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Predicting responses to conservation interventions through scenarios: A Cambodian case study

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ABSTRACT

In this paper, we demonstrate how predictive methods can be used to investigate the effectiveness of conservation interventions prior to their implementation and ensure that limited resources are invested in those interventions that will achieve the strongest outcomes for conservation. Too often, operational, financial and logistical constraints lead to the design of interventions based on past experience and expert opinion, without an assessment of the probable outcomes of alternative approaches. Here, we employ a simple method that can be used by conservation managers to evaluate a range of credible alternatives and select the intervention predicted to have the greatest impact. We apply scenario-based interviews to investigate the effectiveness of interventions aimed at reducing household forest clearance at a REDD + site in Cambodia. In this context, we show that collective performance payments, structured either as payments to individual households or to village development funds, have the greatest potential to reduce household clearance. In comparison, greater enforcement effort and individually contracted performance payments – options that might otherwise have been considered credible choices – are predicted to perform poorly, with only negligible reductions in forest clearance.

1. Introduction

For those charged with the conservation of wildlife, one of the most critical questions faced is how best to use the resources at their disposal to effect desired outcomes. Yet, as the practice of conservation and the science underlying it have evolved, this question has in many ways become more difficult to answer. In the early days of conservation, forcible evictions from protected areas (PAs) and the removal of access or use rights to the resources within were commonplace (Adams, 2004), the legacy of which is still clearly visible today as PAs and the enforcement of access restrictions continue to be the mainstay of conservation efforts around the world. The underlying logic of this approach of the separation of nature and people is simple but in practice can be difficult to police effectively, not least because the establishment and enforcement of PAs may inflict significant negative impacts on local people (Adams et al., 2004; Brockington et al., 2006; Cernea and Schmidt-Soltau, 2006; Colchester, 2004). Recognition of this and the resentment it fosters has helped to give rise to a raft of less punitive incentive- and rights-based approaches to conservation, most notably integrated

conservation and developments projects (Barrett and Arcese, 1995; Wells and Brandon, 1993), community based natural resource management (Kellert et al., 2000; Singleton, 2000) and payments for ecosystem services (Engel et al., 2008; Ferraro and Kiss, 2002; Wunder, 2007). Yet, while these developments have significantly expanded the options available to conservation managers, the question of which approach, or combination thereof, is most likely to result in the best outcomes for conservation in any given situation remains.

This has brought increasing attention to evidence-based approaches to improving conservation decision-making and evaluating whether or not conservation interventions have been successful in achieving their stated goals (Pullin and Knight, 2003; Sutherland et al., 2004; Stem et al., 2005; Ferraro and Pattanayak, 2006; Pullin and Knight, 2009). But the success of conservation interventions is often difficult to define or measure and may be highly dependent on the local social, political, economic and institutional context (McShane et al., 2011). In many cases, despite a wealth of case studies of how particular approaches have been applied, there is insufficient evidence of outcomes or post-project monitoring to be able to draw conclusions (see recent reviews of the efficacy of livelihood based approaches for examples of this problem; Roe et al., 2015; Wicander and Coad, 2015). Where advances have been made, such as through the application of quasi-experimental matching approaches (e.g. Andam et al., 2008, 2010; Arriagada et al., 2012; Ferraro and Hanauer, 2014; Clements et al., 2016; Clements and

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Milner-Gulland, 2015), barriers remain. In the case of impact assessments, they require technical expertise that may not be available to conservation managers to be done well, are expensive (Agrawal, 2014) and are conducted after projects have been implemented for long enough to provide sufficient data to make the assessment. As such, even if approaches such as adaptive management (Salafsky et al., 2002; Stem et al., 2005) have been put in place to allow for changes in project implementation in light of new evidence, opportunities for improvements, time or goodwill may be lost in the interim. From the perspective of conservation managers, whose immediate concerns are more likely to be the programmes under their control rather than furthering a wider body of knowledge, more relevant tools are those that enable them to estimate the effects of interventions prior to implementation (either in absolute terms or relative to alternative options). Such predictive tools offer the potential to get things right first time and guide decision-making to minimise the risk of unnecessary failures.

One option is to pilot approaches on a small scale. However, when the aim of an intervention is to effect behaviour change and subsequent ecological outcomes, detectable change can take a long time to occur. Even in situations where a change can be detected, it can be difficult to control for other possible drivers of that change or to persuade donors to fund the additional monitoring necessary to do so (Saterson et al., 2004). Yet the alternative, predicting the future response of those targeted by conservation programmes, is rarely considered, with the result that expert judgement and experience are often relied upon (Fazey et al., 2004; Pullin and Knight, 2005; Cook et al., 2010). Such approaches are often flawed or based on insufficient evidence, and so may lead to inferior outcomes, particularly for the complex contexts typically encountered in conservation.

