Does Community-based Management Improve Natural Resource Condition? Evidence from the Forests in Nepal

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Abstract

Does community management improve the condition of local natural resources? Do interventions by official agencies enhance the functions of voluntary communal management? With 101 randomly-sampled natural forests in the Middle Hills of Nepal, we address these questions. Forest condition was evaluated by aerial-photo interpretation and forest inventory. We find that user groups that did not receive official support substantially improved forest condition. This is likely the result of reduced forest fire occurrence. Community management with external support can also be effective. Our analysis shows that, controlling for the possibility of self-selection in applying for support, such management improved tree regeneration.

I. INTRODUCTION

The majority of rural populations in developing countries have been sustaining their livelihood by utilizing natural resources around their settlement: inshore fishery, range land, forest, etc. It is estimated that, for example, 80% of the world's extreme poor use firewood as their main energy source (World Bank 2004, A-3). Economic development tends to put these local natural resources under increasing demand from growing rural populations and external markets. Consequently, for many developing countries, how to maintain and improve local natural resources is the most pressing environmental concern.

Various policy frameworks have been applied to the management of local natural resources. For the last few decades, a participatory approach has been in fashion. In forest policies, community management has been promoted by many governments and international donor agencies (e.g., FAO 1989). [1]

Along with participatory practices, there appeared a flourishing literature on communal management of local natural resources (Ostorom 1990; Dayton-Johnson 2000; Baland and Platteau 2003; Tarui 2007, and the references therein). In particular, the cases of voluntary cooperation stimulated the curiosity of researchers, and these studies therefore focused on the factors that facilitated collective action. In contrast, a vital concern in local natural-resource management has not received much attention: the impacts of communal management on resource condition. One should note that the establishment and survival of community management do not necessarily conserve local natural resources. For example, the motivation for collective action may be a desire to symbolize community identity, not resource management (Baland and Platteau 1996, 191-192). For the challenges in local natural-resource management, the ultimate policy goal is not to stimulate collective action, but to improve the welfare of resource users in a sustainable manner. An indispensable task for shaping such policies is to assess the impacts of various management arrangements on natural-resource condition. [2] This paper tries to do so by exploiting a unique data set from Nepal: the measurement of 101 randomly-sampled natural forests.

The most valuable information in our data set is the institutional variation in forest management. It contains the cases of government management, community management, and co-management of local forests. Co-management in this paper indicates management by user groups which are officially approved and registered at local forest offices. By complying with the management criteria set by the forest offices, the registered user groups receive various supports from government agencies.

Co-management programs, or devolution policies, are becoming a major tool in local natural-resource administration (Brent M. Swallow and Daniel W. Bromley 1994; R. Quentin Grafton 2000; Jean-Marie Baland and Jean-Philippe Platteau 2003; Charles Blessings, Laurence Jumbe and Arild Angelsen 2006). An important question in this policy

[1] The fad has passed. Several studies have pointed out the problems in community forestry programs (e.g., Campbell et al. 2001; Brett 2003). The World Bank has become cautious about too much emphasis on the role of local-level organizations (World Bank 2004, A-6).

[2] It can be misleading to directly measure the contributions of management arrangements to users' welfare. In natural-resource management, it is not uncommon that optimal long-run harvesting policies deteriorate users' welfare in the short run.

framework is what is the appropriate extent of government interventions in communal management, which is originally voluntary self-governance. Vishwa Ballabh, Kulbhushan Balooni and Shibani Dave (2002) provided several cases for India, where government involvement had negative consequences on community management. In Nepal, government involvement in forest co-management has been less intensive than in many other countries. In particular, there is no sharing of the sales of forest products between user groups and forest offices. Our statistical analysis on Nepal forestry adds empirical knowledge regarding the appropriate level of official involvement in co-management programs.

Specifically, this paper addresses the following two empirical questions. First, after controlling for geographical, social, and vegetation differences, we examine whether community-based management has improved the forest resource condition. Second, we investigate whether the registration of user groups (co-management) has improved the function of community management.

