

RESEARCH ARTICLE

UN Decade on Ecosystem Restoration



The role of agroforestry in restoring Brazil's Atlantic Forest: Opportunities and challenges for smallholder farmers

Yara Shennan-Farpón^{1,2} | Morena Mills³ | Aline Souza⁴ | Katherine Homewood²

¹ZSL Institute of Zoology, London, UK

²UCL Department of Anthropology, University College London, London, UK

³Faculty of Natural Sciences, Centre for Environmental Policy, Imperial College London, London, UK

⁴IPÊ Instituto de Pesquisas Ecológicas, Rua Ricardo Fogaroli, São Paulo, Brazil

Correspondence

Yara Shennan-Farpón
Email: yara.shennan-farpon.17@ucl.ac.uk

Funding information

Natural Environment Research Council,
Grant/Award Number: NE/L002485/1

Handling Editor: Tobias Plieninger

Abstract

1. Restoring the degraded Atlantic Forest is one of the biggest conservation challenges in Brazil. In a biome with high human presence, understanding the potential for restoration approaches, such as agroforestry, to provide benefits to smallholder farmers and biodiversity is essential in developing equitable restoration strategies.
2. Smallholder or family farmers are essential to national food security, producing most fruit and vegetables consumed in Brazil. Their farms can also provide ecological stepping stones for biodiversity. To better understand their role in Atlantic Forest restoration, this study explores the use of agroforestry by smallholder farmers from the *Movimento Sem Terra* (MST), the Rural Landless Workers' Movement, in Pontal do Paranapanema.
3. We use quantitative and qualitative data to assess farmer perceptions of the measures which support agroforestry farming, barriers to implementation and its impact on indicators of wellbeing. We find agroforestry farmers report significant benefits in 8 of 18 tested indicators. Attitudes to agroforestry are varied, but common themes emerge including the high value of tree cover for shade and cooling effects, and the difficulties in selling agroforestry products. Our results show lack of policy support and initial investment needs are the biggest constraints to agroforestry, but opportunity cost is not considered a large barrier.
4. Tailored policies and financial measures are needed to integrate thousands of smallholder farmers into the Atlantic Forest restoration agenda, helping to reach biome restoration targets while supporting rural livelihoods and national food security. Further research is required into links between additional socio-economic and biogeographical variables and agroforestry uptake in the region.

KEYWORDS

agroforestry, Atlantic Forest, forest landscape restoration (FLR), rural livelihoods, smallholder farmers

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2022 The Authors. *People and Nature* published by John Wiley & Sons Ltd on behalf of British Ecological Society.

1 | INTRODUCTION

Forest landscape restoration (FLR) has become a central part of efforts to combat the ongoing global ecological and climate crises (Holl, 2017a; Suding, 2011) by restoring millions of hectares of degraded and deforested lands. Generally defined as 'the process of regaining ecological functionality and enhancing human wellbeing across deforested or degraded forest landscapes' (Adams et al., 2016; IUCN, 2017), it aims to combine biodiversity conservation with livelihood development goals and is incorporated into many international policy commitments, such as REDD+planning (Verchet et al., 2015), and the Bonn Challenge (IUCN, 2011). Ecological restoration continues to gain momentum and large-scale restoration targets are being mainstreamed into global policy-making (Chazdon et al., 2017; Ota et al., 2020; Strassburg et al., 2020), culminating in the declaration of the UN Decade on Ecosystem Restoration 2021–2030 in 2019 (UN Environment, 2019). But despite many FLR projects referencing the importance of socio-economic development, the effects of landscape restoration approaches on rural livelihoods across the tropics remain under-studied (Adams et al., 2016; Erbaugh et al., 2020; Reed et al., 2017).

The increasing interest in FLR has led various studies to identify global 'restoration hotspots', regions of top priority and ideal conditions for ecological restoration (Brancalion et al., 2019; Potapov et al., 2011; Strassburg et al., 2020). Among these is Brazil's Atlantic Forest, one of Brazil's most degraded biomes (Brancalion et al., 2019; Joly et al., 2014). Thought to have once been one of the largest forests in the Neotropics, covering around 150 million ha (Myers et al., 2000; Ribeiro et al., 2009), centuries of human occupation and deforestation mean native forest remain in 11%–16% of the estimated original range (SOS Mata Atlântica & INPE, 2019). Despite severe degradation and fragmentation (Joly et al., 2014; Ribeiro et al., 2009), it remains a hotspot for endemism and biodiversity (Mittermeier et al., 2005) and provides essential ecosystem services to millions of Brazilians, including water provisioning and climate regulation (Joly et al., 2014; Prist et al., 2021).

The Atlantic Forest is the focus of many international restoration initiatives (IUCN, 2011; WRI, 2016) and is part of Brazil's ambitious national target of restoring 12 million ha of native vegetation by 2030 (National Decree No. 8972, 2017). Despite a strong policy agenda, the potential of forest restoration approaches which improve rural livelihoods for smallholder farmers, such as agroforestry (de Souza et al., 2016), remains poorly understood in the Brazilian context (Miccolis et al., 2019; Sagastuy & Krause, 2019). Agroforestry farming involves creating mixed landscapes where native vegetation is combined with fruit trees, agricultural crops and/or livestock (FAO, 2017). The benefits of restoration through agroforestry in terms of habitat provision and ecosystem services are increasingly apparent (de Souza et al., 2016; Jose, 2012; Uezu et al., 2008). However, a deep understanding of the local context and the socio-political characteristics of the rural population is key to ensuring agroforestry restoration projects can benefit, instead of further disenfranchising, rural people and smallholders. Family

farmers play a vital role in feeding Brazil's growing population, with data suggesting they provide up to 70% of the national food supply (Nolasco et al., 2017; Rocha et al., 2012) mainly from fruit and vegetable production. With an average farm size of 18.4 ha, the latest agricultural census shows 77% of the country's farms are family farms (Graeub et al., 2016; Instituto Brasileiro de Geografia e Estatística - IBGE, 2017). Many of these lie within settlements derived from Brazil's Landless Rural Workers Movement (*Movimento Sem Terra*) (MST), a socio-political mass movement formed mainly of family farmers who occupied land during the 1980s and 90s and campaign for land reform across Brazil (Carter, 2015).

The biome's remaining forests are separated by large agricultural areas, creating barriers to dispersal and threatening the survival of many species (Banks-Leite et al., 2014). Restoration of small forest patches through agroforestry could play a huge role in connecting wildlife populations, providing ecological stepping stones to small mammals, birds and insects (Badari et al., 2020; Matos et al., 2017). Although Brazil's Native Vegetation Protection Law (NVPL) (Law #12,651; 2012) was modified in 2012 to include agroforestry as an accepted method of forest restoration (Miccolis et al., 2019), understanding of the impacts of this type of farming on local livelihoods and rural development remains largely theoretical (Erbaugh & Oldekop, 2018). While some evidence suggests agroforestry can provide additional income opportunities and socio-economic benefits (FAO, 2017; Miccolis et al., 2017), the potential negative consequences of engaging in forest restoration, such as the opportunity cost of lost agricultural land, or financial stress due to initial investment, require further attention. As restoration programmes and strategies are developed to increase forest cover in the Atlantic Forest and meet national and international targets, it is important to ensure that marginalised social groups, such as the MST, are considered and included in these plans, and that potential benefits, challenges and policy needs are explored (Erbaugh et al., 2020).

In this paper, we use the Pontal de Paranapanema region (São Paulo) as a case study to better understand the interaction between MST farming communities and FLR through agroforestry. To do so, we seek to answer the following research questions: (1) Are there differences between how agroforestry farmers and non-agroforestry farmers rate indicators of wellbeing?; (2) What do farmers identify as the main challenges in using agroforestry restoration, and what helps its implementation?; and (3) What are farmer perceptions of restoration using agroforestry within MST settlements?

2 | MATERIALS AND METHODS

2.1 | Study site

2.1.1 | Geography and land use

Pontal do Paranapanema covers nearly 19,000 km² in the State of São Paulo (Southeast Brazil), and is the second poorest region in the State (Chazdon, Cullen, et al., 2020; Figure 2). The landscape is characterised

by extensive agricultural use (mostly monocultures of soybean, sugarcane and cattle farming; Badari et al., 2020), private rural properties, MST settlements and forest fragments (Uezu, 2006; Uezu & Metzger, 2016). Deforestation in the region began with its occupation between 1850 and 1930, a period characterised by violence, land grabbing, extermination of the indigenous population and destruction of the natural environment (Leonidio, 2009). Deforestation peaked in the mid-20th century with land cleared for cattle production and coffee plantations (Leonidio, 2009; de Rezende et al., 2015), leaving almost no native forest outside the 36,000 ha protected Morro do Diabo State Park (MDSP) the second largest area of semi-deciduous tropical forest in the Atlantic Forest biome (Uezu et al., 2008).

2.1.2 | The landless rural workers movement in Pontal do Paranapanema

Pontal do Paranapanema is one of the largest and oldest settlement areas in Brazil (Meszaros, 2007) where the battle for land reform during the 1970s and 1980s put the MST's struggle on the national agenda (Carter, 2015; Meszaros, 2007). 'Landless' rural communities request the right to live and work on abandoned farmlands and vast cattle ranches, owned by a handful of families (Paulino, 2014), by forcibly occupying them, often leading to violent confrontations. Over 5,000 families had settled in landless camps across the region by 1997 (Carter, 2005). In 2020, there were around 120 MST settlements in Pontal do Paranapanema (Chazdon, Cullen, et al., 2020; Mazzini, 2007), 63 within the three municipalities in the study area. MST communities in the region are mostly first or second generation farming families. Many lack historic and traditional agricultural knowledge (Francesconi et al., 2014). Instead, they are a grassroots movement, predominantly dedicated to family farming, but organised by a centralised body of members. MST settlements across the study region vary in size, but some have over 100 families spread across a vast area. Most settlements in the region today are legalised and managed by two government bodies; the São Paulo Land Institute Foundation (Itesp) or the National Institute for Colonization and Agrarian Reform (INCRA).

2.1.3 | Biodiversity value

The Pontal do Paranapanema, region, thought to once be continuous dry tropical forest (Francesconi et al., 2014; Pimenta et al., 1991), is today a highly fragmented landscape characterised by forest patches of 2–2,000 ha (Cullen et al., 2005; Uezu et al., 2008). Forest fragments are important stepping stones and some also serve as wildlife corridors for larger animals such as jaguars *Panthera onca* and tapirs *Tapirus terrestris*. The MDSP is home to one of the last remaining populations of jaguars in the Atlantic Forest, as well as the endangered endemic black lion tamarin *Leontopithecus chrysopygus* (Cullen et al., 2005; Galetti et al., 2013). The importance of these remaining areas of forest is well documented (Banks-Leite et al., 2014;

Matos et al., 2017; Paviolo et al., 2016), as is the need to engage local stakeholders, given most biodiversity conservation plans involve restoration corridors or agroforestry plots (Badari et al., 2020) on private land or MST settlements (Cullen et al., 2005; Francesconi et al., 2014; Metzger et al., 2017).

2.2 | Methodological framework

Building on a 3-week pilot study to the region in February 2019, we undertook semi-structured interviews using a questionnaire (White et al., 2005; SM5) to understand experiences, behaviour and perceptions related to restoration through agroforestry. The pilot study was used to compile initial qualitative contextual data, meet key interlocutors, select study sites, ensure communities were comfortable with the fieldwork and use of data, and secure informal permission to carry out research.

The questionnaire was designed to collect data relevant to the local socio-ecological and agricultural context, documenting household socio-economic indicators, farming activities and ecosystem services deemed to be important for the study region (FAO, 2017; Leakey et al., 2006; Palomo-Campesino et al., 2018; Table S2). Building on a literature review and following discussions with relevant actors during a workshop with MST farmers and local conservation researchers and practitioners (see Supporting Information Section 5; Figure 1), questions were formulated to capture perceived social, economic or ecological benefits of agroforestry which may influence willingness to participate in similar projects in future (FAO, 2017; Harvey et al., 2018). The questionnaire was divided into six areas to answer the three research questions, covering: (i) socio-economic farm characteristics (e.g. household income, employment and education) and land use; (ii) restoration activity and history, and attitudes towards agroforestry restoration; (iii) indicators of wellbeing; (iv) mechanisms which support agroforestry implementation; (v) barriers which prevent agroforestry implementation and (vi) open-ended question to collect qualitative data on farmer perceptions.

2.3 | Questionnaire data collection and sampling design

We conducted 92 household interviews across 13 MST settlements in three municipalities: Euclides da Cunha, Teodoro Sampaio and Mirante do Paranapanema (Figure 2), between September and December 2019. These three municipalities were chosen because all three border the Morro Diabo State Park and present similar potential to influence biodiversity conservation through the creation of biodiversity stepping stones within settlements. The settlement's farming communities within the three municipalities have similar socio-economic status, having been granted land ownership at similar times during the 1990s (Carter, 2015).

