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Measuring impacts of conservation interventions on human well-being and the environment in Northern Cambodia

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About this report

3ie accepted the final version of the report, *Measuring impacts of conservation interventions on human well-being and the environment in Northern Cambodia*, as partial fulfilment of requirements under grant DPW1.1045 awarded through Development Priorities Window 1. The report is technically sound and 3ie is making it available to the public in this final report version as it was received. No further work has been done. This report has not been professionally copy-edited.

The 3ie technical quality assurance team for this report comprises Rosaine Yegbemey, Deeksha Ahuja, Sayak Khatua, Marie Gaarder, an anonymous external impact evaluation design expert reviewer and an anonymous external sector expert reviewer, with overall technical supervision by Marie Gaarder. The 3ie editorial production team for this report comprises Anushruti Ganguly and Akarsh Gupta, with David de Ferranti providing overall editorial supervision.

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Measuring impacts of conservation interventions on human well-being and the environment in Northern Cambodia

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Summary

Protected areas (PAs) are one of the most commonly implemented approaches to conserving threatened habitats and species, having been the cornerstone of conservation policy since the late nineteenth century. However, the potential for PAs to have detrimental impacts on local people has been widely documented. More recent policies, such as payments for environmental services (PES), seek to incentivise environmental outcomes through the provision of conditional benefits for local people. However, this has rarely been tested empirically.

The evaluation described in this report focused on the Northern Plains landscape of Cambodia, an area containing globally important populations of threatened species as well as several local communities. The landscape contains three protected areas managed by the Cambodian Ministry of Environment, with technical and financial support provided by the Wildlife Conservation Society (WCS) since 2005. In addition to interventions primarily associated with protected area management, such as ranger patrols and biodiversity monitoring, WCS has implemented three PES interventions aimed at complementing PA management. These consist of a direct payments scheme conditional upon protection of nests of globally threatened birds; a community-managed ecotourism intervention that provides conditional support if villagers engage in bird and habitat protection; and Ibis Rice, a programme that provides farmers with premium prices for rice if households comply with pro-environmental commitments.

The overall aim of this evaluation was to quantify the environmental and human wellbeing impacts of the PAs and PES interventions in the Northern Plains landscape. This report focuses on the following research questions:

1. Do PAs and PES interventions protect forests in comparison with controls?
2. Do PAs have positive or negative impacts on human wellbeing?
3. Do PES interventions deliver additional benefits to human wellbeing in comparison with controls?
4. Do the different environmental conservation interventions being implemented at the two PAs have different impacts on different livelihood strategies, focusing on rice farmers, growers of cash crops and non-timber forest product collectors?
5. Do households reduce land-clearing behaviours as a result of the payment interventions?

The evaluation built on a nine-year monitoring programme, initiated in 2008, to assess the human impact of conservation interventions in the Northern Plains. This followed a quasi-experimental evaluation design, in which a socio-economic household survey has been conducted with the same panel of households every three years (2008, 2011, 2014 and 2017) in control and treatment villages. The results of the evaluation showed that households living inside the PAs are no worse off relative to households in similar villages outside the PAs for any of the indicators considered, and have improved their economic status at a greater rate than matched control households over the period from 2008 to 2017. No impact of PAs, either positive or negative, was found for total rice harvest or household food security. For the three PES interventions, participation in the Ibis Rice intervention was found to be positively associated with increased economic status, increased rice harvest and improved household food security in the period from 2014 to 2017. This coincides with a period of significant expansion of the intervention to

include five more of the within-PA villages, as well as a transition to organic certification and subsequent significant growth of the end market for the product. No impact was found for participation in the bird's nest protection intervention, while participation in the ecotourism intervention was found to have a positive association with household food security for the period from 2014 to 2017.

An analysis of deforestation rates between 2000 and 2018 was carried out for areas surrounding villages within the PAs and matched control villages outside PA boundaries. Deforestation was found to be significantly lower for points surrounding within-PA villages than for matched points in control villages. A further analysis of points surrounding within-PA villages was used to measure the effect of implementation of the Ibis Rice programme. This analysis found little evidence of reduced annual deforestation for villages in which the Ibis Rice programme had been implemented, with the exception of two villages, including the village with the highest level of participation both in terms of the proportion of households that had participated at least once in the programme and the length of the implementation period in the village.

To investigate the impact of the Ibis Rice programme on household behaviour, a randomised control trial (RCT) was conducted during the 2018 growing season. The target group was households that had expressed a desire to participate in the Ibis Rice programme. Although caveated by the small sample size, the results of the RCT showed that households that participated in the Ibis Rice programme were four times less likely to have cleared than households in the control arm of the trial.

The findings of the evaluation are broadly positive for the interventions assessed, showing that management of the PAs has had a positive impact on households living inside PA boundaries and has significantly reduced deforestation relative to matched control villages. Similarly, household wellbeing was found to be significantly higher for participants of the Ibis Rice programme in comparison to non-participants. This is a particularly encouraging result, as it suggests that the intervention has evolved to a state where households are benefiting through their participation and that these benefits are not just financial but also relate to household food security, a key target of the Sustainable Development Goals. Although deforestation rates were not found to be lower in villages in which the Ibis Rice programme was implemented than non-implementation villages, the RCT found that households participating in Ibis Rice (the treatment group) were significantly less likely to clear forest than those that had expressed willingness to participate in Ibis Rice but were not selected to join it in the 2018 growing season (the control group).

Key recommendations made to implementers of the Ibis Rice programme include:

i) Develop ways to integrate poorer farmers into programme

Poor farmers, often with insufficient land to produce a surplus of rice, represent approximately one third of households across the landscape. Consequently, identifying routes though which participation in the Ibis Rice programme may be increased among poorer farmers is vital for maximising uptake. Potential options include a commitment to buy all varieties of rice grown in participating villages, production exchanges within villages and formalisation of land use plans to ensure legal mechanisms exist for poor or newly-formed households to obtain land.

ii) Increase farmer uptake of the programme in existing villages

Although Ibis Rice was found to reduce clearance among participating farmers, minimal effects were observed in total deforestation rates surrounding participating villages. It is therefore recommended that the programme focus efforts on increasing participation within existing villages. Such efforts should focus on those villages neighbouring areas of the greatest conservation importance. This should then enable the benefits of individual-level reductions in clearance to translate to overall deforestation rates in the vicinity of the participating villages.

iii) Adopt an iterative approach to adaptive management that incorporates randomised control trials to incrementally increase effectiveness.

It is recommended that the programme adopt a new approach to adaptive management to test potential improvements to the existing Ibis Rice model. Such efforts should focus on increasing participation among farmers and maximising behaviour change of participants. An iterative process of randomised trials that test potential improvements against the current model offers a robust route for adopting such an approach.

Contents

List of figures and tables

Acronyms

BNS	Basic necessity survey
CI	Credible interval
GFC	Global Forest Change
IRCC	Ibis Rice Conservation Company
PA	Protected area
PES	Payments for environmental services
RCT	Randomised control trial
SMP	Sansom Mlup Prey
SVC	Sam Veasna Center
ToC	Theory of change
WCS	Wildlife Conservation Society

1. Introduction

Human dominance of the earth is leading to unprecedented changes in the world's natural ecosystems and climate, causing increasing use and scarcity of environmental resources, including land, tropical forests and biodiversity. In response, the global community has approved a series of international agreements and targets (Convention on Biological Diversity 2010), and invested an estimated $21.5bn for biodiversity conservation between 2001 and 2008 (Waldron *et al*. 2013). Despite these investments there is relatively little evidence about whether conservation interventions work, why they work, and under what circumstances.

A critical question for environmental conservation policy is whether interventions incur net costs or provide net benefits to the local people who are the most directly affected. There is now widespread acceptance that environmental conservation policies should, at the very least, do no harm, and where possible should contribute to poverty alleviation (Convention on Biological Diversity 2010). Protected areas (PAs) are one of the most widely adopted policies, covering >15% of the terrestrial land surface, with a global target of 17% (UNEP-WCMC, IUCN & NGS 2018). The debate around the impacts of PAs has, however, been particularly contentious. Large numbers of case studies document costs PAs have imposed on local people, such as restrictions on agriculture or access to natural resources (West *et al.* 2006). Consequently, newer policies, such as payments for environmental services (PES), which are designed to provide benefits to local people conditional upon achieving an environmental outcome or a change in behaviour, have gained popularity (Engel *et al.* 2008; Sommerville *et al*. 2009; Wunder 2013). It is hypothesized that PES improves human well-being and changes behaviour to enhance conservation outcomes. This hypothesis has rarely been tested with empirical data.

Rigorous impact evaluation methods are widely credited with having transformed development policy by quantifying the contribution that specific interventions make to improvements in human well-being (Datta & Mullainathan 2014) and there have been calls for the adoption of similar methods in environmental policy (e.g. Ferraro & Pattanayak 2006; Agrawal 2014; Puri *et al*. 2016). For PAs, most published studies to date have focused on assessing environmental rather than social outcomes; for example, using impact evaluation methods to show that PAs do indeed protect forests (e.g. Andam *et al.* 2008). Studies that have evaluated the social impacts of PAs are rarer, but increasing in number (e.g. Andam *et al*. 2010; Pulin *et al*. 2013; Naidoo *et al*. 2019). One recent global meta-analysis of studies on 165 PAs found that PAs associated with positive impacts for local people were more likely to have positive outcomes for conservation also (Oldekop *et al.* 2016).

For PES policies, few studies have evaluated the impact of PES on well-being in a developing country (but see Clements & Milner-Gulland 2015; Beauchamp *et al.* 2018b; Pynegar *et al.* 2018). A recent systematic review found that PES programmes may act to both increase household income and reduce deforestation, but that the quality of existing evidence is low (Snilsveit *et al*. 2019). This matches a similar observation made by Börner *et al.* (2017), following a review of existing literature on the effectiveness of PES interventions. In countries, such as Costa Rica and Mexico, where PES programmes have been implemented at a national scale, it is possible to evaluate the impact of PAs and PES independently. Such evaluations have found that the level of protection granted

by PAs can have an impact on how well environmental and social outcomes are balanced (Sims & Alix-Garcia 2017) but that PAs and PES policies may be more effective if implemented in spatially distinct areas (Robalino *et al*. 2015). However, such circumstances are rare and it is important that evaluations are conducted to investigate the impacts of PES programmes in contexts where they are implemented in conjunction with other policies.

Integrated conservation and development programmes (such as PES) are often promoted within environmental policy for their supposed 'win-win' benefits in terms of the protection of biodiversity (SDG 15) and eradication of poverty (SDG 1). However, the prospect of such win-win outcomes is often aspirational and designed to appeal to political considerations. Trade-offs between objectives are often the norm (Börner *et al.* 2017) and current evidence of projects achieving both positive social and environmental benefits is weak (Samii *et al*. 2015). Understanding and quantifying these trade-offs, both in terms of average effects and impacts for different subsets of society or biodiversity, can provide decision-makers with a stronger evidence base when designing environmental conservation interventions.

2. Objectives of the evaluation

2.1 Evaluation aim

The aim of the impact evaluation was to quantify the impact of PAs and PES on environmental and human wellbeing outcomes in the Northern Plains landscape of Cambodia for a panel of intervention and matched control villages and households. This extended the analysis in Clements *et al*. (2014, which covered 2008-2011) and Beauchamp *et al*. (2018b; which covered 2014) by a further three years and increased the sample size to allow for the application of more rigorous evaluation methods, including matching at household level to test for causative effects.

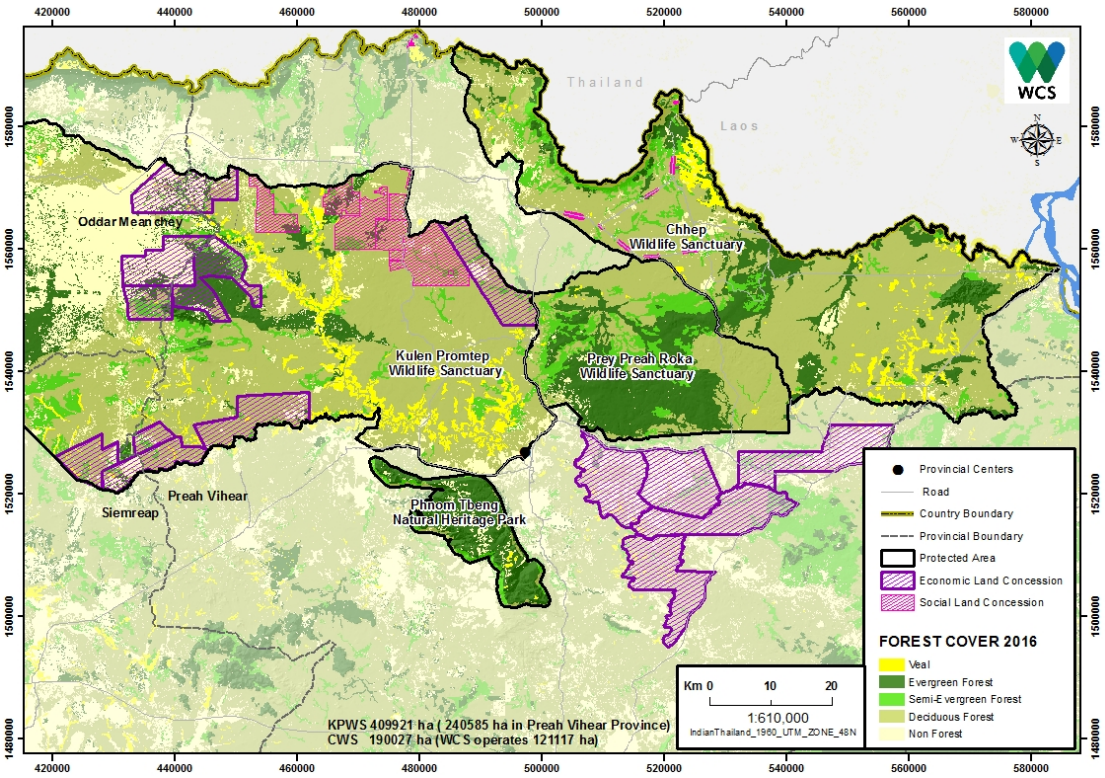
Both environmental and human wellbeing outcomes are of interest to the implementing agencies in this landscape, and to global policymakers who are interested in the extent to which both positive environmental and human well-being outcomes can be attained by a single intervention. Northern Cambodia is an ideal study site because the PA and PES interventions are well understood and data exist to evaluate before-after impacts. Developing a nine-year dataset from the same households should therefore enable specific questions to be asked about the dynamics of livelihood changes and impacts of the interventions on different groups of people. The results of the evaluation therefore have relevance to the debate around the costs and benefits of environmental conservation nationally in Cambodia, in Southeast Asia and globally. The PES interventions in particular have been widely publicised and are seen as best-practice examples both nationally and in the region, hence the results will have significant policy impact both on the government implementing agencies (Ministry of Environment, MoE), other countries and bilateral and multilateral funding agencies.