The results, in general, indicate affirmative answers. In brief, we find that user groups that did not receive official support improved forest condition. This positive impact was so substantial that it was identified even on small-scale aerial photographs. Our results also show that co-management improved tree regeneration within a short period. This result is robust for the possible self-selection bias in applying for support. Due to the short period under co-management, however, we cannot evaluate the long-run consequences of government intervention in community management.

This paper proceeds as follows. Section 2 provides a description of the study area and our data set. In Section 3, along with a summary of major variables, we discuss our empirical specifications for evaluating the impacts of management systems on forest condition. Section 4 reports the estimation results, and discusses the potential mechanisms that cause our findings. Section 5 concludes the paper.

II. BACKGROUND

Nepal has been known as a leading country of community forestry programs. Our study area is its Middle Hills, where we find useful variations for assessing the institutional impacts on forest resource condition. Brief descriptions are as follows.

Geography and Economy

The Middle Hills is a physiographic zone occupying about 30% of the country with average altitudes ranging between 700 and 2,000 meters (Figure 1). As its name indicates, the Middle Hills has a rugged geography filled with continuous hills. The economic and cultural centers of Nepal had been located in the Middle Hills. After the eradication of malaria in the 1960s, however, the Terai plain lying along the Indian border has emerged as an agricultural and industrial center. Since then, there has been a significant migration flow from the Middle Hills to Terai. Even with this out-migration, more than 40% of the Nepal's population of 22 million still lived in the hill zone during our investigation period of the 1990s.[3] Although Indo-Aryan origins tied to the Hindu caste have been the majority, there are many groups with Tibetan-Mongoloid origins in the Middle-Hills' population.

Due to the rugged geography, both land productivity and access to markets are limited in the Middle Hills. Most of the farms are on terraced slopes with little irrigation facilities. The motorable roads are not many. Even now, there are many villages where travel to the nearest market town requires a few days of walking. These factors make more than 90% of the Middle Hills' population rural, and have made subsistence farming with limited use of purchased inputs the main economic activity. People depend on forests for agricultural inputs such as fodder and leaf-litter for animal bedding and composting. Moreover, more than 90% of families collect firewood as their main fuel for heat and cooking (CBS 1986, 38-39).

History of Forest Management System

In Nepal, the hundred-year long feudal regime was overthrown in 1950. In an attempt to replace local feudal systems, the new government promulgated the Private Forest Nationalization Act in 1957, which aimed to bring all forest area under the control of the government. With an insufficient number of forest officers, however, the nationalization policy was ineffective in many parts of the country.

Subsequent political upheavals and accelerated population growth gradually intensified population pressure on forest resources. Responding to forest-resource shortages, there emerged community management of forest resources. That is, some indigenous groups spontaneously began to manage the forests they utilized, although the government had legal ownership (Gilmour and Fisher 1991, Ch. 1). In addition, traditional forest-management systems were brought once again to the fore. Partly through an increase in forestry projects supported by international donor agencies, the indigenous management system spread over the Middle Hills (Negi 1994, Ch. 4).

In 1987, signaling the deadlock of the science-based forest policy trusted to foresters, the government of Nepal altered its forest policy to promote communal management (Acharya 2002). Since 1991, upon satisfying several prerequisites, the district forest offices (DFOs) have provided legal status to well-functioning user groups by registering them. An example of the prerequisites is that user groups must establish an election system for the committee responsible for forest management. To apply for registration, user groups also need to prepare a documented management plan of their forests. The current regulation, the Forest Act of 1993, further aims to transfer the official use right of forests to well-functioning registered groups.[4] In 1991, there were a few hundred registered user groups. As of December 2005, more than 1.2 million hectares of forest have been handed over to 14,333 user groups (Ministry of Forests and Soil Conservation, 2007).

[3] Hill zone is a topographical area in the official statistics of Nepal. Hill zone includes the Middle Hills.

[4] On paper, the Forest Act of 1993 expects the DFOs to create user groups from scratch (Acharya 2002; Edmonds 2003). At least in our study period, however, many of the co-management arrangements evolved through the identification and registration of indigenous user groups. In our 101 samples, for example, 56 user groups were organized after 1987. Only 18 out of these 56 groups listed the suggestion from DFOs as a reason for group formation.

