developmental ideas and reassess the nonhuman world and their relationship to it.

We suggest that this line of inquiry is particularly important in the Amazon, which, despite decades of human-driven ecological destruction, continues to be one of the most biodiverse ecosystems on the planet (Guayasamin et al., 2024). The Amazon region, moreover, sustains regional and global climate patterns as well as various biogeochemical cycles and rainfall dynamics (Fearnside, 2005; Lovejoy & Nobre, 2019). Replacing biodiverse forests with monocultures has led to drier, fire-prone landscapes and increasingly frequent and severe droughts and fires (Dias-Filho &

Lopes, 2020; West & Fearnside, 2021), which today place the region at risk of large-scale ecosystem collapse (Flores et al., 2024).

None of the above ecological attributes means much in the context of the dominant rural development efforts that mobilize technologies and methods designed to transform whole landscapes in the shortest time possible (Domingues & Sauer, 2022). Grounds for livestock, for instance, can be quickly established by eliminating native vegetation cover and then seeding the land with engineered seeds that in a few months can already feed cattle (Walker et al., 2009). In our fieldwork we heard from farmers about defoliating areas by spraying herbicides by plane and then seeding grass from the air. Contact with the land in this type of case is limited to the moments when cattle are transported in and out of the area. Although this is an extreme case, the point is that conventional, large-scale agricultural approaches require little familiarity with the land and rely on the application of pre-made technological "solutions" to the problem of how to produce as much and as quickly as possible (Ikendi, 2023; Thompson, 2017; 2020).

This conventional agricultural model (the productionism paradigm) has helped Brazil become one of the world's largest exporters of rural commodities such as soybeans and beef (Hecht et al., 2024; Ioris, 2015 ). However, almost none of this wealth from the exports goes to family farmers in the Amazon, most of whom rely on small agricultural activities to make a living. Monoculture agriculture tends to deplete soil nutrients over the years, which leads to dwindling pastures, shrinking herds, collapsing revenue, and, for many families, selling their land to wealthier farmers (Dias-Filho & Lopes, 2020). Many families have been displaced to urban centers that offer few economic opportunities, while landed elites have grown their estates by incorporating land previously managed by impoverished families. This process results in the Amazon being one of Brazil's poorest regions, with some of the highest levels of income inequality (de Oliveira & de Souza, 2021; Ioris, 2015).

All these problems are hard to address in a cultural context in which monoculture-based systems continue to be seen as the most desirable food production method. A culture of "clearing the land" is very much rooted among large segments of the population in the Amazon who, having come to the region from other parts of Brazil, embrace the notion that agriculture is synonymous with replacing native ecological conditions (Weihs et al., 2017). In this context, we argue that finding alternatives to monoculture-based food production systems is both a technical or ecological problem and a socio-cultural issue. We address it by focusing on efforts to implement silvopastoral systems that emulate traditional and ecologically oriented practices by maintaining pastures, cattle, crops, and native vegetation in biodiverse areas (de Almeida, 2010).

### *Silvopastoral Systems*

Establishing silvopastoral systems differs from conventional pasture building by requiring site-specific assessments of topography, soil, water availability, and the relationships between native species, cattle, and grass (Dias-Filho, 2006). Once a system is established, landholders engage in long-term vegetation management—trimming, adding species, and protecting them from threats such as insects—while adapting to unexpected outcomes under changing climate conditions. Iterative experimentation produces heterogeneous landscapes with tree clusters, humid microclimates, diverse forage patches, rotational grazing areas, and streamside vegetation shaped by local topography (de Castro & Paciullo, 2006).

Research on silvopastoral systems emphasizes their dual production-and-conservation benefits (de Almeida, 2010; Olival et al., 2022). Compared to conventional pastures, silvopastoral systems maintain greater vegetation cover, which increases humidity and shade, maintains cooler temperatures, enhances soil microbial activity, promotes nutrient retention, and sustains cattle-friendly microclimates (de Almeida et al., 2019; de Azevedo et al., 2010; Parron et al., 2019). These conditions improve soil fertility, raise productivity, and reduce costly inputs like fertilizers (Chará et al., 2019; de Andrade et al., 2012; Dias-Filho, 2023; Wilson & Lovell, 2016). Biodiversity sustained by silvopastoral systems also enhances landscape connectivity and gene flow among native trees, increasing resilience to climate change (Breed et al., 2011; Peri et al., 2016).

We advance this literature by addressing the underexamined question of "what factors facilitate and limit the implementation of silvopastoral systems in socio-cultural contexts that largely favor conventional agricultural practices?" In many rural Amazonian communities, cultural norms value the flat homogeneity of conventional pastures, while native vegetation growing among grass is viewed as a sign of laziness that has resulted in an "unkept" property. Similarly, maintaining good personal ties with agribusiness companies' representatives and government officials who supply standardized agricultural "solutions" is often considered essential to the economic survival of rural operations. In contrast, silvopastoral system initiatives facilitate alternative understandings of native ecological conditions as supporting the economic activities of families as well as the notion that rural communities can themselves be the source of knowledge on which livestock operations can be based (Altieri, 2019; Canuto et al., 2013).

Working with family farmers who have taken part in projects supporting the implementation of silvopastoral systems, we ask three questions:

1. How did family farmers come to view pasture monocultures as a viable livestock practice?
2. What, in contrast, led farmers to question conventional agricultural practices?
3. What benefits do innovative silvopastoral strategies offer, and to what extent do farmers believe these systems could become their main source of income?

