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RESEARCH ARTICLE

Governance and Deforestation: Understanding the Role of Formal Rule-Acknowledgement by Residents in Brazilian Extractive Reserves

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Brazil has one of the most extensive and effective sets of deforestation control policies in the world. One of the main deforestation control policies implemented by the Brazilian government over the last 15 years has been the creation of an extensive system of protected areas, including extractive reserves. Our study addresses the challenges of reducing deforestation in the Brazilian Amazon. We analyze the role of institutions in controlling deforestation, focusing on the formal rules contained within the Management Agreements of extractive reserves. We chose two extreme cases: the Rio Ouro Preto Extractive Reserve and the Rio Cautário Extractive Reserve, in the state of Rondônia, Brazil. Within each case, we analyzed the association between the recognition of the formal rules and the extent of deforestation. We collected data through eight focus groups, with a total of 61 reserve residents, which used a didactic story to understand reserve residents' familiarity with the Management Agreement rules. In both cases, there was high recognition of the formal rules governing natural resource use in the reserves, although there was heterogeneity among communities and in the mechanisms that facilitate recognition. The factors contributing to the recognition and non-recognition of the formal rules by reserve residents included: learning strategies (theoretical and practical); speed of institutional change; rules content (ambiguous and not well-adapted); endogenous factors (e.g. leadership, relationships); and exogenous factors (e.g. economic change, conflict and pressures).

Keywords: Amazonia; Brazil; deforestation; governance; livelihoods; natural resource management

Introduction

Brazil has had one of the most extensive and effective sets of deforestation control policies in the world. This combination of policies reduced deforestation in the Amazon biome by 83% from 2004 to 2012 (INPE/PRODES 2018). However, this efficient suppression of deforestation in the Amazon ended in 2012, and in the following five years Brazil became again the scene of rising deforestation rates (Rochedo et al. 2018). These processes have returned the country to the status of having the highest net annual forest loss in the world (FAO 2016). A rich literature describes deforestation trends in the Amazon biome (Schmitt 2015; Humphries et al. 2012; Reydon 2015; IPAM 2013; Moutinho et al. 2016).

One of the main deforestation control policies implemented by the Brazilian government over the last 15 years has been the creation of an extensive system of protected areas (PPCDAM 2016). Protected areas have been particularly efficient in controlling deforestation (Soares-Filho et al. 2010; Nolte et al. 2013; Spracklen et al. 2015; Kere et al. 2017; Nogueira et al. 2018). As such, ongoing efforts to prevent deforestation

through protected areas in Brazil proceed in two ways: the implementation of new protected areas, and the governance of existing protected areas in order to maintain or improve their effectiveness (TCU 2013).

The governance literature on protected areas is extensive (Castro 2016; Worboys et al. 2015; Pfaff et al. 2014; Nolte et al. 2013; Borrini-Feyerabend et al. 2013).Within this literature, the establishment and adherence to rules is one of the principal themes studied within protected area governance (Heikkila and Gerlak 2019; Wehkamp et al., 2018; McGinnis and Ostrom 2014), and several scholars have sought to understand the role of rules in governance (Patterson and Beunen 2019; Solorzano and Fleischman 2018; Fovargue 2017; Vadjunec 2011; Paavola 2007; Ostrom 2005). Ostrom (2005) and Kiser and Ostrom (1982) defined rules as regulations that drive behavior and guide the way in which a given activity should be performed and as the ordering in which social and work relations should take place – necessary, prohibited or permitted actions.

Ostrom (2005, p. 20) noted that "the stability of rule-ordered actions is dependent upon the shared meaning assigned to words used to formulate a set of rules". In this paper, we assume that rules-acknowledgement is necessary for developing a shared meaning (Gerlak et. al. 2017; Short and Duane 2016; Noguera-Mendez, Molera and Semitiel-Garcia 2016; Salvini et. al. 2016). To understand what determines the level of rules-acknowledgement in a given context is a first step towards understanding why communities are compliant with the rules or not and how and why they create protocols about what actions are required, permitted, or forbidden (Ostrom 2005). Prior research has tried to understand the mechanisms that determine rules-acknowledgement: the IAD Framework, grammar of institutions and design principles are all efforts in this direction (Ostrom 2005, Wilson et. al. 2013, Ostrom 2015).

In situations with high levels of rules-acknowledgement individuals have more opportunities to create collective actions that are ordered, predictable and, as a result, efficient (Ostrom et. al. 1994; Ostrom and Walker 2003). In our case, high levels of rules-acknowledgment may be associated with efficiency in collective actions for management of common pool-resources and for avoided deforestation. These kinds of associations have been tested empirically (Banana et. al. 2007; Goetter and Neudert 2016; Tschopp et. al. 2018) and theoretically (Ostrom et. al. 1994; Gibson et. al. 2000).

The aim of this study was to analyze the governance of protected areas in the Brazilian Amazon. We focused on two extractive reserves (Rio Ouro Preto and Rio Cautário), which were characterized by dramatically different deforestation rates. We analyzed the dynamics of formal rule-acknowledgement among rubber tappers living in these extractive reserves. We analyzed the formal rules that comprise the reserves "Management Agreements", which are tools collectively developed by rubber tappers and government agencies to help organize land, forest, and natural resource use, as well as assisting reserve governance. We sought to understand the dynamics of formal rule-acknowledgement and their relation to deforestation rates. We hypothesized that the more strongly acknowledged the formal rules were by rubber tapper communities, the likelihood of avoiding forest resource degradation (i.e., the deforestation rates would be lower within areas where the formal rules were well-understood).

We contributed to these topics by answering two research questions: 1) is formal rule-acknowledgement an important factor for environmental governance, and 2) What factors contribute to higher or lower formal rule-acknowledgement?

Our study focuses on governance, institutions, and institutional change. We draw on the IAD-framework model (Ostrom 2015) to explore the governance of common-property resources, with an emphasis on the "rules in use", defined as a set of instructions that direct actors' behavior (Cole and McGinnis 2017).

