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Sustainable Forest Management and Social-Ecological Systems: An Institutional Analysis of Caatinga, Brazil

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Abstract: Sustainable Forest Management (SFM) has globally gained support as a strategy to use and manage forest resources while maintaining forest ecosystem services. However, type, relevance, and utilisation of forest ecosystem services vary across eco-regions, countries, and policy implementation pathways. As such, the concept of SFM is subject to a series of translations within the social-ecological context in which it is implemented. This article discusses translations of SFM in Caatinga biome—a tropical dry forest in the north-eastern semi-arid region of Brazil. Our analysis is based on a qualitative analysis of 24 semi-structured interviews and 30 documents. We discuss SFM and the interplay of resources, governance, and actors. Results for Caatinga show that (1) a technical approach to SFM that focuses on firewood and charcoal production is dominant; that (2) SFM implementation practices hardly address the needs and interests of local populations; and that (3) local actors show little support for the implementation of SFM. We conclude that the social-ecological context of Caatinga shapes translations of SFM mostly in a techno-bureaucratic rather than a socially embedded way. As a result, local practices of forest use are excluded from the regional SFM approach, which negatively affects its implementation.

Keywords: Critical Institutionalism; institutional translations; SFM; Caatinga biome; Brazil

1. Introduction

Translations of Sustainable Forest Management within a Specific Social-Ecological Context

Today, debates on implementing Sustainable Forest Management (SFM) to combat deforestation are especially focused on natural forests in tropical regions. Since the early 1990s, SFM has gained global support as a strategy that simultaneously promotes the use of forest resources and the conservation of forest ecosystems [1,2]. More recently, SFM has become part of strategies aiming to protect natural forest resources against deforestation pressures resulting from land use change [3]. This support for SFM implementation in natural forest contexts follows the broad application of SFM within several international environmental policies.

Natural forests in tropical regions are often hotspots of deforestation, harbour high levels of biodiversity, and play a key role in regulating global climate [2,3]. As such, natural tropical forests are targeted by an international forest regime consisting of multiple international agreements and policy instruments in which SFM plays a key role [4,5]. Natural forests are also subject to a diversity of domestic governance regimes linked to international policy debates, including climate change, biodiversity, desertification, poverty, and human rights [6]. Moreover, SFM is likely to be shaped by the social-ecological context in which it is implemented. This brings challenges to the implementation of SFM on the ground, including how to align domestic governance regimes with the needs and specificities of local social-ecological systems [7,8].

Located in North-eastern Brazil, Caatinga biome, hereafter called Caatinga, harbours one of the most biodiverse tropical dry forests in the world [9,10]. A biome is "*a geographical area defined mostly by the climate conditions, but also by the vegetation, soil and altitude*" [11]. For the purpose of this paper, the division of the Brazilian territory in biomes is also linked to a division based on similarities of policies, governance, cultural identity and social contexts [12]. In Caatinga, forest resources are central to the livelihoods of local populations and an important source of biomass for energy supply (firewood and charcoal). Forest resources provide 30% of the energy supply in the region [13]. Implementation of SFM in Caatinga started in the 1980s as a way to combine the use of forest biomass as a source of renewable energy with forest conservation. SFM is considered to have the potential to decrease biodiversity loss, desertification vulnerability, and poverty [9,14]. However, a research gap exists with regard to the understanding of how SFM implemented in Caatinga is shaped by social-ecological factors.

Caatinga is an indigenous word from the 'Tupi' language (kaa'tinga ⇒ '*kaa*': vegetation, plants + '*tinga*': white, clear), meaning 'white forest' [15]. The biome is located in North-eastern Brazil and covers 84 million hectares spread over 9 federal states (see Figure 1 below). It is the third most populated biome with 12.9% of Brazilian inhabitants [16], and presents the highest poverty index among the biomes: of the 200 poorest Brazilian municipalities, 153 are found in Caatinga [17]. Located in a semi-arid area, Caatinga is exposed to long dry seasons. The dry season that started in 2011 continues till today—even though there was a rainy season in 2017—and has been reported as the most intense of the last 30 years [18].

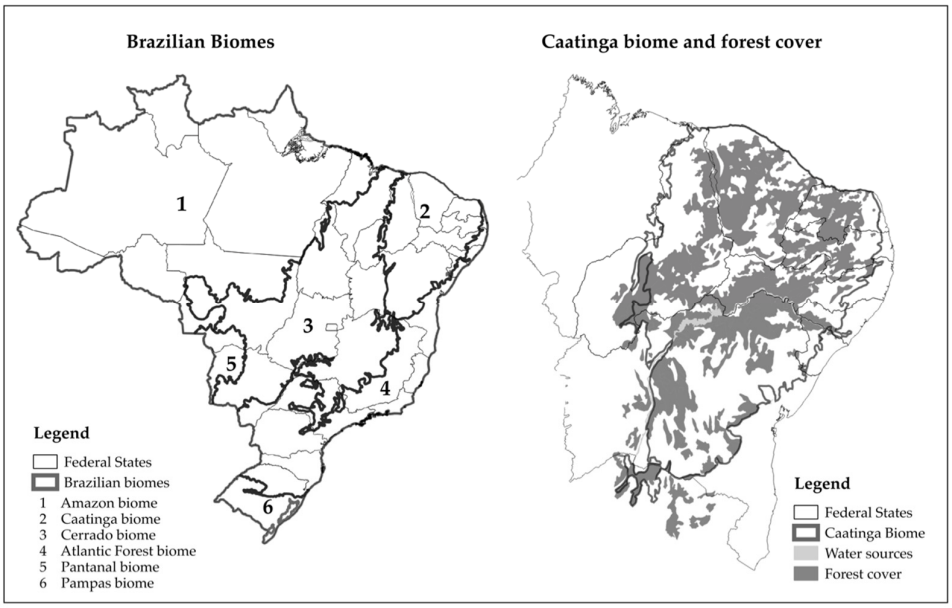

Figure 1. Brazilian biomes and forest cover in Caatinga biome (Elaborated by the author cf. [19,20]).

