

Introduction

The human population is dependent on ecosystem services which are being degraded at a globally significant scale (Costanza et al., 2014). Tropical forests are a focal point of dramatic land-use change, much of which has been associated with land clearance through intentional management fires (from small to large scale), which can escape creating uncontrolled ‘wildfires’ (Aragão & Shimabukuro, 2010; Soares-Filho et al., 2012). Once a relatively fire-free biome, the Brazilian Amazon now experiences frequent and extensive wildfires (Alencar, Brando, Asner, & Putz, 2015; Cardoso, Hurr, Moore, Nobre, & Prins, 2003; Cochrane & Barber, 2009). Wildfires exemplify the governance challenges associated with complex social-ecological systems (Carmenta, Parry, Blackburn, Vermeulen, & Barlow, 2011) and are expected to become a larger challenge in the future due to extending fire weather seasons, increased ignition sources, previous fire activity and forest fragmentation generating positive feedbacks favouring fire (Hardesty, Myers, & Fulks, 2005; Jolly et al., 2015; Nepstad et al., 2001).

In response to chronic rates of forest loss and degradation, diverse forest conservation interventions have been implemented across the Brazilian Amazon. These range from the classic protected area model to integrated policy approaches (e.g. the Programme to Control Deforestation in the Amazon, PPCDAM (Portuguese acronym)) that solicit sanctions (e.g. economic boycotts) on deforesting municipalities (Assunção, Gandour, & Rocha, 2015). Sustainable use reserves aim to achieve conservation through reconciliation with sustainable development. More recently incentive programs, including Reduced Emissions from Deforestation and Degradation (and associated co-benefits) (REDD+) aim to induce conservation through conditional rewards (Gebara & Agrawal, 2017).

The comparative performance of forest conservation initiatives is a research topic of much debate (Bruner, Gullison, Rice, & da Fonseca, 2001; Engel, Pagiola, & Wunder, 2008;

Ferraro & Hanauer, 2014; Joppa, Loarie, & Pimm, 2008; Nelson & Chomitz, 2011; Nepstad et al., 2006), within which fire is identified as a key stressor though is often overlooked in their design (Barlow et al., 2012; Friess, Phelps, Garmendia, & Gómez-Baggethun, 2015). Despite the importance of reserves for conservation, sustainable development and stabilizing climate change (Ricketts et al., 2010; Silvestrini et al., 2011; Soares-Filho et al., 2010), their effectiveness at mitigating fire prevalence is not fully understood (Morello, Parry, Markusson, & Barlow, 2017). In some cases, reserves show a decline in fire, in others, reserves do not impact fire density or fire management (Carmenta et al., 2016; Nelson & Chomitz, 2011; Nepstad et al., 2006). Different approaches to conservation necessitate particular approaches to fire management due to distinctions such as the presence (or absence) of smallholders using fire in swidden agricultural systems.

Policy responses to extensive forest fires in the Legal Brazilian Amazon have also been diverse and were initially catalysed by the extreme forest fire events in 1997/1998. These ‘mega-fires’ captured international attention and secured conditional loans (e.g. from the World Bank) in support of anti-fire policies (Sorrensen, 2008). A shift in policy logic occurred in the 2000s when fire-free agriculture was promoted through international partnerships (Denich et al., 2004; Joslin et al., 2011; Pedroso.Jr., Murrieta, & Adams, 2008; Sommer et al., 2004). Some interventions explored ‘best-practice’ fire management in collaboration with smallholder communities, but these did not scale-up (Carvalho, Mello, Souza, & Silva, 2009). Since 2009 Brazilian fire policy returned to a command-and-control type approach, along with the ban-surveillance-sanction model effective in reducing deforestation (Morello, Parry, Markusson, & Barlow, 2017). This phase has included states beyond the deforestation frontier also enacting fire restrictions (e.g. Acre’s Zero Burn policy).

