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Does Collective Action Sequester Carbon?

The Case of the Nepal Community Forestry Program

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Abstract

This paper estimate the effects of collective action in Nepal's community forests on four ecological measures of forest quality. Forest user group collective action is identified through membership in the Nepal Community Forestry Programme, pending membership in the program, and existence of a forest user group whose leaders can identify the year the group was formed. This last, broad category is important, because many community forest user groups outside the program show significant evidence of important collective action. The study finds that presumed open access forests have only 21 to 57 percent of the carbon of forests governed under collective action. In several models, program forests sequester more carbon than communities outside the program. This implies that paying new program groups for carbon sequestration credits under the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Degradation in Developing may be especially appropriate. However, marginal carbon sequestration effects of program participation are smaller and less consistent than those from two broader measures of collective action. The main finding is that within the existing institutional environment, collective action broadly defined has very important, positive, and large effects on carbon stocks and, in some models, on other aspects of forest quality.

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1. Importance of the Issues and Introduction

Evidence published in March 2013 suggests that the earth is now hotter than it was about three-quarters of the last 11,000 years (Marcott et al., 2013) and IPCC (2014) evaluated with medium confidence that the period 1983-2012 was hotter than the last 1,400 years. Based on ice core evidence, IPCC (2014) also notes that the concentration of greenhouse gases (GHG) in the atmosphere is now greater than at least the last 800,000 years and the rate of increase in the last 100 years is unprecedented in the last 22,000 years (high confidence).

GHG concentrations continue to rise and the climate will adjust to the existing concentrations by warming for over 1,000 years (Archer, 2009). In principle, therefore, all possible means need to be used to slow climate change. The United Nations Framework Convention on Climate Change (FCCC) of 1992 is the international agreement that governs these international efforts. It is generally agreed, that, despite the severity of the challenge, to-date the FCCC has yielded insufficient results or agreements for concerted action. As a consequence, atmospheric carbon concentrations continue to rise and in 2011 increased approximately 3% (Gillis and Broder, 2012).

One reason for the relative lack of progress on climate change is that under the FCCC only the 41 countries listed in Annex 1 out of a total of almost 200 countries have obligations to reduce GHG emissions. This regulatory regime is in place even as non-Annex 1 country

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emissions make up more than a majority of global emissions, since 1992 have increased much faster than those from Annex 1 countries and are projected to reach two-thirds of global emissions by 2030 (Stern, 2013).

Non-Annex 1 countries must be enticed to reduce emissions and one important area of cooperation is land use change. The UN Collaborative Programme on Reducing Emissions from Deforestation and Degradation (REDD+) is a still-emerging program by which FCCC Annex 1 countries provide financial support to non-Annex 1 countries, such as Nepal, in exchange for measurable reductions in deforestation and forest degradation.

These reductions represent potentially important climate change contributions, because deforestation and forest degradation account for between 12% and 20% of annual GHG emissions. In the 1990s, largely from the developing world, forests released about 5.8 Gt per year, which was more than all forms of transport combined (Saatchi et al., 2011; van der Werf, 2009). Total carbon stored in forests is estimated at 638 gigatons (UNFCCC, 2011), with approximately 80% in above ground biomass.[2] Virtually all net deforestation occurs in developing countries (Saatchi et al., 2011).

While REDD+ is being rolled out, an important outstanding question is how to incorporate the approximately 25% of developing country forests that are managed by communities (World Bank, 2009; Economist, 2010). These community forests may contain significant carbon that could be protected under REDD+ and perhaps collective action even now is sequestering carbon. If forests are a key source of greenhouse gas emissions and community forests are about a quarter of developing country forests where virtually all net biomass loss is occurring, it is difficult to imagine addressing climate change without bringing community

[2] For comparison, total carbon emissions by humans since 1750 are estimated to be approximately 375 gigatons (IPCC, 2013).

forests into REDD+. The possible tradeoff, however, is that in most low-income developing countries forests provide products that are essential to the daily lives of people, including fuelwood, forest fruits and vegetables, building materials and animal fodder (Cooke et al., 2008).

The question we examine is whether, using three different measures, forest collective action in Nepal is consistent with larger carbon stocks per hectare. As carbon is not necessarily the same as forest health, we also test whether collective action results in greater tree density per hectare, additional canopy cover and more regeneration measured as seedlings per hectare.

The chain connecting better collective action and carbon stocks runs through better management and higher forest quality. Better quality forests have more biomass, because reduced fuelwood, timber and fodder collections reduce pressures on forests allowing them to regenerate. Better management is what drives these results and in community settings are potentially the result of more effective collective action.

We test our hypotheses using a nationally representative random sample of forest dependent communities and forests that are part of the Nepal Community Forestry Programme, which is the most important forest devolution program in Nepal. Over 18,000 registered forest user groups are in existence, representing over 35% of the population.

This treatment group is matched with an equal number of forests that are not part of the program. A total of 130 forests made up of 620 forest plots are analyzed and the effects of collective action, including being part of a registered community forest (CF), are evaluated using panel data regression, OLS regression and propensity score matching.

Our main finding is that within the existing institutional environment, collective action has very important, positive and large effects on carbon stocks and often on other measures of forest quality. Depending on our measure of collective action, we are able to identify effects at both the forest and plot levels, but especially at the plot level when plots are matched based on plot and forest characteristics. We also find, though, that the Nepal Community Forestry Programme does not provide a unique collective action path to forest health or carbon sequestration. Indeed, in several models CFs do no better than non-community forests (NCFs), while broader measures of collective action show consistent effects, particularly on carbon.

To continue our examination, in Section 2 we provide a very brief discussion of the literature at the intersection of carbon sequestration and collective action. We present the Nepal community forestry experience in Section 3. In Section 4 we discuss our sample frame and data. Our empirical approach is presented in Section 5 and Section 6 discusses our results. Section 7 draws key conclusions, policy implications and highlights areas for further research.

2. Key Literature on Carbon Sequestration and Collective Action

Forests play a critical role in climate change, because they are a source of greenhouse gas emissions and offer sequestration opportunities (Chaturvedi et al., 2008). Deforestation and forest degradation in tropical countries constitute about 17.4% of global anthropogenic emissions (IPCC 2007), but carbon sequestration in forests may also be particularly cost-effective climate investments (McKinsey & Company 2010; Kindermann et al., 2008).

An estimated 15.5% of global forest is under the control of communities, providing key subsistence products and the trend toward community control is increasing (RRI, 2014). Using worldwide, but fairly coarse, forest data and highly aggregated forest collective action elements, Chhatre and Agrawal (2009) demonstrate there are possibilities for both tradeoffs and synergies between carbon sequestration and community livelihoods. They conclude by suggesting the need for detailed studies to better understand the implications when forests are controlled by communities. Similarly, in the Amazon, Bottazoi et al. (2014) recommend focusing on the intersection of institutional, socio-economic and biophysical factors to better understand the implications of REDD+. Beyene et al. (2013) estimate that the quality of local institutions may be one of the most important determinants of carbon sequestration.

A number of researchers have focused on the risks of REDD+ for communities, including the potentially difficult economic transitions and negative impacts on rural livelihoods (e.g. Sikor et al., 2010; Morgera 2009; Campbell, 2009; Coomes et al., 2008; Putz and Redford, 2009; Caplow et al., 2011). As the focus of our paper is on the carbon sequestration potential of community forests within REDD+ rather than the effects of REDD+ on communities, we do not discuss this literature. Yadav et al. (2003), Gautam et al. (2003) and others claim that CFs in Nepal can help reduce deforestation and forest degradation, which could imply that it also reduces carbon emissions, increases sequestration and should be promoted under REDD+. This is not universally agreed, however, and broadening our understanding of forest biomass dynamics in both CFs and NCFs is important.

A variety of indicators are used to assess forests, but all include variables that estimate the health and vitality of forest ecosystems, such as tree and seedling density, crown cover and primary productivity measured as biomass and/or carbon stock. Carbon constitutes approximately 50% of forest biomass (Gibbs et al., 2007) and this is also the IPCC (2006) default value. While there are no universally accepted methods to measure all forest biomass or carbon stocks, forest attributes, such as tree dimensions and densities can be converted into estimates of carbon stocks using allometric equations (Gibbs et al., 2007). There remains a need to sharpen and tailor models to estimate biomass and carbon (Manandhar 2013).

Assessing baseline carbon is critical for calculating carbon increments and assuring REDD+ additionality and a range of remote sensing and ground based measurement methodologies available. One widely used and important tool is the Normalized Difference Vegetation Index (NDVI), which is a measure of vegetative cover based on remotely sensed data. The NDVI is directly related to photosynthetic capacity and energy absorption of plant canopies (Sellers 1985; Myneni et al., 1995), which is linked to carbon. Though it cannot be used to estimate carbon *per se*, the NDVI provides an important measure of baseline land quality.

3. Brief Overview of Community Forestry in Nepal

Nepal introduced the Community Forestry Programme in the late 1980s in the context of serious deforestation and forest degradation, because centralized forest management was not working (Guthman 1997; Ojha et al., 2007; Hobley 1996, Springate-Bejinski and Blaikie 2007; Carter and Gronow 2005; Mahanty et al., 2006). The introduction of the National Forestry Plan in 1976, Decentralization Act of 1982, National Community Forestry Workshop of 1987 and Master Plan for the Forestry Sector of 1989 were important policy steps leading to the present day CF programme. The Master Plan for the Forestry Sector (MPFS) of 1989 made the most significant policy shift toward CFs. It recognized the role of local communities in forest management, redefined the role of the state from policing to facilitating local initiatives and appreciated that forests have to meet diverse forest product needs at the local level.

The Master Plan was followed by the Forest Act of 1993, which provided a clear legal basis for CFs, enabling the government to ‘hand over’ national forest to community forest user groups (CFUGs). The provisions were later detailed in the 1995 Forest Regulations and were backed by CF Operational Guidelines in 1995, which were revised in 2009. According to this regulatory framework, the CFUGs are recognized as self-governing, independent, autonomous, perpetual and corporate institutions that can acquire, possess, transfer or otherwise manage property (HMGN/MoLJ 1993: Article 43). According to the Act, the District Forest Officer

(DFO) can hand over the forests to identified user groups "who are willing and capable of managing any part of national forests" (HMGN/MoLJ 1993), allowing them to develop, conserve, use and manage forests. They can also sell and distribute forest products according to an Operational Plan approved by the DFO.