These questions illuminate socio-cultural aspects of alternative livestock methods that could play a role in the urgent task of transforming dominant food systems in response to the climate emergency (Intergovernmental Panel on Climate Change [IPCC], 2023). Succeeding in this task requires a better understanding of economic or ecological issues and also a deeper insight into enabling shifts in cultural perceptions and social relations (Mackay-Smith et al., 2025).

## Research Context

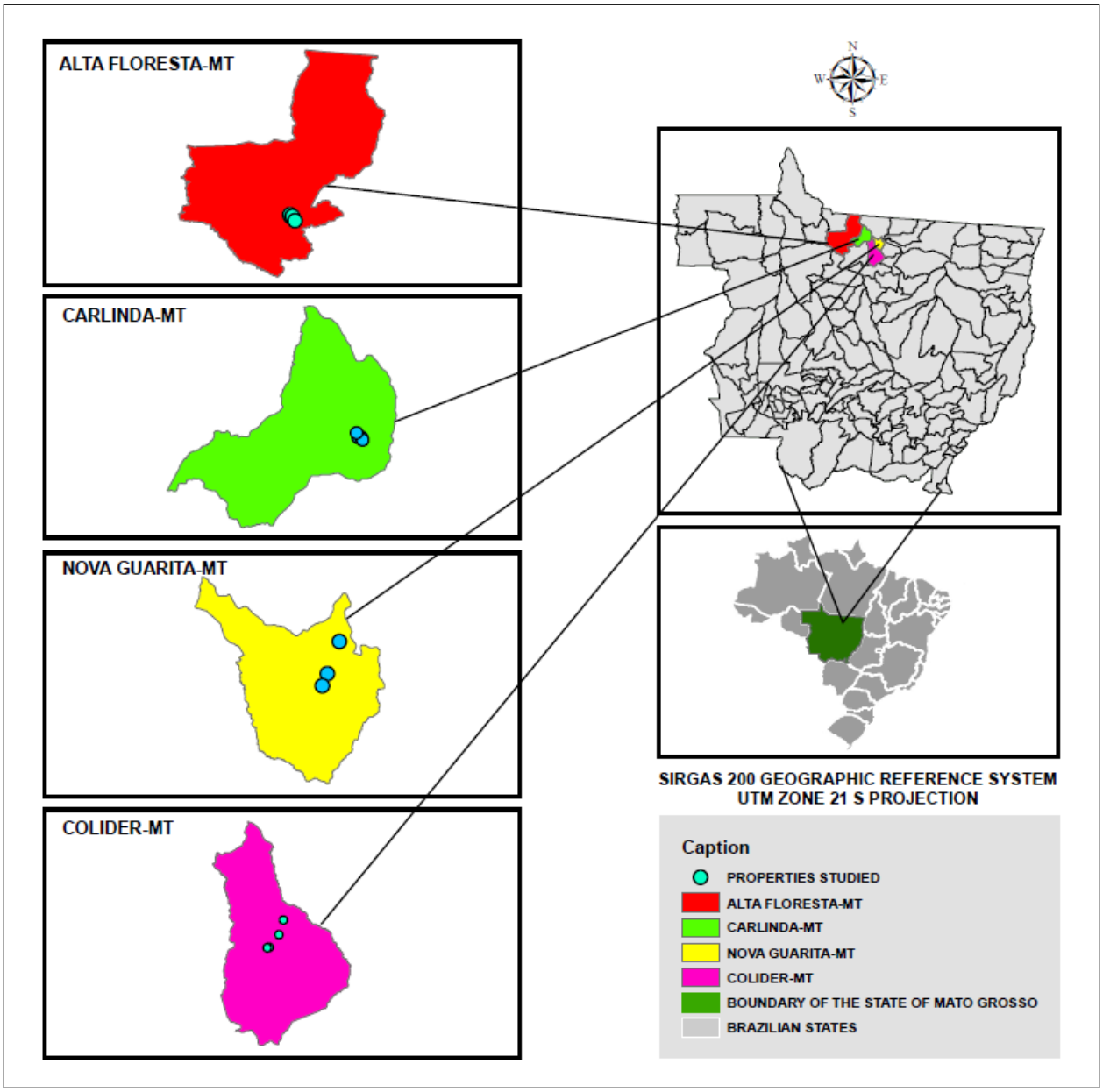
Our research draws on in-depth, semi-structured interviews conducted with 17 family farmers living in four municipalities (Figure 1) that were established through colonization efforts carried out by Brazil's military government beginning in the late 1960s. As documented by the National Truth Commission's investigations (2012–2014) into human rights violations under the dictatorship that ran Brazil from 1964 to 1985, these colonization projects entailed widespread violence against Indigenous peoples (Torelly, 2018). Military units tasked with opening highways across Amazonia frequently used force to displace Indigenous groups, thereby facilitating the transfer of their lands to private companies responsible for founding new agricultural settlements (Telo et al., 2021). Gold miners, loggers, farmers and ranchers were similarly implicated in processes of displacement and dispossession that remain underexamined despite ongoing efforts by Indigenous organizations to document them (Trinidad & Faria, 2025). Today, more than 95% of the population in the cities in the region self-identifies as non-Indigenous, and the overwhelming majority have no contact whatsoever with Indigenous peoples living in territories located in areas that colonization companies deemed too remote or economically unviable (Instituto Brasileiro de Geografia e Estatística, 2025).

