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Landholders' perceptions on legal reserves and agricultural intensification: Diversity and implications for forest conservation in the eastern Brazilian Amazon

Daniel Pinillos [a,b,*], René Poccard-Chapuis [b], Felix J.J.A. Bianchi [a], Marc Corbeels [b,c], Carl J. Timler [a], Pablo Tittonell [b,d,e], Maria Victoria R. Ballester [f], Rogier P. Schulte [a]

[a] Farming Systems Ecology, Wageningen University & Research, Bornsesteeg 48, Building 109, P.O. Box 430, 6708 PE Wageningen, the Netherlands
[b] Agroecology and Sustainable Intensification of Annual Crops (AIDA), University of Montpellier, French Agricultural Research Centre for International Development (CIRAD), Avenue Agropolis, 34398 Montpellier Cedex 5, France
[c] International Maize and Wheat Improvement Center (CIMMYT), Sustainable Intensification Program, United Nations Avenue, P.O. Box 1041-00621, Gigiri, Nairobi, Kenya
[d] Agroecology, Environment and Systems Group, Instituto de Investigaciones Forestales y Agropecuarias de Bariloche (IFAB), INTA-CONICET, Av. De Los Pioneros 2350 (CP: 8400), San Carlos de Bariloche, Río Negro, Argentina
[e] Groningen Institute of Evolutionary Life Sciences, Groningen University, Nijenborgh 7 9747 AG, P.O. Box 11103, 9700 CC Groningen, the Netherlands
[f] Environmental Analysis and Geoprocessing Laboratory, Center for Nuclear Energy in Agriculture, University of São Paulo, Av. Centenário, 303, Piracicaba, SP, 13416-000, Brazil

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ABSTRACT

Forest conservation on privately owned lands is a cornerstone of the Brazilian environmental policy framework. Brazilian legislation requires that all farms in the country maintain and protect forest areas known as Legal Reserves. Since Legal Reserves have major implications for forest conservation and agricultural production, it is key that we understand landholders' perceptions towards Legal Reserves. We applied Q methodology to identify different perspectives of medium and large landholders on Legal Reserves and their relation to agricultural intensification in the municipality of Paragominas, eastern Amazon. We conducted 31 interviews in which landholders sorted 36 statements in a quasi-normal distribution array. Three groups of landholders were identified: 1) Land use planning enthusiasts (n = 16) were interested in zoning initiatives to explore alternative landscape designs and legislation that may deliver better conservation and production outcomes; 2) Agrochemical-based agriculture supporters (n = 7) held the most critical views against Legal Reserves and perceived their costs as higher than the potential environmental and life quality benefits; 3) Policy complacent-market responders (n = 4) showed no interest in Legal Reserves reforms and were the most market driven group.. While Paragominas has achieved notable successes in halting large-scale deforestation through a social "Green Municipality" pact, addressing persisting forest degradation and fragmentation in the region remains a key priority. Local governance initiatives that account for multi-stakeholder perceptions on forest conservation can foster dialogue and mutual understanding to effectively conserve and restore Legal Reserves. Insights on large landholders' perceptions on Legal Reserves can inform such governance processes to reconcile forest conservation and sustainable agricultural intensification in Paragominas.

1. Introduction

Reconciling agricultural production and forest conservation is a major challenge in many parts of the world. In tropical countries, deforestation is often linked to the expansion of croplands and pastures as global demand for agricultural commodities keeps increasing (Angelsen and DeFries, 2010; Henders et al., 2018). In the Amazon region of Brazil, the development of agriculture has been linked to deforestation since its colonization in the 1960s. Currently roughly 40% of the country's total cattle population and soybean monocultures are located in the Amazon biome (Koch et al., 2019). In the last forty years, the Brazilian Amazon forest has lost 20% of its area (da Cruz et al., 2021)

* Corresponding author at: Farming Systems Ecology, Wageningen University & Research, Bornsesteeg 48 Building 109 6708 PE Wageningen, the Netherlands.
E-mail address: danielalfredopinillos@gmail.com (D. Pinillos).

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even though policies requiring forest conservation on private farms date back almost ninety years. As a result, stricter policy measures were put in place since the beginning of the 2000s such as the expansion of protected areas and the enforcement of command-and-control measures on rural landholdings leading to an 80% drop-in deforestation rates between 2004 and 2014 (Soares-Filho et al., 2010; Börner et al., 2015; PRODES, 2017).

The most important piece of conservation legislation on private land in Brazil is the so-called Legal Reserve (LR), which requires landowners to maintain a fixed amount of area as native vegetation within their properties to protect biodiversity, varying from 80% in the Amazon, 35% in transition zones between the Amazon and Cerrado, and 20% in the Cerrado, Atlantic forest, Caatinga, Pantanal and Pampa biomes. The legal concept of LRs is unique to Brazil and it is also the most controversial piece of environmental legislation because it limits agricultural activities within rural landholdings without apparent compensation (Santos, 2004). Legislation, however, does allow forest logging for commercial purposes within LRs under an approved management plan[1] including the introduction of exotic species (inciso I-III do Artigo 22, Lei 12.651/2012). Currently, LRs cover one third of Brazil's native vegetation and thus, play a key role for biodiversity protection and provisioning of a wide range of ecosystem services for Brazilian society at large (Metzger et al., 2019).

At the same time, efforts to link compliance of LRs with trade of agricultural commodities through value chain interventions have recently emerged in the Amazon. These include most notably a soybean moratorium which was the first voluntary zero-deforestation agreement in the region where soybean traders committed to avoid purchasing soybean coming from deforested lands after July 2006 (Gibbs et al., 2015). Other examples include the Federal Public Prosecutor's Offices (Ministério Público Federal, or MPF) TAC agreement (Terms of Adjustment of Conduct) and the G4 agreement, both signed in 2009, where meatpacking companies committed to block trade with ranches with illegal deforestation (G4 agreement prohibits any forest clearing) or unregistered in the Environmental Rural Registry (CAR) (Gibbs et al., 2016). Simultaneously, frequent modifications and political disputes around LRs have caused confusion and juridical uncertainty in its application and hampered its effective adoption (Mueller, 2018; da Fonseca, 2019). Even if effectively implemented however, there is a need for policy tools that go beyond the mere maintenance of forest cover that take into account aspects such as forest disturbance (e.g., selective logging and forest fires) and habitat fragmentation (Barlow et al., 2016).

While rural landholders are in charge of operationalizing the LR in the Brazilian Amazon, they are at the same time its major critics presumably because of perceived disadvantages related to, e.g., financial burden, obstacle to develop infrastructure, and liability for forest fires. This discontent fits within a historical pattern of landownership in the Brazilian Amazon that has been characterized by violence and conflicts between different social actors (Simmons et al., 2002; Simmons, 2005). Thus, the exercise of private property in the region has to be understood in the context of tension between wealth acquisition through the exploitation of natural resources and forest conservation and protection (da Fonseca, 2019). This convoluted land governance context has far reaching implications for forest and biodiversity conservation and for land management. Therefore, understanding landholders' perspectives on LR is fundamental for any prospect of environmental governance that aims at forest and biodiversity conservation in agricultural commodity frontiers of the eastern Amazon region.

Here we assess landholders' perceptions on LRs in northern Pará State to further understand if LRs and agricultural intensification are perceived as antagonistic, synergistic, or if more nuanced views exist that may help to elucidate entry points for enhanced implementation and compliance. We define perception as an individual's interpretation of external stimuli based on prior experiences which closely relates to "attitude" as a predisposition to behave in a particular way (Pickens, 2005; Lindsay and Norman, 2013). To assess these perceptions, we applied Q methodology, a method developed in the field of psychology to understand individuals' subjective viewpoints based on quantitative and qualitative data (Stephenson, 1935; Brown, 1993, 1996). This methodology has been used in the Amazon region to study perspectives on agricultural technologies (Pereira et al., 2016), REDD+ (Schneider et al., 2015), forest fires (Cammelli et al., 2019), and jaguar (*Panthera onca*) conservation (Bredin et al., 2018).