Brazilian forest governance has historically focused on the Amazon biome, which embraces the largest tropical rain forest in the world, and on the Atlantic Forest biome, the most deforested among the Brazilian biomes [21]. Recently, federal government's strategies, especially those dealing with deforestation threats, also started to focus on the Cerrado biome (Savannah), where deforestation rates have been increasing in the last five years due to land use change as part of agribusiness expansion in the region [22]. Caatinga and its tropical dry forests receive little attention in terms of domestic actions targeted at conservation or sustainable use of natural resources [5,23], even while it is home to the poorest and the third largest population of the country [11] and has the second larger forest cover in relation to the total area of the biome, coming just after the Amazon [24].

Considering the above, this article investigates how implementation of SFM in Caatinga contends with multiple issues. First, it explores how technical aspects of SFM are translated to the natural

tropical dry forest ecosystem of Caatinga. Arguably, this involves both technical expertise and the adaptation of legal frameworks to be suited to this context [8]. Second, the article addresses questions over governance, such as which actors are involved, and how SFM implementation strategies seek to introduce and/or change already existent institutions [25]. Finally, the article addresses how SFM in Caatinga might be shaped by socially embedded values and beliefs that are particular to this social-ecological system [26,27]. We thus hypothesize that the social-ecological interactions particular to Caatinga will shape translations of SFM. In the following, we first present our analytical framework based on the Social-Ecological System model [26–28], and the Critical Institutionalism approach [25,29,30]. After that, we discuss our methodology and present our results. We conclude the article by discussing how social-ecological interactions shape translations of SFM in Caatinga and how these translations affect the uptake of SFM on the ground.

2. Analytical Framework

Social-Ecological System Model and the Critical Institutionalism Approach

To understand how social-ecological interactions within a biome affect and shape translations of SFM in a specific context, we integrate ideas from literature on Social-Ecological Systems (SES) [26,31] and Critical Institutionalism (CI) [25,30] into our own analytical framework (see Figure 2 below). In particular, we use the SES model to discuss how interactions between actors, institutions, and resource uses shape SFM within a specific social-ecological context [26,27]. Accordingly, we understand the emergence of technical approaches, rules, and cultural values and beliefs on SFM to result from social-ecological interactions within a specific context or region [32].

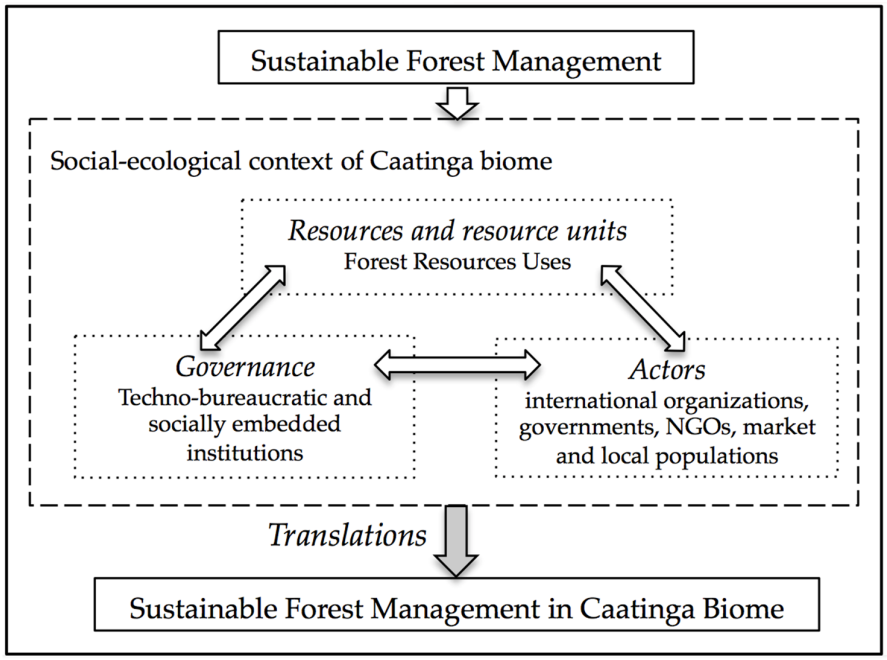

Figure 2. Translations of SFM in a social-ecological system framework (Elaborated by the authors cf. [26,27].

The SES model presents a complex system of interactions across resources, resource units, actors, and governance sub-systems within specific social-ecological contexts [26,27]. When applying the SES model to a specific case, each of these sub-systems comprises a set of variables that depend on *"the particular question under study, the type of SES, and the special and temporal scales of analysis"* [26] (p. 420), We adapt the SES model to our case and argue that institutions (rules, norms, and values) are shaped by a given social-ecological context [33]. To identify variables for the study of translations of SFM in

Caatinga in recent years, we consider a *translation* to be a process through which rules, norms, and cultural values linked to SFM are shaped by interactions among actors, governance, and resources use.