The agricultural counterpart to the anti-Indigenous violence was a set of state programs promoting the expansion of monocultures. In the 1970s, government institutions began supporting the replacement of native Amazonian vegetation with permanent crop monocultures such as cocoa, guaraná, and coffee. These efforts were part of a broader national development model in which Amazonia was envisioned as a supplier of cheap agricultural commodities to meet the growing demand of an expanding urban population in southern Brazil (Bunker, 1988). Unexpected difficulties in producing and transporting these crops led to a second wave of rural development beginning in the 1990s, centered on cattle ranching. The government actively encouraged this shift through credit lines and agronomic research focused on pastures and cattle breeds suited to Amazonian conditions (Hoelle, 2015). More recently, the region has witnessed the spread of large, capital-intensive soybean plantations oriented primarily

toward European and East Asian markets (de Oliveira & de Souza e Silva, 2021).

All 17 families in our study are non-Indigenous, part of an impoverished rural population whose labor fueled successive waves of development in Amazonia after they migrated from other regions of Brazil (Hecht et al., 2024). Encouraged by state institutions seeking to defuse growing land inequality in traditional agricultural zones without pursuing land redistribution, these families were promised the chance to claim land in the Amazon if they could demonstrate "active possession"—a requirement that effectively meant clearing native vegetation to establish monocultures (Neto, 2021).

**Figure 1. Map of the Municipalities in Which the Research Was Conducted**




Note: The authors created this map using ArcGIS Tools with administrative layers adopted from the Brazilian Institute of Geography and Statistics (IBGE), Malha Municipal Digital, SIRGAS 2000 coordinate system (https://www.ibge.gov.br/en/geosciences/territorial-organization/territorial-meshes.html)

The smallholder development programs our interlocutors encountered created top-down flows of agronomic knowledge, directing them to purchase standardized "packages" of seeds, chemicals, and tools from large agribusiness. The livestock farming approaches promoted provide small landholders with some cash flow but rarely lift them out of poverty (Hoelle, 2015). This approach poses problems for the eight families in our study living in *assentamentos*—settlements officially designated by the federal government for smallholder farming. Unlike large ranches and farms near urban centers that benefit from good soils, infrastructure, and market access, *assentamentos* often have degraded soils and poor transportation that hinder both production and commercialization. These conditions further reduce the already slim revenue margins of conventional agricultural strategies. Our research involves populations struggling with rural development strategies which are not designed for small landholders' needs and make them dependent on externally designed agricultural techniques.

## Positionality

The five authors of this paper are moved by a shared interest in applied academic research to support grassroots efforts to advance rural development approaches that meet the needs of poor families left behind by traditional models of agricultural growth. We have carried out this work from different positionalities. Three of us are Brazilian, all born in Southern Brazil but with a long experience in Amazonia after arriving in the late 1970s (Weihs) and early 2000s (Olival and Sodre). The other two authors are foreigners but with considerable experience in the region, with one (Rojas) working there since 2009 and the other (Petersen) since 2020. With these varied trajectories, we have all established collaborative relations with the Instituto Ouro Verde (IOV), an NGO that has worked in Amazonia since 2004 supporting the adoption of agroecological strategies among family farmers. None of us, however, is employed by this organization. In 2015, the IOV began supporting silvopastoral system methods among family farmers; in 2023, Sodre began a master's research project under the supervision of Olival and with advice from Weihs.

This article grew out of master's research which we built upon following Bendfeldt et al.'s (2021) insights regarding the need for "engaged" and "generative" research that supports farmer knowledge rather than technocratic agendas that may be at odds with community needs. Although the IOV was instrumental in introducing us to the 17 families included in this study, the data collection and analysis was carried out by us independently of the IOV. While Weihs conducted the data collection, all of us were involved in data analysis. Moreover, our goal is not to identify "best practices" that may be monetized as part of a ready-made agricultural solution some institution could sell. Rather, ours is an effort to co-produce knowledge alongside family farmers by illuminating the conditions under which communities respond to rural problems by creating new applied knowledge based on their specific conditions and needs (Blay-Palmer et al., 2016). Crucially, this approach entails a critical analysis of current silvopastoral system programs, which highlights the limits of IOV's actions.

## Applied Research Methods

This section describes the research methods used in the study for data collection and analysis.

### *Conceptualization, Recruitment of Research Participants, and Data Collection*

Our exploratory case study (see Yin, 2009) began at a 2022 meeting attended by one of the authors alongside IOV technicians and the smallholder families collaborating with IOV. Silvopastoral efforts were discussed at this event as responses to pressing economic and ecological challenges. Participants also expressed strong interest in learning from one another's experiences and in understanding what they had collectively achieved through their experiments to date. Recognizing both the relevance of these practices and farmers' willingness to engage in research that could illuminate the outcomes of their efforts, we developed an interview script that included questions about each family's trajectory in the region (e.g., year of arrival, initial land conditions) and the current situation of their family and property (e.g., household composition, main income sources, land area). Rather than

testing a hypothesis about why families adopted silvopastoral systems, our exploration approach aimed to create conditions for open-ended dialogue in which smallholders' reflections would guide our understanding of their motivations and practices.