Across the forested tropics fire policy is largely situated within a pervasive anti-fire rhetoric (Rachel Carmenta, Vermeylen, Parry, & Barlow, 2013; Carvalheiro, 2004; Costa,

2006; Harwell, 2000; Mathews, 2005). Anti-fire discourse targeting smallholders exists across the tropics from South America, to Asia and Africa (Carmenta, Zabala, Daeli, & Phelps, 2017; Harwell, 2000; Kull, 2002; McDaniel, Kennard, & Fuentes, 2005). The prevailing discourse is one of nefarious fire within which fire-based agriculture (and associated practitioners) is systematically discredited (German, 2010). The burdens of escaped fire underwrite the discourse and relate primarily to the globally significant quantities of carbon emissions generated (Gatti et al., 2014; Phillips et al., 2009). Beyond carbon emissions, burdens include losses in: agricultural and plantation based investments (Bowman, Amacher, & Merry, 2008; Gaveau et al., 2017), national revenues (de Mendonça et al., 2004), biodiversity (Barlow et al., 2016) and public health (Shannon et al., 2016; Smith, Aragão, Sabel, & Nakaya, 2014).

The anti-fire rhetoric however disregards the local utility, historic importance and cultural relationship that relates to intentional fire use (Carmenta et al., 2013; Carvalheiro, 2004; Costa, 2006), rather it situates all fire as bad and in so doing it conflates distinct fire-types (i.e. intentional and accidental). Conflating fire types impedes our understanding of the drivers and subsequently, the policy solutions, to tropical wildfire and contributes to the formulation of policies intent on fire restriction which can serve to further disempower already marginalized groups (Carmenta et al., 2013) and can be used to further the power and control of established hierarchies (Mathews, 2005). Additional factors make prohibitive approaches attractive, including the challenges of defining attribution (Gaveau et al., 2017), difficulties of implementing licensing requirements and weak processes surrounding liability cases in court (Mistry, 1998).

The standard model of forbidden fire precludes initial dialogue and meaningful experimentation of possible alternatives that may empower traditional land management and practitioners while also preventing fire escape (wildfire) (McDaniel et al., 2005; Padoch &

Pinedo-Vasquez, 2010). Indeed swidden farmers employ a series of techniques to manage intentional fire and prevent wildfires (Carmenta et al., 2013; Denevan & Padoch, 1987; McDaniel et al., 2005). In tropical savannah regions where fire plays an adaptive role in ecosystem functioning, traditional fire management, often consisting of controlled fires in specified areas, not only maintains ecological integrity, but can mitigate wildfires (Eloy, Bilbao, Mistry, & Schmidt, forthcoming; Sletto, 2008; Sletto & Rodriguez, 2013). While not without conflict, traditional and indigenous peoples living in savannah regions are increasingly recognized for their knowledge of fire management, and are often stakeholders in discussions of fire management and policy, especially in regards to conservation areas orientated towards ecosystem protection (Eloy et al. this volume, (Mistry, Bilbao, & Berardi, 2016; Schmidt, Fonseca, Ferreira, & Sato, 2016).

In tropical forest biomes fire is neither natural nor necessary from an ecological perspective, and fire use is resolutely castigated. Yet, the anti-fire approach has underperformed. Further, the absence of available alternative agricultural technologies combined with the contemporary context of changing forest ecologies (e.g. fragmentation and degradation) and increasingly flammable landscapes suggests that management methods require urgent attention and adaptation to secure improved performance (Moran, Adams, Bakoyema & Boucek, 2006; Nepstad et al., 2001; Nepstad, Stickler, Soares, & Merry, 2008). We are interested in assessing the hypothesis that the restriction of fire use decreases the potential of farmers to adapt their fire management practices and jeopardizes their livelihoods and their contribution to forest conservation thus warranting an alternative solution.

We ask the following research questions in three conservation initiatives in the Brazilian Amazon: what are the fire management policies within the conservation sites and what are the burdens of wildfire? What is the importance of fire to smallholders and what are the alternatives to fire? Is there evidence that prohibiting fire is contributing to, or subtracting

from, conservation interventions? What are the efforts employed to improve fire management in swidden agriculture? Finally, we ask, what commonalities exist between sites? The cases are situated along a gradient of anthropization and taken together provide insights concerning the conservation policy and fire context, they are - RESEX (sustainable use extractive reserves) (Arapíuns), REDD+ (reduce emissions from deforestation and forest degradation) (Middle Solimões) and a Green Municipality Pact (Paragominas).