The distinction between CF and NCF forests is a legal one and CF status is very well defined. Becoming a CF requires that communities document their claims to forests. They must then organize themselves into user groups, elect officers, commit to participatory governance and agree to negotiate operational plans with DFOs every 5 years. DFOs provide technical support for forest management and issue permits for timber harvests. In sum, the main driver of CF status is local collective action with the state playing important enabling and oversight roles.

The CF Programme has expanded to include 17,685 CFUGs and over 1.6 million households (almost 35% of the total) managing 1.2 million hectares (MoFSC 2013). Three-quarters of CFs are in the hills, 16% in the high mountains and only 9% are in the *Terai* (MOFSC 2013). CFs generate 10% of Nepal's Gross Domestic Product (GDP) and a significant portion of tax revenues (MoFSC 2013).

In its short history of 30 years, the CF Programme is believed to have delivered demonstrable ecological, economic and social benefits. First, there is evidence of positive changes in both forest quality and quantity, including increased growing stock and biodiversity (Branney and Yadav 1998; Gautam et al., 2003; DoF, 2005). Second, the CF Programme is believed to have increased community infrastructure, social services and rural incomes and helped create conflict resilient and democratic community institutions (Kanel and Niraula 2004; MoFSC, 2013). Nepal officially joined REDD+ in 2010 and since that time its readiness activities have largely focused on the CF Programme, including assessments of carbon stocks and sequestration (Oli and Shrestha 2009), capacity building (Luintel et al., 2013), social and environmental safeguards and benefit sharing. In Nepal, CFs are perhaps the most important REDD+ institution and it is especially important to understand the linkages between CF collective action, deforestation and degradation.

4. Sample Frame and Data

4.1 Sampling and Data Collection Methodologies

This paper relies on forest and plot level data divided into legally defined community forests (CFs) and non-community forests (NCFs), which are government forests used by communities. All forests have names and these are provided in Appendix1. Forest inventory and community level data were collected in spring 2013 from 130 study sites in the middle hill (approximately 700 – 3000 meters in altitude) and *Terai* areas of Nepal. The high mountains, which can be remote, are generally less populated and have limited carbon sequestration potential, are excluded.

The Ministry of Forest and Soil Conservation (MoFSC) in 2010 conducted an evaluation of the CF Programme (MoFSC, 2013). The evaluation randomly selected 137 CFs (no NCFs) from 47 out of 75 districts throughout the country, with the objective to obtain a nationally representative sample. To preserve this essential randomness, representativeness and take advantage of previously collected data, we sample all 15 *Terai* CF sites and randomly select 50 CF sites from 122 hill CF sites in the sample of MoFSC (2013).

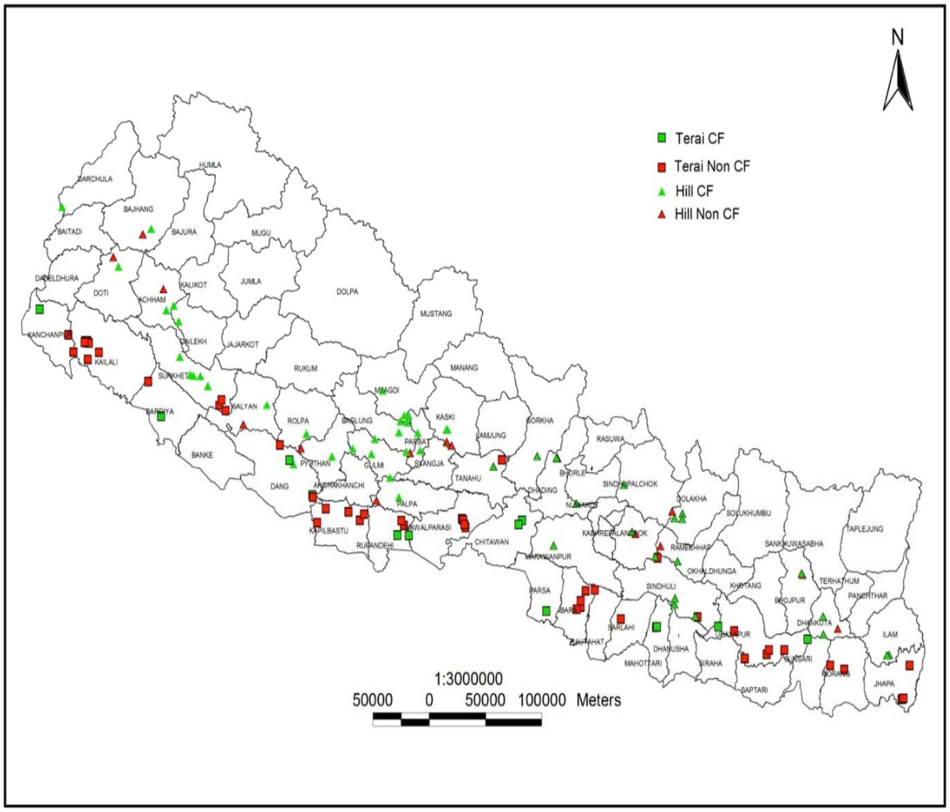
Researchers at ForestAction Nepal, based on their field knowledge, then chose 65 NCF sites in areas close to CFs that were ecologically and socially similar. NCF sites were selected so they resemble the CF sites to the extent possible in terms of ecological zone, forest type and village ethnic composition, farming system, socio-economic characteristics, etc. in all senses except they had not been handed over as CFs. Therefore, the intent is that sample CF and NCF forests should be fully comparable and using propensity score matching and regression we evaluate the effect of CF status on carbon stocks. The quality of the matches at the forest level is formally addressed in Sections 4.2 and 6.

Selected NCFs are also proximate to comparator CFs (e.g. in the same district), but NCF sites are not adjacent to CFs. This was avoided in case forest users simultaneously use both forest types. If many NCF sites were believed to be good matches (as was the case in the *Terai*), NCF sites were chosen randomly. In the middle hills NCFs are relatively rare and identifying NCF matches with randomly selected CFs was sometimes difficult. Table 1 presents numbers of sites by CF/NCF and Hill/*Terai* status. The map of Nepal in Figure 1 shows the spatial distribution of CFs and NCFs. CFs tend to be concentrated in the hills and NCFs in the *Terai*, which reflects the population of CFs, which is highly concentrated in the hills.

Table 1
Sites by CF Status and Physiographic Region

	CF	NCF	Total
Hill	50	15	65
Terai/Inner *Terai*	15	50	65

Figure 1
Map of Research sites



The forest inventory was carried out in 130 forests, with 325 randomly selected plots in CFs and 295 in NCFs.[3] The number of plots was calculated for a 10% error and 95% level of confidence using the standard formula (Saxena and Singh, 1987).[4]

(1) $n = C_v^2 t^2/E^2$, where $C_v = s/\mu$, s is the standard deviation, μ is the sample mean and $E = s/\sqrt{n}$, where n is the number of samples, t is the value of the student t distribution with degrees of freedom (n-1).

[3] 30 NCF plots were omitted because of data quality concerns.

[4] A pilot survey was used to estimate the number of plots required for the forest inventory. A total of 45 plots from 9 forests (3 each from mountains, middle hills and *Terai*) were randomly selected from the 137 forests. In each pilot forest a boundary survey was conducted using GPS and the five plots were randomly chosen. The pilot forest inventory was then carried out using the forest inventory guidelines of Subedi et al. (2010).

The sampled forests are of different sizes, with the smallest forest 1.1 hectares and the largest 1,088 hectares. Table 2 presents descriptive statistics by CF status and physiographic region. Larger forests in both the hills and *Terai* on average tend to be CFs.

Table 2
Forest Size in Hectares by CF Status and Physiographic Region

	CF (50 hills, 15 Terai)			NCF (15 hills, 50 Terai)		
	Mean	Min.	Max.	Mean	Min.	Max.
Hill (50 CF, 15 NCFs)	105.31	1.12	526	30.5	4.75	84
Terai (50 NCFs, 15 CFs)	240.41	1.10	1088.00	129.22	1.68	805
Overall	149.00	1.10	1088.00	106	1.68	805

It is important to take more samples in larger forests, but there is little guidance on how the plots derived from Equation 1 should be distributed. Table 3 presents the distribution of plots across quintiles of the size distribution for CF forests.

Table 3
Numbers of Plots Sampled in CF Forests

Quintile of Size Distribution	Total Forests	Plots/Forest	Total Plots
First (top)	13	7	91
Second	13	6	78
Third	13	5	65
Fourth	13	4	52
Fifth (last)	13	3	39
Total	65		325

After forest boundaries were identified, sample plots were chosen using randomly generated GPS points. If a GPS point proved inaccessible (e.g. on a very steep slope) or inappropriate (e.g. in a stream), additional random points were generated. The GPS point chosen served as the center of a circle with a total area of 250 m^2 and radius of 8.92 m. This 250 m^2 area was the sample area for estimation of tree biomass, where trees are defined as plants larger than 5 cm DBH (1.3 m height from ground). Trees were counted on each plot (sample mean of 14.3 trees per plot) and tree heights were measured using clinometers. Measured trees were marked with enamel or chalk to avoid double counting.

Forest carbon is comprised of above ground biomass (AGB) made up of above ground tree biomass (AGTB) and sapling biomass, below ground biomass (BGB), leaf litter, dead wood and soil organic carbon (IPCC, 2006), but in this paper only AGB is estimated. Biomass was converted to carbon by multiplying the biomass by the 0.5 (IPCC, 2006) conversion factor. The forest carbon inventory methodology used is similar to that of the International Center for Integrated Mountain Development (ICIMOD) REDD+ pilot project in Nepal[5] and relies on allometric equations from Chave et al. (2005) that take account of diameter at breast height (DBH), tree height and density to calculate AGTB. The allometric equations are the following[6]:

$AGTB = 0.0509 * \rho D^2H$ for moist forest stands[7]
$AGTB = 0.112 * (\rho D^2H)^{0.916}$ for dry forest stands
$AGTB = 0.0776 * (\rho D^2H)^{0.940}$ for wet forest stands

Where,
AGTB = above ground tree biomass in kg;
ρ = specific gravity of wood in (g/cm^3)
D = DBH in (cm)
H = Tree height in (m)

[5] The "Design and Setting Up of a Governance and Payment System for Nepal's Community Forest Management under Reducing Emissions from Deforestation and Degradation (REDD)" project is implemented in three Districts with financial support from the Norwegian Agency for Development and Cooperation (NORAD). This pilot project seeks to evaluate the feasibility of REDD payment mechanisms in CFs.