2. Historical and political background of Legal reserves

The first attempt to protect forests on private lands in the Brazilian Amazon dates back to the first Forest Code from 1934 (Lei Federal no.23.793/34) that stipulated no landowner could clear more than 75% of the forest within the property limits (da Fonseca, 2019). Later in 1965, a new Forest Code (Lei Federal no.4.771/65) was issued prohibiting forest exploitation in the absence of an authorized management plan as well as clear cuts beyond 50% of the property area (da Fonseca, 2019). The 1965 Forest Code defined LR as a forest area inside rural properties necessary for the sustainable use of natural resources, the conservation and rehabilitation of ecological processes, and the conservation of biodiversity. It also defined the location and dimensions of Areas of Permanent Protection[2] (APPs) for the protection of riparian forests, springs and slopes (Brasil, 1965).

In 1989, a federal law (Lei Federal no. 7.803) introduced the obligation for rural landowners to register LRs in the official Property Registry (Registros de Imóveis), establishing a formal mechanism to prove the maintenance of LRs (Brasil, 1989; Santos Santos, 2004; Castro, 2013). This signified a radical change for landholders from the 1970–1980 period when government investments, tax incentives and subsidized credits for large cattle ranching were major drivers for colonization and deforestation of the Amazon (Fearnside, 2005).

In 2012, the Native Vegetation Protection Law (NVPL) (Lei no. 12.651) replaced the 1965 Forest Code with important implications for LRs and APPs (Brancalion et al., 2016). Even though this legislation aimed to preserve biodiversity and contain the expansion of agriculture into native vegetation, several subsequent modifications compromised forest conservation. For instance, there was an amnesty for 37 M ha of illegal deforestation that under previous regulations was subject to forest restoration (Guidotti et al., 2017). Furthermore, buffer areas for APPs along rivers were reduced from 30 to 500 m to 5–100 m (Kröger, 2017), which implied that 5.7 M ha of riparian forest could remain deforested in the state of Pará alone (Nunes et al., 2019). Another amendment included a forest trading mechanism that allowed landholders who deforested more than was legally allowed before 2008 to buy Environmental Reserve Quotas (CRA) to compensate for forest deficits. Legislation (Decreto no. 9.640/2018) established that CRA can be issued on forest surpluses of existing LRs when forest cover proportions are higher than those defined by the state's Ecological-

[1] LRs in the Amazon are allowed to extract up to 30 m^3 in logs/ha with cycles of 35 years, and 10 m^3 in logs/ha with cycles of 10 years. (Brancalion et al., 2012). Despite being allowed by legislation under a management plan, the actual sustainability of these have been put into question c.f., (Fearnside, 2017).

[2] The definition of the APP is related to geomorphology and the transition between aquatic and terrestrial systems of ecological fragility both in urban and rural areas; LRs are meant for the protection of natural vegetation specifically in rural properties and can be economically exploited under a sustainable management plan (Pereira et al., 2017). LRs and APPs also differ from Environmental Protection Areas (Área de Proteção Ambiental, APAs) which are one category of federal conservation units both in public or private lands that allow human occupation as they tend cover large areas such as a basin (Olavo Leite, 2015).

Economic Zoning Plan (EEZ) (see below) (Brasil, 2018). The NVPL also advanced new control measures including the Environmental Rural Registry (CAR), which provides a digital framework to monitor LRs, and the Rural Environmental License (LAR), which regulates activities within farms, CRA trade, and access to rural credits.

In 2019, however, influential senators pushed for a law amendment (Projeto de Lei. 2362/19) aiming at eliminating LRs altogether. Its supporters argued that LRs impede the development of the agribusiness sector and violate property rights. Eliminating LRs would mean that 167 M ha could be legally deforested in Brazil (Metzger et al., 2019). The proposal was challenged by sectors of society as well as by national research and conservationist institutions and after an open letter signed by more than a hundred Brazilian scientists was issued, the proposal was dropped (Globo Rural, 2019).

The relaxation of provisions in the new forest legislation in 2012, and the 2019 attempt to dismantle LRs, exemplify how factions of economic and political sectors have historically framed the forest as idle lands impeding Brazil's modernization (Fearnside, 2008; Kröger, 2017, 2019). In contemporary times these actors embody the agribusiness and landowners' caucus (i.e., Ruralista or "ruralist") advancing a political-economic agenda that prioritizes private land ownership as guarantor of resources, generally in opposition to social movements, of which most fiercely, the Landless Workers' Movement (Movimento dos Trabalhadores Rurais Sem Terra, MST) (de Mendonça, 1997; Lima, 2016). For the Ruralista, the agribusiness sector and the production of export commodities provide both an economic engine and vision for the development of rural Brazil (Lima, 2016). In this paper we investigate perceptions towards LR and agricultural intensification from medium and large landholders because these are stakeholders that a priori ascribe to the Ruralista vision of development in the Brazilian Amazon, and because they possess most of the land and consequently most of the forest under a LR requirement in the region. Elucidating their perceptions on LR can therefore provide pathways for consensus towards effective forest conservation in the eastern Amazon.

3. Methods

3.1. Study area

Our study was carried out in the north-eastern region of Pará State in the municipality of Paragominas (19,342 km^2). The municipality was founded in 1965 in proximity to the federal road BR-010 that connects to the capital Brasilia (Verissimo et al., 1992). For six decades, this region was exposed to land degradation and deforestation due to the activities of pioneers who originated from other regions of the country and opened and expanded the agricultural frontier (Poccard-Chapuis et al., 2014). These activities initially consisted of extensive cattle ranching, followed by intense logging during the 1980s until the late 1990s, and diversified into eucalyptus plantations and soybean monocultures since the early 2000s (Veríssimo et al., 2002; Piketty et al., 2015).

In 2008, the municipality was blacklisted by the Federal Government as one of the highest deforester municipalities in the region. This brought the imposition of punitive measures (i.e., land embargos, credit restrictions and fines for illegal activities) conditioned to reducing deforestation under 40 km^2/year, deforestation rates below 60% of the average rate from the past two years, and having 80% of the territory registered in the CAR (Piketty et al., 2015). In response, a social pact formed by the rural elite and the municipal government launched the Green Municipality Initiative to end large-scale deforestation and register each rural property in the CAR (Viana et al., 2016).

The required proportion of LRs in Paragominas can vary for each landholding as the NVPL allows a resizing from 80 to 50% of the total farm when a state has an approved EEZ plan developed by the state's Environmental Secretary, and at least 65% of the state is covered by national parks or public conservation units. Therefore, Pará State legislation (Lei Stadual no.7.243/2009) allows the reduction of LRs to 50% for farms inside consolidation zones (i.e., areas delimited by the EEZ that were deforested up to July 2008) that acquired forest liability before May 2005. According to the CAR database (http://www.car.gov.br/publico/imoveis/index), 53% of the 2259 registered landholdings in Paragominas comply with the LR and APP requirements (covering 1 M ha), 44% of the registered landholdings are pending approval due to some anomaly (covering 0.84 M ha), and 3% (63,000 ha) have had its approval cancelled due to misinformation or infractions. Paragominas, nevertheless, has a positive balance of LR of 0.36 M ha (Nunes et al., 2016), although roughly half of its APPs are deforested (Nunes et al., 2014).

