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Consequences of actor level livelihood heterogeneity for additionality in a tropical forest payment for environmental services programme with an undifferentiated reward structure

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ABSTRACT

Primary tropical forests provide crucial environmental services, including carbon storage and hydrological regulation. Options for promoting forest conservation include payments for environmental services (PES) programmes that provide financial incentives to local actors, in exchange for reduced forest clearance. The success of voluntary PES (defined in terms of avoided primary forest conversion) is contingent upon behavioural changes in enrolled actors. As both the degree of enrolment and likelihood of sustained behavioural change depend upon how PES compensation structures interact with existing actor economies, local heterogeneity in livelihood strategies may play a strong role in the ultimate success of PES programmes, particularly when compensation is not differentiated with respect to opportunity costs. We examined the influence of livelihood heterogeneity on the potential success of a deforestation-reduction PES with an undifferentiated reward structure. We collected socioeconomic and demographic data at the household and community levels across two large Amazonian extractive reserves where a spatially extensive PES programme (*Bolsa Floresta*) operates. We show that demographic and socioeconomic status varies widely across households and communities, and found that both households and communities that are most and least likely to convert primary forest receive similar financial incentives. Those households most engaged in manioc agriculture (the primary driver of local primary forest conversion) both benefitted from the highest annual incomes and incurred the greatest opportunity costs. We show that avoided primary forest conversion could be greatly increased with differentiated payment structures adjusted for local differences in opportunity costs and livelihood strategies, and present two metrics that could help to achieve that goal.

1. Introduction

Tropical forest biomes harbour the highest levels of terrestrial biodiversity on Earth, provide key environmental services, and support the livelihoods of millions of rural people (Chhatre and Agrawal, 2009). However, tropical forest loss continues—driven by a multitude of factors including human-induced land-use change and forest degradation (Rudel et al., 2009). In the last two decades, emissions from tropical deforestation have contributed 15–23% of the annual global carbon emissions, particularly if subsequent land-use is considered (van der Werf et al., 2009). To stem future losses of forest cover, government and non-governmental agencies are increasingly embracing the implementation of payments for environmental services (PES) programmes (Farley and Costanza, 2010).

Environmental services (ES) are aspects of ecosystems used to produce human wellbeing, either actively or passively (Boyd and Banzhaf, 2007; Fisher et al., 2009). PES programmes provide a variety of mechanisms by which the values of these services can be converted into financial incentives for conservation (Shelley, 2011). As economic decision-making often fails to fully account for environmental service provision (Liu et al., 2010), direct or market-based incentives such as PES seek to transfer funds from those that benefit from environmental services to those that contribute to their production or conservation by inducing benign land-use practices (Wunder, 2005; Sommerville et al., 2009; Shelley, 2011). PES have been defined as "(1) a *voluntary* transaction where (2) a *well-defined* ES (or corresponding land use) is (3) being 'bought' by a (minimum one) ES *buyer* (4) from a (minimum one) ES *provider* (5) if and only if ES provision is secured (*conditionality*)" (Wunder, 2005, p. 3). Recently, attempts to

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describe PES programmes in practice have embraced more pragmatic definitions of "PES-like" initiatives that are broadly compliant with the concept of reward or compensation for altered land management practices (Muradian et al., 2010), even if they fail to meet one or more of the criteria above (e.g. strictly voluntary participation, e.g. Vatn, 2010).

There is a growing demand to understand the extent to which PES programmes contribute to concrete environmental gains (Redford and Adams, 2009; Wunder et al., 2008). The overall success of any given PES programme can be measured in terms of enrolment, conditionality, additionality, permanence, and leakage (Engel et al., 2008). Firstly, potential service providers must be voluntarily attracted to *enrol* in the programme, and to remain enrolled over time to secure long-term gains in ES provision. Secondly, the granting of compensation must be *conditional* on compliance with ES provision. This requires not only adequate compensation for enrolled providers but also a monitoring system and penalty structures that can influence continued production and continued voluntary enrolment (Meijerink, 2008). Thirdly, enrolment and compliance must jointly produce *additionality*; a change in land-use (and therefore ES provision) beyond what would have happened in the absence of the programme (Engel et al., 2008). Finally, whether additionality can be expected to persist over time (*permanence*) and whether gains in additionality come at the cost of displacing ecologically perverse land-use practices to areas outside the project boundaries (*leakage*) are important additional metrics of success for any PES programme.

Fundamental to enrolment, compliance, and ensuing additionality is the underlying payment structure of a PES programme (Wunder et al., 2008). Many programmes compensate enrolled participants according to the opportunity cost incurred during the transition to a PES-compliant land use. To estimate appropriate payment amounts, PES programmes use various metrics to assess the degree of behavioural change entailed or the relative value of the land involved. Programmes with such *differentiated payments* are more often seen in user-financed (rather than government-sponsored) programmes implemented across small spatial scales (Wunder et al., 2008). Examples of PES structures involving some degree of differentiation include the *Pago de Servicios Ambientales Hidrológicos* (PSAH) in Mexico (Muñoz-Piña et al., 2008), the Vittel watershed protection programme in France (Perrot-Maître, 2006), and the *Pimampiro* programme in Ecuador (Wunder and Albán, 2008). The degree of refinement of differentiated payment schemes varies greatly; from broad categories of land type (e.g. the PSAH pays a higher rate to landowners protecting cloud forest), to custom pricing for individual plots within landholdings (e.g. the Vittel PES). In contrast, other programmes uniformly distribute benefits across all enrolled ES providers, regardless of variance in individual opportunity costs (i.e. *undifferentiated payments*). Such programmes include many government-financed schemes and pay undifferentiated rates per unit land area. This flat-rate reward structure is often necessary as a consequence of vast spatial extents, equity concerns or intractable transaction costs. Examples of undifferentiated payments programmes include *Socio Bosque* in Ecuador (de Koning et al., 2011) and *Los Negros* in Bolivia (Asquith et al., 2008). Finally, some PES programmes have payments that are neither differentiated by opportunity cost nor by the extent of land area committed, including the *Simanjiro* PES agreement in Tanzania (Nelson et al., 2010) and *Bolsa Floresta* in Brazil (Viana, 2008).