[6] If trees are lopped, as can be important in Nepal, branch biomass will be missing and AGTB will be over-estimated. We address this issue by analyzing a variety of forest quality measures, including percentage of canopy cover. Such measures are less subject to lopping bias.

[7] District average annual rainfall data was used to categorize stands. Dry stands have average annual rainfall of <1500 mm. Moist stands are those having average annual rainfall of 1500-4000 mm. Wet stands are in areas with average annual rainfall of >4000 mm.

Sapling biomass (trees less than 5cm at a height of 1.3 m) was estimated using a 100 m^2 concentric circle within the 250 m^2 circle. Biomass was estimated for stem, branch and foliage. On average, sapling biomass is only 3% of total plot biomass, however, and virtually all biomass is contained in trees. Seedling biomass was not estimated, but numbers of tree seedlings were counted using a 3.14 m^2 concentric circle (1 m radius). On average, 1 meter radius plots contained 3.03 seedlings, implying 30,356 seedlings per hectare.

During the plot survey a variety of environmental data were collected that are believed to affect biomass and carbon. Community level data were also collected and four variables are used in the analysis. Community data are directly collected for NCFs and for CFs taken from MoFSC (2013). Both sources use interviews with executive committee members. For CFs, pairing communities with forests was straightforward, because forest metrics and user lists are approved at CF establishment and any changes must be recorded. For NCFs the <u>one</u> forest analyzed is the forest identified by users and/or their leaders as the most important forest used by communities to collect subsistence products, such as fuelwood and fodder and for grazing. NCFs present other challenges. For example, NCFs generally have not been officially mapped. Forest mapping was therefore done based on identification of the periphery by user group leaders, GPS points were taken, area calculated, etc. User households may also be less well defined than in CFs. Member lists sometimes do not exist and there may even be disagreements about the composition of NCFs. Numbers of households in NCFs were therefore calculated on-site after developing user group lists in consultation with user group leaders.

4.2 Variables

Forest data are collected at the plot level and it is at this level that all dependent variables and most independent variables are measured. Relying on our random sampling methodology, dependent variables, such as carbon, that are countable are converted to per hectare values. For the forest-level analysis we then average across plots (e.g. across 7 plots for forests in the top quintile of the size distribution). Dependent variables are analyzed in logs at the forest level and in unlogged values at the plot level to avoid losing observations when plot values are zero.

Though our main interest in this paper is carbon sequestration and the possibility that collective action and particularly the formal Nepal CF system sequesters carbon, carbon is not the only measure of forest health. Our first alternative to sequestered carbon as a forest quality metric is number of trees per hectare, which attempts to address the possibility that the carbon stock on a plot could consist of a few or even one giant tree; hardly an indicator of a robust forest. The third dependent variable measure is percent canopy cover from the center of each sample plot, which evaluates the extent of side branches in sample plots.[8] Lower canopy cover in Nepal typically indicates that branches have been lopped for fuelwood and fodder. Finally, the extent of regeneration, measured as number of seedlings per hectare, provides an indication of the degree of grazing. Little regeneration may indicate that domestic farm animals like goats, cattle, sheep and water buffalo have passed through and grazed in forest areas. Of course, mature forests also have little regeneration, but in Nepal such near climax forests are unusual. The dependent variables analyzed at both forest and plot levels are the following:

- Total carbon in kg per hectare
- Number of trees per hectare
- Canopy cover in percent
- Seedlings per hectare

Our primary interest is in the effects of collective action, which are measured using three dummy variables. The first is CF status, which is a legal designation. We test whether this legal

[8] This is a key measure of forest quality used in Agarwal (2010).

designation affects carbon storage. CF designation is in reality, however, a subset of broader forest collective action and there is evidence in the data that some NCFs engage in significant collective action. For example, even though they have no legal status, 37 of 65 NCF leaders are able to identify the year their forest user group was formed. The first group started in 1991 and the most recent NCF "group" was established in 2012. Whether forest user groups can identify the year they were formed is therefore a potentially important alternative and more inclusive measure of collective action[9].

Many NCFs not only identify their formation year, but also claim collective action behaviors. For example, in our community survey 74% of NCF leaders agreed or strongly agreed with the statement "*the community forest has clear boundaries between legitimate users and nonusers and nonusers are effectively excluded.*" Furthermore, 68% of NCF leaders report that they have "*… formal, informal or customary rules and regulations that govern the access, use (harvesting) and maintenance (management) of the forest*" and 22 say these rules are in writing. Appendix 2 provides descriptive statistics at the household level from a 1300 household survey that indicate NCF households also perceive significant forest collective action in their user groups.

In our sample a total of 23 NCFs claim to be proposed CFs. We do not know the quality of those proposals, but many are likely to have been waiting for many years and may never be approved by DFOs. Of these 23, a total of 18 proposed CFs have identifiable start dates and 5 do not.

Our collective action variables therefore run from narrow to broad and include the following:

- Narrow definition: Forest and community are registered CFs (CF)

[9] All CFs can, of course, identify such years, because it is legally recognized.

- Modest definition: Forest and community are registered *or* proposed CFs (CForPROPOSED)
- Broad definition: Forest and community are NCFs, but village leaders are able to report the year forest user groups were established (CanIDFUGyear)

We also include environmental variables, such as total forest area, altitude, forest type, plot slope, ecosystem type (hill versus *Terai*), soil quality and whether plots have evidence of erosion and fire as explanatory variables. All these variables are expected to affect plot biomass and carbon, but are not of primary interest. In addition, we adjust for the baseline vegetation level in forests using the 1990 normalized difference vegetation index (NDVI) for our forests. These forest level vegetation indices are calculated from Landsat data images collected in November/December 1990, which is before any of the group formation years in our dataset and three years before the Forest Act of 1993 that established CFs was passed. These particular months are chosen, because the sky is typically very clear in Nepal and Landsat images are unimpeded by clouds.[10] We view the 1990 NDVI variable as a particularly important independent variable. Forests that, for example, had sparse vegetative cover before groups were formed or CFs established are likely to have less carbon in 2013 than forests that started out well-forested. The 1990 NDVI adjusts for this historical baseline and helps avoid endogeneity bias.

Our last three independent variables are at the community level and capture extraction pressures. The first variable is the total number of households in forest user groups and the second is total forest area in hectares per household. The third variable is the forest user group migration rate, which is defined as the fraction of sample household members in forest user groups that are reported to have migrated. This variable is included, because migration is

[10] We thank Charles Maxwell of Portland State Universityfor assuring clear satellite imagery and estimating the NDVI.

significant in many Nepali villages and in our sample several forest user groups had over 20% migration rates.[11] Nationally, remittances made up 15% of GDP and 32% of households received remittances in 2004/2005 (Bohra and Massey, 2009). More than a million adults are working outside Nepal and it has been estimated that 20% of the reduction in poverty between 1995 and 2004 is attributable to migration and remittances (Loksin et al, 2010).

In all plot level models robust standard errors are clustered at the community level to incorporate unobserved community factors like total cattle in the community, ethnic group, religion, etc., for which we do not have data. As discussed in the following section, the panel data models adjust for key plot level unobservables.

The independent variables are given in Table 4 along with means for CFs and NCF and the results of Wilcoxen rank-sum tests of whether CF and NCF forests are drawn from the same distribution. The test accommodates non-normal distributions by comparing medians, with p values giving the level of confidence with which we can reject that the variables are from the same distribution. There are some statistically significant differences, particularly with regard to ecological conditions, because most CFs are in the hills and NCFs tend to be in the *Terai*. This yields differences in altitude, soils, slope, etc. Community variables in Table 4, as well as average household-level socioeconomic variables (caste, wealth class, access to roads, etc.), presented in Appendix 2 are not significantly different. These suggest that the communities and individuals that make them up are broadly the same and key differences are ecological and CF status. In the Appendix are comparisons of respondent-perceived forest institution differences. Though the results suggest significant collective action in NCFs, there are also major mean differences across CF and NCF households, including in participation, forest management structure and quality, with CFs on average reported as performing significantly better than NCFs.

[11] We thank Baskar Karki of ICIMOD for suggesting that we take account of migration.

Our hypothesis is that better performance will be reflected in better forest quality, including carbon sequestration.

Table 4
Independent variables

Independent Variables of Primary Interest		CF Mean	NCF Mean	P value
Variable Name	**Variable Description and Coding**			
CFdummy	1=CF; 0=NCF	N/A	N/A	
CanIDFUGyear_dummy	1= Can identify year of forest user group formation; 0=Cannot identify	1.0	0.57	0.00
CForProposed	1= Either a registered or proposed CF 0 = NCF that is not a proposed CF	N/A	N/A	
Environmental Variables (Plot or Average Across Plots by Forest)				
NDVI_1990	1990 average NDVI by forest	0.41	0.44	0.02
Altitude	Altitude in meters	1037.23	509.83	0.00
Fire	1=Evidence of fire; 0=none	0.23	0.34	0.11
Foresttype	1= Natural, 2= plantation	1.10	1.03	0.02
Slope	Percent (flat=0)	21.26	10.31	0.00
Hill	1= hill; 0=*Terai*	0.67	0.23	0.00
Totalforestarea	Forest area in hectares	149.0	106.44	0.11
Community Variables				
Forestperhh	Forest area in hectares per household	0.90	0.75	0.17
HHsinfug	Total number of households in forest user group	295.80	296.63	0.70
Migrationrate	Fraction of forest user group members that have migrated from the village	0.094	0.077	0.09
Plot Level Environmental Variables in Plot Level Models Only				
Soilcolor	1=black/black; 0=gray/red/white/yellow/other	0.69	0.6	0.02
Clayloam	1= clay/loam soil; 0= sandy/rocky soil	0.52	0.66	0.00
Sal[12]	1=Sal forest, 0=other forest	0.37	0.63	0.00
Aspect	N=1;NE/NW=0.75;E/W/flat=0.50;SE/SW=0.25;S=0	0.53	0.50	0.03
Erosion	1=yes, 0=no	0.24	0.27	0.37

[12] Sal (*Shorea robusta)* is a member of the Dipterocarpaceae family. It is a particularly valuable timber species found in Nepal at lower elevations. 308 of 620 plots are primarily sal. Other species include broadleaf, pine, *bel* and *chilaune*.