Study sites: three forest conservation initiatives along a gradient of human influence in the Brazilian Amazon

We select three forest conservation initiatives each with experience of wildfires and the presence of smallholder farmers, yet distinguished by their context and their approach to achieving sustainable outcomes (Figure 1). The GMP operates through subsidy and sanction (Viana et al., 2016), RESEX through collective management and secure land rights (Cardoso, 2002), PES and REDD+ through conditional incentives (Wunder, 2005). Each of these forest conservation initiatives is home to smallholder communities of *ribeirinhos* (riverside people) and to a lesser extent, *assentados* (smallholders settled through agrarian reform). Taken together these cases offer insights regarding the interplay between conservation and fire policy.

[insert Figure 1 here]

Ribeirinhos are the most numerous rural inhabitants of the Brazilian Amazon, though often are on the periphery of Brazilian society (Adams, 2010). They are of mixed descent (African, Indigenous, Portuguese) (Harris, 2000; Lima, 2005) with diverse livelihoods that include swidden agriculture, fishing, hunting, and forest extraction (Adams, Murrieta, Neves, & Harris, 2008; Brondizio, 2004; Brondizio & Siqueira, 1997; Murrieta & WinklerPrins, 2003). *Assentados* may also combine swidden with cattle ranching (Moran, F, 1993; Schmink & Wood, 1992). More recently rural Amazonians integrate cash incomes from state welfare

packages to their domestic economies (Adams et al., 2008; Steward, 2007).

Green municipality pacts in the Brazilian Amazon: Paragominas site, Pará

Paragominas in Pará state, the least remote site, has a population of 91,000 (22% are rural) and from 2010-2013 hosted a brigade of 6 Federal firefighters. However, extensive accidental fires (e.g. 1,700km² of forest burnt in 2015) are frequent owing to large extents of degraded forests and pastures. Pastures and soy agriculture dominate the state and 95% of private land is held by ~500 large-landholders. Smallholders (~6000 families) are mainly settled on public land relatively far from the town. The GMP was established in 2009 with the goal of zero-deforestation (Guimarães, Veríssimo, Amaral, & Demachki, 2011) as part of an initiative to counter the blacklisting issued by the Federal government in response to high rates of deforestation (Viana et al., 2016). The landholding elite has the dominant political voice and were the principal advocates of the GMP, pursued mainly through land regularisation, increased monitoring and “green” agribusiness production (Viana et al., 2016).

Extractive reserves: Arapíuns site, Pará

The *Tapajós-Arapíuns* RESEX, along the Arapíuns river in Pará was created in 1998. The reserve experienced large scale (400km²) accidental fires in 1998 (Barlow, Haugaasen, & Peres, 2002) and again in 2005 and 2015. The RESEXs are the original model that sought to integrate environmental and socio-economic imperatives (Cardoso, 2002). RESEX residents are required to use resources in line with regulations specified at the Federal level and as determined via a collective management plan created in partnership with reserve councils and Federal management agencies (i.e. ICMBio). Theoretically, reserves reduce fire through securing land tenure (to avoid repeated cycles of land abandonment), building social capital and collective sustainable resource management (Larson, Cronkleton, Barry, & Pacheco, 2008; Persha, Agrawal, & Chhatre, 2011). Formal land title makes significant welfare allowances (*bolsas*) available to households (Adams et al., 2008). Additional cash increases

access to labour and other resources, that when constrained reduce investments in fire management (Bowman et al., 2008), though may also be related to investments in agriculture and expansion (Phelps, Webb, & Agrawal, 2010).