Although the development and poverty alleviation goals of PES programmes are usually considered secondary to their environmental aims (Engel et al., 2008), PES are often implemented in poor areas, where perceived or actual financial, development or social benefits may influence both the initial commitment and subsequent adherence to programme requirements by individual actors (Kosoy et al., 2008; Vatn, 2010). Given that payments in PES programmes are often targeted at both the actor (households) and community levels, an understanding of local economic or livelihood factors that influence enrolment or compliance at both levels of organisation will have strong implications for ultimate programme success (Wunder, 2007). However, few data are available to explicitly link local livelihood strategies to the effect size of alternative PES payment structures.

The rural livelihood strategies of individual households and communities within legally occupied Amazonian reserves (hereafter, *extractive reserves*) tend to be very heterogeneous, with variable engagement with agricultural and extractive activities and consequential reliance on different forest types (Takasaki et al., 2001; Long, 2010). Households show strong congruence in livelihood strategy within any given community, but accessibility to alternative forest types results in strong inter-community variation in both livelihood strategy and the degree to which local economies rely upon forest conversion into agricultural land (Newton et al., in press). Households and communities enrolled in a PES programme designed to avoid small-scale deforestation will therefore incur variable opportunity costs, depending on the extent to which their behaviour must change in order to ensure PES compliance.

Here we consider how local heterogeneity in economic or livelihood factors affects the effectiveness of undifferentiated payment structures in a PES programme designed to reduce rates of primary forest conversion. As a case study, we examined the *Bolsa Floresta* (Forest Conservation Allowance), an extensive PES programme established across extractive reserves within Amazonas, the largest Brazilian state. Bolsa Floresta (BF) began in 2007 and provides compensation to traditional populations for ES flowing from primary forest retention, in the form of cash payments and developmental support. The BF programme explicitly suppresses clearance of primary forest areas, limiting agricultural expansion to the extent of previously available swidden fields (*roçados*) and secondary forest (*capoeira*). With 7971 households enrolled across 15 reserves to date, and an ambitious projected expansion into other reserves, BF represents one of the largest-scale PES programmes implemented in a tropical forest region (FAS, 2011a). Like many PES in developing countries, BF is a hybrid programme, mixing government and user financing (via international agencies, private investors and NGOs) with local, NGO-based administration.

Heterogeneity in the livelihood strategies of actors voluntarily enrolled in PES programmes with undifferentiated payment structures may result in reduced social and environmental benefit, when payments do not adequately exceed opportunity costs, or are inefficiently spent on areas with low expected additionality. Within agricultural communities, the opportunity costs of prohibited primary forest conversion depend heavily on the availability of existing swidden fields (*roçados*) and secondary-forest patches (*capoeiras*). For example, compared to newly established communities, older communities may have a greater pool of surrounding secondary-forest to draw upon as a result of previous cycles of swidden/fallow agriculture. Conversely, the largest communities may have saturated all of the forest (primary and secondary) within a viable travel distance. Each of these scenarios would lessen the likelihood of primary forest clearance in the absence of PES payments, with a lower associated opportunity cost of foregone primary forest conversion.

We assessed the potential scope of BF payments based on pre-PES livelihoods and incomes, using data obtained across two large extractive reserves in western Brazilian Amazonia. We explored the relative economic impact of BF compliance on recipients' incomes, and discuss the likelihood of the programme achieving its goals.

2. Methods

2.1. The Bolsa Floresta PES programme

The Bolsa Floresta is a voluntary PES programme that grants financial compensation to individual households and communities in exchange for a commitment to zero conversion of primary forest (Viana, 2008). Deforestation in this region is largely driven by chainsaw-operated clearance of small (0.1–6.6 ha, in our study area) patches of primary, upland (*terra firme*) forest to cultivate food crops—primarily manioc, which is the staple source of carbohydrates in Amazonia. Annual monitoring of deforestation inside reserves is performed by partnering institutions using a combination of site inspections and satellite images. All residents of participating reserves are actively invited to enrol in the programme.

Following explanatory workshops that set out the BF concept, conditions, and reward structure to community representatives, individual households are invited to enrol in the programme (Viana, 2010). BF offers compensation at four different levels that can be accessed simultaneously by participating communities. *Bolsa Floresta Familiar* (BFF) is a monthly payment of R$50 (∼USD 30) awarded to individual families. Equal payments are awarded to all enrolled households, regardless of the extent of intended avoided primary forest conversion. In addition, two different compensation grants can be accessed at the community level. *Bolsa Floresta Renda* (BFR) supports alternative income-generating activities that do not rely on deforestation, including fishing and the extraction of non-timber forest products such as natural oils, fruit, and honey. Enrolled communities are awarded through development support averaging R$4000 (∼USD 2560) per community per year (based on an average community size of 11.4 households). The second community-level support programme, *Bolsa Floresta Social* (BFS), offers enrolled communities a range of development infrastructure; also averaging an annual cash reward of R$4000 per community, this grant funds improvements in water sanitation, basic education, health, communication, and transport (Viana, 2008). Finally, *Bolsa Floresta Associação* (BFA) supports the political organisation and cooperatives of residents' associations active within each protected area. The BFA is calculated as 10% of the aggregate value of all BFFs within a given extractive reserve and provides logistical support to local leaders to promote social justice and guard the interests of reserve residents. The benefit of the BFA is thus effectively divided evenly across all enrolled communities within a target reserve. This study considers all four components, although we focus on the BFF because this is the largest cash payment to individual families.

