Exploring trade-offs between development and conservation outcomes in Northern Cambodia

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Abstract

The success of conservation interventions often depends on the multifaceted and sometimes competing interests and motivations that lead local people to sustainably manage natural resources in the first place. Yet despite an extensive literature exploring the effects of conservation on human livelihoods, there is a lack of robust evidence about which type of conservation intervention works, for whom, and how. This is partly because the social impacts of conservation interventions often affect multiple aspects of human well-being, with changes taking place over long periods during which unintended feedbacks can occur. This paper assesses the medium-term impacts of Protected Areas (PAs) and of three Payment for Environmental Services (PES) projects on three socio-economic indicators across 16 villages in Northern Cambodia. We present a multi-period evaluation including three panel surveys over six years from villages inside and outside PAs to clarify the mechanisms through which social effects of conservation take place and how this translates into the development pathways adopted by households. While livelihood improvements were recorded across all villages, we found that PAs slightly reduce households' socio-economic status, though does not impede their development. PAs also protect traditional livelihoods. Participants in one of the three PES projects recorded higher economic status and agricultural productivity than non-participants, suggesting that there can be important social co-benefits to conservation interventions when programmes are well-designed to respond to local contexts.

Keywords: Protected Areas; PES; impact evaluation; rural development; objective well-being; Cambodia

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Highlights

- Long-term and landscape-scale studies are necessary to capture social effects of conservation
- We present a multi-period evaluation involving 16 villages inside and outside PAs
- PAs have slightly limited the increase in socio-economic status
- Yet PAs have successfully protected tenure security for traditional livelihoods
- Participants in one of three PES recorded significantly higher status

Assessing medium-term impacts of conservation interventions on local livelihoods in Northern Cambodia

1.1 Introduction

The effect of conservation interventions on human lives has long been a topic of contentious debate (Wells et al. 1992; Brockington & Wilkie 2015), continuing to this day as methods for assessing impacts constantly evolve (Baylis et al. 2015; Woodhouse et al. 2015) . There is an increased consensus among international policy circles that conservation should at very least 'do no harm' to the local populations affected by interventions (CBD 1992; IUCN World Parks Congress 2003, 2014), and a wide range of conservation interventions now aim at mitigating poverty, improving local livelihoods, and further, enhancing human well-being (Leisher et al. 2013; Milner-Gulland et al. 2014). Despite an extensive literature exploring the effects of conservation on human livelihoods, studies rarely point to clear cut arguments about net outcomes and often suffer from lack of methodological robustness (McKinnon et al. 2016; Oldekop et al. 2016). Credible evaluations of conservation interventions continue to be rare, especially with regards to recent mechanisms for conservation such as Payments for Environmental Services (PES) (Miteva et al. 2012; Pattanayak et al. 2010; Samii et al. 2014).

Conservation projects rarely operate in isolation, with spatially overlapping interventions often having disconnected, if not conflicting objectives (Pender et al. 2004; Scheidel et al. 2013). Teasing out heterogeneous effects within a fast-paced context featuring a myriad interventions at play is challenging partly because social changes take time to translate into observable household livelihood strategies (Baral et al. 2007). Despite these challenges, understanding heterogeneous impacts is

critical in order to determine which subsets of society benefit or incur costs from interventions.

Additionally, investigations of the depth, magnitude and distribution of the social effects of conservation must take a long term perspective over multiple time periods in order to identify differentiated impacts as well as potential unintended consequences; even after the intervention has ended (Pressey et al. 2015; Pullin et al. 2013). A landscape approach is necessary to identify the social impacts of interventions on different sub-groups within communities, and how these interacting effects vary geographically across multiple treatment and counterfactual sites (Agarwala et al. 2014; Pomeroy et al. 2011). Only by recognizing the different pathways through which livelihoods change within a broader socio-economic context can practitioners gain external and internal validation for projects and ultimately achieve both positive conservation and livelihood outcomes (Bottrill et al. 2014; Suich et al. 2015).

Recent research using quasi-experimental methods for rigorous scientific impact evaluation have provided new and promising insights on the social effects of different types of conservation interventions on local communities. Studies from Bolivia (Hanauer & Canavire-Bacarreza 2015), Cambodia (Clements & Milner-Gulland 2015), China (Samii et al. 2014), Costa Rica (Ferraro & Hanauer 2014; Robalino & Villalobos 2014), Indonesia (Gurney et al. 2014), Mexico (Alix-Garcia et al. 2015), Mozambique (Hegde & Bull 2011) and Thailand (Andam et al. 2010) point to conservation interventions having either no additional impact on local communities or making positive contributions to poverty mitigation, when compared to

counterfactuals. More importantly, these studies have underlined the importance of not only exploring whether conservation interventions are beneficial or detrimental to local livelihoods, but also of understanding the mechanisms through which these effects take place (Brockington & Wilkie 2015; Ferraro & Hanauer 2015).

Due to the novelty of applying quasi-experimental designs to evaluate conservation intervention impacts and the difficulty in applying such designs retrospectively, few studies have been able to provide a medium to long-term, landscape perspective on conservation issues (Ahmadia et al. 2015). In fact, most such studies to date still focused on indicators determined via a single metric of poverty (Liu et al. 2009), used recall data as baselines (Alix-Garcia et al. 2015), considered effects over a single time period (Hegde & Bull 2011), or over a small number of study sites (Gurney et al. 2015).

Here we present one of the first multi-period impact evaluation study including three panel surveys over six years, to explore how conservation interventions have impacted households' development pathways in the context of a dynamic socio-economic landscape, increasing general economic development, and environmental change. The project was first evaluated three years after inception by Clements & Milner-Gulland (2015), to measure the effects of Protected Areas (PAs) and PES projects on three socio-economic indicators of local livelihoods in Northern Cambodia. This study takes Clements & Milner-Gulland's (2015) evaluation of short-term social impacts of conservation interventions to the medium term, in order to clarify the mechanisms through which social effects take place and how this translates into the development pathways adopted by households.

We aim to answer the following questions: First, how has household socio-economic status developed in a landscape of fast land use change? Second, how does this vary for different groups between and within villages? Third, how much do conservation interventions, in terms of PAs and additional PES programmes, contribute to this change and on what time scales?

We first present an assessment of the effects of PAs on three socio-economic indicators in Northern Cambodia over two three-year time periods between 2008 and 2014. We use quasi-experimental and mixed methods to estimate the changes in household economic status, rice harvests and rice surplus, in villages inside PAs compared to villages outside PAs across the landscape. We then focus on a set of four core villages that have been the focus of PES activities since 2008 to assess the additional effect of PES on the three socio-economic indicators.

1.2 Study site

Cambodia has seen a series of fast-moving societal, political and economic transitions from the onset of the Khmer Rouge in 1975 and throughout the 1980s, when reconstruction post-Khmer Rouge begun under the scrutiny and choreography of international interveners (Hughes 2003). These changes meant that Cambodia went from command economy to free-market economy, from war to peace, from authoritarian rule to democracy (Chandler 1998; Kent 2006; Hughes & Un 2011). More recently, Cambodia has experienced rapid economic progress and globalization over the past decade (Mah 2015). Despite a sharp reduction in 2009, Cambodia's GDP has been growing at nearly 7% between 2008 and 2014, along

with an average annual population growth rate of 1.7% between 2000 and 2013 (ADB 2015; World Bank 2013). Government figures show that the national poverty more than halved between 2004 and 2011. But despite its economic growth and heavy overseas development aid, Cambodia still only ranks 138th on the Human Development Index, with a low GDP per capita at US$1,020 in 2014 (Sobrado et al. 2014) and an estimated 20% of its population living under the poverty line (CIA, 2013). Twenty-nine percent of its population lives in urban areas, the remaining 71% living in rural areas and depending primarily of on agriculture for their livelihoods (NIS 2014).

Government policies to promote development include infrastructure improvements such as road and communication networks, as well as the promotion of agri-industrial developments through the granting of land for Economic Land Concessions (ELCs). Disputes have arisen specifically around unfair eviction of local communities from their land and the patchwork pattern of ELCs granted over high value forests and protected areas, thus affecting local livelihoods (Bues 2011; Hor et al. 2014; Ullenberg 2009). Due to a continuing lack of transparency in the granting of ELCs, the mechanism has been implicated as primarily serving the interests of elite wealth accumulation through land grabbing for high value timber logging, rather than the intended provision of development and agricultural goods (Neef & Touch 2012; Biddulph 2010; Vrieze & Naren 2012; Un & So 2011). In fact, Cambodia has recorded the fifth highest rate of deforestation worldwide between 2000 and 2012 (Hansen et al. 2013), primarily due to land grabbing and illegal logging (Beauchamp et al. in review.; Davis et al. 2015). These macro development drivers are often felt

disproportionately in rural areas, where trade-offs from environmental depletion can hinder human development (LICADHO 2009; Scheidel et al. 2013).

