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Community Forest Management: The story behind a success story in Nepal

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Gestion communautaire des forêts : l'histoire derrière la réussite du modèle népalais

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Résumé : Depuis 1993, le Népal a mis en œuvre l'une des politiques de décentralisation de la gestion des forêts les plus ambitieuses et étendues au monde. Cette politique basée sur la gestion communautaire des ressources est largement mise en avant pour sa réussite. En se basant sur des méthodes quasi-expérimentales, nous quantifions les gains nets dans le couvert arboré lié à la mise en œuvre et l'expansion du programme dans les zones de collines et de montagnes du Népal. Nous décrivons ensuite l'évolution de ces gains dans le temps. Pour conclure, nous mettons en relief les mécanismes qui sous-tendent la régénération forestière, tant par le rôle que les communautés jouent dans l'accroissement de la biomasse forestière et de l'étendue des zones boisées que par la réduction de la demande de bois énergie.

Mots-clés : gestion de forêt ; gestion communautaire de forêts ; Népal ; énergie ; développement participatif

Community Forest Management: The story behind a success story in Nepal

Abstract : Since 1993, Nepal has implemented one of the most ambitious and comprehensive program of decentralization of forest management in the world, which is widely considered a success story in terms of participatory management of natural resources. Using quasi-experimental methods, we first quantify the net gains in tree cover related to the program in the Hills and Mountains of Nepal, and describe their temporal evolution. We then discuss the mechanisms driving forest restoration, highlighting that, while community forestry played a role in increasing forest biomass and forest size, it also reduced demand pressures by altering energy choices.

Keywords : Forest management ; Community forestry ; Nepal ; Energy ; Participatory development

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1 Introduction

Over the past 25 years, the government of Nepal has implemented one of the most ambitious and comprehensive program of decentralization of forest management in the world. This major institutional change resulted in the transfer of the management of almost 50% of the forests Nepal to no less than 18,000 Community Forest User Groups (CFUGs). More than one third of the Nepalese population is directly involved in the management of forests, a key natural resource in everyday life, which provide not only firewood or timber, but also fodder for livestock, fruits, nuts and medicinal plants. Thus, in the Hills and Mountains, about 45% of rural households report their first source of firewood as being the community forest.

The program, formally launched in 1993, entrusts forests to CFUGs at the village level, who are then in charge of their daily management. Through their formal constitution and their operational plans, CFUGs lay down the rules of access and use of forests, manage their monitoring, and develop planting and harvesting programs. User fees and the sale of timber and other forest products generate income, which is reinvested in the forest or used for collective projects and public infrastructure at the village level. These income sources are important and largely exceed the budget of the 'local development committee'. (In a private conversation, the Head of the CFUG Division in the Department of Forests and Soil Conservation estimated that CFUGs incomes were four times larger than the total budget of the local village committees.) The success of the program has been widely advertised, and has received lot of attention internationally, for instance by UNEP (Sukhdev and Nuttall, 2010).

However, we still know very little about the effects of the program at the country level and the potential channels underlying these positive changes (For a similar assessment at the world scale, see Bowler et al. (2012)). From recent studies in Nepal, the evidence is mixed. Using propensity score marching on a broad sample of community forests in Nepal, Bluffstone et al. (2018) find that formal CFUGs do not sequester more carbon than forests under informal community management. Oldekop et al. (2019) compare changes in forest cover and poverty following the creation of CFUGs between 2001 and 2011. They find that subdistricts that are otherwise similar at baseline tend to experience reductions in deforestation and in poverty. On a more limited scale (in the Arun Valley at the early stages of the program), Edmonds (2002) finds that the creation of CFUGs reduces firewood collection at the household level.

In the neighbouring Indian Himalayas, Somanathan et al. (2009) compare forests under community management (Van Panchayat) to neighbouring forests using satellite imagery. They conclude that, compared to situations of open and unregulated access, Van Panchayats are as effective in preserving forest cover in community forests than the Indian Forest Department in State forests, but at a much lower cost in terms of fiscal resources and bureaucratic management. Using a cross section of forest measures taken in randomly chosen forest patches, Baland et al. (2010) show that, despite the fact that Van Panchayats are initially given more degraded forests, they rapidly succeed in reducing excessive lopping and tree damages, leading to a much healthier and denser forest in the long run. By contrast, in the context of Madagascar the during economic and political crises of the early 2000's, Desbureaux (2016) shows that community forest management led to increased deforestation, particularly in villages neglected by the central authorities in which local collective action was traditionally strong. With the possible exception of the civil war that ended in 2006, the situation in Nepal differs from the latter as the Department of Forests and Soil Conservation in Nepal strongly supported and accompanied the community forest policy in the creation of forest user groups in the villages.

In this paper, we first show that the CFUG program contributed to substantial increases in forest cover in the Hills and Mountains of Nepal. To this end, we create a 14-year panel data set that combines remote sensing data with administrative data and household surveys. Given that the creation of CFUGs cannot be considered fully random, we model the spread of the program in a district by instrumenting the creation of a CFUG with the interaction between the time since the start of the program in a given district and the distance between a given village and the district headquarters. This approach allows us to isolate the effect of CFUGs on forest cover, independently of the fact that, for instance, CFUGs may have been created in more degraded or less valuable forests. We also investigate the time structure of these effects, firstly by adopting a purely descriptive approach, and, secondly, by relying on the methodology proposed by de Chaisemartin and

D'Haultfoeuille (2020) and that applies nicely to our context with staggered adoption and, most probably, heterogeneous treatment effect across CFUGs and across time. The results of based on this methodology reveal a steady increase in canopy density, consistent with an immediate reduction in lopping, followed by a slow and steady regeneration process. A placebo exercise over 10 years shows that the leaf area index (LAI) in villages where CFUGs are created does not systematically vary in the decade before the program effectively starts.

We then investigate the potential mechanisms underlying these forest improvements. On the supply side, forest areas increased substantially at the expense of agricultural land and shrubs, and replanting took place with needle-tree and mixed forests increasing much more than broadleaf forests. CFUGs also reduce the demand for biomass. We find that small-scale biogas installations, a direct substitute to firewood for cooking, are widely adopted in areas of CFUGs expansion. Using household data, we also find that firewood collection times are higher and firewood collection lower in villages in which CFUGs are newer, while these correlations vanish for older CFUGs. This evidence is consistent with the idea that CFUGs start by first imposing restrictions on firewood collection, but later, as forest conditions improve, allow a larger collection of forest products, and in particular firewood, by the villagers.

In the following, we leave the Terai region aside, as the Terai is specific in several ways. First, forests have long been cleared in Terai, with patches of forests remaining in the Northern part of the Terai, on the first slopes of the Siwalik. Second, Terai forests are mostly covered by sal trees (*Shorea robusta*), a highly valued commercial species traded on the legal and illegal markets, particularly along the Indian border. These two features completely change the nature of local community management there (see Libois (2021)). Third, because of the milder climate in those plains, energy needs differ, particularly for heating in the winter season. Finally, the methodology adopted in this paper is much less appropriate for the Terai forests.[1]

The paper is organized as follows. Section 2 describes the data used. In section

[1]First, the Leaf Area Index is less precise in Terai as the seasonality of cropping patterns is much less standardized, with green fields persisting in November and December. Second, the dynamics of CFUG creation in the Terai differs as transportation costs across these flat plains are much lower.

3 we present the effects of community forestry on forest conditions. Section 4 discusses potential mechanisms behind the gains in tree cover, while the last section concludes.

2 Data

To measure tree cover, we rely on two main data sources. First, we use the yearly village-average November LAI constructed using the algorithm by Verger et al. (2014) applied to the data from the SPOT-VEGETATION sensor over the period 1999-2013, and to the data from the PROBA-V sensor from 2014 onwards.[2] LAI is a vegetation parameter commonly used to monitor the spatial and temporal variation in leaf density. Considered as one of the essential climate variables (Bojinski et al., 2014), it is defined as half of the area covered by all the leaves per ground unit area (Bréda, 2008). The LAI gives us a continuous measure of tree cover that reacts to increases in leaf density. (It is less subject to saturation than other possible measures, and is thereby able to better capture variations in canopy density.) We average the LAI at the 'village' level where the 'village' corresponds to the smallest administrative division in Nepal, corresponding to the Village Development Committee (VDC), often composed of different hamlets. Henceforth, we refer to a VDC as a 'village'. We use November data because, in the Hills and Mountains of Nepal, the deciduous trees still have their green leaves, whereas the crops have just been sown. During that period, the green photosynthesis visible by remote sensing comes essentially from tree leaves (Niraula et al., 2013). This observation has been used in several remote sensing based methods to map forest cover in Nepal (ICIMOD, 2014a,b), and has been corroborated by our field visits and observations of the phenology of the different types of vegetation.[3]

We also rely on the MODIS land cover type product (MCD12Q1), a data set that provides an annual classification of land cover at 500m-resolution. The

[2]The data set relies on a neural-network based algorithm trained with older generation LAI datasets in order to merge their respective pros. It also includes a procedure in order to make up for the gaps in the time series due to the presence of clouds, as cloud cover can occur even outside of the rainy season (June-September).