After obtaining approval from the research ethics committee, we piloted an initial version of the interview script with farmers of similar socioeconomic profiles who were not included in the final study. We then revised the script to facilitate meaningful exchanges capable of illuminating silvopastoral systems from the perspective of those establishing and maintaining them. We identified 17 families to participate, selecting them based on (1) having implemented silvopastoral systems since at least 2019, (2) their stated interest in joining the study, and (3) the relative proximity of their sites to urban centers, which facilitated travel. Participating families had relatively small properties (compared to regional and national farm sizes) and small households of two to four members.

Interviews were conducted at participants' sites, which are located in areas characterized by high deforestation rates. Each interview lasted between one and two hours and involved the household members most actively engaged in establishing and managing silvopastoral systems. The participants included five women and 12 men, aged 34 to 67. To protect confidentiality, we identify them as E1 through E17. Interviews were audio-recorded and often evolved into open-ended conversations in which participants described their biodiverse agricultural strategies within the broader context of their efforts to work the land.

### *Data Analysis*

Following transcription, we manually coded the interviews, identifying emergent themes using an inductive approach inspired by Bogdan and Biklen's (1994) understanding of human knowledge as a multifaceted assemblage of ideas and experiences that intersect, diverge, and take shape through practice. This approach allowed us to trace patterns in how smallholders understood silvopastoral systems, the challenges they faced, and the kinds of ecological knowledge generated through their experimental livestock practices. Following the coding process, all authors collaboratively reviewed the initial codes and refined the themes that emerged from farmers' accounts of their knowledge and experiences with both conventional agriculture approaches and silvopastoral systems.

## Results and Discussion

We identified six interrelated themes that illuminate the socio-ecological conditions shaping the adoption, implementation, and perceived outcomes of silvopastoral practices. These themes consist of:

1. Culturally dominant views of the relationship between agricultural practices and Amazonian ecologies.
2. Farmers' experiences of ecological problems associated with conventional agriculture.
3. The role of community relations in sustaining traditional farming practices and enabling alternative approaches such as silvopastoral systems.
4. Relationships between farmers and technicians involved in supporting silvopastoral system implementation.
5. Emerging understandings of Amazonian ecologies and the key insights farmers gained through their work establishing silvopastoral systems.
6. Perceived limits and constraints of innovative silvopastoral agricultural methods.

These themes collectively offer insight into how long-standing agricultural practices become entrenched, even when they produce deleterious socio-ecological outcomes, and how situated practices and collaborations can open possibilities for rethinking and transforming human–environment relations. In the sections that follow, we examine each theme in detail, showing how farmers articulate the challenges and potentials of silvopastoral systems within the broader political-ecological context of Amazonian cattle ranching.

### *The Culturally Dominant View*

Assessing silvopastoral system implementation among small landholders requires understanding how the economic and social conditions of their

arrival in Amazonia produced practices and ideas that framed local ecological conditions as problems to overcome. Our interviews with the family farmers illuminate how arriving as workers who cleared forests and managed monocultures led them to embrace conventional agricultural approaches. Crucially, pressure to establish monocultures often emerged through informal conversations and everyday interactions.

One participant described arriving in Amazonia during the 1980s as monoculture farming expanded and how the dominant views of the forest as an obstacle became normalized for him. "Before we had our own land, we lived our whole lives in the middle of [a large monoculture] farm [that was owned by landed elites]," he said. This system limited his opportunities to learn about local ecology, while witnessing fortunes made from monoculture landscapes created associations between prosperity and forest removal. "We [in our family] thought that the important thing was for the pasture to be clean [without any native vegetation], we didn't have that notion [that native vegetation could support economic endeavors]" (E17).

Beyond describing monocultures as economically desirable, interviewees revealed a context where alternatives to dominant thinking were scarce. One participant explained how, arriving as a worker in the 1980s, he helped create landscapes with no apparent room for anything beyond monoculture. "I worked a lot on farms cutting forests at the time [in the 1980s], cutting with an axe and everything," he said, describing crews who moved deep into forests, spending weeks or months in isolation cutting and burning native vegetation without heavy machinery. He repeated this work across the region, experiencing the construction of landscapes that excluded other ways of engaging land. "I moved to one part of this region [cutting the forest for landholders who were claiming territory]. Then [after that work ended] I moved to another area [doing the same thing for someone else]. There was nowhere to go [as the years went by and more of the forest was cut]" (E1). Thus, the dominance of monoculture-based agriculture not only determined how workers could claim land and seek to generate an income but restricted alternative engagements with native ecologies.

In this historical context, a monoculture society emerged not from direct state coercion but primarily through implicit cultural notions reinforced by everyday interactions. "When we arrived here [at our site], even the ideas [about deforestation] were different," one participant explained. "We tried to clean all native vegetation up to the edge of the stream [running through our property], cleaning all of it, nobody explained anything to us [regarding forest conservation]. We had a notion of keeping things clean, of cleaning it up" (E6). Another described similar ideas circulating through daily conversations: "A lot of people would say, 'you cannot leave shades [of trees] in the pastures because it will ruin your grass.' That was our outlook. If we had two shades [from two trees] we would cut one [tree] to protect the grass." Coming from other Brazilian regions and with little contact with native populations these families followed common-sense assumptions that produced uniform landscapes.