In this paper, we employ a simple alternative, scenario-based interviewing, that overcomes the shortcomings of such approaches by providing evidence of probable responses to a range of possible interventions or policy changes prior to their implementation. Although scenario-based approaches have often been used in environmental sciences to predict changes under conceivable futures (Alcamo, 2001), their use to date in conservation has so far been limited (see Cinner et al., 2009 for an exception to this). Yet, by limiting the length of time and changes considered within each scenario, scenario-based approaches can be used to control for contextual complexity to produce meaningful predictions of behaviour (Gordon, 1992), making them highly suitable for predicting conservation outcomes under different policy or intervention conditions.

As scenarios are presented in the form of qualitative narratives, they can be easily understood by respondents, which enable them to be used to examine behaviour in contexts that might be more difficult to investigate using alternative methods. Discussing the future in this way provides valuable insight into not only *how* people are likely to respond to the scenarios presented, but also the reasons *why* they might respond that way. It can also serve to help minimise the risks presented by heterogeneity amongst the target populations for conservation interventions, or by exogenous changes such as external market fluctuations. Accounting for such complexity is one of the principal challenges facing conservation; something that integrated conservation and development projects are often said to have failed to do (Blom et al., 2010; McShane and Newby, 2004; Waylen et al., 2012). In part, this is because conservation often operates within highly complex socio-ecological systems in which relationships between society and natural systems are dynamic and multi-scale (Berkes, 2004). Even at the site level, heterogeneity within target populations may be high (Chan et al., 2007; Waylen et al., 2013). Scenario-based approaches enable the response to conservation interventions to be tested for different agents and, hence, the extent of homogeneity of response to be estimated for a target group.

Such qualitative methods are not without limitations however. For example, the ability of respondents to accurately forecast their actions reduces as scenarios become more complicated. There is also a possibility of strategic responses (Carson and Groves, 2007), particularly in situations in which respondents may prefer the implementation of one particular scenario over another, or social desirability bias, whereby responses may be influenced by the desire to conform to social norms and be viewed favourably by others (Fisher, 1993). Although such limitations are impossible to negate entirely, careful follow up questioning and triangulation of responses can do much to improve the external validity of results.

Here, we use scenario-based interviews to examine the potential outcomes of different approaches to changing incentives within Keo Seima Wildlife Sanctuary, a protected area in eastern Cambodia. We do this through an analysis of the stated responses of smallholder farmers from several villages within the project area to seven future scenarios, which include exogenous changes to the sale price of cassava (the dominant agricultural commodity in the area) and different intervention options aimed at reducing deforestation at the site (increased enforcement effort, communal and individual conditional payments and a village fund for infrastructural development). For each scenario, interview respondents were asked how their land use and livelihood practices might change and, hence, the responses given provide an indication of the expected variation in farmer reactions to the intervention options under consideration at the study site. Within this methodological framework, we investigate the predicted effectiveness of each option for incentivising reductions in forest clearance and compare this against the response to exogenous changes in the price of cassava. By analysing responses at the household level but within three distinct livelihood zones, we examine the effect of economic well-being and livelihood strategy on the responses given to each scenario. In this way, we seek to identify, in the context of our case study, which intervention would result in the greatest reduction in household deforestation and whether opportunities exist to target interventions towards the livelihood zones with households most likely to respond positively.

2. The Keo Seima Wildlife Sanctuary REDD + demonstration project

Keo Seima Wildlife Sanctuary (formerly Seima Protection Forest) is a protected area located in eastern Cambodia and covers an area of 2927 km^2 consisting of a complex mosaic of forest types that is rich in biodiversity (Fig. 1; Evans et al., 2012). Management of the PA is split into a core protection zone and outside buffer areas. Since 2002, the site has been managed by the Cambodian government, with technical and financial assistance provided by the Wildlife Conservation Society (WCS), and has been designated as one of two national REDD + demonstration sites since 2010.