Despite being an old forest frontier, more than half of Paragominas is still covered by forest (Table 1). Moreover, since large-scale deforestation in Paragominas has been under control since 2010 (Brandao et al., 2020), it may be considered a consolidated frontier with relatively high land prices. This, in addition to access to national and international markets of commodities through the federal highway BR-010 (Pinillos et al., 2020), implies higher opportunity costs for LRs in Paragominas than in other municipalities of the region. Therefore, studying the perceptions of LR in Paragominas is representative of similar consolidated Amazon frontiers and may provide anticipatory insights for other less advanced frontiers in the region.

3.2. Q methodology

Q methodology is a method originating in the field of psychology to study people's subjectivity to explore individual's viewpoints on an issue and to cluster respondents into groups (Brown, 1993). Therefore, Q methodology describes a population of ideas in relation to other ideas rather than in isolation. Q methodology is implemented through a statements-sorting exercise where participants receive a deck of cards with printed statements and a board with a fixed sorting distribution (see below). The construction of our statements regarding LR was based on views expressed by landholders during semi-structured interviews that were conducted prior to the sorting exercise. Clustering of opinions is then based on a factor analysis when similar statements significantly load on the same factor allowing for interpretation and narrative articulation (Brown, 1993, 1996; Ockwell, 2005).

3.2.1. Sample selection

Q studies usually follow stratified sampling (Lee, 2017), but given the contemptuous nature of the topic in question (i.e., LR), we decided to follow a random approach to avoid the sole inclusion of participants presumably open to discuss LRs. Nor was our objective to generalize our results to the entire population. Accordingly, we aimed for our sample to include sufficient diversity of landholders to allow for contrasting patterns of perceptions on LR. Selection of participants was based on a random sample that we generated by associating random numbers to the online CAR database with properties larger than 300 ha. We selected

Table 1
Land use and land cover classes and area size for Paragominas in 2019.

Land use/land cover category	ha	%
Forest[a]	1,313,816	67.9%
Agriculture[b]	130,837	6.8%
Pasture	477,009	24.7%
Mining	2936	0.2%
Urban infrastructure	2704	0.1%
Water bodies	6918	0.4%
Total	**1,934,220**	100%

Data source: Mapbiomas (https://mapbiomas.org/estatisticas).

[a] Approximately 26% corresponds to secondary forest (340,000 ha) and 1% to forest plantations (13,300 ha) (Piketty et al., 2015). The rest corresponds to primary forest with different degrees of forest degradation due to fire, selective logging or both (Martins et al., 2013; Berenguer et al., 2014; Bourgoin et al., 2018).

[b] 84% of agriculture is under soybean cultivation (110,173 ha).

properties larger than 300 ha as this landholder population represents medium- and large-scale landholders, so-called "fazendeiros", who hold by far most of the land in Paragominas and excludes smallholder family farmers (average size 25 ha), who hold less land.[3]

3.2.2. Semi-structure interviews for statement formulation

During the first phase of our fieldwork in March 2018, we conducted 31 farm surveys on farm structural characteristics followed by semi-structured interviews that we initiated by asking landholders two questions: (i) what requirements are needed for the intensification of your farm and increase production? And (ii) how do you perceive the requirement of LR in the region? The reason for asking these two questions in this specific order was first, that by starting the conversation focusing on agricultural intensification, we were able to ease the way for discussing the likely uncomfortable topic of LR in a more nuanced way. The second reason is that we aimed at understanding perceptions towards LR in connection to agricultural intensification, i.e., do landholders perceive these as synergistic, antagonistic, or other. We did not provide landholders with a specific definition of agricultural intensification as we sought to capture landholders' own ideas and definitions.

The semi-structured interviews entailed a 60–90-min conversation with each landholder. After each interview, we assembled the main ideas expressed by the participant into statements regarding LR, agricultural intensification or a combined statement of both topics. This step followed a qualitative content analysis approach (Mayring, 2014; Erlingsson and Brysiewicz, 2017) to code and categorize statements into three main categories i.e., "Agricultural intensification (AI)", "Legal Reserve (LR)", and "Legal Reserve and agricultural intensification (LR-AI)". From this analysis a total of 36 statements were selected as the final pool of statements (i.e., Q-concourse) to avoid overlap and maintain representativeness of opinions expressed during the semi-structured interviews (Table 2).

3.2.3. Q sorting and wrapping-up discussions

The 36 statements were printed on numbered cards to be sorted in a pre-formed, eleven-column, normal distribution pattern (i.e., forced distribution as participants were forced to distribute statements) from "I completely agree (+5)" on the right, through "I feel neutral or indifferent (0)" in the middle, to "I completely disagree (-5)" on the left (Fig. 1). In May 2018, landholders were revisited and conducted the card-sorting exercise. The reasons for their particular sorting were discussed afterwards and provided an opening to discuss contentious topics that otherwise would have been difficult to approach in a regular semi-structured interview. We report some of these views in the Discussion section of this paper.

3.2.4. Factor analysis

The scores of the 31 interviews (i.e., Q-sorts) were arranged in a matrix (36 × 31) with statements as rows, and Q-sorts as columns to perform factor analysis. The number of factors were assessed based on the Latent Root Criterion (i.e., eigenvalues larger than 1), variance explained (at least 40%), number of Q-sorts significantly loading (Table A1 of the Appendix), and feasibility for interpretation (Hair et al., 1998, 2006). The factor score array delivered the prototypical sort and indicated distinguishing statements (i.e., statements highlighted in the analysis as significant to the interpretation of a particular factor at a significance level between $p \leq 0.05$ to $p \leq 0.001$, see Table A2 and A3 of the Appendix) associated with each factor calculated as the weighted average of the Q-sorts. Interpreting distinguishing statements (Table A2) and prototypical sorts (Table A3) allowed articulating the common perspective and narrative of each factor (Kamal and Grodzinska-Jurczak, 2014). Factor analysis was conducted in R 4.1 using the package qmethod (Zabala, 2014).

4. Results

We extracted three factors (i.e., viewpoints) that accounted for 47% of the variance (Table 3). Factor loads indicated the association of each respondent to the three different factors. From the 31 Q-sorts, 16, 7 and 5 loaded significantly on Factor 1, 2, and 3, respectively. The responses of one participant loaded negatively for factor 3 (Q-sorts 1) denoting reverse viewpoints. This so called "bipolar" participant was not interpreted as separate factor but was examined individually. Furthermore, three sorts did not load significantly for any factor (i.e., unflagged sorts) and were left out of the interpretation (Table A1 of the Appendix). There were five consensual statements, three of them belong to the AI category (S13, S18 and S19), one to the LR category (S7), and one to the combined LR-AI category (S35). On the other hand, there were 20 distinguishing statements for a particular factor, and 7 statements that distinguished them all (Table A2 of the Appendix).

4.1. Factor 1: Land use planning enthusiasts

Factor 1 accounted for 22.6% of the variance and represented the largest group with 16 respondents. These respondents strongly agreed (+4) that Paragominas needs a zoning of the agricultural sector to produce on the most fertile soils and conserve forest in areas where production is not feasible (S31). They favored (+4) the implementation of a land use exchange mechanism (i.e., "troca de areas" meaning exchanging or swapping areas) that would allow reforestation and restoration of sandy valleys in exchange of clearing degraded forests located on clayey plateaus suitable for crop production (S28). Consistently with that view, they disagreed (−2, S29) that such mechanism could turn into a negative incentive to clear areas of primary forest. They strongly disagreed (−5) that the municipal government does enough to maintain infrastructure to incentivize agricultural intensification (S11), and perceived (+5) the lack of secure land tenure through property titles for accessing credits as the main barrier for agricultural intensification (S14). Participants in this group opined against the efficiency of current environmental policies and governmental mechanisms to incentivize compliance (−4, S32), but were unique to acknowledge that LRs and APPs have a positive effect on productivity as it obliges landholders to be efficient with the land that is already cleared (+1, S2). Therefore, the distinctiveness of these landholders pertains to their view that new land use planning policies and approaches are needed in Paragominas. They are predominantly soybean producers originating from Brazil's southern and south-eastern regions with landholdings located in the central region of Paragominas, while other landholders in this group focused on livestock and one on agroforestry (Table 4).