In order to ensure representation of agroforestry-practising farms in the sample—essential to the research objectives but greatly

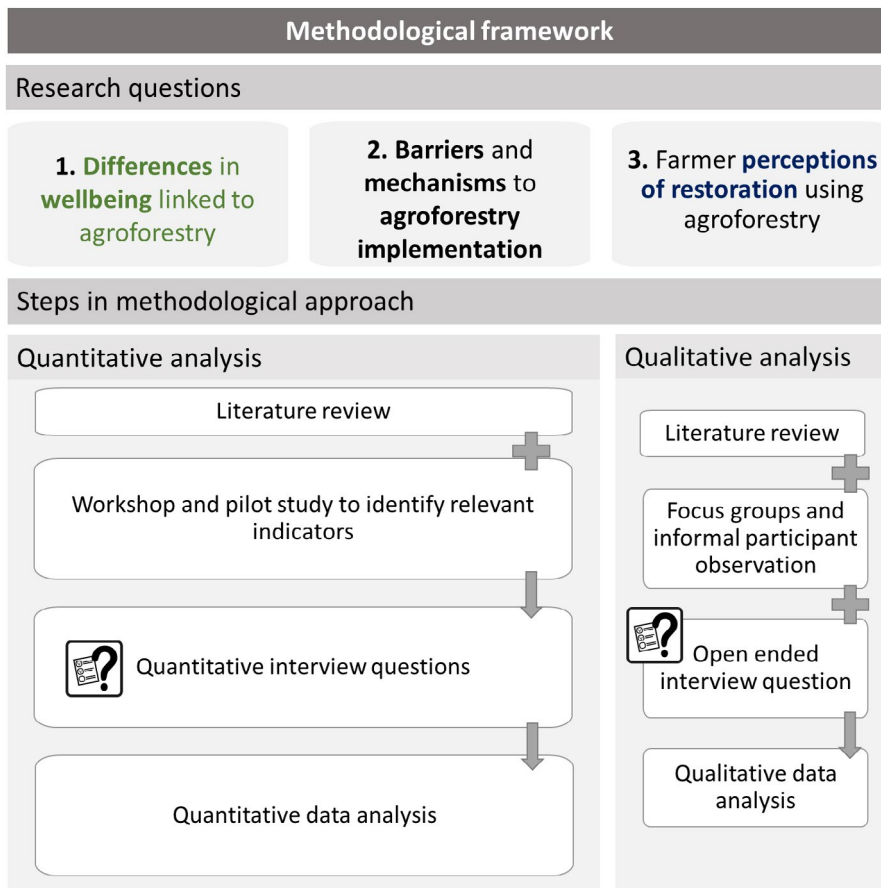


FIGURE 1 Methodological framework showing the three research questions and methodological approach corresponding to each one, mixing quantitative (questions 1 and 2, column 1) and qualitative (question 3, column 2) analyses. Columns in the framework show the activities leading to the choice of indicators and creation of questionnaire. Further information is included in the Supporting Information

under-represented in the population—a mixed sampling approach was used combining purposive sampling with simple random sampling, following a case–control methodology (Bernard, 2006). Case–control sampling involves choosing a purposive sample on the bases of specific criteria, in this case the use of agroforestry, and then matching sampled individuals with households having similar general characteristics (socio-economic conditions, biogeographical variables, social facilities, etc.), but not the chosen criterion (Bernard, 2006; Palinkas et al., 2015). This approach was deemed best suited to the research aims and the characteristics of the population, as it allows both exploratory and comparability analyses between the sub-groups, and across the entire sample population (Palinkas et al., 2015), but it means conclusions cannot be robustly inferred for the wider population, and this must be taken into account when interpreting results. The sample thus comprised two groups: MST farmers using agroforestry as a restoration technique, and MST farmers not using agroforestry, relying instead on conventional agriculture methods (mainly cassava and cattle monocultures using chemical pesticides and/or fertilisers, and not seeking to minimise environmental damage: MMA, 2015). Following FAO definitions (FAO, 2017), farmers were categorised as using agroforestry when they had native trees planted in the same unit as exotic trees (usually for fruit), agricultural crops and/or livestock. Non-agroforestry farmers relied mainly on cattle farming with mixed crops on farms bare of trees.

Based on data of agroforestry use in the settlements obtained from the São Paulo Land Institute Foundation (Fundação Instituto

de Terras do Estado de São Paulo, Itesp), the National Institute for Colonization and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária, INCRA) and local research centre Instituto de Pesquisas Ecológicas (IPÊ), we calculated that on average only 5% of households in study settlements use agroforestry. To create the sampling list, we used the number of known households practicing agroforestry from each MST settlement, interviewing all listed households or, where these represented over 5% of the settlement population, randomly selected agroforestry households up to a capped sample size of 5% of the settlement's population. The same approach was used to randomly select 5% of non-agroforestry households, thus balancing sample size error (Newing, 2010; Bernard, 2006), ensuring equal representation between groups, and available time and resources for fieldwork. This resulted in a total sample size of 92 households, 9.8% of the total sample population ($N = 940$; Table S1): 40 agroforestry farmers (representing 98% of these in the three municipalities) and 52 non-agroforestry households (Table 1). All agroforestry households (representing either the complete sample for the settlement or a randomly selected 5%) agreed to be interviewed, except one case where the household was found empty on two separate visits. Where a chosen non-agroforestry household declined interview, or was not in, the neighbouring household was chosen.

Interviews were performed in Portuguese and lasted between 45 and 90 min. All household data were anonymised, using only house numbers to locate chosen households. All interviews were carried out

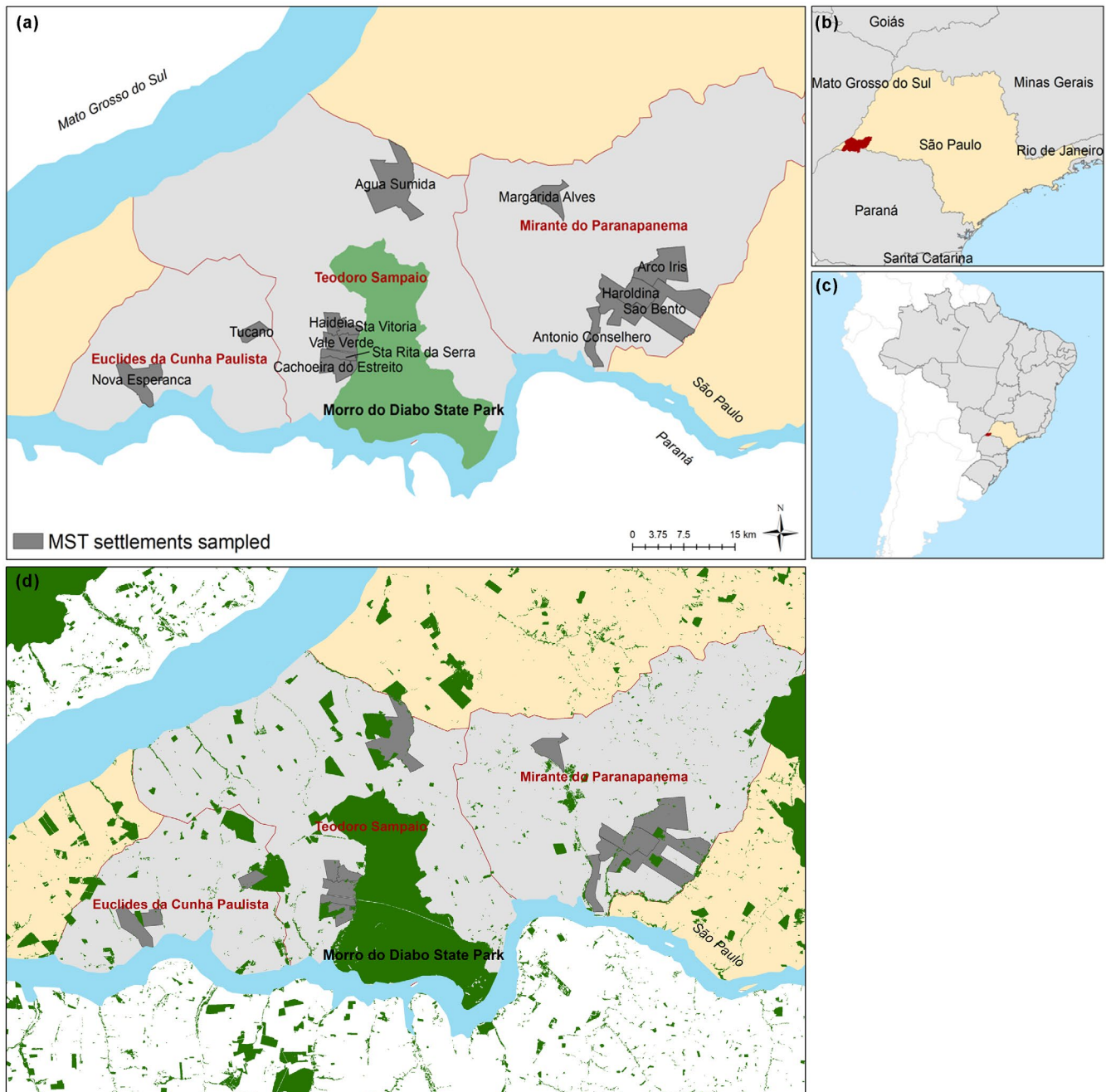


FIGURE 2 Map of study site: three municipalities in Pontal do Paranapanema and the 13 MST settlements where interviews were conducted (a); inset maps showing the location of the study region in São Paulo State (b) South-West Brazil (c); and forest cover fragments in the study region (d) (source: Rezende et al., 2018)

with the self-identified household head. Ethical approval for this work was obtained from the UCL Research Ethics Committee (ID number 15193/001). Prior informed consent was obtained using both verbal and written communication (in Portuguese) with each interviewed participant before the questionnaire was conducted, explaining the reasoning for the research and that all data would be collected, stored and analysed anonymously. All participants were given the option to (a) not participate, (b) stop the questionnaire interview at any point and have the collected interview data deleted and (c) request the collected interview data to be deleted after finalising the interview.

2.4 | Analysis

2.4.1 | Quantitative analysis

To understand differences in perceived wellbeing between the two groups, data were collected through questions based on 18 indicators. In line with the literature on multidimensional wellbeing (Loveridge et al., 2020; Mcgregor et al., 2015; Woodhouse et al., 2015) we defined wellbeing in terms of material, subjective and relational dimensions and developed indicators of each based on

TABLE 1 Sample population and sub-groups within the 13 MST settlements where agroforestry practices have been recorded, across three municipalities

Municipality	Number of MST households in each municipality		Sampled households in each municipality	
	Known agroforestry farmers ¹	Non-agroforestry farmers ²	Agroforestry farmers	Non-agroforestry farmers
Euclides da Cunha	12	120	9	7
Mirante do Paranapanema	19	484	21 ^a	28
Teodoro Sampaio	10	285	10	17
Total	41	889	40	52

^aNote: The list of households using agroforestry was used as a guide, but in some settlements households had abandoned or adopted agroforestry and the sample was adapted as required.

¹MST farms using agroforestry (source: IPÊ).

²MST farms using non-agroforestry farming (source: INCRA, Itesp).

TABLE 2 Classification of indicators within dimensions of material and subjective wellbeing ($N = 18$), and categories of barriers and mechanisms to agroforestry implementation linked to relational wellbeing included in questionnaire

Wellbeing dimension	Category	Related indicators
Material wellbeing	Financial security	Agricultural income derived from farm; Amount spent on pesticides
	Food sovereignty and security	Proportion of household food that was self-produced
	Key ecosystem services	Soil moisture and shade availability; impact of storms on the farm
Subjective wellbeing	Key ecosystem services	Shade moderating temperature; impact of pests and invasive species on agricultural production; abundance of birds and insects ^a
	Food sovereignty	Access to local cultural and dietary needs and preferences, key components being fruit, coffee and honey
	Comfort	Perceived quality of life; working conditions
	Key ecosystem services	Medicinal plants
Relational wellbeing	Social, political, technical and financial	Farmers' experiences with actions which support and barriers which prevent agroforestry implementation, linked to their relationship with the local cultural and institutional context

^aBirds and pollinating insects are classified as an ecosystem service from an ecological perspective; it is true that some farmers may view birds as pests, and not beneficial nor as an aspect of subjective wellbeing. However, qualitative data and observations did not suggest this was the case in the study region.

participants' own descriptions. Indicators are summarised here and listed in full in Table 2:

- Significant dimensions of material wellbeing emerged as financial security, food sovereignty and security and key ecosystem services. Financial security is captured by the ability to sell produce (encompassing access to markets, transport and yields). Food security and sovereignty is captured by proportion of household food that was self-produced. Ecosystem characteristics such as soil moisture and shade, enhancing productivity, are indicators of material wellbeing.
- Subjective wellbeing also encompasses ecosystem characteristics but further embodies access to local cultural and dietary needs and preferences (key components being fruit, coffee and honey). Coffee is consumed daily by most adults in the region. Honey production, especially from native stingless bees

(*Apidae*, *Hymenoptera*; Meliponiculture), is culturally important to many smallholder communities (Monique Amâncio de Carvalho et al., 2014) and is widely believed to hold nutritional and medicinal value, especially as a food supplement for children. Thus, coffee and honey production, while listed here primarily as subjective wellbeing indicators, also cross over into food security (material wellbeing; Kabalo et al., 2019; Mbow et al., 2019; van der Sluijs & Vaage, 2016).

- Key dimensions of relational wellbeing in the study communities are captured in the support, or lack of, from national, regional and local networks and institutions (Liveridge et al., 2020; Woodhouse et al., 2015). The relationship with governance bodies, community leaders and local organisations represents relational wellbeing components which, in the study context, can be linked to agroforestry implementation opportunities. These are explored in Section 3.3.

Indicators of material and subjective wellbeing were represented by 13 questions using 5-point Likert scale ranking (Likert 1923) and five using nominal yes/no responses (Table S2). Descriptive statistics break down responses for each indicator across the entire sample and between agroforestry ($N = 40$) and non-agroforestry farmers ($N = 52$). Differences between groups were explored using Mann–Whitney U tests (Wilcoxon rank sum) for Likert scale responses and Chi-square tests for nominal variables.