The PA is characterised into three livelihood zones in which different livelihood activities dominate: a cash crop zone, a lowland paddy zone and an upland zone. These zones reflect the major inter-community heterogeneity with respect to bio-physical characteristics, institutional framing, opportunity costs of stopping deforestation and economic well-being. As such, the majority of variation in clearance behaviour is expected to be represented by these zones. The cash crop zone is characterised by easy road access and mature cash crop markets (predominantly cashew and cassava, with some rubber) and is currently experiencing the highest rate of land conversion (WCS, 2013). The lowland paddy zone is located in the most remote part of the site. Access to this area is difficult (particularly during the wet season) and the dominant livelihood strategy is centred on the cultivation of paddy rice, supported by liquid resin collection from native dipterocarp trees. The upland zone is also located further from market centres, although access is largely better than for the paddy zone. In this zone, households cultivate a greater diversity of crops, including upland rice varieties, vegetables and maize, and have recently made the transition towards commercial production of cassava and cashew. It has previously been shown that economic well-being as measured by the basic necessity score, a participatory poverty score calculated as a weighted proportion of a list of assets and services that a household owns or has access to (Davies and Smith, 1998), varies between the three livelihood zones
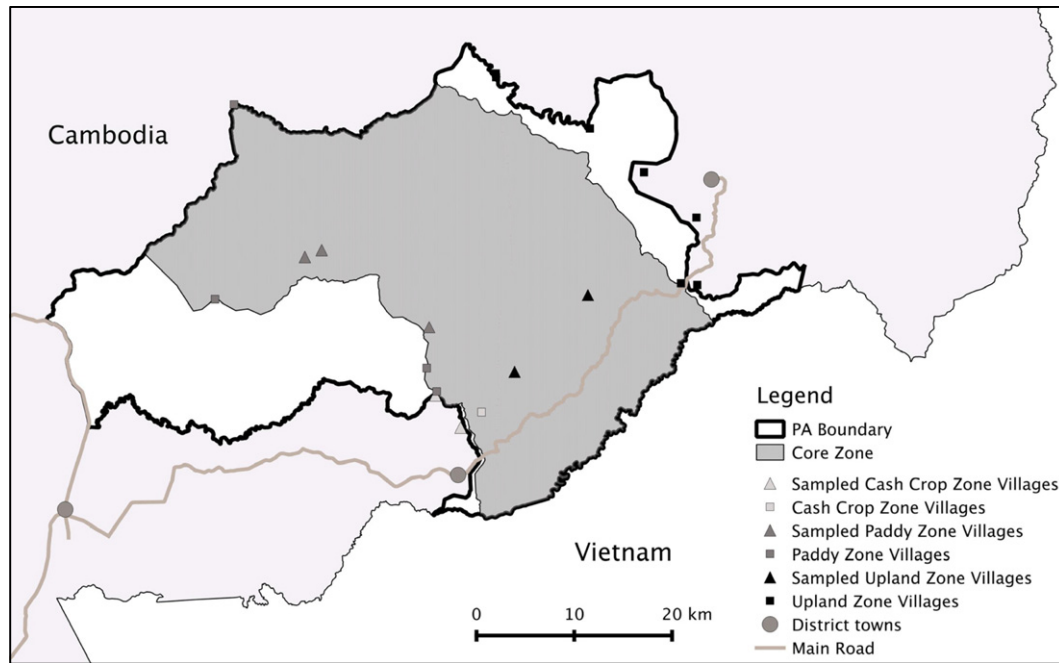
Fig. 1. Map of the site showing sampled villages in the three livelihood zones.

(Travers and Evans, 2013), with households in the cash crop zone better off on average than households from villages in the other two zones. Within each zone, heterogeneity in poverty score at the household level is high.

Although, household livelihoods within the project area have traditionally been based on subsistence agriculture and the collection of forest products (Evans et al., 2003), increasingly farmers are turning towards the production of cash crops, such as cassava and cashew, and encroaching further into the protected area (Travers et al., 2015). Immigration of households seeking land from neighbouring provinces has helped to drive expansion of agricultural land and fuel encroachment (Milne, 2013; Travers et al., 2015). While these two processes are helping to drive deforestation within the proposed REDD + project area, the rate and extent of change vary between villages.

A programme of participatory tenure reform is currently underway or complete in 15 of the 20 villages participating in the REDD + project (A. Diment, *pers. comm*.). Under this process, communal land title is granted to each officially recognised indigenous community, with land inside village boundaries divided into different use areas. Land use inside the communal title is governed by a set of rules designed to protect customary practices and ensure long-term sustainable use of communal land. Clearance of forest is only permitted inside designated community areas. Hence, clearance outside the titled area is illegal and subject to enforcement by PA authorities. However, arrests are only made when offenders are caught in the act of clearing so detection rates are low and vary throughout the landscape. Clearance inside community areas is governed by village institutions.

At the time that data collection for this study took place, five indigenous communities living within the boundaries of the protected area had received official communal land title. Assistance for this process was prioritised in the most accessible villages subject to both high immigration and increasing commercialisation of agriculture because land and forest resources were judged to be under the greatest threat in these villages. This has added to the institutional complexity across the study site, as different villages are now at various points along the tenure reform process. In theory, the areas granted to indigenous communities in recognition of their customary rights should reduce pressure on the forest outside community boundaries but the reality has so far been very different, with clearance rates high both inside and outside titled areas (Travers et al., 2015). One of the principal aims of activities undertaken as part of the REDD + project will be to incentivise communities to restrict clearance in areas designated to community use through the tenure reform process.