4.2. Factor 2: Agrochemical-based agriculture supporters

Factor 2 accounted for 15.2% of the variance with seven respondents. Landholders in this group opposed (−2) LRs as an investment for biodiversity and life quality in Paragominas (S8). They were both neutral (0) regarding the possibility that LRs may have positive effects on productivity (S2) and regarding the CAR as a useful tool to protect biodiversity (S1). As factor 1, they strongly supported "troca de areas" (S28, +4), and disagreed that this would be a negative incentive to clear primary forest (S29, −5). A distinctive opinion from this group concerned the disagreement of agrochemicals as a problem for human health and the environment (S26, −3). In line with this view, they also opposed to the idea of changing their production system in response to a

[3] Paragominas is a municipality with one of the highest levels of land concentration in the region (Simmons, 2004; Soares et al., 2016). Pará State has a Gini index for land possession of 0.68 (Pinto et al., 2020). The Gini index ranges from 0 to 1 and measures the degree of inequality in the distribution of wealth or land. The more equal the distribution is, the lower its Gini index (Gastwirth, 1972).

Table 2
Categories of statements: agricultural intensification (AI), Legal Reserve (LR) or combined statements (LR-AI).

Category of statement	No of statement in Q-sort	Statement
AI n=17	11	The performance of the municipality concerning the maintenance of roads and bridges is adequate enough for landholders to invest to intensify its production.
	12	The duration of land leasing agreements should be defined according to the minimum time that is necessary to consolidate production areas and ensure its viability.
	13	The current local, economic and political context is favorable for investments that allow industrialization and adding value to the products originating in the agribusiness sector of Paragominas.
	14	Lack of secure land tenure through property titles to access credits is the main barrier for a landholder in Paragominas to increase production and efficiency.
	15	Precision agriculture and silvo-pastoral systems are fundamental technologies for an efficient intensification that should be more applied in Paragominas.
	16	The current research projects developed in the region match landholders' demand for information and data.
	17	Pisciculture is a productive activity that will have a great development in the municipality in the upcoming years and I pretend to invest in this sector.
	18	If the investment capacity of landholders would increase due to credits or government incentives, it would be used mainly for horizontal expansion rather than for vertical integration.
	19	Paragominas does not have comparative advantages in relation to other municipalities of the region.
	20	Currently the work of landholders in the region is valued and has the support of different sectors of society.
	21	The agricultural sector of Paragominas has skilled labor and personnel that meets the demands of agricultural and cattle ranching activities.
	22	There is in the region a cultural aspect of entrepreneurship spirit and agricultural culture that allows the development of the municipality's potential.
	23	The bureaucracy that surrounds the agricultural sector in Paragominas is excessive and affects its productivity and compliance with environmental legislation.
	25	The lack of effective phytosanitary control of machinery and equipment that come into the municipality from other regions is a source of diseases in my property.
	26	The use of agrochemicals is a problem for human health and for the environment but given the absence of alternatives I am forced to use these products.
	27	Some consumers in Brazil want products free of agrochemical products and that demand could change my production system eventually.
	34	It is necessary to produce technology and varieties to grow grains in sandy valleys with the same productivity that in clayey soils.
LR n=6	1	The CAR is a useful tool to protect Paragominas' biodiversity and nature in rural properties.
	4	The location of LR should be planed to a larger scale than that of a single property taking into account soil conditions and topography to guarantee its positive effect in the whole municipality.
	6	In remote areas LR can be a problematic requirement for a landholder due to the risk of land invasion and extractivism of wood and non-wood resources.
	7	When a landholder needs to compensate areas of LR outside his or her property he or she has knowledge of what happens in the area that is leased.
	32	The current policies and governmental mechanisms are efficient to incentivize compliance with the Environmental Regularization Plan and generate a structural network of connected habitats.
	33	Reforesting valleys, where water springs and rivers pass through is necessary to create biological corridors that allow wildlife safe access to water sources.
LR-AI n=13	2	LR and APP have a positive effect on productivity, since it obliges landholders to be efficient with the land that is already available.
	3	LR is a burden imposed by the federal government that does not know the local context and prevents my property to be profitable according to my expectations.
	5	Some areas of my property could be converted into forest, without that causing an economic loss for me and in order to preserve hydrological resources, soils and biodiversity.
	8	The money that a landholder stops earning in order to maintain areas of LR is an investment for biodiversity and life quality in Paragominas.
	9	Enrichment planting with fruit trees would be economically interesting if production chains were more consolidated in Paragominas.
	10	The presence of dwellers in proximity to LR of farms do not increase the risk of forest fires in the LR.
	24	In Paragominas there is certainty in relation to the integrity of rural properties, natural resources, material goods, inputs and infrastructure.
	28	Reforesting sandy valleys in exchange of degraded forests due to fire and logging located in clayed plateaus for agricultural production would be optimizing land use according to soil's properties.
	29	A mechanism to reforest sandy valleys in exchange for areas with degraded forest due to fire and logging in clayey plateaus, would be a negative incentive to clear areas of primary forest.
	30	In areas where the concentration of agricultural land is high, the incidence of pests is less than in areas where agriculture is surrounded by forest and pastures.
	31	Paragominas needs a zoning of the agricultural sector to produce in the most profitable areas and conserve in areas where production is not interesting.
	35	It is important to maintain forest and avoid some agrochemical products to protect bees and pollinators that are important for crop productivity.
	36	The geography of Paragominas is characterized by areas of low economic potential that have high ecological potential for biodiversity, hydrological services and carbon storage.

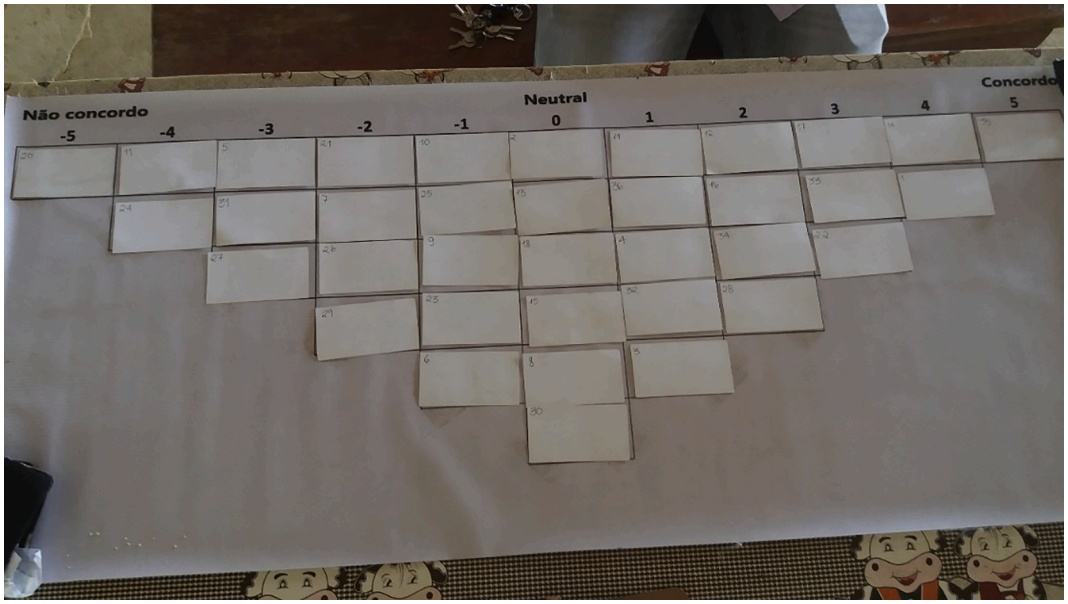

Fig. 1. Forced normal distribution for the Q-sorting procedure in Paragominas.