The general understanding on which the SES model is based holds that interactions among resource and governance systems entail institutions that steer actors' behaviour as they participate in the management of natural resources [26–28]. For our analysis, we specify two groups of institutions that we adopt from CI: techno-bureaucratic and socially embedded institutions. Techno-bureaucratic institutions comprise formal rules and norms, such as regulations and technical approaches linked to SFM. Formal rules can be seen as deliberate interventions to change or strengthen a specific actors' behaviour and can be applied across different contexts. Although norms are not always formalised in rules, they are nonetheless specific enough to be recognised as standards or codes of conduct by which to act and behave [34]. Socially embedded institutions are related to cultural values and beliefs guiding actors' behaviour. This type of institutions differs from techno-bureaucratic institutions in that it is generally much stronger anchored in a society or community in a historical, cultural, and political sense. As it is socially embedded, this type of institutions is more diffuse in its articulation and less likely to travel across different contexts [35].

Critical Institutionalism (CI) answers questions about how institutions are translated from one context to another. According to CI, processes of "*reusing, reworking, and refashioning*" of already existent socially embedded institutions happen when they interact with new techno-bureaucratic institutions that arrive 'from outside' [30]. CI argues that if institutions from different origins and scales interact, then new local arrangements will be produced, thus leading to governance outcomes that in many cases are unintended and/or unexpected [30,36]. According to CI, such processes of institutional change involve *bricolage*, a process by which people (un)consciously draw upon existing socially embedded institutions to shape new arrangements and outcomes in order to cope with change [25,30]. For the purpose of this paper, we speak of 'translation' instead of 'bricolage'. The latter is particularly tailored to address individual actors' behaviour in a new institutional setting, whereas 'translation', we believe, better expresses the change of institutions and outcomes from a collective action perspective. That is to say that we consider institutional actors such as governments as well as local communities to play a key role in shaping institutions, and hence as the relevant actors in the process of institutional change.

For our analysis, we are interested in how SFM—introduced in the social-ecological context of Caatinga—is translated and shaped by: (1) the nature and availability of biome-specific forest resources; (2) their use and management by regional and local actors; and (3) their governance through techno-bureaucratic and socially embedded institutions (see Figure 2 above). In particular, our analytical framework brings out how actors, resource use, and governance influence each other to shape SFM on the ground. As such, we hypothesise that the uptake of SFM as a practice on the ground—and therefore SFM implementation in general—is strongly related to the extent to which these categories do or do not interact.

3. Material and Methods

Analysing Translations of Sustainable Forest Management in the Social-Ecological Context of Caatinga

We analyse SFM implementation in Caatinga for two main reasons. First, in a country such as Brazil with at least four different tropical forest biomes (Amazon, Atlantic Forest, Cerrado, and Caatinga), SFM strategies need to engage in dialogue with the social-ecological specificities of these different territories for them to be successful. Caatinga is the least researched forest biomes of the four [23]. Second, the biomes of Brazil do not only refer to geographical territories that share biophysical similarities but also correspond to territories with shared social, economic, political and cultural contexts [12], thus representing social-ecological systems.

We apply a simplified SES model to Caatinga as a composition of three sub-systems: (1) *Resources* and *Resource Units*—including the uses of forest resources and the ecosystem services provided by

these uses; (2) *Governance*—including techno-bureaucratic and socially embedded institutions; and (3) *Actors*—including international organizations, federal and state governments, non-governmental organizations, market actors, and local populations. We understand these actors to both shape institutions and forest use on the one hand and to be shaped by institutions and forest use on the other hand. As these sub-systems continuously interact, we present our results below by discussing both resource use and governance in relation to the actors that use and implement them.

Our analysis is based on data obtained from *24* semi-structured interviews with representatives of the Brazilian government in federal (central) and state (regional) levels; non-governmental organizations; universities; private companies; international organizations; and experts (see Table 1 below). The selection of key-actors to be interviewed was based, first, on the previous working experience of the first author at the Brazilian Forest Service supporting governmental strategies of SFM implementation in Caatinga. Second, we adopted the 'snowballing' qualitative method, where interviewees were asked to indicate other potential interviewees [37]. The interviews had an average duration of 50 min and followed a semi-structured script to explore the interviewees' opinion on experiences and ideas linked to SFM implementation in Caatinga. We also collected data from around 30 additional documents, comprising of governmental documents, policy reports, and an event called the 'First Symposium of the Caatinga biome', organized by the Brazilian Agricultural Research Corporation (*Embrapa*), in Petrolina, Pernambuco. Qualitative coding of the interviews was based on an inductive approach to qualitative data analysis [38], which means that the first round of analysis generated empirical codes that in the second and further rounds of analysis were organized in various blocks corresponding to analytical frames distilled from literature. As qualitative coding was iterative, it also contributed to the design of the analytical framework.

Table 1. List and profile of interviewee.

	Brazilian Federal Government (13)
Interviews 1 and 2	Brazilian Forest Service (Ministry of the Environment)
Interview 3	National Fund for Forest Development (Ministry of the Environment)
Interview 4	National Fund for Climate Change (Ministry of the Environment)
Interview 5	Department of Sustainable Rural Development (Ministry of the Environment)
Interview 6	Department to Combat Desertification (Ministry of the Environment)
Interview 7	Caatinga Nucleus (Ministry of the Environment)
Interviews 8, 9 and 10	Northeast Regional Office of the Brazilian Forest Service (Ministry of the Environment)
Interview 11	Office of the Ministry of Agrarian Development in Pernambuco state
Interview 12	'Dom Helder Câmara' Project (Ministry of Agrarian Development)
Interview 13	National Institute for the Semiarid (Ministry of Science, Technology, and Innovation)
	States' Government (2)
Interview 14	Environment Agency of Paraíba (Sudema)
Interview 15	Environment Agency of Pernambuco (CPRH)
	Non-Governmental Organizations (3)
Interview 16 and 17	North-eastern Plants Association (APNE)
Interview 18	Center for Sustainable Industrial Production (CEPIS)
	Universities (2)
Interview 19	Federal Rural University of Pernambuco (UFRPE)
Interview 20	Federal University of Campina Grande (UFCG)
	Private Company (1)
Interview 21	Northeast Reforestation (*Nordeste Reflore*)
	International Organization (1)
Interviews 22a and 22b	Inter-American Institute for Agriculture (IICA)
	Experts (2)
Interview 23	Current director of the Climate Observatory (*Observatório do Clima*)
Interview 24	Former director of sustainability of the Brazilian office of the United Nations Development Programme (UNDP)