2.2. Study site

This study was conducted within the context of a 3-year, interdisciplinary research project aiming to understand the dynamics of extractive practices within multiple-use Amazonian forest reserves. The study was conducted within and around two contiguous extractive reserves; the federally managed Médio Juruá Extractive Reserve (hereafter, *ResEx Médio Juruá*) and state-managed Uacari Sustainable Development Reserve (hereafter, *RDS Uacari*) (Fig. 1). The reserve complex is bisected by the Juruá River, a large white-water tributary of the Amazon (Solimões) River in the State of Amazonas, Brazil. A wide band of seasonally flooded (*várzea*) forests along the main river channel is inundated between January and June, while *terra firme* forests on higher elevation have not been flooded for hundreds of years. The elevation is 65–170 m above sea level and the terrain is flat or undulating.

The ResEx Médio Juruá and RDS Uacari were decreed in 1997 and 2005, respectively, and are currently inhabited by some 4000

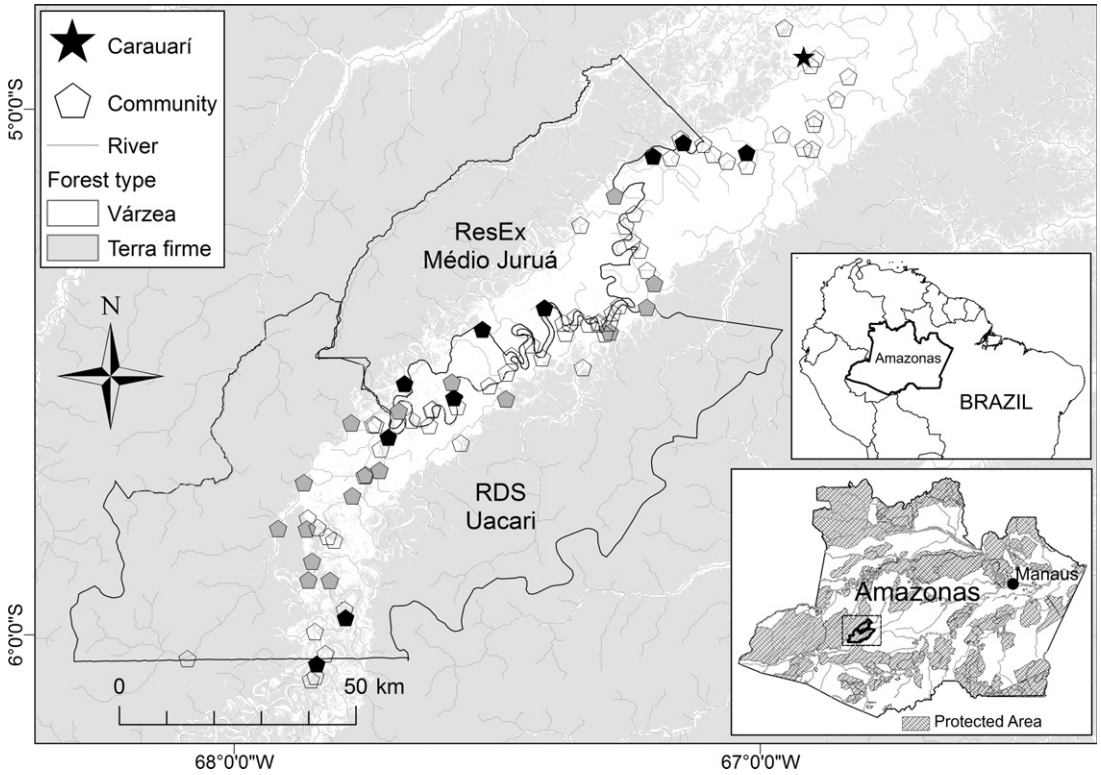

Fig. 1. Location of communities within, and immediately outside, the boundaries of the Uacari Sustainable Development Reserve and the Médio Juruá Extractive Reserve in the state of Amazonas, Brazil. Black pentagons indicate communities that were surveyed on a weekly basis; grey pentagons indicate communities that were interviewed only once; hollow pentagons indicate other communities. Insets show the locations of Amazonas within Brazil (above), and the study area within the full protected area network of Amazonas (below).

legal residents distributed across approximately 60 settlements of between 1 and 89 households (mean ± SD = 10.3 ± 13.2, median = 7, N = 50). Household occupancy was also extremely variable (mean ± SD = 7.0 ± 3.0, range = 1–17, N = 179). Most communities are located along the main river channel, while others are settled on the banks of tributaries and oxbow lakes on either side of the Juruá River. Reserve residents variously engage in agricultural, extractive and fishing activities for both subsistence and cash income (SDS, 2010). We collected socioeconomic data from 181 households across eight communities in the ResEx Médio Juruá, 17 communities in the RDS Uacari, and two communities immediately outside these reserves, all of which were located along a 380-km section of the Juruá River (Fig. 1).

Currently, only residents of the RDS Uacari qualify for the BF programme, since the programme has yet to be implemented in the ResEx Médio Juruá. However, to explore the range of household and community livelihoods and economies, we consider data from both reserves, because the geographic, sociopolitical and economic conditions faced by residents of the ResEx Médio Juruá are essentially identical. *De facto* reserve management by either federal or state agencies is of relatively little practical consequence to the livelihood strategies or income opportunities of reserve residents. Our data were collected at the very inception of the BF programme, since our study aimed to assess whether existing heterogeneity in livelihood strategies would affect the degree to which payments benefited households with different revenue sources and annual incomes. By studying incomes at the outset of the programme, we can be sure that PES payments made negligible impact on the income-generating activities of reserve residents and that behavioural patterns recorded in this study had not been pre-adjusted in response to the BF cash rewards.