2.2 Intervention

2.2.1 Overview

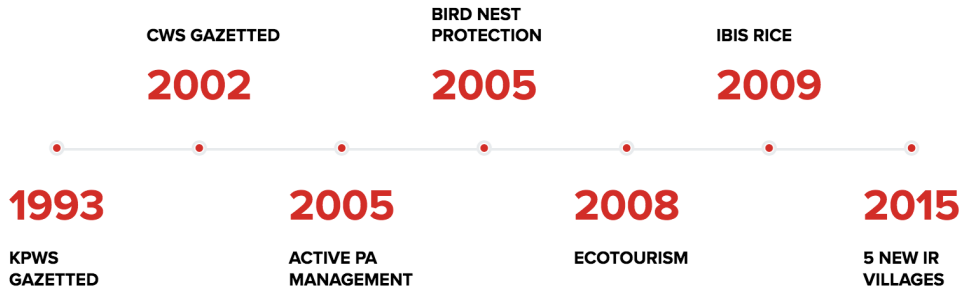
The evaluation focused on two mainstream environmental conservation policies: establishment of PAs and PES in the Northern Plains landscape of Cambodia, one of the largest remaining complexes of the mixed deciduous dipterocarp and lowland evergreen forests that once covered much of mainland Southeast Asia (Fig. 1). Once called the 'Serengeti of Asia', these forests supported one of the greatest aggregations of large mammals and waterbirds outside the African savannah (Wharton 1966), and are still home to an almost complete assemblage of species, albeit at reduced densities. Since 2002, the Wildlife Conservation Society (WCS) has been supporting government and local community partners to develop sustainable conservation models in the landscape, focusing on the three core protected areas, Kulen Promtep (established 1993), Chhep (established 2002) and Prey Preah Rokha (established 2016) Wildlife Sanctuaries. The PAs are now managed at provincial level by the Provincial Department for Environment following the decentralisation of protected area management in 2016. However, wider conservation policy is set at national level by the General Department of Administration of Conservation and Protection within the MoE.

Figure 1: Map of protected areas receiving support from WCS within the Northern Plains landscape (source: WCS).



Prior to 2005, when active management by government first started with support from WCS (Fig. 2), the PAs were paper parks. Although the landscape incorporates three PAs, the evaluation focused only on Kulen Promtep and Chhep Wildlife Sanctuaries as no villages are located inside Prey Preah Rokha Wildlife Sanctuary.

Figure 2: Timeline of key interventions in the Northern Plains landscape.



The two PAs are located in remote forest areas and contain 19 long-established villages that had 1,820 households in 2005. At that time, local people were primarily subsistence farmers, practicing either rain-fed paddy rice or shifting cultivation and were dependent on forest resources as a safety net and for cash income, particularly from the sale of resins from dipterocarp trees. Since then, there has been significant growth in the production of cash crops, such as cashew and cassava, in many upland areas of Cambodia (Travers *et al*. 2015) and a concurrent decline in the importance of resin collection. This has been assisted by improvements in road infrastructure that has seen access become significantly easier for many of the villages inside the PAs (Beauchamp *et al*. 2018b).

Under Cambodian law, local uses of natural resources within PAs are legal, although forest clearance, commercial logging, and hunting or trade in threatened species are illegal. Villages were permitted by PA authorities to expand agriculture to a limited extent within agreed land-use plans. Under the 2008 Protected Area law, which determines the governance of PAs and management responsibilities of MoE, PAs should be zoned into distinct areas within which different levels of natural resource use are permitted. However, these zones, which have been agreed for the Northern Plains PAs at provincial level, have yet to receive final approval from central government. As a result, most farmers do not hold private title over their land, but instead have local approval to claim individual land parcels from village, commune or district officials. This has not stopped land within the PAs becoming increasingly commercialised, further increasing the pressure on intact forest.

There is no national PES policy in Cambodia. Instead, PES programmes have primarily been developed by international NGOs at particular sites, with the consent of the relevant government body. In the Northern Plains, three PES interventions were designed to complement PA management by providing incentives for local communities living within the two PAs to engage in conservation (Clements *et al.* 2010): direct payments conditional upon protection of nests of globally threatened birds; a community-managed ecotourism intervention that provided conditional support if villagers engaged in bird and habitat protection; and providing premium prices for rice if households limited field expansion to within the land-use plans (Ibis Rice). All three interventions are classified as PES following Sommerville *et al.* (2009). The bird nest protection intervention started in 2005, and by 2016 was operating in all within-PA villages. The ecotourism intervention was piloted in one village, and then scaled up in that village and expanded to cover three villages inside the PAs from 2008 onwards.

2.2.2 Ibis Rice

Following recent expansion, Ibis Rice is now the most significant of the three PES interventions that were designed to complement PA management by providing incentives for local communities to engage in conservation (Clements *et al.* 2010). This programme was initiated by WCS in 2008 in two villages as a means of generating incentives for individual households to reduce forest and wetlands clearance and hunting of protected species, by benefiting local people. Crucially, these incentives are created by increasing the profitability of rice production, the principal livelihood activity of smallholder farmers. Since 2008, the programme has been expanded to cover nine villages inside the two PAs. Participation is voluntary, with all households inside participating villages eligible to participate provided they have not previously been found to have broken PA rules. Each participating household signs a conservation agreement in which all of the household's land parcels under cultivation are mapped and the household commits not to expand these parcels or clear additional areas of forest. Compliant households are guaranteed a minimum price for production of Phka Romdoul (a local variant of jasmine rice) provided certain quality standards, including those required for Organic certification, are met. This provides certainty to producers and a 45-65% premium above market prices on the sale of their rice, depending on the quality and moisture content of the rice.

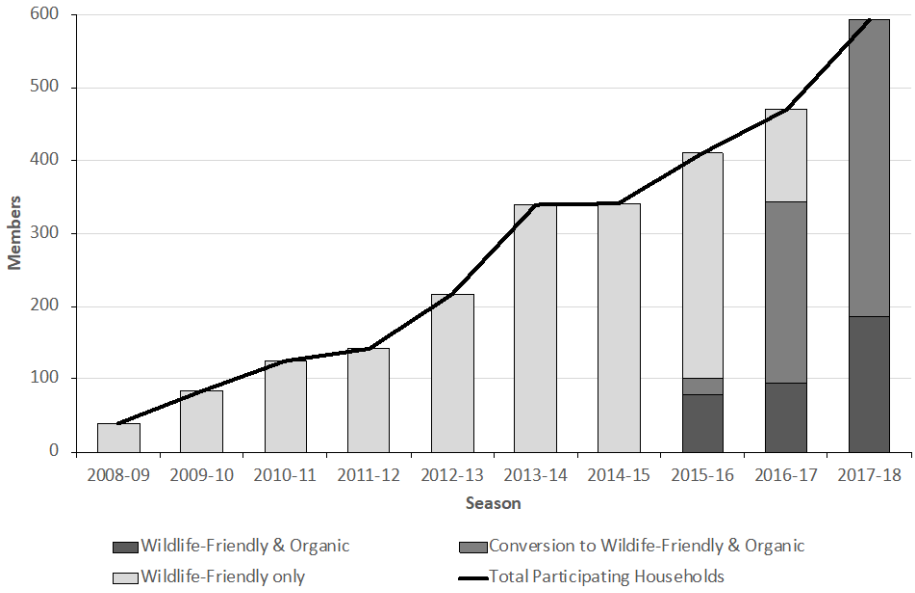
As the Ibis Rice programme is designed to provide positive incentives to farmers to reduce hunting and forest clearance behaviours, the initial challenge was to define what land farmers can use, and where the forest boundary starts. In each participating village, the PA managers and WCS worked with local authorities and farmers to develop village land use plans, through a participatory process over a period of two or three years. These land-use plans established forest management zones and clarified ownership over land and natural resources. Each land use plan was approved by the relevant government authorities and is managed by an elected village committee. It specifically sets out which areas can be used for agriculture and residential land, including expansion into areas that are currently forest. Only households who are compliant with the land use plans are able to benefit from Ibis Rice.

Ibis Rice is led by the Ibis Rice Conservation Company (IRCC), a limited company owned by WCS that is responsible for the purchasing and sale of Ibis Rice. A local NGO partner, also established by WCS, called Sansom Mlup Prey (SMP), works with the farmers, providing extension services and liaising over the purchase of the rice. At the village level, management committees of local farmer associations known as Village Marketing Networks were engaged to promote the programme, ensure that farmers understood the conditions of participation and inform the compliance monitoring process. Initially, Ibis Rice was marketed nationally to supermarkets and upmarket hotels and restaurants under the international 'Wildlife Friendly' certification. In 2014, the programme was awarded Organic certification under European Union and United States Department of Agriculture standards, opening up the opportunity to market Ibis Rice internationally and increase the premium offered to participating farmers. Exports to Europe of Organic-certified rice began in 2016.

Over time, the Ibis Rice programme has grown significantly, initially starting in two villages, and now operating in nine villages across the landscape, with the number of participating farmers increasing from 39 households to approximately 600 over that

period (Fig. 3). At the same time, the purchase of rice from local farmers has grown from 39MT to over 700MT tonnes, with 68% of the rice purchased in 2017 certified as organic.

Figure 3: Participation in the Ibis Rice programme since its inception in 2008.



2.2.3 Previous findings from the Northern Plains

Previous studies conducted by Clements *et al*. (2014), Clements and Milner-Gulland (2015) and Beauchamp *et al*. (2018b) provided initial evidence that household economic wellbeing was higher inside the PAs of the Northern Plains landscape than in similar control villages during both the baseline survey in 2008 and two subsequent surveys up to 2014. Over this period, the average economic wellbeing of surveyed households (both inside and outside the PAs) increased significantly. However, Beauchamp *et al*. (2018b) found that the economic wellbeing of households living outside the PAs increased at a faster rate than household living inside the PA between 2008 and 2014. Households inside the PAs were found to have greater rice production but were similarly food secure as households outside the PAs over the same period. Participants in Ibis Rice improved their economic wellbeing at a faster rate than non-participating households.

With respect to forest loss, Clements and Milner-Gulland (2015) found that deforestation rates reduced significantly up to 2011 after management of the PAs began in 2005/6, whereas deforestation increased in matched control sites outside the PAs. This analysis was extended by Beauchamp et al (2018c) to include a wider area for the period between 2008 and 2013. Deforestation rates were found to be lower in the two managed PAs but not in Boeng Per Wildlife Sanctuary, a paper park not under active management. Within the PAs, villages in which the PES programmes were implemented had significantly lower deforestation up to 2011 than other villages (Clements & Milner-Gulland 2015).

2.3 Monitoring plan of the intervention

2.3.1 Household wellbeing

The evaluation builds upon a long-term research programme into the environmental and social impacts of PAs and PES that was initiated in the Northern Plains in 2008. The design was based upon WCS's experience in the study landscape since 2002, and a

qualitative research phase that investigated the livelihood strategies and perceptions of local communities. This was used to design social assessment methodologies that would capture the salient aspects of local livelihoods and livelihood changes driven by internal and external factors. Examples include reliance upon sale of liquid resins for cash, the transition to semi-mechanized farming and diversification to cash crops. Between 2005 and 2008, landscape-level surveys were used to map out villages, markets, roads and deforestation trends. These variables were used to select matched controls for the intervention villages. Without this prior research, the launch of the impact evaluation programme would have been impossible.

Two phases of the impact evaluation had been completed prior to the evaluation. The first, in 2008-2011, investigated changes in the social and environmental outcomes that could be attributed to the PA and PES interventions, in comparison with appropriate counterfactuals (Clements *et al.* 2010; Clements *et al.* 2013; Clements *et al.* 2014; Clements and Milner-Gulland 2015). The second, in 2011-2014, continued the same methods and also used qualitative methods to assess changes in perceived human well-being (Beauchamp *et al.* 2018a; Beauchamp *et al.* 2018b).

Both phases of the evaluation applied a quasi-experimental panel survey design of 16 villages and approximately 700 households (both intervention and matched controls), using three primary indicators of human well-being outcomes:

1. The Basic Necessities Survey (BNS; Davies and Smith 1998), which incorporates multiple aspects of poverty into a single score for each household in the sample, relative to a locally-derived definition;
2. Annual data on rice harvests, the Cambodian staple food crop;
3. Household food security, measured as the difference between a household's annual rice harvest and its total rice needs for the year.

In addition to the intervention monitoring conducted under previous phases of the impact evaluation, WCS has implemented long-term monitoring of participation in the three PES programmes at the household level, recording data on the years each household participated in the interventions and the financial reward received.

2.3.2 Ibis Rice compliance

Compliance for the Ibis Rice programme is assessed biannually through an integrated monitoring system, implemented by WCS, SMP and the Provincial Department for Environment, that combines information collected by the local protected area authorities, remote sensing monitoring of farmer fields, and information from SMP and local people. There are 14 rules with which Ibis Rice participants must comply. However, only three relate to conservation outcomes: no unapproved clearing of forest, no hunting and no logging. Any household found to have broken these rules is excluded from the programme until they have taken mitigating action (e.g. given up land cleared without approval). Land clearance is assessed through remote sensing analysis and household-level monitoring of agricultural plots. High resolution satellite imagery is ordered for each village in May, with the households responsible for new areas of clearance identified by field teams prior to September each year. Illegal hunting and logging are monitored through monthly ranger reports. This allows compliance to be monitored over time at a household level and ensures that Ibis Rice has access to the information required to support fair and transparent decision-making.

2.4 Theory of Change (ToC)

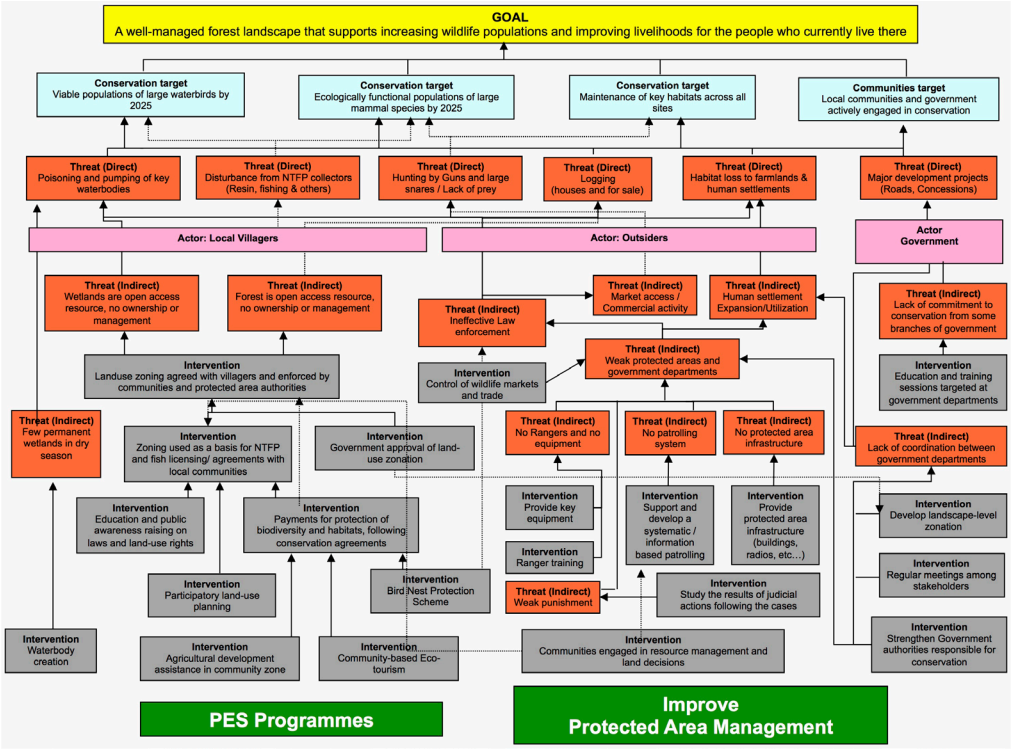
The Northern Plains programme uses the Open Standards for the Practice of Conservation (http://cmp-openstandards.org) to describe the theory of change and the causal pathways underlying the interventions. The Open Standards have been developed since 2002 by the Conservation Measures Partnership, a consortium of international conservation organisations and funders, and can be operationalized using the Miradi software (https://www.miradi.org). The original theory of change for the Northern Plains program was developed during 2003 and 2004 in workshops with government agencies and local village authorities, and has subsequently been refined multiple times.