The Northern Plains of Cambodia is a landscape located in the province of Preah Vihear along the border with Thailand and Lao (Figure 1). It is one of the largest remaining areas of deciduous Dipterocarp forest and is considered an area of high biodiversity interest (Myers et al. 2000; O'Kelly et al. 2012). The core and contains two Protected Areas (PAs): Kulen Promtep Wildlife Sanctuary (KPWS) managed by the Ministry of Environment (MoE) and Preah Vihear Protected Forest managed by the Forestry Administration (FA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF). While PVPF was declared in 2002, KPWS was established in 1993 as part of Cambodia's first protected area network.

[Figure 1]

Since 2005, international non-governmental organisation the Wildlife Conservation Society (WCS) has assisted the MoE and FA's conservation efforts in both PAs (Clements & Milner-Gulland 2015). Additionally, three PES programmes were instituted to complement PA management in a number of villages: a bird nest protection programme, a premium payment scheme for eco-friendly rice (Ibis Rice), and an ecotourism programme. The three PES schemes were designed in response to a high level of threat where conservation opportunity costs, at least for conversion of forest lands, were also moderately high (Clements et al. 2010). PES have been defined as a voluntary, conditional agreement between at least one "seller" and one "buyer" over a well-defined environmental service — or a land use presumed to

produce that service (Wunder 2007). In this study, we consider that the three PES projects provide the maintenance of natural forests as an environmental service (Samii et al. 2014).

Ecotourism projects have been established in three villages to date: the most prominent one of which started in 2005 in Tmatboey, followed by the second project established in Dongplat in 2008, and the last in 2010 in Prey Veng (Clements et al. 2010; Clements 2012). The three sites contain the presence of high profile target species, such as the Giant Ibis, to attract international bird watchers. The ecotourism programme aims to conserve the globally threatened wildlife by establishing local village-level tourism that directly links the revenues received from tourists to the preservation of the species' habitat.

The Ibis Rice scheme started in the four core villages of Tmatboey, Dongplat, Prey Veng and Narong in 2008. This programme was designed as a more viable option for large-scale replication across the Northern Plains, compared to the restricted number of ecotourism opportunities possible. The scheme has now been expanded to 11 villages. Under this agri-environment payment programme, farmers who keep to local land-use planning rules and the no hunting rules of the PA are allowed to sell their rice at a higher rate than the traders' price through to the third party marketing organisation Sansom Mlup Prey (SMP) through a village-level committee responsible for the management of the land-use plan.

Last, the bird nest protection programme, which started in 2003 and is now implemented across over 24 villages, provides small direct payments (up to 5

USD/day) to local villagers who report and protect the nest of a specific endangered bird species during nesting period (Clements et al. 2013). The endangered bird species found in the Northern Plains are particularly vulnerable to human disturbance and particularly the collection of nests for eggs and chicks by local people for consumption and trade (Clements et al. 2013). This programme was designed to rapidly locate, monitor and protect nesting sites around villages, providing a small direct payment to individuals who would report and successful protect the nests until the chicks fledge as an alternative incentive.

Implementing PES in the context of weak institutions can be difficult (Wunder 2007), thus both the ecotourism and Ibis Rice projects worked towards strengthening local village institutions and land rights, for example by developing Participatory Land Use Plans (PLUPs) against which compliance is measured (Clements et al. 2010; Clements et al. 2014; Travers et al. 2014). In each PLUP village, a locally elected Community Protected Area (CPA) committee manages the compliance to rules for participating households and oversees that these rules are respected around the village. For example, Ibis Rice payments to individual farmers are linked to CPA monitoring of their compliance with the land-use plan and no-hunting rules, with external verification by WCS.

Households across the landscape are subsistence farmers whose livelihoods revolve around small-scale rice farming, with additional non-timber forest product harvesting and fishing around villages. Collecting liquid resin from Dipterocarp trees has also traditionally been an important livelihood in Northern Plains' communities (Rainey et al. 2010; Clements et al. 2014). Resource use rules within the protected area under

Cambodian law allows local uses such as NTFP collection, although forest clearance, commercial logging, and hunting or trade in threatened species are illegal. Villages are however permitted by PA authorities to expand agriculture to a limited extent within agreed land-use plans.

1.3 Methods

1.3.1 Survey design

This analysis first investigates the effects of PAs on households living within PAs, compared to households living in matched non-PA villages, and second explores the effects of PES programmes in a sub-set of villages within PAs. The survey design is based on the original study of Clements & Milner-Gulland (2015), using co-variate matching at the village level to establish counterfactuals from a 2005 pre-intervention baseline. Matching is used in quasi-experimental designs to control for sources of bias by ensuring that intervention and control groups are comparable in all aspects except that the controls have not received the intervention (Rosenbaum & Rubin 1985). This design uses four key factors characterizing village-level poverty and environment prior to the initiation of the PAs in 2005: forest cover within 5 km of the village, village size, and distances to roads and markets (Clements 2012). Five villages that were located at least 20 km away from the PA border, to control for spillover effects, were selected for the counterfactual to 11 villages in PAs. The PES projects have been implemented at different scales across the 11 PA villages, four of which have been the focus of higher conservation activities by WCS and are considered in this paper for the subset of PES models.

Causal inference in impact evaluation rests on the comparison of outcomes in an intervention with a relevant counterfactual (Ferraro 2007). However it is rare that all control and treatment units would have evolved with similar trends apart from the intervention over a medium-term period in a dynamic environment. We thus combine covariate matching with difference-in-differences (DiD) estimation to increase confidence that this assumption is met in the current analysis (Abadie & Imbens 2011). We use post-matching regressions to further control for additional non-observable factors influencing the socio-economic indicators and to disaggregate influential factors at the household level, allowing the inference from the treatment of PA and PES interventions. While the PA intervention is applied at a regional level, PA rules affect socio-economic status at the household level and the PES interventions are applied at the household level; justifying the need for a household level analysis. This approach was used instead of matching at the household level for two main reasons. Firstly, although data on the socio-economic indicators were available in 2008 from our baseline survey prior to PES start, households had not yet signed up to the PES programmes. Thus it wasn't possible to conduct a matching at the household level in the baseline year. Secondly, this would have required data on every single household in the village across all villages, which would have been logistically unfeasible to collect.

A qualitative scoping research phase was conducted prior to the latest re-assessment to validate the content of the forthcoming household survey questionnaires and to justify the selection of the most important covariates correlating with the socio-economic outcomes (Steiner et al. 2010). For example, participant observation was used to legitimise the list of Basic Necessity Survey

items and services used to create a localised index of socio-economic status. From these personal observations and prior research, hypotheses on the macro and micro factors that have influenced livelihoods and well-being in the landscape since 2008 were developed. Both the 2008 baseline survey and the 2011 repeat assessments identified that livelihood strategies were significant factors influencing the socio-economic development of rural subsistence farmers of the Northern Plains, suggesting that two main pathways out of poverty; agricultural modernization or livelihood diversification. Thus assets and farming practices were also deemed critical variables to explore in this study, along with key household and village-level demographic factors such as education, household size, and gender of head of household.

Availability of productive land is central to livelihoods for most families in rural Cambodia. Based on the baseline survey, prior research and the qualitative scoping phase, household socio-economic status is expected to be higher outside PAs in comparison with inside PAs (Clements & Milner-Gulland 2015). This is because land expansion within PAs is controlled, whereas outside PAs there has been a recent rush by local people to acquire land resources, driven by a decrease in land availability due to population growth and competition with ELCs (Dwyer 2015). Because households have different levels of access to and use of natural resources, effects are also expected to vary according to the type of livelihood strategy a household follows, as well as their original socio-economic status at the start of the study. Households practicing traditional livelihoods such as resin tapping and shifting agriculture are expected to have lower socio-economic status than families that have mechanized and intensified farming by practicing both rice paddy farming and

shifting agriculture (Clements et al. 2014). It is also expected that families that have diversified away from agriculture into non-farm activities due to land unavailability, for example selling labour, will be more prominent outside PAs and have lower status than households with a large land base (Scheidel et al. 2014).

1.3.2 Data collection

Survey data were collected for a longitudinal panel of households in 2008, 2011 and 2014 across the 16 villages identified through matching. In 2008, a total of 709 households were interviewed across the 16 villages included in this analysis; 889 were surveyed in 2011; and 944 in 2014, to account for the increasing number of participants in the PES projects (Figure 2). The resulting panel household dataset contains 596 household interviewed across all three time periods, 173 of which are located in the four core PES villages.

[Figure 2]

All research protocols were approved by Imperial College Research Ethics Committee before the start of the research. Prior and informed consent was acquired at every survey. Before each interview, the purpose of the research and content of the interview were explained. Participants were informed they were not obliged to participate, that they could stop the interview at any point, and that all their answers would be kept anonymous. Due to low levels of literacy, participants gave their verbal consent to continue. Interviews were coded and family names were only known to the main researchers for the purpose of data collection. To avoid strategic bias in responses and reduce conflict of interest, the survey team was recruited and

operated independently of WCS and the research group was clearly introduced as independent social researchers. Surveys were implemented by Cambodian research assistants and supervise by the lead researchers who also spoke Khmer for the purpose of this research.