2.3. Weekly monitoring

Weekly surveys were conducted in 127 households across 14 communities between March 2008 and July 2010. This sampling effort represented ~23% of all active households in the two reserves. One previously trained resident from each community visited up to 10 randomly selected households per community on a weekly basis and recorded all extractive and agricultural activities of each household. Because median community size was 7 households (Section 2.2), our weekly sampling protocol effectively captured most households within a given settlement. Each week, this trained resident (*household monitor*) questioned a senior household member about three types of cash-income activities: (i) cultivation of agricultural products; (ii) extraction of plant forest resources; and (iii) fishing. For each activity, the household-scale quantities of all resources collected or produced were recorded, together with the transaction values of traded goods. We analysed data from all households for which data acquisition included at least 40 weeks spread over a period of at least 365 consecutive days, resulting in a subset of 82 households from 10 communities (mean number of weekly samples per household = 66.6 ± 10.3). Other households sampled (N = 45) failed to capture a full year-round seasonality cycle, and were therefore excluded from the analyses. All monetary values are reported in Brazilian Reais (exchange rate R$1 = USD 0.61, 16th May 2011). In this study, we focus on household income from agricultural activities since this is the main driver of primary forest clearance and the primary source of revenue affected by the BF programme. The full livelihood strategies of the focal communities are described in Newton et al. (in press).

2.4. One-off interviews

Two modes of voluntary, one-off interviews targeting all 181 households belonging to 27 communities were conducted by PN and WE between June and December 2009. Quantitative data acquisition took place during household interviews, which on average lasted 20 min. These were undertaken with one or more senior members of each household to document household scale demographic profiles, income, and perceptions of the BF programme (RDS Uacari communities only). Community-level interviews lasted an average of 50 min and obtained both quantitative and qualitative data. These were conducted with a senior member of each community (usually the locally elected leader) to document the overall demographic profile, physical geographic setting, infrastructure, and material assets of each community. Both forms of interviews were structured, although additional information was recorded on an ad hoc basis whenever offered.

3. Results

3.1. Household cash economies

Mean monthly income varied widely between households (R$563 ± 349, N = 82, range = R$55–R$1656 per household). Community-level income, estimated as the sum of all household incomes and extrapolated to additionally account for those households that were not surveyed weekly, was also highly variable (R$11,701 ± 17,880, range = R$2722–R$61,308 per community per month, N = 10). Unsurprisingly, communities with more households had a higher total community income (r = 0.995, $p < 0.001$).

Manioc production accounted for 62.3% of all agricultural yield, but varied widely across households (47.5 ± 50.6 kg, range = 0–270.4 kg of manioc per household per week, N = 82). Production for consumption ranged from 0 to 59.9 kg per household per week (mean = 14.5 ± 12.1 kg), while revenue generated from sales ranged from R$0 to R$227.72 per household per week (mean = R$29.78 ± 42.25). Prices per 50-kg sack were relatively stable both temporally and spatially (R$46.11 ± 16.20, N = 1441 50-kg sacks).

Most interviewed households (139/180; 77.2%) received at least one form of cash state benefit other than BF. In particular, 73.3% of households received a *Bolsa Família* allowance, which is paid at a rate of R$68 per family plus R$22 per school-aged child, for up to a maximum of three children. Additionally, 14.4% of households contained one or more persons (elderly or disabled) in receipt of a state pension, who on average were paid R$453 per month.

3.2. Potential role of Bolsa Floresta payments in household cash economies

The monthly R$50 BFF flat-rate payment to individual households accounted for between 2.9% and 69.5% of mean monthly income (N = 82, mean ± SD = 11.9 ± 11.1%). In addition, the cash value of community-level grants (BFR and BFS) each equated to an extra R$29.24 per household per month (R$4000 per 11.4 households per year). The *per capita* value of the set-rate payments of BFF ranged between R$2.9 and R$50.0 (R$9.2 ± 6.5) per month, depending on the number of occupants within the household. The majority of households (135/180) were in receipt of a higher cash income from other welfare payments than offered by the direct cash payment of the BFF (mean ± SD recipient household income per month: from *Bolsa Família* = R$122 ± 277, N = 132; from pensions = R$558 ± 210, N = 26).

3.3. Livelihood heterogeneity

The relative subsistence and monetary importance of manioc cultivation was highly variable across households and communities, implying that opportunity costs incurred in forgoing future

cultivation in former primary forest areas varied widely across individual families and communities. There was a positive correlation between household size and the number of equally spaced stems of manioc in cultivation (a good proxy of aggregate crop volume) in neighbouring swidden fields ($r = 0.341$, $N = 171$, $p_{\text{one-tailed}} < 0.001$). Manioc crop size and estimated planted area were strongly correlated ($r = 0.719$, $N = 22$ fields, $p_{\text{one-tailed}} < 0.001$), indicating that larger families tended to cultivate larger areas, thereby placing correspondingly higher demand on suitable agricultural land in unflooded terrain.

The proportion of total income represented by manioc agriculture also varied widely between weekly surveyed households (mean ± SD = 21.1 ± 22.3%, $N = 82$). Most household and community-level variation in manioc cultivation in this swidden agriculture system was driven by accessibility of surrounding terra firme forest (Newton et al., in press). Hence, entire terra firme communities tended to engage heavily in manioc agriculture, with a high level of intra-community congruence in the overall livelihood of individual households. The proportion of total community income represented by manioc was accordingly highly variable (range = 0–32.6%, mean = 11.2 ± 13.2%, $N = 10$).

3.4. Implications of income heterogeneity for Bolsa Floresta

Households that produced more manioc reported higher total income ($r = 0.465$, $N = 82$, $p < 0.001$), thereby receiving a lower proportion of their total income from the set-rate payments of the BFF, compared to households engaged principally in alternative income-generating activities. The relative contribution of BFF payments to mean monthly household income was therefore lower for those households more heavily reliant on agriculture (Fig. 2).