The conceptual model underlying the entire Northern Plains programme is shown in Fig. 4. The goal of the programme is “A well-managed forest landscape that supports increasing wildlife populations and improving livelihoods for the people who currently live there”. Four high-level targets are used to measure progress at meeting this goal:

1. Recovery of large waterbird populations to viable breeding levels.
2. Recovery of large mammal populations to ecologically functional levels.
3. Maintenance of key habitats across the PAs, including reductions in deforestation.
4. Local communities and governments are actively engaged in conservation.

The threats to achieving these targets are also shown in Fig. 4. Direct threats include poisoning and pumping of waterbodies; habitat loss; human disturbance; hunting; logging and major development projects (including large scale economic land concessions).

Figure 4: Programme theory of change developed for the Northern Plains landscape by WCS.

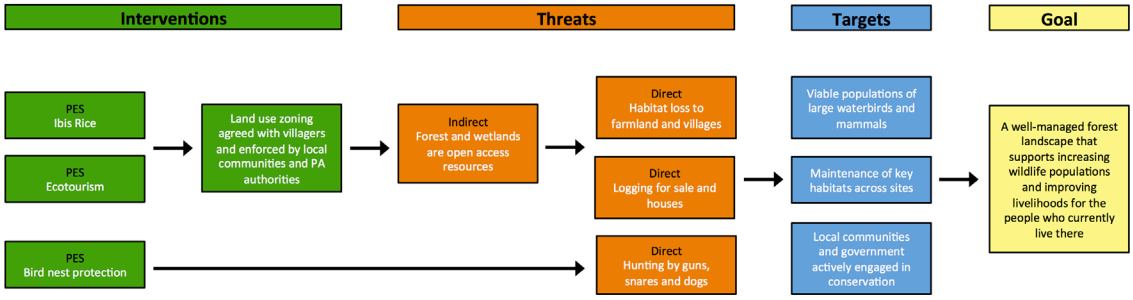


Underlying indirect threats include the perception that forests and wetlands are unmanaged open access resources, to be exploited by anyone; ineffective law enforcement; weak PA management authorities; increasing market access for forest and agricultural products; in-migration and human settlement expansion; lack of commitment to conservation by government; and lack of coordination between government agencies. Interventions can broadly be grouped into four categories: (1) supporting local communities to secure access and management rights over the land and forest resources that they use; (2) developing PES programs to provide positive incentives for sustainable use; (3) improving PA management and enforcement of the law; and (4) working with higher-level government agencies on landscape-level zonations and development plans to ensure that conservation priorities are incorporated into development planning.

The PA management component is implemented by the lead government agencies with the support of WCS. These are the Ministry of Environment in Kulen Promtep Wildlife Sanctuary and the Forestry Administration in Preah Vihear Protected Forest (until 2016). In 2016, the protected forest was also moved to the Ministry of Environment. Although the government implementing agencies were different for some of the evaluated period, the modality and activities were very similar. WCS's causal pathway for PA management support assumes that, through capacity-building and support, it is possible to establish functional PA management authorities that have the capacity, interest and sufficient political support (local and national) to undertake patrolling and law enforcement actions. Although often associated with many of the negative social impacts of conservation (e.g. West *et al*. 2006; Duffy 2014), law enforcement is a key component of PA management that has been shown to successfully reduce illegal activity in some conservation contexts (Jachmann & Billiouw 1997; Hilborn *et al*. 2006; Johnson *et al*. 2016). If successful, law enforcement coverage will be adequate, perpetrators will be detected and successfully prosecuted, and law enforcement will act as an effective deterrent to hunting and further encroachment. A recent study from a WCS-supported PA in eastern Cambodia found evidence of such an effect (Brozovic 2019). As a consequence, deforestation rates should decline and populations of wildlife species should increase.

The PES interventions build upon a foundation of the agreed village land-use and natural resource management plans (Fig. 5) and are implemented by WCS and two non-government organisations, the Sam Veasna Center (SVC, Ecotourism) and SMP (Ibis Rice). SVC and SMP were both established as non-profit social and environmental enterprises to market the tourism and agricultural products at a price premium, in order to fund the two PES interventions. The bird nest payment intervention is managed and funded directly by WCS. Two of the PES interventions – ecotourism and Ibis Rice – are designed to support the village land and natural resource agreements by providing positive incentives to comply. This forms a key part of the ToC. Secure land tenure rights have been shown to be an important predictor of the success of conservation interventions (Shahabuddin & Rao 2010; Larson *et al*. 2013; Sunderlin *et al*. 2014; Robinson *et al.* 2019). However, in Cambodia, implementation of tenure-based approaches has mostly been restricted to indigenous groups, with mixed success (Travers *et al*. 2015).

Figure 5: Theory of change pathway for the three PES programmes.



Ibis Rice also supports households to increase agricultural productivity from existing fields, thereby reducing the incentive to expand cultivation. This is mainly achieved through the provision of high-quality rice seed which produces greater yields and higher quality rice. The village authorities administer both interventions, in order to generate support for their efforts to encourage households to follow the land-use plans. Combined with the enforcement capacity of the PA, these two mechanisms are hypothesised to provide sufficient incentive for households to change behaviour and reduce habitat clearance. This is a key assumption – it is equally possible that the households could accept the benefits on offer (cash rewards, land and resource management rights) and continue to disregard the land-use plans. Monitoring household behaviour directly is therefore critical in order to detect whether or not the programmes are having an impact, and this is a key research question in this proposal. A related question, and one that is central to the success of PES policies (Wunder 2014), is whether the cash benefits on offer from the PES interventions are sufficient to compensate for the opportunity cost of not clearing further land.

Critical assumptions include that villages are interested to receive secure land titles and resource management rights in exchange for constraints on behaviour, and that village authorities administer the programs in a manner that is acceptable to the local population. Generating peer pressure, in terms of social pressure within the village to comply, is an important aspect of the theory of change that has been shown in experimental games to be an important factor influencing behaviour in the Northern Plains landscape (Travers *et al*. 2011). The theory of change also assumes that central government respects the village agreements, once developed, highlighting the importance of good governance structures for PES programmes (Snilsveit *et al*. 2019). Finally, it assumes that the PA authorities have sufficient capacity to monitor, detect infringements, and take action when offences occur, which links with the PA management results chain.

The bird nest protection intervention is not linked to the village land-use plans and natural resource agreements and is administered directly to households by WCS. It should have no impact on land-clearing behaviours and therefore acts as a quasi-control to other PES interventions.

2.5 Evaluation questions

The purpose of the evaluation was to assess the social benefits and conservation impacts of PAs and PES for households practicing a range of livelihood strategies in villages in the northern forests of Cambodia.

The main research questions of the study were:

1. Do PAs and PES interventions protect forests in comparison with controls?
2. Do PAs have positive or negative impacts on human wellbeing?
3. Do PES interventions deliver additional benefits to human wellbeing in comparison with controls?
4. Do the different environmental conservation interventions being implemented at the two PAs have different impacts on different livelihood strategies, focusing on rice farmers, growers of cash crops and non-timber forest product collectors?
5. Do households reduce land-clearing behaviours as a result of the payment interventions?

3. Methods

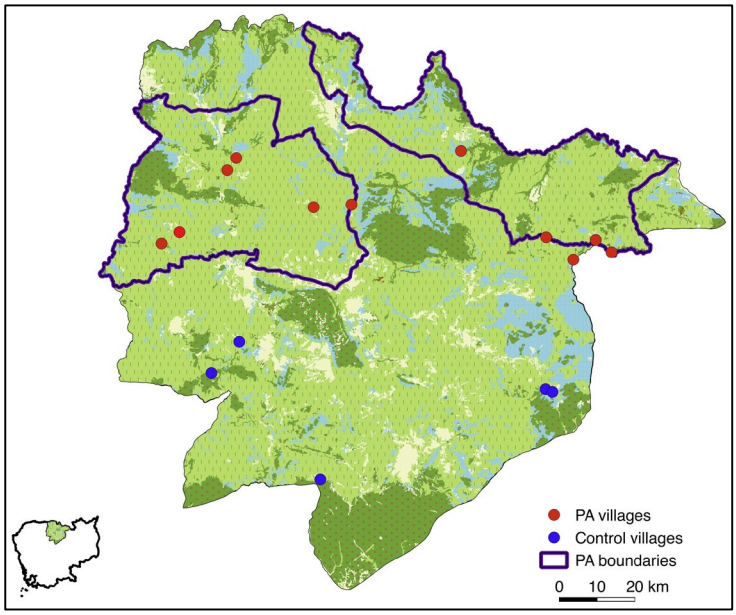
3.1 Evaluation design

The evaluation was designed with three main components: a quasi-experimental assessment of household wellbeing, a desk based deforestation analysis and a randomised control trial (RCT).

3.1.1 Household wellbeing assessment

The survey was conducted in 11 villages located within the two PAs and five matched control villages (Fig. 6).

Figure 6: Map of project area, including treatment and control villages (source: WCS).



Sampling

The quasi-experimental panel survey built upon a survey design first developed in 2008, hence the sampling strategy and sample sizes were already determined. At the village level, 11 villages inside the two protected areas were selected on the basis that they were located inside the core management area defined at the start of the conservation programme in 2005. Villages inside the protected areas but outside the core

management areas were not included. Potential matches for the within-PA villages were selected from a database of all 211 villages in Preah Vihear province, choosing only those more than 20km from the PA boundaries to minimise spillovers. A total of five matches were selected, which were all villages in similarly remote forest areas within the province, similar to the within-PA sample in 2005 (see Clements *et al*. 2014).

The matching variables used to select control villages were: (1) number of families in the village in 2005 from the Commune Database and updated by field surveys; (2) distance to nearest all-weather road in 2005, from the Cambodia Reconnaissance Survey Digital Data (MPWT/JICA, 2003) and updated by field; (3) distance to nearest full-day market in 2005 based on field surveys; and (4) percentage of forest cover within 5 km of the village based on the national forest cover assessments from 2005/2006 (Forestry Administration, 2008). Balancing tests were used to evaluate the results of matching estimators, by comparing the matching covariates for the intervention and matched control groups (Sekhon 2011). Statistics calculated included the means for each group; the mean, median and maximum difference in the empirical quantile-quantile plot of intervention and control groups on the scale in which the variable was measured; the mean, median and maximum difference in the empirical cumulative distribution function; the variance ratio of intervention over control groups; t-tests comparing the samples before and after matching (the two sample t-test was used pre-matching and the paired t-test was used post-matching); and the bootstrap Kolmogorov-Smirnov test, which tests for a significant difference across the entire distribution (as indicated by the empirical quantile-quantile plots).

The survey sample within each study village was constrained by historical sampling, as well as previous sample attrition resulting from households moving away from the study area. These households were initially selected in 2008 through random sampling at the village level:

- 2008: within-PA group, 504 treatment households; 205 control households.
- 2011: within-PA group, 443 treatment households; 185 control households.
- 2014: within-PA group, 453 treatment households; 191 control households.

Where possible, the 596 households interviewed in all three previous survey rounds (2008, 2011 and 2014) were included in the sample. However, due to adverse weather affecting the rice growing season, there was higher than average attrition after the first round of interviews reported here. Of the 596 households included in the 2008-2011-2014 panel, 111 households were not available for interview at the time of the survey. An additional survey was completed in May 2018, which increased the number of interviewed panel households to 535 (383 treatment households and 151 control households). Although sample attrition between 2014 and 2017 was greater than expected, only one household refused to give their consent to participate in the 2017 round of the evaluation. As such, non-response through refusal to participate was not an issue. If the original respondent was not available, another adult member of the household was interviewed.

In addition to the full panel households interviewed in all four surveys between 2008 and 2017, each survey from 2011 onwards included additional randomly selected replacement households in each of the survey villages. This gave a total sample of 946 households that were interviewed during at least two consecutive surveys.

For the analysis of the impact of PAs on household wellbeing, households in the 11 PA villages were matched with households from the five control villages. Matching variables were selected on the basis of the tests of difference between the control and treatment groups: (1) education, (2) age, (3) resin-tapper, (4) >1 ha, (5) cash crop farmer, (6) shifting rice farmer, (7) cattle, (8) economic status, (9) rice harvest and (10) food security. Matching was conducted once, based on 2008 values, and balancing tests were carried out as described above. This left a matched sample of 220 households (150 in the treatment group and 70 in the control). Whilst matching removed the majority of imbalance between the two samples, balancing tests showed some minor imbalances remained (Table C8).

For the analysis of the impact of participation in the Ibis Rice programme on household wellbeing, participant and non-participant households living in the 11 PA villages were matched at the beginning of each three year period between surveys. In this instance, rather than being restricted to panel households that were interviewed for every survey, any household that was interviewed for two consecutive surveys (i.e. the two surveys spanning each three year time period) was included in the matching process for that period. Households that participated in the Ibis Rice programme were matched with similar households that had not participated in the programme previously, nor during the relevant time period. This meant that there was a balanced sample for each time period. The matching variables used to select control households were: (1) education, (2) female headed, (3) resin-tapper, (4) >1 ha, (5) shop, (6) cattle, (7) mini-tractor and (8) wellbeing indicator. Matching was based on values at the start of each period. BNS scores were calculated using the weighting for the relevant survey year. This gave samples of 14, 15 and 16 treatment and 14, 14 and 15 control households (for economic status, rice harvest and food security respectively) for the period from 2008 to 2011; 163, 158 and 161 treatment and 111, 112 and 108 control households for 2011 to 2014; and 180, 169 and 171 treatment and 113, 104 and 103 control households for 2014 to 2017 (Tables C9-C17).

Survey instrument

The quasi-experimental wellbeing assessment made use of the survey instruments used in the previous rounds of the evaluation. Participant households were interviewed using a standardised questionnaire (see Appendix A1). In each village, the village chief was interviewed using a questionnaire designed to collect village level data (see Appendix A2).

The assessment used three measures of household wellbeing to investigate the social impact of PAs and PES. The main measure, derived from the Basic Necessity Survey, was calculated using a list of 35 items of household assets and basic services. This list was compiled for the first survey in 2008 and has been used for each subsequent survey. Items in the list were weighted by the proportion of respondents that thought they were a basic necessity, defined as the minimum requirement for living that all households of the community should have and no-one should not have, with only items with a weighting of greater or equal to 0.5 contributing to household score. An individual household's score is calculated using Equation 1:

$$S_j = \sum_{i=1}^{n} w_i p_{ij}$$

where S is the household basic necessity score, w_i is the weighting applied to item i and where p_{ij} is equal to 1 if household j owns item i, else p_{ij} is equal to 0.

Weighting each item and applying a minimum threshold for that weighting has the advantage that items that the majority of people think are basic necessities become more important for the score, while items which less than 50% of participants think are basic necessities are excluded. However, for longitudinal studies, weightings may vary between surveys. For some items, this variation can be significant, making it necessary to control for the variation in the analysis. To account for this, a revised score was calculated only using items for which the proportion of households responding that each item was a basic necessity stayed within limits of ±10% over the four surveys from 2008 to 2017. This gave a final list of 26 items. A further two items were excluded from the score as they were used as predictor variables in the analysis, plus seven items that did not meet the required 0.5 weighting. There were no significant differences in weighting factor between control and treatment households for any of the items used to calculate household scores.

