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Working Paper No. 95–15

REDD+ Impacts: Evidence from Nepal

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Published by the South Asian Network for Development and Environmental Economics (SANDEE)
PO Box 8975, EPC 1056, Kathmandu, Nepal.
Tel: 977-1-5003222 Fax: 977-1-5003299

SANDEE research reports are the output of research projects supported by the South Asian Network for Development and Environmental Economics. The reports have been peer reviewed and edited. A summary of the findings of SANDEE reports are also available as SANDEE Policy Briefs.

National Library of Nepal Catalogue Service:

Bishnu Prasad Sharma, Subhrendu Pattanayak, Mani Nepal, Priya Shyamsundar, and Bhaskar S. Karky
REDD+ Impacts: Evidence from Nepal

(SANDEE Working Papers, ISSN 1893-1891; WP 95–15)

ISBN: 978-9937-596-26-8

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August 2015

South Asian Network for Development and Environmental Economics (SANDEE)
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Contents

Abstract

Reducing emissions from deforestation and forest degradation (REDD and REDD+) is an international mechanism for mitigating climate change impacts. The ambitiously designed architecture that makes REDD+ win-win for high emitting developed countries and forest rich developing countries has led to high hopes and expectations as well as a fear of failure. However, we do not as yet know if and whether REDD+ would succeed. This paper discusses the findings from one of the first rigorous quasi-experimental studies using a 'before-after-control-intervention' design that encompass all major aspects of REDD+: forest carbon and bio-physical, ecological, livelihood and welfare. The analysis of the outcome indicators from two years of REDD+ incentive payments indicate that there are positive signs of improved forest condition for carbon additionality and livelihood improvements, while no harm has been done to local livelihoods, which is generally feared in REDD+ literature. Although there is no change in forest carbon components in REDD+ communities compared to controls, important changes are observed in ecological indicators such as reduction in forest fires, timber extraction and encroachments that could contribute to carbon enhancement in the future. We find a decline in the share of firewood in household cooking that is consistent with the observed increase in biogas, a cleaner and convenient renewable energy source. These findings support the broader sense that REDD+ initiatives must and can work in tandem with other global initiatives (e.g., ENERGY + and the Sustainable Development Goals), in this case, indicating that a shift to biogas fuel could improve livelihoods and ensure REDD+ success in Nepal.

Keywords: sustainable forest management, forest carbon, livelihood, REDD+ impact

REDD+ Impacts: Evidence from Nepal

1 Introduction

Climate change is real and its consequences are growing in terms of extent and intensity (Stern 2007; IPCCC 2012). Reducing Emissions from Deforestation and Forest Degradation (REDD and REDD+, where "+" stands for conservation, sustainable management, and enhancement of forest carbon stocks) has emerged as a leading near-term option to mitigate the impacts of climate change (Sills et al. 2014). Carbon effectiveness, cost efficiency and equity and co-benefits, generally referred to as the 3E+s are the core markers of REDD+ success (Angelsen et al., 2008, 2009).

In view of REDD+'s potential to be the world's largest payment for eco-system services (Corbera 2012), there has been an unprecedented flow of global resources directed at REDD+ readiness, experiments and activities. However, very little evidence exists on whether REDD+ can be successful (Caplow et al. 2011; Visseren-Hamakers et al. 2012; Sills et al. 2014). Evidence on both bio-physical and social outcomes of REDD+ pilot projects, including counterfactual scenarios, is much needed (Corbera and Schroeder 2011).

In this context, we present findings from one of the first field-based studies where payments were made to the forest user communities to conserve forest carbon. Our objective was to understand whether REDD+ incentive payments can simultaneously improve forest carbon, ecological and socio-economic outcomes. We used a quasi-experimental design, comparing REDD sites to matched control sites to account for observed differences between REDD sites and control sites (Sunderlin et al. 2010; Sills et al. 2014). Double differencing was used to deal with time-invarying ("fixed") unobserved differences, whereas matching addresses the selection on observables. Our results after two years of intervention (2011 – 2013) provide outcomes in three dimensions – forest carbon, forest ecology, and household welfare.

Our results suggest no impact on the forest carbon pool. However, we see that REDD+ payment motivates communities to change forest management behaviors that address important drivers of deforestation and forest degradation in Nepal, such as forest fires and illegal logging. We find improved ecological outcomes such as reductions in forest fires, forest encroachment and timber extraction and an increase in grass cover, and wildlife sightings; all of which might change the carbon profile over the longer run. The household data indicates an increase in the households adopting biogas for cooking, and associated reduction in firewood use.

This article is structured as follows. Section 2 describes the background to the study and the site, section 3 discusses the methods used in the study, section 4 discusses our findings, and section 5 features a discussion and some conclusions.

2. Background and Study Site

REDD+ has emerged as a potential climate change abatement measure, given its projected relatively low carbon enhancement cost (Gupta 2012). Forest-rich developing countries have a heightened expectation of selling forest environmental services for an attractive carbon price, while developed countries with high emissions hope to address climate change impacts quickly and effectively at a cheaper mitigation cost (Angelsen et al. 2012). For instance, Stern (2007) estimated the cost of avoiding deforestation in high deforestation areas at approximately US$ 1–2 per tCO2 on average. These expectations have initiated REDD+ piloting experiments worldwide (Caplow et al. 2011; Sills et al. 2014).

Nepal represents an interesting setting for innovative forest research and experimentation partly because of its pioneering success in implementing decentralized and community-based forest management since the early 1980s (Ives and Messerli 1989; Brockhaus and Gregorio 2014). Strategies identified via years of learning from community managed forests can contribute to designing REDD+ initiatives (Agrawal and Angelsen 2009). These experiences indicate that forest management regimes with more local power to govern forests can ensure greater forest stocks and carbon, alongside improvements in livelihoods (Chhatre and Agrawal 2009). Policymakers concerned with REDD+ initiatives can learn from community forest management both from a production efficiency and equity point of view. This is because community forestry is associated with achieving more equitable social outcomes at lower costs (Agrawal and Angelsen 2009; Cronkleton et al. 2011).

Though the share of tropical forest with carbon and high deforestation potential is not very large in Nepal (unlike in Brazil or Indonesia (Murdiyarso et al. 2012)), successful conservation activities in Nepal's forestry sector make it an attractive pilot for the REDD+, rather than REDD. Further, it is important to incorporate countries with smaller forest areas into REDD+ initiatives to ensure that diverse vulnerable carbon stocks, with their associated biodiversity, ecosystem services and co-benefits, are protected (Phelp et al. 2010a). For all these reasons, REDD+ is now a high priority program for the Government of Nepal. The Government signaled its interest in implementing REDD+ by locating the REDD Implementation Centre, the lead institution to undertake REDD+ readiness, directly under the Ministry of Forests and Soil Conservation.[1]

While there are multiple forms of forest management regimes in Nepal,[2] community forests are managed through Community Forest User Groups (CFUGs). In 2011, more than 15,000 community forest user groups encompassing 1.8 million households managed 1.35 million hectares of forest and shrub-land. Thus, 23% of the country's forest area was managed via community forestry, with 33% of the total households in the country being their members (CBS 2011; MOF 2011). Management committees (called Executive Committees), elected through a democratic system of voting, manage these forests, with roles and responsibilities assigned by the community forestry guidelines of the Government of Nepal. The guidelines require representation of Dalits,[3] indigenous groups, women and the poor on Executive Committees. The Federation of Community Forest Users Nepal, an umbrella association of community forest user groups in the country, advocates for the rights of these user groups in all 75 districts of Nepal. This institutional architecture makes Nepal a worthwhile location for experiments in REDD+.

As a part of REDD+ preparation in Nepal, several REDD+ pilot projects have been implemented (MFSC/RFCCC 2011), including a pilot titled "Design and setting up of a governance and payment system for Nepal's Community Forest Management under REDD+", which was implemented from 2011 to 2013.[4]The project made performance-based incentive payments to forest communities for three consecutive years. Instead of being based purely on forest carbon increments, pilot payments were based on weights assigned to the baseline carbon stock, annual carbon growth, and social safeguard components (Shrestha et al. 2014).[5] These payments, with associated guidelines and capacity building, were expected to enhance user groups' capacity to undertake forest management and livelihood improvement activities effectively (MOFSC/RFCCC 2011). We were fortunate to initiate an evaluation of this payment scheme at the design stage – thereby ensuring that we could collect baseline data in both REDD+ and matched control sites early in the process.