Table 1. *Cont.*

	'First Symposium of the Caatinga Biome' (5)
Interview 25a	Food and Agricultural Organization of the United Nations (FAO)
Interview 25b	Department to Combat Desertification (Ministry of the Environment)
Interview 25c	Federal University of Campina Grande (UFCG)
Interview 25d	Federal University of Ceará (UFC)
Interview 25e	North-eastern Plants Association (APNE)
	Total: 24 interviews + 5 presentations at a Symposium

Elaborated by the authors.

4. Results

4.1. Forest Resources Uses in Caatinga

In Caatinga, pressures on forest cover and uses of forest resources include: use as a natural pasture for animals (cattle and goats); use as a source of biomass for energy supply (firewood and charcoal); use as a source of non-wood forest products (NWFP) (such as fruits, fibres and oils); and use linked to local knowledge and practices. In the following, we discuss each of these forest resources uses.

Long-term land use change from forest to agriculture is not present in Caatinga on a large scale, due to its extreme climate conditions and lack of water resources [39]. Instead, cattle and goat breeding happens mainly through the occupation of natural forest cover areas that are used as natural pasture. In other words, cattle and goat breeding is a simple matter of inserting animals in the natural environment [40,41]. The use of land under forest cover as a natural pasture for cattle and goats is a central livelihood strategy of local populations, especially to face periods of drought. At the same time, this strategy is closely linked to forest degradation.

"For local populations, it is interesting to maintain the natural forest cover even if it is over-exploited and degraded by animals over-pasturing [40] (p. 4)."

"When we talk about forest resources in Caatinga we are talking about a huge livestock-grazing system, with animals that roam freely in these forest areas [41] (p. 2).

Another important use of forest resources in Caatinga is as a source of biomass for energy supply. The use of biomass from forests happens through using firewood in the household (cooking), and through producing firewood and charcoal used by local and regional business (bakeries and barbecue restaurants), and industries (brick, roof tile, and plaster) [13]. The domestic use of firewood is hardly quantifiable because local people collect the wood that is already on the ground as part of their daily practice [42]. However, pressure on forest resources from the energy supply of business and industries is a historical presence in Caatinga that continues today; indeed, the largest area of deforestation in the biome is located exactly around the area where most of the plaster industries are concentrated, in the Araripe region, state of Pernambuco [39,43]. The plaster industry in the Araripe region produces around 95% of national demand for plaster and has a huge impact on the Caatinga biome [44].

In addition to firewood from natural forests, industries and business also get their energy supply by using biomass from exotic tree species, such as *Algaroba*, and pruning of *Cajun-nuts* trees. The management of both species is allowed by environmental agencies in Caatinga [45]. The proportion of biomass for energy supply of industries and business in Caatinga is as follows: around 20% comes from SFM schemes in natural forest cover areas, around 30% comes from management of *Algaroba* and from pruning of *Cajun-nuts* trees, and around 50% comes from non-authorised (illegal) forest management sources. The latter type of use is considered to be the leading cause of deforestation of natural forests in Caatinga [43].

"Even if there is a huge offer of these alternatives sources, more *Algaroba* than pruning from *Cajun-nuts* trees, still almost half of the firewood consumed comes from the natural forest cover. This is a reason why it is important to control the use of this resource [40] (p. 5)."

The use of forest resources in Caatinga is also linked to non-wood forest products (NWFP). Most of these products, such as fibres, oils, and fruits, are intended for the direct consumption

of local populations and are not under any formal regulation of use and management [46]. Commercialization of NWFP in Caatinga happens mainly on a local scale [39]. Most of the NWFP are seasonal and strongly dependent on the intensity and duration of the dry seasons. Accordingly, most local people prefer to invest in other livelihood strategies, such as cattle and goats, and in the production of firewood and charcoal—whether that is sourced through SFM or illegal forest management—as biomass for energy supply has a permanent demand.

"Although NWFP in Caatinga have the potential to generate income for local people, their related value chains are more complex and more difficult to be maintained in a social and economic vulnerable situation. The value chain for firewood and charcoal, for instance, is permanent, even though not completely legal [47] (pp. 6–7)."

An additional important forest use is linked to its function as an indicator of environmental conditions. This forest use is embedded in local practices and can be understood as part of a system of local knowledge of environmental performance, for instance to deal with dry seasons or to identify the quality of soils [48].

"The *Juazeiro* tree, which during rainy seasons loses leafs, and during dry seasons is the only green tree in Caatinga, gives an indication of climate conditions. The *Jurema* tree is also an indicator of desertification or poor soils conditions, as it is the first species to grow in very poor soils. The *Pereiro* tree can be an example of how to deal with poor soil conditions. Fertile soil accumulates around its base giving it the necessary nutrition for growth. Accordingly, the *Pereiro* tree is known as the 'professor of restoration' [48] (p. 7)."