The two other measures used were total annual rice harvest, calculated as the sum of all rice household rice production (estimated in rice sacks filled to minimise recall error), and an indicator of food security, which was calculated as the total annual rice harvest for a household minus the household's expected consumption needs over the year (calculated as a function of household adult male equivalents). Although household production is not the only source of income in the study area, it is an essential component of food security and wellbeing, even for households that secure their income through non-farm based livelihood activities. As such, these two measures are considered to be important indicators of wellbeing by members of the study villages.

Survey implementation

The first phase of the survey was undertaken between October and November 2017 across the 16 evaluation villages (11 within-PA and 5 matched control villages), with the second phase completed in May 2018. The gap between the two survey phases was necessary to ensure that panel households that had temporarily moved away to seek livelihood opportunities in other provinces, who were therefore unavailable during the first survey phase, had returned to their villages. Prior to the implementation of the survey, enumerators contracted to the Multi-Angles Centre were trained in the survey instruments and data collection protocols. This training period included a pilot survey in three control villages previously included in the survey to enable the enumerators to become familiar with the sampling strategy taken. All enumerators had worked on similar previous surveys, including a recent social impact survey at another WCS-supported PA in eastern Cambodia that made use of many of the same indicators.

The evaluation was granted research ethics approval from the Wildlife Conservation Society's Institutional Review Board and the University of Oxford's Social Sciences and Humanities Inter-Divisional Research Ethics Committee (Ref No: R52023/RE001). All data collectors received prior training in ethical concepts for human subject research. Permission for the survey was granted by the Provincial Governor for Preah Vihear.

Statistical Power
The baseline BNS score was 9.0 in 2008, with a pooled Standard Deviation of 3.3 and an intra-cluster correlation of 0.10. At a significance level of 0.05 and a power of 0.8, the analysis was calculated to detect changes in BNS Score of at least 1.9. In Clements & Milner-Gulland (2015) the observed increase in BNS Score between 2008 and 2011 was 2.5 units over only three years. As a significant proportion of the variance is explained by covariates, such as distance to road or distance to village, this is a conservative estimate of the statistical power; assuming only 40% can be explained, the minimum detectable effect was reduced to 1.5. For rice harvests, the baseline was 1310 kg, standard deviation 365, intra-cluster correlation 0.04 and minimum detectable effect 147. Rice harvests more than doubled in the 2008-2011 period.

Attrition from the sample was expected as a result of households moving away from sample villages, being subsumed into another household or selecting not to participate in the latest survey. In 2011, only 89% of the households interviewed in 2008 were located, mostly because households were busy in their fields or in the forest when the survey teams visited. In 2014, a more intensive effort was made to find the original households and 91% were found, with attrition rates of 10.9% for the PA treatment households and 7.3% for controls. As such, attrition over the three year period from 2014 to 2017 was expected to remain stable at approximately 10% of the remaining sample. Attrition at this level was not expected to affect the ability to detect changes in BNS scores or rice harvests, as the expected change based on previously observed changes was significantly greater than detectable changes at a significance level of 0.05 and a power of 0.8.

Limitations of data collection and challenges faced
Although the extreme weather in 2017 was unavoidable, it is possible that this may have affected the data for the 2017 survey, particularly the two outcome measures of total harvest and household food security as a result of crop damage. Furthermore, the fact that some households were not interviewed until May 2018 may have introduced seasonality effects. All analyses were run both with and without these households to test for such affects and all findings were unchanged.

3.1.2 Deforestation analysis
The aim of the deforestation analysis was to assess the impact of PAs and PES programmes on forest clearance rates using a full BACI survey design.

Sampling
The analysis focussed on assessing deforestation trends within 5km buffers surrounding within-PA and matched control villages after PA management started (2006-2018). At village level, 19 within-PA villages were selected. As for the wellbeing analysis, matched villages were selected in 2008, prior to the first assessment, from a database of all 211 villages in the province, choosing only those >20 km from the PA boundaries in order to reduce spillovers. The matching variables used were forest cover within 5 km of the village (the area used by people), village size, and distances to roads and markets; all from 2005, the year PA management was initiated. These variables were the main factors thought to have influenced PA placement. All the variables selected are exogenous to the interventions being evaluated. Selecting from within the same province ensured that all villages had benefited equally from major social programs (which are

implemented at the provincial scale). Matching procedures and balancing tests were followed as per the wellbeing analysis.

For each village, 250 points were randomly generated within 5km buffers. Points which fell outside national borders (in Lao PDR) or which were initially classified as non-forest were excluded from the analysis. This gave a pre-matched sample of 7086 points (3554 within-PA and 3532 control) for the analysis of the impact of PAs on deforestation, of which the 3554 points within PA boundaries were used for the analysis of the deforestation impact of PES. Point level matching was conducted using values from 2006, when WCS began support for PA management (prior to this the PAs can be considered paper parks without management). Only points forested in 2006 were included in the matching procedure. This created a balanced sample at the beginning of the evaluation period in 2006. The matching variables used to select controls were: (1) slope, (2) elevation, (3) road and (4) canopy cover. As canopy cover values were only available for the year 2000, these values were used instead of values for 2006. Matching procedures and balancing tests were followed as per the village matching (Table C18). This gave a sample of 2687 points (832 surrounding 19 control villages and 1846 surrounding 19 treatment villages). For this analysis, rather than assess annual deforestation of each point, the status of each point was assessed (i.e. whether forest had been cleared or not) over the whole of the evaluation period from 2006 to 2018. This was possible because all points remained in either the control or treatment groups for the whole evaluation period. This approach avoided the need to control for pseudo-replication introduced by taking multiple measurements for each point over time.

Survey implementation

The deforestation assessment made use of the Global Forest Change (GFC) data that covers change in forest cover between 2000 and 2018 (Hansen *et al.* 2013). This time series dataset was derived using composite Landsat satellite imagery at a 1 arc-pixel (approximately 30x30m) resolution. For each randomly generated point, initial canopy cover values in 2000 were extracted from the GFC data. Each point was classified as forest provided canopy cover in 2000 was greater or equal to 10%, the threshold value corresponding to the Cambodian national definition of forest. Any points which had canopy cover below this threshold in 2000 were classified as non-forest and excluded from the analysis.

Forest loss was measured annually for each point using the GFC dataset. This defines loss as a stand-replacement disturbance (see Hansen *et al.* 2013 for further details of methodology used).

Statistical Power

Previous deforestation analyses conducted as part of the on-going assessment of WCS activities in the Northern Plains found that baseline deforestation was 1.083 ha per 1km^2 grid square between 2001/2 and 2005/6 (the year PA management started), with a pooled Standard Deviation of 4.481 and an intra-cluster correlation of 0.006. At a significance level of 0.05 and a power of 0.8, the analysis should detect changes in deforestation rates of 0.726 ha/grid square. In Clements and Milner-Gulland (2015) the observed difference in deforestation rates between the two treatment types from 2005/6 to 2009/10 was 1.366 ha/grid square, or nearly double. Assuming 20% of the variance

can be explained by covariates, such as distance to the nearest main road, the minimum detectable effect was reduced to 0.649.

Limitations of data collection and challenges faced
For the analysis of the impact of PA management on deforestation levels, it was necessary to conduct matching at point level to control for the unbalanced sample at village level, despite prior matching. This resulted in a significant reduction in sample size, of approximately one third of points, but was necessary to provide a balanced sample for the analysis.

3.1.3 Randomised control trial

The randomised control trial component of the evaluation was designed to assess the impact of the Ibis Rice programme on compliance, with randomisation conducted at the household level. Given that the RCT could only be implemented over one year, this was too short to evaluate wellbeing benefits of participation, but compliance could be expected to be an immediate outcome of participating in the intervention. The trial was designed with two arms: a control arm, in which households were told they would have to wait to join the programme and a treatment arm in which participant households would receive the intervention in the year they registered their interest in participating.

Sampling
All new participants in the Ibis Rice programme across the nine villages in which the programme is currently being implemented were recruited to the trial. The intention prior to the trial had been to recruit a minimum of 250 participants, with 125 to be allocated to each arm of the trial. Households that had previously participated in the Ibis Rice programme prior to 2018 were excluded from participating in the RCT but not excluded from participating in the intervention.

Recruitment to the trial was undertaken at meetings held to promote the Ibis Rice programme within each village. At these meetings, information relating to the trial was given orally, as many participants were expected to be illiterate. Lists of people who wished to participate in the trial were drawn up, as well as of those who attended the meeting but chose not to participate in the programme in 2018. Prospective participants were put under no pressure to participate and SMP staff ensured that they understood the conditions and any potential risks of participation. Once participants had been recruited, allocation to the two arms of the trial was conducted publicly to ensure transparency and local acceptance of the allocation process, through a ballot.

Survey implementation
Participants in the trial were surveyed using the same socio-economic survey instrument used in a quasi-experimental assessment of the impact of Ibis Rice on household wellbeing. Interviews were conducted in August 2018 prior to the assessment of compliance over the trial period. In addition to the socio-economic component of the interview, open-ended qualitative questions were included relating to motivations for participating in the Ibis Rice programme. At the same time, 57 households for which one member or more attended the village meetings held to recruit people to the programme, but who did not choose to participate, were also interviewed. For these households, the qualitative component of the interview addressed their reasons for not participating.

Of the three behaviours that comprise non-compliance, illegal land clearance is the most prevalent, and therefore the main focus of the programme, with 95% of cases of non-compliance in 2016/17 resulting from illegal clearance. Infractions for illegal logging and hunting are recorded infrequently at the household level, although this is likely to be due to the difficulty in detecting these activities. As a result, an effect of the Ibis Rice programme on compliance with these rules would be difficult to detect. Consequently, for the purposes of the RCT, illegal hunting and logging were included with illegal land clearance in a broader measure of compliance. The use of chemicals on rice fields, which is banned under the conditions of organic certification, is not a significant conservation issue in itself and, as such, was not considered.

Statistical power

A power analysis was conducted prior to the RCT. This analysis showed that changes in the proportion of compliant households of 0.11 or greater could be detected at a significance level of 0.05 and a power of 0.8. The most representative data from which estimates of baseline compliance and effect size could be derived were from villages to which the Ibis Rice programme had recently expanded. The recent addition of organic certification and the additional compliance requirements and monitoring that this has brought, meant that data from more established villages would not be representative of expected behaviour during the trial.

Data collected in a village to which the intervention was expanded in the 2016/17 growing season, gave an estimate of baseline compliance of 0.83, where compliance was defined as compliance with the three main conditions of participation in the Ibis Rice programme. Although high, this baseline rate of compliance is not unusual. Most individual households do not clear forest every year so a high rate of compliance was expected on an annual basis. Taking the difference in average compliance for non-participating and participating households for Bra village gave an estimate of the effect size of 0.12.

Design effects

The risk of contamination was considered to be low, as no other conservation interventions were being conducted in the study area. Similarly, it was considered unlikely that there would be spill-over effects between trial arms, despite both control and treatment arms being present in the same villages, as the intervention could only be accessed by treatment households. However, it is possible that households placed in the control arm may have engaged in strategic behaviour, either by pre-emptively clearing land prior to their expected participation in the programme or avoiding illegal behaviour to ensure later acceptance into the programme. As data on household behaviour in both arms of the trial was to be collected through routine monitoring conducted as part of the management of the two protected areas, Hawthorne effects were expected to be negligible. John Henry effects were not expected, as control households had no incentive to perform better than treatment households

Limitations of data collection and challenges faced

The original approach proposed for the randomised control trial was to make use of the planned phased expansion of Ibis Rice to employ a stepped wedge clustered randomised trial. However, a review of possible methodologies highlighted the option of using an individually randomised trial to evaluate the impact of the programme on

behaviour. Such an approach has several advantages over a stepped wedge design, including randomisation at the household rather than village level, a larger pool of villages from which to select trial participants, more robust procedures to avoid recruitment and selection biases, as well as greater freedom for the implementing agencies to manage the planned programme expansion.

The decision was taken to conduct an individual RCT in 2018. However, while interest in Ibis Rice remains high in participating villages, the ability of households to participate in 2018 was constrained due to extreme weather conditions during the 2017 rice growing season. As a result, only 87 households were recruited to the RCT, which is significantly lower than the estimated minimum sample size of 243 households.

3.2 Data analysis

3.2.1 Wellbeing assessment

Treatment effects for wellbeing assessment

Six hypotheses were tested to assess the impact on wellbeing of PAs and household participation in the three PES programmes, based on the presumptions in the literature of the likely negative effects of PAs (through restrictions on households' activities) and positive effects of PESs (through provision of benefits). As the three PES programmes are implemented within the two PAs, the effects of these programmes are included within the effects of the wider management of the PAs.

Hypothesis WH1: PAs decrease household economic status as measured by the basic necessity score.
Hypothesis WH2: PAs decrease household rice harvests.
Hypothesis WH3: PAs decrease household food security.
Hypothesis WH4: PES programmes increase household economic status as measured by the basic necessity score.
Hypothesis WH5: PES programmes increase household rice harvests.
Hypothesis WH6: PES programmes increase household food security.

Table 1 gives the key response and predictor variables considered in the wellbeing analyses. All variables follow the specification applied in Clements *et al*. (2015) and Beauchamp *et al*. (2018b).

Table 1: Key response and explanatory variables used in the analysis of household wellbeing. Response variables in grey shading.

Variable	Description	Type
Economic status	Difference in household economic status as measured by the BNS (range 0-17)	continuous
Rice harvest	Difference in total annual rice harvest in kg for a household	continuous
Food security	Difference in rice harvest – annual household rice requirement (kg)	continuous
Treatment	Whether a household lives in a village within a PA	binary
Participation	Whether a household participated in at least one PES programme for at least one year per period	binary
Ibis Rice participation	Whether a household participated in the Ibis Rice programme for at least a one year per period	binary
Bird nest participation	Whether a household participated in the bird nest protection programme for at least a one year per period	binary
Ecotourism	Whether a household participated in the ecotourism programme for at least a one year per period	binary
Household size	The number of members of a household (defined as an economically independent unit)	continuous
Dependency ratio	Ratio of household members aged under 14 or over 60 to those aged between 14 and 60	continuous
Female headed	Whether the household head is female (%)	categorical
Education	Years spent in education by household head	
Age	Age of household head	continuous
>1 ha	Whether household owns an area of land greater than 1 ha	binary
Resin-tapper	Whether a household collects liquid resin	binary
Rice farmer	Whether a household farms rice	binary
Cash crop farmer	Whether a household farms cash crops	binary
Rice farmer type	Type of rice cultivation used by household: paddy, shifting, both, none	categorical
Shop	Whether household runs a shop	binary
Employed	Whether at least one household member has salaried employment	binary
Service	Whether at least one household member provides a service, such as rice milling or battery charging	binary
Labour	Whether at least one household member participates in wage labour	binary
Mini-tractor	Whether a household owns a mini-tractor	binary
Cattle	The number of cattle owned by a household	continuous
PC distance	The distance to the provincial capital	continuous
Schooling	The maximum grade offered by schools in a village	categorical

Previous research (Clements *et al*. 2015; Beauchamp *et al*. 2018b) has indicated that four household types are particularly of interest: resin-tappers (a form of non-timber forest product harvesting), rice farmers, growers of cash crops such as cassava and relatively rich versus poor households. Resin-tappers benefit from conservation interventions because resin trees are protected in the forest from illegal loggers and forest land clearance. Rice farmers, and in particular growers of cash crops, are likely to be negatively affected by conservation interventions because their ability to expand fields is limited by the land use plans. Marginalised groups, who would be expected to be relatively poor, include shifting cultivators and female-headed households.