Thus, in our investigation period of the late 1990s, there were three types of forest management in Nepal. The first is management by user groups which are registered at the district forest offices (DFOs). Some of these groups have already acquired an official forest use right. The DFOs must provide various supports, notably technical advice, to the registered user groups. To clearly identify the involvement of the DFOs, we hereafter refer to the registered user groups as formal user groups, and management by them as co-management. The second is management by indigenous user groups which are not registered. We refer to these unregistered user groups as informal user groups, and management by them as community management. The last is direct management by the DFOs. The forests managed under this arrangement are often left as *de facto* open access areas. Table 1 shows the distribution of the three types of management over our sample forests. Since the Forest Act of 1993 set a goal to transfer all accessible forest land to user groups, this kind of wide variation in the type of forest management can be found only in our investigation period in the 1990s.

Characteristics of Community-based Management

Three notes on community-based management are in order here. First, there are a variety of management arrangements of forests by informal user groups. For these groups, the image of well-defined rules and decision-making mechanisms is sometimes misleading. Some informal user groups are simply ongoing traditional systems. The most noted in the literature is the *mana pathi* system. In this system, villagers hire forest guards and pay them in grain. They, however, neither form a management committee nor have general meetings. One of our sample forests shows another case of an ongoing traditional system. The users of this forest have trusted management to the family of a local traditional king, whose political authority was lost more than one hundred years ago.

In contrast, there are cases of informal user groups with well-defined rules. In one sample forest, as early as 1986, the users were aware of the shortage of forest products, and made up their own regulations on forest use. Furthermore, the users planted trees without any external support. In fact, our aerial-photo analysis confirms that this forest was shrub land in 1978, and recovered to a broad-leaved forest in 1992. The users of this forest, however, did not form a user group. They trusted a local administrative leader to enforce their own regulations. In the field survey, we paid special attention to identifying all types of indigenous community management.

The second note is about the major differences between formal and informal user groups. Due to approval and support from the district forest offices (DFOs): the management committees of formal user groups usually have more authority than the leaders of informal user groups. However, the formal user groups, to some extent, lose flexibility in making management decisions because they have to follow the guidelines set by the DFOs. For example, it becomes impossible to trust forest management to local administrative leaders or the family of a local traditional king. In some regards, the registration of user groups is a standardization of indigenous community management to the bottom line set by the government. The pros and cons of registration is one of the empirical questions of interest. [5]

[5] In the case studies of Vishwa Ballabh, Kulbhushan Balooni and Shibani Dave (2002), through reducing flexibility in decision making, government intervention in community management eroded user groups' capacity for resource management.

The last note is about the procedure for registration. In our investigation period, there were mainly two courses of action for becoming a formal user group. First, informal user groups could voluntarily apply for registration to forest rangers or directly to the DFOs. Second, the forest rangers could request leaders of informal user groups to comply with the DFO's guideline and to be registered.[6] In either case, informal user groups had substantial leeway in registering their groups. If an informal user group did not find the benefits of legal status satisfactory, it would neither actively apply for registration nor comply with the DFO's request to register the group. In other words, in our data, there is sample self-selection in the co-management arrangement.

Data

We utilize the data set constructed by the International Food Policy Research Institute (IFPRI).[7] The majority of the field survey was conducted between 1997 and 1999, while a resurvey for some data clarification was implemented in 2001. The authors attended the survey from its initial phase. The unit of data is forest as defined by users. If a physically continuous forest patch is divided and separately utilized by the two different bodies of users, the continuous patch is considered as two forests.

The sampling procedure was as follows. Over the Middle Hills, all forest patches (including shrub and grass land) with an area of 10 hectares or greater were identified on the aerial photographs in 1992/96. The minimum patch size of 10 hectares was imposed to conduct aerial-photo interpretation.[8] The same number of forest patches was randomly sampled from the accessible and remote areas, respectively. Remoteness is defined by the distance from local towns and motorable roads: at least 15 km away from the former and 10 km away from the latter. In most cases, it is about a one-day trek to reach a remote forest patch after leaving a vehicle. For each listed patch, the field research team identified its users and forest boundary. If a patch was divided and separately utilized by more than one body of users, we randomly chose one of them. In the end, we have 101 sample forests: 51 from the accessible area and 50 from the remote area.