The study area was located in three districts: Dolkha, Gorkha and Chitwan, which represent three separate ecological regions, the mountains, mid-hills and the plains. The treatment communities were the community forest user groups (CFUGs) near by the three watersheds covered by the project. These watersheds, the Charnawati in Dolkha district, Ludikhola watershed in Gorkha district and Kayarkhola watershed in Chitwan district, cover a total area of over

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1 The REDD Implementation Centre, created in 2014, was formed by restructuring the REDD Forestry and Climate Change Cell (REDD Cell) established by the Government of Nepal in 2009 as a focal point for co-ordinating and carring out REDD+ readiness activities (Bushley and Khatri 2011; MFSC 2015).

2 Nepal practices other forms of community-based forest management as well such as leasehold forestry, collaborative forestry and buffer-zone forest management in areas adjoining protected areas.

3 The Dalits were deprived groups of people traditionally considered untouchable.

4 The Project was conducted by ICIMOD in partnership with the Asia Network for Sustainable Agriculture and Bio-resources (ANSAB) and the Federation of Community Forest Users, Nepal (FECOFUN). The carbon baseline for the project was conducted in 2010. The intervention in the form of REDD+ incentive payments started in 2011.

5 The carbon incentive and safeguard criteria accordingly assigned weights: forest carbon stock constituted 24% while the carbon increment above baseline was assigned 16% weight. The remaining 60% weight was distributed among indigenous households (10%); Dalit households (15%); poor households (20%); and (15%) female population in the community.

10,000 ha of community-managed forests, involving more than 18,000 households. The intervention covered 58, 31 and 16 forest user groups respectively, making a total of 105 forest user communities across the three districts.

3. Methodology

3.1 Research Design

We applied a quasi-experimental impact evaluation design by combining matching with the Difference-in-difference approach (Pattanayak 2009). The method, also labeled the Before-After-Control-Intervention (BACI) approach, has been used for conducting REDD+ evaluations by research groups such as CIFOR (Sunderlin et al. 2010). Under this approach, we first identified comparable control sites for each REDD+ community forest user group (CFUG) using propensity score matching (see for example Somanathan et al. 2009). Next, we collected data on all CFUG activities from both the treatment and the control communities before and after the intervention, noting that only the treatment communities conducted REDD+ pilot program activities.[6] The actual data collection for matching is described below.

The intervention program comprised of activities directed towards reducing deforestation and forest degradation for emissions reduction and enhancing carbon stocks. Thus, it included activities such as forest carbon monitoring, awareness raising and capacity building. Activities were directed at improving local livelihoods, the use of alternative fuel and cooking technologies, income generation and poverty reduction, among others. Institutional structures such as Program Management Units, Watershed Fund Advisory Committees, and the Watershed REDD+ Network were created for effective guidance and monitoring of program activities from the central to district and local levels. These structures were represented by various stakeholders and civil society organizations and they contributed towards creating a 'real-life' scenario for the pilot experiment (CFRP/N 2011; Shrestha et al. 2014). These activities were expected to bring about changes in the forest carbon, ecology, forest dependence and livelihood outcomes. The control communities served as counterfactuals to what would have happened without the intervention.

3.2 Sample Selection

In order to select comparable matching non-project communities, we conducted a rapid appraisal of 84 communities collecting data from 14 project and 14 non-project communities in each of the three districts to develop a pool of potential CFUGs for the evaluation. Following Sunderlin et al. (2010) and we identified 26 indicators related to community characteristics such as forest dependence, NGO presence, road access for matching. After checking for completeness and collinearity of indicators, the final set of matching variables included 11 variables (see Table 1). For instance, the area of the community forest and the number of households were converted into a density measure – i.e., number of households per hectare of community forest.

The matching was conducted on a covariate (Mahalanobis) index, which is essentially a weighted average, where weights were the inverse of the elements of the variance-covariance matrix of these variables for each of the potential communities (see Sills et al., 2014). The variable with the highest variance received the lowest weight. The matching step resulted in a shorter list of seven REDD+ "treatment" and seven "control" communities, which were most similar in terms of this covariate index and the 11 variables used in the construction of the index (further details are reported in Sharma et al. 2015).

Once the matching treatment and control communities were identified, we determined a sample size for forest carbon and ecology data. That is, we identified 153 forest plots in each of the 21 treatment CFUGs (7 CFUGs in each of three districts) to collect forest carbon and ecology data. Similarly, we established 124 forest plots for the 21 control CFUGs to collect a data set similar to the project data. Carbon monitoring in these forest plots followed a technical guideline which follows the international standard defined by the Intergovernmental Panel on Climate Change (IPCC; ANSAB/FECOFUN/ICIMOD 2010). This constitutes of data on carbon stock in aboveground tree biomass, aboveground sampling biomass, herbs and grass, leaf litter, belowground biomass and soil organic carbon. These were aggregated to obtain the carbon stock in tons of carbon per hectare (t C ha^{-1}). The total forest carbon

[6] Pattanayak et al. (2010) illustrate this two-step logic (pre-matching & DID) for the evaluation on community water and sanitation schemes in rural Maharashtra, India.

stock was converted to tons of CO_2 equivalent. The baseline carbon data in the treatment community forest were collected from February to April 2011, while the baseline carbon data in the control communities were collected from July to August 2011. The end line carbon data from the treatment CFUGs were collected in February–April 2013, while the end line carbon data from the control CFUGs were collected in July–August 2013, exactly two years after the baseline data collection.

Besides carbon data, the forest ecology indicators were gathered by seasoned technical foresters in each forest plot on factors such as signs of forest fires, grazing, firewood collection, encroachment, signs of wildlife, and types of vegetation. The forest plot surveyors also collected data on biophysical factors such as altitude, slope and aspect.

The project made the carbon payment to the management committees in July 2011, following the collection of baseline carbon data. These management committees then created criteria for the allocation of funds and disbursed the available funds to various activities, including grants and loans for livelihood improvement or income generating activities, after November 2011.

A multi-stage random sampling was designed to collect information at the household level. The households in the forest user group were divided into three major strata: (i) the highest social stratum, comprising of the Brahmin and Chhetri ethnic groups, (ii) indigenous groups, who occupy the middle stratum, and (iii) Dalits, who are traditionally considered "untouchable" and are in the lowest social stratum. A systematic random sampling was then conducted to obtain a total of 15 households in proportion to the ethnic composition of the members of each CFUG. Accordingly, there were 105 treatment households and 105 control households for each of the three districts, representing the ethnic composition of each stratum. Thus, in total, we have 630 households in the baseline survey, and 614 households in the end-line survey. Sixteen households were lost because of their lack of availability, mostly due to household members being away from their homes for temporary employment in cities.

The study collected socioeconomic and livelihood data at the household level. For instance, data were collected on household demographics, forest product extraction practices, number of days involved in silviculture activities such as thinning and pruning, and time spent at user group meetings. Data was also collected on participation and benefit flows to households from community-forest-initiated activities, perceptions of community forest management, land and livestock holdings, household consumption expenditures, major sources of household income, access to alternative fuel, participation in community institutions, and access to public services, among others. Local prices for forest products and wage rate data were also collected in order to establish the economic value of extracted forest products.

The baseline socioeconomic data was collected from August to November 2011. The household survey questionnaire was developed after several focus group discussions and expert consultations to ensure that it reflected and captured the reality on the ground. The data on the local prevailing agricultural wage rate was collected so that the value of household time could be estimated. The end-line data was collected from August to November 2013.

The questionnaire was pre-tested in the out of sample REDD+ and non-REDD+ communities in two of the three districts and subsequently revised to ensure coherence and ease of use. Enumerators and supervisors were trained in workshops and in the field prior to being sent out to collect data. The mechanism used was as follows: the questionnaire was filled out by one enumerator, checked by another enumerator, and a final check was performed by a team supervisor to ensure data quality.