Difference-in-difference matched analysis

For both the analysis of the impact of PAs and PES, the initial samples were unbalanced, with panel households inside the PAs and Ibis Rice participants having significantly higher BNS scores than households outside the PAs and non-participants respectively. This has specific implications for the use of BNS scores. It is often assumed that the basic necessity survey provides a linear score, which is typically normally distributed, so that is can be analysed using suitable linear regressions. However, as household score increases, it becomes harder to achieve the same marginal increase than for a household with a lower score. For example, taking the results from the 2017 survey, a household could achieve an increase in BNS score of +1.0 either for gaining a large knife or for gaining a motorbike; these items represent very different capital investments. Richer households will already have the cheaper items. As a result, it was easier for poorer households, who had low BNS scores in 2008, to make marginal gains than better off households. A second implication of this feature of the BNS score is that, in situations where the average household score is increasing over time, it becomes harder to achieve the same average gain in wellbeing as was observed in previous periods.

This becomes important when assessing the difference-in-difference of BNS scores between residents and non-residents of PAs or participants and non-participants of Ibis Rice. In these cases, because of the imbalance between the two samples, a situation may arise in which the average score of one group rises more slowly than the other, when in actual fact the first group have increased their absolute wealth by a greater degree. For example, for the sample of households interviewed as part of the panel survey and living inside the protected areas (N=384), the average BNS score in 2008 of households that participated in Ibis Rice (between 2008 and 2011) was 11.95 against an average of 9.23 for non-participant households. The relative increases in BNS score between 2008 and 2011 for these two groups was 2.86 and 3.09 respectively. As a result, it appears that non-participants increased their economic wellbeing at a faster rate than participant households. Yet, given the disparity between the average baseline scores in 2008, it is not possible to say with any confidence whether this is actually the case. This effect was controlled for using a matched analysis in which households that had received an intervention (i.e. PA or Ibis Rice participant households) were matched with similar households that had not, creating a balanced sample at the beginning of the evaluation period.

Self-selection into the intervention

For the evaluation of the impact of the two protected areas, there was a limited degree of potential self-selection to the treatment, as respondent households were free to shift residence from control to treatment villages. No surveyed households did so over the evaluation period, although it is possible that non-surveyed households moved between control and treatment villages and became replacement households.

For the evaluation of the three PES interventions, participation in each of the interventions is voluntary. As such, by the very nature of the interventions, households can self-select into and out of the interventions. This has been controlled for by only considering households as participants if they have participated at least once during the three-year period prior to each of the surveys, so that it is possible for household to be considered participants in one time period but not in the next. For the matched analysis,

households that had previously been participants but had dropped out of the programme in subsequent periods were not included in the pool of potential control households for matching.

Spillover and contamination
Due to the voluntary nature of the Ibis Rice intervention, there is potential for spillover effects to reduce the impact on household economic status. This is because rice traders in villages participating in the intervention have increased their prices to compete with IRCC. As a result, the premium which farmers gain through participation in the intervention has been reduced. However, since the transition to organic production in 2016, the threat of spillover effects was reduced, as the organic certificate is held by IRCC rather than by individual farmers. This means that independent traders are unable to market rice bought from participating farmers as organic and, therefore, are not in a position to offer competitive prices. As such, it is unlikely that there has been any spillover following the transition to organic. Hence, although minor spillover effects may have occurred during the period from 2008 to 2014, these will have resulted in conservative estimates of the impact of the three PES interventions during that period and are not considered a source of serious bias.

3.2.2 Deforestation analysis
Treatment effects for deforestation analysis
Two hypotheses were tested to assess the impact of PAs and PES programmes on deforestation, based on the theory of change outlined in Fig. 4:

Hypothesis DH1: PAs reduce conversion of forest to non-forest within 5km of a village.

Hypothesis DH2: PES programmes reduce conversion of forest to non-forest within 5km of a village.

The key variables considered in the deforestation analysis are described in Table 2. Population data was not available for all years and so was not included in the analysis. Distance to nearest all-weather road was calculated using an annually updated spatial roads layer where the presence of roads was identified using national road data and high resolution satellite imagery. Ibis rice participating villages were defined as any village included in the Ibis Rice programme in any given year, regardless of the total or proportion of households that participated that year. The proportion of forest cover within each 5km buffer around study villages was calculated using GFC data. Population, although originally specified in the pre-analysis plan (Appendix B) was not included in as the analysis, as the main source of annual data available was inconsistent and found to contain a number of inaccuracies.

Table 2: Key response and explanatory variables used in the analysis of deforestation. Response variable in grey shading.

Variable	Description	Type
Deforestation	Loss of forest cover	binary
Village	The nearest village to a grid square	categorical
PA	Whether a point was within or outside a PA	binary
PES	Whether a point was within 5km of a village participating in the Ibis Rice programme	binary
Year	The year forest cover was classified	categorical
Road	The distance to the nearest all-weather road (km)	continuous
Cover	The proportion of forest cover within 5km of a village	proportion
Slope	The mean slope for a given point (unit?)	bounded
Elevation	The elevation for a given point (m)	continuous
ELC	Whether a point was within an economic land concession	binary

To analyse the effect of protected areas on deforestation, it was necessary to control for significant differences in the characteristics of the randomly generated points surrounding within-PA and control villages. These differences were controlled for by matching at point level between within-PA and control groups.

The analysis of the impact of the Ibis Rice programme on deforestation looked at the effect of Ibis Rice being implemented in a village. Given that implementation villages were selected over a ten year period in a non-random manner, it was not possible to match implementation villages with other within-PA villages where the Ibis Rice programme had never been implemented. Of the 19 within-PA villages, households in 14 villages have participated in the Ibis Rice programme. However, within these villages, participation levels have varied significantly both in terms of the number of years the programme has been implemented in a village and in the proportion and absolute number of households that have participated each year. Participation rates also varied over time within individual villages. Given that the intervention was open to all households, regardless of whether they chose to participate or not, the intent-to-treat measure of participation is simply whether or not the programme was being implemented in a village during a given year. Therefore we assume no lagged effects of the presence of the programme on behaviour, and that any participation has the same effect regardless of its intensity. To investigate the effect of Ibis Rice on deforestation, a panel of 3554 points was analysed annually over the period 2001 to 2018. Sample attrition occurred when a point had been deforested in a previous year.

3.2.3 Estimation of treatment effects

For all wellbeing hypotheses, treatment effects were estimated by applying a Bayesian multi-level hierarchical linear regression model (1, following Gelman & Hill [2006]), including cluster-level predictors. The deforestation analyses applied a similar approach but used logistic regression models to account for the binomial error structure of the data. Multi-level regressions were applied because of the nested nature of grouping factors (household nested in village for the wellbeing analyses and point nested in village for the deforestation analyses).

$$y_i \sim N\left(X_i B_{j[i]}, \sigma_y^2\right), \text{ for } i = 1, \ldots, n \quad (1)$$

$$B_j \sim N(U_j G, \Sigma_B), \text{ for } j = 1, \ldots, J$$

Where y_i is the response indicator, X_i is the n x K matrix of predictors, *B* is the J x K matrix of grid square level coefficients, *U* is the J x L matrix of cluster level predictors, *G* is the L x K matrix of coefficients for the cluster level regression, n is the number of households, J is the number of groups, K is the number of individual-level predictors and L is the number of group-level predictors.

Models were analysed using the rstan package (version 2.8.0; Stan Development Team 2015a) in R (version 3.2.2; R Core Team 2015). Where appropriate an uninformative LKJ prior (shape factor = 1) was assigned to the covariance matrix. Adequate convergence was indicated by taking Gelman-Rubin statistics with values <=1.1 and visual inspection of traceplots. Four chains were analysed in parallel, with the number of burn-in iterations set to achieve time convergence. Credible intervals for probability estimates at the 95% level were found by calculating the probability distribution of each response state using the estimated parameter values for each post-warm up run. Continuous variables were centred and scaled by dividing by twice the standard deviation (Gelman 2008). This included the response variables for household rice harvest and food security, as these variables had different scales to other variables, which can affect the efficiency of the MCMC algorithms used. Contemporaneous values of all predictor variables were used throughout.

3.2.4 Randomised control trial

Despite the fact that recruitment to the trial was not sufficient to meet the minimum sample size, it was still possible to monitor the compliance outcomes of the three groups: participant households in the control and treatment arms, and non-participant households who attended the same village meetings. As a result, even at reduced numbers, it was possible to analyse the data from the RCT. The aim of the RCT was to test the primary hypothesis that participation in the Ibis Rice programme impacts household illegal behaviour (forest clearance, hunting, logging):

> *Hypothesis BH1: The Ibis Rice programme decreases household involvement in illegal activities.*

The reduced number of participants necessitated simplified models to those originally included in the pre-analysis plan (Appendix B). Specifically, the lack of non-compliant households in certain villages created singular fitting models where village was included as a grouping factor. As a result, the data were analysed using generalised linear models with logit link functions to account for the binomial error structure, but without village as a grouping factor. Key demographic and livelihood variables were included in the initial model (Table 3). Model selection was conducted using backwards selection on the basis of the Akaike Information Criterion (Akaike 1974).

Table 3: Response and explanatory variables considered in the analysis. Response variable in grey shading.

Variable	Description	Type	Code
Compliance	Whether a household is compliant with the three conditions of participation in the Ibis Rice programme	binary	B1
Treatment	Whether a household is receiving the intervention	binary	B2
Gender	Gender of the household head	categorical	B3
Age	Age of household head (y)	continuous	B4
Household size	The number of members of a household (defined as a economically independent unit)	continuous	B5
Dependency ratio	Ratio of household members aged under 14 or over 60 to those aged between 14 and 60	continuous	B6
Education	Number of years household head spent in education	continuous	B7
Poverty score	Household BNS poverty score (range 0-17)	continuous	B8
Rice harvest	Total annual rice harvest for a household (kg)	continuous	B9
>1 ha	Whether household owns an area of land greater than 1 ha	binary	B10
Resin-tapper	Whether a household collects liquid resin	binary	B11
Cash crop farmer	Whether a household farms cash crops	binary	B12
Employed	Whether at least one household member has salaried employment	binary	B13
Shop	Whether the household runs a shop	binary	B14
Service	Whether at least one household member provides a service	binary	B15
Labour	Whether at least one household member participates in wage labour	Binary	B16
Mini-tractor	Whether a household owns a mini-tractor	Binary	B17

4. Results of the wellbeing assessment

4.1 Description of the quantitative sample

4.1.1 Full panel

Before the regression analysis was carried out, basic descriptive statistics for key socio-economic and demographic variables were calculated for the 2017 sample (Table 4). In addition, a comparison of key variables was made between households interviewed in 2008, 2011 and 2014 and households who were unavailable for interview during at least one subsequent wave of the survey (Tables C1-3). These comparisons were made for both treatment and control groups to test for differences between these groups and showed that unavailable households tended to be older, smaller and poorer than those who were available for interview. Although more significant differences between the two groups were found for the households inside the PA, this is partly due to the larger sample size for this group. The tests of difference suggested that the results of the regression analysis may be vulnerable to slight biases introduced through sample attrition.

Table 4: Descriptive statistics based on 2017 values for key response and explanatory variables used in the analysis.

Variable	Description	Mean	SD
Economic status	Household BNS poverty score	10.6	2.5
Rice harvest	Total annual rice harvest for a household (kg)	3760	2954
Food security	Rice harvest – annual household rice requirement (kg)	2656	2916
Participation	Whether a household participated in at least one PES programme for at least one year per period (%)	23.0	42.1
Ibis Rice participation	Whether a household participated in the Ibis Rice programme for at least one year per period (%)	17.8	38.3
Bird nest participation	Whether a household participated in the bird nest programme for at least one year per period (%)	4.1	19.9
Ecotourism participation	Whether a household participated in the ecotourism programme for at least one year per period (%)	7.7	26.6
Household size	The number of members of a household (defined as a economically independent unit)	5.9	1.9
Dependency ratio	Ratio of household members aged under 14 or over 60 to those aged between 14 and 60	0.8	0.7
Female headed	Whether the household head is female (%)	10.5	30.7
Education	Number of years spent in education by household head	4.2	3.7
Age	Age of household head	45.8	11.5
>1 ha	Whether household owns an area of land greater than 1 ha (%)	93.6	24.4
Resin-tapper	Whether a household collects liquid resin (%)	30.0	45.9
Rice farmer	Whether a household farms rice (%)	98.1	13.6
Cash crop farmer	Whether a household farms cash crops (%)	49.3	50.0
Shop	Whether a household runs a shop	6.7	25.1
Employed	Whether at least one household member has salaried employment (%)	10.5	30.7
Service	Whether at least one household member provides a service (%)	29.2	45.5
Labour	Whether at least one household member participates in wage labour (%)	50.9	50.0
Mini-tractor	Whether a household owns a mini-tractor (%)	73.2	44.3

4.1.2 PES panel

There have been significant changes over time in the number of panel households participating in the three PES interventions and in the mean earnings of participant households over time (Table 5). The intervention experiencing the greatest growth since monitoring began in 2008 is the Ibis Rice programme, which has expanded from 7.6% sample participation in 2009-2011 to 25.0% in 2015-2017. There has also been a significant increase in the average annual earnings of participant households from the programme over this period. However, over the nine year period from 2008 to 2017, the average number of years in which participant households (i.e. those who participated in the programme at least once) participated was 2.7 years. This is partly skewed by participants in villages that the programme expanded to more recently but, even accounting for the number of years that the programme was available in each village, participating households only participated in one out of every three possible years on average. This suggests that households are best considered participants only within a

given survey period, rather than for the full nine year monitoring period. The average annual earnings for participation in the programme ranged from US$455 in 2009-2011 to US$1020 in 2015-2017. However, it should be noted that these figures are the average total sums paid to participating farmers and not the premium that farmers gained over the market price, which varied within seasons, between seasons and between villages. In 2017 organic farmers were offered a 40% premium above market price (equating to an average financial benefit of approximately US$281 per household).

Table 5: Summary statistics of household participation in the three PES interventions between 2006 and 2017 (N=380)[1].

	2006-2008	2009-2011	2012-2014	2015-2017	2006-2017
Ibis Rice					
No. participants		29 (7.6%)	101 (26.6%)	95 (25.0%)	130 (34.2%)
Years participated		1.8	1.7	1.3	2.7
Annual earnings [USD]		553	455	1020	671
Bird Nest					
No. participants	14 (3.7%)	28 (7.4%)	19 (5.0%)	22 (5.8%)	58 (15.2%)
Years participated	1.5	1.4	1.6	1.7	2.2
Annual earnings [USD]	362	294	453	270	337
Ecotourism					
No. participants	42 (11.1%)	66 (17.4%)	61 (16.1%)	45 (11.8%)	92 (24.2%)
Years participated	1.8	2.1	2.1	2.0	4.7
Annual earnings [USD]	126	143	182	380	209

[1] Earnings figures refer to absolute earnings and do not include direct or opportunity costs incurred through participation.