Payments for Environmental Services and REDD+: Middle Solimões, Amazonas

The Mamirauá (decreed 1996, population of 11,532) and Amanã (decreed 1998, population of 3,860) Sustainable Development Reserves in Amazonas form part of the largest area of protected tropical forest on the planet (Queiroz, 2005) and constitute the least deforested site where accidental fires are uncommon, but were recently reported during the drought year of 2015. The two reserves incorporate a similar institutional design as the RESEX yet are integrated in to REDD+ programs, introduced in 2011 and 2013 respectively (Steward, Rognant, & Vieira do Brito, 2016). REDD+, for which Brazil has been a leading country since 2004 (Coudel et al., 2015), has been implemented as a forest-carbon Payments for Environmental Services (PES) in which payments provide a conditional incentive for behavioural change and are released on performance (Wunder, 2005).

Methodology

Case study sites were selected due to their previous experience with wildfires, the range of anthropization they cover, the presence of swidden agriculture and their position within a forest conservation initiative. The research questions were cross-cutting across sites (see Introduction). Community meetings were held to introduce the research projects, solicit input from residents and to secure consent to begin research following ethics procedures. A mixed methods approach provided the data for the study, and included collectively two years observation in the communities, open and semi-structured key stakeholder interviews (these were community leaders, union leaders and conservation managers), household interviews and questionnaires, participatory mapping and focus group discussions. Communities and households for questionnaire samples were selected at random (GMP, RESEX), or using

snowball sampling (REDD+). Participatory meetings addressed issues related to fire management including collective expectations of intentional fire, the impacts of and solutions to escaped fire and traditional knowledge of fire management. Household surveys included questions about land management, agricultural practices and extension services, experiences and perceptions of fire policy, fire risk and fires' utility. Table 1 details the methods applied in each site, the results that follow pertain directly to these site-specific methods. Data analysis was qualitative following coding and thematic analysis, descriptive statistics help to quantify the impacts of wildfire in the sites.

[insert table 1 here]

Results

Fire policy in the forest conservation initiatives

All sites are subject to the regulations specified at the Federal level (eg. burn licences required by the Forest Act, c.f. Carmenta et al., 2011) and experienced policies directed at prohibitive burning particular to their context (Table 2). Each site had a strong narrative against fire largely perpetrated by external agents and municipal services (radio, TV). In practice, according to interviews with conservation managers (GMP) and surveys with smallholder farmers (RESEX), few sanctions for fire escape had been enacted.

[insert Table 2 here]

Frequency of accidental fires confirms policy failure

In all sites, even following policy implementation, damages reported in surveys (e.g. to forests and livelihoods) had accrued from escaped fires demonstrating that neither fire management policies nor forest conservation initiatives are mitigating wildfires (Table 3).

In the GMP, ~50% of households had at least 2 fire accidents in their property in the past 5 years, and over two-thirds incurred damages exceeding 2000 R\$ (Cammelli, 2013). Following the fire ban, smallholders continued to consider fire a threat to their property, mainly from surrounding large properties (interviews and focus groups).

In the RESEX, over a third of households had experienced accidental fires and associated burdens which included lost crops, forest degradation and poor hunting and over a third of the households believed fire threatened their homes and land. Residents perceived the awareness raising related to the illegality of fire explained a positive shift towards better fire management. However, accidental fires have returned to the region (Globo, 2017).

In the REDD+ site losses of mature agroforestry systems had occurred following the first escaped fires in the area, and were considered to be related to recent extreme drought events.

[insert Table 3 here]

Centrality of fire to smallholder agriculture, identity and social practice

In all sites, swidden agriculture was a significant element of cultural identity enabling autonomous production and yet appeared under threat from anti-fire rhetoric. In all sites, qualitative results highlighted numerous expressions of the cultural importance of fire-based swidden, including individuals admiring the agricultural work of their neighbours, showing pride for the bounty of their efforts and referring to planted land as “beautiful”. Fire was valued as a tool to maintain, clean and improve agricultural and living areas. The independence swidden afforded smallholders was referred to as an endogenous form of (non-monetary) wealth, necessary in a context of limited state support. Social reproduction was integrated with the swidden process and parents encouraged even young children to contribute

labour to agricultural work in the field and thereby obtain the essential skills to swidden. Reciprocal work parties to prepare, sow and harvest fields were important social events that seemed to strengthen family and community ties.