5. Empirical Methods

Forest and plot-level analyses are conducted. At the forest level we estimate OLS regression models with dependent variables in logs and robust standard errors to adjust for heteroskedasticity. CFs are a form of local collective action that has been formalized by government, but CF communities are in no sense chosen and are rarely encouraged by the state. We therefore do not see CF designation as subject to endogeneity, but any tendency of CFs to be formed to take advantage of valuable forests should be captured by our 1990 NDVI variable. We complement our carbon and tree forest quality measures with percent canopy cover and regeneration, which are quality measures with few incentives to assert property rights.

We also note that simply being able to identify a forest user group formation year is a measure of collective action that is particularly immune to selection and endogeneity bias. Establishing a CF requires paperwork, time and negotiation outside the community that is generally costly; communities therefore have skin in the game when they apply for CF status. For example, using a survey of 309 households belonging to eight different forest user groups in the middle hills of Nepal, Adhikari and Lovett (2006) find that transaction costs for CF management as a percentage of resource appropriation costs are as high as 26%. The same is not true for NCFs engaging in collective action. Self-organizing to the level that community leaders can identify a user group start year is much less costly than forming an official CF. Indeed, anecdotal evidence suggests that some NCFs are highly organized, but perhaps to avoid transaction costs choose to remain under the radar.

Viewing forest collective action in Nepal as exogenous to current forest quality seems particularly appropriate in areas where communities are stable and have traditionally controlled forests using customary methods. Indeed, having a core of households that were able to cooperate settle in an area and several generations later their descendants formalize collective action as a CF could reasonably be considered an exogenous treatment.

We test whether 1990 NDVI adequately adjusts for baseline carbon levels by running forest level regressions of average carbon per hectare on the 1990 forest NDVI. We then examine whether forests that are governed by each of the three types of collective action have total carbon that is statistically different from the predicted values. For example, carbon above the full-sample prediction might suggest that forests having a particular governance form (after adjusting for the 1990 NDVI) also have more carbon than the overall sample. Using t tests for differences in means, we find that no collective action institutions systematically have excess carbon after controlling for 1990 NDVI. We do find, however, that NCFs for which leaders cannot identify a user group formation year (presumably open access) have significantly less carbon than predicted by the 1990 NDVI. On average, these 28 forests have 52 tons per hectare less carbon than predicted by the regression, which suggests that lack of collective action reduces carbon sequestration.

To complement our OLS estimates of the effects of collective action on our dependent variables, we estimate average treatment effects using propensity score matching based on observables. Though not addressing unobservable factors affecting the probability of treatment (e.g. the existence of a strong leader), matching on observables is a potential way to appropriately construct a counterfactual (i.e. what would have happened to a forest or plot had it not become a CF) and is often used for such observational data (Rosenbaum and Rubin, 1983).

Propensity scores estimate the probability that an observation is in the treated group using a probit model. Explanatory variables in our probit models utilize the environmental and community variables in Table 4 and it is on this basis that CF treated and control NCFs are assigned propensity scores, matched and levels of dependent variables compared.[13] As estimates are very similar across various propensity score matching methods tried, only nearest neighbor matching results are reported. Other matching results are available from the authors.

The possibility that unobservables affect our dependent variables is addressed in the plot level models, where we run random effects-by-plot models. In taking this approach we assume that unobservable cross-forest variation is random (i.e. given by nature) and uncorrelated with independent variables. Given that we are analyzing natural phenomena, such an assumption seems reasonable. We also choose a random effects approach because we are interested only in variation in plots across forests. If we were interested in intra-forest inter-plot variation, a fixed effects approach would be most appropriate. The final reason we choose random effects is that several variables, including CF status and CanIDFUGyear, do not vary across plots within forests. Using a fixed effects model would cause such variables to drop out of the models.[14]

As we do for CF status, we estimate average treatment effects of CanIDFUGyear using nearest neighbor propensity score matching. As 100% of CFs can identify these years, we focus on NCFs to avoid confounding CanIDFUGyear and CF status. Comparing the effect of CanIDFUGyear within NCFs also gives a relatively equal number of treatment and control forests. Whereas within the sample of NCFs there are 37 treatment and 28 control, using the whole sample we have 102 treatment and 28 control, which leaves many treatment forests without matches. Finally, we examine the effects on forest quality of an intermediate form of

[13] As discussed below, in plot level models balance of treated and untreated plots could not be assured when propensity scores were estimated using all variables in Table 4. Balance is critical to the method and a subset of observed variables for which balance is assured are therefore used to estimate the propensity scores.

[14] Results of pooled OLS with errors clustered at the forest level are very similar to the random effects results and are available from the authors. One can also estimate models with time varying and time invariant variables using Mundlak (1978) or Hausman-Taylor (1981) estimators. Results for the Hausman-Taylor models are available from the authors.

collective action that combines both formal and proposed CFs into one variable called CForProposed. Empirical methods used are the same for all collective action measures. [15]

6. Results

We begin this section with simple descriptive statistics. Table 5 presents means and standard deviations for our four forest quality measures, which are our dependent variables. Table 6 breaks total carbon down by CF/NCF and hill/*Terai*. Average carbon per hectare in CF forests is similar to those in NCFs and the difference is not significantly different from zero. The difference between hill and *Terai* forests is, however, significant, with *Terai* forests having on average 42% more carbon than hill forests. This difference reflects the generally more productive ecosystems and differing species compositions in the *Terai*.

Table 7 presents descriptive statistics delineated by whether village leaders can identify the formation years for their forest user groups. As discussed in the previous section, we analyze only NCFs to avoid confusion with CF status and to better balance our samples.

Table 5
Descriptive Statistics for Dependent Variables

Variable	Observations	Mean	Standard Deviation
Total carbon in kg per hectare	130	92410.33	76074.89
Number of trees per hectare	130	560.6894	402.1309
Canopy cover in percent	130	48.61507	19.73628
Seedlings per hectare	130	30356.32	26124.46

[15] For proposed CFs we test whether 1990 NDVI adequately adjusts for baseline carbon levels by running a plot level regression of total carbon on 1990 NDVI. We find that 45 of the 108 proposed CF plots (out of a total of 620 plots) are below the regression line (i.e. actual carbon is less than the full sample would predict). We do, however, reject the hypothesis that adjusting for 1990 NDVI the difference between the actual and predicted carbon is zero ($p<0.01$).

Table 6
Average Carbon per Hectare by Forest (kg)
Standard deviations in parentheses

	Hill	*Terai*	All CF/NCF
CF	76091.67	118327.4	89737.05
	(71102.69)	(102999.5)	(84310.32)
NCF	72068.45	101988.1	95083.6
	(70414.55)	(65616.93)	(67397.78)
All Hill/*Terai*	75068.82	106820.9	
	(70342.33)	(78111.61)	

Table 7
Average Carbon per Hectare (kg) by Forest for <u>NCFs only</u>
Standard deviations in parentheses

	Hill	*Terai*	All ID FUG form year
Can ID FUG form year	122056.4 (74800.52) n=7	116354.2 (61143.91) n=30	117433 (62843.28) n=37
Cannot ID FUG form year	28329 (20865.43) n=8	80439.07 (67697.46) n=20	65550.48 (62550.86) n=28
All Hill/*Terai*	72068.45 (70414.55) N=15	101988.1 (65616.93) n=50	

We see that forest groups that can identify the formation year of their forest user group have more carbon per hectare on average than forests without an identifiable formation year. Whether forests are located in the hills, the *Terai* or in total, average carbon per hectare is greater if a formation year is identifiable. In the *Terai*, for example, forests without an identifiable formation year have only 70% of the carbon of those with an identifiable year. Overall, though, the value is about 55%.

Tables 8 and 9 present the forest level OLS regression results for our four dependent variables with and without the CF dummy and the CanIDFUGyear dummy.

Table 8
OLS Forest Level Models of Total Carbon per Hectare and Total Number of Trees per Hectare

	Carbon per hectare (kg)			Number of trees per hectare		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CFdummy	-0.674		-0.338	0.084		0.078
	(2.20)**		(1.04)	(0.53)		(0.56)
CanIDFUGyear	0.793	0.438		-0.014	0.028	
	(3.72)***	(1.60)		(0.08)	(0.18)	
NDVI_1990	3.891	3.993	3.826	1.448	1.445	1.449
	(3.12)***	(2.95)***	(2.96)***	(2.00)**	(1.99)**	(2.00)**
Totalforestarea	0.002	0.002	0.002	0.000	0.000	0.000
	(3.24)***	(3.44)***	(3.73)***	(1.02)	(1.15)	(1.03)
Hills	0.033	-0.051	0.031	0.287	0.297	0.287
	(0.12)	(0.18)	(0.11)	(1.51)	(1.57)	(1.52)
Altitude	0.000	0.000	0.000	0.000	0.000	0.000
	(1.05)	(0.74)	(0.94)	(0.62)	(0.69)	(0.62)
Slope	-0.001	-0.008	-0.004	0.016	0.017	0.017
	(0.10)	(0.72)	(0.28)	(2.00)**	(2.12)**	(2.01)**
Fire	0.595	0.489	0.347	0.781	0.791	0.785
	(1.90)*	(1.40)	(1.15)	(4.75)***	(4.83)***	(5.05)***
Foresttype	-0.360	-0.621	-0.498	-0.414	-0.380	-0.412
	(0.70)	(1.42)	(0.87)	(1.57)	(1.49)	(1.56)
Forestperhh	-0.011	-0.016	-0.017	0.040	0.041	0.040
	(0.15)	(0.28)	(0.26)	(0.89)	(0.88)	(0.89)
HHsinfug	0.000	0.000	0.000	0.000	0.000	0.000
	(1.06)	(0.76)	(1.37)	(2.03)**	(2.18)**	(2.06)**
Migrationrate	2.043	1.618	2.825	1.124	1.173	1.110
	(1.27)	(0.94)	(1.66)*	(0.86)	(0.91)	(0.87)
Constant	8.568	9.077	9.218	4.958	4.890	4.948
	(8.31)***	(9.68)***	(8.08)***	(9.20)***	(9.68)***	(9.16)***
R^2	0.34	0.29	0.29	0.34	0.34	0.34
N	130	130	130	129	129	129