[3]In the economics literature, in the same spirit, Alix-Garcia et al. (2013) also use a greenness index outside the rainy season to compute annual measures of tree cover for Mexico.

product is created using supervised classification of MODIS reflectance data (Friedl et al., 2002, 2010). We use the class description of the International Geosphere-Biosphere Programme and focus our analysis on forest related classes (see Sulla-Menashe and Friedl (2018) for more details). We also make extensive use of the 2017 census of CFUG provided by the Department of Forests and Soil Conservation in Nepal, which records the creation date of all groups since the inception of the program. It also contains information about the area managed by the CFUG, its administrative location, as well as some information about the membership of the group and the steering committee composition.[4] Our main variable of interest is the share of a village area managed by the CFUG, with the village area being measured using a digitized map of the village boundaries established by the Nepal Central Bureau of statistics.

In figure 5 we plot the evolution of the November LAI and the share of village area managed by CFUGs over the last 20 years. The overall trend in tree cover is overall positive and correlated with a sharp increase in the area managed by CFUGs, with one eight of the territory under community management at the end of the period.

[Insert Figure 5 here]

2.1 Additional data sources

We also make use of additional data sources to investigate the mechanisms driving the evolution of tree cover. We first exploit the census of biogas installations of Nepal over the period 1994-2015 from the Alternative Energy Promotion Center. It contains very detailed information on all biogas installations subsidized by the government of Nepal and constitutes the most comprehensive database on biogas at the village level in Nepal.

Our main source of information on household choices are the second and third wave of the World Bank Living Standards Measurement Survey (LSMS) for Nepal, also known as the Nepal Living Standard Survey (NLSS). The Nepal Central Bureau of Statistics, in collaboration with the World Bank, interviewed households

[4]We also use the 2010 CFUG census in one figure to provide descriptive statistics about the type of forests managed by CFUGs.

about several aspects of their production and consumption activities. The surveys cover 123 villages and 1474 households in 2003-4 and 178 villages and 2116 households in 2010-11 in the Hills and Mountains region, selected randomly with a probability proportional to their population. The quality of the surveys has been tested by Hatlebakk (2007), who also discusses them in greater details. CBS (2011) provides additional information about the technicalities of the sampling, the methodology, and the implementation of the surveys.

Our analysis relies extensively on additional controls derived from various data sources. To compute walking distances between district headquarters and villages, we use the third version of the 30m-resolution ASTER digital elevation model (Abrams and Crippen, 2011; Fujisada et al., 2011).[5] The same source of information provides village level median elevation and its standard deviation. Temperature related controls were extracted from the MODIS product MOD11A2 that provides an 8-day average land surface temperature at a 1km-resolution (Wan et al., 2015). Snow cover comes from MOD10A2 product, an 8-day snow cover measure provided by Hall and Riggs (2021) at a 500m-resolution. Lastly, we compute village level annual rainfall based on the daily estimates of the tropical rainfall measurement mission (TRMM, 2011).

While remote sensing allows us to have high frequency information on the environment, data become less frequent and less precise as we go back in time. We have therefore digitized and geocoded US army paper maps of Nepal from the 1950s. Using a semi-automatic classification tool, we have extracted areas depicted as forest on these maps.[6] This information gives us a historical measure of forest cover around 1950, largely before the start of the community forestry program.[7] Lastly, the Informal Sector Service Centre (INSEC), a very active Nepali human rights organization, collected extensive data on conflict intensity during the entire duration of the civil conflict. The INSEC database (INSEC, 2009) is considered to be the most reliable data source on the civil war, which spanned the period

[5] We follow the formula of Aitken (1977); Langmuir (2013) based on Naismith's rule of thumb to compute walking time, implemented in GRASS GIS.

[6] We could rely on the Historical Map plugin in QGIS to perform this analysis.

[7] We use this variable with caution as it predates the huge population expansion in Nepal as well as the colonization of Terai. This internal migration from the Hills to the plains was accompanied by a huge deforestation process in the low lands, as well as structural changes in the Hills.

1996-2006. For more details on this data source see Libois (2016) and Joshi and Pyakurel (2015). Tables (1) and (2) below provide the main descriptive statistics of the village and household variables used throughout our estimations. Some additional household information is given in Table A1 in the Appendix.

[Insert Table 1 here]

[Insert Table 2 here]

3 Community forestry and forests

3.1 Empirical strategy

To investigate the consequences of the community forestry program, we first compare forest conditions, as measured by tree cover at the village level, before and after the creation of a CFUG. Given the dynamics of forest regeneration, we then analyse the evolution of tree cover over time, once a forest user group is created.

The main empirical strategy relies on the following specification:

$$LAI_{vt} = \alpha CFUGshare_{vt-1} + \beta_k X_{kvt} + \eta_v + \delta_t + \varepsilon_{vt}. \tag{1}$$

where LAI, stands for the average leaf area index in village v in year t. The main explanatory variable, $CFUGshare$, is the share of the village area under CFUG management in year t. In all specifications, we control for a set of time-varying village level controls X, such as total rainfall, average snow cover, growing degree days, or the local intensity of the civil conflict. We also include village and time fixed effects parameters to avoid potential biases caused by village characteristics or country level shocks, such as altitude or national political cycles. The parameter of interest, α, quantifies the change in the average LAI that follows a change in the share of the area managed by the village CFUGs.

As such, a causal interpretation of α is questionable, given the non-random nature of the creation of CFUGs. For instance, if members of a CFUG are systematically more pro-social, with stronger social ties and more awareness of environmental issues, we may expect increases in LAI to occur in places where CFUGs are created, independently of the intrinsic properties of the program, biasing upwards the estimated α. Alternatively, the latter may be downward biased if the Department of Forests and Soil Conservation systematically chooses to hand over the less productive or more degraded forest plots to local communities. To reduce these potential biases, we follow an instrumental approach and estimate equation (1) by two-stage least squares. The first-stage equation is given by:

$$CFUGshare_{vt} = \beta_1 \text{Proximity}_v \times \text{TO}_{dt} + \mathbf{Z_{vt}\Theta} + \gamma_v + \tau_t + \varepsilon_{vt} \tag{2}$$

The instrument used is the interaction between *Proximity*, the inverse of the distance between the village and the district headquarters where the district forest office is located (as measured by the walking time in hours), and TO, the number of years since the onset of the CFUG program in district d. We again control for a large set of time and space varying variables, including TO and a broad range of environmental controls, as well as village and time fixed effects. The instrument we propose is relevant both from a statistical point of view, and given our insights from the field and interviews with forest officers. The first CFUGs were typically created close to district forest offices after the nomination of a forest officer willing to implement this new program. The creation initially involved numerous visits and extensive efforts to persuade villagers to join this new program. Once the program starts in a district, the first CFUGs are almost always created close to the district office of the Department of Forests and Soil Conservation. Indeed, in the 90s, travelling within districts would typically occur by foot or by riding horses.[8] Forest officers, therefore, had strong incentives to minimize travel distance.

We proxy travel time to villages by computing the fastest walking time between district headquarters and the village development committee in this district, relying on a digital elevation model of Nepal.[9] There are large variations in the creation of the CFUG program across districts; some started in the early 90s, while the last district to launch a CFUG was Bara, where the first CFUG was created in 1999.[10]

[8] Some districts were not even connected to the capital city Kathmandu by paved road.

[9] Travel distance may be correlated with other factors influencing forest cover, which we control for by village fixed effects.

[10] There is no CFUG in Mustang because CFUGs are not created in Conservation areas, and the whole district is part of the Annapurna Conservation Area.

We do not consider these variations as exogenous as such, but assume that the interaction between the two sources of variations is an exogenous predictor of the creation of a CFUG, conditionally on the controls included in the regression.[11] In a sense, this instrument is a generalization of Edmonds (2002)' approach over a larger spatial and temporal coverage. As we see in Figure 5, villages located further away from district headquarters are increasingly incorporated in the program. Figures A, A3 and A4 in the Appendix illustrate this expansion process, which looks like an oil spill starting in each district's headquarters at different points in time.[12]

[Insert Table 5 here]

On top of being statistically strong, the instrument has to be exogenous, conditionally on the other control variables. To violate this exogeneity assumption, one would have to find a variable which affects tree cover and is correlated with a district-specific expansion starting from the district headquarters in the inception year of the CFUG program by the specific district. The development of infrastructure could be such a threat, but it requires the onset of the road construction programs to be correlated with the start of a CFUG program in the district. This is not what we observe in the spatial distribution of the launch of a CFUG program. Another possible threat could be that economic development accelerates in a district at the same moment as the launch of a CFUG program, and that this economic development induces rural exodus or changes in domestic energy choices that occur at the same temporal and spatial pace as CFUG creation. This looks in our view to be rather unlikely.