After the household baseline survey was completed, a balancing test was conducted to see whether the treatment and control communities selected through propensity score matching were balanced. Among the 11 variables used in the PS matching, data for 5 variables could be collected in the household survey.

A balancing test of these variables indicated that two of the five household level variables were statistically different for the treatment and control households while the other three were similar. These two variables between the treatment and the control CFUGs were taken into account during the impact analysis. The six variables for which data was collected during matching were not statistically different from the treatment and control CFUGs.

3.3 Econometric Model

Our research design is based on a BACI approach that allows us to use the difference in difference estimator to evaluate the effect of REDD+ intervention on carbon and non-carbon benefits. Equation (1) provides the basic difference in difference estimator.

$$Y_i = \beta_0 + \beta_1 Treat*Year_i + \beta_2 Treat_i + \beta_3 Year_i + \varepsilon_i \quad (1)$$

where Y_i is the vector for outcome variable of interest; $Treat_i$ is an indicator for treatment group, *Year* is an indicator of the endline survey, and *Treat*Year* is an interaction of these two indicator variables, while ε_i is the vector for the stochastic error term. β_1, the coefficient of *Treat*Year* measures the DID estimator and thus the impact of REDD+ intervention.

The vector Yi is comprised of three sets of outcomes. The carbon outcome consists of the various components of the forest carbon stock in the aboveground and below-ground biomass such as litter, herbs, saplings, tree biomass, and soil organic carbon. The forest ecology outcomes consists of variables such as evidence of forest fires, soil erosion, encroachment, firewood collection, fodder collection, grass cover, shrub cover and tree cover. The socioeconomic characteristics variables were: household size, ethnicity, literacy status of household head, remittance recipient status, household food and non-food expenditure, and sources of household income. The socioeconomic outcome variables were: quantity of firewood, fodder-grass, leaf-litter, other biomass products from various sources, and the production and transaction costs of participation in community forests. The other outcome variables were related to livelihood and household welfare, such as: benefits from community forest user-group-initiated activities, the adoption of alternative fuel, share of firewood in household cooking, livestock herd size etc.

Two variables used in the matching were not balanced for treatment and control groups: (i) the average number of local non-governmental organizations (*NGO*) existing in the community that were started through local initiatives or through external support; and (ii) the percent of households using liquid petroleum gas (*LPG*) for household energy in the community. To ensure post-matching balanced, we used these two additional variables as controls to estimate equation (2). This provided us with two models for DID estimation.

$$Y_i = \beta_0 + \beta_1 Treat*Year_i + \beta_2 Treat_i + \beta_3 Year_i + \beta_4 NGO_i + \beta_5 LPG_i + \varepsilon_i \quad (2)$$

4. Findings

We present the findings of our study on the three aspects of the REDD+ outcomes – forest carbon, forest ecology and socioeconomics of the households in REDD+ and control CFUGs. We also try to triangulate these findings to create a coherent explanation of the changes that were taking place and try to explain what may happen in the future.

Before we move on to the three sets of outcomes, we discuss the forest management regimes that existed in the community before the REDD+ intervention took place. Data revealed that there were several kinds of forest management practices prevailing in the study area. They were self-owned private land, community forests, leasehold forests, government managed forests and open access forests. Leasehold forests are patches of degraded forest land handed over to identified groups of poor households for a period of 40 years, which are regenerated to extract household biomass needs such as firewood, fodder grass and leaf-litter (Sharma, 2011).

The baseline scenario in 2011 revealed that on the basis of volume of extractions, community forest was the largest source, taking 52%, 72% and 52% shares of firewood, fodder-grass and leaf-litter respectively. Private land ranked second followed by leasehold forests ranked third. A similar trend was observed for non-REDD+ communities. Other sources such as government forest, open access and purchase were not very significant. Though these various forms of forest management regimes existed in these communities with different levels of dependence, this study mainly focuses on the community managed forests. Accordingly, we examine the impact of REDD+ incentive payments on community forest related outcomes.

4.1 Forest Carbon

The standard method for estimating total forest carbon stock consists of aggregating carbon content in the forest in terms of biomass from litter, herbs, saplings, tree and soil carbon. Carbon content in vegetation biomass and soil organic carbon constituted around 59% and 41% respectively of the total forest carbon in the base year in the treatment and control CFUGs. Among the total vegetation biomass, tree and below-ground biomass constituted the largest chunk with 81% and 16%, followed by sapling 2%, litter 1% and herb biomass with negligible shares. Forestry literature tells us that while litter biomass, herb biomass and saplings can change within a short period of intervention, it takes relatively longer for tree biomass and forest soil carbon. We looked for changes in these components as well as the total forest carbon stock in the treatment and the control CFUGs. We estimated the regression equation mentioned in the methodology section clustering by CFUG groups for robustness.

Our analysis suggest no statistically significant changes in any of the components of the forest carbon pool including (i) herbs, (ii) litter, (iii) saplings, (iv) tree biomass and (v) soil organic carbon. As a result, there was no statistically significant increase in the total forest carbon for treatment versus control communities during the period of experimentation and these results were consistent across both the models (Table 3). Thus, we found that the total forest carbon stock in both the treatment as well as the control community forests did not increase significantly in the two-year period (2011–2013). For instance, average forest carbon stock in the treatment plots increased from 248 to 255 tons per hectare while it increased from 221 to 225 tons per hectare in the control plots. The change in forest carbon between the treatment and control sites within two years, however, was not statistically significant.

4.2 Forest Ecology

Ecological indicators in the community forests are the outcome of human-nature interactions. Perhaps these are more susceptible to change in 2 years, and we find several improvements in forest ecology. For instance, there were statistically significant reductions in incidences of forest fires, timber extraction and encroachment (Table 4). Model 1 and Model 2 reveal that compared to control site, REDD+ CFUGs saw a relative decline in signs of forest fires, one of the major causes of deforestation, in treatment forests by about 34%. This result is consistent with other studies conducted in the project sites (Maraseni et al. 2014; Shrestha et al. 2014). The timber extraction rate declined by 16% and 18% respectively for the two models. Forest encroachment declined by 20% in both models.

Likewise there were statistically significant increases in signs of wildlife, grass cover and tree cover. Signs of wildlife increased by 24% and 27%, grass cover increased by 11% and 14%, and tree cover increased by 4% and 5% respectively in the two models in the intervention sites compared to the control sites (See Appendix Table 4).

Ecological data showed an increase in firewood collection by 20% for both the models (Figure 2). Sustainable harvesting of forest products is one of the goals of REDD+ but high rates of extraction of firewood can affect carbon sequestration. We examine this issue further using household level data in following section. There were no statistically significant changes in the REDD+ communities for fodder collection, open grazing, soil erosion and shrub cover.

4.3 Socio-economic Outcomes

We estimated Equations 1 and 2 for forest product extraction and livelihood variables. As the plots are clustered at the CFUG level, we use CFUG level clustered standard errors.

Firewood, fodder-grass and leaf-litter are the primary forest products extracted by households for their livelihood needs and firewood is a major factor influencing forest cover and consequently carbon stocks in the forests of Nepal. The results revealed that there were no statistically significant changes in the total quantity of firewood, fodder-grass and leaf-litter extraction by households between treatment and control communities (Table 5). So how might evidence from household data that there is no statistically significant increase in loads of firewood collected relate to our findings from forest plots on the same outcome? Greater occurrence of firewood collection signs in the ecological data could be due to same amount of harvesting of firewood being distributed over wide area following improved thinning and pruning practices in the treatment forest after the introduction of REDD+, rather than the intensive harvesting of firewood only in areas nearby settlements.

CFUGs are required to conduct various forest management and livelihood improvement activities in their communities – these can be considered "business as usual" activities. In addition to these activities, the REDD+ forest communities conducted several new activities such as the provision of income-generating and livelihood-improvement grants and loans, additional forest management activities, the distribution of improved cooking stoves and grants for biogas installation (CFRP/N 2011; Shrestha et al. 2014). We find no statistically significant changes in household income for these community forest user group-initiated activities compared to the control communities.