3.5. Perceptions of opportunity costs

In general, *Bolsa Floresta* participants were positively engaged with the concept of the PES programme, with 43/45 respondents stating that they supported the general idea of the programme. However, all six respondents that commented on the reward structure indicated that the fixed value of the payments was too low. For example, one informant from an upland community commented that "a swidden field can make much more money [than the monthly R$50 BFF grant]" (interview number: J183). A second informant commented that "Bolsa Floresta does not fully compensate the loss of not being able to plant manioc in a cleared primary forest area, since swidden fields in cleared secondary forest areas are not nearly as productive" (J185). In contrast, an interviewee from a seasonally flooded forest community whose income was principally derived from fishing rather than manioc cultivation stated that he supported the programme "because I don't need to change anything I do [to qualify for the BFF grant]" (J131). Another highlighted inter-community heterogeneity, noting that "some [communities] have more secondary forest available than others" (J184), which permits continued agricultural expansion into secondary forest, while remaining compliant with BF requirements.

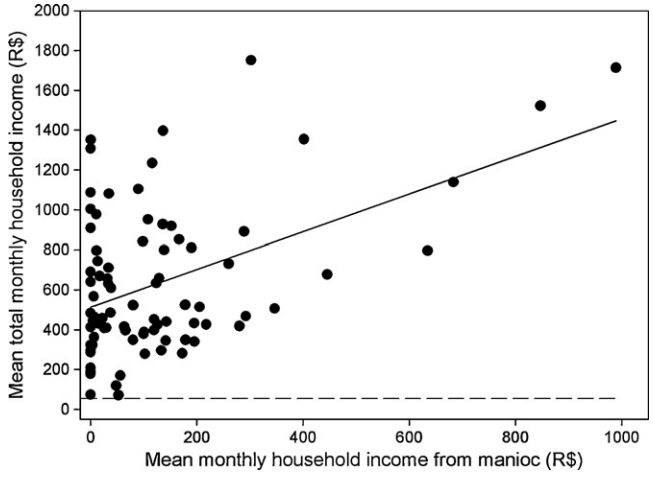

Fig. 2. Relationship between agricultural income derived from manioc cultivation and total income from all sources for 82 households in the Médio Juruá region of western Brazilian Amazonia (R$1 = USD 0.61). The distance between the linear regression (solid) line and the monthly R$50 grant awarded by the *Bolsa Floresta* programme (dashed line) indicates the relative contribution of BFF to the total household income.

4. Discussion

The implementation of PES programmes in tropical forest regions is still largely incipient and is beset by poorly explored questions of optimal design and administration. Using the Bolsa Floresta case study, we explored how local heterogeneity in demographic, economic or livelihood factors affects the opportunity costs incurred by rural Amazonians in the context of a PES programme with an undifferentiated payment structure. In designing and implementing the BF programme, its proponents stated "that to promote forest conservation and sustainable development, different strategies should be formulated for each Amazonian sub-region, since it is clearly heterogeneous" (Viana, 2008). We agree with this assertion, and additionally highlight the importance of taking into account local and landscape-scale heterogeneity in incomes and livelihood strategies of PES participants to maximise the value of conservation programmes while minimising local opportunity costs.

Evidence suggests that the economies of individual households and communities of tropical forest dwellers vary significantly according to geography and local demographics (Takasaki et al., 2001; Newton et al., in press). Our data show that household and community income, family size, and livelihood strategy vary widely across the two focal reserves. This is likely to contribute to similarly varying opportunity costs faced by individual actors (households) as they decide to join the BF programme, or to comply with its zero-primary forest conversion policy following enrolment.

4.1. Cash-payments

PES cash rewards can make significant contributions to rural households' cash incomes (Corbera et al., 2009; Lee and Mahanty, 2009; Pham et al., 2009). The monthly fixed-value R$50 BFF payment awarded to individual families represented between 3.0% and 90.2% of mean monthly household cash income. The large variation in household size (1–17 people per household) resulted in much lower *per capita* values for the monthly BFF payment for larger families. A family of two received R$25 per person per month, compared to just R$2.94 per person per month in a household of 17 people.

In addition to this wide-ranging *per capita* contribution to household revenues, BFF represents a lower cash contribution to household incomes relative to other existing welfare payments. *Bolsa Família*, for example, is a poverty-alleviation government subsidy available to all families with a mean monthly income lower than R$140 (Lindert et al., 2007). Most households interviewed received a *Bolsa Família* grant, with a mean value of R$122 per month that was 2.5-fold greater than the BFF payment. In addition, monthly state pensions (for the elderly or disabled) of ~R$453 per entitled person again accounted for a much higher

contribution to recipient households. While these other forms of welfare support are conceptually and administratively isolated from the PES programme, recipient households tended to associate them together and frequently compared the benchmark value of one against the other. In this light, BFF not only carries a lower cash value than other subsidy programmes, but additionally demands behavioural changes in cultivation practices that potentially incur a cost far exceeding its benefit.

Securing financial assets is a necessary, but not sufficient, contribution to sustainable livelihoods; the process must also develop social and physical assets (Lee and Mahanty, 2009). Household-level cash payments are just one component of the BF programme, which also includes reserve-level grants to residents' associations (BFA) and community-level grants for health and education programmes (BFS) and extractive industry infrastructure (BFR). Translated into monetary worth this represents an estimated annual investment of R$13,560 to the RDS Uacari (number of enrolled households in September 2010 = 226), plus a mean R$5193 per community (mean RDS Uacari community size = 7.14 households). These payments effectively increase the benefit to each household to a total of R$113.48 per month, with the total BF investment thus representing a much higher proportion of the sum of households' annual income (range = 6.5–157.6%, mean = 27.1 ± 25.2%, N = 82).