3.2 Main result

Table 3 reports the estimation results of the effect of CFUGs on the November LAI following equation 1. (In all our estimations, we weight the observations

[11] In practice, the onset of a program in a given district has arguably some random component as it is partially driven by changes and promotions in the Department of Forests and Soil Conservation, which exhibits a relatively high level of turnover.

[12] In the Terai plains - the twenty Southern districts bordering India - this expansion is less systematic as it is much easier to travel across these flat areas, and forests have been cleared in most places except the national parks and the foothills of the Siwalik.

by the village area to reflect changes in tree cover at the country level and we cluster standard errors at the district level. This is the natural level since our instrument assumes that there are common shocks at the district level inducing CFUG creation.) Column (1) indicates that a 10% increase in the share of village area managed by a CFUG is followed by an increase in the LAI of 0.04. In terms of magnitude, with an average LAI of 1.3 and 12% of the village area managed by a CFUG in 2013, the contribution of the CFUG program to the increase in tree cover is estimated to be about 4%.[13]

[Insert Table 3 here]

Given our previous discussion, we expect some selection in the forest plots that the Department of Forests and Soil Conservation hands over to local communities. We therefore estimate the main equation using our instrument, and report the results in column (3) of table 3. The two-stage least-squares approach reinforces the conclusions of the simple panel approach, and indicates a larger effect of CFUGs on the LAI. Point estimates actually increase tenfold, and a 12% increase in CFUG coverage increases the LAI by 0.55, a 40% increase. These large estimates are consistent with our field observations whereby the Department of Forests and Soil Conservation tends to hand over forests plots that are already degraded. CFUGs are first created close to urban centres where the pressure on land is the largest and the need for forest products remains high. Forests that are easier to protect and less at risk of degradation tend to remain under the Department of Forests and Soil Conservation for longer.[14] This is a typical source of downward bias for the OLS coefficient, which explains why instrumenting for CFUG creation amplifies the point estimate: given low initial levels of forest cover, changes can only be large. The first stage estimates are reported in the second column of 3. Ten years after the program starts in a district, a village located at five walking hours from the district headquarters is expected to have an increase of one percentage point of its area managed by CFUGs.[15]

[13] $0.04=0.12 \times \frac{.448}{1.33}$

[14] Baland et al. (2010) also report similar stories in the Indian Himalayas.

[15] $0.011 = \frac{10}{5} \times 0.0055$. The first quartile of the walking time between a village and its district headquarters is equal to 5.57 hours.

In the last three columns of Table 3, we report the estimations obtained when we additionally control for population density and the prevalence of biogas (in number of installations per household). One can indeed suspect that migration accelerates at the same pace as the CFUG program by starting in places close to urban centres and later expanding to more remote locations. The spread of new technologies, such as biogas, could have also followed a similar pattern in time and space. These additional controls do not substantially change our results. The minor changes in the estimated coefficients could possibly indicate that part of the CFUG effects are mediated through the adoption of biogas and the resulting reduction of firewood use. (A genuine correlation between CFUGs and biogas should have substantially reduced the estimated coefficient of CFUG). As a matter of fact, the biogas program, which involves subsidies and subcontracting to private companies, developed much later than the CFUG program, and was managed by an independent administration (the Alternative Energy Promotion Center) with no links to the Department of Forests and Soil Conservation. Our field observations indicate that biogas companies would typically take advantage of CFUG assemblies to promote their technology. The expansion of biogas can thus be viewed in some ways as a by-product of CFUG expansion, an expansion we further address in section 4.Population density should capture outmigration in the most relevant way for firewood collection, and the estimated coefficient has the expected sign. Our measure, however, is far from perfect, as it is based on a log-linear interpolation of the information available in the 2001 and 2011 population census. (Some villages are also lost due to missing data in the 2001 population census.)

3.3 Longer-term effects

Forest cover is a biological process, and trees take time to grow. Moreover, forest user groups result from collective action at the village level, which also requires time to manifest. We therefore expect the effects of community forestry to be heterogeneous across time, something that could not be captured by the specification of equation (1), which provided an 'average' measure constant through time. To investigate this temporal process, we now follow an alternative approach based on the following equation:

$$LAI_{vt} = \sum_{z=0}^{20} \alpha_z \text{Proportion of VDC area managed by FUG}_{vt-z} + \mathbf{X_{vt}\Theta} + \gamma_v + \delta_{dt} + \varepsilon_{vt} \quad (3)$$

where the LAI in village v at time t is a function of the share of the village area managed by a CFUG created in year $t - z$. As in the previous specifications, we control for $\mathbf{X}$, a vector of time-varying village-specific controls, γ is a vector of village fixed-effects, δ captures district-time specific variations and ε stands for the error term. The coefficients of interest, α_z, measure the change in LAI in year t which follows the creation of a CFUG over a given share of the village area z years before t.

We report the estimates over a time span of 20 years in Figure 5. The first years of the existence of a CFUG see a moderate increase in the LAI, a consequence of the first management measures which typically consist of reducing lopping, creating rules about fodder collection, and restricting firewood collection to dry wood. Over the years, we observe a gradual increase in the LAI consistent with a slow process of forest regeneration. After 20 years, point estimates more or less double in size compared to years closer to the creation date of the CFUG. The standard errors are also larger, given that fewer groups reach 20 years of age in our sample.

[Insert Figure 5 here]

In Figure 5 below, we provide an alternative estimation using the de Chaisemartin and D'Haultfoeuille (2020) approach. This approach is appropriate in our context, as we have a staggered process of CFUG creation and we expect the effect of the 'treatment' to be heterogeneous across space and time.[16] This estimator differs from the descriptive approach followed above by better defining the appropriate comparison group when estimating the 'effect of the treatment'. It indeed compares villages which are initially similar in terms of CFUG area, but where some move to the next - higher - treatment category. Villages with lower initial shares are therefore excluded from this comparison, while they are the basis of comparison in the first approach followed above. However, this estimator requires

[16] As highlighted by de Chaisemartin and D'Haultfoeuille (2020), this pattern of treatment can generate negative weights in the OLS estimation of the average treatment effect.

a discrete treatment, while our measure at the village level is continuous. We have therefore decided to group CFUG coverage at the village level into six categories (one at zero, and the others at intervals of 20%). These alternative estimations show that there is no clear trend before the treatment (up to 10 years before the treatment), while the LAI increases steadily after the creation of a CFUG. [17] When compared to our instrumental approach in section 3.2, one can argue that, by properly defining the comparison group for various levels of treatment, this estimation provides an alternative way to get at the causal effect of CFUGs.

[Insert Figure 5 here]

4 Supply and demand mechanisms behind changes in tree cover

Two main reasons may explain why tree cover increases under community forest management. First, CFUGs may implement better management practices than under nominal management by the Department of Forests and Soil Conservation, for instance, by favouring some species or planting saplings. These mechanisms directly affect the supply of forest biomass. On the demand side, CFUGs may reduce the demand for forest products and alleviate human pressure on forests. As shown in Baland et al. (2018), firewood collection is an important driver of forest degradation in the Hills and Mountains. Therefore, by modifying the energy choices of households, CFUGs may induce faster forest regeneration and tree cover gains.

4.1 The supply of biomass

We first investigate changes in land use based on the Vegetation Cover Fields of MODIS, which distinguishes between different types of vegetation covers. Table 4 follows the specification of equation 1 on a set of land-use variables. The estimations indicate that a 10% increase in a village area managed by a CFUG translates

[17] In terms of interpretation, a change of one unit in this new variable should be interpreted as a 20% increase in the share managed by a CFUG.

into an average gain of 0.8 percentage points in the overall share of forest in the village. When instrumenting for the creation of a CFUG, this effect goes up to 5.8 percentage points, which is sizeable (column (5)). The large increase in forest cover is mostly driven by an increase in mixed forests and, more modestly, in needle-leaf forests (columns (6) and (7)).

[Insert Table 4 here]

By contrast, as shown in Table 5, we observe no significant changes in broadleaf forests, while the area covered by crops and shrubs decreases substantially following the introduction of CFUGs in the village. The increase in forest cover is therefore driven by mixed and needle-tree forests replacing crops, open (deforested) land and shrubs, which fosters overall biodiversity, particularly in mixed forests. These changes partly follow from the plantation activities undertaken by CFUGs, and particularly *Pinus Roxburghii* and *Shorea robusta* for their market value as a source of timber. [18]

[Insert Table 5 here]

4.2 The demand for biomass

4.2.1 Community forestry and household access to energy

Community forestry also affects villagers' demand for energy. By restricting access to forests and limiting firewood collection, CFUGs encourage the development of alternative energy sources, such as individual biogas production units. In Table 6, we show that the construction of biogas installations, whether measured by the number of biogas units in the village or the number of units per capita, increases with the presence of CFUGs in the village. In terms of magnitude, a 10% increase in CFUG coverage increases the number of biogas installations in a village by 407 units, which correspond to an increase in terms of coverage per household of about 8.5 percentage points (column 5).