The number of participants in the bird nest protection intervention has been relatively stable over time across the panel, while mean annual payments per household have ranged from US$270 to US$453. However, participant households on average only participated for 2.2 years between 2005 and 2017, suggesting a relatively high turnover of participants. This makes sense as the scheme involves finding a nesting tree and committing to guard it until fledging; it requires no long-term investment decisions by the participant, analogous to selling labour rather than growing rice as a livelihood strategy. In contrast, participation of the ecotourism intervention has been more consistent, with participant households on average participating for 4.5 years over the same period and earning US$209 for each year of participation. In terms of total benefit to sampled households, the ecotourism programme has delivered approximately double that of the bird nest protection intervention (US$89,655 and US$42,151 respectively), although both have delivered less than Ibis Rice (US$232,890). Unlike the bird nest protection intervention, the average annual earnings from the ecotourism intervention have continued to increase over time.

As the Ibis Rice intervention, unlike the bird nest protection and ecotourism interventions, was not implemented until after monitoring began in 2008, it is possible to compare baseline values of participant and non-participant households. This was done for the four original villages in which the intervention was implemented and we labelled any household that had participated in at least one time period as a participant (Table C4). The tests of difference show that there were few significant differences between the two groups in 2008, with the exception of the three indicators of household wellbeing and

mini-tractor ownership. This suggests that while participant and non-participant households were largely similar, households that produced more rice, and had the capital capability enabling them to do so, were more likely to choose to participate in the intervention. This is unsurprising given that most people in the study area prefer to produce their own food and would therefore only be likely to participate in the intervention if they produced a surplus.

4.2 Impacts of protected areas on wellbeing

The difference-in-difference matched analysis of the impact of PAs on household wellbeing found that, relative to similar households in the control group, the economic status (BNS score) of households living inside the PAs increased by 1.82 between 2008 and 2017 (Table 6).

Table 6: Posterior distribution means and 95% credible intervals from the regression models on the matched dataset (220 HHs) of the effect of protected areas and other predictor variables on the three household wellbeing indicators between 2008 and 2017[1].

	Economic status		**Rice harvest[2]**		**Food security[2]**	
	mean	**95% CI**	**mean**	**95% CI**	**mean**	**95% CI**
Intercept	-1.41	(-4.29, 1.19)	0.06	(-0.44, 0.54)	0.10	(-0.35, 0.58)
Time and treatment						
PA interventions	-0.28	(-1.86, 1.38)	0.04	(-0.25, 0.33)	0.06	(-0.21, 0.33)
2008-2014	-2.47	(-3.35, -1.57)	-0.05	(-0.22, 0.12)	**-0.29**	**(-0.46, -0.13)**
2008-2017	-2.83	(-3.72, -1.93)	0.00	(-0.17, 0.17)	-0.12	(-0.28, 0.05)
PA * 2008-2014	0.44	(-0.62, 1.47)	-0.04	(-0.24, 0.16)	-0.03	(-0.22, 0.17)
PA * 2008-2017	**1.82**	**(0.75, 2.88)**	-0.10	(-0.30, 0.10)	-0.11	(-0.31, 0.09)
PA * Resin tapper	0.03	(-0.86, 0.92)	0.07	(-0.09, 0.24)	0.09	(-0.07, 0.25)
PA * Shifting	0.45	(-1.79, 2.66)	-0.20	(-0.62, 0.22)	-0.28	(-0.68, 0.13)
PA * No rice	0.22	(-1.86, 2.30)	-0.09	(-0.48, 0.30)	-0.10	(-0.48, 0.28)
PA * Paddy only	-0.50	(-1.54, 0.54)	0.04	(-0.15, 0.24)	0.02	(-0.17, 0.20)
Household variables						
Household size	**-0.50**	**(-0.91, -0.10)**	0.05	(-0.03, 0.12)	0.01	(-0.07, 0.08)
Dependency ratio	0.38	(0.11, 0.65)	0.00	(-0.05, 0.05)	-0.01	(-0.06, 0.04)
Female headed	0.00	(-0.56, 0.57)	**-0.16**	**(-0.27, -0.05)**	**-0.17**	**(-0.28, -0.07)**
Education	0.00	(-0.05, 0.05)	-0.01	(-0.02, 0.00)	0.00	(-0.01, 0.00)
Household age: mature	0.35	(-0.10, 0.81)	0.02	(-0.06, 0.11)	0.08	(0.00, 0.17)
Household age: aging	-0.10	(-0.72, 0.53)	-0.10	(-0.22, 0.02)	-0.04	(-0.15, 0.07)
Livelihood variables						
> 1 ha	0.14	(-0.41, 0.69)	0.06	(-0.04, 0.16)	0.07	(-0.03, 0.17)
Resin tapper	0.33	(-0.43, 1.09)	**-0.16**	**(-0.30, -0.02)**	**-0.16**	**(-0.30, -0.03)**
Cash crop farmer	-0.14	(-0.60, 0.33)	**-0.13**	**(-0.22, -0.04)**	**-0.10**	**(-0.18, -0.01)**
Employed	-0.17	(-0.85, 0.53)	0.00	(-0.13, 0.13)	0.09	(-0.04, 0.21)
Labour seller	0.58	(0.22, 0.94)	-0.05	(-0.12, 0.02)	-0.07	(-0.13, 0.00)
Service provider	-0.09	(-0.51, 0.32)	0.12	(0.04, 0.19)	**0.10**	**(0.02, 0.17)**
Shop owner	-0.19	(-0.93, 0.56)	0.24	(0.09, 0.38)	**0.22**	**(0.08, 0.36)**
Mini-tractor	**1.05**	**(0.63, 1.46)**	0.01	(-0.07, 0.09)	-0.04	(-0.11, 0.04)
Cattle	-0.02	(-0.07, 0.02)	0.01	(0.00, 0.02)	**0.01**	**(0.00, 0.02)**
Rice farmer: shifting	-0.79	(-2.78, 1.23)	-0.13	(-0.51, 0.25)	-0.09	(-0.46, 0.28)
Rice type: no rice	0.11	(-1.57, 1.78)	**-0.38**	**(-0.70, -0.07)**	**-0.33**	**(-0.63, -0.02)**

	Economic status		Rice harvest[2]		Food security[2]	
	mean	**95% CI**	**mean**	**95% CI**	**mean**	**95% CI**
Rice farmer: paddy only	0.35	(-0.39, 1.10)	**-0.22**	**(-0.36, -0.08)**	**-0.15**	**(-0.29, -0.02)**
Village variables						
PC distance	0.24	(-0.07, 0.64)	-0.02	(-0.08, 0.04)	0.00	(-0.07, 0.05)
Schooling	0.30	(-0.01, 0.62)	0.04	(-0.02, 0.10)	0.03	(-0.03, 0.09)
N	220		220		220	

[1] Results shown in bold are non-zero at 95% credible intervals.

[2] Both the rice harvest and food security indicators were centred and standardised to two standard deviations prior to analysis (Gelman *et al.* 2008).

This suggests that, contrary to hypothesis WH1, households living in villages inside the PAs enjoyed a significant benefit relative to households in similar villages outside the PAs over the evaluation period.

For rice harvest and food security, there was little difference observed between households living inside the PAs and the matched control group. The exception to this was that household food security was found to be lower for households in the PAs than control households between 2008 and 2014. However, this effect was not observed over the longer period from 2008 to 2017. There were no deviations from expectations in effects of the social-demographic variables.

This suggests that there is little evidence in support of hypotheses WH2 or WH3.

4.3 Impacts of payments for environmental services on wellbeing

The difference-in-difference matched analysis was used to correct for sample imbalances in the comparison between Ibis Rice participants and non-participants within each period (Table 7). The effect of participating in the Ibis Rice programme was estimated to increase household economic status by 0.34, with the effect positive in 95.6% of model runs. This was approximately equivalent to the estimated effect size of owning a mini-tractor, which is known to have a transformational impact on household productive capacity. The (non-significant) negative effect of time is likely to be because of the non-linear nature of the BNS score. Of the significant social-demographic variables with large effect sizes, there was an unexpected negative effect of being a cash crop farmer on economic status, but the others are as expected.

Overall, there is consistent evidence to support hypothesis WH4 that participating in the Ibis Rice programme increased household economic status over the course of the evaluation period.

Participation in the Ibis Rice programme had no effect, either positive or negative, on household rice harvest. This is unsurprising given that the main focus of the intervention is increasing the price at which farmers are able to sell their crops, rather than yield. Larger households were found to have greater harvests. For food security, the result of the regression was marginal. Participants in the Ibis Rice programme had an average annual surplus of 381kg more than matched non-participants, with the effect being positive in 95.0% of model runs. Cash crop farmers, households practicing only shifting cultivation and participants in the bird nest protection programme were all found to have

reduced food security. It should be noted, however, that the matching was conducted to balance the analysis with respect to Ibis Rice participation.

There is no evidence to support hypothesis WH5 that participating in the PES programmes increased household rice harvest. The evidence with respect to WH6 is mixed, with marginal support for the findings that participation in the Ibis Rice programme improves household food security but participation in the bird nest protection programme is associated with reduced food security.

Table 7: Posterior distribution means and 95% credible intervals from the difference-in-difference regression models on the matched Ibis Rice dataset on household wellbeing between 2008 and 2017[1].

	Economic status		**Rice harvest[2]**		**Food security[2]**	
	mean	95% CI	mean	95% CI	mean	95% CI
Intercept	**-3.12**	**(-6.04, -0.25)**	-0.98	(-1.96, -0.08)	-0.01	(-0.67, 0.62)
Time and treatment						
2008-2014	-0.59	(-1.50, 0.34)	0.25	**(0.05, 0.46)**	-0.25	**(-0.44, -0.07)**
2008-2017	-0.15	(-1.16, 0.86)	0.34	**(0.08, 0.61)**	0.15	(-0.06, 0.36)
Ibis Rice participant	0.34	(-0.07, 0.74)	0.03	(-0.06, 0.13)	0.07	(-0.01, 0.16)
Household variables						
Household size	0.03	(-0.38, 0.44)	0.13	**(0.04, 0.22)**	0.04	(-0.05, 0.13)
Dependency ratio	0.24	(-0.04, 0.51)	0.01	(-0.05, 0.07)	0.00	(-0.06, 0.05)
Female headed	0.21	(-0.48, 0.90)	0.02	(-0.13, 0.18)	0.05	(-0.09, 0.20)
Education	**-0.07**	**(-0.14, -0.01)**	0.00	(-0.02, 0.01)	-0.01	(-0.02, 0.01)
Household age: mature	-0.22	(-0.71, 0.26)	0.00	(-0.11, 0.11)	0.05	(-0.06, 0.16)
Household age: aging	**-0.64**	**(-1.18, -0.10)**	-0.03	(-0.15, 0.10)	0.02	(-0.10, 0.14)
Livelihood variables						
> 1 ha	**1.73**	**(0.85, 2.61)**	0.08	(-0.12, 0.27)	0.01	(-0.18, 0.20)
Resin tapper	-0.09	(-0.47, 0.29)	-0.08	(-0.17, 0.01)	-0.04	(-0.12, 0.04)
Cash crop farmer	**-0.72**	**(-1.17, -0.26)**	-0.08	(-0.19, 0.03)	-0.11	**(-0.21, -0.01)**
Employed	**0.57**	**(0.03, 1.10)**	0.02	(-0.11, 0.14)	0.09	(-0.03, 0.20)
Labour seller	0.04	(-0.34, 0.41)	-0.11	(-0.19, -0.03)	-0.02	(-0.10, 0.06)
Service provider	0.07	(-0.34, 0.48)	0.08	(-0.01, 0.18)	0.06	(-0.03, 0.14)
Shop owner	-0.10	(-0.89, 0.70)	0.14	(-0.07, 0.36)	0.06	(-0.14, 0.25)
Mini-tractor	0.41	(-0.19, 1.00)	0.06	(-0.07, 0.18)	0.02	(-0.10, 0.13)
Cattle	-0.03	(-0.07, 0.01)	0.01	**(0.00, 0.01)**	0.01	(0.00, 0.02)
Rice farmer: shifting	-0.26	(-1.52, 1.00)	-0.32	(-0.65, 0.00)	-0.30	**(-0.59, -0.01)**
Rice type: no rice	1.61	(-0.31, 3.50)	-0.34	(-0.69, 0.01)	-0.30	(-0.65, 0.04)
Rice farmer: paddy only	0.18	(-0.67, 1.02)	-0.03	(-0.21, 0.16)	-0.09	(-0.27, 0.09)
Ecotourism participant	-0.12	(-0.59, 0.35)	-0.03	(-0.13, 0.08)	0.01	(-0.09, 0.11)
Bird nest participant	0.16	(-0.52, 0.86)	-0.08	(-0.24, 0.09)	-0.16	**(-0.32, -0.01)**
Village characteristics						
PC distance	0.14	(-0.17, 0.47)	0.07	(-0.05, 0.22)	0.00	(-0.07, 0.08)
Schooling	**0.30**	**(0.08, 0.54)**	0.06	(-0.03, 0.16)	0.00	(-0.05, 0.06)
N	595		573		572	

[1] Results shown in bold are non-zero at 95% credible intervals.

[2] Both the rice harvest and food security indicators were centred and standardised to two standard deviations prior to analysis (Gelman *et al.* 2008).

5. Results of the deforestation analysis

5.1 Description of the quantitative sample

Before matching at point level and conducting the regression analysis, basic descriptive statistics for key explanatory variables were calculated for all points included in both the PA and PES analyses based on values in 2000 (Table 8). Despite matching at the village level, there were some significant differences in key variables between points surrounding within-PA and control villages at both the beginning of the evaluation period in 2000 and at the beginning of the intervention period in 2006 (Table C5). The differences observed in 2000 continued into 2006; the rate of change for both the proportion of forest within 5km of each village and the distance to the nearest all weather road was slightly greater for control villages than for within-PA villages.

Table 8: Descriptive statistics based on values from 2000 for key explanatory variables used in the analysis of the impact of PAs and PES on deforestation.

Variable	Description	Mean	SD
PA sample			
Canopy cover	Initial Global Forest Change estimation of canopy cover at point (%)	54.4	27.8
Slope	The mean slope for a given point	1.8	2.0
Elevation	The elevation for a given point (m)	94.3	31.2
Cover	The proportion of forest cover within 5km of a village	78.5	10.4
Road	Distance to nearest all weather road (km)	21.4	16.4
PES sample			
Canopy cover	Initial Global Forest Change estimation of canopy cover at point (%)	48.7	27.1
Slope	The mean slope for a given point	1.5	1.3
Elevation	The elevation for a given point (m)	88.9	21.5
Cover	The proportion of forest cover within 5km of a village	81.0	10.3
Road	Distance to nearest all weather road (km)	23.5	16.3

5.2 Impact of PAs on deforestation

The analysis of matched points surrounding within-PA and control villages found strong evidence that management of the PAs has reduced clearance rates relative to similar areas outside the PAs (Table 9). Controlling for other factors, points surrounding control villages were estimated to have had a probability of being cleared of 0.09 over the evaluation period from 2006 to 2018, whereas the probability of points surrounding within-PA villages being cleared was just 0.03. There were no deviations from expectations in effects of the key topographic or spatial variables, with the exception of whether a point was located within an Economic Land Concession (ELC), which was expected to increase the probability of a point being cleared.

Overall, there was strong evidence to support hypothesis DH1 that PAs reduce conversion of forest to non-forest within 5km of a village.

Table 9: Posterior distribution means and 95% credible intervals from the deforestation regression models of matched points surrounding within-PA (1846 points) and control (832 points) villages between 2001 and 2018[1].