To capture the relational aspects of wellbeing, and further explore the challenges surrounding agroforestry implementation across the sampled settlements, participants were asked to rank 12 barriers which could prevent them from implementing agroforestry practices on their farm (from 'very small' to 'very big' barrier) and the importance of 15 mechanisms which could support implementation (mechanism/action of 'very low importance' to 'very high importance'). Questions were divided into four thematic groups (financial; political; social and technical; Tables S5 and S6) and scored using a 5-point Likert-like scale (Likert 1923). Two analyses were performed. First, the R `LIKERT` package (Bryer & Speerschneider, 2016) was used to analyse frequency of responses and visualise results between farmer groups, and across the entire sample. Second, a Wilcoxon rank sum test was used to test for differences between groups in participants' ranking of individual barriers and mechanisms.

To add robustness and reduce the risk of false discoveries of differences when performing comparative analysis on multiple indicators ($N = 13$), mechanisms ($N = 15$) and barriers ($N = 12$) using ranked responses between groups, two p -value correction methods were applied to the results: the Bonferroni (Bland & Altman, 1995) and the false discovery rate (FDR; Benjamini & Hochberg, 1995) p -value adjustment methods were both used for comparison and interpretation (Tables S3, S7 and S8). The Bonferroni correction is considered by some to be too conservative, potentially creating type II errors (Jafari & Ansari-Pour, 2018) so the Benjamini and Hochberg FDR method was also used to minimise the risk of rejecting valid comparisons found (Benjamini & Hochberg, 1995). A p -value correction was considered unnecessary for nominal variables tested using a Chi-square test ($N = 5$; with only four comparisons). All analyses were conducted using R Studio version 4.0.3 (R Core Team, 2021). Maps were produced using ArcMap v10.6 (ESRI, 2011).

2.4.2 | Qualitative data analysis

Farmers' attitudes to agroforestry were investigated using qualitative data collected through field notes and open-ended questions asking specifically about willingness to use agroforestry, and reasons for and against it (see Supporting Information). Responses were recorded either as participant's own written responses or verbal responses written by the interviewer. These were then entered and analysed using NVIVO software (QSR International, 1999). Inductive coding (Nowell et al., 2017) was used and nodes were created to

visualise responses and investigate farmers' perceptions of agroforestry restoration, their reasons for and against using this form of agriculture, and their general concerns related to agroforestry, farming and the study region environment.

In addition to qualitative data collected through the questionnaire, two focus groups with regional and local stakeholders and experts were organised to discuss the ecological, economic, agricultural and social challenges facing the region, in October and November 2019 (Supporting Information Section 5). These focus groups were used to record local views and learn from local actors to support interpretation of the results of both quantitative and qualitative analysis.

3 | RESULTS

3.1 | Characteristics of the sample population

Household surveys were conducted with the head of household (55% men; 45% women). Questionnaire response rate was 97.8%. The vast majority of farmers had completed only primary education (63%), with 28% reaching secondary education, 4% higher education and 4% identifying as illiterate or with under 2 years of formal education. The subsistence farmers selected for interview, from both sub-groups, were all small-scale family farmers working on farms averaging 17.8 ha (range 6–29 ha). Thirty-six per cent of all farmers interviewed derive their primary income from mixed agriculture, selling a combination of fruit, vegetables and dairy and meat products, while 21% derived their income primarily from cattle farming for the beef and dairy industry and 20% from retirement pensions (Figure 3). Most farmers used organic farming in food production (88%; we defined organic farming as techniques which do not use pesticides, e.g., relying on natural forms of pest control, but not related to certification). Of these, 47% used organic farming exclusively and 40% mixed organic with non-organic farming for the control of specific pests or weeds (Table 3; qualitative data and field observations reveal that, for health and cultural reasons, most families use only organic farming on fruit and vegetables as these crops are most commonly used for subsistence, despite use of pesticides elsewhere on the property). The most common form of livestock farming is cattle farming and breeding for the dairy and beef industry, followed by chickens and horses, with a few engaging in aquaculture and beekeeping. Other sources of income included off-farm work at local sugarcane mills and biofuel factories, and seasonal agricultural work.

3.2 | Indicators of material and subjective wellbeing

Of the 18 tested indicators representing aspects of wellbeing (including ecosystem services, Table 2), eight differ significantly between farmer groups (Table 4). In terms of ecosystem service indicators

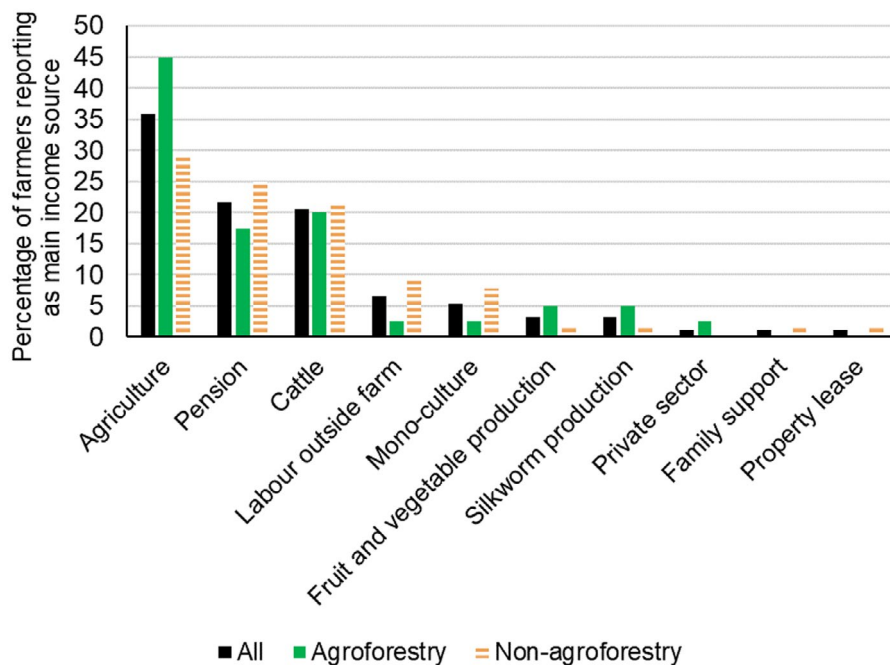


FIGURE 3 Main source of income for all farmers ($N = 92$) and within groups (agroforestry farmers, $N = 40$; non-agroforestry farmers, $N = 52$). Agriculture is defined as mixed farming (production of fruit, vegetables and livestock)

(defined from an ecological perspective), agroforestry farmers were significantly more likely to rank bird abundance on their farm 'high' or 'very high' (Figure 4b), report less severe storm damage to their farm (Figure 4c), report higher soil moisture content (Figure 4d) and a cooler micro-climate compared to the rest of the settlement (Figure 5). Agroforestry farmers were significantly more likely to report most or almost all of their food came from the farm, whereas non-agroforestry farmers often ranked this low (Figure 4a). Agroforestry farmers are significantly more likely to produce coffee and honey (47.5% and 27.5% respectively: only 8% non-agroforestry farmers produced coffee and none honey, Figure 5). A higher percentage of agroforestry farmers also reported the presence of medicinal plants (47.5%) compared to non-agroforestry farmers (11.5%; Figure 5).

3.3 | Barriers and mechanisms related to agroforestry implementation

Both agroforestry and non-agroforestry MST farmers ranked relational elements—lack of government support (at all levels) and lack of community organisations—as the main barriers preventing or limiting their implementing agroforestry farming (Figure 6; Figure S2). Government support is understood (as expressed by participants) as logistical or bureaucratic support (representing relational value). The opportunity cost of lost land when planting native trees as part of agroforestry plots was ranked the lowest barrier across all groups. Differences between farmer groups are significant for lack of knowledge (71% agroforestry vs. 20% non-agroforestry farmers ranking it a 'big' to 'very big' barrier)

Type of farming and pest control	All		Agroforestry		Non-agroforestry	
	N	%	N	%	N	%
Organic	43	46.7	23	57.5	20	38.5
Both organic and pesticides used on property	36	39.1	17	42.5	19	36.5
Pesticides	10	10.9	0	0	10	19.2
Integrated pest management systems	1	1.1	0	0	1	1.92
Organic and integrated pest management systems	1	1.1	0	0	1	1.9
NA ^a	1	1.1	0	0	1	1.9
Total	92		40		52	

TABLE 3 Types of farming techniques used and reported by interviewed farmers, for all farmers and within groups

^aNot defined by participant.

TABLE 4 Indicators showing significant differences between groups. Multiple p -value comparisons were not required for Chi-square tests on nominal indicators. We report only indicators showing p -values significant at the 95% level in at least one correction method, in addition to unadjusted p -values. See Figures 4 and 5; Figure S1 for further details

Indicator (significantly different between farmer groups, $N = 8$)	Group reporting higher score	p -value \pm adjustment		
		Unadjusted	Bonferroni	FDR
Damage to farm created by storms	Non-agroforestry	0.0040*	0.0524	0.0426*
Farm micro-climate (temperature perceived higher compared to settlement)	Non-agroforestry	1.474e-12*	–	–
Perceived bird abundance	Agroforestry	0.0108*	0.1408	0.0426*
Soil water content (moisture)	Agroforestry	0.0131*	0.1705	0.0426*
Proportion of family food self-produced	Agroforestry	0.009*	0.1227	0.0426*
Production of coffee	Agroforestry	0.0001*	–	–
Production of honey	Agroforestry	0.0004*	–	–
Presence of medicinal plants	Agroforestry	0.0009*	–	–

*Indicates significance ($p < 0.05$).

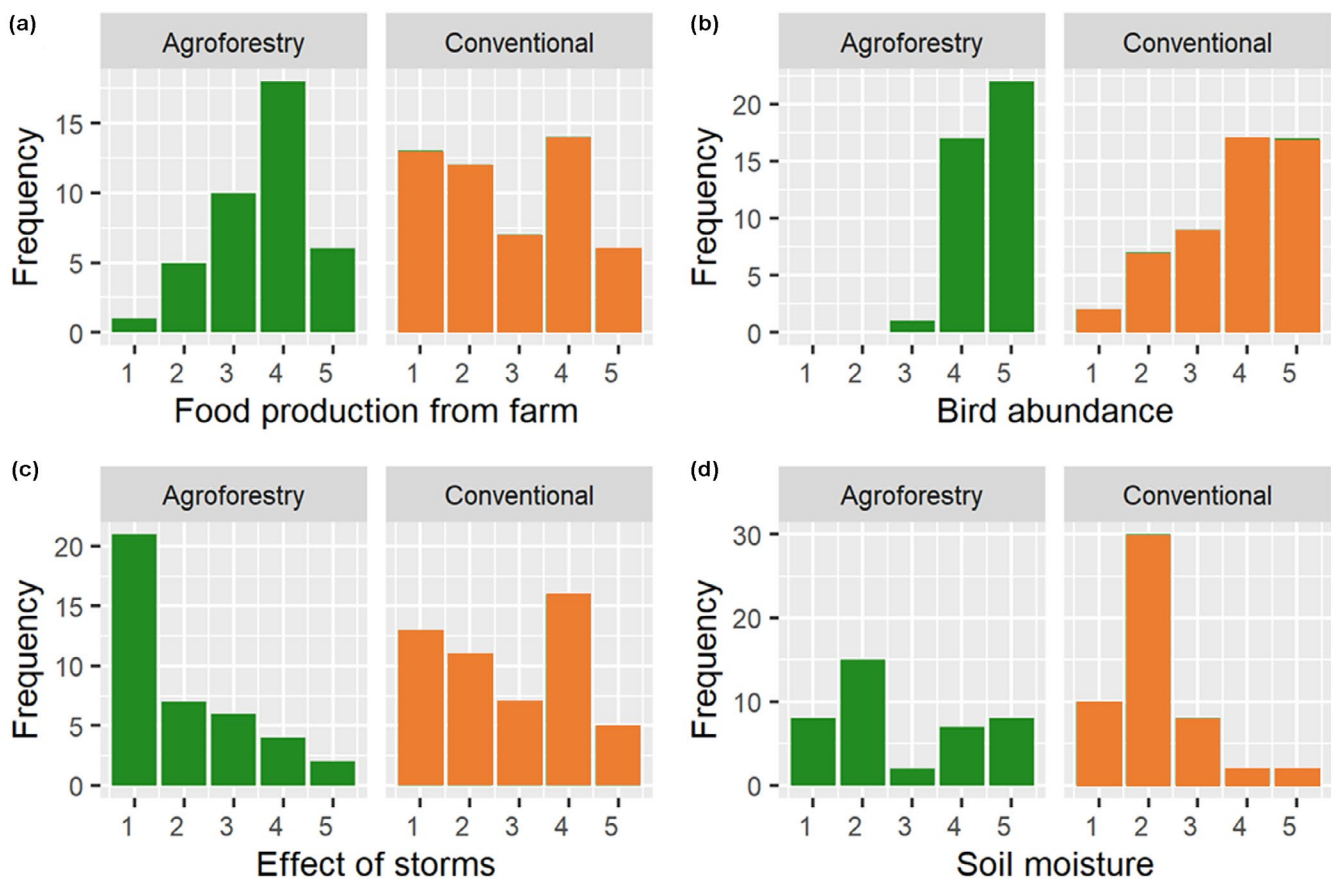


FIGURE 4 Frequency of Likert scale responses (1 = very low, 5 = very high) for indicators with significantly different responses between groups of farmers (agroforestry, $N = 40$; non-agroforestry, $N = 52$). Graphs show participants' responses to (a) proportion of family food sourced from the farm, (b) perceived abundance of birds, (c) the effect of storms and (d) soil moisture (water content) on farm

and opportunity costs (95% agroforestry vs. 52% non-agroforestry farmers ranking it as a 'very small' to 'small' barrier; Figure S2). Other barriers are ranked in similar ways across both groups. The lack of community organisations was considered more of a barrier by farmers

not using agroforestry, with 79% reporting it as a 'big' or 'very big' barrier to implementation. Agroforestry farmer responses were more varied, with 62% reporting it as a 'big' or 'very big' barrier, 20% ranking it as a 'medium' barrier and 18% as a 'small' or 'very small' barrier.