Methodology

Case studies

We conducted a qualitative study based on a case study approach (Gerring 2012). We selected two sustainable development reserves as our case-studies: Rio Ouro Preto Extractive Reserve and Rio Cautário Extractive Reserve (**Figure 1**). Sustainable development reserves in Brazil are public areas created to protect the livelihoods and culture of these populations by ensuring the sustainable use of the natural resources. People living within sustainable development reserves enjoy usufruct rights to access and extract many of the natural resources (e.g. rubber, Brazil nuts, açai) within the reserve, but they do not have individual tenure or rights to specific parcels of land. As such, the natural resources and, specifically, rubber resources present within those reserves represent a form of common pool-resources, with all reserve residents equally able to extract natural resources from all parts of the reserve. The natural resource, therefore, represent a non-exclusive, subtractable, and competitive common pool-resource.

Our case selection was based on the technique of identifying 'extremes', whereby cases are selected based on some variable presenting extreme values (Gerring 2006). In our study, the cases were selected

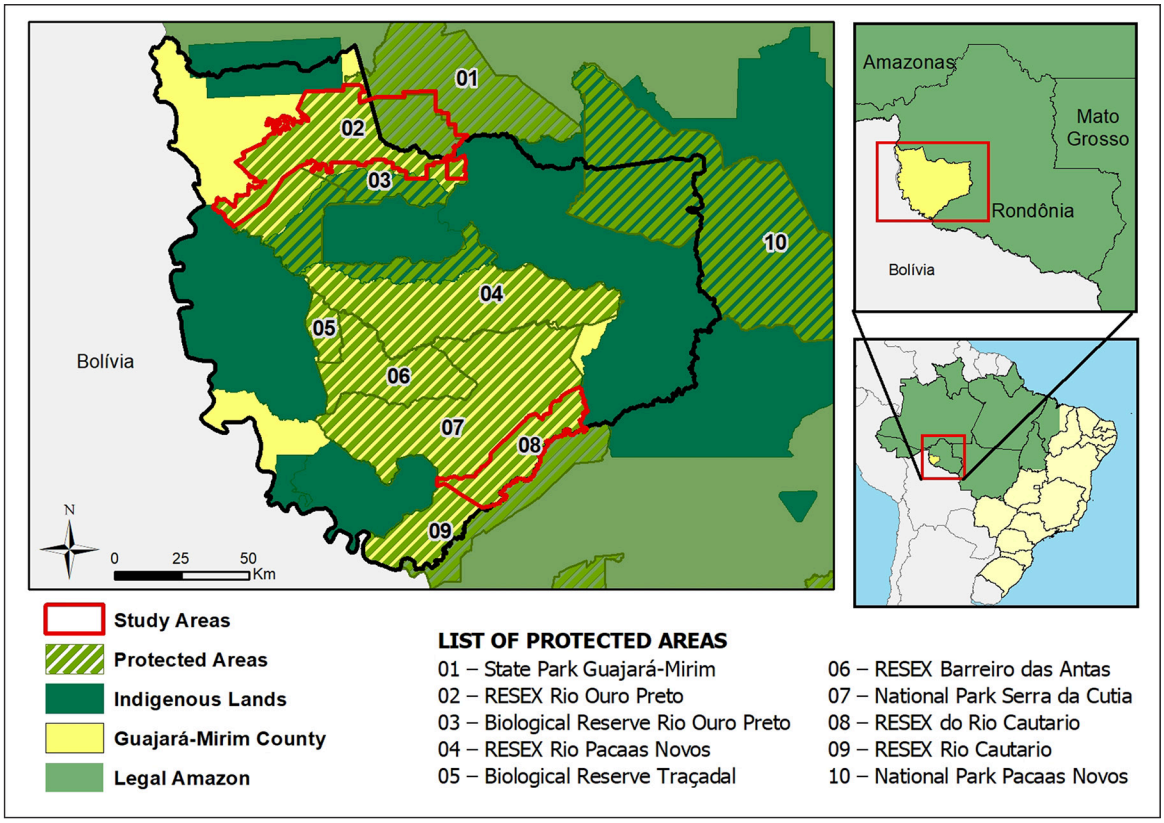

Figure 1: The legal Brazilian Amazon, municipalities, protected areas, and study areas.

based on the variable of the rate of deforestation. The rate of deforestation between 2000 and 2016 within these two extractive reserves represented extreme cases within a dataset of thirty three such extractive reserves located in the Brazilian Amazon (INPE/PRODES 2016). Rio Ouro Preto Extractive Reserve had very high rates of recent deforestation, while Rio Cautário Reserve had very low rates of recent deforestation.

Our case selection was also guided by an effort to identify cases for which other important variables were as similar to each other as possible, such that there would be a stronger case for attributing any differences in outcome to the differences in deforestation rate. These additional variables included those that Ostrom referred to as second-order criteria, which are responsible for facilitating (or impeding) efforts to overcome the collective action dilemma between individuals (Poteete et al., 2011). These variables included: the number of resource users (families); the size of the extractive reserve; the distance among areas; and the importance of rubber as the principal extractive resource. Relative to the variance in these variables across the 33 extractive reserves in the Brazilian Amazon, the two selected reserves were very similar with regards to all four of these additional variables.

Focus groups

We collected primary data through focus groups (Stewart and Shamdasani 2015). We conducted eight focus groups in eight different communities, with four in each of the two reserves, between October and December 2015. In the Rio Ouro Preto reserve the research communities were a random subset of the seven communities; in the Rio Cautário there were only four communities and so all four were selected. We randomly selected focus group participants, seeking to be no fewer than seven and no more than 15 participants per group (Stewart and Shamdasani 2015). Our sample included seven groups with seven participants, and one group with 12. The difference in the number of focus group participants was a function of varying interest between different communities.

The focus groups aimed to characterize the extent to which focus group participants conveyed knowledge and understanding of the reserves' management agreements. As such, the focus groups were led by a guiding instrument that contained questions and scenarios derived from the rules and regulations contained within those management agreements. The focus groups were conducted around a didactic story oriented around a fictional main character named "Mister X" (**Table 1** and **Table 2**).