3. Methods

3.1. Survey design

All households surveyed as part of this study were randomly selected from a list of households that had previously participated in a wider household survey conducted in each of the study villages. Only household heads were interviewed, with an alternative household selected if a selected household head was unavailable at the time of the survey. This meant it was possible to stratify each household by two variables: poverty score and livelihood zone. Sampling was spread equally across poverty score terciles, which were derived for the whole survey area, and the three livelihood zones, such that an equal proportion of households from the three poverty score terciles were interviewed for each zone. In total, 45 households were interviewed: five households for each poverty score tercile in each of the three livelihood zones. For each livelihood zone, two or three villages were selected so as to cover the full range of conditions found in villages within each zone. Two villages were selected in both the upland (n = 7 and 8) and cash crop (n = 9 and 6) zones and three villages in the paddy zone (n = 4, 4 and 7). The number of households sampled in each village varied with the availability of household heads from each of the three poverty terciles.

Interviews were semi-structured, with respondents presented with a baseline business as usual scenario and a further six scenarios in which one aspect of future conditions was changed. Scenarios were presented sequentially, with respondents asked to explain how their agricultural and other livelihood activities would change over a five year period. Follow-up questions were asked to explore responses in greater detail and to triangulate between responses to different scenarios.

As the research involved human participants and centred on illegal behaviour, verbal informed consent was received from all respondents. Land-use is a potentially sensitive issue in Cambodian protected areas

and so respondents were assured that all data collected would be confidential and all data were anonymised before being shared with WCS. In order to check for errors, a subsample of responses from two villages was validated by comparing landholdings reported during the scenario interviews with those reported in Travers et al. (2015), with all responses comparing favourably.

The study was reviewed and approved under Imperial College London's procedures for research ethics approval.

3.2. Scenarios

The scenarios presented to respondents were developed to represent different intervention options under consideration to reduce smallholder land clearance at the site. Consequently, the parameters selected for each scenario were chosen to reflect the most likely option for that scenario at the time the fieldwork was undertaken (March 2013). These scenarios were piloted in four interviews to ensure that they were understandable and credible to respondents. Hypotheses regarding the expected response to individual scenarios relative to a baseline business as usual scenario or to scenarios representing other institutional changes were developed from the authors' prior understanding of the site and the behaviour of resident smallholder farmers. This enabled *a priori* expectations to be assessed against predicted behaviour.

3.2.1. Baseline business as usual scenario

In this scenario, it was explained that current conditions or trends would stay constant over the next five years. All average prices would remain at a stable level, although some small variation could be expected between years. Law enforcement effort would remain constant but, in cases where indigenous land title had yet to be granted, tenure reforms would progress as currently planned. As such, respondents were asked to predict their expected clearance under business as usual institutional arrangements.

3.2.2. Performance payments

In these three scenarios, respondents were offered the option of receiving an annual payment of $200, which equates to approximately 10% of average household earnings, in return for agreeing not to clear any additional land, including inside areas designated for use under communal land title. Payments were set at $200 as this was felt to be representative of the likely sum offered in the future as part of the REDD + project (T. Evans, *pers. comm.*). In the first of these scenarios, payments were to be made on an individual basis and were dependent solely on the compliance of the household interviewed. In the second scenario, payments would be made based on the behaviour of groups of ten individual households from within the same neighbourhood as the respondent household. Each household would receive $200 if all households in the group chose not to clear any additional land, otherwise they would receive nothing. In the third of these scenarios, $200 would be paid into a village level development fund to support infrastructural development or other development projects identified by the community and would again be dependent on the collective behaviour of groups of ten households from the same neighbourhood. It was expected that collectively conditional performance payments would perform better than individual payments because individuals would be less willing to clear if that meant that others in their village would lose out.

Hypothesis H1. *The offer of performance payments will reduce predicted forest clearance relative to a) the business as usual baseline, and b) the increased enforcement effort scenario (see next scenario).*

Hypothesis H2. *The two collectively conditional performance payments will reduce predicted forest clearance more than payments conditional only on individual compliance, but the type of collective payment offered will not make a difference to land expansion.*

3.2.3. Increased enforcement effort

Unlike the rate of successful prosecution and the subsequent severity of sentences, the effectiveness of law enforcement patrols in detecting illegal clearance in under the control of conservation managers. In the increased enforcement effort scenario, respondents were told that enforcement effort within the study site would be doubled, such that it would be twice as likely that illegal land clearance would be detected. The likelihood of prosecution once caught was unaffected. This additional enforcement activity would be restricted to conservation areas, i.e. clearance inside titled areas designated for communal agricultural use would not be subject to increased law enforcement as these areas are subject to community management.