Farmers in both groups (including all agroforestry farmers) ranked government support (at all levels), technical support and environmental education as the actions which would most encourage the adoption

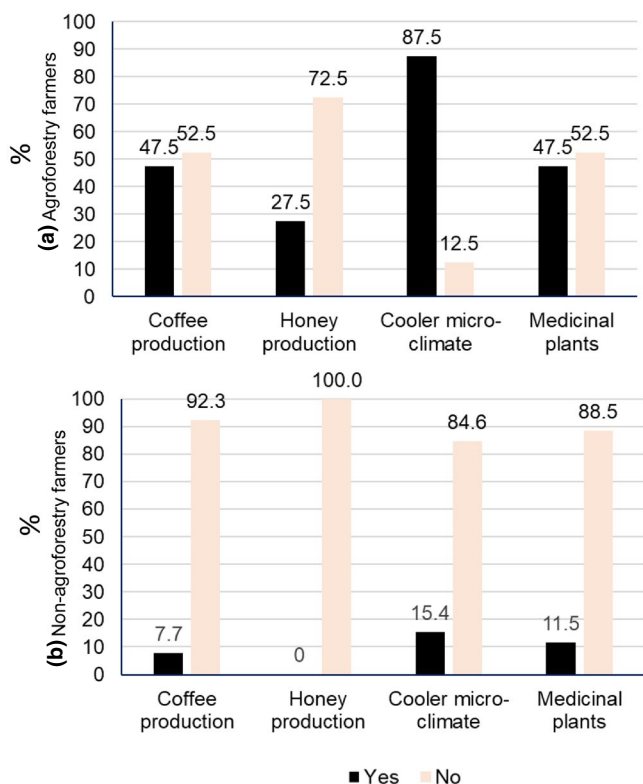


FIGURE 5 Percentage of responses from each group (agroforestry farmers, $N = 40$; non-agroforestry farmers, $N = 52$) to wellbeing questions related to farm production and ecosystem services for variables which show significant differences between groups

of agroforestry (Figure 7). Access to organic markets for selling agroforestry products was ranked almost equally by both groups, with 79% of non-agroforestry farmers and 80% of agroforestry farmers ranking it as an 'important' to 'very important' mechanism (Figure S3). More agroforestry farmers saw financial support to buy tools and equipment as of 'high' to 'very high' importance (60% of agroforestry farmers vs. 27% of non-agroforestry farmers: Figure S3). Transport links and access to native plants were ranked of lowest importance in supporting agroforestry implementation (Figure 7), but with some differences between the two groups. Non-agroforestry farmers saw a lesser need for better transport options (60% of non-agroforestry farmers ranked it as a mechanism of 'very low' to 'low' importance vs. 30% of agroforestry farmers). The majority of non-agroforestry farmers considered accessing native plants a mechanisms of 'very low' to 'low' importance (63%), whereas for agroforestry farmers answers were spread across the Likert scale categories (Figure S3).

Three of 12 barriers (Table S7) and 8 of 15 mechanisms (Table S8) differed significantly between farmer groups. Agroforestry farmers ranked both the barriers and the supporting mechanisms higher than non-agroforestry farmers overall (Figures S2 and S3).

3.4 | Attitudes to agroforestry as a restoration method

Qualitative data analysis of open-ended interview question confirms quantitative analysis conclusions and patterns. Fourteen themes emerged from inductive coding as common to both groups (Figure 8). When discussing agroforestry adoption, the most common themes among agroforestry farmers were linked to material and subjective wellbeing (such as the value of native trees for nature,

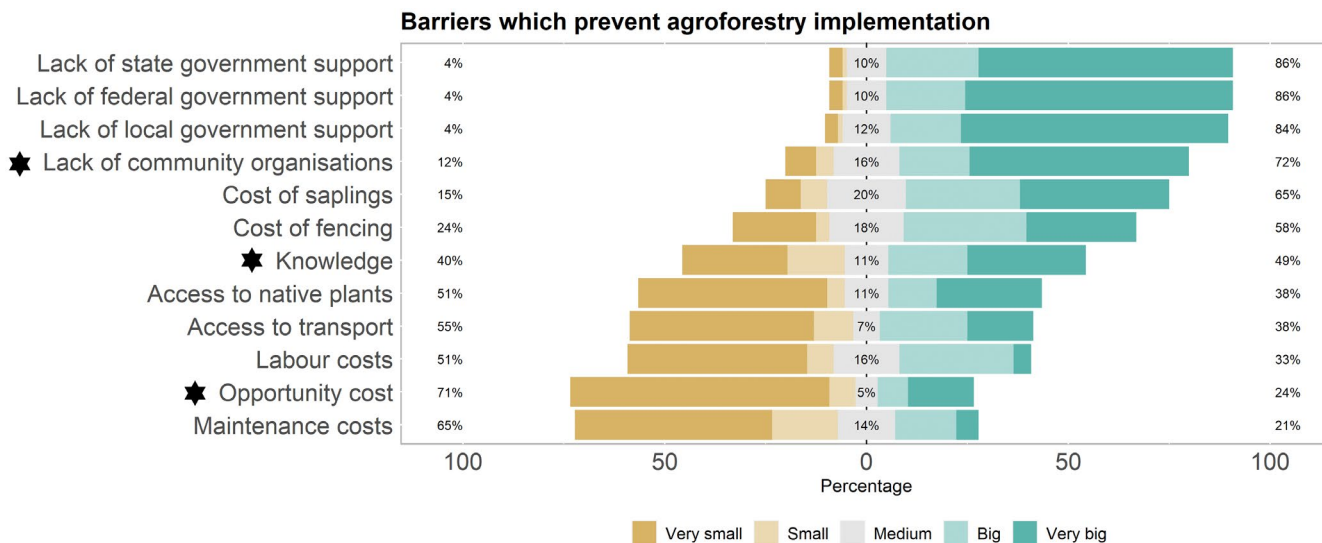


FIGURE 6 Barriers related to implementing agroforestry practices ranked by both agroforestry and non-agroforestry farmers ($N = 92$) using Likert scale ranking (1, 'very low barrier' to agroforestry implementation-5, 'very big barrier'). Percentages on either side of the bars show the percentage of responses which ranked each barrier in the 'big' or 'very big' category (right) and the percentage of responses which ranked each barrier in the 'small' or 'very small' category (left). Barriers ranked significantly differently between farmer groups are starred ($p < 0.05$)

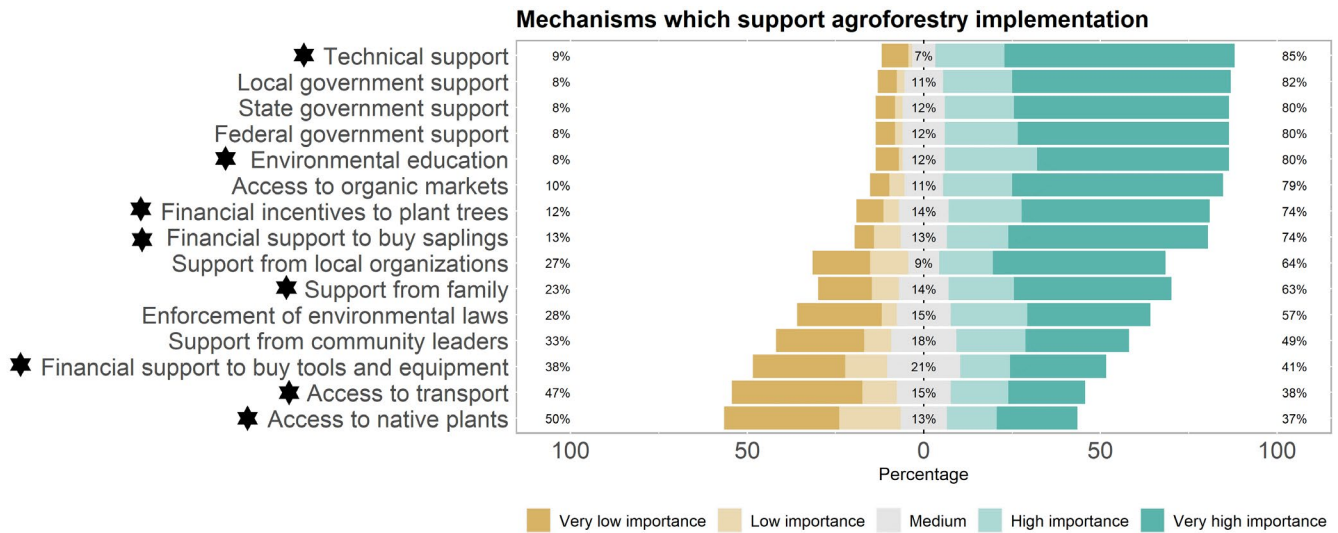


FIGURE 7 Importance of mechanisms or actions which could support the implementation of agroforestry practices ranked by agroforestry and non-agroforestry farmers ($N = 92$) using Likert scale ranking (1, 'very low importance' to 5, 'very high importance'). Percentages on either side of the bars show the percentage of responses which ranked each barrier in the 'high' or 'very high' importance category (right) and the percentage of responses which ranked each barrier in the 'low' or 'very low' importance category (left). Mechanisms ranked significantly differently between farmer groups are starred ($p < 0.05$)

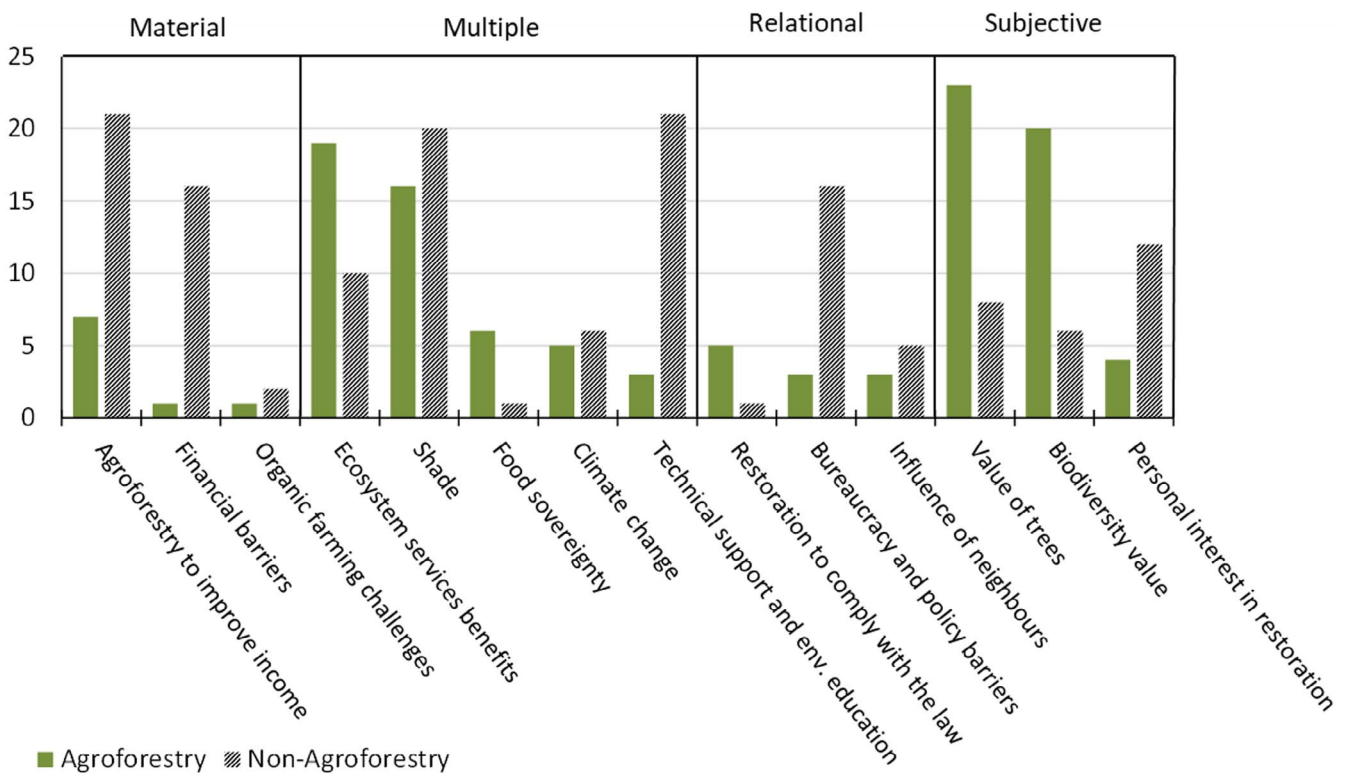


FIGURE 8 Common themes emerging among MST farmers using agroforestry versus non-agroforestry farming methods when discussing agroforestry adoption, its benefits and its challenges. Bars show the frequency of mentions for each theme. Themes are classified into wellbeing categories (with some covering multiple categories)

aesthetic or cultural reasons), ecosystem service benefits (such as improved soil quality and cooler temperature) and the value of support from local organisations (Figure S4). Themes mentioned most by non-agroforestry farmers were the possibility of agroforestry to

improve income (e.g. through selling fruit, diversifying production and/or reducing reliance on cattle), desire to increase on-farm shade (to reduce cattle heat stress, which affects milk yields and quality), lack of technical agroforestry knowledge and environmental

education, and financial and bureaucratic barriers to adopting agroforestry and developing environmentally friendly farming practices (Figure S4; such as delays or lack of processing paperwork related to land ownership, permission to modify vegetation on settlements and lack of assistance with legal processes).