Table 1: Focus group implementation script (Rio Ouro Preto Reserve).

Mister X's story – Rio Ouro Preto	
"Mister X" is 50 years old; he is married and has four children. He is a new resident in Rio Ouro Preto RESEX. He came from Acre State, where he already performed rubber taping and other extraction activities in the RESEX. One month ago, "Mister X" and his family took a place of residence in the community (***say the name of the studied community***) due to an agreement set with the ICMBio, the leaders and the community. "Mister X" came to Rio Ouro Preto RESEX with the purpose and will to settle down for the rest of his life. As he is new in the reserve, he needs information on how to perform his daily place-of-residence use and management activities. So, he asks the focus group about how to proceed. His questions are presented below:	
Management Agreement Rules	**Scenarios**
45 and 46	Can I already consider myself a beneficiary or do I need to undergo some period of extractive activity practice? Did I perform the admission procedure correctly?
19	I thought about using wood from (some tree of the region) to reform the house that already exists in my place of residence, can I cut down 2 trees? Windfall.
11	I want to plant cassava to make flour and I need to open a planting area in my place of residence. How many hectares can I use to do so?
9	There are a few açaí, buriti and pequi trees around my residence. If I need to set up a planting area, can I cut down these trees?
10	Can I use paxiúba to cover my house? Can I trade it?
15, 16 and 17	Can I breed unconfined chicken and pigs? I used to breed some cattle where I lived, can I do it here too?
23	Can I fish for my own consumption? I brought with me two casting nets and some longlines, are they allowed?
24	Am I allowed to take fish to the city? How should I proceed?
33 and 37	Some of my relatives still live in the Acre State RESEX. They will come to visit me twice a year, during festivities. Is it okay for them to come and stay for a few weeks? Are there restrictions?
39 and 40	I would also like to visit them from time to time. Can I leave the area? For how long?
4	Can I buy a place of residence from my neighbor and keep the 2 of them?
4.1, 5 and 43	My place of residence does not have rubber trails, but I am extremely interested in extracting latex. Can I open some rubber trails in the place of residence of another resident who does not perform rubber taping activities? How many rubber trails can I open at most? Do I need to ask someone's permission?
8	What type of cut should I make in the rubber trees? How many cutting days do I have per trail?
22	Can I trade fruits such as pequi, buriti and bacuri? What do I have to do to trade them?
21	Can I trade timber products? Do I need forest management?
12	Can I burn the planting area? Do I need to be careful with chestnut trees? Which ones?
6	Can I cut down chestnut trees? What do I do when they are in the planting area?
31 and 32	How does reserve monitoring work? Who does monitor it?

The focus group participants were told to imagine the following scenario. Mister X had recently settled in their reserve on the basis of a transfer agreement made with the reserve's governing agency and the reserve residents, who accepted him. Mister X had a family (wife and four children). Since they were new to the area and did not know the activities allowed within the reserve, he gathered the residents to ask them about the subsistence and income-generating activities that he might engage in while living in the reserve. Specifically, he had doubts about the rules that comprised the reserve's management agreement. The purpose of the focus group was to investigate whether participants would properly guide Mister X,

Table 2: Focus group implementation script (Rio Cautário Reserve).

Mister X's story – Rio Cautario	
"Mister X" is 50 years old; he is married and has four children. He is a new resident in Rio Cautário RESEX. He came from Acre State, where he already performed rubber taping and other extraction activities in the RESEX. One month ago, "Mister X" and his family took a place of residence in the community (say the name of the studied community) due to an agreement set with the ICMBio, the leaders and the community. "Mister X" came to Rio Cautério RESEX with the purpose and will to settle down for the rest of his life. As he is new in the reserve, he needs information on how to perform his daily place-of-residence use and management activities. So, he asks the focus group about how to proceed. His questions are presented below:	
Management Agreement Rules	**Scenarios**
16 and 17	Do I need to present documents to prove my extraction origin in order to establish myself in the reserve? Who do I introduce myself to?
56	I thought about using wood from (some tree of the region) to reform the house that already exists in my place of residence, can I cut down 2 trees?
34	I want to plant cassava to make flour and I need to open a planting area in my place of residence. How many hectares can I use to do so?
32 and 38	Can I burn the planting area? Do I need a firebreak?
10 and 20	I want to tap rubber trees, how many rubber trails can I have in my place of residence?
22 and 25	What type of cut should I applied to the rubber trees? Are there forbidden cuts?
2	I noticed that my place of residence does not have açaí trees. Can I extract this product out of my place of residence? How does it work?
27	How does the chestnut extraction work? Does each resident have his chestnut trail?
39	Can I extract copaíba? Are there restrictions?
49 and 50	Can I breed unconfined chicken and pigs?
51 and 53	How do hunting matters are treated inside the reserve? Is it allowed? Are there restrictions?
45	Can I fish for my own consumption? I brought with me two casting nets and some longlines, are they allowed?
18	If the place of residence is a dry line, can the owner go fishing in the river without problems? Is the river a common area?
12 and 14	I would like to visit some relatives who live out of the reserve once a year. Can I leave the area? How long can I stay away from the reserve? What is the procedure?
57	Can I trade timber products? Do I need forest management?

and in doing so convey insights into the level and nature of formal rule-acknowledgement among reserve residents. The scenarios and questions in the focus group guiding instrument referenced most of the clauses of the reserves' management plans that addressed reserve use and management activities.

Data analysis

We created categories based on the reserves' management agreements. While differences between the two management agreements did not allow us to construct identical categories for the two reserves, we were able to make them very similar (**Table 3**). We coded the data, to transform the qualitative data into categorical quantitative data, based on the development of an acknowledgement ranking (**Table 4**). We classified and scored each response through the ranking, and then used the simple arithmetic mean of each category to understand the extent (in percentage) to which each of them was acknowledged in the four communities and in the entire reserve. The percentages, therefore, represent a level of acknowledgement across the entire reserve based on the arithmetic mean response of each of the four communities. We qualitatively analyzed field data using NVIVO 10 software to help organize the content of the focus groups, based on arguments capable of helping us to understand variations in rule-acknowledgement.