The various uses of forest resources in Caatinga as part of the livelihoods of local populations are relevant when considering how they face socio-economic vulnerability. Especially during long dry seasons, forest resources become key to sustaining livelihoods [40]. On the one hand, forest resource uses are integrated in local livelihoods such as a natural pasture for cattle and goats, and as a source of biomass to rapidly generate income in emergency situations. On the other hand, some livelihood strategies, notably those related to commercial firewood, may cause degradation of forest resources in the biome. Promoting SFM is therefore considered an important strategy to contribute to the biome conservation [49]. Moreover, conservation strategies in Caatinga may also need to consider the uses of forests resources by local populations, as they may contribute to promoting integrated sustainable practices [39].

"In truth, local people already use and manage forest resources through local knowledge practices. Organizing an activity that is already part of their production system might be a key element in promoting sustainability [49] (p. 1)."

4.2. Techno-Bureaucratic Institutions Linked to SFM in Caatinga

Below, we discuss two types of techno-bureaucratic institutions found for SFM in Caatinga. First, we analyse the technical approach of SFM that has been developed in order to provide technical guidance on how to implement SFM in Caatinga. Second, we analyse formal rules and governmental support on SFM implementation in Caatinga. In Caatinga, the technical approach of SFM is mainly focused on the production of firewood and charcoal. Most of the formal rules and governmental support on SFM implementation are equally related to firewood and charcoal. As a result, techno-bureaucratic institutions do not integrate other important uses of forest resources, for example as a source of NWFP or as a natural pasture for animal breeding.

4.2.1. Technical Approach of SFM in Caatinga

Discussions on SFM in Caatinga are reported to have started in the end of the 1980s through a project funded by the Food and Agricultural Organization of the United Nations (FAO) and implemented by the Brazilian federal government [40]. This initiative provided the first experiments on the ground aiming to assess the ecological dimensions of SFM, even if it was focused on the production of forest biomass for energy supply alone [48].

"The FAO project in Caatinga produced a lot of data related to forest management focused on producing biomass for energy supply: from forest regeneration to studying the calorific power of the different wood species [50] (p. 13)."

One of the results of the FAO's project showed that regional consumption of forest biomass for energy supply is between 30 and 60 million stère meters per year. Supplying this annual energy demand through a non-sustainable use of forest resources could result in the loss of all forest cover in Caatinga within 40 years. Therefore, early discussions focused on the viability of forest plantations to answer the demand for biomass for energy supply. However, experiments clarified that the introduction of exotic species for biomass production would not give positive results mainly due to the extreme weather conditions of the biome [40]. Changing their focus to reforestation with native species, FAO researchers concluded that while working with natural forests to produce biomass, there was no need of reforestation due to the high resilience capacity of the native tree species. As a result, research started to explore techniques that could allow natural restoration of the managed forests [40].

By the end of the 1990s, new research initiatives started through governmental projects in partnership with the United Nations Development Program (UNDP) and the Global Environment Facility (GEF) [13]. Results of this second wave of projects, also focusing on biomass for energy supply, established technical guidelines for SFM in Caatinga, such as standardizing the best practice of clear-cutting while respecting a non-use cycle of a minimum of 15 years between exploitations in the same area [9]. Norms linked to SFM, such as the definition of techniques of clear-cutting, closely resembled the practices of local populations when managing natural forest resources in Caatinga [40]. However, the non-use cycle between clear-cutting is almost unfeasible as it is a common practice to use these areas as a natural pasture for cattle and goats breeding [43,50].

Even though most of the research on SFM in Caatinga is clearly focused on biomass for energy supply, it more recently also produced the insight that SFM must include 'multiple uses' of forest resources. Some researchers now recognise that the management of NWFP and using forest cover as natural pasture are important elements of the livelihoods of local populations and cannot be put aside when talking about the management of natural forest cover in Caatinga.

"There are places where managing natural pastures for animals is more important and can bring better results in terms of conservation; there are other places where bee and honey production can have a more positive impact, and so on. We need a more integrated approach in using forest resources in Caatinga and leave aside the strategy that is focused only on firewood and charcoal [47] (p. 6)."

The federal government has also supported a research initiative aiming to define best practices of managing specific trees as a potential source of NWFP (20 tree species were elected from a list of 67 species). This initiative resulted in 'working books' published by the federal government that indicate sustainable practices for managing forest focusing on NWFP, such as the definition of an ideal quantity and ideal intervals for its exploitation, sustainable extraction practices of products, and information on natural regeneration [39]. Research that focuses on the use of forests resources as natural pasture is being developed since the 1990s, and is closely related to agroecology strategies [51]. Even so, these initiatives are still barely integrated into the SFM technical approach and governmental strategies to support SFM in Caatinga.

4.2.2. Formal Rules, Regulations, and Governmental Support to Implement SFM in Caatinga

Legal use of forests in Brazil requires compliance with both Federal law and State regulations. The use of forest resources is, first of all, subject to the main federal legislation in force: the Forest Code (*Lei n.12.651* 25/05/2012) [52]. This code prescribes, among others, the mandatory maintenance or implementation of conservation areas in a rural property: (a) the Permanent Conservation Area (APP—*Área de Preservação Permanente*) mainly aiming to protect water and soil; and (b) the Legal Reserves (RL—*Reserva Legal*), aiming to maintain forest ecosystem services locally [52]. Besides federal legislation, the use of forest resources is, secondly, also subject to States' regulations. All forest uses

need to be authorized by a State Environmental Agency, which regulates and controls any activity that might harm the environment (*Resolução* CONAMA n.237 19/12/1997) [53].