1.3.3 Variables

Economic status was calculated using the Basic Necessities Survey (BNS) methodology, which incorporates multiple aspects of poverty into a single score for each household in the sample (Davies & Smith, 1998; Pro-Poor Centre & Davies, 2006). This method uses a locally-derived list of assets and services to assess the level of local livelihoods by weighting which items respondents classify as basic necessities (BN) that “everybody in the village should have, and nobody should go without” among the presented list (Wilkie 2007). The economic status of individual households is then calculated as the product of how many items within the list a household possesses and the weighting of that item.

Perceptions of what a BN is vary over time, potentially influencing the modelled effect of change between years through the weighting used to calculate scores. As an extreme example, having a mobile phone was considered a BN by 32% of the households interviewed and owned by 12% in 2008, whereas 93% considered it to be a BN and 75% owned one in 2014 (see Appendix 4). Density plots comparing BNS weighting show only minor differences when applying the 2008 versus the 2014 weightings. This paper thus uses the 2014 BNS weights retrospectively as it accounts slightly better for variance between households.

While poverty indicators are one of the key measures used to assess social development in impact evaluations, it is recognized that economic proxies do not often reflect all of people's priorities (Stiglitz et al. 2009). This study thus assesses the effect of conservation interventions on two further objective socio-economic indicators: agricultural productivity and rice surplus. Agricultural productivity is measured in total annual rice harvest in kilograms, rice being the primary diet and source of income for Cambodian subsistence farmers. Rice surplus comprises all rice sources (harvested, bought, received) and deducts annual food requirements for the household, which are measured by multiplying stated daily rice requirements during the surveys. Analysing rice surplus allows to capture a potential path of differentiation in livelihoods; for example shop owners may divest from agriculture yet be able to buy rice from alternative incomes.

The diversity of actors and sectors at play in Cambodia's development make it difficult to assert that one variable is paramount to the socio-economic transformations in rural households (Naron 2011). This paper considered academically and empirically supported theories of change to characterize the causal mechanisms driving socio-economic rural transitions in fast-paced land use change patterns (Miteva et al. 2012). These hypotheses guided our data collection and the selection of the explanatory variables included for quantitative modelling in order to explore links to rural transitions in the Northern Plains. The content of the 2014 survey thus included original items from the 2008 and 2011 surveys, to ensure consistency in measuring medium-term outcomes, and other variables hypothesized to contribute to changes in socio-economic status identified from scoping insights

and recent literature. Linear transformations were used by adding a constant to variables to avoid negatives values.

1.3.4 Statistical analysis

We first used DiD methods on a longitudinal panel of households in matched villages inside and outside PAs to assess the effects of being within a PA (the treatment) on changes in household economic status, agricultural productivity and rice surplus between 2008 and 2014 (Gertler et al. 2011). The dataset consisted of the value of each variables for the same household at the three time points, formatted into a 'long format' to support panel analysis. We tested for the effect of time and treatment by modelling time as a dummy variable, which accounts for the baseline status of households (Walter et al. 1987). Accounting for confounding factors in a post-matching regression further improves the attribution of the effects to the intervention versus other external elements occurring at a similar temporal and spatial scale (Andam et al. 2008). After controlling for other factors, a significant interaction between treatment and time indicates that the PA had an effect on the response variable. Conversely, a non-significant interaction and a significant treatment effect would indicate that the response variable differed significantly between within PA and outside PA villages, but that this was not due to the presence of the PA, because the difference didn't change over time and was present before the intervention began.

We then used DiD models to assess the effect of PES participation on the same response variables within a reduced longitudinal dataset of four core villages within

the PAs where the PES programmes have been in place since 2008. Participation in the PES schemes varied over time, we thus measured participation separately for the two time periods. We modelled it as time variant binary variables of whether or not a household participated in each PES programme for at least a year between 2008 and 2011, and then between 2011 and 2014. The approach of DiD and controlling for other confounding factors through multivariate modelling was deemed superior to matching at a household level between the four villages for this analysis. This is because of the small number of villages involved in the analysis, all of which were very different, thus matching may induce correlation across observations even after controlling for treatment status and covariates in the study designs (Hanson & Sunderam 2012). For example, matching two households of the same absolute wealth between two villages in which the average wealth and socio-economic context was very different would not represent a fair comparison. Model selection was done as for the full dataset models.

For both model types, *a priori* predictor variables were included to control for exogenous trends as well as endogenous household and village-level factors hypothesized to contribute to changes in response variables (Appendix 1). We explored results for different types of livelihood strategies, in order to interpret pathways of impacts across different types of household. Impact attribution cannot be established at the level of confounding factors, yet inference from regression correlations about the non-treatment conditions associated with the measured changes can still be drawn if livelihood strategies are relatively similar across the landscape studied, as in this case. Explanatory variables were tested for collinearity before their inclusion in the model and their distribution was examined to determine

transformations of skewed variables. Village was included as a random effect to reflect the nested structure of the data (Colin Cameron & Miller 2015; Maas & Hox 2004).

Full models were first formulated, then backward selection of supported variables was done with AICc values calculated using maximum likelihood, removing variables and interactions that did not improve the model with an AICc > 4 until all variables contributed to the model above that threshold. Models were checked by plotting residuals against fitted values and using QQ-plots to examine the normality of errors as well as examining the residual variance of the random effect. Modelling was done in R version 3.2.2 using package lme4 (Bates et al. 2014).

1.4 Results

1.4.1 Change in socio-economic indicators over time

Average economic status, rice harvest and rice surplus all improved considerably in the surveyed population between 2008 and 2014 (Table 1). Average economic status in the PA villages was significantly higher than in non-PA villages at all three survey times, however the average economic status within PAs rose by 34% while villages outside PA saw a 50% improvement between 2008 and 2014. Higher rice harvests and higher rice surpluses were also found on average in PA villages compared to villages outside PAs in both 2008 and 2014.

[Table 1]

Other characteristics and livelihood strategies of households within PAs varied significantly from households living outside PAs at each survey time. Household heads tended to be older and more educated in PA villages, yet within similar average household sizes. All villages had rice farming as the dominant livelihood, with 100% of the panel households practicing rice farming in 2014. Households outside PAs were also more likely to practice shifting cultivation in 2008 and 2011, but this practice decreased overall by 2014. This coincided with an increasing number of households having over one hectare of paddy land outside PAs by 2014, almost reaching the level seen amongst PA households.

With increased land holdings, households were able to switch from shifting agriculture to more intensive and productive practices of rice and cash crop farming. Cash crop farming saw a substantial increase in uptake across the landscape, with the percentage of PA households practicing it tripling by 2014.

While PA households still had a higher number of resin-tappers, numbers fluctuated, producing a decrease in tappers below 2008 levels by 2014. In parallel, non-traditional livelihoods such as selling labour and providing services also increased between 2008 and 2014. Selling labour was more likely to be undertaken as a livelihood strategy by families outside PAs, while families within PAs had a higher employment rate in 2011 and 2014, most likely due to hiring of local villagers for conservation activities (Clements et al. 2014).

Improvements in the three socio-economic indicators was seen for both the highest and lowest economic status quintiles in the sample (Appendix 2). However, the

richest quintile improved their economic status, agricultural productivity and rice surplus at a faster rate than the average population, and almost 50% faster than the poorest quintile. More families within the richest quintiles included additional livelihoods over the period, with the exception of there being a decreasing number of shifting agriculture farmers. By 2014, 97% of richer families owned at least one hectare of rice land and almost half were still resin tapping. Cash crop farmers were twice as numerous in 2014 and employment rates tripled since 2008. Richer households were more likely to own a shop and provide a service, to own a mini-tractor and a higher number of cattle, and to be involved in all three PES programmes. While the poorest quintile also increased the number of livelihoods undertaken since 2008, both the absolute values and rates of change were lower. In 2014, only 54% of the poorest quintile owned over one hectare of rice land and more families tended to practice shifting agriculture and sell labour compared to the population average.

1.4.2 Factors driving medium-term changes in socio-economic indicators

Absolute values show the average economic status of households in PAs is significantly higher across years when compared to outside PAs, yet increases in economic status were higher outside PAs (Table 1). After controlling for other factors in the DiD post-matching regression, the presence of a PA slightly slowed household economic status over the study period, when compared to households outside PAs (Table 2). However, the effect of PAs over the six-year period is relatively small compared to other factors influencing change in economic status; household characteristics, livelihood strategies and village-level factors such as years of schooling.

Larger, more educated, and more agriculturally productive households tended to have higher economic status and agricultural productivity. Households that had transitioned to mechanized agriculture and owned a mini-tractor as well as one hectare of rice land further had higher agricultural productivity, especially if they practiced both shifting and paddy rice farming.