Table 3: Category definitions.

Rio Ouro Preto RESEX Categories	Rio Cautario RESEX Categories
PLACE OF RESIDENCE: It concerns the rubber tapper's location/place of dwelling. This category comprises the number of places of residence per family; the possibility of having two places of residence; the absence from the place of residence in terms of time and authorization; the extractive activity performed outside the place of residence and the common-use areas within the reserves. (rules: 4, 5, 39, 40, 43)	***PLACE OF RESIDENCE:*** It concerns the rubber tapper's location/place of dwelling. This category comprises the number of places of residence per family; the possibility of having two places of residence; the absence from the place of residence in terms of time and authorization; the extractive activity performed outside the place of residence and the common-use areas within the reserves. (rules: 2, 12, 14)
ANIMAL BREEDING: It concerns rules addressing the breeding of small animals within the reserve. (rules: 15, 16, 17)	***ANIMAL BREEDING:*** It concerns rules addressing the breeding of small and large animals within the reserve. (rules: 49, 50)
PLANTING: It concerns the size of the planting area and its opening limits, as well as the cutting of plants and the handling of rubber trees within the planting area. (rules: 6, 9, 11, 12)	***PLANTING:*** It concerns the limits of the planting area and the use of fire within it. (rules: 32, 34, 38)
RUBBER TAPPING: It concerns the number of rubber trees each family can have, as well as the allowed and forbidden cuts. (rules: 4.1, 8)	***RUBBER TAPPING:*** It concerns the number of rubber trees each family can have, as well as the allowed and forbidden cuts. (rules: 10, 20, 22, 25)
FISHING: It concerns fishing guidelines as for tools and quantity of fish allowed. (rules: 23, 24)	***FISHING:*** It concerns fishing guidelines as for tools and quantity of fish allowed. (rules: 45, 46, 47)
TRADING: It concerns the handling and trading of straw and forest products in general. (rules: 23, 10)	***TRADING:*** It concerns the management of chestnut, as well as the trading of chestnut and copaíba. (rules: 27, 39)
NEWCOMERS: It concerns new families who want to settle in the reserve, as well as the consent and authorization procedures. (rules: 45, 46)	***NEWCOMERS:*** It concerns new families who want to settle in the reserve, as well as the consent and authorization procedures. (rules: 16, 17)
TIMBER: It addresses the exploitation and use of timber and timber products within the reserve. (rules: 19, 20)	***TIMBER:*** It addresses the exploitation and use of timber and timber products within the reserve. (rules: 56, 57)
MONITORING: It addresses the rubber tapper-monitoring rules adopted in the reserve. (rules: 31, 32)	***ANIMAL SLAUGHTER:*** It addresses the slaughter of wild animals for non-internal consumption. (rules: 51, 53)
VISITS: It addresses the authorization and the responsibility of residents receiving visitors and of those visiting the reserve.	

Table 4: Description of three rule-acknowledgement evaluation points.

Acknowledgement (10 points)	The "Management Agreement" rule-acknowledgement level refers to the correct answer about a particular rule. Thus, the rule was considered internalized when the group showed knowledge about it by answering to the question in a way that the answer fully complied with the "Management Agreement". The order of words did not matter in this case, just the content of the answer and the adherence of such content to the formal rule described in the "Management Agreement".
Intermediate Acknowledgement (5 points)	The intermediate "Management Agreement" rule-acknowledgement level translates moments of confusion and doubt among the actors, although they found the correct answer in the end. Although there were wrong individual answers in these moments, the group's motivation to find and give the correct answer allowed considering it an intermediate internalization. The partial knowledge about the rule – i.e., when the final answer did not contemplate the whole formal rule, either because something was missing or because they went beyond and inserted elements that did not belong to the rule – was also considered intermediate.
Non-Acknowledgement (0 points)	The "Management Agreement" rule non-acknowledgement level refers to wrong answers, i.e., when the group confirmed an answer that did not comply with the formal rule. This level also comprised wrong answers emerging in times of doubt and confusion within the group. At such times, although there were correct answers, the mere fact that the wrong answers stood out at the end was the reason to consider it as non-internalization.

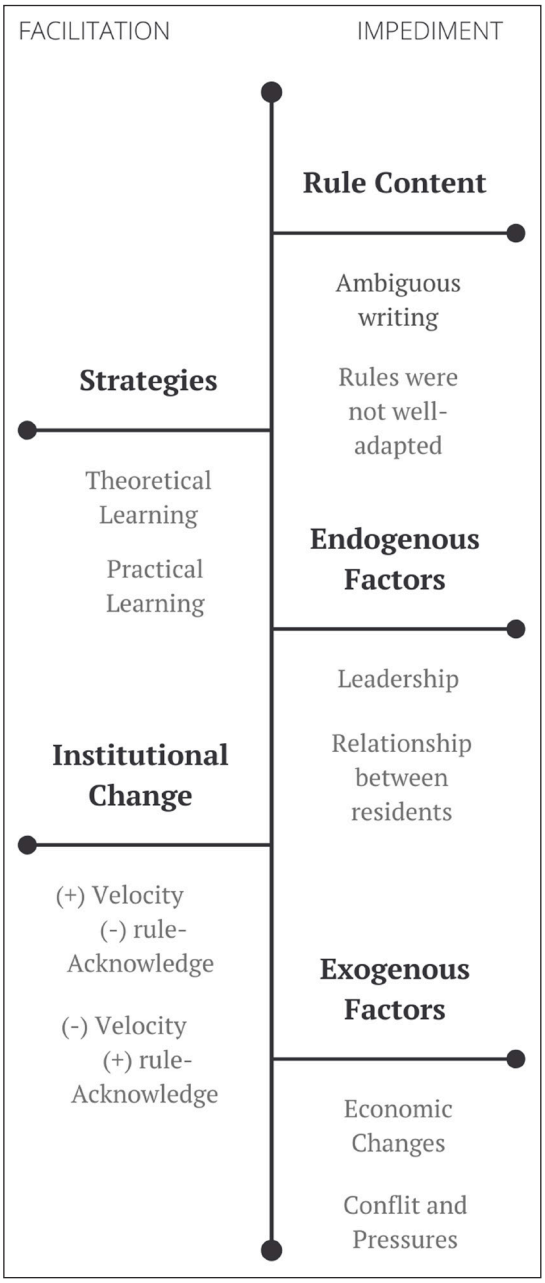

Figure 2: Summary results.