When forests are used according to SFM principles, this means that a SFM plan needs to be authorized by a State Environmental Agency. The implementation of SFM in Caatinga is mainly guided by a federal government's regulation (*Instrução Normativa* IBAMA n.1 25/06/09) [54], which describes technical parameters and bureaucratic steps for licensing and monitoring a SFM plan. With this normative document, the federal government regulates the production of firewood and charcoal through SFM plans. The use of forest resources embedded in the livelihoods of local populations is generally not (clearly) regulated by the States' Environmental Agencies [46], and thus neither clearly considered illegal nor legal by authorities even when it involves sustainable practices.

The bureaucratic steps to get an environmental license for a SFM plan involves an analysis of technical documents, monitoring, and control by the state's environmental agencies. In addition to the environmental license, an authorization of exploitation is needed for each yearly cycle of clear-cutting (AUTEX—*Autorização de Exploração*), which involves again another yearly round of analysis on technical documents, monitoring, and control by the environmental agencies.

"Every year you have to request exploitation license with the environmental agency, and most of the times due to a very slow bureaucracy process in these agencies, it is possible to obtain this annual license only after the time that the cutting was planned, and this is a year of lost work. Only those who have savings can deal with this bureaucratic instability [55] (p. 4)."

One of the central challenges in turning the licensing of a SFM plan more efficient is the lack of technical staff in the state's environmental agencies, both in terms of the number of people and their technical capacity. This lack of bureaucratic capacity has two main consequences: (1) the discontinuity of the activity on the ground; and (2) a lack of offer of biomass from SFM plans for energy supply. At the same time, the demand for biomass for energy supply by industries (plaster, roof tiles, and bricks) and business (bakeries and barbecue restaurants) is continuous and covered mostly by illegal forest management.

"If there is no firewood from SFM plans in the market the industries are not going to stop their activities, they then buy firewood from illegally managed forests and those who manage forest illegally take a huge advantage in filling this supply gap [56] (p. 2)."

Considering that surveillance to prevent illegal forest management is sporadic when compared to the control of a licensed SFM plan, forest users having a SFM plan are, in practice, under a higher level of control [43]. A community that is waiting for analysis, monitoring, or control as part of the licensing of a SFM plan competes with illegal practices that are not under the same level of control creating an "inverse effect": is not the better choice to be legal in a market that is mainly illegal [45]. The "inverse effect" also happens on the consumer's side. Once the industries and business are regulated to be a consumer of firewood from SFM plans, for instance, they are also subject to a higher level of control by environmental agencies when compared to the sporadic controls on consumers of illegal firewood and charcoal [40]. These non-regulated consumers are also supported by the fact that the alternative sources of biomass, such as *Algaroba* and *Cajun-nuts* do not need a SFM plan to be managed and consumed. A consumer that use firewood from illegal forest management, for instance, will always have an amount of these alternative sources in their back yard to show in case of an unexpected control [40].

"To buy firewood from a SFM plan the industry needs to be completely regulated and answer to all the environmental and commercial rules, and this is also a challenge because most of the industries are still operating informally. We work with 24 ceramic industries and only 7 are able to buy firewood from SFM plans [56] (pp. 6–7)."

A lack of funding through credit programs is another issue for SFM implementation as it threatens its economic viability. There is a lack of credit programs to finance planning and licensing; most available credit programs only support the activity when a community or landowner already has an environmental license approved [47,55,57]. In the scenario where local communities are economically and socially vulnerable, landowners that have better financial conditions have also better conditions to

deal with all the challenges of implementing a SFM plan. Accordingly, there are different conditions among social groups to deal with challenges in implementing a SFM plan. For certain communities, these challenges imply a lack of income from firewood and thus contribute to their economic and social vulnerability [49].

Recently, the federal government's initiatives to support SFM in Caatinga started to focus on increasing income generation in areas where the most vulnerable communities live: rural settlements [45,49]. Although they mainly focus on the production of firewood and charcoal, federal government's initiatives for SFM implementation in rural settlements in Caatinga increased significantly during the last five years. The Department to Combat Desertification and Droughts Effects of the Ministry of Environment was the governmental actor that mainly articulated these initiatives [58]. However, after the impeachment of president Dilma Rousseff, this department was extinguished in 2016. As a result, the political articulation and integration of federal government's initiatives around sustainable use of natural resources in Caatinga has again weakened significantly today.

"Even though federal government actions to support SFM in Caatinga increased in recent years, an integrated strategy such as a National Program for Caatinga is still lacking, which could bring to these actions a more integrated approach. Resources have been increasing, but without a formal structure to guide their application the effort can be lost [47] (p. 5)."

4.3. Socially Embedded Institutions Linked to SFM in Caatinga

In rural areas in Caatinga, livelihoods of local populations are mainly based on small-scale agriculture, cattle and goat breeding, and on the use of forest resources for direct consumption and trading in local and regional markets. The cultural and social values of these different activities vary according to their timing, efficiency in income generation, and value-chain stability. Agriculture, cattle, and goat breeding have high levels of social legitimacy for local populations and are strongly linked to local cultural values.

"Agriculture and livestock are activities that are more 'traditional' even if local farmers know that they probably will face some kind of loss in agriculture or need to spend more money to feed animals during the dry seasons. Having animals and huge areas of agriculture are practices that are, socially, more valorised [49] (p. 9)."

Social legitimization of forest-related activities in Caatinga is lower than agricultural activities, which relates also to the under-valorisation of forest products. Forest resources are part of the livelihoods of local populations, but often yield low-value products that are culturally linked to poverty and social vulnerability. Having an agriculture area, some cows, and goats, symbolizes a much more social and financial success. Even if agriculture and cattle are culturally more related to progress and development, in practice, SFM focused on firewood and charcoal can potentially bring an effective financial success [59].