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; Dependent Variables in Logs, Robust t Statistics in Parentheses

Table 9
OLS Models of Average Crown Cover and Number of Seedlings per Hectare

	Crown Cover (%)			Seedlings per hectare		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CFdummy	0.057		0.001	-0.500		-0.420
	(0.50)		(0.01)	(2.68)***		(2.42)**
CanIDFUGyear	-0.134	-0.105		0.194	-0.069	
	(1.11)	(0.96)		(1.04)	(0.41)	
NDVI_1990	1.949	1.946	1.956	4.156	4.305	4.132
	(2.46)**	(2.46)**	(2.46)**	(3.98)***	(3.97)***	(4.04)***
Totalforestarea	0.000	0.000	0.000	0.001	0.001	0.001
	(1.70)*	(1.77)*	(1.56)	(2.41)**	(1.97)*	(2.54)**
Hills	0.073	0.081	0.074	0.631	0.574	0.635
	(0.54)	(0.59)	(0.53)	(2.76)***	(2.33)**	(2.76)***
Altitude	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000
	(0.14)	(0.08)	(0.11)	(2.27)**	(2.48)**	(2.31)**
Slope	0.011	0.011	0.011	0.001	-0.004	0.000
	(2.30)**	(2.34)**	(2.24)**	(0.06)	(0.47)	(0.01)
Fire	0.307	0.314	0.350	0.038	-0.036	-0.023
	(2.96)***	(2.92)***	(3.30)***	(0.21)	(0.19)	(0.14)
Foresttype	-0.304	-0.281	-0.282	-0.882	-1.073	-0.915
	(1.18)	(1.10)	(1.13)	(2.48)**	(3.01)***	(2.54)**
Forestperhh	-0.008	-0.007	-0.007	-0.045	-0.051	-0.047
	(0.36)	(0.32)	(0.28)	(0.73)	(1.06)	(0.82)
HHsinfug	0.000	0.000	0.000	-0.000	-0.000	-0.000
	(2.21)**	(2.31)**	(2.19)**	(4.51)***	(4.37)***	(4.28)***
Migrationrate	-0.574	-0.541	-0.705	1.360	0.957	1.505
	(0.53)	(0.50)	(0.63)	(0.83)	(0.57)	(0.93)
Constant	3.037	2.991	2.931	9.195	9.532	9.358
	(5.99)***	(5.86)***	(5.57)***	(11.33)***	(12.11)***	(11.88)***
R^2	0.28	0.28	0.28	0.41	0.38	0.41
N	129	129	129	122	122	122

* p<0.1; ** p<0.05; *** p<0.01; Dependent Variables in Logs, Robust t Statistics in Parentheses

The four metrics represent very different measures of forest condition, but only the 1990 NDVI results in positive effects on all four measures, including sequestered carbon. The base vegetative cover therefore appears to be a particularly important determinant of contemporary forest health, with a 10% increase in 1990 NDVI correlated with 15% to 40% increases in forest quality. Larger forests by area also have more carbon and higher levels of all other forest quality measures except trees per hectare. Forests controlled by larger forest user groups have more trees per hectare and percent crown cover, but fewer seedlings per hectare, probably reflecting more trampling by humans and animals. Carbon is not affected. It is notable, though, that this important measure of population density is often positively associated with forest quality. Forestperhh is not a statistically significant determinant of forest quality. More migration generally does not affect forest quality, though in one model a 1% increase in migration is associated with a 2.8% increase in carbon at the 10% significance level. Forests in the hills are estimated to have more seedling regeneration and forests with more average evidence of fire, somewhat paradoxically, have better forest quality by several measures.

Of course, our main interests are in the CF and CanIDFUGyear dummies. These models suggest that CF status has at best no effect on forest quality. CanIDFUGyear is, however, positively associated with carbon per hectare in both models in which it appears, with a marginal effect of 44% ($p<0.12$) to 79% ($p<0.01$). The OLS models therefore suggest that NCF communities that can identify the year of user group formation sequester substantially more carbon than those who cannot. Our conjecture is that this effect is due to collective action proxied by CanIDFUGyear that matters for forest quality, suggesting that collective action may potentially be important for REDD+.

If this conjecture that collective action is important for forest quality is correct, it may follow that collective action that has been in play for longer (and therefore had more time to affect forests) would lead to more carbon sequestration (and perhaps other measures of forest quality) than newer collective action. Tables 10 to 12 present OLS models analyzing the effect of forest user group vintage (for groups that were able to identify formation years) on our four measures of forest quality for the full sample, CFs and NCFs.

As time under collective action progresses we would expect to see diminishing returns to collective action. We therefore include quadratic and cubic terms to allow for curvature. In the

CF models we see some statistically significant effects of vintage on forest quality for the quadratic specification, but due to multicollinearity between the moments of vintage not when we add the third moment. For CFs, we therefore use a quadratic specification. In the interest of brevity, because covariate variable results are similar to those in Tables 8 and 9, they are not presented. These results are, of course, available from the authors.

Table 10
Effect of Forest User Group Formation Vintage (years since 1991) on Forest Quality in all Forests that Can Identify Formation Year

	Carbon per ha. (kg)	Trees per ha.	Crown Cover (%)	Seedlings per ha.
Years after 1991 that FUG was formed	-0.115	-0.266	-0.088	-0.377
	(0.56)	(2.64)***	(0.91)	(2.16)**
Years after 1991 that FUG was formed <u>squared</u>	0.010	0.023	0.004	0.035
	(0.48)	(2.16)**	(0.39)	(2.10)**
Years after 1991 that FUG was formed <u>cubed</u>	-0.000	-0.001	-0.000	-0.001
	(0.37)	(1.89)*	(0.08)	(1.91)*
R^2	0.24	0.34	0.29	0.41
N	102	101	101	95

* *p*<0.1; ** *p*<0.05; *** *p*<0.01; Dependent Variables in Logs, Robust t Statistics in Parentheses

Table 11
Effect of Forest User Group Formation Vintage (years since 1991) on Forest Quality **<u>in CFs</u>**

	Carbon per ha. (kg)	Trees per ha.	Crown Cover (%)	Seedlings per ha.
Years after 1991 that FUG was formed	-0.034	-0.199	-0.093	-0.243
	(0.28)	(2.70)***	(2.45)**	(1.95)*
Years after 1991 that FUG was formed <u>squared</u>	0.002	0.010	0.004	0.011
	(0.32)	(3.32)***	(2.55)**	(2.32)**
R^2	0.33	0.34	0.31	0.55
N	65	64	64	61

* *p*<0.1; ** *p*<0.05; *** *p*<0.01; Dependent Variables in Logs, Robust t Statistics in Parentheses

Table 12
Effect of Forest User Group Formation Vintage (years since 1991) on Forest Quality **in NCFs**

	Carbon per ha. (kg)	Trees per ha.	Crown Cover (%)	Seedlings per ha.
Years after 1991 that FUG was formed	0.316	-0.379	-0.117	0.275
	(1.35)	(1.59)	(0.62)	(1.14)
Years after 1991 that FUG was formed squared	-0.038	0.037	0.007	-0.025
	(1.64)	(1.52)	(0.34)	(1.00)
Years after 1991 that FUG was formed cubed	0.001	-0.001	-0.000	0.001
	(1.67)	(1.52)	(0.16)	(0.92)
R^2	0.53	0.55	0.41	0.42
N	37	37	37	34

* p<0.1; ** p<0.05; *** p<0.01; Dependent Variables in Logs, Robust t Statistics in Parentheses

We do not find evidence that older groups sequester more carbon, but number of trees per hectare, seedlings per hectare and canopy cover appear to benefit from older collective action. An additional year older increases canopy cover by 7% to 9% or 3 to 4 percentage points from the mean canopy cover of 48.6%, though these effects diminish by about 0.04% (0.1 percentage points) per year.

Vintage appears to have particularly broad effects in CFs (all of which have well defined formation dates) and include impacts on trees, canopy cover and seedling density, but not carbon sequestration. At the mean, first order effects are 20% (about 109 more trees) per year and 24% (about 7500) more seedlings per additional year of vintage, decaying at about 1% per year. Canopy cover effects are a bit smaller at 9% (about 4 percentage points per year older).

Other results are similar to previous models, except leaving out forests with no evidence of collective action and including vintage appears to bring out the importance of forests being located in the hills. We find that the hill dummy is positive and significant in four of eight models, with marginal effects in the 35% to 80% range.

Table 13
Forest-Level Average Nearest-Neighbor Propensity Score Matching

Forest Quality Metric	ATT of CF Status			ATT of CanIDFUGyear (NCFs only)		
	Treated/Control	ATT	t-stat	Treated/Control	ATT	t-stat
Carbon/Hectare (kg)	65 / 25	12905.39	0.66	37 / 15	73627	3.812***
Trees/Hectare	65 / 25	14.12	0.116	37 / 15	-9.56	0.053
Canopy Cover (%)	65 / 25	2.563	0.418	37 / 15	3.028	0.292
Seedlings/Hectare	65 / 25	2604.70	0.319	37 / 15	18302	1.772*

* $p<0.1$; ** $p<0.05$; *** $p<0.01$. All treated forests were matched with control forests.

We now turn our attention to the propensity score matching models, where the treatments are CF status and CanIDFUGyear (for NCFs only to avoid conflating with CF status). Both propensity scores are estimated using the full sample and are balanced, indicating that the treatment and constructed control are comparable. Matching is only done within the region of common support of the propensity score, which assures we are analyzing comparable forests and excluding unmatched observations. All estimation results are available from the authors.

To estimate the propensity score for CanIDFUGyear, all environmental and community variables are included. In the propensity score model of CF status the environmental variable Totalforestarea was dropped, because it allowed us to increase our matched sample by 7 forests. With that variable included, treatment and control groups were still balanced, however.