However, female-headed households recorded lower economic status across years. Households living in villages where a higher level of education was available were further advantaged while villages located far away from the provincial capital were in a more disadvantaged position. Families that either provided a service or owned a shop in the village had higher economic status, followed by those who were employed or farmed cash crops. Resin tapping households saw lower economic status overall, but within PAs the status of resin tappers was higher than non-resin tappers.

[Table 2]

With regard to rice harvests, a similar trend appears; while absolute values for agricultural productivity were higher within PAs, PA households correlated with lower rice harvests between 2008 and 2011. The effect of being within a PA is however not significant between 2011 and 2014, nor does it influence results between the different rice farmer types over the 2008-2014 period.

Being in a PA had no significant effect on rice surplus over time. The overall effect of being in a PA is therefore limited to slightly reducing the average economic status between 2008 and 2014, with the exception of it benefitting resin tapping households, and to reducing agricultural productivity between 2008 and 2011, relative to non-PA villages outside the PAs.

1.4.3 PES participation

Panel data for the four core PES villages included 173 households or 41% of the total panel dataset.

[Table 3]

More households joined the Ibis Rice and the Bird Nest programme between 2008 and 2014, while the number of families involved in ecotourism slightly decreased. Ibis Rice had a large and increasing number of households from 2011 to 2014, with 25% of the overall panel households involved for more than one year (Table 3). The ecotourism programme had a higher proportion of participating families being involved for more than one year, most likely because, once trained, households were more likely to continue to participate.

Between 2008 and 2014, both the ecotourism and the Ibis Rice programmes included at least four times more families in the richest quintile than in the poorest quintile (Appendix 2). Participants in each of the PES programmes had greater economic status, agricultural productivity and rice surplus when compared to non-participants in the respective project across villages for both the 2008-11 and 2011-

14 periods (Appendix 3). In similarly-sized households, families involved in all three PES programmes were more likely than non-participants to be more educated, to own a shop and to provide a service. A greater number of the PES participating families owned mini-tractors and had more livestock in average. Non-participants were generally more likely to practice shifting agriculture and sell labour. Average annual payments per participating household were the highest for Ibis Rice participants and increased during the second period.

1.4.4 Additional effect of PES on changes in household livelihoods

After controlling for other factors, households involved in the Ibis Rice programme improved their economic status and their agricultural productivity faster than non-participants between 2008 and 2014 (Table 4). However, there are no significant effects of the Ibis Rice programme on economic status and rice harvest for the earlier 2008-11 time period, which suggests the benefits from participation may have taken some time to trickle down into well-being improvements. The ecotourism and the bird nest programmes showed no significant effect on changes in economic status, rice harvest or rice surplus.

[Table 4]

A number of trends appear across both the full panel and the PES subset models. Providing a service and owning a larger number of cattle were associated with improvement in all three socio-economic indicators. Owning one hectare of rice land increased a household's agricultural productivity and rice surplus models, while households that were not practicing both paddy and shifting cultivation agriculture

experienced lower improvements. Lastly, female-headed households and households located in a village far from the provincial capital had reduced socio-economic improvements, while the opposite was true for households with greater rice harvests and for cash crop farmers across the landscape analysis and within the PES villages. The prevalence of effects related to the livelihood strategies undertaken by families at both the landscape and PES scales of analysis, rather than treatment effects, highlights that despite a higher level of conservation activity in the four PES villages, other micro and macro elements still prevailed as the primary drivers of and barriers to change in development pathways in the study area.

1.5 Discussion

1.5.1 Livelihood diversification and agricultural intensification over two time periods

From the 2008 baseline survey, Clements et al (2014) had hypothesized that rural subsistence farmers of the Northern Plains would follow one of two main pathways out of poverty; agricultural modernization or livelihood diversification. From the repeat assessment in 2011, Clements & Milner-Gulland (2015) concluded that mechanization of agriculture was underway, yet differences between livehood strategies remained between households within and outside PAs. The current analysis further confirms the importance of micro and macro development factors driving socio-economic change both inside and outside PAs, pointing to a homogenization of lifestyles across the landscape, influenced by better roads, access to markets and increase in trade across Preah Vihear province.

Differences remain in the livelihood strategies adopted inside and outside PAs, but these gaps are narrowing. This is due to an intensification and modernization of

agricultural practices and to a pronounced diversification from traditional livelihoods into labour-based activities. The general increase in mini-tractor ownership and the move away from rice shifting cultivation practices across the landscape illustrate these trends. The divestment away from traditional livelihoods into nonfarm activities was probably fuelled by an increase in roads providing access to markets and goods, facilitating the movement and marketization of labour as well as the desirability of direct cash payments in preference to the commodification of non-agricultural resources such as cattle and liquid resin.

These trends however did not affect all groups within communities similarly; an increasing discrepancy between the livelihood status of the top and bottom economic status quintiles can be observed between 2008 and 2014. The top quintile was most likely to undertake both mechanization and diversification at the same time, while the poorest families showed limited improvements in all three indicators. This suggests families with enough assets could invest in a mini-tractor, thus increasing yields, and in turn both income and rice surplus. The additional income, as well as time freed up by mechanisation, enabled their entry into new livelihoods. Conversely, households unable to acquire enough natural, livestock or agricultural resources to launch an alternative livelihood or mechanize their agricultural practices remained in a poverty trap. The bottom quintile was more likely to practice shifting agriculture and to sell labour, which potentially provides an alternative stepping stone out of poverty to agriculture - a strategy expected as a response to shortage of land (Scheidel et al. 2014).

1.5.2 Livelihoods pathways inside vs. outside Protected Areas

This analysis demonstrated that PAs in the Northern Plains have slightly reduced increases in economic status and agricultural productivity for households between 2008 and 2014, when compared to households outside PAs. However this is based on changes in 2011-14, with no significant effect being recorded for the first period 2008-11. This is similar to Clements & Milner-Gulland's (2015) impact evaluation results from 2011, and is unsurprising as Cambodian PAs are primarily designed to protect ecosystems from external drivers of loss and do not aim to improve communities' livelihoods. In turn, the greater change experienced in villages outside PAs between 2011 and 2014 can be explained by the lack of constraints on household land expansion, combined with the pressure for households to acquire and develop new land before other competing actors or ELCs appropriate it (Scheidel et al. 2013; Rudi et al. 2014).

Despite this, conservation interventions have not prevented households from developing livelihoods to provide routes out of poverty, as increases in all three outcome variables was recorded across the landscape. In fact, PAs have successfully provided tenure security for resin trees and allowed resin tappers to improve their economic status, unlike resin tappers outside PAs who appear comparatively disadvantaged. The importance of resin to household economies in Cambodia has been well documented (Evans et al. 2003; Clements et al. 2014). However the lack of formal tree tenure, the time-consuming nature of resin-tapping and the lack of centralized markets for its resale may have contributed to an overall move away from practising tapping, especially outside PAs.

The measured change in economic status may be partly explained by the fact that BNS scores do not increase linearly with improvements in household wealth. In Cambodia, a large number of the items used in the BNS menu are relatively cheap to buy or easy to access. It was therefore relatively easy for a household to move from a low to a medium score. By contrast, at the upper end of the scale the items were usually very expensive or hard to obtain, for example a house made of concrete. Consequently it is harder for a household to move further up the scale. A related consequence is that decreases in scores are easier to detect, thus suggesting that our results are a conservative, non-inflated measure of change in livelihood status. Therefore, the lower wealth status of households in PAs may partly be due to the fact they already had higher BNS scores on average in 2008. However the fact that the agricultural productivity and rice surplus results are similar to the economic status results gives confidence that the observed effects are real.

1.5.3 Additional benefits of Ibis Rice programme

Households involved in the Ibis Rice programme improved their economic status and agricultural productivity more than non-participants in the same villages between 2008 and 2014, while the ecotourism and Bird Nest programmes showed no significant effect. There is no sign of any of the three programmes impacting household livelihoods negatively.

The fact that Ibis Rice's impacts are most significant in the 2011-2014 period is possibly a case of benefits taking time to be converted into lifestyle gains. Continued investments by WCS in the Ibis Rice project have also contributed in the growth of

the scheme. This supports the idea that longevity is key in achieving integrated conservation and development goals (Baral et al. 2007; Liu et al. 2009).

This analysis supports the contention that there can be important social co-benefits to conservation interventions when programme design is well thought out and local conditions are favourable (Pagiola et al. 2005; Clements & Milner-Gulland 2015). In fact, while the primary goal of Ibis Rice is to reduce the conversion of important forest and wetland habitat for several globally important populations of endangered bird species to agricultural use by smallholder farmers, it also delivers benefits to participants' livelihoods. Although PES programs are designed to change behaviour by compensating participants for at least the opportunity cost of the constraints of their activities (Wunder 2007), the perceived risk of altering livelihood strategies might still hinder marginal households' participation. This study suggests that the extent of Ibis Rice's economic impact is more limited due to the reduced opportunities for the poor to participate, an outcome observed by other quasi-experimental evaluations of the impacts of PES on household welfare (Hegde & Bull 2011; Liu et al. 2009). Yet this study points to PES as a form of institutional innovation that can provide access to development opportunities for villagers.