[18] In the 2010 CFUG census, which contains information on forest type at creation date, needle forests (mostly *Pinus Roxburghii*) represent 29% and Sal forests (*Shorea robusta*) 34% of the area operated by CFUGs. *Schima Castanopsis* accounts for 10% of the CFUG forest area, and Subtropical deciduous forest 14%. *Alnus Nepalensis*, oak, rhododendron and upper slope mixed hardwood forest are more marginal. See Figure A5 in the Appendix for more details.

[Insert Table 6 here]

This is sizeable and should be put in perspective. First, biogas units in Nepal are rather small and require no less than two cattle heads to operate. The penetration rate of this technology is high, and concerns, according to the Alternative Energy Promotion Center, 4% of households in 2013, with an average of about 50 installations already constructed in each village of the Hills and Mountains. Second, according to our field visits, managers of biogas companies take advantage of CFUGs assemblies to promote this technology and enter into contact with potential customers. Moreover, CFUGs themselves affect access to energy, and may offer support to biogas adoption by providing credit or subsidies.

4.2.2 Community forestry and access to firewood

One of the main drivers of forest degradation in Nepal is the demand for firewood, which is used as a source of cooking and heating energy. Thus, in 2010, rural households in the Hills and Mountains collected, on average, five cubic meter of firewood per year.[19]. Using the large-scale household surveys NLSSII and NLSSIII data, we analyse below household energy choices by estimating the following equation:[20]

$$Y_{hvt} = \alpha CFUG_{vt} + \mathbf{X}_{vt}\beta + \mathbf{W}_{ht}\gamma + \delta_d + \tau_t + \varepsilon_{hvt} \tag{4}$$

where the dependent variable Y stands for the number of bharis of firewood collected by household h in year t in village v, or the number of hours it takes to collect one bhari of firewood. The main explanatory variable is $CFUG$, the share of the village area managed by a CFUG in year t. As above, we also include a large set of village-level control variables $\mathbf{X}$, household-level controls $\mathbf{W}$, belt-zone fixed effects δ and survey-wave fixed effects τ. ε_{hvt} is the idiosyncratic component. The coefficient of interest is α. It indicates how cross-sectional variations in the share of the village area managed by a CFUG at time t are related to changes in the dependent variable Y. Given the previous discussion about the endogenous

[19] Households report 79 bharis (headload) of firewood. We converted this by assuming that one bhari weights 30kg, and 500kg of wood correspond to one cubic meter.

[20] We could not use NLSSI data due to lack of information on some important control variables, such as rainfall or temperature.

placement of a CFUG, this is not a causal estimate, a point that we discuss below. Taking into account the forest regeneration process driven by CFUGs, we also investigate the possibility that the effects of the CFUGs vary with time by distinguishing between new and old (more than 15 years) CFUGs.

The first two columns of table 7 report the estimations for firewood collection time. The presence of CFUGs is typically correlated to larger collection times. As column (1) indicates, a 10% increase in a CFUG area is associated with an increase of 0.12 hours in collection time. This correlation vanishes for older CFUGs (more than 15 years) as the sum of the coefficient estimated for current CFUG coverage, and this coverage 15 years ago is insignificant and close to zero (column (2)).[21] These results indicate that, if anything, CFUGs tend to initially restrict access to forests and households have to rely on forests located farther away for firewood. Once the forest regenerates, these restrictions are gradually relaxed.

[Insert Table 7 here]

Quite surprisingly, the presence of CFUGs does not, on average, correlate with the amounts of firewood collected (column 3 of table 7). This is probably an artefact as, when we consider separately young and old CFUGs, we find that young CFUGs are associated with significantly lower levels of firewood collection, while older CFUGs have, if anything, a net-positive effect on collection. This is consistent with our previous results on forest expansion, but also with repeated stories from our field interviews claiming that, after a restriction period, improved forest management raises biomass production and provides more forest products to villagers. In the last two columns, we introduce firewood collection time as an endogenous control, as it represents the main direct cost associated with household firewood collection. It reduces the point estimates of the CFUGs coefficients, but only partly. This suggests that CFUGs may also affect the demand for energy in ways other than through variations in collection time, for instance by collecting collection fees, banning access to fragile areas, or restricting collections to specific periods and dry wood.

[21]Since 7% of rural households do not collect firewood, they do not report collection time. As a robustness check, we also estimate a village-level regression by taking the village median collection time as the dependent variable. We report estimation results in table A3 with similar results.

Finally, we also investigate how CFUGs coverage in a village affect other fuel expenditures. Table 8 indicates a (weakly significant) positive correlation between CFUG coverage and the amounts households spent on fuel. Thus, in villages with 10% more CFUG coverage than other villages, households spend 158NPR more on fuel (the average fuel expenditures per household are equal to 2100NPR). This relation seems to be essentially driven by firewood collection times.

[Insert Table 8 here]

This last set of results is based on a cross-section of households and suffers from potential endogeneity issues in the creation of a CFUG. As discussed previously, there are reasons to believe that the forests handed over to the communities were mostly degraded forests, lying close to market centres, and under large pressure by users. Under this argument, older CFUGs correspond to places where households enjoy better access to markets and alternative energy sources. To reduce these potential biases, we control for a large set of observable factors that can influence forest conditions, CFUG creation and household behaviour, such as the distance between the village and a paved road, the distance to district headquarters, or population density, and household-level characteristics, such as access to land, livestock ownership, non-farm business assets, or the number of migrants in the households. However, this may not be sufficient. In particular, the selection problem should be more severe around the creation date of the CFUG rather than several years after their creation. In this sense, the fact that more recent CFUGs are associated with lower collection levels and higher collection time, while older CFUG, created closer to the district center, are associated with higher collections and lower collection times is reassuring, confirming CFUG effectiveness as time passes.[22] This is very much in line with related findings on the Indian Himalayas (Baland et al., 2010).[23]

[22]We would have preferred to have a continuous variable picking both the age of CFUGs and their spatial coverage. But, as discussed in subsection 3.3, we could not find a sensible way to do so since there are several CFUGs per village, each of them being potentially different both in terms of area managed and age. We therefore prefer to split the area managed by CFUG by age groups.

[23]We did try to instrument the share of the area managed by a CFUG, following the approach described in equation (2), but the instrument, even if statistically significant, is not strong enough given the smaller number of villages in the household-level approach.

5 Discussion and conclusion

In this paper, we first assess the positive contribution of community forestry in the Hills and Mountains of Nepal on forest regeneration, using an instrumental variable approach in the spirit of a program roll-out. We then investigate the potential mechanisms driving this increase, and show that CFUGs played a role both on demand, for instance by increasing the costs of firewood collection in the short run, and supply, by increasing the size of the forests and changing their composition.

A few remarks are in order that help qualify the interpretation of our results. First, CFUGs work with the Department of Forests and Soil Conservation. Some of the effects of CFUGS on forest conditions may arise as a consequence of continuous interactions between foresters and managers of CFUGs. Given our data, we cannot find a formal test of the complementarity between the effort of the Department of Forests and Soil Conservation and the one of CFUGs managers, but this hypothesis is probably true. What we show is that with CFUGs, the LAI is higher than without it, knowing that in both situations, the Department of Forests and Soil Conservation is involved in forest management, directly in the absence of CFUGs and indirectly as advisor and last resort monitor when management has been handed over to these local institutions.

Second, the presence of CFUGs is measured at the 'village' level and not at the plot level. We therefore measure the average effect of CFUGs at the village level both on forest plots that are managed by CFUGs, but also on nearby areas in the village. In terms of interpretation, the effect that we highlight is therefore a net of spillovers across plots within the same village. If the CFUGs protect the forests under their control, increasing tree cover, but induce increased pressure and forest degradation in nearby plots, we actually measure the net weighted average of these two effects.

Environmental awareness or better access to new sources of energy may also reduce the pressure on overall forest resources. Moreover, the development of community forestry may also encourage the expansion of trees on other plots of land, as villagers may start planting trees on their private plots to compensate for the reduced access to firewood and fodder from common land. All these are also accounted for in the average effect we estimate at the village level. Whatever the precise mechanisms, we believe that the net effect we highlight is crucial for policy makers, as it shows that the program is, on average, positive for forests in Nepal. Note, however, that we could not exclude negative spillovers on neighbouring villages in which CFUGs are absent. Given the size of the villages and the large number of controls we used, we believe, however, that this potential bias is arguably negligible. Using a different methodology, we intend to evaluate the importance of these within- and across-village spillovers in future research.