The stratification based on remoteness is intended to capture the effects of the external pressures on management arrangements. An external pressure of interest is intervention by the DFOs. Due to budget and human resource constraints, the DFOs have mainly assisted the forest users that are accessible from major roads (Edmonds 2002). The lower block of column (3) of Table 1 demonstrates the effects of such DFO intervention. In the accessible area, 67% of the sample forests are already under co-management. In contrast, in the remote area, merely 22% of the samples are under co-management.

For each sample forest, we conducted a social survey, an aerial-photo interpretation, and a forest inventory. In the social survey, we collected various information on forest management and its history. The aerial-photo interpretation utilized two sets of photographs. The first set was taken in 1978, while the second set was taken in 1992 in the eastern

[6] The other way was that rangers identified and persuaded unorganized users of a forest to set up a user group, to make rules following the DFO's guidelines, and to be registered. Refer to footnote 4.

[7] Otsuka and Place (2001) present a detailed description of the IFPRI research project.

[8] One sampled forest happened to have an area less than 10 ha: 7.5 ha.

part of Nepal and in 1996 in the remaining parts of the country. These aerial photographs were taken at a fairly small scale of 1:42,000, but with relatively good quality. On the aerial photographs, the research team analyzed forest area, forest-cover type, crown coverage, etc. In the forest inventory, we measured the diameter at breast height (DBH) and the height of all the stands in randomly sampled plots. The number of saplings and the impact of human activities (fodder collection, grazing, fire, etc) were also recorded.[9]

The advantages of exploiting the IFPRI data are straightforward. First, the data set is not confined to a specific administrative unit or a project area. It contains 101 randomly-sampled forests throughout a physiographic zone: the Middle Hills of Nepal (Figure 1).[10] Second, in the IFPRI data, we have the objective indices of forest condition: the aerial-photo interpretation and the many results of the forest inventory. It is usually difficult to measure the resource condition of natural forests. This is the main reason why few studies have statistically evaluated the impacts of forest management systems. The exceptions are pioneering studies that adopted the subjective indices of overall forest condition as judged by foresters or users (Rasmus Heltberg 2001; Clark C. Gibson, John T. Williams and Elinor Ostorom 2005; Arun Agrawal and Ashwini Chhatre 2006). The rich and objective information in the IFPRI data enables us to derive widely-applicable lessons about the impacts of community-based management on natural-resource conditions.

III. EMPIRICAL SPECIFICATION

Our main objective is to get consistent estimates of the impact differential between community management and co-management on changes in forest condition, where the benchmark is the *de facto* open access of the government forests. The basic specification is

$$\begin{aligned}\text{(Changes in Forest Condition)}_i = \; & \beta_1 \text{(Years under Community Management)}_i \\ & + \beta_2 \text{(Years under Co-management)}_i \\ & + \beta_3 \text{(Dummy for Project in Forest Area)}_i \\ & + X_i \theta + \epsilon_i \qquad [1]\end{aligned}$$

for forest $i = 1, \ldots, 101$. Here, X_i is the matrix of covariates, β's and θ are parameters, and ϵ_i is the error term. Along with the two types of community-based management, we control for the projects implemented in sample forests. In addition, X_i includes the variables of population pressure, topographic condition, and vegetation type. There are several complications in the estimation of equation [1], each of which will be discussed in turn along with the description of major variables. The summary statistics of the other variables (X_i) are collected in Table 2.

[9] The target of the measurement intensity was set at 1% of the total forest area, which is admittedly low. We, however, should note that the intensity of forest measurement in the IFPRI data is, in general, higher than those adopted by the previous forest inventories in Nepal. See, for example, Forest Research and Survey Center and Forest Resource Information System Project (1994).

[10] For detailed area-specific studies in the Middle Hills, refer to, for example, Fox (1993); Edmonds (2002); Gautam et al. (2003).