4.2. Livelihood options and opportunity costs

Livelihood strategy is a crucial determinant of the pressure that an individual household or community may place on standing forest (Lee and Mahanty, 2009). Since manioc production in swidden/fallow systems is the principal driver of primary forest loss in these reserves, opportunity costs incurred by enrolling in BF are higher for participants depending heavily on agriculture than for those engaged primarily in fishing or plant extractivism. Within our two focal reserves, economic specialisation is typical of most households, which derive over half of their income from either agriculture or extractivism of fish or plant forest products (Newton et al., in press). Heterogeneity may occur on a community level, with congruence in livelihood strategy between households within the same community but considerable variation between communities. Extractive communities in Amazonia are often located closer to seasonally flooded (*várzea* or *igapó*) forest habitat and often plant the majority of their crops in cleared várzea forest patches and on fertile beaches which require no regular clearance of additional forest, since they are annually replenished by floodwater nutrients. They have a greater reliance on annual crops that can be harvested within the six-month period during which these areas are above water. Agricultural communities tend to be sited in upland areas located on oxbow lakes and tributaries farther from the main river channel. These communities also tend to be larger than extractive communities and swidden fields in these terra firme areas require fallow periods of over 3 years between successive crops; two factors that result in a higher demand for cleared forest areas. In this system, payments to households within communities surrounded by seasonally flooded forest are far less effective than payments to households within communities embedded in terra firme forest. Extractive households place the least pressure on primary forest, yet receive an equal value of reward (Fig. 3).

We show that those households and communities that derive the highest incomes from manioc agriculture (as opposed to plant extractivism, fishing or other agricultural yields) are also those that

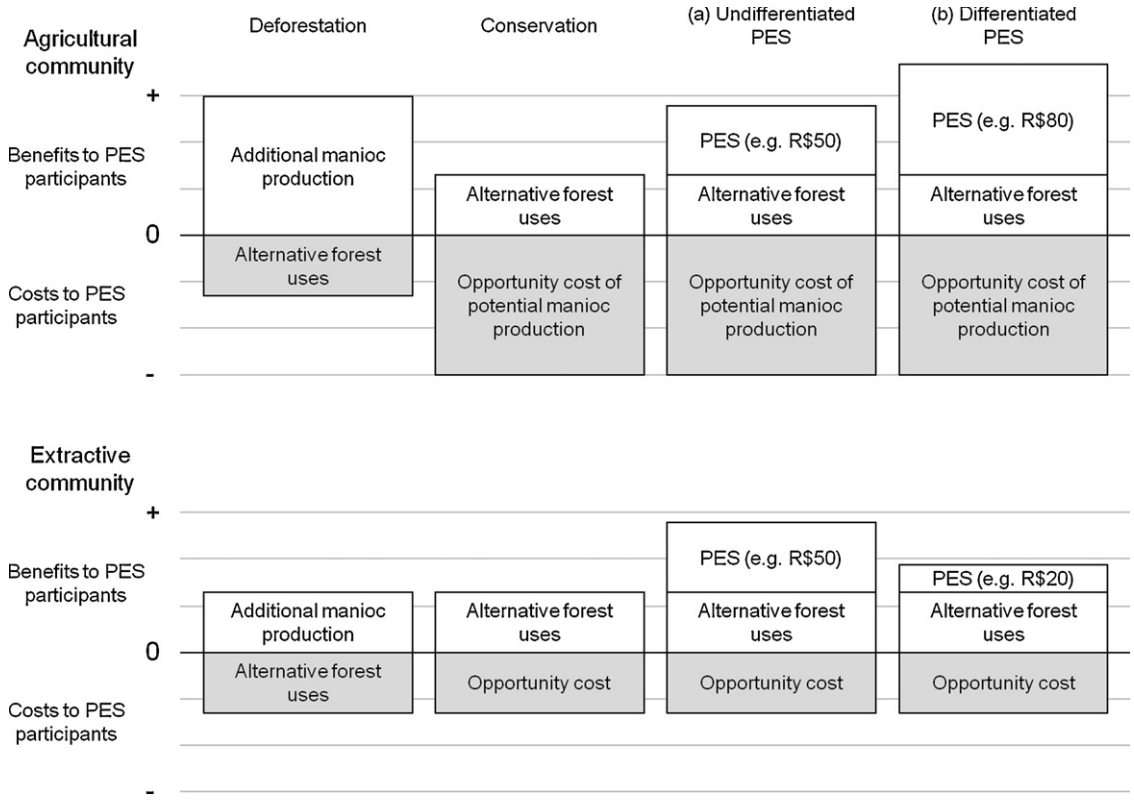

Fig. 3. The logic of differentiated payment structures in payments for environmental services (PES) programmes, in which the costs and benefits to potential PES participants are schematically illustrated. In the study system of the Médio Juruá region of the Brazilian state of Amazonas, suppression of primary forest clearance confers greater opportunity costs to an agricultural community than it does to an extractive community. (a) Under the *undifferentiated payment structure*, the extractive community is unnecessarily over-rewarded; as a result, limited funding means that the higher opportunity costs of the agricultural community may not be adequately compensated. (b) Under the *differentiated payment structure*, on the other hand, benefits outweigh the costs for both communities.
Adapted from Engel et al. (2008).

generate the largest overall cash incomes. As a consequence, the relative value of BF payments is lower for these households. Therefore, ironically, heavily agricultural households, whose behaviour the BF programme specifically aims to alter, receive the lowest financial incentives from its introduction.

Finally, if a PES programme precludes an economic activity it should consider the substitute income-generating activities available, since it is usually easier for some households to adapt than others. The opportunity costs incurred by a given household reflect not just the proportion of income provided by PES compensations, but the availability of income-generating activities that do not demand new forest clearance (Fig. 3). Terra firme forests in our study landscape tend to have lower natural densities of frequently marketed non-timber forest products (e.g. *Hevea* spp. rubber and *Carapa guyanensis* oilseeds). This poses additional questions for the appraisal of the economic viability of alternative income-generating extractive activities that can be pursued within relatively undisturbed forests.