Particularly in the GMP and REDD+ sites, interviews with farmer leaders showed that the cultural familiarity with fire and the independence that it enabled was jeopardized by the awareness raising regarding the illegality of fire (e.g. via radio and in rural workers union meetings). In all sites a sense of constant surveillance (e.g. awareness of satellite observation) was contributing to a new uneasiness in a previously autonomous space of agricultural decision-making.

Seu Geraldo, REDD+: ‘we know that they [REDD+ coordinators] are watching us by satellite and can see all clearings we make in the forest.’

Criminalizing fire and negative legacy of interventions undermines FCI partnerships

In the RESEX and GMP sites restrictions on fire use were commonly acknowledged as being part of a broader narrative and norm of policies that are neither supportive nor cognizant of rural Amazonian realities and contexts. In interviews and focus groups, farmers spoke about being “half forgotten” in relation to their “condition” (their capacity) and felt dismissed by outsiders who were seen to either draft policies that are unrealistic to adhere to, or arrive with interventions misaligned to local realities. In the GMP site, farmers considered that the zero-fire initiative and municipal law banning fire directly ignored their dependence on fire in agricultural practices and emphasized the divide between the municipal “elite” and the rural farmers. Although farmers were genuinely preoccupied with the increase of wildfires and associated burdens, they felt no obligation to stop agricultural fires in order to “serve” a

political project that did not respond to their livelihood needs.

Seu Careca, RESEX: ‘we are half forgotten here, those that make the rules sit in their offices in Brasilia and don’t know the conditions of the rural worker’.

In the RESEX, restrictions on swidden plot sizes and locations were introduced in 2010 along with increased monitoring. In focus groups and participant observation, residents voiced their fear of being fined and spoke about the burning restrictions in relation to confining their farming choices. While establishment of the reserve represented a victory to the residents, the burden of these new regulations and the subsequent livelihood restrictions were considered a cost. The lack of engagement to solicit farmers’ inputs and expertise was recognized by community members as a major factor contributing to project failure and a key driver leading to a general scepticism of the potential of interventions introduced by external agents. A similar situation occurred in the REDD+ site, where frustrations related to socio-economic development initiatives were associated with projects not being in line with regional ecologies, local realities and infrastructure.

In the REDD+ sites, swidden practices, including burning, were portrayed as environmentally destructive. According to practitioners and reserve residents, REDD+ initiatives lacked the transparency of previous conservation initiatives in the area and relied less on alliances between practitioners and farmers. The REDD+ narrative appeared to attach a stigma to burning, for example through the promise of benefits conditional on switching from fire-based agriculture. This created a context in which farmers became cautious about their fire use.

Restricting fire in the absence of alternatives

Although residents in all sites expressed interest in alternatives to fire, in practice access to fire-free agriculture was extremely limited. Across sites, even where external support was greatest (i.e. GMP) the majority of farmers (75%) relied exclusively on fire to establish their annual crops (Table 3). In Paragominas, interviews showed that paradoxically those with experience of state-supported tractors tended to reject them as a viable alternative because their use induced harvest failures (since other necessary inputs, such as lime and fertilizers, were not available). Further, the municipality-provisioned tractors were only able to till pre-cleared land while farmers expressed a preference for tractors capable of felling mature vegetation. Even farmers with access to private tractors continued to utilize fire to clear vegetation and provide initial fertilization.

Seu Zé, GMP: ‘they say the smallholder shouldn’t deforest, that agriculture needs to change, without fire, but until today I ask myself, how will we do this? We have a tractor, between 1000 families, if each family takes one day, even in three years we won’t have finished.’

Dairy production in the GMP was supported, however, policy makers recognized in interviews that few farming households (<50) benefited and farmers still deemed fire use essential for pasture renewal and for manioc cultivation in swidden. Surveys showed that cultivating perennials was practiced by ~10% of farmers, and 40% of respondents would switch to perennials if fire risk declined. The PrevFogo brigade promoted fire-free options, and initiated two agro-ecological demonstration units, however both were observed to be abandoned after the brigades withdrew (in 2013).