Hypothesis H3. *Doubling the probability of detection will decrease predicted forest clearance relative to the business as usual baseline.*

3.2.4. Cassava prices

For these two scenarios, respondents were asked to imagine that the price of cassava halved or doubled over the next five years, with some small yearly variation. Cassava has quickly become the dominant commercial crop grown in most areas of the study site and the price at which farmers are able to sell this crop is of particular importance in determining future land use (H. Travers, *pers. obs.*). However, the cassava market in the project area is imperfect and prices can be volatile. These two scenarios were included to explore the effect that a consistent increase or decrease in average cassava prices would have on future forest clearance and to compare the effect of such changes against those predicted to result from conservation interventions.

Hypothesis H4. *Doubling the price of cassava will increase predicted forest clearance relative to the business as usual baseline.*

Hypothesis H5. *Halving the price of cassava will decrease predicted forest clearance relative to the business as usual baseline.*

3.3. Analysis

Responses to the six scenarios were compared against those to the baseline business as usual scenario. Responses were then coded into different categories depending on their likely impact on forest cover. In certain cases, in which direct changes in clearance behaviour were not described, coding was based on existing understanding and knowledge of land use practices within the study area. For example, where respondents intended to buy land already in use, this was coded as a resultant increase in forest clearance as it is common practice for individuals to clear forest specifically for sale or to sell land within village boundaries but subsequently clear additional forest to compensate for the loss (Milne, 2013). In both instances, the act of buying land fuels additional indirect clearance. Where the conditions presented within a scenario were contingent on the behaviour of others, interview respondents were asked to describe their response to the scenario based on whether others in their group cleared. Responses were then coded as conditional or unconditional depending on whether they were contingent on the behaviour of others or not.

Two Bayesian hierarchical ordered logistic regression models were constructed to analyse the effect of the different scenarios considered on household land clearance. Each model used 'individual' as a grouping factor to account for the pseudo-replication introduced through survey participants providing responses to multiple scenarios. Village was not included as a grouping factor as spatial and institutional variation were captured by including livelihood zone as a predictor variable. The first of the two models analysed conditional responses (those dependent on the reciprocation of others) and the second unconditional responses (those independent of reciprocation). In each case, the response variable could take one of three states: reduce clearance, no change or increase clearance relative to the baseline business as usual

scenario. Two predictor variables were included in the models: a response level variable representing the scenario responded to and an individual level variable for the livelihood zone in which each respondent lived. Other household socio-demographic predictors were not included in the final models presented in Section 4 because they were not found to be significantly associated with behavioural responses (for details see Supplementary materials; Table A.1).

All analysis was conducted using the package rstan, version 2.8.0 (Stan Development Team, 2015a), in R, version 3.2.2 (R Core Team, 2015). Following the Stan reference manual (Stan Development Team, 2015b), weakly informative half-Cauchy prior distributions (mean = 0, std. dev. = 5) were assigned to predictor standard errors and an uninformative LKJ prior (shape factor = 1) was assigned to the covariance matrix. Gelman-Rubin statistics with values ≤ 1.01 were taken to indicate adequate convergence. Four chains were analysed, with 1000 warm up iterations and a further 4000 sample iterations for each chain. Credible intervals for probability estimates were found at the 95% level by calculating the probability distribution of each response state occurring using the estimated parameter values for each of the 16,000 post-warm up runs.

4. Results

Under the baseline business as usual scenario, 82% of respondents reported that they would continue to increase their agricultural land over the next five years, while the remaining 18% stated that they had no intention of expanding their land. This illustrates the high level of smallholder forest clearance at the site. The coded responses of each household showed significant variation between scenarios, ranging from a large increase in the rate of forest clearance under increased cassava prices to a potentially large decrease under collective payments or a village development fund. Overall, however, a high proportion of respondents reported that their behaviour would be unaffected by the conditions presented. This proportion was particularly high for both the enforcement and individual payment scenarios, for which only 11% of respondents reported that they would change their behaviour relative to business as usual. The results of the two regression models confirm many of the observational results above (Fig. 2).

4.1. Options for benefit sharing

The two collective payment scenarios performed significantly better than individually contracted payments. Provided others in the group reciprocated, the probability of a household reducing clearance relative to the baseline scenario was 0.73 (95%CI: 0.15–1) for the collective payments scenario and 0.40 for the village fund scenario (95%CI: 0.05–0.84), but only 0.02 (95%CI: 0.00–0.09) for the individual payment scenario (Fig. 2). The probability that the reduction in clearance was higher than the individual payment was 0.9998 for the collective payment scenario and 0.9979 for the village fund. However, this effect was only observed for conditional responses. When unconditional responses were considered, the probability that clearance was lower for the collective payment and village fund scenarios than for the individual payment was only 0.49 and 0.79 respectively. This illustrates the considerable importance of collective action if group level incentives are to be effective. As such, there is strong support for Hypothesis H1a, plus strong support for Hypothesis H2 with regard to collective payments and weak support with regard the village fund, but only when reciprocal behaviour is considered.