When discussing changing farming practice to incorporate agroforestry methods, participants highlighted the lack of cooperatives dedicated to agroforestry products and the lack of institutional support and funding for family farms and agroforestry systems, compared to non-agroforestry agriculture. Evidence from participant responses, workshops and focus groups suggested that the focus on cattle farming for the dairy industry as a principle income source was largely driven by organised institutional support, mainly from the regional dairy industry (e.g. through the collection of milk at individual households once a week, and visits from vets and technical experts to the settlements). Younger MST farmers also raised concerns about their ability to support themselves in the future without having to emigrate from the settlements, due to a lack of opportunities for employment, but also the influence of climate change making farming practices more challenging.

When discussing the reasons for switching to, or continuing, agroforestry farming, the ability to grow coffee was highlighted by nine agroforestry farmers and two non-agroforestry farmers. Statements such as 'the region which has coffee does not have misery' (*miséria*, in Portuguese, referring to socio-economic status) reflect the importance of the crop both as a food staple and as part of subjective wellbeing, as reported by others (Slovak, 2017). Sixteen non-agroforestry farmers and six agroforestry farmers mentioned fruit as a key reason for agroforestry adoption (Figure S4), mainly in the context of improving income from sales, and to a lesser extent for family consumption.

4 | DISCUSSION

4.1 | The role of MST farmers in restoring Brazil's Atlantic Forest

Research exploring the potential of FLR approaches to safeguard biodiversity and improve the resilience of degraded landscapes across the Atlantic Forest is essential, as it remains an area of great importance for biodiversity and ecosystem services provisioning. While understanding of the benefits of FLR for biodiversity, ecosystem services and global climate regulation continues to grow (Latawiec et al., 2015; Stanturf et al., 2019), social aspects of large-scale forest restoration plans remain unclear (César et al., 2020; Erbaugh & Oldekop, 2018; Fischer et al., 2021). Agroforestry accounts for a much smaller percentage of recorded restoration action and research across Latin America than in Sub-Saharan Africa and South Asia restoration hotspots (Coe et al., 2014; NYDF Assessment Partners, 2019), and remains under-studied in Brazil (Miccolis et al., 2017). It has a low presence in national and regional restoration plans (de Oliveira & Carvalhaes, 2016) and the

possible negative impacts of agroforestry on rural communities (such as social disruption, power dynamics exacerbating inequalities within and across communities, opportunity costs, etc.) are rarely considered.

However, evidence of agroforestry's potential co-benefits for climate change mitigation, ecosystem services, yields and food security in the Atlantic Forest is growing (Alves-Pinto et al., 2017; Cechin et al., 2021; Reis et al., 2020). Agroforestry plots within MST settlements offer important stepping stones linking wildlife populations (Badari et al., 2020; Chazdon, Cullen, et al., 2020) and support land-sharing practices beneficial for biodiversity (Grass et al., 2019). Our results show agroforestry farmers report higher soil moisture on their plots, and higher proportions of household food produced on-farm, than non-agroforestry farmers. Our methods cannot attribute causality, and there may be underlying differences inherent to farmers who engaged with agroforestry farming. However, farmers' perceptions concur with evidence that agroforestry improves soil conditions and yields (FAO, 2017; Tamburini et al., 2020) and can help mitigate the effects of climate change (FAO, 2017). This is especially relevant in dry climates such as the Atlantic Forest, where climate change has led to increased periods of drought and higher temperatures (Joly et al., 2014). Agroforestry farmers were much more likely to report lower farm temperatures than the rest of the settlement, indicating ecosystem service benefits of higher tree cover, enhancing farmer wellbeing and agricultural production, as found by other studies (Trevisan et al., 2016).

Brazil's estimated 4 million family farms (Berdegué & Fuentealba, 2014) and 1.5 million MST farmers (Carter, 2005) cover over 7.5 million ha of land. They are involved, or leading, in many restoration initiatives, including plans to restore over 400,000 ha using agroforestry in the Atlantic Forest region alone (MST, 2017). They also play a huge role in safeguarding food security (De França et al., 2009; Leakey, 2014; Rocha et al., 2012) and are essential to the national agricultural economy, with the latest census (IBGE, 2017) reporting family farms produce around 87% of cassava, 60% of milk, 70% of beans, 30% of cattle and 34% of the rice consumed in Brazil. Thus, although the involvement of large landowners in FLR has greater potential benefits in terms of total area available for restoration, the role of family farmers, at national and local scales, should not be discounted. Despite the MST's promotion of healthy and environmentally friendly approaches to farming and diets (Carter, 2005; Clements, 2012), their position as a politicised, anti-establishment social group creates animosity and conflict with many private land owners and government factions. Tensions which reduced during the Lula da Silva administration (2002–2010; Clements, 2012; Meszaros, 2007) have re-surfaced since 2018 under President Bolsonaro. This has contributed to MST farming communities, and other smallholders (such as those from *quilombola* communities (Thorkildsen, 2014)), being overlooked in policy-making and funding (Carvalho, 2000; Clements, 2012), despite their importance to local food security, as the source of fruits and vegetables at affordable prices, and their existing involvement in restoration action (MST, 2021).

Well-documented and in-depth case studies of FLR approaches, including those using agroforestry, are lacking (Chazdon, Gutierrez, et al., 2020). This study has shown farmers perceived benefits for multiple dimensions of material, subjective and relational wellbeing, such as food security, quality of life and working conditions derived from increased shade, enhanced ecosystem services and health. Farmers' perceptions align with scientific evidence, with agroforestry plots up to 6°C cooler than un-shaded agricultural plots on the same land (de Souza et al., 2012). These micro-climatic changes are extremely significant for family farmers who, together with indigenous peoples, face increased risks to livelihoods from climate change (Morton, 2007; de Souza et al., 2012).

4.2 | Barriers to agroforestry implementation for smallholder farmers

To assess agroforestry's potential as a positive solution to land degradation which improves MST farmer livelihoods, lessons learnt must include information on challenges and barriers to implementation, and not just successes (Coe et al., 2014). The lack of government support at local, state and federal levels, was identified as the biggest constraint by both groups of interviewed farmers. Lack of knowledge, education and technical expertise was reported as a large barrier by non-agroforestry farmers, but not by agroforestry farmers. This suggests that existing training and support already accessed by farmers using agroforestry (e.g. Chazdon, Gutierrez, et al., 2020; Cullen Jr. et al., 2006) has supported learning, while farmers who have not been using agroforestry continue to lack the skills and knowledge needed to change farming practices. Farmers indicated they feel ill-prepared to tackle the changes and assume the costs and difficulties associated with successfully developing agroforestry plots individually, and would feel more confident with higher community involvement and the integration of training and education within settlements. Financial barriers, overall, were not ranked as highly by farmers, especially by those using agroforestry already.

To better inform policy-making and creation of context-specific community FLR projects, MST farmers were also asked to rank the mechanisms they consider most important in supporting a switch to agroforestry farming. Mirroring the results of the main barriers, government support at all levels was ranked by both farming groups as the most important support mechanism. This highlights the lack of schemes promoting environmentally friendly farming or agroecological practices, but also shows the importance of political support to these communities. Financial incentives to buy and plant native trees were also considered important, though less so than technical support (95% of agroforestry farmers ranked it an 'important' or 'very important' mechanism, compared to 77% of non-agroforestry farmers) and environmental education (ranked as an 'important' or 'very important' mechanism by 90% of agroforestry farmers and 73% of non-agroforestry farmers). While there is diversity within MST family farming communities, their background and history as migrant

settlers, often first generation, means a lack of agricultural expertise and technical knowledge on farming techniques—especially non-traditional farming—is common (Carter, 2015).

Lastly, farmers highlighted practical limitations to agroforestry farming linked to lack of transport and collection of agroforestry products, the lack of support to access organic or agroecological certification schemes, and importantly, the lack of markets dedicated to these type of products, a problem highlighted by other community farming groups across Brazil (Cechin et al., 2021) and well recognised in the wider literature (Coe et al., 2014; Leakey et al., 2006). Settlements in the region, as in much of Brazil, lack adequate road and electrical infrastructure, many connected by long dirt tracks which become inaccessible with heavy rains. Despite this, the region's dairy cooperatives collect milk directly from each household in the settlement once a week, covering the cost of transport. This is a consequence of decades of investment and government support, which has led the region to be the second highest dairy producer in São Paulo state (Pontes & Ferrante, 2018); similar transport options for fruit and vegetable produce do not exist in the region. Many MST farmers interviewed expressed concerns about their reliance on dairy as their single or principal source of income, given vulnerability to low milk yields caused by droughts and cattle heat stress from lack of shade, and to fluctuations in the price of milk. The lack of support, investment and local farmers' markets create limited options to sell fruit and vegetables produced in agroforestry plots, disincentivising MST farmers who already use this type of agriculture. This is reflected in questionnaire data, which shows agroforestry farmers were more likely to consider access to transport as important in supporting agroforestry implementation, compared to non-agroforestry farmers.

4.3 | Going forward—Including smallholder farming communities in the Atlantic Forest Restoration agenda

Agroforestry restoration and the role of family farmers and marginalised rural communities are often missed from large-scale restoration planning research and international policy-making (FAO, 2013). The biophysical characteristics of agroforestry systems and the benefits family farmers may get from them (e.g. improved crop yields, 'multi-cropping', improved working conditions from shade), are not easily quantifiable and so cannot be included in many global cost-benefit and restoration prioritisation analyses. Despite the success of some participatory and stakeholder-led approaches to restoration, such as the Atlantic Forest Pact (Brancalion et al., 2013; Pinto et al., 2014), the policy and financial needs of smallholders and family farmers are yet to be fully recognised (Holl, 2017b). Although this study is restricted to the Pontal do Paranapanema region, we believe it gives a detailed picture which is useful in restoration planning when smallholder farmers (from MST, *quilombola* or indigenous communities) are involved, and evidence shows similar patterns found in other parts

of the biome (Lacerda et al., 2020; Reis et al., 2020; Sagastuy & Krause, 2019). Thus, we highlight key areas of focus for research and policy to improve involvement of smallholder farmers in FLR in Brazil:

- **Bottom-up approaches to FLR:** The success of commitments to restore millions of hectares of forest across the tropics will depend on working with local communities to combine top-down with bottom-up approaches (Holl, 2017a). These approaches exist elsewhere at the national scale (e.g. Nepal's Community Forest Programme, Luintel et al., 2018), and in the Atlantic Forest will require recognising the ethnic, social and economic diversity of rural communities and attempting to value the needs and motivations of smallholders and family farmers equally to those of large landowners from agribusinesses and the private sector.
- **Long-term partnerships and building trust:** The challenges associated with local communities' mistrust in conservation and restoration projects are well known (Sapkota et al., 2018) and long-term projects where trust has been built and sustained are likely to impact uptake of restoration (Chazdon, Cullen, et al., 2020). This must be better acknowledged by funders and research bodies. FLR in the case study region is being carried out with long-term involvement of local actors (Chazdon, Gutierrez, et al., 2020), helping to build trust and establish more equal power relations. We find evidence that this can lead to successful partnerships with smallholders who are willing to join agroforestry schemes, but multiple challenges and barriers mean uptake in the sampled settlements is still low (approx. 5% of households). Thus, farmers can only take advantage of offered support if they have the ability to join schemes, and barriers to this remain high. Trust building increases the chances of farmers using agroforestry and having positive experiences, but it cannot make up for other barriers.
- **Promote access to certification and markets for organic and agroecological products:** support for smallholder farmers to be included in commercial market-oriented organic food networks is essential to promote environmentally friendly farming, including agroforestry, but is lacking across Brazil (Blanc & Kledal, 2012; Cechin et al., 2021). Many MST farmers use organic farming and reject the use of pesticides on crops, but lack the bureaucratic and logistical support to carry out complicated certification requirements. In addition, many settlements are bordered by industrial sugarcane plantations which are frequently air-sprayed with pesticides from planes, creating further barriers to organic certification for high-income crops such as coffee (Liu et al., 2018; Maguire-Rajpaul et al., 2018; Sagastuy & Krause, 2019).
- **Tailored financial mechanisms:** While it is hugely important to engage large landowners and agri-businesses in FLR through Payment for Ecosystem Services (PES) schemes and financial incentives (such as tax reductions or carbon credits), these schemes rely on assumptions about access to finance, investment capacity, logistics and technical knowledge which do not apply to family farmers. The experiences of MST farmers and other smallholders and their approaches to assessing the financial risk, costs and benefits involved with investing in agroforestry vary widely. The importance of crop yields and diversity, as well multiple wellbeing components, are likely to be much higher for smallholders and subsistence farmers (Cechin et al., 2021; Lazos-Chavero et al., 2016). We also find MST farmers consider the opportunity cost of land set aside for restoration as a barrier of relatively low importance, while access to finance for initial investment remains a big concern.
- **Tailored legislation and policy support:** There are multiple policies designed for family farmers in Brazil: the National School Meals Programme or 'Merenda Escolar' (*Programa Nacional de Alimentação Escolar*, PNAE), which requires at least 30% of food used for school meals to be sourced from family farmers; the PAA (*Programa de Aquisição de Alimentos*), which encourages smallholder farmers to sell their products directly to governmental institutions (Sagastuy & Krause, 2019); and the National Policy on Agroecology and Organic Production (*Política Nacional de Agroecologia e Produção Orgânica*, Pnapo). In Pontal do Paranapanema, as in many other regions across Brazil, these policies provide a stable demand for MST farmers' organic produce. However, many of the interviewed farmers expressed concerns that these policies were ending following cuts to the PNAE and removal of agricultural policies, such as the Pnapo, accelerated by the Bolsonaro government (Melito, 2020; Sabourin et al., 2020). Schemes will only work with long-term and specialised support, especially for MST farmers, many of whom rely on government agencies for veterinary, technical and logistical assistance and subsidies to cattle farming, creating a reliance on the dairy industry. Existing agricultural policies in Brazil often follow a 'one size fits all' approach and will require adjustments for smallholders specifically (Sakai et al., 2020).
- **Land ownership:** Evidence shows small farmers are more likely to restore on their own land (Pacheco et al., 2021) and land tenure, food sovereignty and empowerment are common drivers of agroforestry adoption across landless peoples' settlements (Altieri et al., 2012). In Brazil, widespread uptake of agroforestry among smallholder communities such as the MST, as well as by indigenous peoples and *quilombolas*, will require a legal and policy environment that guarantees rights to—and ownership of—the land they live and farm on, and the native vegetation on it. The settlements in this case study are all legally recognised, as is the case with around 80% of family farmers in Brazil (Carter, 2015; IBGE, 2017), but further work is needed to ensure legal ownership and agency is granted to smallholder communities, an increasing challenge in the current national political environment.