One of the major impact pathways expected from REDD+ is a shift from forest-based fuel to cleaner and convenient non-forest fuel sources. The alternatives to firewood in Nepal are liquefied petroleum gas (LPG) and biogas fuel. For instance, while 83% of households in Nepal use firewood, around 18% of households use LPG, and around 5% of households have biogas plants (CBS 2011; AEPC 2014). These fuel sources are not mutually exclusive as households 'stack' using more than one fuel to complement household cooking (Lewis and Pattanayak, 2012). LPG is a non-renewable imported fossil fuel while biogas is a renewable fuel that can be produced from by-products such as animal dung and other biomass sources. One of the supports the REDD+ project offered was the provision of partial grants for the installation of biogas plants. Once biogas plants are installed they are operated via farm inputs and household labor. Another support was the provision of improved cooking stoves.

We find a statistically significant decline in the share of firewood for household cooking by around 5% (Model 2). This was accompanied by a complementary increase in households adopting biogas by 4% and around 5% for Model 1 and Model 2 respectively for the treatment compared to the control CFUGs. However, we found that REDD+ had no statistically significant impact on the adoption of improved cook stoves.

We also examined if there was any change in livestock holding behavior between the communities. Communities might be expected to shift to a few improved and more productive varieties of livestock from a large unproductive herd size. Contrary to Lamichhane et al. (2014) we found no statistical difference in livestock holding.

5. Discussion and Conclusions

REDD+ is being proposed as one of the most significant incentive mechanisms for climate change mitigation. Whether reality will match theory is an open question, and the answer to this question is central to the success of REDD+. In this study in Nepal, we tried to answer this question using a careful and comprehensive quasi-experiment with a counterfactual scenario in a real-world setting (Pattanayak 2009; Caplow et al. 2011).

Reliable impact evaluations of forest conservation interventions are best undertaken after some years have passed after the intervention (Sunderlin et al. 2010). For example, we might not have seen changes in some indicators (carbon stocks, household assets) because the project duration was inadequate, even if some behaviors had been motivated by a REDD+ incentive payment. While this is an important caveat, given the severity of climate change impacts and the urgency of addressing it (Phelp et al. 2010b), pilot projects cannot afford to wait long. In this context the present study should be considered an intermediate outcome evaluation, with more follow-up studies to examine sustainability in the years to follow.

Our main findings indicate that there is cause for optimism regarding REDD+ success in the short term that has implications for the long term. None of the components of forest carbon and total forest carbon declined in REDD+ CFUGs. On the flip side, the fact that there is no decline in forest carbon even for control CFUGs indicates that communities are sustainably harvesting and effectively conserving their forests, with or without REDD+.

One reason for the lack of attribution to REDD+ payments is that the pilot project implemented payments that placed a small weight (only 16%) on the carbon increment, which could have been viewed as a token payment, rather than a real market-based REDD+ payment. Perhaps once REDD+ payments become institutionalized and larger, we can expect more visible contributions to the forest carbon pool in the long term. This expectation seems reasonable because we find improvements in several forest ecology indicators that are more evident in the short term. For example, we find declines in forest fires, timber extraction and forest encroachment, all cross-validated by increases in grass and tree cover and improved signs of wildlife.

It is also critical to consider household forest dependence, especially because rural communities in Nepal are highly dependent on forests for firewood and fodder. For instance, more than 80% of households use firewood as a source of household energy and more than 90% of the households in Nepal own livestock (Nepal et al., 2007, 2011). A reduction in forest product extraction without adequate provision of alternative fuel and livestock quality improvement would obviously impose hardship on the livelihood of the communities. This is one of the fears about REDD+ frequently raised in the literature (Phelps et al. 2010b; Bushley and Khatri 2011; Cronkleton et al. 2011; Visseren-Hamakers et al. 2012; Luttrell et al. 2013; den Besten 2014). We find that REDD+ incentives did not change in the quantities of firewood, fodder-grass and leaf-litter extractions – that is, REDD+ "does no harm" to the communities.

To the contrary, there was an increase in the adoption of biogas, a clean and convenient fuel, among the REDD+ treatment communities. This finding was cross verified by a relative decline in the share of firewood used in household cooking, though there was no decline in firewood consumption overall. Most of Nepal's climate is moderate in the summer and cold in winter. Therefore, in addition to cooking, households need firewood to keep their houses warm. About 85% of rural households in Nepal use tripod and traditional clay stoves that can be used for household cooking as well as to keep the house warm (CBS 2011). Only 4% of rural households have smokeless firewood stoves and studies have shown that even households that use these improved stoves do not use less firewood, probably due to the demands of household heating (Nepal et al. 2011).

We examined other dimensions of welfare and livelihood improvement in terms of the benefit received from activities initiated by CFUGs, other than direct forest product extraction by households. We do not find statistically significant differences in additional livelihood benefits. This indicates that the REDD+ incentive payments disbursed by the project were more token in nature than being significant enough to make a difference in the receipt of benefits between the treatment and the control communities.

A major contribution of our study is that it is based on a real-life REDD+ payment to communities with simultaneous analysis of forest carbon, ecology and social outcomes in multiple districts and multiple ecological belts of Nepal. Most of the previous research on forest carbon and biodiversity has strikingly missed the social outcomes, depriving us of an understanding of potential trade-offs (Caplow et al. 2011). The project covered 105 REDD+ communities, comprised of more than 18,000 households. The comparison of such a large group with a statistically matched counterfactual group provides a robust field based impact assessment.

REDD+ has the potential to mitigate climate change in an efficient (relatively cheap) and significant manner with several potential co-benefits for forest-rich but economically backward countries (Angelsen et al., 2008, 2009). However, there is little or no evidence whether this payment for environmental services adequately motivates communities to ensure carbon effectiveness, cost efficiency and equity. Our study is the first of its kind to show – other things being equal or held constant – that REDD+ improves ecological indicators such as forest fires, timber extraction, forest encroachment, grass cover, tree cover and wildlife. Without this kind of careful, time- and resource-intense evaluation, we would remain in the dark about a potentially important environment and development policy. A follow-up study in the next few years could provide evidence of the medium and long impacts of REDD+.

Acknowledgements

This study was conducted with financial and technical support from the South Asian Network for Development and Environmental Economics (SANDEE) and the International Centre for Integrated Mountain Development (ICIMOD). While both ICIMOD and SANDEE are funded by multiple donors, we would like to particularly thank NORAD for supporting the pilot REDD+ project. The authors are thankful to the Asia Network for Sustainable Agriculture and Bioresources (ANSAB) for conducting the carbon inventory. We would like to thank the field survey team of the students from Patan Multiple Campus, Tribhuvan University. We are very grateful to the households, community forest user group members, and the Federation of Community Forest Users Nepal (FECOFUN) District Offices of Dolkha, Gorkha and Chitwan for their support throughout the study.

References

AEPC (2014) Household Biogas, Alternative Energy Promotion Centre, http://www.aepc.gov.np/?option=renewable&page=subsubrenewable&mid=2&sub_id=16&ssid=16&cat=Household%20Biogas: (Assessed on 31 December, 2014)

Agrawal, A; Angelsen, A (2009) *Using community forest management to achieve REDD+ goals*. Realising REDD+: National strategy and policy options,1, 201-212

Angelsen, A; Brockhaus, M; Kanninen, M; Sills, E; Sunderlin, WD; Wertz-Kanounnikoff, S (eds.) (2009) *Realising REDD+: National strategy and policy options*. CIFOR, Bogor, Indonesia

Angelsen, A; Brockhaus, M; Sunderlin, WD; Verchot, LV (eds.) (2012) *'Introduction', in Analysing REDD+: Challenges and choices*. CIFOR, Bogor, Indonesia

Angelsen, A; Wertz-Kanounnikoff, S (2008) 'What are the key design issues for REDD and the criteria for assessing options?', in Angelsen, A. (2008) (ed.). *Moving ahead with REDD: Issues, options and implications*. CIFOR, Bogor, Indonesia