Additionally, our study stresses the importance of distinguishing between short- and long-run effects in the context of natural resources, such as forests, as they take time to regenerate. Shortly after their creation, CFUGs typically restrict access to forest resources, such as firewood or timber. When effective, these restrictions lead to larger, richer and more dense forests, allowing better harvests in the long run than at the time of the CFUG creation. Thus, in Nepal, we show that the amount of firewood collected in villages with older CFUGs are similar to those in villages without CFUGs, and larger than the average collection levels in villages with young CFUGs. Our field visits also indicate that several old CFUGs are now able to also supply timber in a sustainable manner and actually generate sizeable incomes. The long-term success of CFUGs is, however, conditioned to the short-term ability to reduce the demand for forest products. In our context, where firewood is an important driver of forest degradation (Baland et al., 2018), access to other sources of energy is of paramount importance. More broadly, this implies that the development of a community forestry program with the goal of restoring forests should go hand-in-hand with a proper understanding of their main use. Well-designed policies should therefore provide temporary solutions to alleviate the burden of forest conservation on the regular users of the forests. These solutions can then be lifted when the forest is again dense enough to provide ecosystem services in a sustainable manner.

By focusing on the average benefits of community forestry at the local level, we could not investigate the distribution of its costs and benefits across villagers. Thus, more ecosystem services also mean that the population of wild animals increases, causing crop damages in nearby cultivated plots or killing poultry and livestock, as several villagers told us during field work, and as mentioned by Baral et al. (2021) about some community forests in the Mid-Hills of Nepal.[24] The distribution of forest benefits also changes as a consequence of community forests. For instance, a typical claim of women is that men leading CFUGs focus on pine trees that can be sold as timber, whereas they would prefer more broadleaf trees as a source of firewood and fodder, the collection of which is a task traditionally done by women (see in particular Agarwal (2010), Leone (2019) and Bocci and Mishra (2021)).[25]

Community forestry in Nepal is a game changer at the local level. This institutional change empowers local communities to restore degraded forests and possibly escape a poverty-environment vicious cycle (Dasgupta and Mäler, 1995). At the global level, community forestry in Nepal increases carbon sequestration and contributes to the mitigation of global warming. Our study probably overestimates this contribution as some of the reductions in firewood used are partly compensated for by the use of other energy sources. Clearly, the development of biogas is beneficial for climate. However, when these alternative energy sources come from the market in the form of charcoal, firewood collected further away, LPG, or kerosene, the pure local effect of CFUGs on forest restoration overestimates their contribution to climate change mitigation.

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[24] See Gulati et al. (2021) for a broader discussion of the costs of human wildlife conflict around protected areas in nearby India.

[25] The change in the composition of forests may also have adverse effects in terms of biodiversity, by favouring species that prefer coniferous forests over broadleaf forests or bocage-like landscapes.