1.5.4 Long-term sustainability of the conservation programme

Given Cambodia's economic development rate, improvements in infrastructure and trade at the local and national levels, overall increases in socio-economic well-being were to be expected. The presence of PAs has not hindered these improvements, and the PES schemes seem to have enhanced it on some dimensions thus

supporting the potential of achieving win-win outcomes. But are these conservation interventions sustainable?

Findings from this study point to two themes issues related to fairness and social inclusion that must be addressed in order for the PES programmes to be effective and sustainable in the long-run. Firstly, the lack of inclusion of the poorest households in the current PES schemes is problematic as material improvements resulting from interventions are unlikely to achieve improved well-being if wealth inequalities aren't addressed (Dawson & Martin 2015). The inaccessibility of PES projects for poorer segments of communities has been noted in other quasi-experimental evaluations (Alix-Garcia et al. 2015; Hegde et al. 2015; Liu et al. 2009). Thus, interventions must find a way to lower the opportunity costs of participating so they become more accessible (Milder et al. 2010). For example, the Ibis Rice project could allow for pro-poor 'positive action' by including participation quotas for poorer households (Grieg-Gran et al. 2005). Along with lower costs of participation through better technical assistance, such as facilitating access to mini-tractors, this could effectively attract poorer families to participate in the scheme. However, pro-poor inclusions should not disincentivise other families, nor distort the conditionality of the delivery for the environmental services, a point which has been shown to be an important factor in changing behaviour for conservation purposes (Nilsson et al. 2016; Sommerville et al. 2009).

Secondly, a key objective for the long-term viability of both the Ibis Rice and ecotourism programmes must rest on empowering local communities to strengthen their governance and institutions, to combat the weak governance of Cambodian

land management institutions. The main goal of the Northern Plains' PES programmes is to protect targeted species of endangered birds by avoiding the conversion of their habitats around villages, and through direct nest protection.(Clements et al. 2010). The attribution of the successful environmental protection achieved is blurred due to the multiple interventions at play in the villages, which are monitored and implemented by the same village entities and often started at similar time. Arguably, this is one of the strengths of the overall Northern Plains programme, which provides both individual and collective incentives for conservation. Continued efforts towards capacity-building and awareness raising should be a focus of the programmes, with the ultimate aim of local communities autonomously managing resources and the conservation programmes as a sustainable development pathway (Brooks et al. 2013; Lambrick et al. 2014; Fry et al. 2015; Porter-Bolland et al. 2012).

1.5.5 Unexpected external drivers of change

Understanding to what extent conservation affects human well-being in the context of wider socio-economic change, how, and for whom, requires the use of methods that allow the attribution of changes in well-being to the intervention versus other confounding factors; exploration of the causal linkages enabling the pathways to occur, as well as consideration of the heterogeneity of effects within the subgroups studied (Porro et al. 2015; Woodhouse et al. 2015). However social change takes time to transform into new livelihood habits. This can take years to unfold, and unintended feedbacks can occur on these long timescales.

Despite the strength of currently deemed ‘gold standard’ impact evaluations for attributing change to interventions (Pattanayak 2009), quasi-experimental designs can become inadequate reflections of the realities of rural transitions, as mechanisms of change and development pathways are dynamic, heterogeneous and unpredictable. In the case of the Northern Plains, the widespread granting of ELCs has affected the mechanisms of land use change over the six years considered in this study and the different villages have potentially diverged onto different livelihood pathways due to this. The reality of shifting baselines due to unpredictable and dynamic change leads one to question the long-term appropriateness of using quasi-experimental designs to evaluate social impacts. In fact, the attribution of impacts to interventions can be largely inflated without further controlling for other factors such as livelihood strategies in post-matching regressions (Honey-Rosés et al. 2011).

Thus the statistically established ‘control’ villages used in the short term evaluation cannot still be considered as such, as the design violates the assumption that no other factors affect the treatment and control except for the intervention itself (Rosenbaum & Rubin 1985). Using post-matching regressions that further control for village-level factors and household characteristics across time allows support for the associations between impacts and conservation interventions (Honey-Rosés et al. 2011). By exploring the sub-group variations we were additionally able to uncover the detail of drivers of rural transitions, such as the mechanization of agriculture and diversification of livelihoods into labour-based activities. While these inferences are not based on household-level matches, we were able to verify the assumption that village-level characteristics and trends affected sub-groups similarly in both

treatment and counterfactual villages through in-depth qualitative research (Beauchamp et al. in review). To a certain extent, it is questionable whether matching at such disaggregated levels, which can only be done on observable factors, would be a resource-efficient way of documenting pathways of development at the scale of this study (Camfield & Duvendack 2014; Harrison 2014). That said, not matching at the household scale means concerns remain around the selection bias of the surveyed households which may overstate the effects of the treatment. For example, households participating in PES tend to be wealthier and in turn acquire wealth more rapidly.

1.5.6 Quantitative rigor in the face of dynamic changes

Despite the problem of maintaining statistically robust counterfactuals over long periods of time, re-assessing the study villages will be essential to unearth the varying time scales over which different impacts take effect, and whether the socio-economic improvements recorded in this study can be sustained. Four points should be taken into accounts by future assessments to examine the robustness of long-term quantitative evaluation methods that emerge from this study. Firstly, future impact evaluations should test the difference in results from matching with the same covariates using different baselines, to ensure the validity of control villages in re-assessments. In this case, the original matching with a 2005 pre-intervention baseline should be compared with matching results with later datasets to ensure covariate means remain balanced before continuing with the current survey design (Stuart 2010). If this is the case, it is certain that interesting results would stem from an evaluation of the nine year, four time-point dataset; yet the sample size of a longitudinal dataset such as this is bound to be constantly decreasing.

Secondly, new horizons for evaluations should focus on comparing results between original designs against a design with a new set of covariates, which would mirror the developments that have occurred along years. For example, a survey design based on pre-2011 intervention levels could take into account ELC presence, or a measure of development pressures at the village level such as connectivity, which would provide a more accurate picture upon which conservation intervention attribution could be based. Adjusting evaluation baselines can allow the better capturing of effects along series of “evolving snapshots” rather than aiming to statistically attribute long-term impacts, which may be impossible or even undesirable (Rogers & Peersman 2014). Longitudinal panel research remains useful to test if development pathways have evolved as theorised; but evaluations should pay close attention to assessing not just the impacts of interventions, but also confidence in attributing impacts and their related mechanisms against historical baselines in changing socio-ecological systems (Befani & Mayne 2014; Ton et al. 2014).

Third, given the challenges experienced using quantitative evaluations of social impacts over long-term periods, it is necessary to complement any quantitative assessment with contextualised exercises. For example, exploring attitudes and perceptions of local communities towards the conservation interventions can provide important insights into understandings of the social impacts and ecological outcomes of conservation, of the legitimacy of conservation governance and the social acceptability of the intervention (Bennett 2016). Diversified social assessments using mixed and qualitative methods that focus on the participation of communities can

provide a solution to discrepancies between research results and realities, and can supply the continuous evidence required for adaptive management at reasonable cost (Armitage et al. 2012; Young et al. 2006).

Last, the deforestation analysis done by remote sensing for the 2008 to 2011 impact evaluation (Clements & Milner-Gulland 2015) must be continued to track the environmental impact of the PAs and PES jointly (Blackman 2013). This will allow considering the trade-offs in outcomes between the multi-dimensional aspects of human well-being and natural resources (Miteva et al. 2012; Samii et al. 2014). Characterizing such trade-offs is essential to fully capture the impacts of the Northern Plain programme when considering that additional income in subsistence communities can lead to increased intensive land-uses and deforestation in isolated areas (Alix-Garcia et al. 2013).

1.6 Conclusions

Given its initially matched survey design and the number of iterated assessments, the Northern Plains of Cambodia represents a site of global importance to follow long-terms trends in the social effects and mechanisms of conservation interventions, as well as to test current and future best practice methodologies in impact evaluation. This case study shows that the PAs in the study site were not detrimental to households' economic development, and that well-designed PES programmes can bring additional livelihood pathways for rural economies amidst a complex and dynamic social and economic landscape. Longer term monitoring of this site will allow understanding of whether the currently minor limiting effect of PAs on economic status will further constrain well-being improvements in PAs, despite

the increasing presence of development. Alternatively, the resource protection offered could provide a longer term and more sustainable basis for pathways out of poverty compared to resource depletion from the rush to resources occurring outside PAs; hence increasing the resilience of households living in PAs against external shocks. Whether conservation interventions can protect households from land shortages while stimulating sustainable development pathways and protecting nature in the presence of strong external drivers is still an open question.