These results show that the two collectively conditional performance payments had the potential to be the most effective benefit sharing options at reducing forest clearance. Crucially, however, this reduction was dependent on the high proportion of respondents who stated that their response was conditional on the cooperation of others. This group was evenly split into two categories: those households who would only stop clearing provided that most or all others in their group reciprocated and those who would only clear if most or all others in their group cleared also. Consequently, while both scenarios potentially offer a significant reduction in clearance, there is a risk that compliance would be undermined: first by the minority of respondents who rejected the payment outright and subsequently by those respondents who would only cooperate if everyone else did likewise.

Responses to the individual payments scenario were similarly nuanced. While the majority of respondents rejected the offer of $200, the reasons for doing so varied. For many of the respondents, the payment offered was simply insufficient to compensate for the opportunity costs of halting agricultural expansion. Other respondents raised the concern that if they did not clear any more land, their land currently in use would gradually lose fertility and they had insufficient land to rotate cultivation. In these cases, some respondents reported that they would be happy to comply with the conditions of the payment once they had secured sufficient land. In other cases, however, respondents rejected the payment conditions even though the projected earnings of the land they proposed to clear (based on current earnings from the land they held already) were lower than the payment offered. For these households, the reasons for clearing related less to the potential income from the land but rather in securing land for their family's future. Concerns were frequently raised that, unless cleared, the land
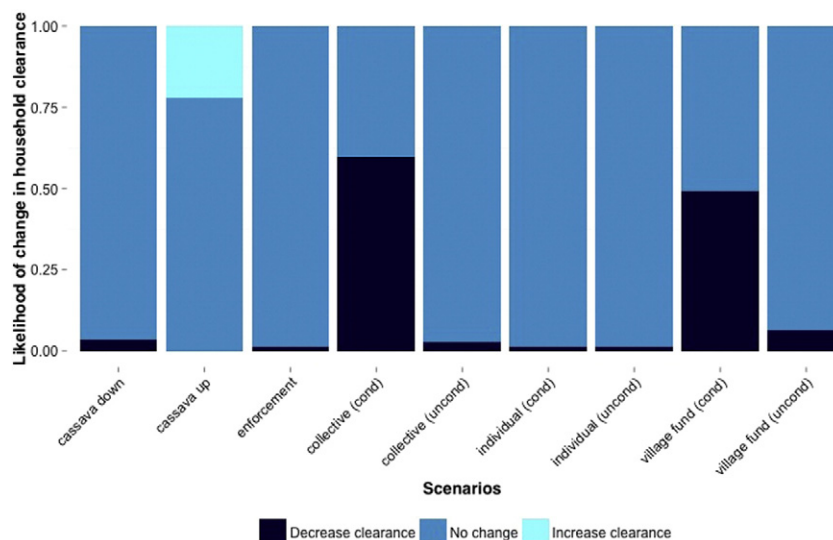

Fig. 2. Response predicted by the two regression models of conditional and unconditional behaviour averaged across the three livelihood zones.

was vulnerable to seizure by outside interests, a significant issue across Cambodia. A similar concern related to whether sufficient land would be available when their children married. In these cases, the opportunity cost of not clearing related less to the potential income that could be generated than to perceived failures in the long-term management of the land titling process.

4.2. Enforcement vs benefit sharing

One of the decisions facing PA authorities in Seima is how best to invest REDD + revenues to reduce forest clearance. To this end, we compared investment in the most effective benefit sharing option, collective payments, with investment in additional enforcement effort. However, doubling the detection rate for illegal clearance had only a 0.02 (95%CI: 0.00–0.08) probability of reducing clearance relative to the baseline estimated (Fig. 2). This provides no support for Hypothesis H3 that increasing the rate of detection would reduce predicted forest clearance. Similarly, assuming that cooperation is reciprocated amongst groups under the collective payment scenario, increased enforcement effort was found to be a poor alternative to benefit sharing (the probability that clearance would be reduced more under collective payments was 0.9996), providing strong support for Hypothesis H1b.

One of the reasons behind the lack of effectiveness of the enforcement scenario lies in the recent land tenure reforms that have been implemented throughout the study area. In all but one of the villages sampled, indigenous communal land title has been granted or is in the process of being applied for. Consequently, land has been identified for future expansion of agricultural activities in each village. As such, clearance on this land is not subject to law enforcement by protected area staff, but governed by community land use rules drawn up by the overseeing village committee. Interview respondents were therefore able to claim that they would be unaffected by increased law enforcement effort as none of their proposed expansion would encroach on conservation areas.