Dependent Variables

For the purpose of our study, the dependent variables must be the indices of *changes* in forest condition, not of current forest condition. This is due to the fact that forest-resource condition is a stock variable. It usually takes several years to improve forest vegetation. The correlation, if any, between current forest-management activities and current forest condition is most likely due to a causality from the latter to the former. To eliminate such inverse causality, this paper employs two dependent variables which capture changes in forest condition. One is the intertemporal changes detected by the aerial-photo interpretation, and the other is the regeneration rate of saplings. Both indices have advantages and disadvantages.

Between the 1978 and 1992/96 aerial photographs, the first index compares each sample forest according to three quality measures: crown-cover density, maturity class of stands, and diversity of major tree species. The results are summarized in Table 3. Here the improved forests are, *ceteris paribus*, those with at least one improved measure among the three. The degraded forests are defined conversely.[11] In the sample, there are three forests where improved and deteriorated measures coexist. These forests are classified as "mixed".

Three interesting features stand out in Table 3. First, forest-resource condition shows substantial intertemporal changes. More than half of the sample forests experienced changes in their resource condition (columns (2), (4), and (5)). Second, and most importantly, more than 25% of the sample forests have experienced improvement in their resource condition since 1978 (column (2)). This contrasts with the findings of Metz (1991). Comparing the 1964-65 and 1978 aerial photographs, Metz (1991) found that there was significant degradation in forest-resource condition in the Middle Hills. Comparing the 1978 and 1992/96 photos, we find that the trend of forest-resource degradation before 1978 was partially reversed.[12] We are interested in the contribution of community-based management to this reversal. Lastly, there were more cases of improvement in accessible areas than in remote areas (columns (2) and (6) of Table 3). The four shrub lands in 1978 which regenerated into forests in 1992/96 are all located in accessible areas. This observation suggests that population pressure may not be the main cause of forest-resource degradation.

The major advantage of the first index is that it actually measures intertemporal changes in forests by comparing the aerial photos taken in different years. The major weak point of this index is its roughness. With a scale of 1:42,000, all we can extract from the aerial photographs are categorical variables for each quality measure of forests: crown coverage 0-20%, 20-40%, etc. Another weak point is that in the eastern part of Nepal, where 39 sample forests are located, the aerial photographs were taken in 1992. The period up to 1992 may be too short to evaluate the impacts of co-management systems in this area. Although several DFOs independently initiated the registration program in the

[11] For the number of major tree species, we make one exception for Sal trees. As will be explained later, Sal has been considered as the most valuable tree in the Middle Hills. Thus we consider that a forest is degraded when it changes from a Sal-dominant forest to a diversified forest with Sal and other tree species.

[12] The main thesis of Metz (1991) is that the forest *area* in the Middle Hills did not decrease between 1964 and 1978. Our aerial-photo interpretation on land-cover changes indicates that there was little change in forest area between 1978 and 1992/96. That is, the forest *area* in the Middle Hills has not decreased since the 1960s.

1980s, it was officially introduced in 1991.

The second index, the regeneration rate summarized in Table 4, is constructed from the forest inventory. It is the count of saplings weighted by their size. Established saplings with 4 cm ≤ DBH (diameter at breast height) < 10 cm, for example, have the largest weight. The regeneration rate responds to forest management activities, e.g. controls on rampant grazing, much more quickly than vegetation stock. Our interpretation is that the regeneration rate reveals *upcoming* changes in forest condition.

The advantage of the regeneration rate is that it was directly measured in 3,793 plots over 101 sampled forests. Thus it captures more detail on resource condition than the aerial photographs. With the regeneration rate, we can run plot-wise regressions to control for plot-wise specific conditions such as slope, stand density, and stand composition. Moreover, forest-wise random effects can be introduced in plot-wise regressions, which substantially reduces the probable estimation bias from unobserved forest characteristics. The major weak point is that, strictly speaking, the regeneration rate shows the static condition at the time of forest inventory. The validity of the analysis turns on the assumption that a higher regeneration rate results in better forest condition in the future. Without proper silvicultural management, for example, high regeneration might not improve future biomass due to overcrowded stand density.