Results and Discussion

We present our results under five category headings (**Figure 2**). Two of these represent factors that facilitate rules-acknowledgement while three represent elements that made rules-acknowledgement more difficult.

Rule Acknowledgement: Contemplating the Facilitating Mechanisms

Overall, the mean level of formal rule-acknowledgement in the two extractive reserves was extremely similar. Among residents of the Rio Ouro Preto Extractive Reserve we observed 84% formal rule-acknowledgement, whereas in the Rio Cautário Extractive Reserve this figure was 89% (**Figure 3**). These high figures suggest that, in general, residents of both reserves demonstrated a strong understanding of the land use and management rules and regulations governing their respective reserves.

Despite overall similarity in the level of formal rule-acknowledgement, the processes by which rule-acknowledgement was developed and achieved was substantially different between the two reserves. The models of rule-dissemination and consolidation were different in the two reserves in two ways: they employed different strategies to recognize the rules and they experienced different rates of institutional change.

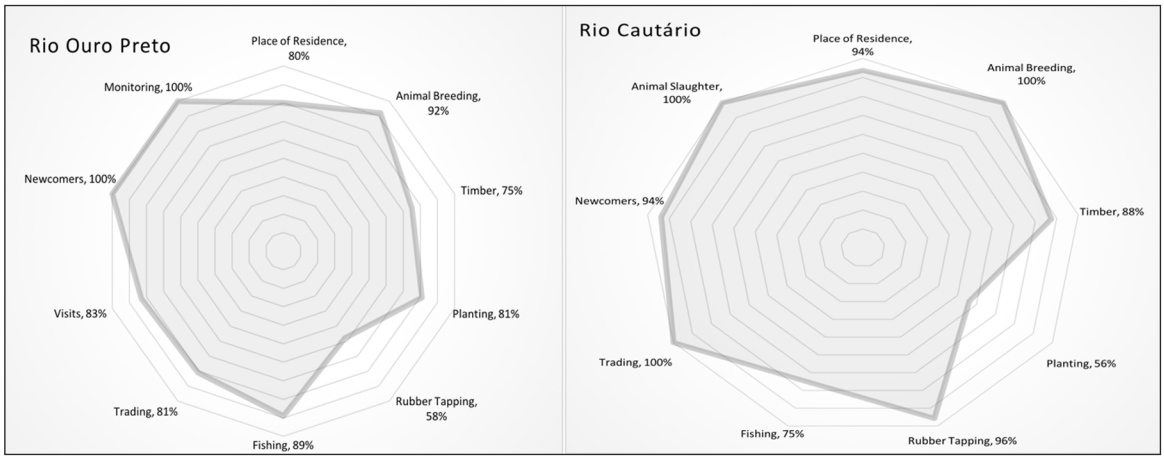

Figure 3: Radar chart of the two study reserves. In each case, we identified the percentage of formal rules acknowledged, by category. The mean level of formal rules acknowledged, as indicated in the text, was 89% for the Rio Cautário Extractive Reserve and 84% for the Rio Ouro Preto Extractive Reserve. The mean level in each reserve was calculated by the sum of the categories (presented in the chart) divided by the number of categories (arithmetic mean). The percentages of the categories were calculated from the um of the each of the four communities surveyed by reserve (totaling eight communities).

Different Strategies to Recognize the Rules

First, we consider differences in the strategies used to recognize the rules. In the Rio Ouro Preto Extractive Reserve, reserve leaders and residents had booklets that presented the reserve rules in an approachable and easy-to-learn way. These booklets took into consideration residents' socio-educational level; these residents mostly had a low level of schooling and almost no literacy in written Portuguese. This booklet represented an accessible means for residents of the Rio Ouro Preto Extractive Reserve to learn the rules. Command and control mechanisms were also actively deployed within the reserve. However, the educational mechanisms (such as the booklet) meant that rubber tappers first had the opportunity to be pro-actively introduced to the set of rules guiding their daily activities. Residents were only punished, and monitoring or sanctions were only implemented, once this educational process had been deployed. Thus, in the event of punishments or sanctions, residents could not and did not argue that they did not know, or were not informed, that a given activity was illegal. This helped give legitimacy to punishment mechanisms. The system of learning in the Rio Ouro Preto Extractive Reserve was thus based on well-defined stages that constituted a virtuous cycle of education-monitoring-punishment/reward.

In contrast, communities in the Rio Cautário Extractive Reserve acknowledged the formal rules in a very different way. There were no booklets in any of the houses in this reserve: neither in the houses of community leaders nor of regular residents. As such, there was no, or insufficient, replication of the method in place in Rio Ouro Preto Extractive Reserve, where the rule-acknowledgement movement began with the rule content-dissemination and consolidation process. Rather, in the Rio Cautário Extractive Reserve, the high rule-acknowledgement level was explained by other factors. In particular, two environmental agencies (one federal-level; one state-level) had a strong presence in the reserve, including monitoring and enforcement mechanisms. The monitoring and enforcement mechanisms appeared to be more organized than in the Rio Ouro Preto Extractive Reserve.

Therefore, the Rio Cautário Extractive Reserve was focused on a rule-acknowledgement process based on practice and experience through an action-monitoring-punishment/reward cycle. The rule education component, which characterized the theoretical learning environment developed within communities in the Rio Ouro Preto Extractive Reserve, was missing from residents' experiences. So, whenever there were divergent opinions about how to behave in the scenarios created for the focus groups, the arguments among residents in the Rio Cautário Extractive Reserve were always based on facts seen and heard by residents themselves or by others. An example:

> *"I was born and raised here in the community and my father would say: plant a banana tree 4 meters away so that we don't have a lot of bush, one bean tree takes one meter from the other to make it look good. (...) To set fire to the fields you have to wait a rain or two for the fire not to invade the forest, not to burn the forest. (...) People who were born and raised here already know the customs here*"

Thus, the rule-acknowledgement in this reserve was based on direct personal experiences and group norms.