4.3. Heterogeneity of response

Understanding how responses to different intervention scenarios vary spatially and between households can help PA authorities to identify opportunities for targeting interventions in specific areas or at different groups. In this instance, separating responses by livelihood zone revealed significant potential differences in behaviour. The greatest difference resulted from over 50% of respondents in the cash crop zone reporting no expansion under business as usual conditions, either because they felt that they already had sufficient land, there was no land available to be cleared or they did not want to clear land illegally.

Under the two collective performance payment scenarios, reductions in household clearance were significantly affected by livelihood zone (Fig. 3). For collective payments, the probability of reductions in clearance was greater in 99.7% of runs in the upland zone and in 86.8% of runs in the paddy zone than in the cash crop zone. For the village fund, the probability of reductions was greater in 99.1% of runs in the upland zone and in 97.7% of runs in the paddy zone than in the cash crop zone. This strongly suggests that implementing performance payments in the paddy and upland zones would lead to greater reductions in overall forest clearance than if they were implemented in the cash crop zone.

In contrast to separating responses by livelihood zone, very little difference was apparent between households with different socio-demographic characteristics, suggesting that differences between the conditions in the three livelihood zones may have greater influence on decision-making than individual household heterogeneity.

4.4. Conservation interventions vs exogenous price changes

While the rapid commercialisation of agriculture has resulted in significantly increased household incomes in areas that have benefited from it, the rate of change threatens to swamp interventions aimed at controlling the expansion of agricultural land. It is therefore informative to compare responses under the exogenous price changes scenarios and the most effective conservation intervention, collective payments.

For the scenario in which the sale price of cassava doubled, the average predicted probability that households would increase clearance relative to business as usual was 0.22 (95%CI: 0.01–0.76), providing some support for Hypothesis H4 (Fig. 2). Not only does this illustrate the significant impact that this one crop has on the landscape, but it also highlights the risk that the positive effects of investment in benefit sharing could be undermined by exogenous changes. However, a closer look at how responses were predicted to vary between the three livelihood zones reveals that a meaningful increase in household clearance was only found for households in the cash crop zone (probability of increase = 0.603 for the cash crop zone, 0.14 for the paddy zone and 0.11 for the upland zone; Fig. 3). This suggests that price rises for cassava would be unlikely to affect benefit sharing interventions in the paddy and upland zones, where they are predicted to be most effective, but would probably result in a significant increase in clearance in the cash
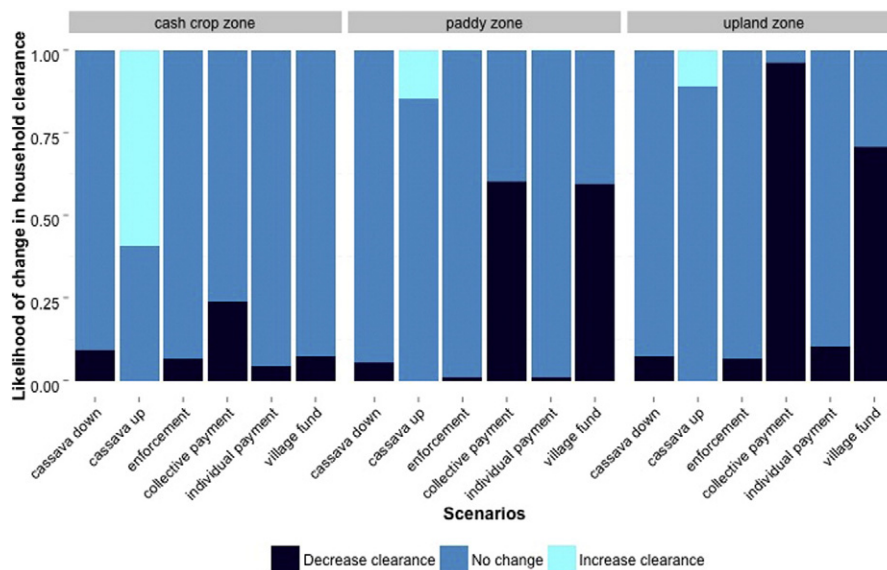

Fig. 3. Response predicted by the regression model of behaviour conditional on the reciprocation of others displayed by livelihood zone.

crop zone that might be difficult to address with any of the interventions considered in this study.

In contrast, the probability that the scenario in which the cassava price halved resulted lower clearance relative to business as usual was only 0.07 (95%CI: 0.00–0.21), providing very little support for Hypothesis H5 (Fig. 2). While the exogenous price reduction did result in marginally greater reductions in clearance than both the enforcement and individual payment scenarios, responses to collective performance payments still led to significantly higher reductions in clearance than that resulting from price reductions. The majority of respondents also reported that their income would suffer under cassava price reductions, as alternative livelihood options available to them are less profitable. This suggests that households may become locked into cassava farming with the result that declining prices would not be sufficient to reduce forest clearance.