### *Experiences of Ecological Problems Arising from Conventional Agricultural Activities*

While socio-economic and cultural conditions promoted negative views of native forests while making monocultures seem desirable, over the years family farmers also recognized mounting ecological problems from conventional agricultural methods. Initially, Amazonian forests may have seemed like an all-powerful environment requiring hard struggle to build roads, farms, and cities. Yet over time, farmers witnessed how human activities undermined ecological conditions, developing increasingly complex views of economic impacts that created fertile ground for silvopastoral system proposals.

Nutrient cycling emerged as one ecological problem apparent to family farmers. As one interviewee explained, "back then [when state-supported agricultural development projects arrived in the region, the forest] produced its own livelihood, and today it does not" (E10). His comments refer to a key ecological feature: dense forest vegetation creates thick layers of decomposing leaves and branches that further nutrient cycling. While newly established pastures can still benefit

from remaining soil nutrients and ash from burned trees, the absence of vegetation leads to soils inexorably losing their fertility.

Family farmers described this as an ecology that was increasingly unable to sustain cattle. "The land no longer responds as it used to," an interviewee (E10) explained, noting that "back then [in the months and years following the cutting of the forests] it seemed that the soil was stronger." Over time, pastures weakened, making feeding the same cattle numbers increasingly difficult. "Today the soil is weak … it is not responding as it should," he concluded. Rather than the promised predictable outcomes, standardized agricultural methods were seen to lead to unexpected problems. And in response to these, state and agribusiness technicians offered only another pre-made response (fertilizing and tilling), but these costly methods remained unaffordable for most family farmers.

As conventional rural development models failed both to prevent ecological problems and to offer viable solutions, farmers became increasingly open to changing their approaches. "Today it is changing," a participant said referring to shifting ecological conditions, "and we need to adapt our practices to keep up with these changes," he concluded (E10). In agreement with these ideas, another interviewee recounted how "we saw that it [conventional agriculture] was not working … and when the grass became less plentiful, everything [including the milk from their cattle] ran out. We wanted to change [our agricultural methods due to these problems] and we did" (E13). Here soil nutrient depletion is more than a technical problem; this raises questions about a conventional development model whose methods lack answers to key challenges. In this situation, as we will see in the next section, farmers became more open to trusting knowledge and land-engagement strategies generated by themselves and other farmers.

### *Building Interest in Alternative Livestock-Rearing Approaches Through Community Networks*

Our interlocutors often described how although silvopastoral systems were at odds with dominant understandings, they were in line with some practices they had developed through years of working on the land. "We used to let some of the small trees we found in the pasture keep growing so they could provide shade," one participant explained. "Over time, the little tree would grow into a full tree, and when we worked in that area, we could enjoy the shade" (E10). Another mentioned that "from the beginning when we cleared the forest, we left some trees standing, because we saw that was good for us" (E11). Despite monocultures being promoted as economically desirable and discussed as the "right" way to do things, some people created desirable work conditions (humid, colder, shaded areas) by engaging with native vegetation.

Even when families saw such creative actions as improving their lives, believing they could generate alternative livestock strategies using their own knowledge remained difficult. This became possible only in the context of community networks that hosted meetings, workshops, and field days through which families came together to discuss the challenges they faced at their sites, and early silvopastoral system adopters shared their experiences. The process made it possible to develop trust in people whose actions contradicted established common-sense knowledge. "I had never seen how [silvopastoral systems that combine native vegetation and grass in the same area] worked. I had never seen or heard of it. [At first] I didn't believe in it" (E8). What ultimately convinced him was not abstract knowledge about silvopastoral systems' technical or economic aspects, but witnessing people like him accomplishing things at their sites. "But [despite not believing in silvopastoral systems,] I said, I'm going to take part [in the meetings of this project]," this participant added, "I am not going to [establish my own silvopastoral systems area] this year, but I'm going to take part [in] meetings, to see how things work [in other sites where silvopastoral systems are being established]" (E8).

Besides meetings, silvopastoral system adoption was encouraged through visits to sites where families were creating places that looked and felt different. "And then [in the context of community interactions] we learned about a project [on the land of a family participating in grassroots interactions] that had shade [trees in the pastures]. We

went there, [to this farmer's site, and] we saw not only the importance of trees for the animals, but for the grass itself" (E17). The interview data showed how our interviewee, who had previously seen trees mainly as sources of shade, came to recognize their role in improving nutrient cycling, retaining humidity, and sustaining healthier pastures. The visit broadened his ecological perspective, revealing ecological conditions that could be improved to the benefit of humans and nonhumans alike.

The community networks that hosted silvopastoral systems meetings and field trips represented the culmination of a decades-long process. When eight of our participating families arrived in this region, they settled in public areas without authorization, and petitioned state authorities for land-tenure recognition with other landless families. These collective actions and mutual support networks are not rare in the first years of settlement, but they seldom last. Isolated family farms are located among large conventional agricultural areas, and families tend to prioritize relationships with landed elites—who control credit, seeds, and chemicals—over connections with local family farmers. Against this trend, families participating in our research preserved solidarity networks beyond initial land claims. The IOV has supported these efforts since 2003, helping communities increase family incomes through collective undertakings such as craft-making initiatives, community markets, reforestation, and silvopastoral system strategies. Community members direct these initiatives through a general council comprising representatives from smaller local councils gathering families in each locality. These meetings have enabled families to cultivate the mutual trust necessary to value their work despite contradicting mainstream cultural norms.