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Figures

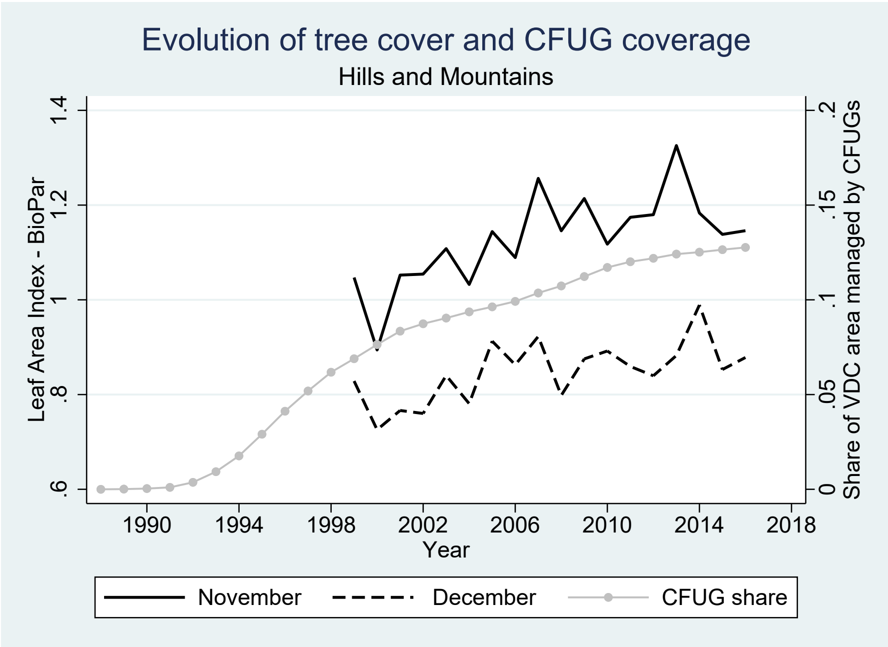

Figure 1: Leaf Area Index and CFUGs in the Hills and Mountains of Nepal

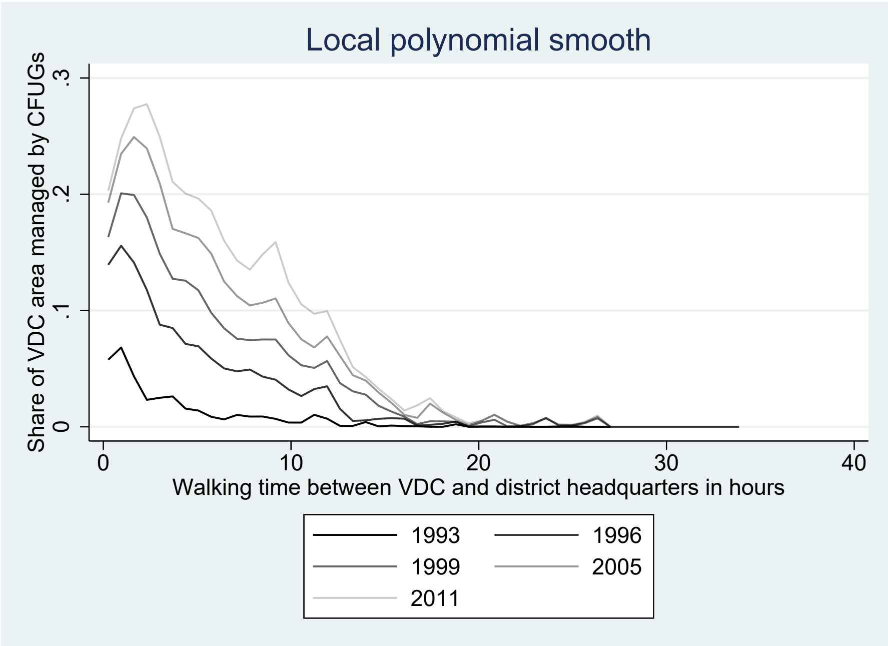

Figure 2: Community forestry expansion in Nepal

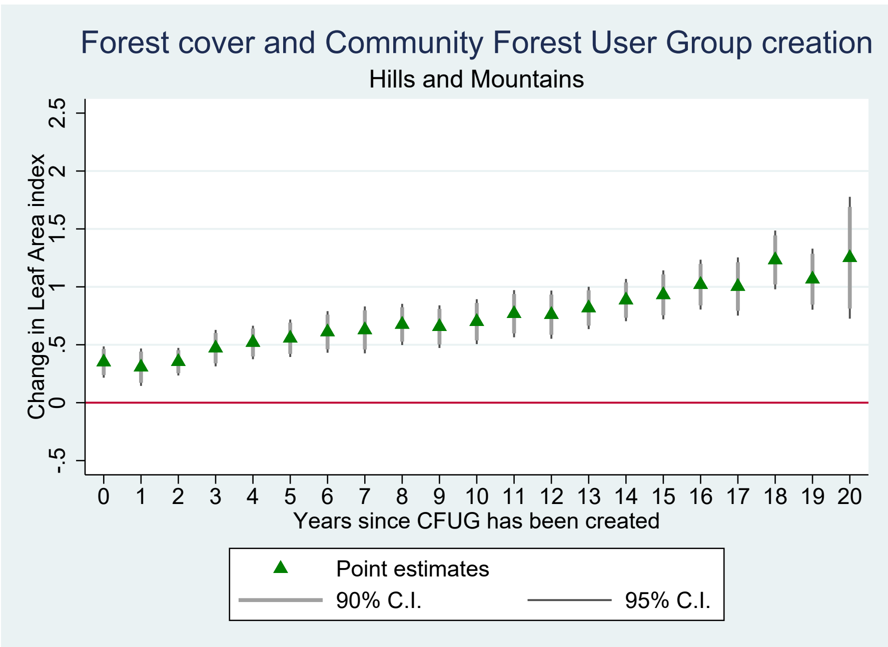

Figure 3: Forest cover and CFUG creation over time

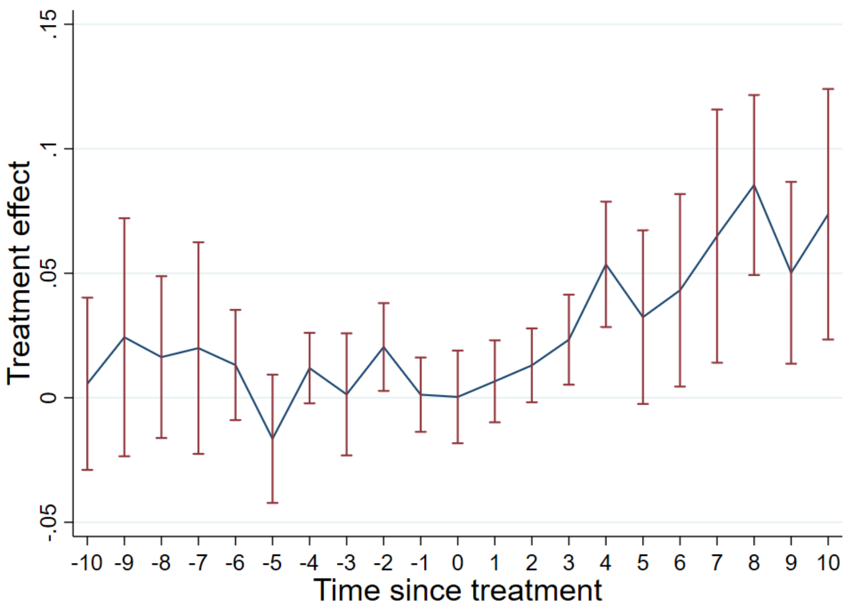

Figure 4: Short- and long- term effects of CFUG creation on Leaf Area Index

Estimation based on de Chaisemartin and D'Haultfoeuille (2020), VDC share has been re-categorized in 6 categories, 0 for VDC without a CFUG, 1 for >0-20%, 2 for 20-40%, etc. The standard errors computed are based on 500 bootstrap replicates.

Tables

Table 1: Descriptive statistics: VDC-level variables, Hills and Mountains 2001-2013

Variable	2001			2013			all years		
	Median	Mean	Std. dev.	Median	Mean	Std. dev.	Median	Mean	Std. dev.
November Leaf Area Index	1.14	1.05	.69	1.43	1.33	.92	1.24	1.15	.78
December Leaf Area Index	.82	.77	.5	.97	.88	.6	.91	.85	.57
VDC share managed by CFUG	.02	.08	.13	.05	.12	.16	.03	.11	.15
VDC area (ha.)	2227.08	4430.01	9141.19	2227.08	4430.01	9141.19	2227.08	4430.01	9139.56
Share forested in 1950	.45	.46	.32	.45	.46	.32	.45	.46	.32
Walking distance to HQ (hrs.)	8.86	10.63	6.48	8.86	10.63	6.48	8.86	10.63	6.48
FUG years in district	10	9.85	1.62	22	21.85	1.62	16	16.35	3.81
Total precipitation	1732.26	1665.9	539.5	1710.98	1570.47	488.67	1519.74	1469.14	526.68
Average snow cover	.01	.02	.02	.01	.02	.02	.01	.02	.02
Growing degree days	2996.74	2914.47	2066.47	2741.87	2725.5	1945.53	2851.22	2810.59	1960.65
Conflict related casualties	3	7.16	12.61	0	0	0	0	6.02	17.56
Population density	.48	1.04	3.66	.56	1.18	5.98	.53	1.11	4.82
Biogas per household	0	.01	.02	0	.02	.07	0	.02	.05
Observations		2578			2578			30936	

Descriptive statistics for the panel of VDC in the Hills and Mountains.

Observations weighted by VDC area (at the exception of VDC area.)

Table 2: Descriptive statistics: household-level variables

Variable	2003		2010		full sample	
	Mean	Median	Mean	Median	Mean	Median
Wood	85.94	72	78.91	60	81.78	70
	(55.4)		(61.68)		(59.29)	
Collection time	3.5	3	3.91	4	3.74	3.5
	(1.69)		(1.9)		(1.83)	
Fuel expenditures	1387.19	813.45	2578.22	884.47	2091.56	845.98
	(2622.16)		(4554.36)		(3926.27)	
% of Vil. area in FUG	.14	.1	.2	.14	.18	.13
	(.14)		(.19)		(.18)	
% of Vil. area in FUG	0	0	.05	.02	.03	0
15 years ago	(0)		(.1)		(.08)	
Years since 1st CFUG	12.54	12	19.42	19	16.61	18
in district	(1.66)		(1.58)		(3.75)	
Walking time to district HQ	5.96	5.5	6.07	5.43	6.03	5.45
	(4.01)		(3.76)		(3.86)	
Forest cover in 1950	.37	.25	.42	.44	.4	.35
	(.33)		(.31)		(.32)	
Observations	1474		2116		3578	

Descriptive statistics for the second and third repeated cross-sections of NLSS in rural villages.

All monetary values expressed in NPR2010.

Standard errors in parentheses.

Table 3: Change in November Leaf Area index as a function of CFUG expansion

	Panel F.E.	First stage	Panel F.E + IV	Panel F.E.	First stage	Panel F.E + IV
	(1)	(2)	(3)	(4)	(5)	(6)
FUG share in VDC	0.448		4.594	0.366		5.281
	(0.0608)		(0.925)	(0.0512)		(1.230)
Proximity Hq		0.00546			0.00449	
× FUG years in district		(0.00119)			(0.00107)	
Population density				-0.00356	-0.00115	-0.00254
				(0.00152)	(0.000417)	(0.00134)
Biogas per household				0.878	0.253	-0.507
				(0.150)	(0.0695)	(0.431)
Years since FUG in district	0.0221	-0.00703	0.169	0.0206	-0.00764	0.178
	(0.00340)	(0.00218)	(0.0223)	(0.00330)	(0.00216)	(0.0241)
Forest in 1950	-0.000184	0.00496	-0.0197	0.00129	0.00547	-0.0248
× FUG years in district	(0.00356)	(0.00150)	(0.00582)	(0.00301)	(0.00138)	(0.00741)
VDC fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Environment controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	136252129	136252129	136252129	131392040	131392040	131392040
Observations (in VDC)	2552x13	2552x13	2552x13	2471x12	2471x12	2471x12
Mean LAI in 2013	1.33					
Mean FUG share in 2013	.12					

Regressions are weighted by VDC area. Environment controls include rainfall, snow cover, growing degree days and conflict-related casualties.
We derive population data from the 2001 and 2011 population census and interpolate figures.
Standard errors in parentheses, clustered at the district level.

Table 4: Land use change as a function of CFUG expansion in the Hills and Mountains

		Panel F.E.		1st stage		Panel F.E + IV	
	(Forest) (1)	(Needle) (2)	(Mixed) (3)	(FUG share) (4)	(Forest) (5)	(Needle) (6)	(Mixed) (7)
FUG share in VDC	0.0764	0.00821	0.0661		0.583	0.0686	0.405
	(0.0163)	(0.00378)	(0.0147)		(0.185)	(0.0372)	(0.177)
Proximity Hq				0.00547			
× FUG years in district				(0.00119)			
Years since FUG in district	0.00138	-0.000121	0.00174	0.000249	0.000781	-0.000193	0.00133
	(0.000444)	(0.0000680)	(0.000410)	(0.000469)	(0.000438)	(0.0000960)	(0.000420)
Forest in 1950 ×	-0.00258	0.0000510	-0.00164	0.00497	-0.00497	-0.000234	-0.00324
FUG years in district	(0.000645)	(0.000185)	(0.000631)	(0.00150)	(0.00107)	(0.000301)	(0.000899)
VDC fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmental controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations (in ha)	139495824	139495824	139495824	139495824	139495824	139495824	139495824
Observations (VDCxyear)	2552x13	2552x13	2552x13	2552x13	2552x13	2552x13	2552x13

Regressions are weighted by VDC area. Environment controls include rainfall, snow cover, growing degree days and conflict-related casualties. Standard errors in parentheses, clustered at the district level, regression weighted by VDC area.

Table 5: Land use change as a function of CFUG expansion in the Hills and Mountains

	Panel F.E.			1st stage	Panel F.E + IV		
	(Broadleaf)	(Crop)	(Shrub)	(FUG share)	(Broadleaf)	(Crop)	(Shrub)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FUG share in VDC	0.00203	-0.0172	-0.0735		0.109	-0.390	-0.494
	(0.00770)	(0.00583)	(0.0170)		(0.0678)	(0.121)	(0.163)
Proximity Hq				0.00547			
× FUG years in district				(0.00119)			
Years since FUG in district	-0.000230	-0.00115	0.0000642	0.000249	-0.000358	-0.000702	0.000565
	(0.000126)	(0.000271)	(0.000421)	(0.000469)	(0.000149)	(0.000252)	(0.000409)
Forest in 1950 ×	-0.000990	0.00136	0.00170	0.00497	-0.00149	0.00312	0.00368
FUG years in district	(0.000275)	(0.000419)	(0.000777)	(0.00150)	(0.000433)	(0.000854)	(0.00115)
VDC fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Environmental controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations (in ha)	139495824	139495824	139495824	139495824	139495824	139495824	139495824
Observations (VDCxyear)	2552x13	2552x13	2552x13	2552x13	2552x13	2552x13	2552x13

Regressions are weighted by VDC area. Environment controls include rainfall, snow cover, growing degree days and conflict-related casualties. Standard errors in parentheses, clustered at the district level, regression weighted by VDC area.