Table 3
Factors, number of loadings and eigenvalues resulting from the factor analysis using three factors.

Factors	*n*	Eigen values	Explained variance (%)
F1	16	7.0	22.6
F2	7	4.7	15.2
F3	5	2.8	9.2

demand for agrochemical free products in Brazil (S27, −3). They were also unique in perceiving areas of high agricultural land concentration as less prone to pest incidence as compared to areas where agriculture is surrounded by forest (S30, +3). Therefore, landholders in this group seemed to adopt a position in which "nature needs to be fought back" with agrochemical inputs and labor in order to accomplish desired agricultural production and regional economic development outcomes. Five of these landholders were soybean producers and two livestock producers with younger farms and in more remote landholdings as compared to factor 1 (Table 4).

4.3. Factor 3: Policy complacent-market responders

Factor 3 explained 9.2% of the variance and represented five respondents with four positive loadings and one negative loading. Landholders in this group were the only ones that appeared somewhat complacent with current forest conservation policies and governance mechanisms to incentivize compliance (S32,0). For instance, they strongly disagreed that LR is a burden imposed by the federal government (S3, −5), and agreed (+3) that the presence of land occupants near LRs does not increase the risk of forest fires (S10), nor that LRs can be problematic due to the risk of invasions by settlers to landholdings (S6, −1). They were the only group who perceived (+2) LRs as an investment for biodiversity and life quality in Paragominas (S8) and acknowledged (+4) the usefulness of CAR as a tool to protect biodiversity (S1). These landholders appeared as the most market-driven by acknowledging (+1) they could change their production systems if the demand for agrochemical-free products increases in the national market (S27). They perceived forest enrichment of LRs for fruit production as economically interesting given more consolidated production chains in Paragominas (S9, +4), but they also perceived a lack of entrepreneurial culture in the agricultural sector of the region (−1, S22). Landholders in this group were also the only ones who did not support "troca de areas" (S28, −1) due to its possible undesired effects (0, S29). These landholders were distributed between soybean ($n = 3$) and livestock producers ($n = 2$) and they represented the oldest farms suggesting an early settlement in the region (Table 4).

One out of five participants in this group (Q-sort 1) was bipolar to this factor, most notably concerning his strong support for silvo-pastoral systems and precision agriculture (S15, +5), considering LR as a burden imposed by the federal government (S3, +4), and strongly disagreeing with the efficiency of policies for environmental compliance (S32, −5).

4.4. Consensual statements among factors

There were 5 out of 36 statements where all interviewed farmers agreed (i.e., consensual statements) (Table 2 of the Appendix). These statements suggest that there is a general perceived lack of knowledge on forest areas outside the boundaries of the landholding when a landholder needs to compensate for LRs (S7). Furthermore, all landholders perceived an unfavorable context for investments towards adding value to agricultural products (i.e., verticalization) (S13). However, landholders disapproved horizontal agricultural expansion given higher investment capacity and perceived Paragominas as a comparatively advantageous municipality in the region (S19). Finally, all landholders seem to acknowledge the importance of maintaining forested areas in the landscape and avoiding dangerous agrochemical products to protect pollinators that can support crop production (S35).

5. Discussion

In this study we assessed the perceptions of medium and large

Table 4
General characteristics for each factor concerning agricultural production focus, origin, landholding size, age of farming production system and remoteness.

Factors (landholder group)	n	Production focus and state of origin		Average landholding size (ha)	Average age of production system (years)	Average travel time to/from Paragominas city (minutes)
Land use planning enthusiasts	16	Soybean	12	1,979±2,089	12±7	70±48
		Paraná	7			
		Rio Grande do Sul	3			
		Minas Gerais	1			
		São Paulo	1			
		Livestock	3			
		Espírito Santo	2			
		Paraná	1			
		Agroforestry	1			
		Pará	1			
Agrochemical-based agriculture supporters	7	Soybean	5	3,915±5,727	15±11	80±45
		Espírito Santo	1			
		Maranhão	1			
		Paraná	1			
		Rio Grande do Sul	1			
		São Paulo	1			
		Livestock	2			
		Paraná	1			
		Rio de Janeiro	1			
Policy complacent-market responders.	5	Soybean	3	1,475±574	25±18	90±73
		Espírito Santo*	2			
		São Paulo	1			
		Livestock	2			
		Espírito Santo	1			
		Minas Gerais	1			

*One bipolar respondent in this subgroup.

landholders on LRs and agricultural intensification. We identified three groups: 1) Land use planning enthusiasts perceived that forest conservation and agricultural intensification can be integrated by modifying policies and reconfiguring the current landscape conveying a sense of a "needed change" in Paragominas; 2) Agrochemical-based agriculture supporters appeared the most disapproving of the current forest conservation legislation and supported further establishment of monocultures in current forested areas with the concomitant use of agrochemicals; 3) Policy complacent-market responders were less interested in policy and land management changes and appeared the most responsive to market demands.

5.1. Factors driving landholders' perceptions on Legal Reserve

A prevailing viewpoint, especially among Land use planning enthusiast and Agrochemical-based agriculture supporters, was the lack of instruments to incentivize effective implementation of LRs. A study conducted in the state of Mato Grosso reports similar views from landholders who considered environmental federal policies too general to be practical at the local level and affected by corruption in its implementation (Bredin et al., 2018). Similar concerns were expressed in Paragominas, where Land use planning enthusiast and Agrochemical-based agriculture supporters stressed the need for reforms to increase local governance and independence from federal regulations. These two groups showed, for example, a strong interest in a "troca de areas" land-use exchange mechanism, which is restricted by the current legislation (see below). Furthermore, Agrochemical-based agriculture supporters pointed out the contradiction between past colonization policies that incentivized forest clearing and current forest conservation policies (Schmidt and McDermott, 2014).

Landholding size, crop diversity and proximity to the urban center can be positively associated with a willingness to preserve LRs in the region (Schneider et al., 2015; Santiago et al., 2018). In Paragominas, Agrochemical-based agriculture supporters had some of the most remote farms and held the least forest-friendly views, probably since they must travel long distances through LRs to reach the paved roads. However, we also found unfavorable forest views in some small soybean-producing farms (~300 ha) close to the paved road managed by Land use planning enthusiasts, while Policy complacent-market responders who had the most remote landholdings on average, seemed relatively content and unaffected by current legislation. Therefore, location and remoteness in Paragominas can relate to perceptions towards LRs beside other factors.