5. Discussion

5.1. Intervention effectiveness

Our results show that there is reason for PA authorities at the study site to be hopeful that judicious investment of REDD + revenues can dramatically reduce the number of smallholder households involved in agricultural expansion, and in turn reduce clearance of biodiversity rich forest. Both of the collective benefit sharing options resulted in significant predicted reductions in agricultural expansion in comparison to a continuation of business as usual. The caveat to this, however, is that reductions were observed for the conditional behaviour model. This result is in common with other studies that have stressed the importance of creating a strong sense of collective action in conditional payments (Kerr et al., 2014; Reynolds, 2012). This could be supported by undertaking a participatory approach to designing the distribution of payments, which has also been found to increase collective action (Gebara, 2013).

Our results also demonstrate the risk of investing in activities that may prove ineffective at changing the incentives for households to reduce expansion. Neither doubling current levels of law enforcement, nor offering payments to individual households had any meaningful effect on reducing overall clearance and both performed poorly in comparison to the two collective benefit sharing scenarios. With respect to enforcement, the results confirm previous studies that suggest that the effectiveness of law enforcement in Cambodia is weak in situations where expected penalties are low (Claridge et al., 2005; Travers et al., 2011). This is unsurprising in a country such as Cambodia, where the "rule of law" is generally weak and corruption levels high (Kheang, 2006). It is possible, however, that the effectiveness of increasing law enforcement effort may have been underestimated, as respondents were able to claim that they planned all future clearance inside community boundaries. Compliance with community boundaries is far from perfect even amongst households with less than five hectares (i.e. those households with less than their allocation for land within community titled areas; Travers et al., 2015). Hence, respondents may have been over-reporting their intention to clear in titled areas. The result for individual incentive payments is important because these have been suggested to be more effective than collective payments in other contexts (e.g. Narloch et al., 2012). From this previous work it might easily have been assumed that individual payments are a viable or superior alternative to collective payments for Seima, yet this has been shown not to be the case.

Finally, the results of the two scenarios in which the price of cassava was changed offer some perspective on the risk of assuming the continuation of business as usual conditions when planning conservation interventions. Until 2005, cassava made up a negligible proportion of total cultivated area in the study site. Since that time, however, the area of land under cassava cultivation has increased exponentially and many households now only grow cassava (Travers et al., 2015). The unforeseen introduction of a new cash crop has, in just a short space of time, had a dramatic influence on both the landscape and people's livelihoods. This is a salutary lesson in how quickly the context in which conservation interventions are implemented can change. From the observed effects of increasing the price of cassava, it is evident that exogenous changes may bring about differences in future clearance rates in some areas that are comparable to the reductions achieved by planned interventions. This may also have implications for interventions aiming to increase the profitability of cassava, for example through agricultural intensification (Milne et al., 2012), which could result in perverse incentives to clear additional forest.

5.2. Value of predictive approaches

Predictive methods, of which scenario-based interviews are one, enable policy makers and conservation managers to test their understanding of a system and allow them to base decisions on evidence rather than opinion (Addison et al., 2013). In this study, the hypotheses for behaviour change under the various scenarios were developed based on expert opinion (in this case the authors' understanding of site to which they are well acquainted) and were largely supported by the model results. In many ways, this suggests that a good understanding of the drivers of behaviour in a conservation area may be sufficient to anticipate the likely effects of certain interventions but it also highlights the dangers of reliance on expert experience, which is predominantly used in conservation management (Pullin and Knight, 2005). Although individual performance payments were not expected to result in as many households reducing clearance than under collective performance payments, they were expected to perform well in comparison to business as usual.

Through this case study, we have illustrated the value that the application of predictive approaches to conservation, such as scenario interviews, can bring to the design of conservation interventions. Amongst predictive approaches, scenario-based interview are one that lend themselves particularly well to being applied by conservation managers, rather than relying on external technical expertise, as they are straightforward to conduct and can be implemented with considerably lower investment in time and money than a pilot of any of the options considered would have required. In this instance, despite a small sample size and the resultant wide credible intervals on the derived probability estimates, we identified the type of intervention most likely to have the desired impact on behaviour (collective performance payments) and recognised that responses to that intervention are likely to be spatially heterogeneous, as well as identifying potential issues that may prevent successful implementation (the need for collective action and possible increases in the price of cassava) and discounting approaches that might otherwise have been considered credible options. In so doing, we were able to control for a number of complex contextual factors, such as the on-going land tenure reform process and the rapid commercialisation of agricultural practices in the area. The evidence provided through this approach is potentially invaluable for conservation managers as they decide how to deploy limited resources.

Appendix A. Supplementary data

Supplementary data to this article can be found online at doi:10.1016/j.biocon.2016.10.040.

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