Table 6: Biogas adoption in the Hills and Mountains

	Panel F.E.		1st stage	Panel F.E + IV	
	(Biogas units)	(Biogas units per hh.)	(FUG share)	(Biogas units)	(Biogas units per hh.)
	(1)	(2)	(3)	(4)	(5)
FUG share in VDC	180.9	0.0743		4074.0	0.848
	(42.46)	(0.0188)		(1391.7)	(0.243)
Proximity Hq			0.00547		
× FUG years in district			(0.00119)		
Years since FUG in district	2.229	0.00142	0.000249	-2.413	0.000499
	(1.146)	(0.000502)	(0.000469)	(1.978)	(0.000431)
Forest in 1950 ×	0.627	-0.000796	0.00497	-17.75	-0.00445
FUG years in district	(3.613)	(0.00112)	(0.00150)	(8.607)	(0.00137)
VDC fixed-effects	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes
Environmental controls	Yes	Yes	Yes	Yes	Yes
Observations (in ha)	139495824	139495824	139495824	139495824	139495824
Observations (VDCxyear)	2552x13	2552x13	2552x13	2552x13	2552x13

Regressions are weighted by VDC area. Environment controls include rainfall, snow cover, growing degree days and conflict-related casualties.
Standard errors in parentheses, clustered at the district level, regression weighted by VDC area.

Table 7: Firewood collection

	collection time (hrs)		Firewood collection (bhari)			
	(1)	(2)	(3)	(4)	(5)	(6)
% of Vil. area in FUG	1.218	1.471	-15.29	-27.94	-9.193	-20.94
	(0.432)	(0.463)	(11.32)	(11.48)	(11.11)	(11.44)
% of Vil. area in FUG 15 years ago		-1.160		65.47		58.05
		(1.064)		(26.11)		(23.75)
Med. collection time					-4.244	-3.876
					(1.417)	(1.372)
Years since	-0.0159	-0.0113	1.988	1.736	1.837	1.627
1st CFUG in district	(0.0428)	(0.0426)	(1.418)	(1.397)	(1.379)	(1.364)
[1em] Proximity	0.0334	0.0331	1.225	1.245	1.311	1.322
to district HQ	(0.0231)	(0.0230)	(0.528)	(0.524)	(0.515)	(0.512)
Forest cover in 1950	-0.00520	-0.0247	3.988	4.834	4.987	5.651
	(0.259)	(0.260)	(7.020)	(7.200)	(6.832)	(6.973)
Household assets	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effect	Yes	Yes	Yes	Yes	Yes	Yes
Belt-Zone fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Village controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3332	3332	3578	3578	3578	3578

Village controls include distance to paved road, war casualties, median elevation and standard deviation,

snow cover, rainfall, growing degree days and cooling degree days

Standard errors in parentheses, clustered at the village level

Table 8: Fuel expenditures

	Fuel expenditures (NPR)			
	(1)	(2)	(3)	(4)
% of Vil. area in FUG	1581.6	1756.1	1044.8	1083.3
	(826.8)	(953.3)	(721.7)	(826.6)
% of Vil. area in FUG, 15 years ago		-902.7		-190.2
		(2043.3)		(1711.8)
Med. collection time			373.6	372.4
			(135.2)	(134.7)
Years since	-277.8	-274.3	-264.6	-263.9
1st CFUG in district	(109.5)	(109.4)	(110.5)	(110.5)
Proximity to district HQ	-86.70	-86.98	-94.32	-94.36
	(47.30)	(47.37)	(46.52)	(46.55)
Forest cover in 1950	-795.1	-806.8	-883.1	-885.3
	(436.8)	(440.8)	(443.7)	(445.7)
Household assets	Yes	Yes	Yes	Yes
Year fixed-effect	Yes	Yes	Yes	Yes
Belt-Zone fixed-effects	Yes	Yes	Yes	Yes
Village controls	Yes	Yes	Yes	Yes
Observations	3578	3578	3578	3578

Village controls include distance to paved road, war casualties, median elevation and standard deviation,