### *Solidarity Networks and Participatory Knowledge-Making*

It may seem unusual that an article about NGO-supported silvopastoral systems efforts principally addresses the NGO's role only at this point in the argument. This reflects the fact that the most decisive factor in the adoption of silvopastoral systems was arguably not external intervention, but the decades of solidarity-building among family farmers themselves. These networks provided the trust necessary to collaborate and challenge entrenched cultural and economic approaches to agriculture. Moreover, silvopastoral system initiatives did not emerge from NGO staff acting as authoritative sources of technical knowledge; rather, silvopastoral system efforts created spaces for farmers to use their community networks to generate knowledge through experimentation and to share results with peers. As noted in the introduction, establishing silvopastoral systems is an iterative process requiring permanent, close attention to local conditions—something only resident farmers can sustain.

One interviewee emphasized that this approach depended on long-term collaboration between NGO staff and farmers: "[IOV staff] were involved in our efforts to claim our sites since the time [when we established a landless peasant encampment] by the side of the road" (E15). Support in their struggle for the land was the starting point, making clear that the NGO's goals were not narrowly environmental but aimed at building livable environments for humans and nonhumans alike. The next step was helping families make a living on their reclaimed land. "I did not have any idea of what to do [in my new site once we succeeded in claiming our land]," the same participant recalled, "because the only thing we had [in the land that became ours] were weeds growing on depleted soils. Then we started to take part in IOV projects, [we] started learning to reforest, to establish silvopastoral areas, all the things we have learned since [those early days]" (E15). From this perspective, silvopastoral system implementation is meaningful only as part of a broader undertaking to develop communal strategies that may enable dispossessed farmers to remain on the land.

These learning processes were grounded in an institutional structure rooted in local populations. All IOV's staff live in the Amazon, and most of its technicians are young and from smallholder farming families. This staffing model fosters expectations on both sides that initiatives such as silvopastoral systems will be carried out through dialogue and horizontal interaction. As one interviewee put it, "We sought knowledge from [IOV

staff] … knowing we had to work in partnership, we tried to give our best, you know, to make it happen, for the project to get to where it is today" (E2). Crucially, for this farmer the project stems from their seeking knowledge and rests on their own hard work, rather than responding and being solely advanced by an external organization.

A sense of farmer ownership was cultivated through knowledge-sharing activities such as organizing visits for groups of six to 20 people to sites where other farmers presented their work, including both challenges and successes. One participant recalled: "I always cut [all native vegetation] but then I started seeing these [silvopastoral system] projects [established by other farmers], and the person would explain how trees offer shade to milk cows who dislike being in the sun constantly" (E5). Seeing innovative sites and hearing directly from his peers about improvements in milk production from shaded pastures encouraged him to let native trees grow and to plant new ones, understanding how they would have positive effects on his herd.

This grassroots approach was dialogical in the sense that knowledge-sharing continued through the implementation stage. As a farmer put it, "It was good to see [sites in which silvopastoral systems were already implemented], it was good because there was that meeting, that chat, that conversation while you were planting [native species in your own pastures]; [while you worked] dividing [your own] pastures [into segments that enabled controlled grazing]; [while you were] planting the trees. It was nice [to have those constant interactions], it was really good" (E3). In this way, farmers and IOV staff enacted a strategy that echoes Freire's (1983) conception of technicians as facilitators who support personal learning processes through which people and communities open themselves to, and generate, new knowledge.

### *Silvopastoral Lessons Learned*

According to Freire's (2005) principles of dialogical education, exchanges between groups such as family farmers and technicians may not only strengthen local knowledge but also generate critical reflection and actions necessary to transform their reality. In this case, such dialogue helped reframe family farms as living laboratories, where farmers engaged in cycles of action and reflection by systematically assessing the diverse outcomes of their interventions in local conditions. The knowledge produced was not limited to technical understandings, such as nutrient cycling or pasture productivity, but also encompassed a subtler, equally transformative capacity: cultivating the observational skills and caring routines required to engage with local ecologies in attentive, responsive ways. These habits of perception and care were themselves forms of praxis, shaping how farmers related to the land and to the broader socio-ecological systems they inhabited.

These relationships between practice and knowledge emerge vividly in families' accounts of the insights they gained through silvopastoral system initiatives. One interviewee, whose profit-maximizing approach had once led him to cut native vegetation despite personally preferring shade trees, was pleased to conclude that "the first thing that [his silvopastoral systems] improves is the soil. Because where you plant a tree, it makes fertilizer for [the pasture]" (E11). Crucially, as he explained, if the tree "makes fertilizer," it is due to the farmer's careful engagement: "Right here, I have to trim this tree … and then leave [the branches and leaves] at its base, and this results in this beautiful thing—fertilizer made by the tree [clippings]" (E11). The lesson here is not only that clippings can enhance nutrient cycling, but that his particular farm benefits when he invests time and attention in the needs of specific trees there: trimming them at the right moment and finding creative uses for the resulting material. A similar point was made by another participant who recalled that in the past, "any little tree I saw in the pasture I would eliminate," but "now I pay attention to trees [that grow in the pasture and] that [I think may] provide something [for my site], [trees that have] a good size, and I don't cut them down anymore" (E5).