ANSAB/FECOFUN/ICIMOD (2010) Forest Carbon Stock Measurement: Guidelines for measuring carbon stocks in community-managed forests. Asia Network for Sustainable Agriculture and Bio-resources/Federation of Community Forest User Groups Nepal/International Centre for Integrated Mountain Development

Brockhaus, M; Di Gregorio, M (2014) 'National REDD+ policy networks: from cooperation to conflict'. *Ecology and Society* 19 (4),14

Bushley, BR; Khatri, DB (2011) *REDD+: Reversing, Reinforcing or Reconfiguring Decentralized Forest Governance in Nepal?*, Discussion Paper 11,3. Forest Action Nepal

Caplow, S; Jagger, P; Lawlor, K; Sills, E (2011) 'Evaluating land use and livelihood impacts of early forest carbon projects: Lessons for learning about REDD+', *Environmental Science & Policy*,14 (2), 152–167

CBS (2011) *National Living Standard Survey 2011*. Central Bureau of Statistics, National Planning Commission Secretariat, Kathmandu

CFRP/N (2011) *Operational Guidelines of Forest Carbon Trust Fund 2011*. Community Forestry REDD+ Project Nepal

Corbera, E (2012) 'Problematizing REDD+ as an experiment in payments for ecosystem services'. *Current Opinion in Environmental Sustainability* 4(6), 612–619

Corbera, E; Schroeder, H (2011) 'Governing and implementing REDD+'. *Environmental Science & Policy* 14, 89–99

Cronkleton, P; Bray, DB; Medina, G (2011) 'Community Forest Management and the Emergence of Multi-Scale Governance Institutions: Lessons for REDD+ Development from Mexico, Brazil and Bolivia'. *Forests* (2), 451–473

Gupta, J (2012) 'Glocal forest and REDD+ governance: win-win or lose-lose?', Current Opinion in Environmental Sustainability, 4(6), 620–627. http://mofsc-redd.gov.np/

IPCCC (2012) 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change' (Field, CB; Barros, V; Stocker, TF; Qin, D; Dokken, DJ; Ebi, KL; Mastrandrea, MD; Mach, KJ; Plattner, G-K; Allen, SK; Tignor, M; Midgley, PM (eds.)), Cambridge University Press, Cambridge, UK, 582 pp.

Ives, JD; Messerli, B (1989) *The Himalayan Dilemma: Reconciling Development and Conservation*. United Nation's University, Routledge, London and New York

Lamichhane, DK; Karky, BS; Aryal, KP (2014) 'Relationship Between REDD and Livestock Production Systems: Multinomial Choice Analysis'. *Journal of Animal Production Advances* 4(4), 388–402

Lewis, JJ; Pattanayak, SK (2012) 'Who adopts improved fuels and cookstoves? A systematic review'. *Environmental health perspectives*, 120(5), 637-645

Luttrell, C; Loft, L; Gebara, MF; Kweka, D; Brockhaus, M; Angelsen, A; Sunderlin, WD (2013) 'Who should benefit from REDD+? Rationales and realities'. *Ecology and Society* 18(4), 52

Maraseni, TN; Neupane, PR; Lopez-Casero, F; Cadman, T (2014) ‘An assessment of the impacts of the REDD+ pilot project on community forests user groups (CFUGs) and their community forests in Nepal’. *Journal of environmental management* 136, 37–46

MFSC (2015) *REDD Implementation Centre*. Ministry of Forests and Soil conservation

MFSC/RFCCC (2011) *Study on REDD Plus Piloting in Nepal*. Ministry of Forests and Soil conservation, REDD Forestry and Climate Change Cell

MOF (2011) *Economic Survey*. Ministry of Finance, Government of Nepal

Murdiyarso, D; Brockhaus, M; Sunderlin, WD; Verchot, L (2012) ‘Some lessons learned from the first generation of REDD+ activities’. *Current Opinion in Environmental Sustainability* 4(6), 678–685

Nepal, M; Nepal, A; Grimsrud, K (2011) ‘Unbelievable but improved cookstoves are not helpful in reducing firewood demand in Nepal’. *Environment and Development Economics*, 16(01), 1–23

Nepal, M; Bohara, AK; Berrens’, RP (2007) ‘The Impacts of Social Networks and Household Forest Conservation Efforts in Rural Nepal’. *Land Economics* 83(2), 174-191

Pattanayak, SK (2009) Rough guide to impact evaluation of environmental and development programs. SANDEE Working Paper 40. http://goo.gl/X47lWy http://www.sandeeonline.org/uploads/documents/publication/847_PUB_Working_Paper_40.pdf

Pattanayak, SK; Poulos, C; Yang, JC; Patil, S (2010) ‘How valuable are environmental health interventions? Evaluation of water and sanitation programmes in India’. *Bulletin of the World Health organization* 88(7), 535–542

Phelps, J; Webb, EL; Agrawal, A (2010b) ‘Does REDD+ Threaten to Recentralize Forest Governance’. *Science* 328, 312–13

Phelps, J; Guerrero, MC; Dalabajan, DA; Young, B; Webb, EL (2010a) ‘What makes a ‘REDD’ country?’. *Global Environmental Change* 20(2), 322–332

Sharma, BP (2011) ‘The welfare impacts of leasehold forestry in Nepal’. SANDEE Working Paper No 61–11

Sharma BP; Nepal, M; Karky, BS; Pattanayak, S; Shyamsundar, P (2015) *Baseline Considerations in Designing REDD+ Pilot Projects: Evidence from Nepal*. SANDEE Working (Forthcoming)

Shrestha, S; Karky, BS; Karki, S (2014) ‘Case Study Report: REDD+ Pilot Project in Community Forests in Three Watersheds of Nepal’. *Forests*, 5, 2425–2439

Sills, EO; Atmadja, SS; de Sassi, C; Duchelle, AE; Kweka, DL; Resosudarmo, IAP; Sunderlin, WD (eds.) (2014) *REDD+ on the ground: A case book of subnational initiatives across the globe*. CIFOR, Bogor, Indonesia

Somanathan, E; Prabhakar, R; Mehta, BS (2009) ‘Decentralization for cost-effective conservation’. *PNAS* vol. 106 (11), 4143–4147

Stern, N (2007) *The Economics of Climate Change: The Stern Review*. Cambridge and New York, Cambridge University Press

Sunderlin, WD; Larson, AM; Duchelle, A; Sills, EO; Luttrell, C; Jagger, P; Pattanayak, S; Cronkleton, P; Ekaputri, AD (2010) *Technical guidelines for research on REDD+ project sites*. CIFOR, Bogor, Indonesia

Visseren-Hamakers, IJ; Gupta, A; Herolds, M; Pen˜ a-Claros, M; Vijge, MJ (2012) ‘Will REDD+ work? The need for interdisciplinary research to address key challenges’. *Current Opinion in Environmental Sustainability* 4, 590–596

Tables

Table 1: Results from the balancing test

Matching Variables	REDD+	Non-REDD+	Difference (REDD+ – Non REDD+)
Variables from household survey			
Number of local organizations/NGOs	3.08 (0.09)	2.37 (0 .07)	0.71***(0.11)
Percentage of households with LPG	0.25 (0.02)	0.18 (0.02)	0.07**(0.03)
Percentage of HHs with biogas among large ruminant owners	0.10 (0.02)	0.08 (0.02)	0.03 (0.02)
Firewood collection time from CF in minutes	229.06 (5.79)	218.23(5.30)	10.84 (7.85)
Average time taken to reach public facilities	83.81 (3.14)	81.90 (2.42)	1.91 (3.97)
Variables from matching data			
Years of CFUG handover	10.9 (1.35)	9.9 (1.15)	1.00 (1.17)
Income per hectare from CFUG product	2683.00 (912.36)	3399.10 (1216.23)	-716.09 (1520.4)
Growing stock per hectare in CFUG	4918.45 (1212.2)	3924.41 (627.32)	994.04 (1364.90)
Household per hectare CFUG	2.59 (0.45)	2.42 (0.44)	0.16 (0.63)
Indigenous and Dalit population in community	69.05 (5.90)	71.29 (6.46)	-2.24 (8.75)
Quality forest cover	77.14 (2.251)	78.81 (1.790)	-1.67(2.876)

Notes: Figures in parentheses are standard errors; *, ** and *** denote t-statistics significant at 10%, 5% and 1% level of significance respectively.
Source: Field survey, 2011.