	Forest loss			
	Estimate	**95% CI**	**Probability[2]**	**95% CI**
Intercept	**-2.40**	**(-3.05, -1.93)**	0.09	(0.05, 0.13)
Time and treatment				
Within-PA village	**-1.14**	**(-1.75, -0.44)**	0.03	(0.02, 0.04)
Point characteristics				
Slope	**0.35**	**(0.07, 0.65)**	0.12	(0.06, 0.18)
Elevation	**1.48**	**(1.12, 1.90)**	0.29	(0.19, 0.41)
ELC	-0.12	(-0.63, 0.35)	0.08	(0.04, 0.13)
Road	**-0.59**	**(-1.00, -0.14)**	0.05	(0.02, 0.09)
Village characteristics				
Cover	**-0.80**	**(-1.59, -0.21)**	0.04	(0.01, 0.09)
N	2678			

[1] Results shown in bold are non-zero at 95% credible intervals.

[2] Probabilities given are the estimated probability of clearance for the period from 2006 to 2018.

5.3 Impact of PES on deforestation

The analysis of points surrounding within-PA villages found little evidence that the rate of deforestation was reduced during years in which the Ibis Rice programme was implemented in a village (Table 10). Deforestation was found to have significantly increased in both Ibis Rice and non-Ibis Rice villages over the last five years. Unsurprisingly, deforestation is also greater inside economic land concessions (ELCs). Unlike the findings of the impact of PAs on deforestation, being near a road was found to decrease the probability that a point would be cleared. Those villages with more initial cover had less deforestation.

Table 10: Posterior distribution means and 95% credible intervals from the deforestation regression models of points surrounding within-PA villages (3554 points) between 2001 and 2018[1].

	Forest loss			
	Estimate	**95% CI**	**Probability[2]**	**95% CI**
Intercept	-2.65	(-5.94, 1.20)	0.15	(0.00, 0.86)
Time and treatment				
Ibis Rice village	-0.40	(-1.20, 0.40)	0.13	(0.00, 0.83)
2001-2002	0.51	(-0.58, 1.75)	0.19	(0.00, 0.89)
2001-2003	-0.59	(-2.25, 0.95)	0.11	(0.00, 0.75)
2001-2004	**1.21**	**(0.19, 2.33)**	0.27	(0.01, 0.94)
2001-2005	-0.03	(-1.41, 1.29)	0.15	(0.00, 0.82)
2001-2006	0.49	(-0.65, 1.72)	0.19	(0.00, 0.88)
2001-2007	0.43	(-0.87, 1.74)	0.18	(0.00, 0.87)
2001-2008	0.68	(-0.57, 1.93)	0.21	(0.00, 0.90)
2001-2009	0.10	(-1.36, 1.48)	0.16	(0.00, 0.85)
2001-2010	1.05	(-0.13, 2.43)	0.25	(0.01, 0.93)
2001-2011	0.43	(-0.83, 1.80)	0.19	(0.00, 0.89)
2001-2012	0.13	(-1.26, 1.54)	0.16	(0.00, 0.86)
2001-2013	0.47	(-0.77, 1.89)	0.19	(0.00, 0.88)
2001-2014	**2.56**	**(1.55, 3.78)**	0.46	(0.03, 0.98)
2001-2015	**2.36**	**(1.31, 3.62)**	0.43	(0.03, 0.97)
2001-2016	**3.10**	**(2.10, 4.28)**	0.55	(0.06, 0.99)
2001-2017	**1.80**	**(0.71, 3.04)**	0.34	(0.02, 0.95)
2001-2018	**2.37**	**(1.28, 3.61)**	0.43	(0.03, 0.97)
Point characteristics				
Slope	-0.12	(-0.35, 0.12)	0.14	(0.00, 0.84)
Elevation	**1.56**	**(1.18, 1.98)**	0.31	(0.01, 0.96)
ELC	**2.41**	**(1.95, 2.92)**	0.43	(0.02, 0.98)
Road	**0.57**	**(0.12, 1.04)**	0.20	(0.00, 0.91)
Village characteristics				
Cover	**-6.42**	**(-11.22, -2.26)**	0.00	(0.00, 0.00)
N	**3554**			

[1] Results shown in bold are non-zero at 95% credible intervals.

[2] Probabilities given are the estimated probability of clearance for the period from 2006 to 2018.

Given the variation in participation levels between villages, it is unsurprising that the effect of Ibis Rice implementation varies between villages. Village-level gradients for the Ibis Rice variable show that points surrounding two villages had a lower probability of being cleared when Ibis Rice was being implemented in the villages. One of these villages is one of the two original villages in which the programme was implemented, which was selected because of the importance of the surrounding forest for key bird species, and which has amongst the highest rates of Ibis Rice participation.

Overall, these findings do not provide sufficient support for hypothesis DH2 that the PES programmes, and Ibis Rice in particular, have reduced the rate of deforestation at the landscape level.

6. Results of the randomised control trial

6.1 Description of the participant and non-participant samples

A total of 87 households were recruited to the RCT: 46 to the treatment arm and 41 to the control treatment. There was no attrition of households in either arm of the trial. A comparison of households participating in the RCT found only one significant difference in key socio-demographic variables between the two arms of the trial (Table C6): the percentage of households who owned a shop.

Of greater interest to the programme is the comparison between households that chose to participate in Ibis Rice for the first time in 2018 and those that did not, despite attending the same village meeting (Table C7). This comparison provides an indication of why certain households may choose to participate, while others given the same information do not. The results show that the main differences between the groups are the age and level of education of the household head, with those choosing to participate being more likely to have younger household heads with more years in education. There are multiple explanations for why this might be the case, including that people who have received more education may have been better able to understand the benefits on offer through the intervention.

6.2 Household compliance

For households participating in the RCT, six out of 41 households in the control arm and three out of 46 households in the treatment arm were found to be non-compliant. The level of non-compliance observed for households in the control arm was less than non-participant households that attended the village recruitment meetings, among whom 13 out of 57 households were found to be non-compliant over the period of the trial, suggesting that strategic pre-emptive clearance by control households is not a serious concern. All recorded instances of non-compliance for both participating and non-participating households were for illegal land clearance.

The generalised linear model selected through stepwise variable deletion shows that participation in the Ibis Rice programme through the treatment arm of the RCT had a significant effect on household compliance (at the 95% confidence level), with households allocated to the treatment arm estimated to have been approximately 4 times less likely to be non-compliant than households in the control arm (Table 11).

In addition to treatment, households with higher levels of dependency and those that owned a mini-tractor were more likely to have been non compliant. The result for mini-tractor ownership is as expected; households that own a mini-tractor are able to prepare greater areas of land for cultivation and so face higher opportunity costs from not clearing. It is possible that the higher levels of non-compliance among households with greater dependency ratios were due to greater pressure to provide land for the next generation. However, further investigation would be required to test this explanation.

Table 11: Results of GLM of household compliance for the RCT[1].

	Non-compliance			
	Estimate	**Std. Err.**	**Probability**	**P value[2]**
Intercept	-2.56	0.7	0.07	***
Treatment	-1.43	0.7	0.02	*
Dependency ratio	0.89	0.4	0.16	*
Mini tractor owner	1.33	0.8	0.23	.
N	87			

[1] Results shown in bold are non-zero at 95% credible intervals.

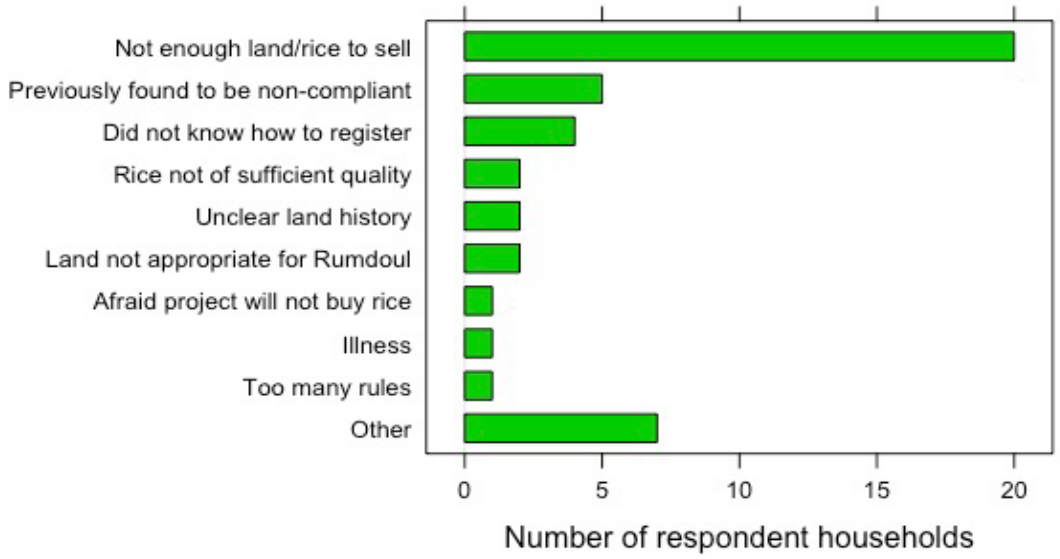
[2] Significance values: 'ns' = non-significant; '.' = P <0.1; '*' = P <0.05; '**' = P <0.01; '***' = P <0.001.

Overall, these findings provide support for hypothesis BH1 that Ibis Rice reduces household-level non-compliance with village land use plans.

6.3 Results of the qualitative analysis

The qualitative analysis is instructive in understanding why some farmers chose to participate in the Ibis Rice programme, while others did not. Of the reasons given by non-participant households, the most prominent was that they did not have enough land to produce a surplus (Fig. 7).

Figure 7: Reasons given for non-participation in the Ibis Rice programme.



However, this is at odds with the comparison between participant and non-participant households that attended the village meetings, which suggested that there were no significant differences between the two groups with respect to mean household food security (defined as surplus rice produced beyond that required for household consumption) or the percentage of households that owned at least one hectare of land in production (a key proxy of whether a household will be able to produce a surplus). It is possible that this disparity in the findings between the qualitative and quantitative components of the study is due to differences in perceptions of household need or risk preferences between the two groups. However, further investigation would be required to ascertain this.

7. Discussion

7.1 Introduction

7.1.1 Protected area interventions

Contrary to the commonly purported narrative that protected areas negatively affect the people living in or around them (Wilkie *et al*. 2006; Brockington & Wilkie 2015), the results of the evaluation of wellbeing found no evidence that households in the treatment area had worse wellbeing outcomes compared to households in the control area over the nine-year monitoring period. In fact, there was strong evidence that treatment households were better off than matched households in the control villages. It appears that, while households inside the PAs may have been less able to take full advantage of wider changes in the economy during the period from 2008 to 2011 than households in control villages, this was no longer the case in later years. This is further evidenced by the mean decline in economic status experienced between 2014 and 2017 by households in the control group but not by treatment households, which may also suggest that households living inside the PAs are more resilient to exogenous change, protecting them from negative trends, such as land-grabbing or conflict over resources.

The findings also suggest that living inside protected areas has not prevented households from diversifying their livelihood strategies or adapting to new opportunities. This is evidenced by the significant increase in the proportion of treatment households that have moved into cash crop production, providing some form of village service or the supply of labour. These changes have coincided with significant drops in the importance of resin collection and shifting cultivation, which again suggests a move away from more traditional livelihood strategies, a finding that has been replicated in other parts of rural Cambodia (Travers *et al.* 2015). While these findings are encouraging, in that they demonstrate that living inside the PAs has not restricted development opportunities, they also suggest that the interventions being implemented inside the PAs must adapt to changing household priorities, particularly the cultivation of cash crops (such as cashew and cassava) that has seen massive growth over the nine-year evaluation period. In the medium- to long-term, this trend is likely to increase pressure on intact forest as the profitability of land increases. However, plans are currently under development to diversity the products procured from farmers participating in the Ibis Rice programme as a means of addressing this increased pressure.

Despite the significant changes in livelihoods, particularly the productive capacity of both control and treatment households, the deforestation analysis suggests that clearance rates surrounding within-PA villages were significantly lower than the matched control villages. This suggests that the increased economic wellbeing observed for households living inside protected areas has not resulted simply because those households were able to clear forest, although it does not preclude involvement in illegal selective logging, which was not detected by the deforestation analysis. It is also possible that there has been leakage of forest loss due to migrants moving or ELCs being established elsewhere. Such leakage is not an issue from a conservation perspective, except in cases where avoided clearance has been displaced to other areas of conservation importance. Indeed, the establishment of protected areas is part of broader spatial planning with regards to which areas to develop for human use and which areas to protect.

7.1.2 Payments for environmental services interventions

The results of the evaluation of the impact of the three PES interventions on human wellbeing are broadly positive, particularly for the impacts of Ibis Rice. Participants of Ibis Rice were found to have better economic status and better food security than non-participant households. The evidence with respect to the two other PES interventions, ecotourism and bird nest protection, is less positive. Neither intervention was found to have an effect on household economic status or rice harvests, while the bird nest protection intervention had a negative effect on household food security. This is likely to be due in part to the fact that mean earnings through participation in the two interventions are lower than for participation in Ibis Rice. However, it is also likely to be affected by the way in which payments for these two interventions are structured. The bird nest protection intervention is widely perceived to have been very successful in achieving environmental outcomes, with numbers of several endangered and critically endangered bird species increasing in areas where the interventions has been implemented (Clements *et al.* 2013). However, because of the way in which the performance payment is structured, participants may end up with relatively low earnings from guarding a nest (e.g. when the nest fails) and, depending on the effort put into guarding the nest, may have invested time that would have been more productively spent on alternative livelihood activities. The level of the payment is also set at around the casual labour wage so that it acts as an alternate income source for relatively low-earning individuals, rather than as a way to improve economic status.

Participation in the ecotourism intervention has been defined as any household that receives a financial benefit, so that even households that earn five dollars for laundry are categorised as participants, along with those who have played significant management roles with commensurate compensation. Consequently, there is a much higher proportion of participants in the bird nest protection and ecotourism interventions who end up with very low earnings compared to participants in the Ibis Rice intervention. This is evidenced by the disparity in the maximum earnings for the bottom quartile of earners participating in each of the three interventions (US$285 for Ibis Rice, US$83 for bird nest protection and US$20 for ecotourism). While the maximum earnings over a three year period for any single household are broadly comparable for Ibis Rice and bird nest protection (US$6577 and US$7119 respectively), the maximum earnings from ecotourism is approximately half (US$3263). As such, it may be possible to achieve greater wellbeing benefits for participants in the bird nest protection and ecotourism interventions by reviewing the payment structures used. However, it is also important to consider the respective aims of the different payment schemes; the primary aim of the bird nest protection intervention has always been the conservation of endangered bird species, whereas the ecotourism and Ibis Rice interventions have several objectives, including improving household wellbeing and building capacity within local collective institutions. The ecotourism programme also generates a significant secondary benefit through a mechanism by which a portion of tourists fees are paid directly into a village fund. This fund is then used for communal investments. The spatio-temporal overlapping nature of the three schemes was intentional, so that each could contribute to the overarching conservation and wellbeing goals in complementary ways (both in terms of means of participation for people with different priorities and capacities to engage, the time-scale over which they were expected to mature, and their long-run sustainability).