Matching was successful for 90 of 127 forests in the CF models and 52 of 59 forests in the CanIDFUGyear models. The estimated average effect of the treatment on the treated (ATT) is positive and CanIDFUGyear is estimated to have statistically significant positive impacts on carbon and seedlings per hectare. Compared with other NCFs, those with an identifiable formation year have 74 tons more carbon per hectare, which is 80% of the mean ($p<0.001$). This estimated average treatment effect is still well within the range of observed carbon values, because the maximum is 360 tons per hectare. NCF forest user groups that can identify their formation year also have more regeneration (seedlings per hectare), which indicates that trampling has been restricted. Compared with the mean, the effect is approximately 60% ($p<0.10$). These forest level findings reinforce the conclusion from the OLS forest level models that it is not CF status *per se* that is good for forests, but collective action.

As shown in Tables 14 and 15 the forest level model results are very much confirmed at the plot level.[16] The panel-by-plot random effects models again suggest that collective action is an important factor in carbon sequestration, but that collective action may not need to be community forestry *per se*. Plots that are part of forests where the formation year was identified by leaders are estimated to have over 30,000 kilograms more carbon per hectare than plots under presumed open access. This represents a marginal effect of approximately one-third of the mean.[17] CF status is again not estimated to be a statistically significant determinant of forest quality except when measured by seedlings per hectare for which CFs are estimated to have fewer seedlings per hectare ($p<0.10$).

[16] Only panel data models are shown. Pooled OLS results are similar and are available by request.
[17] In the plot level random effects model we find that CanIDFUGyear reduces crown cover ($p<0.05$).

Table 14
Random Effects Models of Carbon and Number of Trees per Hectare (Panel by Plot)

	Carbon per Hectare (kg)			Number of Trees per Hectare		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CFdummy	-8,487.571		7,600.603	20.743		5.904
	(0.49)		(0.49)	(0.29)		(0.09)
CanIDFUGyear	39,128.191	34,763.998		-35.991	-25.423	
	(2.59)***	(2.61)***		(0.45)	(0.35)	
NDVI_1990	145,770.325	147,309.483	143,300.952	700.720	695.905	701.707
	(2.48)**	(2.50)**	(2.39)**	(1.95)*	(1.94)*	(1.95)*
Totalforestarea	156.688	152.319	167.560	-0.103	-0.093	-0.113
	(2.45)**	(2.44)**	(2.83)***	(0.84)	(0.73)	(0.97)
Hills	19,657.847	17,868.913	19,193.049	322.515	327.937	323.174
	(1.23)	(1.15)	(1.17)	(3.90)***	(3.98)***	(3.93)***
Altitude	-12.790	-13.780	-13.888	0.010	0.012	0.010
	(1.43)	(1.57)	(1.54)	(0.16)	(0.20)	(0.17)
Slope	-227.715	-259.042	-246.500	2.400	2.439	2.421
	(0.60)	(0.69)	(0.64)	(1.42)	(1.46)	(1.44)
Fire	6,721.456	6,216.976	1,418.738	88.541	89.330	90.940
	(0.59)	(0.55)	(0.13)	(1.77)*	(1.79)*	(1.87)*
Foresttype	-32,342.954	-33,643.059	-35,057.537	-155.173	-153.625	-154.057
	(2.52)**	(2.70)***	(2.68)***	(1.92)*	(1.93)*	(1.91)*
Forestperhh	-5,095.268	-5,208.786	-5,282.483	5.910	6.172	6.202
	(1.08)	(1.14)	(1.18)	(0.37)	(0.39)	(0.38)
HHsinfug	0.209	-0.253	1.786	0.075	0.076	0.074
	(0.03)	(0.04)	(0.27)	(2.92)***	(3.00)***	(2.88)***
Migrationrate	-101,588.661	-104,451.74	-52,280.944	861.879	867.848	812.644
	(0.84)	(0.86)	(0.43)	(1.22)	(1.23)	(1.19)
Soilcolor	13,449.747	13,181.987	13,326.861	53.434	53.697	53.368
	(1.38)	(1.38)	(1.36)	(1.58)	(1.60)	(1.58)
Sal	25,749.355	26,115.502	26,117.655	110.564	110.024	110.343
	(2.57)**	(2.66)***	(2.61)***	(2.85)***	(2.82)***	(2.84)***
Aspect	20,452.780	20,280.512	20,599.299	-10.592	-10.325	-10.418
	(1.31)	(1.29)	(1.30)	(0.18)	(0.17)	(0.17)
Erosion	12,459.351	12,339.529	9,480.500	66.936	67.147	68.355
	(1.08)	(1.06)	(0.82)	(1.21)	(1.21)	(1.24)
Soiltype	25,191.496	25,660.390	26,618.187	-56.189	-56.439	-56.520
	(2.50)**	(2.60)***	(2.61)***	(1.66)*	(1.66)*	(1.67)*
Constant	-14,795.335	-11,822.53	8,336.989	80.470	75.749	62.025
	(0.47)	(0.39)	(0.26)	(0.36)	(0.34)	(0.28)
N	620	620	620	620	620	620
# Groups	130	130	130	130	130	130
R^2 within group	0.02	0.02	0.03	0.05	0.05	0.05
R^2 between groups	0.36	0.36	0.33	0.23	0.23	0.23
R^2 overall	0.23	0.23	0.22	0.17	0.17	0.17
Wald X^2 (17)	147.30	141.36	111.93	66.38	66.10	64.64
Prob > X^2	0.000	0.000	0.000	0.000	0.000	0.000

* p<0.1; ** p<0.05; *** p<0.01; Robust Standard Errors in Parentheses

History matters at the plot level for all measures of forest quality as it did at the forest level. Plots in forests that had more vegetation in 1990 are also of higher quality in 2013. As was true at the forest level, plots in larger forests tend to be of higher quality, adjusting for all other factors, except when measured by trees per hectare, which is not statistically significant. Sal forests are estimated to have more carbon, trees and seedlings per hectare, probably reflecting the greater primary productivity of those ecosystems. Hill plots have more trees and seedlings per hectare than the *Terai*, but an extra meter of plot altitude is estimated to result in 16-20 fewer kilograms of carbon and about the same fewer seedlings per hectare.

Plots governed by forest user groups with more households (i.e. larger groups) have more trees per hectare and more crown cover. As was true at the forest level as well, Forestperhh is not a significant determinant of forest quality in any model. These results again suggest that population pressure is not an important factor and if anything the effects of population are positive. Other variables are estimated to be significant on idiosyncratic bases.

Plot level propensity score matching models presented in Table 16 confirm the results at the forest level and also the panel-by-plot random effects estimates, but due to the larger sample sizes and details on plot characteristics (aspect, soil type and color, sal forest, etc.) these models offer more precise estimates.[18]

[18] As discussed above and detailed in the Appendix, NCFs were chosen to match with CFs sampled by MoFSC (2013). There was therefore no trouble balancing all blocks. Plots within forests, where much more heterogeneity exists and which were sampled randomly, were more difficult to match. While at the forest levels all exogenous variables could be used to estimate the CF dummy and CanIDFUGyear propensity scores, to obtain balance only the following variables were used in the plot level propensity score estimations: NDVI_1990 Sal forest dummy and clay/loam soil dummy.

Table 15
Random Effects Models of Crown Cover Percentage and Seedlings per Hectare (Panel by Plot)

	Crown Cover Percentage			Seedlings per Hectare		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CFdummy	0.645		-2.997	-8,330.237		-5,612.747
	(0.14)		(0.78)	(1.66)*		(1.43)
CanIDFUGyear	-8.866	-8.531		6,617.894	2,365.804	
	(1.84)*	(2.01)**		(1.19)	(0.56)	
NDVI_1990	66.208	66.072	66.544	45,527.345	47,219.55	45,224.32
	(3.54)***	(3.51)***	(3.48)***	(2.05)**	(2.13)**	(2.07)**
Totalforestarea	0.013	0.013	0.010	30.876	26.870	32.991
	(1.45)	(1.48)	(1.09)	(1.96)*	(1.71)*	(2.07)**
Hills	9.800	9.946	9.966	22,625.599	20,645.69	22,522.21
	(2.08)**	(2.21)**	(2.12)**	(3.70)***	(3.25)***	(3.63)***
Altitude	-0.002	-0.002	-0.001	-15.271	-16.192	-15.367
	(0.61)	(0.58)	(0.57)	(3.97)***	(4.25)***	(3.99)***
Slope	0.074	0.076	0.079	4.531	-18.000	0.388
	(0.70)	(0.72)	(0.74)	(0.03)	(0.13)	(0.00)
Fire	4.667	4.691	5.357	-3,804.967	-4,155.998	-4,443.558
	(1.88)*	(1.90)*	(2.14)**	(1.25)	(1.37)	(1.48)
Foresttype	-5.575	-5.525	-5.198	-13,480.380	-14,529.21	-13,824.68
	(0.94)	(0.94)	(0.89)	(2.29)**	(2.48)**	(2.33)**
Forestperhh	-0.177	-0.169	-0.102	-668.489	-784.124	-719.911
	(0.22)	(0.21)	(0.12)	(0.34)	(0.44)	(0.38)
HHsinfug	0.005	0.005	0.005	-1.289	-1.753	-1.055
	(2.67)***	(2.71)***	(2.64)***	(0.64)	(0.84)	(0.50)
Migrationrate	-10.590	-10.393	-22.498	26,340.360	23,771.28	35,008.87
	(0.28)	(0.27)	(0.60)	(0.56)	(0.49)	(0.73)
Soilcolor	3.537	3.549	3.525	2,628.875	2,403.348	2,634.778
	(1.49)	(1.51)	(1.48)	(1.23)	(1.12)	(1.22)
Sal	3.575	3.556	3.538	10,943.950	11,208.19	10,984.47
	(1.33)	(1.33)	(1.31)	(2.35)**	(2.40)**	(2.36)**
Aspect	-1.012	-1.002	-0.969	407.333	257.619	365.874
	(0.30)	(0.30)	(0.29)	(0.06)	(0.04)	(0.06)
Erosion	-1.102	-1.071	-0.650	7,576.889	7,491.324	7,167.991
	(0.35)	(0.34)	(0.21)	(1.44)	(1.42)	(1.37)
Soiltype	-0.279	-0.306	-0.469	2,934.766	3,275.906	3,114.011
	(0.13)	(0.14)	(0.22)	(1.04)	(1.15)	(1.10)
Constant	22.395	22.236	17.710	11,327.237	13,821.88	14,960.96
	(1.80)*	(1.81)*	(1.45)	(0.73)	(0.90)	(0.99)
N	620	620	620	620	620	620
# Groups	130	130	130	130	130	130
R^2 within group	0.02	0.02	0.02	0.04	0.04	0.04
R^2 between groups	0.22	0.22	0.21	0.28	0.27	0.28
R^2 overall	0.15	0.15	0.14	0.20	0.20	0.20
Wald X^2 (17)	65.16	65.48	61.66	86.97	83.05	85.46
Prob > X^2	0.000	0.000	0.000	0.000	0.000	0.000

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; Robust Standard Errors in Parentheses

CanIDFUGyear is again a significant determinant of carbon per hectare, with plots in forests for which the formation year can be identified having about 50% more carbon compared with average plots. They also have substantially more seedlings per hectare, but a lower percentage of canopy cover as was the case in the plot level random effects models.