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Tables & Figures

Table 1: Household characteristics and livelihood strategies for a panel of 596 households within and outside PAs between 2008 and 2014. Tests of difference applied to compare variable values for households in PA villages against non-PA villages at each year.

	Control			PA			Test of difference (PA vs. non-PA)		
	2008	2011	2014	2008	2011	2014	2008	2011	2014
Households	177	177	177	419	419	419			
Household Size	6.0	6.1	5.8	5.8	6.0	5.9	ns	ns	ns
Working Adults	3.0	3.2	2.9	3.2	3.3	3.3	ns	ns	*
Dependency Ratio	1.1	1.1	1.1	1.0	1.0	1.0	ns	.	*
Household head age (yrs)	38.3	40.6	42.8	42.1	44.3	46.4	***	***	***
Household head education (yrs)	2.0	2.0	2.7	3.4	3.4	4.0	***	***	***
Female-headed households (%)	6	5	11	7	7	10	ns	ns	ns
Livelihood variables									
Economic status	7.9	11.5	11.8	9.5	12.1	12.8	***	.	**
Rice harvest (kg)	1305	2355	2802	1879	2554	3325	***	ns	*
Rice surplus (kg)	-628	1140	1302	-228	1375	1532	***	ns	ns
Livelihood strategies									
Resin tapper (%)	31	41	28	58	63	54	***	***	***
Rice farmer (%)	95	95	100	91	97	100	ns	ns	ns
>1 ha of paddy fields (%)	63	79	80	74	85	85	*	.	ns
Mini tractor (%)	27	37	69	30	61	74	ns	***	ns
Rice shifting cultivation (%)	46	40	20	37	26	16	*	***	ns
Cash crops	18	10	24	4	2	12	***	***	***
Employed (%)	3	4	6	6	9	15	ns	.	**
Service provider (%)	2	28	36	3	25	42	ns	ns	ns
Shop owner (%)	13	8	6	14	9	8	ns	ns	ns
Sell labour (%)	1	44	58	3	33	46	ns	*	*
Cattle (number)	3.52	4.11	1.84	4.89	3.63	2.43	***	ns	*

Table 2. Parameter estimates from the final regressions on panel dataset (596 HHs) of the effect of predictor variables on changes in household a) economic status; b) rice harvests; and c) rice surplus, 2008 and 2014. Significance values: 'ns' = non-significant; '.' = P <0.1; '*' = P <0.05; '' = P <0.01; '***' = P <0.001. Shaded variables in the economic status model were excluded from the analysis as they were items calculated within the BSN score.**

	A) Economic status		B) Rice harvest		C) Rice surplus	
(Intercept)	2.19	*	13.09	***	74.58	***
Time and treatment interventions						
Time 2008-2011	2.11	***	11.39	***	11.88	***
Time 2008-2014	2.30	***	14.63	***	12.45	***
PA interventions	0.40	ns	5.90	*	1.87	ns
PA interventions * 2008-2011	-0.58	ns	-5.84	***	-1.71	ns
PA interventions * 2008-2014	-0.65	*	-2.91	ns	-1.43	ns
PA interventions * Resin-tapper	1.09	***				
PA interventions * Shifting cultivation only			3.83	ns	0.63	ns
PA interventions * None			-3.28	ns	-3.33	ns
PA interventions * Rice paddy only			-0.42	ns	0.08	ns
Household characteristics						
Household size	0.65	***	3.23	**	-5.85	***
Nbr working adults			1.59	***	0.61	**
Household head education	0.43	***	1.68	***	1.17	***
Female-headed household	-0.93	***				
Rice harvests (kg)	0.06	***				
Livelihood strategies						
Resin-tapper	-0.56	*				
Owning over one hectare			5.07	***	2.61	***
Rice farmer type: shifting cultivation only			-16.21	***	-5.60	**
Rice farmer type: None			-38.38	***	-8.52	***
Rice farmer type: Rice paddy only			-3.38	*	-1.93	*
Cash crop farmer	0.56	*				
Employed	0.99	***				
Selling labour			-3.28	***	-1.72	**
Service provider	1.14	***	3.76	***	2.11	***
Shop owner	1.71	***	2.52	*		
Owning mini-tractor			-1.42	ns	-0.29	ns
Cattle (heads)	0.16	***	0.61	***	0.36	***
Owning one hectare * Owning mini-tractor			9.72	***	3.90	**
Village characteristics						
Distance from provincial capital	-1.18	***				
Years of schooling in the village	1.11	***				
% residual variance from RE						
Village	13.48%		10.71%		8.86%	

Table 3: Comparison of participation of panel households in PES programmes between all PA villages (11 villages, 419 HHs) and core PES villages (4 villages, 173 HHs) for 2008-11, and 2011-14.

	Core PES villages		All PA villages	
	2008-11	2011-14	2008-11	2011-14
Households	173	173	419	419
Ecotourism				
Participant households	64	59		
% of total panel households in subset of villages	37%	34%		
Households participating for >1 year	37	41		
Average annual payment per participating household	101	119		
Ibis Rice				
Participant households	52	83	52	105
% of total panel households in subset of villages	30%	48%	12%	25%
Households participating for >1 year	24	48	24	55
Average annual payment per participating household	234	289	234	254
Bird Nest				
Participant households	18	14	18	27
% of total panel households in subset of villages	10%	8%	4%	6%
Households participating for >1 year	4	3	4	4
Average annual payment per participating household	53	69	53	66

Table 4. Parameter estimates from the regressions on the subset panel households from four core PES villages (173 HHs) of the effect of predictor variables on changes in household a) economic status between b) rice harvests, and c) rice surplus, between and 2008, and 2008 and 2014. Significance values: 'ns' = non-significant; '.' = P <0.1; '*' = P <0.05; '' = P <0.01; '***' = P <0.001.**

	A) Economic status		B) Rice harvest		C) Rice surplus	
(Intercept)	12.11	***	-69.24	ns	36.83	ns
Time and treatment interventions						
Time 2008-2014	0.31	ns	17.33	**	15.07	***
Time 2008-2011	0.44	ns	24.65	***	15.09	***
Ibis Rice * 2008-2011	-0.17	ns	-1.64	ns	2.87	ns
Ecotourism * 2008-2011	0.80	ns	-4.36	ns	-3.59	ns
Bird Nest * 2008-2011	-0.01	ns	-1.70	ns	1.45	ns
Ibis Rice * 2008-2014	0.70	.	5.12	*	0.55	ns
Ecotourism * 2008-2014	-0.27	ns	2.33	ns	1.97	ns
Bird Nest * 2008-2014	0.05	ns	1.53	ns	0.71	ns
Household characteristics						
Household size			7.19	***	-4.71	***
Nbr working adults						
Household head age: mature			2.81	.		
Household head age: aging			3.18	.		
Household head education					1.55	**
Female-headed household	-1.69	***				
Rice harvests (kg)	0.07	***				
Livelihood strategies						
Owning over one hectare			7.12	**	3.37	*
Rice farmer type: shifting cultivation only			-17.12	**	-7.60	*
Rice farmer type: None			-46.21	***	-15.42	***
Rice farmer type: Rice paddy only			-7.24	**	-4.69	**
Cash crop farmer	1.05	**				
Employed						
Selling labour			-4.35	**		
Service provider	1.02	***	5.47	***	2.56	*
Shop owner	1.23	***				
Owning mini-tractor			7.07	***	3.40	**
Cattle (heads)	0.14	***	0.52	***	0.31	***
Village characteristics						
Distance from provincial capital	-2.85	***	17.81	*	6.35	ns
Years of schooling in the village			12.42	ns	6.57	ns
Distance from market			8.28	.	4.68	.
Random effect	Var	SD	Var	SD	Var	SD
Village	0.43	0.65	64.25	8.02	10.64	3.26