Since substantial deforestation has taken place near the paved roads, landholders may need to lease forest areas further away from their farms to compensate for LR. In several cases we observed that landholders were uninterested about the exact location or state of these rented forest areas. Owners of larger landholdings (~2000 ha) on the other hand, tended to have a more positive perception towards LRs arguably because they have enough cleared areas to expand production and benefit from economies of scale, as it was the case for most Policy complacent-market responders. Furthermore, the place of birth of landholders can be indicative of the time of arrival to Paragominas, which in turn shapes the structure of the farms. For example, three Land use planning enthusiasts were early colonizers in the 1970s and 1980s coming from the states of Espírito Santo and Minas Gerais. As a result, they have large landholdings that have transitioned from cattle ranching to arable farming and are currently a mix of croplands, pastures, and forest. These Land use planning enthusiasts wish to expand their croplands on accessible fertile, clayey plateaus that are often covered by forests, as opposed to old pastures in sandy valleys far away from roads. Therefore, although this segment of Land use planning enthusiasts tends to have a positive perception towards LRs, they would like to relocate forests to less fertile soils. On the other hand, Land use planning enthusiasts originating from the states of Paraná and Rio Grande do Sul and representing a more recent wave of immigrants (i.e., arrived to Paragominas during the 1990s–2000s to produce soybean), possess smaller areas (400–700 ha) under 5–10 years leasing contracts and their perception towards LR tended to be less positive than the early colonizers. This suggests that the diversity of perceptions towards LR in Paragominas is driven by socio-economic conditions and type of agricultural activity as pointed out for other municipalities in the states of Pará and Mato Grosso (Pacheco et al., 2017b), but also by the historical trajectory, remoteness and production orientation within the landholdings.

5.2. Environmental Rural Registry (CAR), property titles and agricultural intensification

One of the most controversial aspects of the policy framework around LR that came up during our interviews was the CAR in connection to land titling. Currently, more than 95% of the landholdings in Paragominas are registered in the CAR electronic database (Piketty et al., 2015). The CAR delineates the boundaries of landholdings and forest area within the landholding to determine the LR requirement. Landholders' expectations were that after the Green Municipality initiative implemented the CAR, granting of land titles would follow, a process that, however, did not happen (Piketty et al., 2015). Therefore, CAR without property titles that guarantees land possession tends to be perceived as an intrusion from the government. Unregistered properties are not uncommon in the Brazilian Amazon (de Oliveira, 2013), and still can be a delicate topic in Paragominas as the region has a long history of violence and land conflicts as recent as early 2000s (Fernandes Fernandes, 2011; L'Roe et al., 2016).

Land use planning enthusiasts and Agrochemical-based agriculture supporters perceived the lack of property titles as the main barrier for agricultural intensification because it restricts access to credits. One Policy complacent-market responder, however, opposed this view: *Everybody blames the lack of property titles, but reality is that nobody wants to change. Productivity is low, stocking rates are minimal, credits have nothing to do with profitability, the property title issue is just an excuse to keep doing things the same way*. Another Policy complacent-market responder argued that: *the agricultural sector must develop research to make at least two harvests or even three harvests per year feasible. So far, we are competitive because prices are high, but if there is a price crisis, we would be very affected*. Therefore, the perceived barriers for agricultural intensification include the lack of property tittles, but also the need for actionable knowledge, agricultural extension services and technical assistance.

5.3. Optimizing the landscape or an indecorous proposal?

A recurring topic during our interviews brought by landholders was the idea of a land use exchange mechanism referred to as "troca de areas" ("exchanging areas" as described in S28 and S29). With this term, landholders referred to the idea of reforesting cleared areas and restoring forests on sandy soils unsuitable for soybean production in exchange of clearing degraded forest on fertile clayey plateaus for soybean production. Since the colonization of the municipality in the 1960s took place by extensive cattle ranching, areas of sandy valleys in proximity to water bodies were cleared to allow cattle access to water. As a consequence, clayey plateaus distant from rivers were left covered by forest that currently have varying levels of degradation due to selective logging and forest fires (Martins et al., 2013; Bourgoin et al., 2018). These forest-covered clayey plateaus are now sought-after in Paragominas for soybean production because these areas offer good soil fertility, accessibility, and a flat terrain allowing mechanization. As stated by landholders, a "troca de areas" mechanism would facilitate agricultural intensification and forest conservation in Paragominas from a financial and logistical point of view.

During our discussions with landholders on "troca de areas" nevertheless, we were not able to pin down clear definitions of crucial ecological importance. For instance, when discussing "degraded forests" ("mata degradada" in Portuguese), landholders would refer to

secondary forests at different successional states (locally known as "juquiras" or "capoeiras"), but also to primary forests affected by fire and/or selective logging. Concerning forest restoration, landholders would refer to it as the introduction of fruit trees or timber species, such as paricá (*Schizolobium amazonicum*), into deforested areas close to water bodies on sandy soils. Therefore, from a biodiversity conservation point of view, the idea of "troca de areas" appeared ambiguous at best, and at worst it could have detrimental, far-reaching implications for forest conservation policies and LRs in Paragominas.

Despite this ambiguity, most Land use planning enthusiasts and Agrochemical-based agriculture supporters shared this view: *for agriculture, this exchange* [troca de areas] *would be very important, it would mean reforesting riparian forests and areas where production is not viable due to distance, topography and soil quality. Instead, now I have to produce 60 km away from the road rather than being able to work right here*. One Policy complacent-market responder on the other hand, observed*: Do you know what is the real intention behind that idea* [troca de areas]*? Cleared areas on top of plateaus are worth around $R 8000 per hectare, while areas on top of the plateau covered by forest are worth only between $R400–500. This is an indecorous proposal just to give value to their lands*. Another Policy complacent-market responder stated: *80% of those plateaus covered by forests are in hand of those who lease out the land and not in the hands of those who work the land. Those guys don't want to produce more, they want to lease those areas suitable for production because they are not able to lease the valley areas*. These opinions suggest that support for "troca de areas" can be underlaid by different motives, e.g., to intensify production on mechanizable, fertile soils, but also to increase the value of land, especially in the case of landholders that lease their land.

In line with Ricardian theory and the von Thünen model, land rent dynamics in Amazonian frontiers are influenced by biophysical conditions and distance to markets (Sills and Caviglia-Harris, 2009), but also by agglomeration economies and marketing networks (i.e., firms clustering together generating positive externalities) (Mertens et al., 2002; Garrett et al., 2013). Furthermore, hedonic land rent approaches suggest that forest areas are perceived as a financial burden in the region and influenced by land speculation particularly in connection to infrastructure development (Merry et al., 2008; Sills and Caviglia-Harris, 2009; Miranda et al., 2019). Therefore, a "troca de areas" mechanism could not only lead to direct deforestation of primary forest but also to land speculation, an activity tightly linked to land grabbing and deforestation in the Amazon (Fearnside, 2008; Bowman et al., 2012; Reydon et al., 2019).

A Policy complacent-market responder raised another issue concerning "troca de areas": *this [mechanism] would not be a negative incentive for the forest, it would be negative for livestock production [because] it would end meat production in the region as all the valley areas in the municipality are for livestock production*. Land competition between soybean monocultures and pastures can be traced back to the beginning of the Green Municipality initiative in 2008 as the resulting decrease in deforestation limited the amount of open areas close to the paved road (Osis et al., 2019). Possibly, monocultures will be favored on clayey plateaus, until shortage of these areas drive croplands on mechanizable sandy soils in the valleys (Osis et al., 2019). This cropland expansion into sandy valleys was supported by Agrochemical-based agriculture supporters who stressed the need to develop soybean varieties that are high-yielding on sandy soils. Expansion of monocultures into valleys, however, would further increase land competition between soybean and meat production, and potentially with APPs when in proximity to riverbanks. Another consideration is that "troca de areas" could potentially interfere with the CRA (Environmental Reserve Quotas for its acronym in Portuguese) system for LR compensation as there are still no clear indications that the CRA can be a sustainable source of income for forestland owners in Paragominas (Brito, 2020). In such case, forest owners would likely opt to substitute forests located in fertile soils for more profitable monocultures if given the option.