5 | CONCLUSION

Brazil is a global leader in FLR and ecological restoration, one of three countries believed to have reached restoration policy targets set out by the Bonn Challenge (Global Partnership on Forest Landscape Restoration (GPFLR), 2019). Huge amounts of land

have been identified as potential forest restoration areas (Melo et al., 2013; Strassburg et al., 2019) creating benefits for biodiversity and ecosystem service provisioning. However, failing to consider the different policy needs of large-scale industrial farming versus smallholder farming communities when designing FLR strategies risks missing opportunities to integrate issues of food security, equity and sustainable rural livelihoods in restoration approaches. With millions of smallholders and family farmers across the country and prominent social and political movements linked to food sovereignty and land reform, Brazil's Atlantic Forest provides an ideal backdrop in which to explore these relationships. We show that interdisciplinary approaches using mixed methods can capture the benefits, costs and perceptions of MST farmers. Beyond this, it is necessary to approach FLR through a transdisciplinary lens, working with academia, NGOs and farmers to find context-specific and innovative solutions which incentivise involvement of rural communities. Forest restoration happens in complex landscapes, where local people, their diverse values and uses of the land need to be fully considered, and respected. This will require more in-depth collaborations across fields of restoration ecology, anthropology, environmental justice and political ecology, among others. As restoration initiatives grow across the tropics, we echo calls from others (Erbaugh et al., 2020) to improve collaboration with social scientists and utilise existing expertise on agroecology, the influence of corporate food regimes and agriculture (De Molina et al., 2019; Muñoz et al., 2021), and food sovereignty in marginalised groups (Clements, 2012; Woodhill et al., 2020) to understand the tensions and compromises rural communities face within FLR strategies.

ACKNOWLEDGEMENTS

We thank all the people from the MST settlements for providing their valuable time and knowledge in answering the interview questions, without which this research would not have been possible. We also thank the team at the Institute for Ecological Research (Instituto de Pesquisas Ecológicas, IPÊ) in Teodoro Sampaio for providing logistical support during fieldwork. This research was funded by the Natural Environment Research Council (NERC), grant number NE/L002485/1.

CONFLICT OF INTEREST

The authors declare no conflict of interest. The funders and collaborators had no role in the design of the study; in the analysis or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

Y.S.-F., K.H. and M.M. conceived the idea and designed the methodology, Y.S.-F. and A.S. collected the data; Y.S.-F. analysed the data and led the writing of the manuscript; Y.S.-F., K.H., M.M. and A.S. contributed to the interpretation of the data and review of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

DATA AVAILABILITY STATEMENT

The data underlying the results presented in this paper will be archived using the UCL Research Data Repository (<https://rdr.ucl.ac.uk/>), <https://doi.org/10.5522/04/17145551> (Shennan-Farpon, 2022).

ORCID

Yara Shennan-Farpón  <https://orcid.org/0000-0002-3635-0913>

Morena Mills  <https://orcid.org/0000-0001-9865-0770>

Katherine Homewood  <https://orcid.org/0000-0001-7391-985X>

REFERENCES

- Adams, C., Rodrigues, S. T., Calmon, M., & Kumar, C. (2016). Impacts of large-scale forest restoration on socioeconomic status and local livelihoods: What we know and do not know. *Biotropica*, 48(6), 731–744. <https://doi.org/10.1111/btp.12385>
- Altieri, M. A., Funes-Monzote, F. R., & Petersen, P. (2012). Agroecologically efficient agricultural systems for smallholder farmers: Contributions to food sovereignty. *Agronomy for Sustainable Development*, 32, 1–13. <https://doi.org/10.1007/s13593-011-0065-6>
- Alves-Pinto, H. N., Latawiec, A. E., Strassburg, B. B. N., Barros, F. S. M., Sansevero, J. B. B., Iribarrem, A., Crouzeilles, R., Lemgruber, L., Rangel, M. C., & Silva, A. C. P. (2017). Reconciling rural development and ecological restoration: Strategies and policy recommendations for the Brazilian Atlantic Forest. *Land Use Policy*, 60, 419–426. <https://doi.org/10.1016/j.landusepol.2016.08.004>
- Badari, C. G., Bernardini, L. E., Almeida, D. R. A., Brancalion, P. H. S., César, R. G., Gutierrez, V., Chazdon, R. L., Gomes, H. B., & Viani, R. A. G. (2020). Ecological outcomes of agroforests and restoration 15 years after planting. *Restoration Ecology*, rec.13171. <https://doi.org/10.1111/rec.13171>
- Banks-Leite, C., Pardini, R., Tambosi, L. R., Pearse, W. D., Bueno, A. A., Bruscagin, R. T., Condez, T. H., Dixo, M., Igari, A. T., Martensen, A. C., & Metzger, J. P. (2014). Using ecological thresholds to evaluate the costs and benefits of set-asides in a biodiversity hotspot. *Science*, 345(6200), 1041–1045. <https://doi.org/10.1126/science.1255768>
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B (Methodological)*, 57(1), 289–300. <https://doi.org/10.1111/j.2517-6161.1995.tb02031.x>
- Berdegúe, J. A., & Fuentealba, R. (2014). The state of smallholders in agriculture in Latin America. In *New Directions for Smallholder Agriculture*. Oxford Scholarship Online. <https://doi.org/10.1093/acprof:oso/9780199689347.001.0001>
- Bernard, H. R. (2006). *Research methods in anthropology: Qualitative and quantitative methods* (4th ed.). AltaMira Press.
- Blanc, J., & Kledal, P. (2012). The Brazilian organic food sector: Prospects and constraints of facilitating the inclusion of smallholders. *Journal of Rural Studies*, 28(1), 142–154. <https://doi.org/10.1016/j.jrurstud.2011.10.005>
- Bland, J. M., & Altman, D. G. (1995). Multiple significance tests: The Bonferroni method. *British Medical Journal*, 310(6973), 170. <https://doi.org/10.1136/bmj.310.6973.170>
- Brancalion, P. H. S., Niamir, A., Broadbent, E., Crouzeilles, R., Barros, F. S. M., Zambrano, A. M. A., Baccini, A., Aronson, J., Goetz, S., Reid, J. L., Strassburg, B. B. N., Wilson, S., & Chazdon, R. L. (2019). Global restoration opportunities in tropical rainforest landscapes. *Science Advances*, 5, 3223–3226. <https://doi.org/10.1126/sciadv.aav3223>
- Brancalion, P. H. S., Viani, R. A. G., Calmon, M., Carrascosa, H., & Rodrigues, R. R. (2013). How to organize a large-scale ecological restoration program? The framework developed by the atlantic forest restoration pact in Brazil. *Journal of Sustainable Forestry*, 32(7), 728–744. <https://doi.org/10.1080/10549811.2013.817339>

- Bryer, J., & Speerschnieder, K. (2016). Package 'likert': Analysis and visualization likert items.
- Carter, M. (2005). *The landless rural workers' movement (MST) and democracy in Brazil (CBS-60-05)*. Centre for Brazilian Studies. Retrieved from <https://www.lac.ox.ac.uk/sites/default/files/lac/documents/media/miguel20carter2060.pdf>
- Carter, M. (2015). Challenging Social Inequality - The Landless Rural Workers Movement and Agrarian Reform in Brazil. In M. Carter (Ed.). Duke University Press. <https://www.dukeupress.edu/challenging-social-inequality>
- Carvalho, G. O. (2000). The politics of indigenous land rights Brazil. *Bulletin of Latin American Research*, 19(4), 461–478. <https://doi.org/10.1111/j.1470-9856.2000.tb00119.x>
- Cechin, A., da Silva Araújo, V., & Amand, L. (2021). Exploring the synergy between community supported agriculture and agroforestry: Institutional innovation from smallholders in a Brazilian rural settlement. *Journal of Rural Studies*, 81, 246–258. <https://doi.org/10.1016/j.jrurstud.2020.10.031>
- César, R. G., Belei, L., Badari, C. G., Viani, R. A. G., Gutierrez, V., Chazdon, R., Brancalion, P. H. S., & Morsello, C. (2020). Forest and landscape restoration: A review emphasizing principles, concepts, and practices. *Land*, 10(1), 28. <https://doi.org/10.3390/land10010028>
- Chazdon, R. L., Brancalion, P. H. S., Lamb, D., Laestadius, L., Calmon, M., & Kumar, C. (2017). A policy-driven knowledge agenda for global forest and landscape restoration. *Conservation Letters*, 10(1), 125–132. <https://doi.org/10.1111/conl.12220>
- Chazdon, R. L., Cullen Jr., L., Padua, S. M., & Padua, C. V. (2020). People, primates and predators in the Pontal: From endangered species conservation to forest and landscape restoration in Brazil's Atlantic Forest. *Royal Society Open Science*, 7, 200939. <https://doi.org/10.1098/rsos.200939>
- Chazdon, R., Gutierrez, V., Brancalion, P. H. S., Laestadius, L., & Guariguata, M. R. (2020). Co-creating conceptual and working frameworks for implementing forest and landscape restoration based on core principles. *Forests*, 11(6), 706. <https://doi.org/10.3390/f11060706>
- Clements, E. A. (2012). Agrarian reform, food sovereignty and the MST: Socio-environmental impacts of agrofuels production in the Pontal do Paranapanema region of São Paulo state, Brazil. (Reforma agrária, soberania alimentar e o MST: Impactos socioambientais da produção de...). *Revista NERA*, 15(21). <https://doi.org/10.47946/rnera.v0i21.2139>
- Coe, R., Sinclair, F., & Barrios, E. (2014). Scaling up agroforestry requires research “in” rather than “for” development. In *Current Opinion in Environmental Sustainability* (Vol. 6(1), pp. 73–77). Elsevier. <https://doi.org/10.1016/j.cosust.2013.10.013>
- Cullen Jr., L., Borges Gomes, H., Ferreira Lima, J., Campos, N., Pavam Beltrame, T., Vicente Moscolgiato, A., & Ronconi, E. (2006). Restauração de paisagens e desenvolvimento socioambiental em assentamentos rurais do Pontal do Paranapanema. *Revista Agrícolas*, 3(3), 24–28.
- Cullen, L., Alger, K., & Rambaldi, D. M. (2005). Land reform and biodiversity conservation in Brazil in the 1990s: Conflict and the articulation of mutual interests. *Conservation Biology*, 19(3).
- de Oliveira, R. E., & Carvalhaes, M. A. (2016). Agroforestry as a tool for restoration in atlantic forest: Can we find multi-purpose species? *Oecologia Australis*, 20, 425–435. <https://doi.org/10.1007/0-387-29112-1>
- de Rezende, C. L., Uezu, A., Scarano, F. R., & Araujo, D. S. D. (2015). Atlantic Forest spontaneous regeneration at landscape scale. *Ecosphere*, 24. <https://doi.org/10.1007/s10531-015-0980-y>
- de Souza, H. N., de Goede, R. G. M., Brussaard, L., Cardoso, I. M., Duarte, E. M. G., Fernandes, R. B. A., Gomes, L. C., & Pulleman, M. M. (2012). Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome. *Agriculture, Ecosystems and Environment*, 146(1), 179–196. <https://doi.org/10.1016/j.agee.2011.11.007>
- de Souza, S. E. X. F., Vidal, E., Chagas, G. D. F., Elgar, A. T., & Brancalion, P. H. S. (2016). Ecological outcomes and livelihood benefits of community-managed agroforests and second growth forests in Southeast Brazil. *Biotropica*, 48(6), 868–881. <https://doi.org/10.1111/btp.12388>
- De França, C. G., Del Grossi, M. E., De, V. P. M. & Marques, A. (2009). *El censo agropecuario 2006 y la agricultura familiar en Brasil*. Retrieved from <https://repositorio.unb.br/handle/10482/14745>
- De Molina, M. G., Petersen, P. F., Peña, F. G., & Caporal, F. R. (2019). *Political agroecology: Advancing the transition to sustainable food systems*. CRC Press.
- Erbaugh, J. T., & Oldekop, J. A. (2018). Forest landscape restoration for livelihoods and well-being. *Current Opinion in Environmental Sustainability*, 32, 76–83. <https://doi.org/10.1016/j.cosust.2018.05.007>
- Erbaugh, J. T., Pradhan, N., Adams, J., Oldekop, J. A., Agrawal, A., Brockington, D., Pritchard, R., & Chhatre, A. (2020). Global forest restoration and the importance of prioritizing local communities. *Nature Ecology and Evolution*, 4(11), 1472–1476. <https://doi.org/10.1038/s41559-020-01282-2>
- ESRI. (2011). *ArcGIS desktop: Release 10*. Environmental Systems Research Institute.
- FAO. (2013). *Advancing agroforestry on the policy agenda; a guide for decision-makers*. (No. 1). Retrieved from <https://www.fao.org/3/i3182e/i3182e00.pdf>
- FAO. (2017). *Agroforestry for landscape restoration: Exploring the potential of agroforestry to enhance the sustainability and resilience of degraded landscapes*. <http://www.fao.org/3/b-i7374e.pdf>
- Fischer, J., Riechers, M., Loos, J., Martin-Lopez, B., & Temperton, V. M. (2021). Making the UN decade on ecosystem restoration a social-ecological Endeavour. *Trends in Ecology & Evolution*, 36(1), 20–28. <https://doi.org/10.1016/j.tree.2020.08.018>
- Francesconi, W., Ramchandran Nair, P., Stein, T. V., Levey, D. J., & Cullen, L. J. (2014). Agroforestry dissemination and the social learning theory in Pontal do paranapanema Center for Subtropical Agroforestry, UF View project Social Vulnerability and Environmental Risk View project. *The International Journal of Environmental Sustainability*. <https://doi.org/10.18848/2325-1077/CGP/v09i04/55101>
- Galetti, M., Eizirik, E., Beisiegel, B., Ferraz, K., Cavalcanti, S., Srbeke-Araujo, A. C., Crawshaw, P., Paviolo, A., Galetti, P. M., Jorge, M. L., Marinho-Filho, J., Vercillo, U., & Morato, R. (2013). Atlantic rainforest's jaguars in decline. *Science*, 342(6161), 930. https://www.academia.edu/5186415/Atlantic_Rainforest_s_Jaguars_in_Decline
- Global Partnership on Forest Landscape Restoration (GPFLR). (2019). *The Bonn challenge*. <http://www.bonnchallenge.org/>
- Graeb, B. E., Chappell, M. J., Wittman, H., Ledermann, S., Kerr, R. B., & Gemmill-Herren, B. (2016). The state of family farms in the world. *World Development*, 87, 1–15. <https://doi.org/10.1016/j.worlddev.2015.05.012>
- Grass, I., Loos, J., Baensch, S., Batáry, P., Librán-Embíd, F., Ficiyan, A., Klaus, F., Riechers, M., Rosa, J., Tiede, J., Udy, K., Westphal, C., Wurz, A., & Tschardtke, T. (2019). Land-sharing/-sparing connectivity landscapes for ecosystem services and biodiversity conservation. *People and Nature*, 1(2), 262–272. <https://doi.org/10.1002/pan3.21>
- Harvey, C. A., Rambeloso, A. M., Andrianjohanarivo, T., Andriamaro, L., Rasolohery, A., Randrianarisoa, J., Ramanahadray, S., Christie, M., Siwicki, E., Remoundou, K., Vélchez-Mendoza, S., & MacKinnon, J. L. (2018). Local perceptions of the livelihood and conservation benefits of small-scale livelihood projects in rural Madagascar. *Society and Natural Resources*, 31(9), 1045–1063. <https://doi.org/10.1080/08941920.2018.1484974>
- Holl, K. D. (2017a). Restoring tropical forests from the bottom up. *Science*, 355(6324), 455–456. <https://doi.org/10.1111/conl.12220>
- Holl, K. D. (2017b). Research directions in tropical forest restoration. *Annals of the Missouri Botanical Garden*, 102(2), 237–250. <https://doi.org/10.3417/2016036>
- IBGE. (2017). *IBGE—Instituto Brasileiro de Geografia e Estatística. Censo agropecuário 2017: resultados definitivos*. 2019. <https://biblioteca.ibge.gov.br/>