Table 2: Share of biomass by sources (base-year)

Sources	REDD+ community group			Non- REDD+ community group		
	Firewood	Fodder-grass	Leaf-litter	Firewood	Fodder-grass	Leaf-litter
Community forest	51.7	71.7	51.6	51.2	71.1	44.7
Private land	34.9	18.8	41.3	41.4	24.0	51.3
Leasehold forest	6.5	6.6	3.4	3.2	3.3	3.1
Government forest	0.7	0.3	0.3	0.4	0.0	0.3
Open access	1.2	1.9	2.9	0.3	0.3	0.6
Purchase	5.0	0.8	0.4	3.3	1.3	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Notes: The calculation is based on the loads of biomass collected from various sources.
Source: Field survey, 2011.

Table 3: DID estimation of forest carbon impacts

	Herb_biomass		Litter_biomass		Sapling_biomass		Tree_biomass		Total_forest_carbon	
Variables	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Treat*Year	-0.18	-0.18	1.45	1.50	-0.61	-0.93	2.30	13.76	1.95	9.35
	(0.25)	(0.25)	(1.22)	(1.25)	(1.65)	(1.89)	(10.81)	(14.83)	(6.10)	(8.94)
Treat	-0.13*	-0.18	1.44**	1.37*	3.52**	4.17**	10.68	-16.91	27.39	8.03
	(0.07)	(0.12)	(0.63)	(0.80)	(1.31)	(1.91)	(45.22)	(38.86)	(25.46)	(22.74)
Year	0.58***	0.64***	-0.99*	-1.08*	0.16	0.42	5.04	1.01	3.57	2.92
	(0.21)	(0.22)	(0.57)	(0.63)	(0.46)	(0.61)	(6.14)	(9.27)	(3.56)	(5.28)
NGO		0.07		0.07		-0.72		30.98		22.00*
		(0.08)		(0.46)		(0.86)		(21.75)		(12.17)
LPG		-0.93***		0.76		0.54		-99.84		-95.37**
		(0.27)		(1.31)		(1.91)		(82.84)		(42.73)
Constant	0.49***	0.48**	3.10***	2.83**	3.39***	4.95**	232.23***	176.30***	221.17***	185.12***
	(0.04)	(0.18)	(0.47)	(1.13)	(0.49)	(2.04)	(15.46)	(46.80)	(9.95)	(25.04)
Observations	554	554	554	554	554	554	554	554	554	554
R-squared	0.07	0.11	0.08	0.08	0.04	0.04	0.00	0.02	0.02	0.06

Notes: the carbon data comes from 153 treatment plots and 124 control plots, for which inventories were conducted in 2011 and 2013, making 306 treatment and 248 control site observations and a total of 554 observations. The forest carbon data consisted of herb, litter, sapling, tree biomass converted into equivalent biomass carbon. The biomass carbon added up with forest soil carbon constituted the total forest carbon. The soil carbon data, which is a component of the total forest carbon, is not shown in the table. Clustered-robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 4: DID estimation of forest ecology impacts

	Forest_fire		Fodder_collect		Grazing		Firewood_collect		Timber_extract		Encroachment	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model2**
Treat*Year	-0.33**	-0.35**	0.02	0.07	0.05	0.07	0.20*	0.20*	-0.16*	-0.18**	-0.20**	-0.20**
	(0.13)	(0.14)	(0.06)	(0.08)	(0.08)	(0.09)	(0.11)	(0.11)	(0.09)	(0.09)	(0.08)	(0.08)
Treat	0.16	0.18	0.06	-0.07	-0.19	-0.26*	-0.11	-0.14	-0.12	-0.11	0.16*	0.15*
	(0.12)	(0.13)	(0.13)	(0.13)	(0.13)	(0.14)	(0.13)	(0.12)	(0.12)	(0.11)	(0.08)	(0.08)
Year	0.09	0.13*	0.02	0.02	0.01	0.03	0.08*	0.12*	0.12***	0.17***	-0.00	0.01
	(0.06)	(0.07)	(0.02)	(0.05)	(0.03)	(0.05)	(0.04)	(0.06)	(0.04)	(0.05)	(0.01)	(0.03)
NGO		-0.02		0.14		0.08		0.04		0.00		0.01
		(0.06)		(0.08)		(0.07)		(0.07)		(0.08)		(0.05)
LPG		-0.34**		-0.55**		-0.58**		-0.57***		-0.57***		-0.19**
		(0.13)		(0.23)		(0.23)		(0.16)		(0.19)		(0.08)
Constant	0.13**	0.24*	0.52***	0.29	0.50***	0.40*	0.59***	0.58***	0.40***	0.49**	0.06**	0.06
	(0.05)	(0.14)	(0.10)	(0.23)	(0.10)	(0.21)	(0.11)	(0.21)	(0.09)	(0.21)	(0.03)	(0.13)
Observations	554	554	554	554	554	554	554	554	554	554	554	554
R-squared	0.06	0.11	0.01	0.08	0.03	0.10	0.05	0.11	0.05	0.12	0.08	0.10

	Wildlife_sign		Soil_erosion		Grass_cover		Shrub_cover		Tree_crown	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Treat*Year	0.24**	0.27**	-0.08	-0.12	0.11*	0.14**	-0.01	-0.02	0.04**	0.05**
	(0.11)	(0.10)	(0.06)	(0.07)	(0.06)	(0.06)	(0.03)	(0.03)	(0.02)	(0.02)
Treat	-0.33***	-0.42***	-0.14	-0.08	-0.14**	-0.17**	0.18***	0.20***	-0.05*	-0.06
	(0.12)	(0.11)	(0.10)	(0.09)	(0.07)	(0.08)	(0.05)	(0.06)	(0.03)	(0.05)
Year	0.10	0.10*	0.02	0.06	0.01	-0.04	0.02	0.00	-0.02	-0.03*
	(0.06)	(0.05)	(0.03)	(0.04)	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
NGO		0.10		-0.06		0.03		-0.02		0.01
		(0.07)		(0.06)		(0.05)		(0.04)		(0.02)
LPG		-0.48***		-0.14		0.34***		0.25**		0.08
		(0.14)		(0.14)		(0.12)		(0.10)		(0.06)
Constant	0.81***	0.65***	0.24***	0.41**	0.62***	0.51***	0.27***	0.28***	0.63***	0.59***
	(0.09)	(0.20)	(0.08)	(0.20)	(0.03)	(0.12)	(0.03)	(0.09)	(0.02)	(0.05)
Observations	554	554	554	554	554	554	554	554	554	554
R-squared	0.14	0.21	0.06	0.08	0.05	0.12	0.11	0.15	0.01	0.02

Notes: The ecological variables data comes from the same 554 plots from the 153 treatment plots and 124 control plots in two rounds from which carbon data were collected. These ecological variables were recorded based on observation of signs in the sampled plots by foresters rather than technical measurements. Clustered-robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Regression results on socioeconomic impacts

Variables	Total_firewood		Total_foddergrass		Total_leaflitter		Percent_share_fw		Have_biogas	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Treat*Year	-0.51	-1.86	17.74	10.07	2.37	-0.22	-1.78	-4.57**	0.04*	0.05*
	(2.59)	(2.61)	(21.15)	(20.31)	(16.23)	(15.94)	(1.94)	(1.93)	(0.03)	(0.03)
Treat	-7.65**	-5.24	-45.49	-34.27	-25.71	-23.61	-6.35	-1.76	0.02	-0.00
	(3.69)	(3.11)	(32.87)	(27.12)	(23.16)	(21.01)	(5.25)	(2.99)	(0.03)	(0.04)
Year	-0.01	1.68	-33.67**	-23.94*	-7.12	-3.71	-3.77***	-0.26	0.01*	0.00
	(1.84)	(1.88)	(13.61)	(13.88)	(11.83)	(11.77)	(1.17)	(0.57)	(0.01)	(0.01)
NGO		-1.69***		-2.21		4.35		-2.32***		0.03***
		(0.58)		(7.05)		(3.07)		(0.78)		(0.01)
LPG		-16.63***		-132.06***		-71.15***		-40.28***		-0.05*
		(3.19)		(33.73)		(11.30)		(3.83)		(0.03)
Constant	62.55***	69.50***	497.98***	526.70***	112.38***	114.72***	87.50***	100.17***	0.09***	0.02
	(2.16)	(1.66)	(22.36)	(29.70)	(18.35)	(18.20)	(3.19)	(2.01)	(0.03)	(0.03)
Observations	1,244	1,244	1,244	1,244	1,244	1,244	1,244	1,244	1,244	1,244
R-squared	0.02	0.11	0.01	0.06	0.01	0.07	0.02	0.35	0.01	0.03