Although educational booklets were not found in the Rio Cautário Extractive Reserve, the formal rule-acknowledgement level there was slightly higher than the one recorded for Rio Ouro Preto Extractive Reserve. Further, its deforestation rates were lower than the ones found in Rio Ouro Preto Extractive Reserve. This result suggests that educational movements were more efficient when they were associated with practical actions, and were best learned from practices and a practice-based approach (Krott and Giessen 2014; Arts et al. 2013).

Although Rio Cautário Extractive Reserve had a more organized monitoring and enforcement environment than Rio Ouro Preto Reserve, practice-based learning proved to be more appropriate than theoretical and booklets-based learning to promote rule-acknowledgement, especially in communities with low levels of formal education like those in our study. At the same time, in cases where new rules did not map well onto previous experience, practice-based learning could prove to be a relatively unresponsive and unflexible mechanism for institutional change and adaptive learning inside the reserves.

Institutional Change

Second, the rate of institutional change differed between the two reserves, with differences in changes to the formal rules over time. This is relevant in understanding and interpreting models of rule-dissemination and consolidation in the two reserves. The rules in the Rio Ouro Preto Extractive Reserve were updated four times throughout the reserve's 20 year existence, whereas in the Rio Cautário Extractive Reserve the rules had been updated only twice in the reserve's 15 year existence. These incremental institutional changes took place at longer intervals in the Rio Cautário Extractive Reserve (approximately every 7.5 years) compared to in the Rio Ouro Preto Extractive Reserve (approximately every 5 years): this difference may have contributed to greater absorption and sharing of information among residents in the Rio Cautário Extractive Reserve. Information-sharing is a crucial factor in facilitating actors to develop trust, reciprocity, and learning relationships (Poteete et al. 2011; Ostrom and Walker 2003). In turn, this helps to inhibit free-riding behaviors by others, by favoring practices focused on the maintenance and conservation of commons from within communities.

Rule Acknowledgement: Contemplating Impediment Mechanisms

Three points emerged in our analysis of which factors hindered formal rule-acknowledgement in the two reserves: 1) the content of the rules; 2) endogenous factors; and 3) exogenous factors. Here, we explore each of these three factors.

Rule Content

Our analysis of the contents of the rules revealed that extractive communities sometimes found it difficult to understand the formal rules: either because they were ambiguously written, or because the rules were not well-adapted to the local context. These two issues explain why, in the Rio Ouro Preto Extractive Reserve, categories such as planting and visits were recorded at acknowledgement levels below average (**Figure 3**). The same issue of ambiguity explained why categories such as fishing and planting were recorded at below average levels in the Rio Cautário Extractive Reserve (**Figure 3**).

An example can help to illustrate the issue of ambiguity. One particular rule was scarcely acknowledged by communities in the Rio Cautário Extractive Reserve. The rule states that: "Reserve beneficiaries can only use forest areas for agricultural, agroforestry and animal breeding activities; they must respect the deforestation limit of a maximum of 5 hectares of undisturbed vegetation and 5 hectares of capoeiras (secondary vegetation) per production unit. The authorization to increase the size of this area will depend on previous studies". The ambiguity lies in the fact that capoeiras are areas previously used for agricultural activity purposes, which were put to fallow due to reduced productivity. Thus, the existence of any capoeira implies that undisturbed vegetation has been previously cut. Therefore, a family who has five hectares of capoeira vegetation has already reached its maximum limit of deforesting five hectares of undisturbed vegetation and could no longer cut this vegetation type. In addition, if such family cuts down undisturbed vegetation again after a few months, it would have a capoeira area bigger than the allowed size; this ambiguity led many reserve residents to misunderstand this rule. According to comments recorded during the focus groups, many residents incorrectly believed that the size of the place of residence to be used for production activity had to vary in multiples of five: such as five, 10, 15 and 20 hectares.

An example of rule poorly adapted to the local context was found in the Rio Ouro Preto Extractive Reserve: "Before receiving visitors, the resident must notify the association or management body in advance by providing the visitor's name, date of the visit and identification document for authorization

issuing (…) the authorization must be written in two copies, one of them to the visitor and the other to the managing body or association". According to this rule, any resident hosting a visitor must personally inform either the association or the managing body by going to the city where the institutions are located. One of the two entities issues the authorization, which must be also signed by the reserve resident and delivered to the visitor. Such authorization can be issued at the day the visitor arrives to the reserve, or prior to their arrival. However, communities hosting most visitors do not follow this rule, because a journey to the city is often extremely costly in terms of money and time. In reality, what often happens is that visitors themselves request the authorization when they arrive at the managing body and/or association host city, without the presence of the reserve resident. This distortion in the application for authorization happens because the rule was not adapted to residents' local reality. It is known that many residents find it difficult to go to the city, either because they live far away from it or because they do not have access to transportation. Thus, many people living in these reserves do not go to the city very often: on average, they travel every twenty-five days to buy groceries and medicines or to access some money. This dynamic of going back and forth from the reserve to the city should have been taken into account at the time of developing the rules for that specific category. The lack of calibration between reserve residents' entry and exit dynamics and the rule guiding the visitation procedure resulted in lower formal rule-acknowledgement levels than expected for some communities, since rubber tappers institutionalized this practice as though it were a formal rule.

The implications of these ambiguous situations and poor adaptation to the local reality go beyond the acknowledgement levels of these rules and contribute to a reduced reliance by rubber tappers on legal management instruments. It can generate internal and external conflicts, as well as hampering progress in cooperation and coordination that could help to overcome the collective action dilemma and, consequently, reduce deforestation (Ostrom et al. 2002; Dietz et al. 2003).