snow cover, rainfall, growing degree days and cooling degree days

Standard errors in parentheses, clustered at the village level

A Appendix

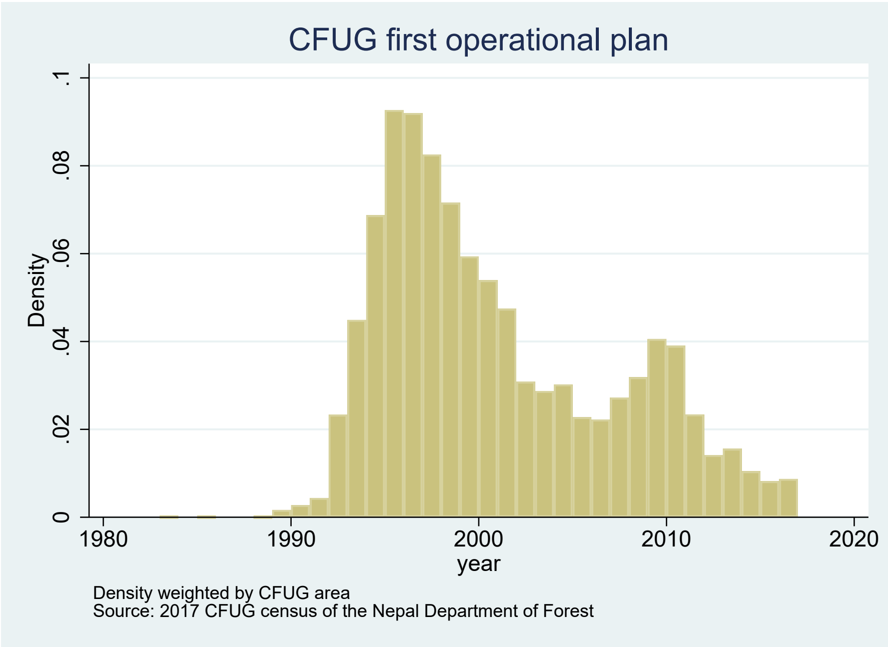

Figure A1: CFUG creation year

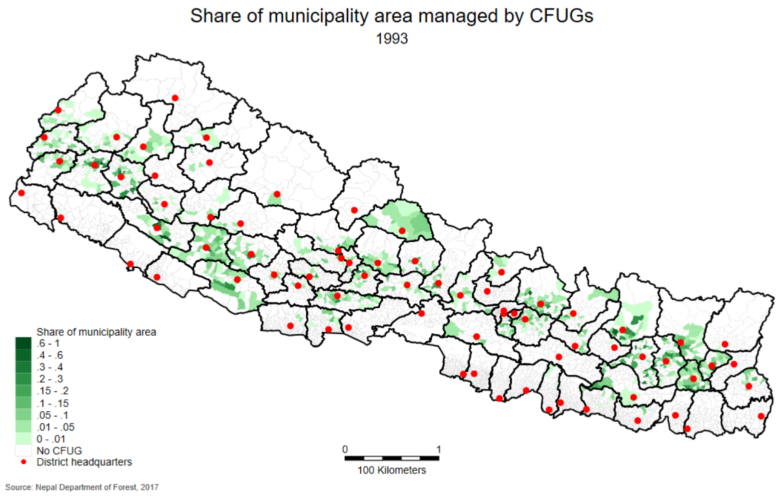

Figure A2: Area managed by CFUGs in 1993

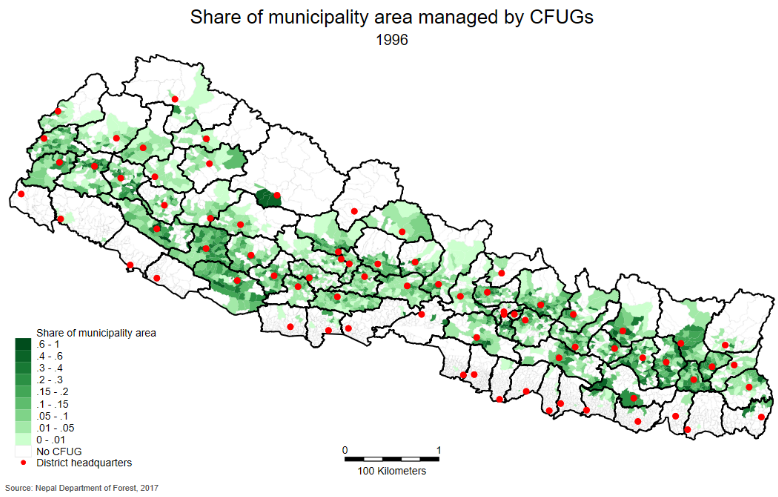

Figure A3: Area managed by CFUGs in 1996

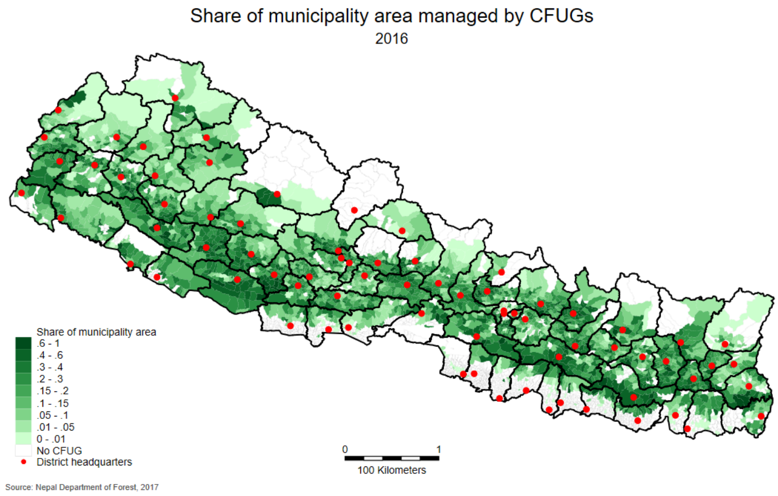

Figure A4: Area managed by CFUGs in 2016

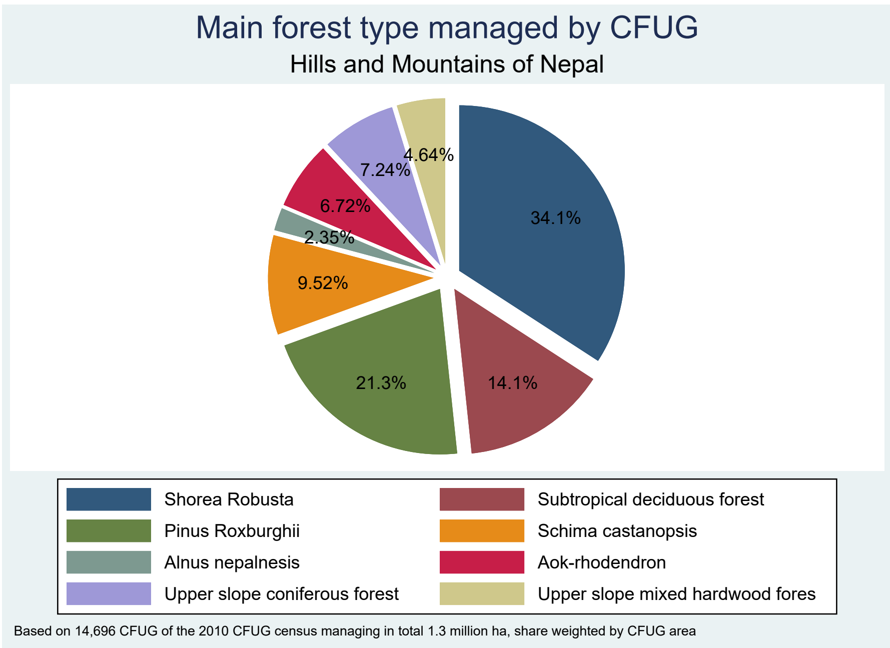

Figure A5: CFUG main forest type

Table A1: Descriptive statistics: household-level variables (continued)

Variable	2003		2010		full sample	
	Mean	Median	Mean	Median	Mean	Median
Big livestock	3.56	3	3.15	3	3.32	3
	(2.91)		(2.56)		(2.71)	
Land owned, ha	.69	.49	.61	.43	.64	.46
	(.76)		(.66)		(.71)	
Household size	5.03	5	4.79	5	4.89	5
	(2.24)		(2.16)		(2.2)	
Prop. female	.35	.33	.37	.33	.36	.33
	(.19)		(.19)		(.19)	
Prop. children	.39	.4	.37	.4	.38	.4
	(.24)		(.24)		(.24)	
Avg. education	2.43	1.67	3.16	2.67	2.86	2.33
	(2.7)		(2.98)		(2.89)	
= 1 if NFBus	.22	0	.28	0	.26	0
	(.41)		(.45)		(.44)	
# Migrants	.4	0	.8	1	.64	0
	(.67)		(.97)		(.88)	
Med. time to road	10.17	5	5.68	2.5	7.52	3.13
	(13.44)		(7.61)		(10.62)	
# killings 20km ar.	79.40	56	151.18	126	121.85	101
	(64.56)		(97.46)		(92.54)	
Vil. elevation: mean	1426.39	1336	1478.55	1332	1457.24	1332
	(738.68)		(782.89)		(765.46)	
Vil. elevation: std. dev.	329.38	290.03	334.56	301.69	332.44	296.55
	(206.06)		(208.08)		(207.25)	
Vil. snow cover	0	0	0	0	0	0
	(.01)		(.01)		(.01)	
Rainfall z-score	.61	.75	-.93	-.91	-.3	-.45
	(.64)		(.65)		(.99)	
Monsoon GDD	1242.86	1361.57	1137.35	1257.03	1180.46	1310.46
	(364.87)		(419.61)		(401.47)	
Cooling Degree Days	166.98	16.14	166.91	9.32	166.94	14.74
	(496.01)		(495.14)		(495.43)	
Observations	1474		2116		3578	

Descriptive statistics for the second and third repeated cross-sections of NLSS in rural villages.

All monetary values expressed in NPR2010.

Standard errors in parentheses.

Table A2: Change in December Leaf Area index as a function of CFUG expansion

	Panel F.E. (1)	First stage (2)	Panel F.E + IV (3)	Panel F.E. (4)	First stage (5)	Panel F.E + IV (6)
FUG share in VDC	0.00323		1.994	-0.0175		2.663
	(0.0721)		(0.591)	(0.0692)		(0.854)
Proximity Hq		0.00546			0.00449	
× FUG years in district		(0.00119)			(0.00107)	
Population density				-0.00262	-0.00115	-0.00206
				(0.000763)	(0.000417)	(0.000712)
Biogas per household				0.197	0.253	-0.558
				(0.120)	(0.0695)	(0.310)
Years since FUG in district 0.00965	-0.00703	0.0499	0.00946	-0.00764	0.0574	
	(0.00163)	(0.00218)	(0.0135)	(0.00166)	(0.00216)	(0.0153)
Forest in 1950	-0.0000519	0.00496	-0.00943	0.000332	0.00547	-0.0139
× FUG years in district	(0.00181)	(0.00150)	(0.00320)	(0.00175)	(0.00138)	(0.00486)
VDC fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Environment controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	136252129	136252129	136252129	131392040	131392040	131392040
Observations (in VDC)	2552x13	2552x13	2552x13	2471x13	2471x13	2471x13
Mean LAI in 2013	.88					
Mean FUG share in 2013	.12					

Regressions are weighted by VDC area. Environment controls include rainfall, snow cover, growing degree days and conflict-related casualties.
We derive population data from the 2011 and 2011 population census and interpolate figures.
Standard errors in parentheses, clustered at the district level.

Table A3: Village median collection time

	Collection time (hr. per bhari)			
	(1)	(2)	(3)	(4)
% of Vil. area in FUG	1.443	1.819	1.677	1.658
	(0.453)	(0.574)	(0.596)	(0.608)
% of Vil. area in FUG, 15 years ago		-1.940	-1.740	-1.745
		(1.023)	(1.065)	(1.017)
Current Leaf Area index				-0.273
				(0.190)
Years since FUG in district	-0.0390	-0.0314	-0.0270	-0.0247
	(0.0453)	(0.0443)	(0.0585)	(0.0567)
Forest cover in 1950	0.247	0.221	0.340	0.400
	(0.387)	(0.391)	(0.395)	(0.395)
Walk time to district HQ	0.0209	0.0202	0.0215	0.0192
	(0.0274)	(0.0273)	(0.0274) (0.0277)	
Year fixed-effect	Yes	Yes	Yes	Yes
Belt-Zone fixed-effects	Yes	Yes	Yes	Yes
Village controls	Yes	Yes	Yes	Yes
Village asset density	Yes	Yes	Yes	Yes
Observations	300	300	300	300

Standard errors in parentheses, clustered at the district level

Village level controls include median access time to road, village median altitude and altitude standard deviation, number of people killed in the 20km around the village in the previous year, as well as previous year snow cover, rainfall deviation, cooling degree days and monsoon growing degree days.