In surveys, RESEX residents (>67%) stated that they knew of few reasonable (i.e. given financial, technological and expertise constraints) alternatives to fire for agricultural production. The most frequently mentioned alternatives were “direct planting” (manual or mechanized land clearance), perennial crops and timber extraction. In the RESEX, community members experienced externally-driven attempts at developing fire-free livelihoods (e.g. through installation of a carpentry workshop) were debilitated by bureaucratic procedures (e.g. the protracted process of acquiring permits for sustainable harvest within an FCI) or by external agents backing activities ill-suited to the local ecology (e.g. equipment to extract oil from species that do not occur locally). Nobody in the communities had experience of a tractor nor ‘direct planting’ (Table 3).

In the REDD+ site, only 2 of 8 farmers responsible for experimental areas continued to manage their agroforests after technicians withdrew following training activities. Further, the high labour requirements of fire-free agriculture (i.e. to organize large working groups to clear land manually) were perceived as prohibitive when compared with burning (which requires as few as two people).

Fire management training to mitigate escaped fires

Across sites, externally-driven policies appeared to leave little space for endogenous solutions and collaboration between stakeholders. Adaptation was circumvented through restriction, rather than encouraged, much less supported. Training in fire management was uncommon.

In the RESEX, awareness-raising regarding “good” fire management had been driven mostly through the radio and through the rural workers union. However, the advice given in these communication campaigns focused on using fire breaks, which farmers routinely disregarded

as a suitable option. In surveys and observations farmers stated that the labour requirements to clear a circumference around the plot was prohibitive and a general opinion that embers are carried on the wind made farmers sceptical of the performance of fire-breaks. In the GMP, community leaders contended that it would be more efficient for the municipality to provision tractors to enable construction of wide fire-breaks to prevent wildfires instead of those for tilling.

Combatting escaped fires was often considered a main challenge and in the GMP fire-fighting was discussed in community meetings (interviews showed that >60% of respondents had been to meetings about fire). Moreover, fire restriction policy itself generated perverse outcomes, as Federal activities (e.g. PrevFogo) were legally prohibited from supporting improvements to fire management because intentional fire is illegal. Moreover, PrevFogo was under-equipped to combat escaped fires (e.g. no water tanks) and fire-fighting actions depended on community mobilization which focussed on saving houses, not saving the fields.

In the RESEX, the head of the rural farmers union was guardian to a cache of equipment for fire combat, but these were chronically inferior (e.g. fire beaters with rotten handles, small water-retaining backpacks) and few - given the size of the reserve and the dispersed nature of the communities and plots (Figure 2.). Community leaders stated that collective action had been employed to combat the fires of 2005 and households worked together carrying water and soaking their homes for protection. Yet, given the size of the area and the volume of fuel, again, this was not sufficient to contain the blaze. State-based support to combat conflagrations was not reported by community leaders or local managers.

[insert Figure 2]

Given the difficulties of combatting wildfires, farmers in the GMP and RESEX sites aspired in interviews to improve fire management through community-level organization. In focus groups, residents also considered externally-led awareness raising, monitoring and training workshops as essential components of a successful intervention. However, formal collaborative discussions on safe use of fire were almost entirely absent across sites.

Common lessons for fire mitigation across forest conservation initiatives

The GMP did not manage to shift behaviour through subsidies nor through sanctions. The sanctions were not administered since agents recognized the infeasibility of fining already marginalized land user groups. The subsidy and support element of the GMP was unable to secure meaningful impact and appeared largely tokenistic because only few farmers benefited and, as discussed above, those that did identified weaknesses in the design which was founded on an agro-business models. Further, the prohibition on fire severed the dialogue between farmers and municipal agents in which finding ways to manage fire safely cannot be discussed and has created a context of suspicion.

In the RESEX people expressed their conviction that the secure tenure safeguards the forest (and their access to it) because new claimants and industrial scale extraction are prohibited. However, the land rights granted with the RESEX were understood to be limited and people were unclear about what will happen when the title expires. Further, the prevailing necessity for harmonious community relations contributed to an acceptance of transgressors of rules. While people complained about careless burning they also stated that there was little they could do to reprimand it since they must live together. When agents of the Federal Environment department made patrols (e.g. for trading game and timber), residents spread the word and hid items that might be confiscated. Prohibition induced farmers to become

reluctant to speak due to a context of fear and instead concealed their actions, their needs and limitations.