Despite all the potential problematic implications of "troca de areas", it is important to recognize that it aligns with the trend among landholders in Paragominas to increasingly adopt intensification strategies based on spatial criteria (Plassin et al., 2017). Landholders are intensifying production on available clayey plateaus and abandoning less suitable areas, generating an incipient forest transition (Mather, 1992; Mather and Needle, 1998) in areas not suitable for soybean production. Therefore, existing ad hoc reallocations of agricultural land through empirical knowledge developed by landholders could, in theory, be a negotiation and engagement opportunity for municipal institutions to formulate, in conjunction with landholders, voluntary land use-planning farm protocols that stipulate forest restoration and conservation objectives.

The relevance of such hypothetical protocols would be that even though large-scale deforestation is under control in Paragominas, LRs are under constant fire threat during the dry season, and existing policy mechanisms have been ineffective so far to prevent forest fires due their multiple drivers and landholdings' size. Therefore, enabling a technical procedure for assessing possible land use and land cover relocations within a landholding might offer an opportunity to incentivize, through a positive inducement rather than through punitive measures, active involvement from landholders to prevent forest fires. However, without the proper institutional vigilance and scientific support, "troca de areas" could become a perverse incentive to weaken LR legislation, especially considering recent spikes of deforestation in Pará State, and persisting illegal logging in Paragominas (Cardoso and Souza Jr, 2020; Fonseca et al., 2020).

Moreover, as mentioned before, key ecological considerations were absent during our discussions with landholders. For example, regarding the ecological value of forests, secondary forests do not substitute primary forests and disturbed primary forest can still retain important biodiversity conservation and carbon storage value (Berenguer et al., 2014; Barlow et al., 2016; Lennox et al., 2018). In addition, it takes 15 to up to 80 years for forests to develop and provide ecological functions, while many disruptors along this period can compromise forest establishment (Teixeira et al., 2020). A critical point therefore would be assessing the environmental performance of forests in Paragominas in terms of ecosystem services such soil and biomass carbon storage, habitat for biodiversity, water and climate regulation, and amelioration of pathogens outbreaks both for crops and human populations. For instance, forest structural characteristics such as canopy height, pioneer species density, Diameter Breast Hight of individuals, and dominance of shrub layer under the canopy layer, are all key variables to assess how vulnerable forests are to droughts and fires in the region (Bourgoin et al., 2018). These basic ecological aspects would need to be carefully examined before any attempt to implement the "troca de areas". Nevertheless, under the current political context where the Federal Government openly opposes regulating agriculture and operates on a pattern of weakening environmental protection in Brazil (Walker, 2019; Vale et al., 2021), a "troca de areas" in Paragominas appears ill-timed.

5.4. Further research

Interactions between private and public sector in the context of a frontier landscape can be framed as co-existence, alignment and orchestration (Pacheco et al., 2017a). The latter refers to hybrid mechanisms that involve both private and public sectors to trigger landscape transitions that aim at minimizing trade-offs between conservation and production (Pacheco et al., 2017a). In Paragominas, important steps towards co-existence and alignment were taken during the Green Municipality initiative and therefore, next steps towards orchestration should be investigated, aiming at preserving the region's natural capital.

A process of orchestration could provide a platform for negotiation around some of the ideas that we captured such as land use reallocations, but also to discuss related issues that require utmost attention, such as forest degradation and fragmentation. One of the focal points of such governance processes at the municipal scale should focus on revalorizing the forest and overcoming the prevalent narrative advanced

by the most extremist faction of the ruralist caucus in the Amazon region, framing the forest as an obstacle for rural development (Fearnside, 2017; Kröger, 2017). In this regard, governance initiatives aiming at fomenting productive forest-based systems in Paragominas could learn from the experience of neighboring municipality Tomé-Açu, where large-scale agroforestry systems have been successfully implemented by Japanese descendants for the last three decades (Bolfe and Batistella, 2011; Porro et al., 2012). Furthermore, the inclusion of smallholder farmers remains a pending task for future research and environmental governance initiatives in Paragominas (Viana et al., 2016), and the implementation of agroforestry systems at scale could offer opportunities to tackle this.

One of the main limitations attributed to Q methodology is the impossibility to claim external validity in relation to the population of respondents as well as the introduction of biases from the researchers (Kampen and Tamás, 2014). On the other hand, capturing perceptions of LRs in the Brazilian Amazon is a challenging enterprise because of the sensitivity of the topic due to its link to illegal deforestation. The merit of Q methodology in this case was to "smoothen" the interaction with landholders by not asking direct questions about LR but to present an interactive board game with a set of cards exculpating landholders from stating controversial ideas. Furthermore, informal interactions with landholders outside the interview setting allowed us to confirm that the perceptions described in this paper do exist in Paragominas. We do not claim that these are the only views or groups, as indicated by the presence of a "bipolar" participants, and the inclusion of a larger sample size could reveal additional factors and viewpoints. However, the viewpoints described in this paper can already suggest entry points to start discussions aiming at policy interventions towards collective land-use management (Dingkuhn et al., 2020). Consensual statements for instance, could provide a starting point to elicit a discussion at the municipal level regarding LR compensation, LR enrichment and adding value to agroforestry products to better account for the perceived comparative advantages of Paragominas. Additionally, consensus on S35 suggests that ecosystem services that had received less attention in the region such as pollination and micro-climate regulation could be important aspects to bring into the discussion that can contribute to revalorize the forest as an integral part of rural socio-economic development in Paragominas.

6. Conclusions

In this study we revealed different perceptions among landholders regarding agricultural intensification and Legal Reserves in the eastern Amazon region. Some respondents acknowledged the potential compatibility between Legal Reserves and agricultural intensification but would like to see a more flexible policy framework to relocate Legal Reserves to facilitate agricultural intensification. Other landholders seemed to prioritize monocultures and input intense agriculture in the landscape and do not perceive clear benefits from Legal Reserves for the local environmental and quality of life. A third group of landholders showed a mix of indifference and relative complacency towards Legal Reserves and conservation policies while paying more attention to market demands. These different perceptions regarding Legal Reserve and agricultural intensification are driven by socio-economic factors and ideological and political backgrounds. Such diversity implies that innovative, inclusive, and diverse governance strategies are necessary to engage with different stakeholders into a constructive dialogue to reconcile forest conservation and agricultural intensification. As our results suggests, in order to engage with a diversity of perceptions, such dialogue ought to address land use planning initiatives, developing markets of alternative products (e.g., agroforestry products), and payment for ecosystem services. Revalorization of the forest for its intrinsic and socioeconomic value should be central in this process to harness sustainable agricultural intensification. After deforestation rates have been resurging across the Brazilian Amazon since 2014, local governance towards forest and biodiversity conservation are increasingly needed to structurally decouple agricultural production from deforestation and forest degradation in the long term.

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Data availability

Data and material available upon request to the corresponding author.

Author's contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Daniel Pinillos. The first draft of the manuscript was written by Daniel Pinillos and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix

Table A1 Q-factor loadings for each Q-sort performed by the respondents in Paragominas. Green background indicates flagged Q-sorts (i.e., significantly loading for that factor), and "*" indicates unflagged Q-sorts (i.e., sorts not significantly loading to any factor).