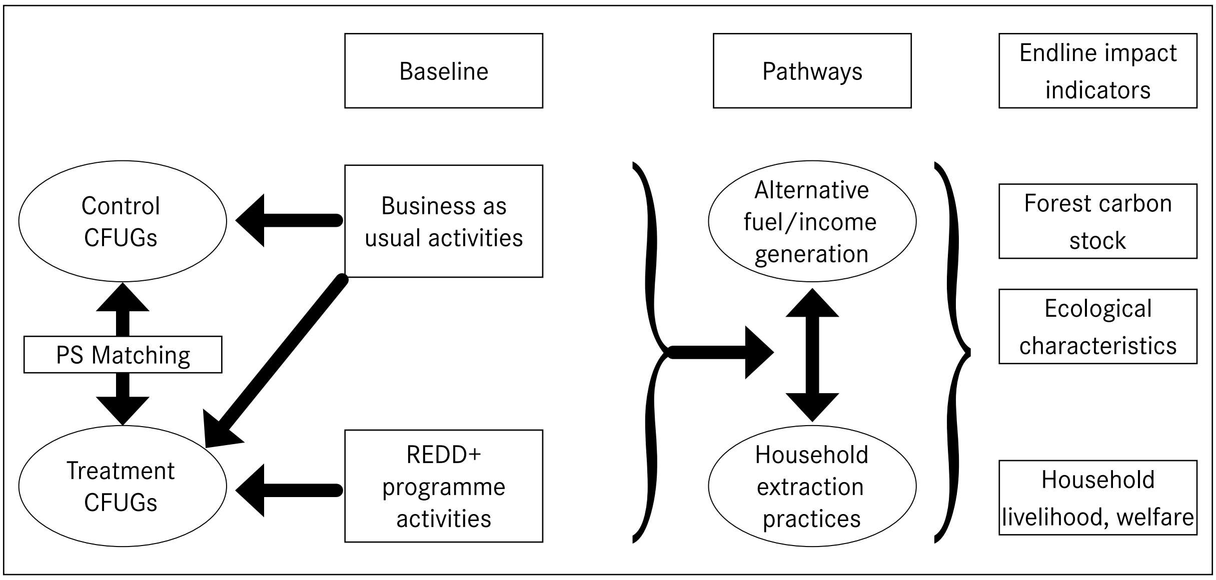
Notes: The household survey consisted of 315 treatment households and 315 control households, making a total of 630 households from the 21 treatment and 21 control CFUGs in the base year. These houses dropped to 614 households, with 16 households migrated or absent from the homestead by the end of the year.

	Have_ics		HH_income_CF_activity		Gross_CF_income	
Variables	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Treat*Year	0.01	0.02	398.43	444.38	945.95	767.04
	(0.05)	(0.05)	(268.80)	(266.56)	(1,803.04)	(1,780.67)
Treat	0.07*	0.07	616.67*	470.44*	-3,764.08	-3,769.32*
	(0.04)	(0.04)	(330.04)	(277.66)	(2,272.42)	(2,072.29)
Year	0.04	0.04	-210.85	-263.12*	236.19	483.81
	(0.04)	(0.04)	(125.57)	(132.97)	(1,166.63)	(1,228.63)
NGO		0.01		252.96**		757.97*
		(0.01)		(98.09)		(395.19)
LPG		-0.03		-460.84**		-7,310.19***
		(0.03)		(197.51)		(1,622.03)
	0.08***	0.06*	579.62***	61.68	17,011.11***	16,513.24***
Constant	(0.02)	(0.03)	(119.46)	(226.81)	(1,694.19)	(2,001.11)
Observations	1,244	1,244	1,244	1,244	1,244	1,244
R-squared	0.02	0.02	0.03	0.05	0.01	0.05