4.3. Participant perception, enrolment and compliance

The perception of land managers of the relative costs and benefits of a given PES programme strongly influences enrolment, compliance and, therefore, programme success (Kosoy et al., 2008; Pham et al., 2009; Sommerville et al., 2010a; Vatn, 2010). Although the BF programme conducts annual independent assessments of primary forest conversion, specific plot-level tracking of land use change that can be associated to enrolled individuals is difficult, complicating the monitoring of recipients' adherence to the BF programme's requirements. Participant perceptions of the programme may therefore be a critical indicator of its likely success in the medium and long-term. Ad hoc comments made by interviewees, and those surveyed elsewhere, indicate that many recipients of BF consider the value of the BFF payments to be too low (FAS, 2011b), and that this perception may be related to the disproportionate opportunity costs incurred by communities more strongly engaged in agriculture. We found that larger households, which are most likely to place the highest pressure on standing terra firme forest, receive the lowest *per capita* compensation for agreeing not to convert forest cover. While our data are insufficient to quantify whether households more heavily reliant on manioc production were more dissatisfied with the value of the BFF payments, anecdotal evidence indicates this to be a widespread concern within our focal reserves across both enrolled and non-enrolled households.

In general, the relationship between PES payments and behavioural change is complex, and this remains an area of active research (Vatn, 2010). The role of financial incentives in altering land management behaviour can focus either on their use as payment for a specified ES (in a buyer-seller context) or, alternatively, as compensation for improved environmental stewardship (in a cooperative reciprocity context). These two approaches have very different implications for how land managers perceive, participate and comply with PES regulations (Kosoy and Corbera, 2010; Vatn, 2010). The former use of financial incentives, as a market instrument, may result in increased gains in compliance and efficiency of ES delivery, but at the detriment of social trust and elevated transaction costs (Vatn, 2010). Alternatively, the use of financial incentives as compensation for stewardship may increase efficiency and trust through enhanced informal monitoring (both self-policing and between enrolled actors), but may diminish control over specific ES outcomes (Meijerink, 2008; Vatn, 2010). The *de facto* perception of the undifferentiated payments within the BF scheme may be as compensation for stewardship, rather than market payments for ES provision. While we did not collect information that allows us to quantify (1) whether BFF payments are perceived as financial instruments or stewardship compensations, or (2) how these perceptions influence BF enrolment or compliance, we suggest that the relationship between PES payment value and behavioural change within the BF programme be further examined before planned programme expansions are implemented.

Financial incentives are seldom the only important motivators of participation (e.g. Kosoy et al., 2008), and economically poor rural households may enrol in a PES programme even if individuals believe the value of payments to be small relative to their opportunity costs. Firstly, access to the community-level benefits of a PES programme may be made contingent upon individual participation. BF provides three inter-related collective payments targeting communities or whole protected areas, in addition to individual household level payments. Enrolled household decisions of whether or not to open a new primary forest clearing, thereby falling out of compliance with the BF programme, can threaten continued community level payments and are therefore modulated by a larger social context. Economic incentives, social norms and community power structures are all important drivers of behavioural change, so individuals who decide not to comply may be exposed to a range of social pressures that together confer a greater likelihood of adherence to the programme's requirements (Chen et al., 2009; Sommerville et al., 2010a). Secondly, participants may decide that any value of payment is better than none at all, particularly when existing power asymmetries prevent ES providers from engaging with ES price setting (Pham et al., 2009; Kosoy and Corbera, 2010).

4.4. Undifferentiated distribution of PES compensation

Maximal economic efficiency may be achieved by a PES programme whose payment levels are determined by the actual opportunity costs (Pham et al., 2009). Many programmes' payments are currently determined by administrative ease or by buyers' budgets, with minimal consultation with programme participants at the design phase. The undifferentiated payment structure of the *Bolsa Floresta* PES programme minimises transaction costs in a spatially extensive and logistically challenging project that pays thousands of enrolled households across multiple conservation units. However, this payment structure may ultimately cap the effectiveness of the BF programme. If the value of PES compensation reflected the degree to which households depend on primary forest clearance, the payments might be more effective in influencing the behaviour of their recipients (Fig. 3).

Most undifferentiated PES programmes implement their payments according to the total land area committed to the programme by the enrolled landowner. The *Socio Bosque* programme in Ecuador awards payments of up to USD 30 per ha per year to farmers based on the area of forest that they preserve (de Koning et al., 2011). Similarly, the programme at Los Negros in Bolivia rewards PES participants with one bee-hive per 10 ha of forest protected per year (Asquith et al., 2008). Since land within Amazonian extractive reserves is not actually owned by reserve residents, who are instead granted long-term usufruct rights of the reserve territory, determining payments directly on the basis of area is not a simple option. However, this in itself does not present an absolute barrier to the development of differentiated payments and the relative opportunity costs of enrolled PES participants can be assessed in alternative ways (Pagiola, 2008).

Differentiated payment structures may bring significant efficiency benefits by employing spatially explicit rates that are tailored to the variable ES provision potential and opportunity costs of different forest landscapes (Wunder, 2005; Chen et al., 2010). Such spatially targeted payments have been successful in a range of existing forest PES programmes involving retention of

carbon stocks or hydrological services. For instance, the PSAH programme in Mexico pays per hectare rate to enrolled landowners, with higher rates in areas where the value of the ES provided is considered to be higher (Muñoz-Piña et al., 2008). The Vittel PES programme discriminates four groups of landowners, each with unique opportunity costs to PES compliance (Perrot-Maître, 2006). While administratively more complex, such an approach may enhance the likelihood of distributing limited funds in a manner most likely to achieve the maximum return in terms of forest protection (Wünscher et al., 2008). Conversely, undifferentiated payment structures risk economic inefficiency, with many payments being directed at low deforestation-risk landowners (Fig. 3).