Later in the interview, he explained that such attention had yielded tangible results: "[My silvopastoral systems] certainly improved [agricultural conditions at this site] a lot," he noted. "It improved the [health of] pastures, [so now the grass can] support more [cattle grazing, even] in the

drought. [My silvopastoral systems] even increase milk production" (E5). Much of this learning emerged through trial and error. One participant, for example, recounted planting several trees in close proximity when first establishing his silvopastoral systems. "So I would do this [in the future]," he said, "I would carry out a more limited [intervention] just to protect the trees. I say that trees in the pasture are fine—just not so close to each other" (E6). Only with time, he began to understand rates of growth, canopy size, the effects trees have on one another, and the site-specific conditions best suited to each species—transforming his farm into an experimental ground. Similarly, another interviewee reflected on species selection: "I would not plant *amarelinho*. I would try [planting] *amoreira* [instead], and would plant some additional *pente de macaco*, which I can do because those that I already planted will fruit this year" (E12). The knowledge emerging here extends beyond pastures or individual tree species, reflecting a deliberate, ongoing engagement with local ecological complexity as part of the everyday work of livestock farming.

From the perspective of farmers, the lessons learned were not limited to the information available on establishing forest in pastures having a range of positive impacts on nutrient cycling and biodiversity, water streams and agricultural productivity (Chará et al., 2011; de Almeida et al., 2019; Olival et al., 2021). It also included lessons regarding the kind of practices that can be relied on to build a family farm site. The notion that what is essential in a farm is access to the kinds of tools and technologies that landed elites can provide gives way to the understanding that there are several other resources available to family farmers: attentive observation to spaces composed of complex ecological relations, conversations with neighbors who share their experiences and insightful observations, and careful engagements with plants, animals and soils.

### *Limits to Silvopastoral Innovation*

By illuminating ways of transforming farm sites, silvopastoral systems' practice-based learning approach not only revealed new ways to shape the material reality of family farmers but also illuminated clear limits to what they could accomplish through such programs. The vast majority of our interviewees appreciated the outcomes of their silvopastoral systems work, with 15 of 17 participants evaluating the areas they established positively. However, they still saw significant challenges they would need to overcome to reach the economic conditions they desired. As family farmers, they confronted challenges exceeding silvopastoral system efforts' reach—complex long-term socio-ecological problems related to unequal land tenure systems and highly exclusionary models for rural development. Family farmers also understood the difficulty of relying on silvopastoral systems as their main agricultural strategy due to labor conditions and ecological obstacles.

These ecological obstacles proved particularly formidable in degraded landscapes. In the previous section we highlighted possibilities for ecological restoration that families found through observation and experimentation, but they also encountered significant hurdles. "The ants attack [destroying tree stems]," one participant recounted. "They attack too much and so it's difficult because we're struggling there, we are planting trees every year, but they [are] not growing because the ants eat the stems" (E1). His story alluded to the absence of native vegetation in monoculture areas leading to extreme food scarcity for insects that seek nourishment from any introduced tree. Hundreds of trees and days of hard work can be lost in a few days under such conditions. Preventative control measures are fundamental to system success, such as choosing tree species adapted to local conditions that are fast-growing, working with high species diversity, using healthy, good quality seedlings, planting at the beginning of the rainy season, with periodic crowning practices and mulch protection (de Castro & Pacciulo, 2006).

Another limiting factor inherited from the recent history of these areas concerns logistical problems in impoverished rural areas. As mentioned above, family farmers often live in areas removed from urban centers with limited infrastructure which means logistical challenges to delivery of key materials such as wood and wire for fencing. For families to be able to work with these materials they have to be available at the right

moment, when the rainy season can benefit the trees, and the grass is not too high so that it hampers the construction of fences. But such timing is complicated by silvopastoral system programs having to reach dozens of families, some of which are hundreds of miles away from one another. One farmer alluded to the issue when he noted that "in the future [the distribution of] things [needs] to be more organized so that it happens sooner. When I received the wire [for fencing], my grass was already grown, I almost died" (E9). The very vivid terms in which the impacts of logistical problems are described illuminates how farmers are working under great pressure under a tight schedule and with very limited resources.

Silvopastoral system strategies are valuable given that they provide alternatives to fertilization, for example, but this comes at the cost of additional investments in time and attention. More complex than monoculture grass pastures, these biodiverse strategies require more planning, constant decision-making, and greater availability of labor and infrastructure (Dias-Filho, 2006). Systematic observation of cattle-tree interactions, constant surveillance of shifting ecological conditions, and time devoted to trimming may seem like minor expenses, but they add to an already heavy workload for the family unit. As one farmer expressed, "the problem with these trees [growing in the pastures] is [that we need to work constantly] trimming them up, maintaining them … that's the hardest thing. It's a lot of work, because you have to keep that area clean" (E4). These hardships are inherent to building complex systems that require specific management practices, which imply costs and constant, skilled labor. Farmers must rethink how they organize and allocate their time to the various activities on their properties, accounting for the seasonality of activities and income sources.