Indices of Forest Management Arrangements

In equation [1], the indices of forest management arrangements are the count of years under community and co-management systems, respectively (columns (2) and (3) of Table 1). What we measure in equation [1] is not the impact of the management system itself, but the impact of additional year of management under each system. Along with the choice of dependent variables, this is a countermeasure against the stock-variable characteristics of forest condition. The extension of a specific management system captures its cumulative impact on forest condition, as well as circumvents the inverse causality from forest condition to the current management system.

In the index of community management, we included the years under community management of current co-management forests (column (2) of Table 1). For example, consider a forest under co-management for 2 years. Suppose further that this user group registered itself 8 years after its initiation. In this case, we counted 8 years for community management, and 2 years for co-management. This is for not neglecting the impact of community management practiced before the registration. Among 45 co-management samples, 33 forests were under community management in the past. The remaining 12 user groups were registered within one year after their establishment, so they have zero year entries for the community-management index.

Control for Vegetation Type

A notable virtue of forest-inventory data is that it allows us to control for vegetation factors in estimating the impacts of forest-management arrangements. Users usually value and take care of forests based on the tree species and non-timber forest products therein. Forests with some tree species may be prone to fire. The inventory data provides the measurement of 13,776 tree stands over 137 species. For the purpose of our study, however, all we need is to observe the two key species in the Middle Hills, *Shorea robusta* and pine trees, summarized in Table 5. [13]

S. robusta is a deciduous broad-leaved species whose local name is Sal. It is the dominant tree species in number, accounting for 32% of all the measured stands. In terms of size, however, pine is the dominant species in the Middle Hills. It accounts for 20% of all the measured stands, but accounts for 44% of the measured stem volume, while Sal accounts for only 24% of the measured stem volume. Both in number and size, the sum of Sal and pine trees accounts for more than 50% of the measured stands.

In the Middle Hills, Sal has been considered as the most valuable tree because it provides good fodder, leaf litter, firewood, and timber (Negi 1994, Chs. 5-7; Storrs and Storrs 1998, 264-267). In contrast, pine trees have not been valued highly by forest users. Pine is a coniferous tree that is good for timber. Their needle-like leaves are, however, of little use for subsistence agriculture.

The lower block of columns (2) and (3) of Table 5 shows that there is a clear difference between the accessible and the remote forests in the distribution of Sal and pine trees. Sal trees are concentrated in the accessible forests, so that even in number, pine trees are the most common species in the remote forests. [14] This difference suggests the importance of controlling for vegetation type in equation [1]. For example, Table 4 demonstrates that there was more regeneration in the accessible forests than in the remote forests. In Table 6 which summarizes the frequency of fire incidence, there was much greater seasonal fire incidence in the remote (14.2%) than in the accessible forests (0.6%). We suspect that these differences are partly a result of the higher ratio of pine trees in the remote forests. Pine trees make soil cover dry, so that there is generally less regeneration under pine trees. Since the fallen leaves of pine trees are slippery, users often intentionally place fire on them to protect livestock from accidents. We test these allegations in our regressions.

Self-selection in User Group Registration

Evaluating the impacts of management systems on forest condition is a case of estimating treatment effects. A likely distortion in the estimation is sample self-selection bias. This is particularly the case for the co-management arrangement. Recall that in our study period, the informal user groups had substantial leeway in registering their groups. If informal user groups which were functioning well in forest management were also good at soliciting support from the DFOs, which might be due to the existence of experienced leaders in the community, simple regression analysis would overestimate the impacts of the co-management system.

To grapple with the possibility of self-selection bias, we resort to the instrument variable method. Along with

[13] The data include three species of pine: *Pinus roxburghii*, *Pinus wallichiana*, and *Pinus patula*. *P. roxburghii* whose English name is Himalayan pine, is the dominant type accounting for 92.3% of pine stands.