Notes: Clustered-robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

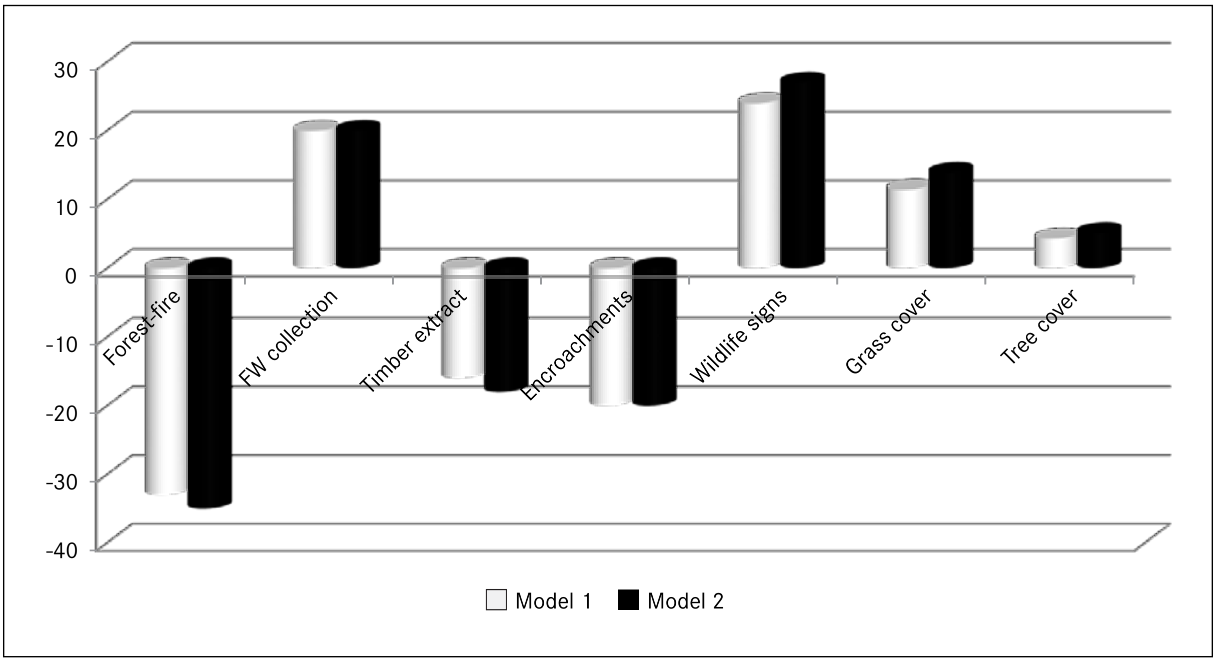
Figures

Figure 1: Conceptual framework



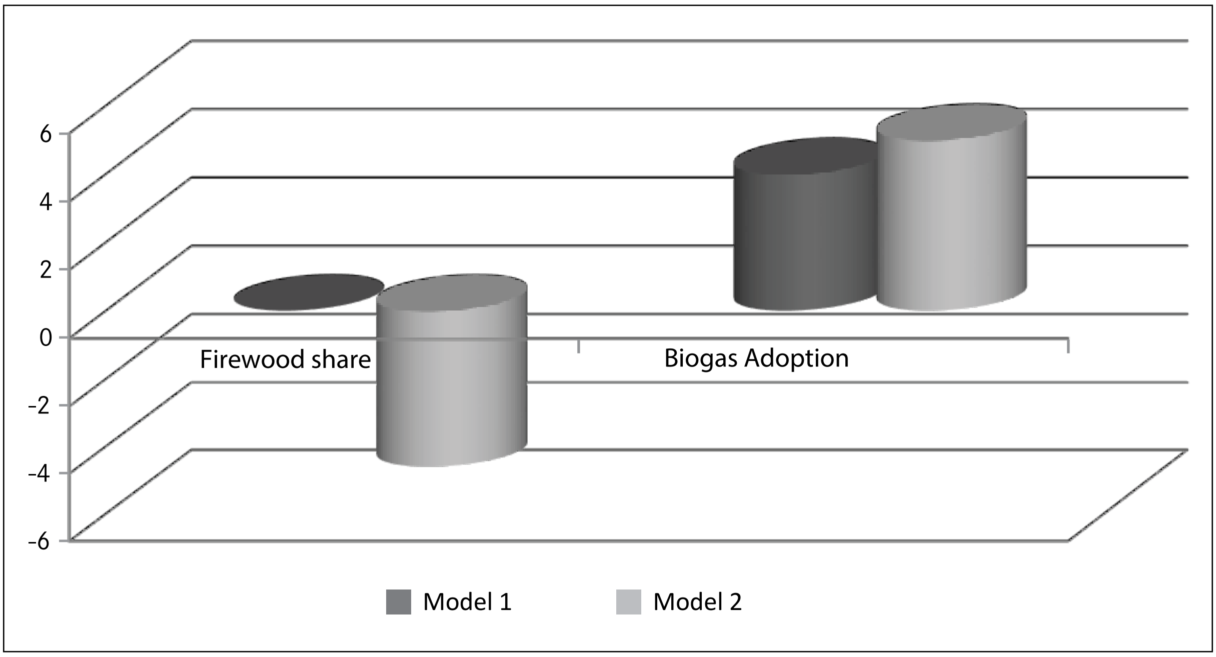
Source: Authors

Figure 2: Percentage change in ecological indicators



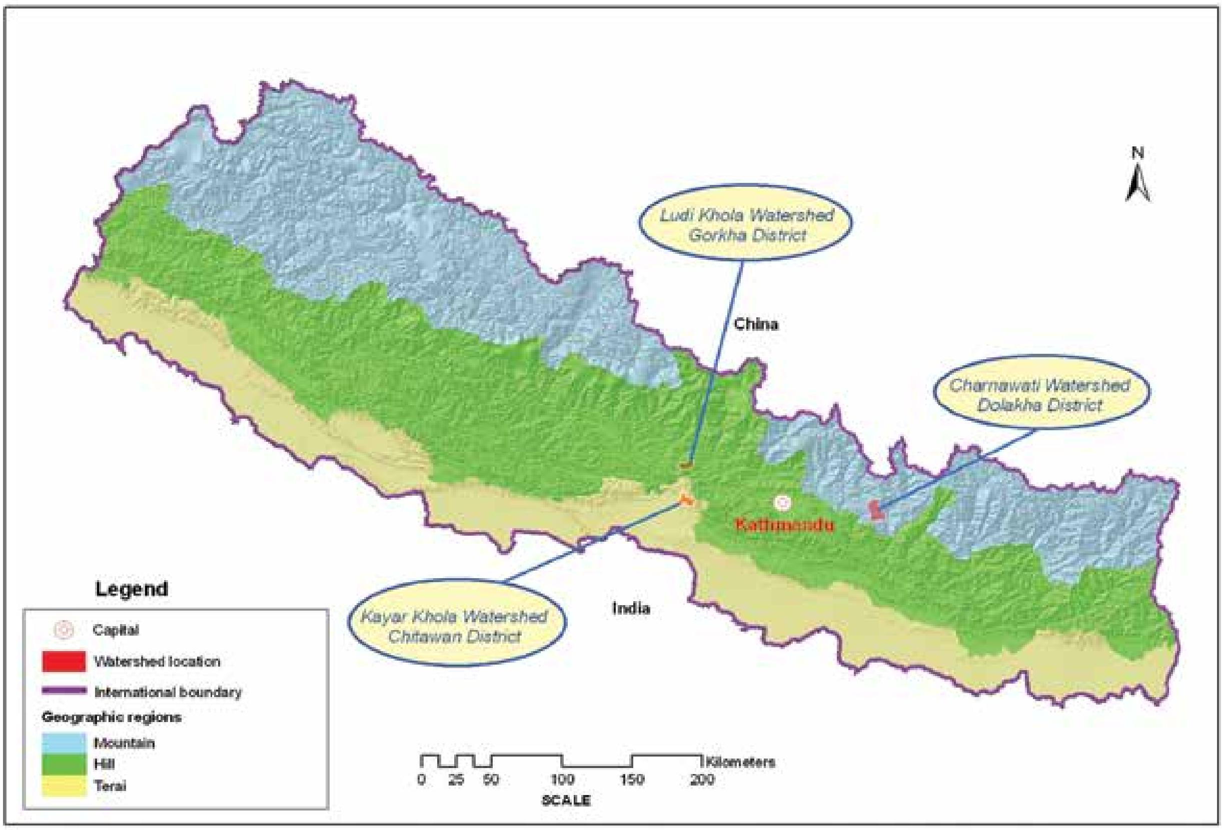
Source: Project data and field survey 2011 and 2013.

Figure 3: Percentage change in firewood share and biogas adoption



Source: Field survey 2011 and 2013.

Figure 4: Location of study area in the three watersheds of Dolkha, Gorkha and Chitwan



Appendix

Table A1: Variable definition of forest carbon data

Variable label	Description of variable	Range
Treat	Plot in the REDD+ treatment CFUG = 1, control CFUG = 0	0–1
Year	Data for end line year = 1, baseline year = 0	0–1
Treat*Year	Interaction variable, a product of treat and year as an indicator of impact based on difference in difference	0–1
NGO	Average number of NGOs in the community, a variable that was found to be unbalanced in the baseline and needed to be controlled for in the impact analysis	0–10
LPG	Percentage of households using LPG in the community, a variable that was found unbalanced in the baseline and needed to be controlled for in the impact analysis	0–1
Herb_biomass	Weight of herb biomass (tons per hectare) in the sample plot	0–12.17
Litter_biomass	Weight of litter herb biomass (tons per hectare) in the sample plot	0–38.85
Sapling_biomass	Weight of sapling biomass (tons per hectare)	0–98.28
Tree_biomass	Weight of tree biomass (tons per hectare)	0.47–998.19
Total_forest_carbon	Weight of total forest carbon (tons per hectare) in the sample plot; measured by summing the forest soil carbon and converted value of biomass into carbon equivalent	49.69–660.64

Table A2: Variable definition of forest ecology data

Variable label	Description of variable	Range
Forest_fire	Forest fire signs observed in the sampled forest plots	0–1
Fodder_collect	Fodder collection signs observed in the sampled forest plots	0–1
Grazing	Open grazing signs observed in the sampled forest plots	0–1
Firewood_collect	Firewood collection signs observed in the sampled forest plots	0–1
Timber_extract	Timber extraction signs observed in the sampled forest plots	0–1
Encroachment	Encroachment signs observed in the sampled forest plots	0–1
Wildlife_sign	Signs of wildlife observed in the sampled forest plots	0–1
Soil_erosion	Soil erosion signs observed in the sampled forest plots	0–1
Grass_cover	Grass cover observed in the sampled forest plots	0–95
Shrub_cover	Shrub cover observed in the sampled forest plots	0–100
Tree_crown	Tree crown cover observed in the sampled forest plots	0–95

Table A3: Household socioeconomic data

Variable label	Description of variable	Range
Total_firewood	Backloads of total firewood collected by household annually	0–240
Total_foddergrass	Backloads of total fodder grass collected by household annually	0–1920
Total_leaflitter	Backloads of leaf-litter collected by household annually	0–720
Percent_share_FW	Percentage share of firewood in household cooking	0–100
Have_biogas	Households with biogas plants installed for household energy	0–1
Have_ICS	Household with improved cooking stove installed for household cooking	0–1
HH_income_CF_activity	Household income from CFUG initiated activities in community Rs.	0–20600
Gross_CF_income	Gross income from CFUGs to the household in Rs.	0–138501

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