In the REDD+ site, the program placed emphasis on signing up beneficiaries and distributing income and material benefits after their participation in training workshops. Little to no investments were made in monitoring activities to assess participants' practices after fire-free training and ensure the conditional element of the reward. Recommendations announced in the training workshops were not matched with investments to equip farmers with skills needed to modify their practices. Thus, they have not motivated fire-free practices, nor achieved additional goals (evidenced by the continued use of primary forest for swidden).

Discussion

Across sites escaped fire represented a socio-environmental burden undermining both the conservation and development goals of the conservation initiatives. Increasing instances of wildfires suggest that contemporary restrictive policy solutions to fire are failing. The conservation initiatives and fire policies exemplify the policy-practice gap inherent in many conservation efforts (Toomey et al., 2016) and in tropical fire management (Kull, 2004; Mathews, 2005). Across the tropics, and within conservation initiatives that permit sustainable use, smallholders depend on fire-based agriculture (Dressler et al., 2016; VanVliet, Adams, Vieira, Guimarães, & Mertz, 2013). The failure of restrictive fire policy indicates that improvements are needed to enhance both environmental and social outcomes in conservation initiatives.

Criminalizing fire: creating risky conditions for conflagrations in conservation areas

We show that conservation initiatives were compromised by the combination of fire-

dependence and lack of discussion on how to manage fire safely. Both conservation initiatives and fire policies criminalize practices that remain indispensable to smallholders and thereby propagate a context in which intentional fire becomes illicit practice (Kull, 2004; Mathews, 2005). Through fuelling a taboo surrounding fire the space for dialogue aimed at identifying and defining ways forward is closed and the gap between conservation practitioners, reserve managers, implementation agents and farmers is widened (McDaniel et al., 2005). Such an approach may perversely increase fire risk by inducing smallholders to burn in secret, to abandon rather than invigilate the burn for fear of sanction (Kull, 2004) and by not supporting adapting techniques and management practices that could mitigate fire escape. This is perhaps particularly problematic in the context of increasingly flammable forests and extended fire weather seasons (Jolly et al., 2015). Further, the importance of incorporating the human dimension in forest conservation initiatives has been acknowledged (Bennet, 2016) and strengthening community alliances is deemed crucial to the future conservation of forests (Brosius & Russell, 2003; Queiroz & Peralta, 2006).

Our sites highlight the weakness of policy development responses to natural resource challenges that are elaborated externally (Toomey, Knight, & Barlow, 2016). Implementation is undermined by a process that introduces external agents with predetermined agendas, little local knowledge or awareness of local capacity and constraints. Further, in some cases, those implementation agents which do engage with local realities may be reluctant to enforce starkly misaligned external policy prescriptions, and institutional structures themselves may need adapting to enable feedback and improvements (Mathews, 2005; Vasan, 2002). The risk of negative legacy of past interventions is considerable and puts additional pressure (through degrading positive perceptions) on defining ways forward collectively (Bennett, 2016). Engaging with local realities, subjectivities, knowledges and priorities might capture

opportunities for solutions that are tenable and that mitigate escaped fires and the associated social and environmental burdens they entail (Bennett, 2016; Biggs et al., 2011). Working towards management that pivots on discussion, deliberation and participation in a multi-way dialogue could provide a better context for identifying solutions to fire escape in mutual agreements (Carmenta et al., 2013; Toomey et al., 2016).

To date, adaptive fire management strategies have encountered some success, but focus almost exclusively on fire-dependent biomes, such as grasslands and savannas (Sletto & Rodriguez, 2013). The potential merits of a fire management approach allowing for fire use has not been evaluated in the tropical forest regions of the Brazilian Amazon.