With respect to analysis of deforestation in areas surrounding within-PA villages, the findings of the evaluation were mixed. There was little evidence that deforestation rates were lower in all villages that Ibis Rice had been implemented in. However, there are several possible explanations why this may have been the case, particularly the varying level of participation in each village. It is also possible that there is a lag in effect, such that it may take several years of implementation before clearance rates decline relative to villages where the intervention has not been implemented. Alternatively, there may be a threshold level of participation beyond which social norms in each village begin to change (e.g. through social conformity norms). Of the 14 villages in which the programme had been implemented at some point during the evaluation period, the implementation period has only exceeded five years in four of the villages. If a lag effect was present, it might therefore be expected that these four villages would exhibit the lowest rates of deforestation in years when the programme was being implemented. However, only one of these villages, was found to have significantly lower rates of deforestation during years in which the programme was implemented. This village was also the only village for which at least 50% of households participated in the programme at least once over the evaluation period. Consequently, this may be evidence that a minimum threshold of participation exists before deforestation is reduced or can be detected using the methods applied here. A final alternative is inter-household leakage, whereby participating households collude with non-participating households to maximise benefits from participation in the programme and clearance. Opportunities for such collusion are reduced through mapping of all fields and crop auditing to ensure that rice grown on areas of unauthorised clearance are not laundered through approved land. In all these cases, further evaluation is required.

7.2 Policy and programme relevance

Protected areas are one of the most important policy tools available to conserve biodiversity and move towards sustainable development. Multiple models exist for both the level of protection offered by PAs and the level of engagement with local people, spanning from the “fences and fines” approach in which access to resources within PAs is heavily restricted and enforced, through to more participatory approaches such as co-management. The 2008 Cambodian Protected Area law allows for both use of certain natural resources, such as liquid resin, and rights over agricultural and residential land within designated zones. In this regard, Cambodian protected areas are less restrictive than in many other countries. Furthermore, where restrictions do exist, regulations are poorly enforced with few arrests or prosecutions. As a result, it might be expected that some of the disadvantages suffered by people living in and around PAs elsewhere would be mitigated in Cambodia. However, the findings of this evaluation show that households living inside the PAs were significantly better off than matched households in control villages. This suggests that, not only did living inside the PAs not negatively impact their wellbeing, but actively benefited them. This has significant policy relevance because it demonstrates that protected areas can both play an important role in the conservation of biodiversity (here, by reducing deforestation rates) and still contribute to the wellbeing of rural households at a time when many countries are in the process of identifying new areas for protection to meet commitments made under the UN Convention on Biological Diversity.

The rationale for payments for ecosystem services stems mainly from recognition of three issues: i) the potential for significant social harm from conservation policies and the inherent inequality of the protection of a global public good with local costs, ii) the potential for improved efficiency that financial mechanisms offer over more traditional enforcement-based approaches to conservation, and iii) the rights local people hold over the use and benefit from natural resources. Hence, for PES programmes to prove effective, it is important that they realise both social and environmental benefits. The combination of relatively permissive regulations and weak enforcement found inside the PAs corresponds to the conditions in which the combination of PAs and PES policies has been found to do this elsewhere (Sims & Alix-Garcia 2017). The findings of this evaluation show that the three PES programmes, particularly Ibis Rice, have met the first of these criteria, demonstrating a causal link between household participation in Ibis Rice and improved economic status. The evidence for environmental benefits is more equivocal. While forest clearance was shown to decline in two of the within-PA villages during the period that resident households were participating in the Ibis Rice programme, these effects were not observed across the implementation area. Conversely, the finding of the RCT shows that Ibis Rice does affect household-level behaviour. As a result, while there is strong evidence that the intended social benefits of the Ibis Rice programme are already being realised, further work is required to ascertain whether there is a causal link between implementation of the programme and reduced deforestation at a landscape level. However, all three PES programmes being implemented within the landscape are integral to the management of the three protected areas, which have experienced significantly lower rates of forest loss than matched control villages outside the PAs, as demonstrated by the deforestation analysis. These findings have important implications for the management of protected areas in Cambodia, as they show that the use of PES programmes can support more traditional protected area management to benefit local people and bring conservation benefits.

With respect to the objectives contained in the project stakeholder engagement and evidence uptake plan, significant progress has been made in preparing decision makers for the publication of the evaluation findings. At the national level, ongoing engagement with the Cambodian government and conservation NGOs about the planned learning and adaptation of the Ibis Rice programme at existing sites and expansion into new areas has proven to be productive. As a result, there are now plans for SMP and IRCC to engage with other organisations to rollout the programme to other sites of conservation importance. Within Preah Vihear, the original site of Ibis Rice implementation, there has been a growing appreciation among decision makers, particularly the Provincial Department of Environment, of the need to balance more traditional PA management activities, such as ranger patrolling, with incentive-based approaches, such as Ibis Rice. There is also appreciation that such market-based approaches can provide a sustainable source of financing for conservation activities, thereby reducing dependence on donor funding. Specific steps that are recommended include greater scrutiny of forest clearance inside the PAs by households not participating in the Ibis Rice programme and refocusing efforts to increase participation within existing villages, with the dual aim of increasing both the social and environmental impacts of the programme. At the national level, there is increasing awareness of the potential for complementary social and environmental outcomes through the implementation of PES policies.

At the international level, the findings of the evaluation have fed into the ongoing debate within the conservation sector surrounding the post-2020 agenda to scale up conservation efforts and reverse biodiversity losses. In particular, it has added to the growing body of rigorous evidence on the effectiveness of both PAs and PES policies to contribute to social and environmental outcomes. The evaluation has also helped stimulate discussions within WCS about developing programmes with a focus on human behaviour change and contributing to the wider evidence base within the sector.

7.3 Challenges and lessons

7.3.1 Scalable effects from household interventions

One of the primary challenges experienced during the course of the evaluation was the problem of measuring landscape-scale effects to evaluate the impact of the Ibis Rice programme, which operates primarily at the household level. Although the deforestation analysis attempted to measure the impact of the programme in participating villages, the relatively low levels of programme participation in many of the villages, coupled with the low frequency with which most households would seek to clear new areas of forest, are likely to have contributed to the overall null result. This highlights the difficulty in attempting to assess impact from a programme that has yet to scale up to a level where landscape-level effects are sufficient to be detected.

The randomised control trial was designed to measure the effect of participation at household level, an important aspect of the overall question of the impact of the programme. Although recruitment to the RCT was low following a poor rice harvest the previous year, the results for the 87 households that were recruited to the trial indicate that households that received the intervention were approximately four times less likely to have cleared forest than those in the control group (Table 11). This result is caveated by the small sample in each arm of the trial but indicates that further opportunities for conducting an RCT should be explored, even if participation rates remain around current levels.

7.3.2 Utility of the wellbeing variables

Another challenge faced by the monitoring and evaluation strategy that has been put in place for the Northern Plains programme is the question of the continuing utility of the wellbeing indicators that were selected when the strategy was developed prior to its rollout in 2008. The first of these issues is the longevity of the items included in the basic necessity survey. When the list of items was first created, the expectation was that some items on the list would become redundant over time as all households came to own them, or in the case of key services had access to them. Such items contribute to household scores but do not help to differentiate between households. They can therefore be useful in tracking household development over time but are less useful in understanding differences between households. The original intention was to future-proof the survey by including items that were already perceived by people in towns as basic necessities but were either not yet widely owned or not perceived as basic necessities in programme villages. As villages developed, the expectation was that these items would replace the function of items that had become redundant for differentiating between households. The problem here is that the weighting applied to these items inevitably varies significantly between surveys, such that it becomes difficult for longitudinal analyses to determine the most appropriate strategy in applying weights to

household scores (e.g. whether to use the relevant annual weights or to apply a consistent weighting throughout the analysis).

A second issue arises for items with greater variance in how they are perceived. This particularly relates to items, such as the ability to attend religious ceremonies, that are more likely to be subjective. There may also be items on the list that do not follow the expected trend in how they are viewed. A good example from the list used in this evaluation is the television. As televisions were common in towns at the start of the programme but rare in villages, it was expected that they would be perceived as basic necessities at some point in future surveys. However, with the emergence of smart phones, televisions are no longer widely perceived as items that people aspire to own, with the result that the weighting applied to them has begun to decline after a period where it rose consistently between surveys. Further, if there are relatively few items with middling levels of ownership, they can have a strong influence on the score, and if the identity of these items changes over time, this could have unforeseen effects on the robustness of inferences. In themselves, none of these issues are insurmountable, particularly for comparisons within years or over short time periods, but they do indicate that, for long-term studies such as this to be successful, BNS lists should include a high degree of redundancy and future-proofing at the start of any monitoring programme.

The remaining two indicators, household rice harvest and food security, were less useful in determining the impacts of both living inside the PAs or participating in the PES programmes. With respect to the PA wellbeing analysis, reduced productive capacity and food security are both impacts of living inside PAs that have been reported from elsewhere but have been consistently shown not to be relevant in this case. For the analysis of the impact of participation in the PES programmes, the case for including these two indicators at the beginning of the programme is less clear, as there have been few activities in the programme aiming directly to influence household productive capacity. This has changed more recently, with participants of the Ibis Rice programme receiving higher quality seed and technical guidance to improve the productivity of their land. Hence, it is recommended that these indicators continue to be measured to assess whether such efforts prove effective.

7.3.3 External validity of the evaluation findings

The external validity of evaluations such as this (i.e. the extent to which the results obtained from the evaluation can be generalised to a wider population) is difficult to assess beyond the institutional conditions of the context in question. The intervention has an environmental goal and is specifically tailored to an individual context, which may limit generalisability. Within the Cambodian context, the rapid increase in household wellbeing observed for both treatment and control groups is reflected in national statistics, which show increases in household income, consumption and rice production across the plateau/mountain zone over the evaluation period (NIS 2018). This zone is where the majority of Cambodia's forested PAs are located and is characterised by rural populations predominantly focused on wet season rice cultivation. As such, the results of the evaluation are likely to be valid for many of Cambodia's key conservation areas. Beyond Cambodia, the basic characteristics of the interventions evaluated are common to much of the conservation sector. Notably, WCS, which has programmes in >60 countries globally, has identified multiple sites where the lessons learned from Ibis Rice may be suitably adapted to the local context and applied to address smallholder forest

clearance. However, it is important that the wider application of PES interventions similar to Ibis Rice should be grounded in the local institutional context and include consideration of the capability of implementing programmes (Woolcock 2013).

8. Conclusion and recommendations

The results of the evaluation presented in this report demonstrate that the interventions evaluated (PA management in the Northern Plains landscape and three PES interventions embedded within the PAs) go beyond the criteria of doing no harm, a key requirement for modern conservation and wider environmental practice, and benefit local people. The results of the evaluation into the impact of living inside the protected areas managed for conservation suggest that within-PA households are significantly better off than similar households in matched control villages. There is also evidence that both policies have reduced deforestation relative to suitable controls.

The results of the evaluation of the impacts of the three PES interventions show that the most promising intervention evaluated, Ibis Rice, has been successful in contributing to improvements in the wellbeing of participant households, particularly with respect to household economic status. Impacts on deforestation have been less significant. The analysis also suggests that the intervention's wellbeing impacts have increased over time, following the transition to organic certification and increased support for local management capacity. However, it is clear that disparities remain in the households that are able to access the intervention. Participating households are on average better off than non-participating households and are more likely to own at least one hectare of productive land. This finding presents challenges for the programme both with respect to the need to avoid increasing inequality within villages and in increasing farmer uptake that will need to be considered as the programme is expanded.

8.1 Develop ways to integrate poorer farmers into programme

One way in which the programme can increase uptake is to tackle the issue of low participation of poorer farmers who lack sufficient land to produce a surplus. Such farmers are likely to be amongst those who stand to benefit the most from participation relative to their existing income but may also be more likely to clear in order to meet their needs. However, there is a strong preference among farmers to consume their own produce, with the result that they are unable to participate in the programme because they hold back the rice they produce for their own consumption. In part, this preference stems from a lack of trust in the production methods of other farmers, particularly in lowland areas where the use of chemical fertilisers and pesticides is common but often poorly managed. However, this represents a missed opportunity for farmers, who would be able to sell the rice they produce at a premium to the programme and use the proceeds to purchase the same quantity of rice while making a profit on the original sale.

The challenge for the programme is that these non-surplus farmers represent approximately a third of all households across the landscape. Hence, for the programme to maximise its impact on clearance, improved targeting is needed to incorporate such farmers into the programme. This is a common finding from studies that have looked at factors that may increase the effectiveness of PES interventions (*Snilsveit et al*. 2019). This may include recent initiatives that were yet to take effect during the evaluation, such

as the commitment to buy all rice varieties, rather than just the fragrant *Phka Romdoul* variety, which has been the main focus of the programme. This initiative will enable farmers who produce a surplus in good years to participate, yet still concentrate on growing the varieties that are preferred for household consumption. A different approach would be to offer a rice exchange so that farmers can choose to exchange the rice they grow for a trusted alternative in addition to the premium offered to all participant farmers. This would add a logistical burden to the programme but would also help to overcome the secondary challenge that not all land is suitable for the production of *Phka Rumdoul.* In this way, the production of *Phka Romdoul* could be maximised while ensuring that farmers are offered a trusted locally produced alternative for their own consumption. To ensure that such an approach does not lead to leakage, where deforestation from the programme area is exported to other areas, it may be necessary to select purchase sites in areas where forest has already been cleared.

8.2 Increase farmer uptake

Uptake of the Ibis Rise programme has increased annually every year since its inception in 2008. However, this has in part been driven by expansion of the programme to new villages. Only one of the villages where the programme has been implemented for the longest, has attained greater than 50% participation. This has probably been facilitated by the fact that this village is one of the smallest villages in the landscape. The results of the RCT show that participation in the programme reduces the probability that a household will clear forest (at least within the first year of participation). However, as has been discussed, for landscape-level conservation impacts to be achieved, participation levels within villages must increase. This has important implications for both the overall effectiveness of the programme in reducing forest clearance within the PAs and the specific aim of protecting important areas for biodiversity, particularly key bird roosting areas. Hence, it is important for the programme to focus on increasing uptake, not just by expanding to new areas, but by increasing participation within villages in which the programme is already being implemented. These efforts should prioritise villages with the greatest conservation value in surrounding forest. They are likely to require detailed qualitative work to understand, and then address, the barriers to participation among farmers who have not yet participated, as well as reasons why participation varies from year to year. Key challenges include understanding how to incentivise farmers who have left the scheme to return, and developing a mechanism whereby farmers found to be non-compliant are allowed to return to the programme.

8.3 Adopt a new approach to adaptive management

The monitoring and evaluation system that was designed for WCS's work in the Northern Plains landscape was primarily created with the aim of evaluating the impact of conservation activities, including the three PES programmes. While this is a valuable exercise in itself and provides useful insights into how the various activities that WCS implements are performing, it does not provide a rigorous framework on which to base decisions about the most effective ways to improve how those activities are implemented. This is also connected to the challenge presented by conducting an RCT in a context where providing a clean sample (i.e. households who had never previously participated in the programme) of sufficient size is difficult. In both cases, a more suitable approach may be to adopt an iterative process of A/B trials in which incremental

adjustments to the standard implementation model for specific activities, most usefully the Ibis Rice programme, are randomly assigned to households in participating villages and compared to performance under the standard model. This would allow all Ibis Rice farmers to participate in each trial and provide more directly applicable information to WCS on how to direct the future implementation of the programme. Such an approach would need to be properly communicated to participating households, and the process followed transparent, to ensure that it would not cause resentment if the adjustment was deemed to be desirable.

Online appendixes

Online appendix A1: Household survey

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1045-Online-appendix-A1-Household-survey.pdf

Online appendix A2: Village survey

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1045-Online-appendix-A2-Village-survey.pdf

Online appendix B: Pre-analysis plan

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1045-Online-appendix-B-Pre-analysis-plan.pdf

Online appendix C: Balancing tables

https://www.3ieimpact.org/sites/default/files/2020-03/DPW1.1045-Online-appendix-C-Balancing-tables.pdf

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