What our interlocutors learned regarding the factors limiting the adoption of silvopastoral systems in regions of the Brazilian Amazon is constrained by several intersecting factors: the need for specialized labor and infrastructure, the absence of local traditions or prior experience with such innovative methods, and the broader trend of declining labor availability in family farming (Canuto, 2013; Dias-Filho, 2006; Olival et al., 2021). These constraints are particularly acute in the initial years, when degraded environments demand intensive management to restore ecological health. At this stage, the systems require frequent interventions—monitoring pasture and tree growth, implementing pest control, and carrying out maintenance—all of which call for sustained, skilled labor. For some, these demands pose significant barriers. Older farmers, or those unfamiliar with the principles of integrated pasture-forestry management, often find it difficult to adapt, particularly when such work must be incorporated into already demanding agricultural schedules and diversified livelihood strategies.

The adoption of this type of system in regions of the Brazilian Amazon faces challenges, such as the need for specialized labor and investment in infrastructure, combined with the lack of tradition and experience with innovative farming practices and the increasing shortage of labor in family farming establishments (Canuto et al., 2013; Dias-Filho, 2006; Olival et al., 2021). These challenges are particularly critical in the initial years of the systems, given the high level of environmental imbalance and the need for more intensive labor actions, especially for those who are of advanced age or have difficulty understanding the new principles of pasture and forestry management.

## Conclusions

This research examined factors supporting and constraining silvopastoral system adoption in the Brazilian Amazon. Six themes emerged from the analysis of our interviews with smallholders: the cultural dominance of monoculture agriculture; experiences of ecological problems from conventional agriculture; alternative, community-based agricultural approaches; farmer-technician relationships supporting implementation; emerging farmers' views and insights on silvopastoral systems; and the limits of biodiverse livestock farming efforts. Drawing on our interlocutors' experiences and insights on these themes, we make four main assertions regarding dominant agricultural approaches and the conditions that facilitate their implementation.

First, historical and cultural conditions can lead small landholder populations to adopt monoculture

strategies despite the profound ecological and economic problems these generate. Small landholders' early experiences in Amazonia, often as laborers clearing forests and working in expanding monoculture operations, shaped a dominant view of native ecologies as hindrances. Everyday interactions reinforced these assumptions, naturalizing the idea that prosperity required "clean" pastures and the removal of trees, while leaving little space for alternative practices or ecological knowledge. As a result, many families arrived at their own properties predisposed to replicate monoculture landscapes.

Second, community networks and NGO interventions (such as those of IOV) built on Freirian models (2005) successfully encouraged small-scale family farmers to take leadership roles in the process of integrating trees with pasture in their livestock farming practices. Such a participatory approach was rooted in long-term relationships between communities and NGO staff that led to the generation of new, site-specific ecological knowledge, with smallholders willing to contribute to efforts which they saw as designed to meet their own needs and concerns. Such knowledge proved transformative when it emerged from dense community networks and a dialogical learning process rooted in farmers' active participation.

Third, these grassroots undertakings resulted in novel practices that led to better socio-ecological and economic outcomes for both farmers and the environment. When farmers are active members of NGO-supported socio-technical networks, they develop new forms of decision-making attuned to local ecological conditions and seasonal variations. Likewise, families incorporated into their work schedules agroecological and agroforestry practices that realized the multifunctionality of trees in improving economic and ecological conditions. These practical skills were grounded in farmers gaining a new perspective on their properties' ecological conditions insofar as the labor of integrating trees, pastures, and animals in the same areas created spaces and moments of reflection and ecological appreciation. Families gradually came to value ecological elements previously considered undesirable, recognizing the importance of native species and local natural resources for maintaining their production systems.

Fourth, the study identified practical agronomic and ecological barriers to silvopastoral system establishment. Farmers valued the ecological and economic potential of silvopastoral systems, yet they also emphasized the challenges imposed by the conditions needed for these systems to be productive, including labor constraints, degraded soils, and logistical complications in remote rural areas. Additional difficulties included pest pressures, precise planning, and the intensive management required in silvopastoral systems' early years. Overall, our interlocutors underscored how despite strong appreciation for silvopastoral outcomes, adoption remained constrained by structural factors tied to land degradation, rural precarity, and the absence of local traditions supporting integrated livestock-tree systems.

### *Recommendations and Implications*

Silvopastoral systems worked well as part of a larger puzzle that included community organizing, political engagement, and continuing ecological work. Our research results provide important insights into the design of public policies aimed at promoting sustainable food production practices that are likely transferable to other locations. It is important for policymakers to consider developing new rural development infrastructure that can offer alternatives to those that have created an agrarian extractive frontier, at great human and ecological cost. Such a task would support both biological *and* cultural diversity, through actions such as instituting local centers for research and knowledge-sharing. These spaces would support the creation of alternative development spaces by training rural extension agents who, embedded in communities, would provide technical support to farmers in developing systems adapted to each specific context. These community networks and knowledge infrastructure additionally could be paired with novel financial mechanisms capable of funding the costs of transitioning from conventional to biodiverse systems (Mier et al., 2018).

The experiences documented in this study demonstrate that alternative rural futures in the Brazilian Amazon are both necessary and possible. Answers to the social and ecological problems posed by dominant rural development approaches,

however, do not come in the form of a quick technocratic fix. They come in the form of participatory encounters involving family farmers, community networks, and NGOs (such as IOV) that enable participants to shift their views of forests as obstacles, to recognizing biodiversity as fundamental to their livelihoods. The profound potential of participatory, community-based efforts to reshape rural development could be further harnessed by larger social and technical infrastructures and policies that could enable participants to create ecologically regenerative and socially just rural landscapes. 

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