"The rural settlement Baixa Grande [in Ceará state] has 8 thousand hectares covered by arboreal Caatinga, of which 2 thousand are under a SFM plan, playing a central role in their income generation. However, they still have the desire to implement agriculture and cattle in the other 6 thousand hectares, even though SFM could bring much more income and would be better for nature conservation [43] (p. 16)."

The social legitimization of specific forest uses also depends on their ability to help local populations face social, environmental, and economic hardships. In social and economic extreme conditions, for instance, selling illegally harvested firewood and charcoal in local and regional markets is an opportunity to generate income rapidly, even with the risk that comes with illegal management. Cultural values linked to managing forest resources illegally also influence SFM negatively. Especially in the case of Caatinga, the visual image resulting from a SFM plan is very similar to the one resulted from illegal deforestation, because SFM in Caatinga includes a clear-cutting technique. Forest areas after a clear-cutting, a truck of firewood, or ovens used to produce charcoal are easier related to simple deforestation, which is illegal, than to SFM, which is legal.

"There is a common sense about SFM practices that compares it to illegal forest cuttings and does not notice any difference in the landscape. In Caatinga, for instance, SFM can mean a clear cutting and this does not mean that is not sustainable [50] (p. 4)."

"When one sees the area after a clear cutting, even as part of a SFM plan, the visual impact is negative, and consequently, there is a tendency to negatively evaluate SFM [39] (p. 2)."

Recent federal government initiatives to promote SFM in rural settlements have faced challenges linked to the fact that this technical approach of SFM is not integrated with other forest uses or production systems and, therefore, the livelihoods of local populations. The federal government's strategy of SFM implementation does not link to social movements, nor is it well connected to other federal or state's governmental initiatives. In the social-ecological context of the long and intense dry seasons of Caatinga, rural development strategies are in place to strengthen the coexistence of livelihoods of local populations with semi-arid conditions [43]. Improving the integration of production systems with environmental conditions is central to these initiatives, especially in extreme weather conditions.

"Only by integrating and supporting different activities does it become possible to adapt the livelihoods of local populations [to weather conditions] and, at the same time, to contribute to decreasing their social and economic vulnerability when facing extreme weather conditions [60] (p. 7)."

Actions to promote integrated production systems with the aim to strengthen the coexistence of livelihoods of local populations with semi-arid conditions did not internalize SFM. The reason for this was mainly a difference in the origin of both initiatives. On the one hand, strategies aiming to strengthen the coexistence of livelihoods of local populations with semi-arid conditions were initiated by social movements and NGOs [48], and only later became part of federal government's initiatives. On the other hand, initiatives to support SFM resulted were supported by international organizations that mainly focused on solving deforestation caused by the use of forest biomass for energy supply. Given the different origins and aims of these initiatives, SFM has only lately been considered as part of a strategy to strengthening livelihoods of local populations [40]. This lack of a historical link to a social demand hinders the effective integration of SFM in other social initiatives in Caatinga on a larger scale as well.

While a broad integration of SFM in productions systems is missing, some small changes in institutions have recently nonetheless become visible, as federal and state's government initiatives linked to rural development strategies have started to insert the forest component in their rural assistance programs.

"In Rio Grande do Norte state, for the first time, the federal government's program for technical assistance in rural communities will include one forest engineer in the team. This is a sign that forest uses started to be thought off as a production activity [40] (p. 8)."

A final aspect of how cultural values are linked to forest use is reflected in the way in which environmental agencies deal with the licensing of different activities. The license to supress (or clear-cut) a forest to implement agriculture is much easier obtained than the license for a SFM plan [42]. In practice, getting the license for SFM plans is much slower and full of technical and bureaucratic resistances compared to the license to implement agriculture on a previously forested land. There is a perception that SFM is an activity that is not part of the 'normality' of managing forest resources, which is more often linked to conservation strategies than other forest uses [40]. At the same time, it is considered normal to give an environmental license for forest suppression to implement a pasture or agriculture.

"Getting the authorization for a SFM plan involves a feeling, especially inside the environmental agencies, that the person is planning to do something that seems to be completely wrong because it involves native forest [40] (pp. 9–10)."

5. Discussion

Table 2 below summarizes the results and schematically visualises how SFM is translated in Caatinga. What follows is a discussion of how the interactions among *forest resource uses*,

actors, and *techno-bureaucratic* and *social embedded institutions* shape translations of SFM in a specific social-ecological context.

Table 2. Translations of SFM in Caatinga.

Translations of SFM in Caatinga						
Governance		Main uses of forest resources				
		Source of biomass for energy supply	Natural pasture	Non-Wood Forest Products	Local knowledge	Main actors translating SFM
Techno-bureaucratic institutions	Technical approach	XX	-	X	-	International organizations, government and market
	Rules and regulations	XX	-	-	-	Government and market
Socially embedded institutions	Cultural values and beliefs	X	XX	X	X	Non-governmental organizations and local population

Elaborated by the authors; 'XX' = present or mostly present, 'X' = present in some cases, '-' = absent or mostly absent.