The clarity of rules and their suitability for the local context are essential factors in helping to successfully protect inhabited forests (Ostrom 2005; Tucker 2010). Residents' understanding of the rules depends on: the way those rules are designed and adapted to local needs; the respect for local and cultural traditions and norms; and on the appropriate incorporation of local knowledge about ecology, flora, and fauna. These factors give legitimacy and enable obedience to the rules by forest-dependent people. For example, the survival of forest reserves in a context of high population growth and increasing demand for forest products in Uganda was directly related to the clarity of rules built to manage those reserves (Vogt et al. 2006). In another example, the low level of assimilation of rules by residents due to a lack of understanding, as well as their low acceptance level, led to high deforestation levels in protected areas in Honduras (Ascher 1999; Tucker 2008).

Endogenous Factors

The internal environment of the reserves includes the profile of the community leadership and the relationships between the reserve residents themselves. Relationships and poor leadership negatively contributed to the formal rule category-acknowledgement within the reserves. The rule categories affected by these endogenous factors were place of residence, in the Rio Ouro Preto Extractive Reserve; and timber, newcomers and planting, in the Rio Cautário Extractive Reserve.

Communities did not record good results in the acknowledgement of the set of rules concerning the place of residence category in the Rio Ouro Preto Extractive Reserve. They realized that some residents were taking advantage of routine social situations taking place in the area. Here, more than in any other situation, our analysis revealed what the IAD-Framework calls rational cost-benefit perception (Ostrom 2007), since those residents who mostly remained in the reserve perceived that some rubber tappers, mainly the ones who owned a house in the city and thus had the right to a second dwelling, were mostly living in the city and only returned to the reserve when it was extremely necessary, although they received equal treatment from the managing body and from entities that funded protection and management activities. This type of cost-benefit thinking led some residents to perceive that they were experiencing higher costs by remaining in the reserve, whereas the benefits were equally divided among everyone entitled to a place of residence. Thus, rules that were more flexible towards the period when rubber tappers were absent from their place of residence were considered more severe. It clearly showed that the perception of families who did not have double dwelling was that the formal rule was more tolerant of residents presenting free-riding characteristics than they should be. They also created a pejorative name – "seri-rua" (off-site rubber tapper) – to illustrate the behavior of these double-dwelling residents, and it was also a clear sign that they felt uncomfortable with the situation.

Conflicts of interest that manifested internally in the reserves were important points of negative influence on formal rule-acknowledgement levels. As in other studies (London et al. 2017; Dhiaulhaq et al. 2015), these

conflicts were barriers to the construction of a cooperative, trust-based, and reciprocity-building environment essential to help support forest conservation. On the other hand, they helped create heterogeneous strata of residents – the ones exclusively dedicated to the reserve and those partially dedicated to it – who do not often gather to solve collective issues. They were all much more interested in solving their individual issues and in generating benefits for their restricted circle of influence.

The factor that seemed to be an important determinant of the dynamics of non-acknowledgement of categories such as timber, newcomers, planting in the Rio Cautário Extractive Reserve was the community leadership profile. The leadership undermined the acknowledgement of rules by rubber tappers, since it acted in a negligible way by showing poor knowledge about the management agreement and by presenting a profile not compatible with the one that reserve residents expected from community leaders. Overall, the role played by leaderships relates to collaborating through interventions in community/manager, community/reserve and community/community relations to allow the activities within the reserve to be carried out in compliance with legislation. In addition to other activities attributed to leaders, such position requires some technical, communication and political skills, which were not observed as dominant traits among the leaders in our focal communities. This factor turned the leader into a common person within the community, someone who did not have the ability to solve the everyday problems affecting their community nor to be responsible for community disagreements about the formal rules.

Accordingly, the leader stopped playing their coordinating role and was no longer an essential element to the development of what the IAD-Framework calls conflict resolution mechanisms within the community. On the contrary, they became part of a set of actors who helped exacerbate conflicts within the community and, ultimately, within the reserve (McGinnis 2011; Ostrom 2015). While there are other forms of learning that are not strictly dependent on community leadership, leadership action often facilitates information exchange and complex decision making (Favero et. al. 2016).

Exogenous Factors

The relationship with the external environment of both studied reserves appeared to be an important factor in explaining the fact that the formal rule-acknowledgement results did not reach maximum levels in some categories. The external environment directly influenced the result of four categories of rules in the Rio Ouro Preto Extractive Reserve: reading, rubber tapping, timber and place of residence; whereas the influence of exogenous factors in the Rio Cautário Extractive Reserve was perceived in the categories of fishing and timber. Changes in the economic profile of the state of Rondônia – and of the country as a whole – increased external pressures on natural resources, which in turn generated conflicts and death threats towards traditional communities. These were the two major counterproductive influences from the external environment on the acknowledgement of rules in the extractive reserves.

The economic environment external to the reserves influenced the dynamics and intensity of forest product-extraction activities, since the price of these products is determined in part by an economic model based on supply and demand. Demand is determined by needs and desires of people living distant from the reserve, including internationally when the product is exported. The low rubber extraction case and its negative influence on the acknowledgement of the rubber tapping category is an example of how the external economic environment may influence the forest product-extraction dynamics and, consequently, the rule-acknowledgement dynamics. The external environment, which buys latex at low prices and has no prospect of improvements in its selling price in the short- and medium-term, is the same environment that raises Brazil nut and copaíba prices to an astronomical level to the point that rubber tappers wish that these two products could be harvested throughout the year. The price of the latex purchased by private companies has fallen sharply in the last fifty years. Thus, the government had to make an intervention through subsidies from the Natural Rubber Production Incentive Program (PROBOR – Programa de Incentivo à Produção da Borracha Natural), which helped some reserve residents to continue extracting rubber latex. However, this activity lost popularity over time, and only a few people, often the older ones, continue doing it.