Equity dimensions of restrictive fire policy

Smallholders are being criminalised for methods which previously have proven relatively benign (RibeiroFilho, Ribeiro, Adams, & Murrieta, 2013). Fire management has been practiced for generations but new forest ecologies (e.g. fragmented and degraded) and new climate contexts necessitate new know-how (Emperaire & Eloy, 2015). The distributional justice of restricting burning by fire-dependent smallholders, shifting the burden of increasingly flammable landscapes (e.g. through fragmentation or climate change) on to smallholders who themselves have no access to alternatives requires scrutiny (Sorrensen, 2008). Implementing fire suppression policies without regard to environmental and social complexities propagates the policy practice gap, supports the power of the state and normalizes the narrative of international conservation agendas (Brosius & Russell, 2003; Kull, 2004; Mathews, 2005). Importantly, prohibiting fire without provisioning alternatives may accrue additional burdens for smallholders, including food insecurity and cultural dilution.

Ways forward: transcending the taboo of fire

Fire management is integral to all forest conservation in swidden contexts and it is therefore imperative to address how previously benign traditional practices (RibeiroFilho et al., 2013) can be modified to suit new challenges. A more nuanced discussion of alternatives, potentially including modified forms of fire use grounded in local realities, may be needed if fire escape is to be averted and sustainability of conservation initiatives enhanced. To enable the emergence of innovative solutions adapted to local conditions, policies must aim at creating spaces for social learning, where new perceptions can emerge, new knowledge can be constructed, and new social interactions defined (Coudel et al., 2017; Röling, Leeuwis, & Pyburn, 2002). Such learning goes beyond a top-down approach of informing to achieve compliance with external rules, it must promote a constructive process of exchange of viewpoints in which stakeholders may perceive a need to engage in change (Marshall & Marshall, 2007).

The wildfire mitigation strategies and policy combinations of all sites underperformed and suggests weaknesses in design. While the RESEX model is expected to engender behavioural change through shifting incentives via securing land tenure, in practice, residents were concerned about the capped temporal availability of these rights, were unable to sanction neighbours, and did not benefit from alternative livelihood initiatives. In the REDD+ site, nuance was lacking in favour of blanket restrictive approaches, the conditionality of the reward was not met and instead recipients continued regular farming methods albeit more covertly. In the GMP site sanctions were not issued, subsidies were very limited, and smallholders felt detached from the goals of the program.

However, the introduction of conservation initiatives has motivated continued organization and access to resources (including rewards, subsidies and land rights) that could potentially be tapped to enhance a dialogue surrounding improved fire management. Our results build on the body of previous work, which highlights the need for transparent approaches to navigate difficult trade-offs to ‘wicked-challenges’ and the significance of champions (Game et al., 2014). Indeed, farmers attested to the attraction of community-level engagement and influence in program design.

Pre-emptive actions are likely the best way forward since capacity to combat escaped fires is extremely limited, particularly in the remote regions such as the REDD+ and RESEX here presented. Fire management interventions, if explored, would need external support and should be targeted to the specific ecological conditions of the site which can be identified in partnerships with local farmers. Interventions will need to be monitored and evaluated to inform an evidence base that can support decisions for improved approaches (Morello et al., 2017; Nobre et al., 2016). Innovative ways of communicating climate forecasts to smallholders would enable burning practices to be aligned accordingly (Moran et al., 2006).

Conclusions

We recognize the risk wildfires pose to social and environmental imperatives across the tropics and within forest conservation initiatives. We assert that the contemporary prevalence of restrictive fire policies that criminalize already marginalized smallholders are not adequately mitigating these risks. Rather, current fire management policy is undermining conservation initiatives, creating a tangible need to move beyond forbidden fire towards identifying approaches that outperform this model for forests and livelihoods. We draw on our results to suggest that given the absence of imminent and viable fire-free alternatives, a new model of fire management in sites where swidden and conservation collide, warrants

experimentation. While we cannot state which solutions would be most effective, we suggest that exploring options that move beyond forbidden fire may in fact serve to reduce fire risk, increase the legitimacy of local level interventions, enable farmers to practice small-scale agriculture, maintain their cultural identity and retain their food security, and subsequently meet the environmental and social imperatives of forest conservation.

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