Techno-bureaucratic and social embedded institutions are both crucial for sustainable natural resource management, as they are shaped by and guide interactions between different actors and forest resources uses in a specific social-ecological context [25]. According to Cleaver, techno-bureaucratic institutions are not necessarily "inclusive, fair and emancipatory", while socially embedded institutions "may reproduce social divisions or gloss over inequality" [25] (p. 28). SFM in Caatinga has currently taken shape as a techno-bureaucratic approach that indeed faces a lack of inclusiveness, as it largely excludes socially embedded practices and their related values and beliefs. While the general idea of SFM conceptually embraces local communities' needs and interests in forests, its actual techno-bureaucratic implementation in Caatinga has implied their exclusion, thus leading to a low legitimization of SFM by local populations. Translations of SFM in Caatinga are particularly focused on production of forest biomass, while excluding other uses of forest resources, such as those linked to livelihood of local populations (livestock, NWFP, and local knowledge). This exclusive focus of SFM on production of forest biomass in Caatinga also confirms an observed tendency of SFM approaches to focus on the provision of one specific ecosystem service alone, and thus hardly achieving the ideal balance between trade-offs and environmental, economic, and social goals [3,61].

A dominance of techno-bureaucratic translations of SFM in Caatinga was expected on the basis of how institutional interventions in resources policy commonly take place [30]. At the same time, we also expected these translations to be shaped by social-ecological context and the interests of a specific group of actors. We found that social power relations among international organisations, governments, and market actors directly influenced the design of research, policies and implementation strategies linked to SFM [62,63]. The promotion of SFM strategies by the Brazilian federal government in Caatinga first aimed to maintain the provision of forest biomass for energy supply of industries and business, and at the same time sought to decrease deforestation linked to this use of forest resources in the biome. Only as an additional aim does government consider the potential of SFM to decrease desertification vulnerability, to conserve biodiversity, and to reduce poverty, and these aims are not translated in to formal or technical norms. Support of international organizations appears to fit this configuration of interests and social demands: SFM was introduced by actors such FAO, UNDP, and others as a strategy to strengthen the use of renewable energy while only addressing broader issues such as deforestation, biodiversity conservation, climate change mitigation, desertification, and poverty as an added benefit [4,64].

Although the use of forest resources as a source of biomass for energy supply is relevant to local populations, we found that SFM initiatives in Caatinga still do not align with many other socially embedded forest uses: forests are also crucial for livestock and as a source of NWFP, forest uses that are neither recognized by authorities nor considered legal or legitimate by them. Moreover, local practices of forest resources use (firewood and charcoal) to generate income in emergency situations

are hardly integrated by the SFM techno-bureaucratic approach either, as it takes long periods of time to be licensed by environmental agencies through a SFM plan. We find that SFM in Caatinga would be much more socially legitimized if it were better integrated with existing strategies and initiatives to strengthen the coexistence of local population with semiarid conditions. These strategies, mostly lead by non-governmental organizations and social movements, are built on the integration of local practices with social and environmental conditions, and are part of a broader strategy of sustainable development for the region [65,66].

The potential contribution of SFM in Caatinga to a broad set of sustainability objectives—i.e., decreasing vulnerabilities to climate change, desertification, biodiversity loss, and poverty [9,67]—thus, appears to remain unrealised. Indeed, we found that translations of SFM in Caatinga have not achieved a balance among these goals, and also do not contribute significantly to decreasing illegal forest use. This makes the crucial question to ask whether SFM implementation strategies that are currently being developed indeed have the potential to balance trade-offs between different uses of forest resources and their linked ecosystem services within the specific social-ecological context of Caatinga.

6. Conclusions

Our findings lead us to conclude, first of all, that social-ecological interactions matter for SFM strategies. Strategies for use and conservation of forest resources and ecosystem services, while balancing economic, social and environmental goals, are highly dependent on which social-ecological interactions are considered [26,27,68]. In particular, the interaction of natural resource use, actors, and institutions strongly influences how strategies of sustainable management of natural resources take shape within a social-ecological system [29,36]. In our case, SFM initiatives were shaped by the social power of different groups of actors involved, regional institutions, as well as the types of forest use in Caatinga. Therefore, understanding interactions between institutions (rules of the game), actors (players), and forest use helped to explain past choices for SFM strategies in Caatinga and may allow for adaptation of those strategies in the future.

Second, we conclude that the consideration of social-ecological interactions in SFM strategies may either support or undermine the very ideas and ambitions that SFM is based upon [25,26,68]. New institutions, such as those linked to strategies for SFM implementation, interact with already existing institutions in a specific social-ecological context. In this interaction, new institutions might reproduce already existent social arrangements, for instance, when regional industry contributes more to setting forest use priorities than local and vulnerable populations are able to. Thus, SFM may reproduce social inequalities as the techno-bureaucratic institutions that are introduced are translated to local social-ecological systems.

Finally, we want to highlight that translations of institutions within a specific social-ecological context often lead to unexpected outcomes. Institutional translations may turn institutions weakened instead of strengthened, or may yield other outcomes than originally intended [25,30]. In SFM initiatives in Caatinga, the dominant techno-bureaucratic approach appears to struggle to find a broad foothold in regional forest management strategies. In the cases were it does connect to more socially embedded institutions and forest uses, it almost exclusively caters to a small, powerful set of actors and forest uses, while more socially embedded strategies are not explored. Consequently, SFM initiatives in Caatinga currently do not achieve their potential of a balance among social, economic and environmental goals.

To more fully explore the potential of SFM in Caatinga, we suggest a broader exploration of forest uses, stronger engagement with and inclusion of local communities and NGOs, and a more balanced consideration of forest ecosystems services by governments and international organisations. This will not only do more justice to the tenets of SFM as they are articulated in the global domain [5], but will also result in a broader uptake of SFM as a strategy to manage one of the last tropical dry forest biomes in the word. We moreover expect such a broad exploration to yield SFM institutions that both strengthen the conservation of natural forest cover and improve local livelihoods.

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