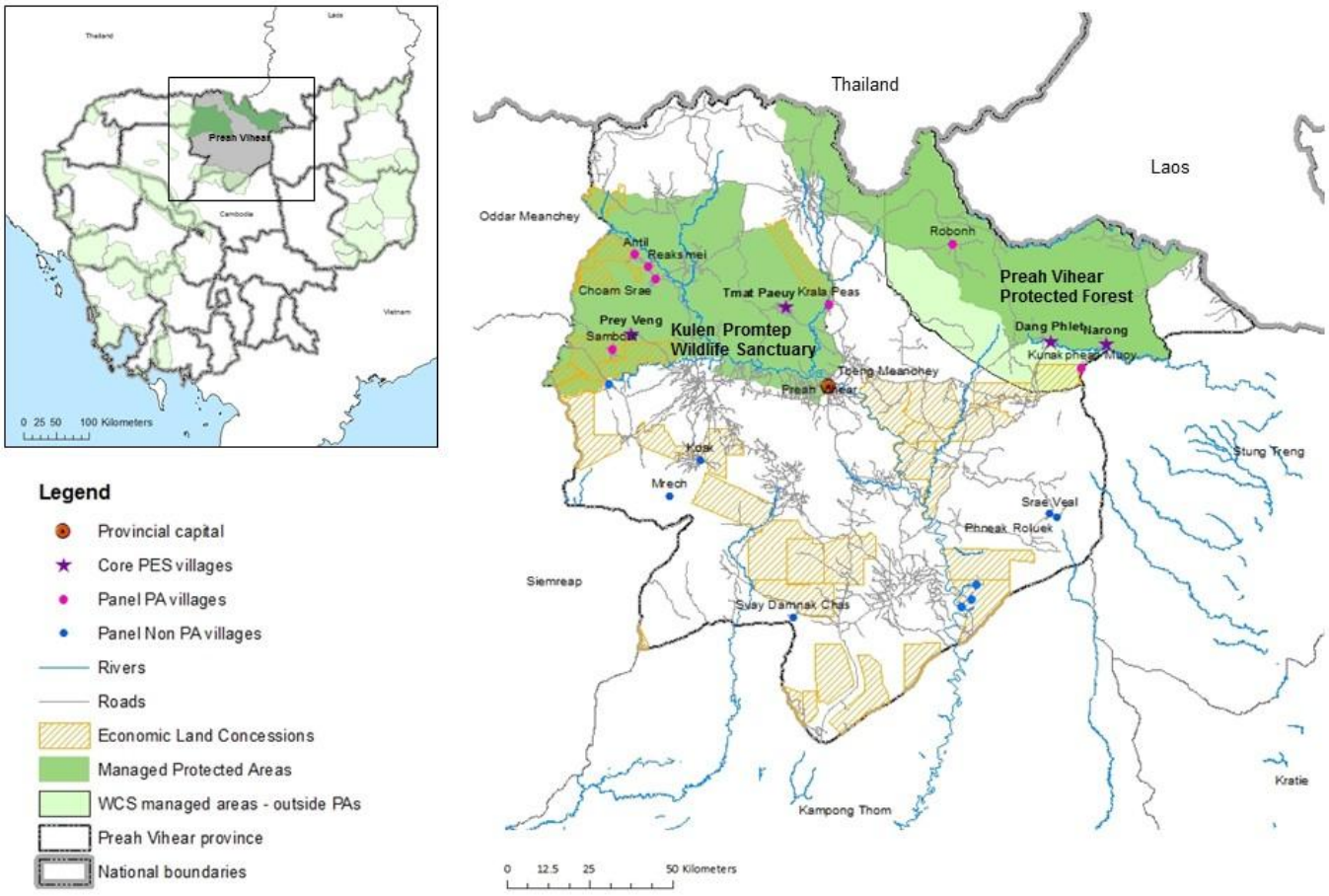

Figure 1: Map of the surveyed villages across the province of Preah Vihear

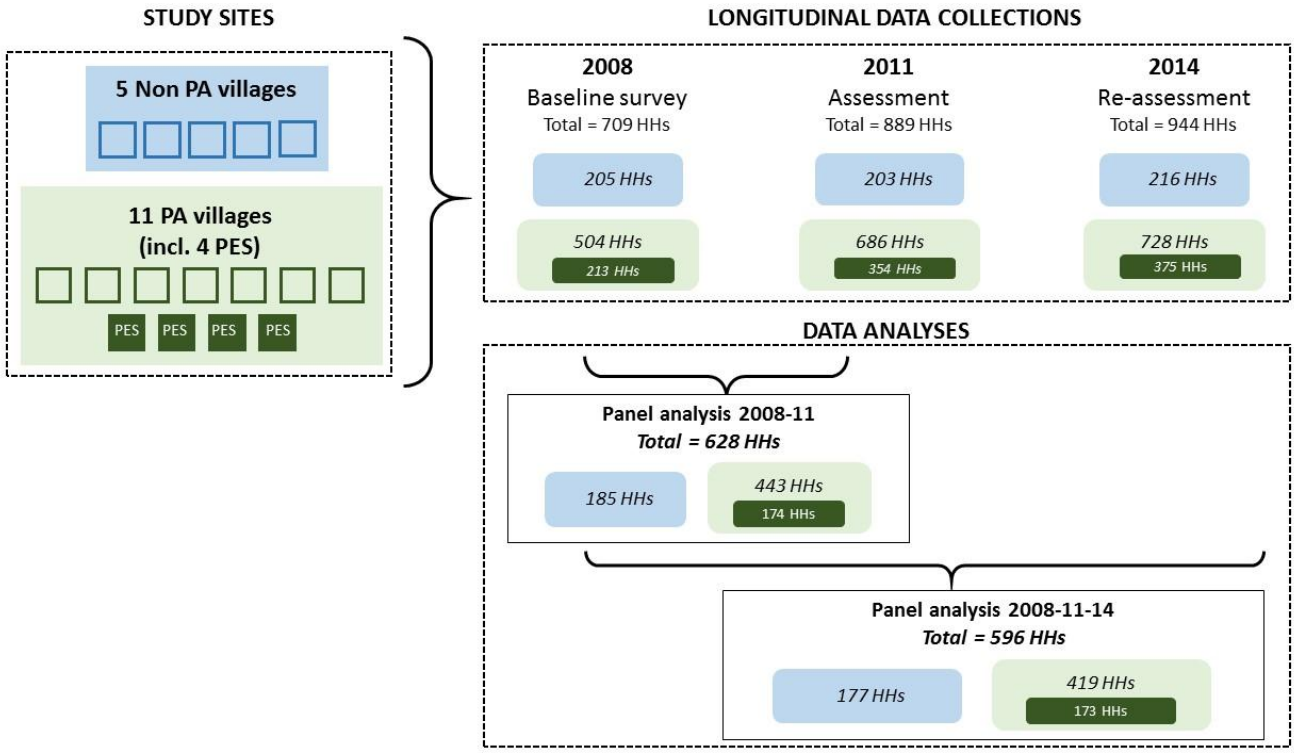

Figure 1: Number of households interviewed in 2008, 2011 and 2014 and number of panel households across treatment type included the panel analyses. The five non-PA villages are indicated in white boxes and the 11 PA villages are indicated in light grey boxes, within which the four core PES villages are indicated in dark grey boxes.

Appendix 1: *A priori* variables included in full model for selection. Variables inputted as time-variant between 2008, 2011 and 2014 except for Protected Area treatment which remained time-invariant.

Variables	Description & comments	Type	Transformed	BNS models	Rice harvest models	Rice surplus models
Wellbeing variables (responses)						
Poverty (BSN score)	BSN score (2014 weights applied retrospectively)	Continuous		N/a	N/a	N/a
Rice harvest (kg)	Total rice harvest (paddy & shifting cultivation).	Continuous	(sqrt +1000)	√	N/a	N/a
Rice surplus (kg)	Rice surplus = Total rice collected (harvested & bought) - annual household rice requirements	Continuous	(sqrt +5000)	N/a	N/a	N/a
Treatment level						
Intervention PA		Binary: 0: Non-protected area; 1: Protected area		Panel dataset models only		
PES participation						
Participation in Ibis Rice	Involved in project at least one year between 2008-14	Binary - Yes/No		PES subset models only		
Participation in Ecotourism	Involved in project at least one year between 2008-14	Binary - Yes/No				
Participation in Bird Nest	Involved in project at least one year between 2008-14	Binary - Yes/No				
Household characteristics						
Household size	Total number of members	Continuous	(sqrt +1)	√	√	√
Female headed household		Binary - Yes/No	(sqrt +1)	√	√	√
Working adults	Working adults = (children<15 yo + elders>60 yo)	Continuous	(sqrt +1)	√	√	√
Household head education	Maximum level of education achieved by the household head across 2008-11-14	Continuous	(sqrt +1)	√	√	√

Household head age	Factorized into 3 category referencing a 1) new household; 2) a mature household; 3) an aging household	Categorical: 1: HH age < 35 2: HH age 35-55; 3: HH age >55		√	√	√
Household Livelihood Strategies						
Own >1 hectare	Owning more than 1 hectare of rice land; included in BNS menu	Binary - Yes/No			√	√
Resin-tapper		Binary - Yes/No		√	√	√
Rice farmer		Binary - Yes/No		√	√	√
Cash crop farmer		Binary - Yes/No		√	√	√
Rice farmer type		Categorical: 0: Both 1: Paddy only; 2: Shifting cultivation only (chamkar); 3: None		√	√	√
Employed	Employed by either private, NGO or public sector (army service excluded)	Binary - Yes/No		√	√	√
Service provider	Service provider (rice threshing & milling excluded)	Binary - Yes/No		√	√	√
Shop keeper		Binary - Yes/No		√	√	√
Sell labour		Binary - Yes/No		√	√	√
Household Assets						
Own mini-tractor	Owning more a mini-tractor; included in BNS menu	Binary - Yes/No			√	√
Number of cattle heads	Number of adult cattle owned	Continuous		√	√	√
Village level variables						
Village Population Size	Number of households in village	Continuous	(sqrt +1)	√	√	√
Years of schooling in the village	Top year of school available in village	Continuous	(sqrt +1)	√	√	√
Time to provincial capital (hours)	Dry season time to travel to Tbeng Meanchey	Continuous	(sqrt +1)	√	√	√
Time to market	Dry season time to travel to nearest full day market	Continuous	(sqrt +1)	√	√	√

Appendix 2. Household characteristics and livelihood strategies for the average, top and bottom quintiles of the panel of 596 households between 2008 and 2014.