Table 16
Plot-Level Average Treatment Effect Using Nearest Neighbor Propensity Score Matching

Forest Quality Metric	ATT of CF Status			ATT of CanIDFUGyear (NCFs only)		
	Treated/Control	ATT	t-stat	Treated/ Control	ATT	t-stat
Carbon/Hectare (kg)	325 / 295	23209	2.271**	169 / 126	40160	4.136***
Trees/Hectare	325 / 295	13.29	0.298	169 / 126	-56.90	-1.193
Canopy Cover (%)	325 / 295	-2.132	-0.842	169 / 126	-7.644	-2.454**
Seedlings/Hectare	325 / 295	-19.27	-0.005	169 / 126	7562.93	2.032**

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

As in other models, CF status is positively associated with carbon per hectare, but when CF and NCF plots are matched based on plot and forest characteristics the estimate is statistically significant at the 5% level. We estimate that compared with matched NCF plots, those in CFs have approximately 26% more carbon.

Results so far indicate that broad measures of collective action have very robust effects on forest quality, including carbon sequestration, but it is difficult to draw firm conclusions about formal CFs, which show mixed results. In the estimation results presented below we evaluate whether an intermediate definition of collective action, which combines CFs and proposed CFs affects forest quality. Other covariate estimates yield no new insights from those already discussed and are therefore not presented. Estimation methods are identical to those previously presented and all results are, of course, available from the authors.

Table 17
OLS Forest Level Models of Total Carbon per Hectare and Total Number of Trees per Hectare
Dependent Variables in Logs, Robust t Statistics in Parentheses

	Carbon/ha.	Trees/ha.	Crown Cover %	Seedlings/ha.
CForProposed	0.193	0.344	0.080	-0.041
	(0.72)	(2.58)**	(0.83)	(0.26)
R^2	0.27	0.36	0.28	0.38
N	130	129	129	122

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 18
Random Effects Models of Forest Quality (Panel by Plot)[19]

	Carbon/ha.	Trees/ha	Crown Cover %	Seedlings/ha.
CForProposed	25,930.635	128.460	-1.777	9,915.939
	(1.95)*	(2.06)**	(0.46)	(2.20)**
N	620	620	620	620
# Groups	130	130	130	130
R^2 within group	0.03	0.05	0.02	0.04
R^2 between groups	0.35	0.24	0.20	0.29
R^2 overall	0.23	0.18	0.13	0.21
Prob > X^2	0.000	0.000	0.000	0.000

* $p<0.1$; ** $p<0.05$; *** $p<0.01$; Robust Standard Errors in Parentheses

Table 19
Forest-Level Average Nearest Neighbor Propensity Score Matching for CFs or Proposed CFs (CForProposed) as the Treatment

Forest Quality Metric	ATT at Forest Level			ATT at Plot Level		
	Treated/Control	ATT	t-stat	Treated/Control	ATT	t-stat
Carbon/Hectare (kg)	88/ 28	31125.5	1.890*	433 / 187	49635.3	5.279***
Trees/Hectare	88/ 28	77.9	0.824	433 / 187	96.06	2.255**
Canopy Cover (%)	88/ 28	1.56	0.257	433 / 187	1.939	0.668
Seedlings/Hectare	88/ 28	11536.7	2.163**	433 / 187	10947.5	3.671***

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

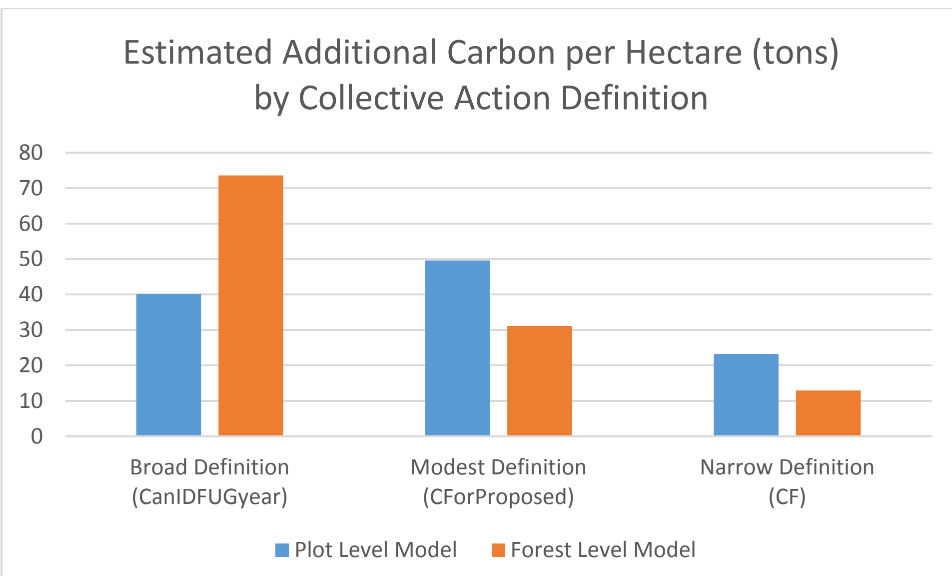
Tables 17 to 19 suggest that the Nepal Community Forestry Programme has effects that may go beyond forests with the legal CF designation, perhaps helping to turn open access NCFs into NCFs that operate like CFs. The effects on forests are estimated to be quite positive, with the most precise estimates again coming from the plot-level models. We estimate that proposed and existing CFs have about 26 tons more carbon and 128 more trees per hectare (34% in the

[19] Covariates are the same as in previous models. Results are available from the authors and are similar to previous.

forest-level model) compared with the 42 control forests and their approximately 200 plots.[20] They also have better regeneration than the control forest plots and therefore better prospects for the future. Indeed, plot level random effects models that consider unobservable forest level characteristics, as well as the plot-level nearest neighbor propensity score matching models, indicate that proposed and existing CFs have better quality forests in all respects except for canopy cover.

The average treatment effect on sequestered carbon by collective action definition is summarized in Figure 2 for the propensity score matching models. In general, the broader measures of collective action are estimated to sequester more carbon and the effects are very large (e.g. 30% to 80%) compared with mean carbon stocks.

Figure 2 Carbon Sequestered due to Collective Action (Tons). Propensity Score Matching Model Average Treatment Effects



* Forest-level model narrow collective action treatment effect not significantly different from zero

[20] In the propensity score matching model, because many forests are either CFs or proposed CFs, only 28 control forests and 180 control plots matched with the treatment group.

7. Discussion and Conclusions

In this paper we use a random sample of CFs matched with NCFs that local experts specifically identified as best possible matches. The forest level propensity score estimates and the comparison of actual and predicted carbon, adjusting for 1990 NDVI, indicate a high degree of balance, suggesting that treatment and control communities are comparable.

To derive results, we use methods that are highly labor intensive, but allow us to carefully estimate carbon for both trees and saplings, count trees, evaluate canopy cover and examine regeneration, which are extremely important measures of forest health and future biomass. Because on-the-ground estimation methods are used, we are also able to gather detailed plot level environmental data like forest type, soil type, soil quality, evidence of fire, altitude, and slope that in many models are shown to be important determinants of forest quality. As our data are collected at one point in time, we include 1990 forest level NDVI estimates to adjust for vegetative baseline. Not surprisingly, we find that baseline vegetation matters for forest quality in 2013.

We find that within the existing institutional environment collective action has very important and generally positive effects on forest quality. Indeed, *in all models, user groups with a well-defined establishment year sequester more carbon compared with NCFs whose leaders could not identify an establishment year*. We believe well-defined establishment year is an important indicator of collective action. It requires a group decision, which is important, but is not subject to nonrandom sample selection because there is no formal opt-in decision.

A policy conclusion that may be drawn from these results is that as part of a robust REDD+ policy, FCCC Annex 1 funders and non-Annex 1 governments would do well to support community collective action. Such support may be significant for communities, because in

Nepal CF formation can be costly.[21] There may also be a need for group facilitation and training.

Though within CFs we find that older CFs generally have better quality forests than younger CFs, we find very limited evidence that forests or forest plots in existing CFs have systematically higher quality than those in NCFs. Indeed, in some models for some measures forest quality is even lower than NCFs. We therefore conclude that in Nepal the community forestry program, while certainly representing collective action, does not provide a <u>unique</u> path to forest health or carbon sequestration.

The finding is not surprising for at least two reasons. First, we know that NCFs in our sample report a variety of sophisticated collective action behaviors, including having written rules, clearly defined boundaries, etc. CF status as a metric may therefore simply be an insufficient measure of collective action. More investigation into these behaviors is an important part of the future research agenda. Second, forest management methods matter. The management of CFs are characterized and governed by operational plans negotiated with district forestry officers. These plans are typically focused on managing subsistence direct use values like fuelwood, fodder and grazing. It is therefore not surprising that particularly carbon is not higher in CFs, because those operational plans do not include carbon values. If CFs are to be brought formally into international carbon mechanisms like REDD+, these findings suggest that carbon management will be necessary. Such a management shift will presumably come at a cost in terms of direct use values and REDD+ may therefore be very important for incentivizing CFs and DFOs to include carbon in operational plans. This is another important area of future investigation.

[21] Author discussions with Kaski District forestry officers suggest that CF formation may cost upwards of $4000.