Our data suggest that there is high potential for BF payments to be distributed across households and communities that are unlikely to contribute to additionality of avoided deforestation in this system, at least in the short-term (May and Millikan, 2010). One means to achieve a more efficient distribution of funding might be to develop a conditional metric by which to assign BF payments to single households or communities. While a community-level assessment of the location, abundance, ownership, and land tenure system associated with secondary forest areas available to expand manioc cultivation would have the highest likelihood of achieving true additionality in avoided deforestation, the transaction costs of such a programme are likely to be prohibitively high. Here we propose two proxies relying on simple household-level interviews that can achieve a large degree of conditionality.

A *demographically adjusted payment structure* would help to lessen the variation in *per capita* value of BFF payments. Although households are the fundamental unit for resource-use decision-making, household traits are rarely considered in determining opportunity costs (Chen et al., 2010). Community payments already acknowledge demographic heterogeneity by calculating the value of the BFR and BFS according to the size of the recipient community. Extending the same logic to take account of household size for BFF payments would also reduce inter-household variability in *per capita* payment values. Other subsidies, such as the *Bolsa Família* grant, already take account of varying family size by adjusting payments in proportion to the number of school-age children. Of the 180 households we surveyed, 73% were already receiving *Bolsa Família*, which was implemented nationwide, implying that the data required to adjust payments by family size are already available.

A *livelihood-adjusted payment structure* could be applied in systems where the relationship between opportunity costs and land-use in different habitat types can be approximated (Fig. 3). Explicit accounting of the pressure of individual households to clear new forest areas can be used as a proxy for opportunity cost. The strong household-scale relationship between *farinha* production and the number of manioc stems planted in swidden fields or the area of these fields (Newton et al., in press) can act as such a proxy in this system. These data can be more readily obtained from a single interview, and in our experience can be accurately quantified by most senior members of households.

The availability of terra firme and seasonally inundated várzea forest within the immediate vicinity of a community is the strongest determinant of household-scale livelihood strategies within Amazonian reserves (Newton et al., in press). Alternatively, therefore, landscape structure and composition can be readily assessed using satellite imagery, thus serving as a straightforward and objective proxy of livelihood pattern. This fails to consider variation in secondary-forest availability, which may be a key determinant of opportunity costs, but even suboptimal payment differentiation is demonstrably more efficient than complete undifferentiation (Chen et al., 2010).

A number of factors can reduce the desirability of a conditional approach in a PES programme such as BF. The first of these is the possibility that non-qualifying households or communities may realign their behaviour to become qualified for PES, but in a manner detrimental to ES provision. For example, a household with no previous history of manioc cultivation in terra firme areas could clear a field in order to claim compensatory benefits or a community considering where to resettle in the imminent future may be influenced by geographic variables that determine their qualification for PES payments. However, this possibility may be precluded either by the inertia associated with behavioural traditions or by ensuring that PES reward values closely reflect the actual opportunity costs incurred.

Secondly, the inclusion of poverty alleviation and socioeconomic development goals in the design of PES programmes remains contentious, since such objectives may not track local variation in the ecological effectiveness of payments, and indeed may demand the undifferentiated distribution of financial and practical investment across all individuals within a system, for reasons of social equity and perceived fairness (Sommerville et al., 2010b). The definition of PES cited in this paper (Wunder, 2005) clearly separates the goals of efficiency and equity, viewing PES primarily as a mechanism for ES conservation and regarding any effects on poverty reduction as positive side effects (Muradian et al., 2010). Explicit adoption of development aims may eventually undermine the efficacy of PES programmes in achieving their conservation goals (Pagiola et al., 2005; Wunder, 2008). However, the potential for payments to contribute to poverty alleviation is clear, and it may be unfeasible for designers of PES programmes to disentangle conservation and development goals (Muradian et al., 2010). By 2030, carbon markets may benefit up to 50 million low-income households in developing countries (Milder et al., 2010), and many PES programmes, including BF, promote development goals as a secondary but core aspiration (e.g. Pham et al., 2009).

Finally, there remains the fundamental question of whether payments are acting solely as financial incentives to discourage primary forest conversion, or also as a reward for those who have sustained forest permanence over the years (May and Millikan, 2010; Muradian et al., 2010). This question applies both to entire protected areas and to individual households, since many of the sustainable development reserves targeted by BF are under little immediate deforestation pressure (INPE, 2011), and we have argued that many households within a given reserve may not engage in forest clear-cutting for manioc agriculture. Such households pose a minimal threat to forest cover, so are perhaps not immediate candidates for incentive-based mechanisms that compensate for the opportunity cost of avoiding primary forest clearance. Their behaviour is unlikely to be altered by anti-deforestation financial payments, which must be interpreted either as economic inefficiency or as a reward for maintaining forest cover rather than an incentive not to diminish it.

Despite these factors, Wunder et al. (2008) note that other government-financed programmes are moving away from undifferentiated payment structures in order to account for local heterogeneity in land use practices. Developing differentiated payment systems based on individual opportunity costs, while maintaining the benefits of a large-scale programme, could considerably strengthen the likelihood of BF and other PES programmes achieving their goals (Fig. 3; Wünscher et al., 2008).

5. Conclusion

Bolsa Floresta is a pioneer and ambitious PES programme that aims to curb deforestation within Amazonian extractive reserves. However, its success is contingent upon inducing behavioural

change in those enrolled; a process which the programme is catalysing by paying resident families an average 12% of their mean annual income while providing financial and practical support to community development projects. Here we draw attention to the economic inequality that an undifferentiated payment structure may create given the large variation in family size, household income, livelihood strategy and settlement geography—particularly in the degree to which different families engage with manioc agriculture. Households and communities pose varying degrees of threat to primary forest integrity and face unequal opportunity costs. The current system of compensatory payments thus results in heterogeneous impacts on recipients' economies and on their willingness to adhere to the programme's requirements. Addressing such challenges in the design and implementation of community-based PES interventions will be critical to the fine-tuning of BF and the development of other PES programmes in tropical forest regions. More broadly, PES programmes should consider this variability in determining the most effective means by which to modulate land-use practices of programme participants.

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