	All			Bottom Quintile			Top Quintile		
	2008	2011	2014	2008	2011	2014	2008	2011	2014
Households	596	596	596	120	120	120	118	118	118
Household Size	5.9	6.0	5.9	5.4	5.7	5.0	6.3	6.4	6.4
♯ Working Adults	3.1	3.3	3.2	3.0	3.1	2.5	3.2	3.4	3.5
Household head education (yrs)	3.0	3.0	3.6	1.7	1.8	2.2	4.0	4.0	4.5
Household head age (yrs)	41.0	43.2	45.2	41.4	43.5	44.4	40.9	43.4	45.4
Female-headed households (%)	6.7	6.0	10	16.7	13.3	25.0	1.7	2.5	4.2
Wellbeing Variables									
Poverty	9.0	11.9	12.5	6.7	9.2	7.3	11.1	14.3	16.8
Rice Harvest (kg)	1708	2495	3170	1018	1482	1443	2236	3172	4866
Rice surplus (kg)	-347	1305	1464	-777	409	656	-61	1902	2352
Livelihood strategies									
Resin-tapper (%)	50	56	47	39	45	33	51	53	49
Rice Farmer (%)	92	97	100	86	93	100	94	96	100
Have >1 hectare of paddyfields (%)	70	83	84	47	74	58	83	91	97
Rice Shifting Cultivation (%)	39	30	17	51	43	18	23	16	15
Cash crop (%)	8	5	16	5	2	8	11	8	22
Employed (%)	5	7	12	0	2	3	9	15	27
Service (%)	14	9	7	5	4	1	25	18	10
Shop (%)	2	26	40	2	12	18	3	45	61
Sell labour (%)	2	36	49	8	48	68	1	25	37
Household Assets									
♯ Cattle (heads)	4.5	3.8	2.3	2.4	1.9	0.8	7.8	6.7	4.7
Mini-tractor (%)	29	54	72	16	26	29	38	78	94
PES participation (08-11 / 11-14)									
Ecotourism participant (%)		11	10		5	6		28	24
Ibis Rice participant (%)		9	18		3	7		11	36
Bird Nest participant (%)		3	5		0	7		41	4

Appendix 3. Comparison of household characteristics and livelihood strategies between participants and non-participants in the three PES programmes within the core PES villages (4 villages, 173 HHs) for 2008-11, and 2011-14.

	Ecotourism				Ibis Rice				Bird Nest			
	2008-11		2011-14		2008-11		2011-14		2008-11		2011-14	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Households	121	52	90	83	109	64	114	59	155	18	159	14
Household Size	5.9	6.2	5.9	5.9	6.0	6.1	5.9	6.0	6.0	6.2	6.0	5.0
♯ Working Adults	3.2	4.0	3.3	3.3	3.1	4.0	3.3	3.5	3.4	3.7	3.3	3.1
Household head education (yrs)	3.6	4.2	3.9	4.8	3.3	4.7	3.9	5.2	3.7	4.4	4.3	4.9
Household head age (yrs)	43.1	45.8	47.3	46.4	43.5	44.6	47.0	46.6	43.9	43.9	46.7	48.6
Female-headed households (%)	6.6	1.9	10.0	7.2	5.5	4.7	9.6	6.8	5.2	5.6	9.4	0.0
Wellbeing Variables												
Poverty	12.2	14.4	13.5	14.5	12.3	13.9	13.9	14.2	12.8	13.5	14.0	13.9
Rice Harvest (kg)	1276	2466	1705	2250	1625	1648	1817	2256	1566	2213	1945	2208
Rice surplus (kg)	2461	3753	3743	4991	2798	2937	4049	4907	2787	3384	4330	4472
Livelihood strategies												
Resin-tapper (%)	68	62	66	43	68	63	61	42	66	61	53	71
Rice Farmer (%)	95	100	100	100	96	97	100	100	96	100	100	100
Have >1 ha of rice field (%)	94	96	91	95	95	94	92	95	94	100	93	93
Rice Shifting Cultivation (%)	8	2	8	4	6	6	5	7	7	0	6	0
Cash crop (%)	3	8	17	11	6	2	18	7	5	6	14	7
Employed (%)	7	17	12	27	7	16	13	31	10	11	18	29
Service (%)	5	15	7	10	6	13	6	12	8	11	8	14
Shop (%)	14	40	34	51	17	31	41	44	21	28	43	36
Sell labour (%)	31	25	38	43	22	41	41	39	30	22	39	57
Household Assets												
♯ Cattle (heads)	3.7	7.6	2.7	3.6	4.0	6.4	2.7	4.0	4.9	5.2	3.2	2.6
Mini-tractor (%)	61	85	76	90	64	75	77	93	68	72	82	86

Appendix 4: Changes in Basic Necessity (BN) weightings between 2008 and 2014. Blue cell = decrease; pink cells = increase.

Items	2008 Is it BN?	2008 Have it?	2014 Is it BN?	2014 Have it?
>90% think are BN and >80% of people have				
Have 3 meals per day	100.00%	86.60%	95.10%	86.90%
Have at least one long knife	96.90%	86.90%	99.40%	93.50%
Have at least one big axe	98.20%	84.20%	99.70%	95.80%
Able to pay for health care without selling any property (chronical disease is not included)	99.90%	94.50%	95.00%	34.40%
>90% think are BN and between 50-80% of people have				
Have mosquito nets for all household members	99.40%	59.90%	99.30%	87.30%
Have at least one big water jar (300-500litres)	99.40%	60.70%	98.20%	75.30%
Have a wooden-wall house	99.70%	57.70%	96.40%	75.50%
Have a big homestead land (20mx40m=800m2)	99.90%	68.80%	99.00%	75.00%
Have at least 1ha rice cultivated land	99.90%	70.00%	96.50%	87.70%
>90% think are BN and between 30-50% of people have				
Have at least 2 big traction animals	97.70%	34.90%	79.30%	17.90%
Have thick blankets for all household members	99.90%	42.60%	81.70%	38.80%
Have a zinc house roof	93.20%	41.70%	96.50%	76.30%
Able to buy at least 2 sets of new cloth for each of all household members per year	97.90%	31.80%	96.20%	68.00%
>90% think are BN and between 0-30% of people have				
Have one hand pump well at home	91.20%	2.00%	73.70%	4.90%
Have access to taxi service from village to provincial town	90.60%	6.10%	61.30%	23.50%
Able to send children to school at least at grade 7	97.40%	15.60%	96.50%	28.10%
Having access to vaccination service for cattle regularly	95.80%	20.20%	78.10%	10.80%
Between 80-90% think are BN and between 0-30% of people have				
Have a battery (for lighting or TV)	80.60%	18.30%	95.00%	82.70%
Have a mini-tractor	89.20%	28.70%	98.20%	67.70%
Have one motobike	89.90%	28.00%	95.80%	53.40%
Able to participate in at least 10 weddings per year	82.50%	9.20%	78.70%	45.90%
Between 50-80% think are BN and between 0-10% of people have				
Have one toilet at home	75.90%	0.70%	67.00%	2.30%
Have one wooden wardrobe	69.00%	0.60%	10.10%	0.80%
Not Basic Necessities				
Between 30-50% think are BN				
Able to access electricity for using in the village	45.80%	3.90%	37.90%	1.30%
Have a TV	37.20%	10.00%	19.20%	6.40%
Have a VCD player	31.50%	9.10%	25.20%	32.70%
Have a mobile phone	31.90%	12.40%	92.80%	74.50%
Having access to clean water supply service	40.30%	0.50%	29.20%	0.50%
Able to initiate at least one ceremony per year	30.10%	2.60%	40.00%	7.80%
Between 0-10% think are BN				
Able to holiday for at least one week per year for tourism outside the	5.10%	0.80%	1.20%	0.50%
Have a gas cookstove (gas: 147kg)	5.20%	0.10%	1.00%	0.90%
Have health insurance for all household members	0.20%	0.00%	12.10%	0.90%
Having a concrete wall house	3.70%	0.10%	1.00%	0.50%
Have an electric rice cooker	2.30%	0.00%	0.50%	0.40%
Have a fridge	1.60%	0.00%	1.00%	0.40%
Added items				
Have a big fan using electricity (2011 & 2014			1.90%	0.60%
Have solar panels at home (2014)			26.40%	5.80%
BNS maximum score	21.44		20.7	