These external economic changes contributed to the emergence of new structural formats in the forest product-trade chain (Tschopp et al., 2018), which the rubber tapping communities in our study reserves seem to be unable to adapt to. With respect to rubber, communities embodied the role of "microentrepreneurs", since they are responsible for cutting the rubber trees and treating the latex, and for negotiating and selling it to processing industries. This burden of administrative functions (logistics, negotiation, and sale) brings constant pessimism and disenchantment towards remunerable commercial activities based on rubber tapping, especially when the value paid per kilo is very low. Thus, this activity has become devalued, not only within our study reserves but throughout the Amazon region (Jaramillo-Giraldo et al. 2017).

The monetary variation of forest products in the market has brought, and will bring, changes in the extractive activities conducted within the reserves. Extractivists are called rubber tappers due to tradition, yet very few of them engage in this activity nowadays; the rubber tapping activity is largely characteristic of individuals older than forty years. Adolescents and young people within the area tend not to be interested in latex extraction due to the effort the activity requires or to the low values derived from the sale of the product. Thus, it appears that the knowledge of how to extract and process latex, which was responsible for the migration of millions of Brazilian citizens from the northeast into the Brazilian Amazonian forests, will be lost in a matter of time. In contrast, the emergence of other income sources encourages the practice and handling of different forest products and of agropastoral activities. Such changes in extractive practices are orchestrated by markets exogenous to the forests (Gomes et al. 2012).

Therefore, economic changes in the prices of forest products were the main reason for reserve residents not to reveal a higher level of rule-acknowledgement related to latex management, which composed the rubber tapping category. The lack of practice in handling rubber, as a consequence of external economic conditions, explains the results even for older, more established communities. This result showed that market forces can be used as essential elements to help fight deforestation in the Amazon (Gibbs et al. 2015a; Gibbs et al. 2015b), although they are also the main driver of deforestation taking place in tropical forests (Armenteras et al. 2017; Krishna et al. 2017).

The increasing pressure for wood and natural resource extraction in general, which have resulted in conflicts and death threats in the two reserves, is the second important point in understanding the external factors negatively influencing the formal rule-acknowledgement dynamics.

In order to illustrate the situation, Santo Antônio and Girau hydroelectric plants were built in Rondônia and, after 1984, the BR 364 highway – the main route for grains and cattle to be transported in northern and midwestern Brazil – was paved. This highway passes the main cities in the state, such as Vilhena, Cacoal, Ji-Paraná, Ariquemes and the capital Porto Velho itself. It also provides access to the state of Acre, as well as to the two aforementioned hydroelectric power plants (Ribeiro et al. 2005; IMAZON 2015). Thus, these developments have left the two reservations cornered. There are also pressures on the extractive dwellers themselves, who witness the continuous invasion of their lands, as well as increased conflicts with neighboring agricultural actors and with logging companies in the region. The prevailing model of economic expansion has led to a worsening of deforestation, and to the disarticulation of traditional communities not only in Rondônia, but throughout the Amazon biome (Castello et al. 2013). This environment of pressures and uncertainties has increased as a consequence of modifications to the country's new forest code, approved in 2012 (Soares-filho et al. 2014).

Categories such as timber and fishing in the Rio Cautário Extractive Reserve presented rule-acknowledgement issues in communities subjected to the strongest external pressures, either because they were closer to the city or because they shared borders with land owners who often did not respect territorial limits. Thus, "territorial invasions" and "illegal fishing" were often mentioned in the focus groups held in these communities, in addition to reports about death threats towards the residents and about their homes and boats being burned.

The formal rule-acknowledgement in the reserves was directly influenced by factors related to exogenous socioeconomic factors. It shows that the governance of these areas is constituted by relational dynamics involving not only actors directly involved in the reserves, but also agents indirectly acting in the management and conservation process.

Our findings consistently pointed out that the influence of factors exogenous to the extractive reserves played a key role in the non-acknowledgement of rules.

After criticism of the IAD framework (Agrawal 2003), Ostrom refined her ideas by highlighting external factors – environmental, social and economic – as important elements for building institutional arrangements, rules-acknowledgement, and environmental governance (Ostrom 2009). An understanding of external factors appears to be a critical prerequisite for successful governance of common environments. This perception was shared by Gray (2016), who called it a "boundary organization". Andersson (2013), Barber et al. (2014), Messier et al. (2015) and Moran (2016) have also addressed the topic.

Conclusions

We conclude that the high rule-acknowledgement levels found in the two reserves poorly explain the deforestation rates recorded in them. Based on our hypotheses, we expected that there would be higher variations in the acknowledgement of formal rules between the two reserves, given the extreme differences in deforestation rates associated with them.

Although rules are important elements of protected area governance, any study that focuses exclusively on rules may encounter limitations in the degree to which they can explain the outcomes of interest. For example, an exclusive focus on rules does not account for value systems (ideas, ideologies, attitudes, values and believes) (Beaumont et. al. 2018; Nahuelhual et. al. 2018; Loft et. al. 2015) or other factors that affect behaviors (Ostrom 2005).

Additionaly, our analysis of the dynamics of formal rule-acknowledgement by rubber tappers showed five factors that contribute to the governance of the two study reserves: learning strategies; institutional change speed; rules content; endogenous factors; and exogenous factors. Our result showed the importance of thinking about and strongly inserting the economic, political, and social environments circumscribing these areas in the discussion and governance models focused on protected areas (Matson et al. 2016). Involving actors external to the reserve means putting on scene the command and control mechanisms (Nepstad et al. 2014; Arrima et al. 2014), as well as companies, entrepreneurs, traders, politicians, citizens and, of course, the rubber tappers themselves in a multilevel, multiscale and multi-dialogue governance model (Ratner et al. 2017; Cole and McGinnis 2015).

Solving deforestation issues in the Amazon through the construction of governance in conservation units is an arduous task. The considerable number of actors, processes, levels, and positions that can be identified composes a complex framework that makes it difficult to identify and understand conservation unit governance mechanisms. Nevertheless, our study addresses elements related to the rules in use, which can suggest and raise alternative ways of dealing with deforestation in the Amazon. It is not the only option, and perhaps not the most important one, but it is certainly an alternative to help keep the Amazon rainforest intact and to assure the survival of socio-environmental and cultural features the forest has protected for thousands of years.

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Competing Interests

The authors have no competing interests to declare.

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