	Factor loadings		
Q-sort	**Factor 1**	**Factor 2**	**Factor 3**
Q1	0.12	0.24	-0.53
Q2	0.00	0.16	0.43
Q3	0.51	0.50	-0.05
Q4	0.52	0.43	0.28
Q5	0.53	0.21	0.25
Q6	0.37	0.66	0.30
Q7*	0.44	0.55	0.34
Q8	0.69	0.26	0.20
Q9	0.71	0.14	0.17
Q10*	0.46	0.40	0.38
Q11	0.56	0.39	0.20
Q12	0.76	0.28	-0.31
Q13	-0.07	0.84	0.00
Q14*	0.43	0.22	-0.39
Q15	0.67	0.19	-0.12
Q16	0.44	-0.07	-0.19
Q17	0.07	0.08	0.61
Q18	-0.10	0.41	-0.02
Q19	0.41	0.11	0.56
Q20	0.53	0.20	-0.02
Q21	0.23	0.61	0.23
Q22	0.58	0.29	0.47
Q23	0.59	0.34	0.33
Q24	0.74	0.15	0.23
Q25	0.17	0.58	0.06
Q26	0.02	0.00	0.53
Q27	0.38	0.71	-0.18
Q28	0.57	0.31	-0.13
Q29	0.51	-0.05	0.02
Q30	0.48	-0.22	0.15
Q31	0.46	0.59	-0.10

Table A2. Distinguishing and consensus statements of a Q methodology analysis with 28 landholders. Red background indicates distinguishing statements for each factor at *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$, ****: $p < 0.0001$, no asterisks: $p \geq 0.05$ (No significant difference between compared factors).

No.	Distinguishing and consensus statements	Factor 1 - Factor 2	Factor 1- Factor 3	Factor 2 - Factor 3
1	Distinguishes all	**	*	***
2	Distinguishes F1 only	*	**	
3	Distinguishes F3 only		6*	6*
4	Distinguishes F2 only	*		*
5	Do not distinguishes factors	*		
6	Distinguishes F3 only		***	*
7	Consensus			
8	Distinguishes all	*	***	6*
9	Distinguishes all	***	***	6*
10	Distinguishes F3 only		6*	6*
11	Distinguishes F3 only		**	**
12	Do not distinguishes factors		**	
13	Consensus			
14	Distinguishes F3 only		6*	6*
15	Distinguishes F1 only	*	***	
16	Distinguishes F2 only	***		**
17	Distinguishes F1 only	6*	6*	
18	Consensus			
19	Consensus			
20	Distinguishes all	***	6*	*
21	Distinguishes F1 only	6*	**	
22	Do not distinguishes factors		**	
23	Distinguishes F1 only	6*	6*	
24	Distinguishes F2 only	6*		**
25	Do not distinguishes factors	*		
26	Distinguishes F2 only	6*		6*
27	Distinguishes F2 only	6*		6*
28	Distinguishes F3 only		6*	6*
29	Distinguishes all	***	***	6*
30	Distinguishes F2 only	6*		6*
31	Distinguishes F1 only	***	6*	
32	Distinguishes all	***	6*	*
33	Distinguishes F3 only		**	***
34	Distinguishes all	6*	***	*
35	Consensus			
36	Distinguishes F3 only		6*	***

Table A3. Statements and factor score arrays of Prototypical Q-sorts.

No.	Statement	F1	F2	F3
1	The CAR is a useful tool to protect Paragominas' biodiversity and nature in rural properties	2	0	4
2	LR and APP have a positive effect on productivity, since it obliges landholders to be efficient with the land that is already available	1	0	0
3	LR is a burden imposed by the federal government that does not know the local context and prevents my property to be profitable according to my expectations	−1	−1	−5
4	The location of LR should be planed to a larger scale than that of a single property taking into account soil conditions and topography to guarantee its positive effect in the whole municipality	1	1	2
5	Some areas of my property could be converted into forest, without that causing an economic loss for me and in order to preserve hydrological resources, soils and biodiversity	0	2	1
6	In remote areas LR can be a problematic requirement for a landholder due to the risk of land invasion and extractivism of wood and non-wood resources	1	1	−1
7	When a landholder needs to compensate areas of LR outside his or her property he or she has knowledge of what happens in the area that is leased	−1	−1	−1
8	The money that a landholder stops earning in order to maintain areas of LR is an investment for biodiversity and life quality in Paragominas	−1	−2	2

(*continued on next page*)

(*continued*)

No.	Statement	F1	F2	F3
9	Enrichment planting with fruit trees would be economically interesting if production chains were more consolidated in Paragominas	3	0	4
10	The presence of dwellers in proximity to LR of farms do not increase the risk of forest fires in the LR	−3	−2	3
11	The performance of the municipality concerning the maintenance of roads and bridges is adequate enough for landholder to invest to intensify its production	−5	−4	−2
12	The duration of land leasing agreements should be defined according to the minimum time that is necessary to consolidate production areas and ensure its viability	2	2	1
13	The current local, economic, and political context is favorable for investments that allow industrialization and adding value to the products originating in the agribusiness sector of Paragominas	0	0	−2
14	Lack of secure land tenure through property titles to access credits is the main barrier for a landholder in Paragominas to increase production and efficiency	5	5	−4
15	Precision agriculture and silvo-pastoral systems are fundamental technologies for an efficient intensification that should be more applied in Paragominas	2	1	−1
16	The current research projects developed in the region match Paragominas' landholder's demand for information and data	−2	0	−3
17	Pisciculture is a productive activity that will have a great development in the municipality in the upcoming years and I pretend to invest in this sector	−1	3	3
18	If the investment capacity of landholders would increase due to credits or government incentives, it would be used mainly for horizontal expansion rather than for vertical integration	0	−1	0
19	Paragominas does not have comparative advantages in relation to other municipalities of the region	−3	−3	−4
20	Currently the work of landholders in the region is valued and has the support of different sectors of society	−2	0	2
21	The agricultural sector of Paragominas has skilled labor and personnel that meets the demands of agricultural and cattle ranching activities	−4	−1	−2
22	There is in the region a cultural aspect of entrepreneurship spirit and agricultural culture that allows the development of the municipality's potential	1	1	−1
23	The bureaucracy that surrounds the agricultural sector in Paragominas is excessive and affects its productivity and compliance with environmental legislation	3	−1	−2
24	In Paragominas there is certainty in relation to the integrity of rural properties, natural resources, material goods, inputs and infrastructure	−1	−4	−3
25	The lack of effective phytosanitary control of machinery and equipment that come into the municipality from other regions is a source of diseases in my property	0	1	0
26	The use of agrochemicals is a problem for human health and for the environment but given the absence of alternatives I am forced to use these products	1	−3	0
27	Some consumers in Brazil want products free of agrochemical products and that demand could change my production system eventually	0	−3	1
28	Reforesting sandy valleys in exchange of degraded forests due to fire and logging located in clayed plateaus for agricultural production would be optimizing land use according to soil's properties	4	4	−1
29	A mechanism to reforest sandy valleys in exchange for areas with degraded forest due to fire and logging in clayey plateaus, would be a negative incentive to clear areas of primary forest	−2	−5	0
30	In areas where the concentration of agricultural land is high, the incidence of pests is less than in areas where agriculture is surrounded by forest and pastures	−3	3	−3
31	Paragominas needs a zoning of the agricultural sector to produce in the most profitable areas and conserve in areas where production is not interesting	4	2	1
32	The current policies and governmental mechanisms are efficient to incentivize compliance with the Environmental Regularization Plan and generate a structural network of connected habitats	−4	−2	0
33	Reforesting valleys, where water springs and rivers pass through is necessary to create biological corridors that allow wildlife safe access to water sources	3	3	5
34	It is necessary to produce technology and varieties to grow grains in sandy valleys with the same productivity that in clayey soils	0	4	3
35	It is important to maintain forest and avoid some agrochemical products to protect bees and pollinators that are important for crop productivity	2	2	1
36	The geography of Paragominas is characterized by areas of low economic potential that have high ecological potential for biodiversity, hydrological services and carbon storage	−2	−2	2

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