- gov.br/visualizacao/periodicos/3096/agro_2017_resultados_definitivos.pdf
- Instituto Brasileiro de Geografia e Estatística - IBGE. (2017). Censo Agropecuário 2017.
- IUCN. (2011). *Bonn Challenge | The Bonn Challenge is a global effort to restore 150 million hectares of the world's deforested and degraded lands by 2020*. <https://www.bonnchallenge.org/>
- IUCN. (2017). *Forest landscape restoration | IUCN*. <https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration>
- Jafari, M., & Ansari-Pour, N. (2018). Why, when and how to adjust your P values? Citation: Jafari M, Ansari-Pour N. why, when and how to adjust your P values? *Cell Journal*, 20(4), 604–607. <https://doi.org/10.22074/cellj.2019.5992>
- Joly, C. A., Metzger, J. P., Tabarelli, M., Joly, C. A., Joly, C. A., Metzger, J. P., & Tabarelli, M. (2014). Experiences from the Brazilian Atlantic Forest : Ecological findings and conservation initiatives Tansley review Experiences from the Brazilian Atlantic Forest: Ecological findings and conservation initiatives. *New Phytologist*, 204, 459–473. <https://doi.org/10.1111/nph.12989>
- Jose, S. (2012). Agroforestry for conserving and enhancing biodiversity. *Agroforestry Systems*, 85, 1–8. <https://doi.org/10.1007/s10457-012-9517-5>
- Kabalo, B. Y., Gebreyesus, S. H., Loha, E., & Lindtjørn, B. (2019). Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: a cohort analysis. *BMC Nutrition*, 5(1), 1–10. <https://doi.org/10.1186/S40795-019-0323-6>
- Lacerda, A. E. B., Hanisch, A. L., & Nimmo, E. R. (2020). Leveraging traditional agroforestry practices to support sustainable and agrobiodiverse landscapes in Southern Brazil. *Land*, 9(6), 176. <https://doi.org/10.3390/land9060176>
- Latawiec, A. E., Strassburg, B. B. N., Brancalion, P. H. S., Rodrigues, R. R., & Gardner, T. (2015). Creating space for large-scale restoration in tropical agricultural landscapes. *Frontiers in Ecology and the Environment*, 13(4), 211–218. <https://doi.org/10.1890/140052>
- Lazos-Chavero, E., Zinda, J., Bennett-Curry, A., Balvanera, P., Bloomfield, G., Lindell, C., & Negra, C. (2016). Stakeholders and tropical reforestation: Challenges, trade-offs, and strategies in dynamic environments. *Biotropica*, 48(6), 900–914. <https://doi.org/10.1111/btp.12391>
- Leakey, R. R. B. (2014). The role of trees in agroecology and sustainable agriculture in the tropics. *Annual Review of Phytopathology*, 52, 113–133. <https://doi.org/10.1146/annurev-phyto-102313-045838>
- Leakey, R., Schreckenberg, K., Shackleton, S., Wynberg, R., Shackleton, C., & Sullivan, C. (2006). Chapter 2: Trees and markets for agroforestry tree products: Targeting poverty reduction and enhanced livelihoods. In *World Agroforestry into the Future*. World Agroforestry Centre (ICRAF). Retrieved from <http://apps.worldagroforestry.org/downloads/Publications/PDFS/bc06142.pdf>
- Leonidio, A. (2009). Violências fundadoras: O Pontal do Paranapanema entre 1850 e 1930. *Ambiente & Sociedade*, 12(1), 37–48. <https://doi.org/10.1590/S1414-753X2009000100004>
- Liu, C. L. C., Kuchma, O., & Krutovsky, K. V. (2018). Mixed-species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. *Global Ecology and Conservation*, 15, e00419. <https://doi.org/10.1016/J.GECCO.2018.E00419>
- Loveridge, R., Sallu, S. M., Pasha, I. J., & Marshall, A. R. (2020). Measuring human wellbeing: A protocol for selecting local indicators. *Environmental Science and Policy*, 114, 461–469. <https://doi.org/10.1016/j.envsci.2020.09.002>
- Luintel, H., Bluffstone, R. A., & Scheller, R. M. (2018). The effects of the Nepal community forestry program on biodiversity conservation and carbon storage. *PLoS One*, 13(6), e0199526. <https://doi.org/10.1371/journal.pone.0199526>
- Maguire-Rajpaul, V. A., Rajpaul, V. M., McDermott, C. L., & Guedes Pinto, L. F. (2018). Coffee certification in Brazil: Compliance with social standards and its implications for social equity. *Environment, Development and Sustainability*, 22(3), 2015–2044. <https://doi.org/10.1007/S10668-018-0275-Z>
- Matos, F. A. R., Magnago, L. F. S., Gastauer, M., Carreiras, J. M. B., Simonelli, M., Meira-Neto, J. A. A., & Edwards, D. P. (2017). Effects of landscape configuration and composition on phylogenetic diversity of trees in a highly fragmented tropical forest. *Journal of Ecology*, 105(1), 265–276. <https://doi.org/10.1111/1365-2745.12661>
- Mazzini, E. (2007). *Assentamentos rurais no Pontal do Paranapanema - SP: Uma política de desenvolvimento regional ou de compensação social?*. Aleph.
- Mbow, C., Rosenzweig, C., Barioni, L. G., Benton, T. G., Shukla, P. R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D. C., Zhai, P., Slade, R., Connors, S., Van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., & Pathak, M., ... Malley, J. (2019). Food Security. In *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*.
- Mcgregor, A., Coulthard, S., & Camfield, L. (2015). *Measuring what matters - The role of well-being methods in development policy and practice*. <http://www.odi.org.uk/programmes/development-progress/valuing-progress>
- Melito, L. (2020, January 28). *No governo Bolsonaro, compras públicas de alimentos viram | Geral*. Brasil De Fato. <https://www.brasildefato.com.br/2020/01/28/no-governo-bolsonaro-compras-publicas-de-alimentos-viram-lenda>
- Melo, F. P. L., Pinto, S. R. R., Brancalion, P. H. S., Castro, P. S., Rodrigues, R. R., Aronson, J., & Tabarelli, M. (2013). Priority setting for scaling-up tropical forest restoration projects: Early lessons from the Atlantic forest restoration pact. *Environmental Science and Policy*, 33, 395–404. <https://doi.org/10.1016/j.envsci.2013.07.013>
- Meszaros, G. (2007). *The MST and the Rule of Law in Brazil* (p. 1). Law, Social Justice & Global Development Journal.
- Metzger, J. P., Esler, K., Krug, C., Arias, M., Tambosi, L., Crouzeilles, R., Acosta, A. L., Brancalion, P. H., D'albertas, F., Duarte, G. T., Garcia, L. C., Grytnes, J.-A., Hagen, D., Vitor, A., Jardim, F., & Kamiyama, C. (2017). Best practice for the use of scenarios for restoration planning. *Current Opinion in Environmental Sustainability*, 29, 14–25. <https://doi.org/10.1016/j.cosust.2017.10.004>
- Miccolis, A., Peneireiro, F. M., & Marques, H. R. (2019). Restoration through agroforestry in Brazil: Options for reconciling livelihoods with conservation. In M. van Noordwijk (Ed.), *Sustainable development through trees on farms: Agroforestry in its fifth decade* (pp. 209–231). World Agroforestry (ICRAF) Southeast Asia Regional Program. Retrieved from <http://apps.worldagroforestry.org/downloads/Publications/PDFS/BC19019.pdf>
- Miccolis, A., Peneireiro, F. M., Vieira, D. L. M., Marques, H. R., & Hoffmann, M. R. M. (2017). Restoration through agroforestry: Options for reconciling livelihoods with conservation in the cerrado and caatinga biomes in Brazil. *Experimental Agriculture*, 55(May), 1–18. <https://doi.org/10.1017/s0014479717000138>
- Mittermeier, R. A., Fonseca, P., Gil, R., Hoffmann, M., Pilgrim, J., Brooks, T., Goettsch Mittermeier, C., Lamoreux, J., & Fonseca, A. B. G. (2005). *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. Cermex.
- MMA. (2015). *Fifth national report to the convention on biological diversity - Brazil*. <https://www.cbd.int/doc/world/br/br-nr-05-en.pdf>
- Monique Amâncio de Carvalho, M., de Carvalho, R., Feitosa Martins, C., & da Silva Mourão, J. (2014). Meliponiculture in Quilombola communities of Ipiranga and Gurugi, Paraíba state, Brazil: An ethnoecological approach. *Journal of Ethnobiology and Ethnomedicine*. <http://www.ethnobiomed.com/content/10/1/3>

- Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences of the United States of America*, 104(50), 19680–19685. <https://doi.org/10.1073/pnas.0701855104>
- MST. (2017). *Cerca de 400 mil ha da Mata Atlântica serão recuperados com sistemas agroflorestais*. <https://mst.org.br/2017/02/14/cerca-de-400-mil-ha-da-mata-atlantica-serao-recuperados-com-sistemas-agroflorestais/>
- MST. (2021). *MST lança aplicativo para acompanhar o plantio de árvores em todo país*. Retrieved from <https://mst.org.br/2021/02/03/mst-lanca-aplicativo-para-acompanhar-o-plantio-de-arvores-em-todo-pais/>
- Muñoz, E. F. P., Niederle, P. A., de Gennaro, B. C., & Roselli, L. (2021). Agri-food markets towards agroecology: Tensions and compromises faced by small-scale farmers in Brazil and Chile. *Sustainability*, 13(6), 3096. <https://doi.org/10.3390/SU13063096>
- Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. B., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, 403(6772), 853–858. <https://doi.org/10.1038/35002501>
- Newing, H. S. (2010). *Conducting research in conservation: A social science perspective*. Routledge.
- Nolasco, C., Soler, L., Freitas, M., Lahsen, M., & Ometto, J. (2017). Scenarios of vegetable demand vs. production in Brazil: the links between nutritional security and small farming. *Land*, 6(3), 49. <https://doi.org/10.3390/land6030049>
- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*. <https://doi.org/10.1177/1609406917733847>
- NYDF Assessment Partners. (2019). *Protecting and restoring forests: A story of large commitments yet limited progress*. New York Declaration on Forests Five-Year Assessment Report. Climate Focus (coordinator and editor). Online at: forestdeclaration.org
- Ota, L., Chazdon, R., Herbohn, J., Gregorio, N., Mukul, S. A., & Wilson, S. J. (2020). Achieving quality forest and landscape restoration in the tropics. *Forests*, 11(8), <https://doi.org/10.3390/f11080820>
- Pacheco, R., Rajão, R., Van Der Hoff, R., & Soares-Filho, B. (2021). Will farmers seek environmental regularization in the Amazon and how? Insights from the Rural Environmental Registry (CAR) questionnaires. *Journal of Environmental Management*, 284, 112010. <https://doi.org/10.1016/j.jenvman.2021.112010>
- Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., Hoagwood, K., Palinkas, A. L., Author Lawrence Palinkas, C. A., & Lomas Feldman Professor of Social Policy, F. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research HHS Public Access. *Administration and Policy in Mental Health*, 42(5), 533–544. <https://doi.org/10.1007/s10488-013-0528-y>
- Palomo-Campesino, S., Palomo, I., Moreno, J., & González, J. (2018). Characterising the rural-urban gradient through the participatory mapping of ecosystem services: Insights for landscape planning. *One Ecosystem*, 3, e24487. <https://doi.org/10.3897/ONECO.3.E24487>
- Paulino, E. T. (2014). The agricultural, environmental and socio-political repercussions of Brazil's land governance system. *Land Use Policy*, 36, 134–144. <https://doi.org/10.1016/j.landusepol.2013.07.009>
- Paviolo, A., De Angelo, C., Ferraz, K. M. P. M. B., Morato, R. G., Martinez Pardo, J., Srbek-Araujo, A. C., Beisiegel, B. D. M., Lima, F., Sana, D., Xavier da Silva, M., Velázquez, M. C., Cullen, L., Crawshaw Jr, P., Jorge, M. L. S. P., Galetti, P. M., Di Bitetti, M. S., de Paula, R. C., Eizirik, E., Aide, T. M., ... Azevedo, F. (2016). A biodiversity hotspot losing its top predator: The challenge of jaguar conservation in the Atlantic Forest of South America. *Nature Publishing Group*, <https://doi.org/10.1038/srep37147>
- Pimenta, H., Antonio, V., Rosa, L., Filho, R., Carlos, J., Lima, A., & De Janeiro, R. (1991). *Classificação da Vegetação Brasileira, Adaptada a um Sistema Universal*. Ministério da economia, fazenda e planejamento fundação instituto brasileiro de geografia e estatística - IBGE.
- Pinto, S. R., Melo, F., Tabarelli, M., Padovesi, A., Mesquita, C. A., de Mattos Scaramuzza, C. A., Castro, P., Carrascosa, H., Calmon, M., Rodrigues, R., César, R. G., & Brancalion, P. H. S. (2014). Governing and delivering a biome-wide restoration initiative: The case of Atlantic Forest Restoration Pact in Brazil. *Forests*, 5(9), 2212–2229. <https://doi.org/10.3390/f5092212>
- Pontes, F. A., & Ferrante, V. L. S. B. (2018). Produção leiteira nos assentamentos rurais do Pontal do Paranapanema: políticas públicas e organização social, seus desafios e dilemas (VIII simpósio sobre reforma agrária e questões rurais terra, trabalho e lutas no século XXI: projetos em disputa).
- Potapov, P., Laestadius, L., & Minnemeyer, S. (2011). *Global map of forest landscape restoration opportunities*. World Resources Institute. www.wri.org/forest-restoration-atlas
- Prist, P. R., Prado, A., Tambosi, L. R., Umetsu, F., de Arruda Bueno, A., Pardini, R., & Metzger, J. P. (2021). Moving to healthier landscapes: Forest restoration decreases the abundance of Hantavirus reservoir rodents in tropical forests. *Science of the Total Environment*, 752, 141967. <https://doi.org/10.1016/j.scitotenv.2020.141967>
- QSR International. (1999). *NVivo qualitative data analysis software [Software]*. <https://qsrinternational.com/nvivo/nvivo-products/>
- R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <https://www.R-project.org/>
- Reed, J., van Vianen, J., Barlow, J., & Sunderland, T. (2017). Have integrated landscape approaches reconciled societal and environmental issues in the tropics? *Land Use Policy*, 63, 481–492. <https://doi.org/10.1016/j.landusepol.2017.02.021>
- Reis, B. P., de Oliveira Neto, S. N., Sarcinelli, T. S., & Martins, S. V. (2020). Farmer's Perception about Agroforestry Systems for Legal Reserves in the Region of São Mateus, Espírito Santo, Brazil. *Floresta e Ambiente*, 27(1). <https://doi.org/10.1590/2179-8087.031317>
- Rezende, C. L., Scarano, F. R., Assad, E. D., Joly, C. A., Metzger, J. P., Tabarelli, M., Fonseca, G. A., & Mittermeier, R. A. (2018). From hotspot to hopespot: An opportunity for the Brazilian Atlantic. *Perspectives in Ecology and Conservation*. <https://doi.org/10.1016/j.pecon.2018.10.002>
- Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. (2009). The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? *Implications for Conservation*. *Biological Conservation*, 142(6), 1141–1153. <https://doi.org/10.1016/j.biocon.2009.02.021>
- Rocha, C., Burlandy, L., & Maluf, R. (2012). Small farms and sustainable rural development for food security: The Brazilian experience. *Development Southern Africa*, 29(4), 519–529. <https://doi.org/10.1080/0376835X.2012.715438>
- Sabourin, E., Craviotti, C., & Milhorance, C. (2020). The dismantling of family farming policies in Brazil and Argentina. *International Review of Public Policy*, 2(1), 45–67. <https://doi.org/10.4000/irpp.799>
- Sagastuy, M., & Krause, T. (2019). Agroforestry as a biodiversity conservation tool in the Atlantic Forest? Motivations and limitations for small-scale farmers to implement agroforestry systems in North-Eastern Brazil. *Sustainability*, 11(24), 6932. <https://doi.org/10.3390/su11246932>
- Sakai, P., Afionis, S., Favretto, N., Stringer, L. C., Ward, C., Sakai, M., Weirich Neto, P. H., Rocha, C. H., Alberti Gomes, J., de Souza, N. M., & Afzal, N. (2020). Understanding the implications of alternative bioenergy crops to support smallholder farmers in Brazil. *Sustainability*, 12(5), 2146. <https://doi.org/10.3390/su12052146>
- Sapkota, R. P., Stahl, P. D., & Rijal, K. (2018). Restoration governance: An integrated approach towards sustainably restoring degraded ecosystems. *Environmental Development*, 27, 83–94. <https://doi.org/10.1016/j.envdev.2018.07.001>

- Shennan-Farpon, Y. (2022). Agroforestry use by smallholder farmers - Raw questionnaire data (anonymised) [Dataset]. *University College London*, <https://doi.org/10.5522/04/17145551.v1>
- Slovak, P. (2017). *Local communities and private protected areas in the Atlantic Forest of Brazil: Implications for sustainable development and nature conservation* (PhD Thesis). University of Sussex. <http://sro.sussex.ac.uk/72319/1/Slovak%2CPeterpdf>
- SOS Mata Atlântica & INPE. (2019). *Atlas dos Remanescentes Florestais da Mata Atlântica - Relatório Técnico 2017-2018*. <http://mapas.sosma.org.br>
- Stanturf, J. A., Kleine, M., Mansourian, S., Parrotta, J., Madsen, P., Kant, P., Burns, J., & Bolte, A. (2019). Implementing forest landscape restoration under the Bonn Challenge: A systematic approach. *Annals of Forest Science*, 76(2), 1-21. <https://doi.org/10.1007/s13595-019-0833-z>
- Strassburg, B. B. N., Beyer, H. L., Crouzeilles, R., Iribarrem, A., Barros, F., de Siqueira, M. F., Sánchez-Tapia, A., Balmford, A., Sansevero, J. B. B., Brancalion, P. H. S., Broadbent, E. N., Chazdon, R. L., Filho, A. O., Gardner, T. A., Gordon, A., Latawiec, A., Loyola, R., Metzger, J. P., Mills, M., ... Uriarte, M. (2019). Strategic approaches to restoring ecosystems can triple conservation gains and halve costs. *Nature Ecology and Evolution*, 3(1), 62-70. <https://doi.org/10.1038/s41559-018-0743-8>
- Strassburg, B. B. N., Iribarrem, A., Beyer, H. L., Cordeiro, C. L., Crouzeilles, R., Jakovac, C. C., Braga Junqueira, A., Lacerda, E., Latawiec, A. E., Balmford, A., Brooks, T. M., Butchart, S. H. M., Chazdon, R. L., Erb, K.-H., Brancalion, P., Buchanan, G., Cooper, D., Díaz, S., Donald, P. F., ... Visconti, P. (2020). Global priority areas for ecosystem restoration. *Nature*, 586(7831), 724-729. <https://doi.org/10.1038/s41586-020-2784-9>
- Suding, K. N. (2011). Toward an era of restoration in ecology: Successes, failures, and opportunities ahead. *Annual Review of Ecology Evolution and Systematics*, 42, 465-487. <https://doi.org/10.1146/annurev-ecolsys-102710-145115>
- Tamburini, G., Bommarco, R., Wanger, T. C., Kremen, C., van der Heijden, M. G. A., Liebman, M., & Hallin, S. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Science Advances*, 6(45). <https://doi.org/10.1126/SCIADV.ABA1715>
- Thorkildsen, K. (2014). Social-ecological changes in a quilombola community in the atlantic forest of Southeastern Brazil. *Human Ecology*, 42, 913-927. <https://doi.org/10.1007/s10745-014-9691-3>
- Trevisan, A. C. D., Schmitt-Filho, A. L., Farley, J., Fantini, A. C., & Longo, C. (2016). Farmer perceptions, policy and reforestation in Santa Catarina, Brazil. *Ecological Economics*, 130, 53-63. <https://doi.org/10.1016/j.ecolecon.2016.06.024>
- Uezu, A. (2006). *Composição e estrutura da comunidade de aves na paisagem fragmentada do Pontal do Paranapanema*. Universidade de São Paulo.
- Uezu, A., Beyer, D. D., & Metzger, J. P. (2008). Can agroforest woodlots work as stepping stones for birds in the Atlantic forest region? *Biodiversity and Conservation*, 17, 1907-1922. <https://doi.org/10.1007/s10531-008-9329-0>
- Uezu, A., & Metzger, J. P. (2016). Time-lag in responses of birds to Atlantic Forest Fragmentation: Restoration opportunity and urgency. *PLoS One*, 11(1), e0147909. <https://doi.org/10.1371/journal.pone.0147909>
- UN Environment (2019). *New UN Decade on Ecosystem Restoration offers unparalleled opportunity for job creation, food security and addressing climate change*. <https://www.unenvironment.org/news-and-stories/press-release/new-un-decade-ecosystem-restoration-offers-unparalleled-opportunity>
- van der Sluijs, J. P., & Vaage, N. S. (2016). Pollinators and global food security: The need for holistic global stewardship. *Food Ethics*, 1, 75-91. <https://doi.org/10.1007/S41055-016-0003-Z>
- Verchot, L., De Sy, V., Romijn, E., Herold, M., & Coppus, R. (2015). *Forest restoration Getting serious about the "plus" in REDD+*. <https://www.cifor.org/library/7045>
- White, P. C. L., Jennings, N. V., Renwick, A. R., & Barker, N. H. L. (2005). Questionnaires in ecology: A review of past use and recommendations for best practice. *Journal of Applied Ecology*, 42(3), 421-430. <https://doi.org/10.1111/j.1365-2664.2005.01032.x>
- Woodhill, J., Hasnain, S., & Griffith, A. (2020). Farmers and food systems What future for small-scale agriculture?
- Woodhouse, E., Homewood, K. M., Beauchamp, E., Clements, T., McCabe, J. T., Wilkie, D., & Milner-Gulland, E. J. (2015). Guiding principles for evaluating the impacts of conservation interventions on human well-being. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370(1681). <https://doi.org/10.1098/rstb.2015.0103>
- WRI. (2016). *Initiative 20x20 | World Resources Institute*. <https://www.wri.org/our-work/project/initiative-20x20>

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Shennan-Farpón, Y., Mills, M., Souza, A., & Homewood, K. (2022). The role of agroforestry in restoring Brazil's Atlantic Forest: Opportunities and challenges for smallholder farmers. *People and Nature*, 00, 1-19. <https://doi.org/10.1002/pan3.10297>