It is perhaps surprising that collective action *per se* is so important for carbon sequestration when at present this value is completely uncompensated. We would like to suggest that this result is really about collective savings. Carbon sequestration is a linear function of biomass, which can to a first approximation be referred to as “fuelwood” and “timber.” In our view communities that engage in collective action are not sequestering carbon, but are allowing forests to grow in the hope that later they will harvest the fuelwood and timber.

Current rules and governance arrangements associated with timber harvest are and have been very conservative, often poorly defined and *ad hoc*. If these rules are clarified and, as would probably be appropriate from a local perspective, loosened, there is every reason to believe that timber harvests will increase, potentially putting sequestered carbon at risk. Under current arrangements carbon sequestration is therefore somewhat impermanent and the policy implication is that it is probably not appropriate to simply consider carbon sequestration as a byproduct of collective action that would have occurred without any international support. The additionality of carbon sequestered in community forests should therefore be evaluated in light of communities’ current and future incentives for harvest.

Our data do not allow us to track forest quality and carbon sequestration across time. This is a limitation that we have tried to minimize through careful random sampling and use of statistical methods. It leaves open, though, the relationship between CFs and NCFs. For example, while CFs may not be a uniquely effective collective action mechanism, there may be spillovers from CFs to NCFs. The Nepal Community Forestry Programme indeed could have engendered norms of behavior and disseminated methods (e.g. those related to group formation, operation and management) that have been adopted in NCFs.

That CFs and NCFs are not completely independent is perhaps suggested by our analysis of proposed CFs. We find that proposed CFs that are clearly affected by, but not yet part of, the Nepal Community Forestry Programme sequester carbon on a level similar to that of our broadest collective action measure (CanIDFUGyear) and have a variety of positive effects on forest quality. It is very important to emphasize that government forests that we here denote NCFs are often weakly controlled by governments. That so many NCFs are no more degraded than CFs as we would expect to occur under open access suggests collective action exists. We are not able to pinpoint why this collective action occurs, but it appears to be important. We conjecture that over time NCF communities have adopted norms from the CF system.

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Appendix 1

Community Forests and Chosen Non-CF Matches

CF		NCF	
Hill			
CF district	**CF Name**	**NCF district**	**NCF name**
Accham	Raniban cf	Accham	Kokila ncf
	Kalikaban cf		
Baglung	Jauchhare cf	Baglung	Furket Salla ncf
	Majhkatera cf		
	Dudeba Chaur		
	Naulo cf		
	Mauribhir cf		
Bajhang	Chiuri Bhandar	Bajhang	Nauli nabodaya ncf
Bhojpur	Kaijale cf	Bhojpur	Salle ncf
Dailekh	Kalika cf	Dailekh	
Darchula	Sewakendra cf	Darchula	
Dhading	Betini cf	Dhading	Dumla Fulkharka
	Takmare cf		
Dhankuta	Dharmashala cf	Dhankuta	saj bot ncf
	Chetmala cf		
Dolakha	Dimal cf	Dolakha	Patiko ban ncf

	Gumfamahavir cf		
	Khorthali cf		
Doti	Punepata cf	Doti	Kalika ncf
Gorkha	Jalgire cf	Gorkha	
Gulmi	Kwanke deurali cf	Gulmi	
	Navajyoti cf		
	Thulo ban mahila cf		
Kaski	Baunnalek Kalsepati cf	Kaski	khalte khola ncf
	Danda pari cf		Kalene ncf
	Sadherani cf		
Kavrepalanchok	Dhobidhara cf	Kavrepalanchok	Tattelatar ncf
Makwanpur	Mendoling	Makwanpur	
Myagdi	Raniban cf	Myagdi	
	Paulatsya ashram		
Palpa	salleri Rajbrikshya cf	Palpa	Sukadamar ncf
Parbat	Thulo Salleri cf	Parbat	
	Kaligandaki cf		
	Damaha Dhunga cf		
Pyuthan	Mallarani Dhaichaur	Pyuthan	Salleri pakha ncf
Ramechhap	Sampuri titekhola cf	Ramechhap	
			Bhumethan ncf
Rolpa	Baraha kshetra cf	Rolpa	
Salyan	Laligurans cf	Salyan	Jyamira ncf
Sindupalchok	Changgekhola cf	Sindupalchok	
Surkhet	Tilaka cf	Surkhet	Deuti ncf
	Sallaghari cf		Hariyali NCF
	Pokharo danda cf		Bheri ncf
	Siddhapaila		
	Bheri cf		
Tanahu	Mandre Kalika cf	Tanahu	Shiva ncf
Sindhuli	Bhiman Paneshi cf	Sindhuli	
	Saleni tare bhi cf		
	Shivashakti cf		Kamala churi ncf
	Indrawati cf		Kuseswor Dumja ncf
Terai			
Udaypur	Saptakoshi cf	Udaypur	Chireshor mahadiv ncf
	Shree nawaprabhat cf		Belka ncf
	Sadabahar cf		Damaiti ncf
			Jajarkhola ncf
			Jogidaha ncf
			Devdar ncf
		Morang	Srijana ncf
			Sri Srijana ncf
Illam	Sarswoti cf	Jhapa	Pragati ncf
	Bhawana cf		Tribeni ncf
			Aviyukteswor ncf
			Dungavitta ncf
Mahottari		Mahottari	Sagarnath

Mahottari	Srijana cf	Bara	Shree bramha baba cf
Parsa	Shikar cf		Kachadiya vdc ncf
			Kakadi vdc ncf
			Haraiya ncf
			Tamagadi
		Sarlahi	Loktantrik ncf
	Siktahan cf		Sukhaula hariyali ncf
	Baunnakoti cf	Rupandehi	Rohini ncf
			Panbari ncf
Rupandehi			Sringighat ncf
		Kapilbastu	Googauli ncf
			Bankasbasha ncf
			Badganda NCF
			Mayur pokhari
	Amrit Dharapani cf		Ankur ncf
	Ajingare	Nawalparasi	Trikon ncf
			Miljuli ncf
Chitwan			Srijanshil kha NCF
	Shri kalika cf		Samjhana ncf
			samauchi ncf
			Laligurans ncf
			Kalika ncf
			Sannikot
			Gwaldeu ncf
			Siwa samaichi ncf
			Moya samaichi
Bardiya		Kailali	Gwasi samaichi ncf
Kanchanpur	Amar cf	Kanchanpur	Sita ncf
			Ban Devi ncf

Appendix 2

Comparison of CFs and NCF Household Characteristics and Respondent perception of Forest Institution Characteristics. P values based on Wilcoxen Rank-Sum Tests. N=1300.

Variable	CF-Proportion	NCF-proportion	p-value
Well-being class			
Rich	0.09076923	0.11076923	0.231
Medium	0.52	0.5138462	0.8243
Poor	0.3892308	0.3753846	0.6075
Caste			
Dalit	0.1446154	0.1769231	0.1128
Indigenous (Janajati)	0.4369231	0.3938462	0.1151
Brahmin/Chetri	0.3953846	0.4107692	0.5718
Material of house roof			

straw	0.1492308	0.1492308	1
slate	0.2615385	0.2692308	0.7535
galvanized	0.4369231	0.4	0.1772
concrete	0.05692308	0.07846154	0.1222
Sanitation			
Toilet in house.	0.8553846	0.7569231	7.11E-06
Sewerage- permanent	0.02	0.009230769	0.1057
Distance from home to road on foot			
Distance < 2 hours	0.6969231	0.7184615	0.3933
Distance >2 hours and < half-day	0.2584615	0.2523077	0.7992
Distance > half-day	0.04461538	0.02923077	0.1413
Food self-sufficiency			
Sufficient	0.2646154	0.3569231	0.000324
Insufficient	0.6707692	0.5553846	1.95E-05
Does not farm	0.02461538	0.03692308	0.1989
Forest Management			
Rules for access, use and management of forest exist.	1.00	0.6784615	2.20E-16
Written rules for forest management exist.	0.9783951	0.8099548	2.20E-16
HH participation in overall forest management in last year - yes	0.8553846	0.6215385	2.20E-16
HH participation in forest monitoring last year - yes	0.6076923	0.4507692	1.45E-08
Membership fee paid for the forest user group - yes	0.5630769	0.4369231	5.40E-06
Forest management quality			
The rule of access and forest use are clear	0.7784615	0.5046154	2.20E-16
The system of deciding who has access to the forest resources is a fair one	0.7384615	0.44	2.20E-16
The forest helps reduce poverty	0.5923077	0.4630769	3.06E-06
Our forest is able to meet our household demand	0.6553846	0.5476923	7.32E-05
The process for distributing and accessing forest products and is fair and acceptable	0.66	0.4538462	7.34E-14
There are limits on how much fuel wood we can collect from our forest?	0.6569231	0.5153846	2.21E-07
There are limits on how much leaf litter we can collect from our forest?	0.4676923	0.2538462	9.92E-16
There are limits on how much grazing or fodder collection we can do on common lands.	0.74	0.4046154	2.20E-16
We are either formally or informally involved in monitoring the forest.	0.7369231	0.5984615	1.16E-07
We feel that we and others in the	0.6153846		

village are able to take the amounts of forest products from common lands that are needed for household use, but not more.		0.5061538	7.25E-05
We have influence on policies for deciding how much forest products people can take from common lands.	0.7015385	0.4723077	2.20E-16
Village authorities monitor who takes what products from our forests.	0.6415385	0.4384615	2.05E-13
Villagers generally watch who takes forest products from our forest.	0.5876923	0.4753846	4.96E-05
The controllers of our forest (who decide how much each person can take) are democratically chosen.	0.6907692	0.4569231	2.20E-16
Other villagers would be very unhappy with us if they found that we had taken more than our allotment of fuel wood, fodder or grazing.	0.6707692	0.5553846	1.95E-05
We could lose some or all of our rights to collect forest products if we were caught taking more than the amounts you are allowed to take.	0.06933426	0.17681958	8.42E-06
All other households have the same allotment of fodder or grazing rights per year as our household.	0.5676923	0.5230769	0.1062
If we took more fuel wood from the forest than we were allowed to take, we would face some sort of punishment.	0.7107692	0.5353846	6.83E-11
If we took more fodder or did more grazing from the forest than we were allowed, we would face some sort of punishment.	0.6169231	0.4676923	6.67E-08
We would feel embarrassed or bad if we took more than our allotment of fuel wood, fodder or grazing.	0.72	0.5892308	7.12E-07