[14] This is mainly due to the difference in the altitude between the accessible and the remote forests. Pine trees usually distribute in higher altitude than Sal. On average, the remote forests are located at an altitude 300 meters higher than the accessible forests (Table 2).

equation [1], the potentially biased co-management variable is accommodated by

$$\begin{aligned}\text{(Years under Co-management)}_i = \alpha_1 &+ \alpha_2\text{(Time to Ranger Office [TR])}_i \\ &+ \alpha_3\text{(Index of Social Capital [SOC])}_i \\ &+ \alpha\text{(All the Other Exogenous Variables)}_i + \upsilon_i \qquad [2]\end{aligned}$$

where α's are parameters. The system of equations [1] and [2] is identified by the instrument variables (IV) which appear in equation [2], but do not directly explain changes in forest condition in equation [1]. The IV utilized in all the estimations is travel time to the nearest ranger office from the sampled forest (TR in Table 2). Additional instruments utilized for some specifications are an index of social capital among users (SOC in Table 2) and the ratio of Sal trees in forest stands (Table 5). The statistical tests and the discussions on the validity of these instruments are summarized in the Appendix.

Endogeneity in Forest-related Projects and Community Management

Projects implemented in the forest area by donor and government agencies are a management factor which is expected to affect forest-resource condition. Column (5) of Table 1 shows that 17 sample forests had projects in their area.[15] These projects consisted of several activities. A major activity was tree planting, with 12 projects that either directly planted trees or subsidized users for tree planting. Another common activity was to provide users with training on community management. In general, these projects exerted more direct intervention in forest management than the DFOs did in the co-management arrangement. In equation [1], these projects are represented by a dummy variable due to missing information on their implementation period.

Similar to the case of co-management, it is possible that forest-related projects and community management are endogenous variables. Donor agencies often choose their project sites based on the characteristics of forests or their users. As was discussed in section 2, many field studies reported that forest users initiated community management to alleviate the shortage of forest resources. The concern is that if projects and community management emerged as a response to degrading forest condition, regressions that do not accommodate for this endogeneity will underestimate their impacts on forest condition. On the other hand, for community management in particular, it is possible that recovering forest resources induce its establishment. A likely case is that users initiate management to regulate the sales of extracted resources. If this was the case, simple regressions would overestimate the impact of community management.

In the final estimations, however, we consider two management variables, years under community management and a dummy for forest-related projects, as exogenous variables. Since our analysis focuses on changes in forest condition, the above-mentioned over- or under-estimation problems are less of a concern than in the analyses on the level of forest

[15] In the 1990s, all the forests in the Middle Hills were nominally covered by the community forestry project. Seventeen forests with projects in the paper are those which the workers of any projects did some activities in the area or on their users.

condition. Furthermore, Table A1 in the Appendix shows that the plausible candidates affecting the evolution of these two management arrangements failed to explain them. Examples of such candidates are the forest condition in 1978, the social capital of users, and the ratio of households with out-migrant members in Table 2. [16]

There are two reasons for this seemingly random assignment of forest-related projects. The first is the wide variety in the organizations implementing these projects. Among 17 projects, 9 were undertaken by international donor agencies (one by Germany, 4 by UK, and 4 by Australia), 6 were undertaken by local government offices (DFOs or watershed management offices), one was undertaken by a local NGO, and the last one was implemented by the management office of a national park. These various agencies had their own criteria for site choice, so that there were no consistent rules. Edmonds (2003), for example, showed substantial differences among international donor agencies in assisting a *common* institutional reform in Nepal: the implementation of the Forest Act of 1993. The second reason is tree planting for watershed management. All of the 6 projects undertaken by local government offices involved tree planting. Most of them were, however, related to watershed management. Tree planting for watershed management is not necessarily on a degraded area.

The exogeneity of community management comes from its long history. On average, the user groups had an 8-year history of community management (column (2) of Table 1). Fourteen user groups experienced more than a decade of community management, and half of them continued it for more than two decades. This long history dwindles the initial inverse causality from degrading forest condition to initiation of community management.

For the possibility that recovering forest condition induces the initiation of community management, we have field observations contrary to it. In the social survey, no user groups listed the need for regulating the sales of forest products as a reason for their initiation. Rather than suffering from invalid instruments for community management, this paper focuses on the endogeneity in the process of switching from community management to co-management.

IV. Estimation Results and Discussions

Effects on the Changes Detected in the Aerial-photo Analysis

Table 7 presents the estimation results of equation [1], where the dependent variable is changes in forest condition detected by the aerial-photo interpretation (Table 3). The number of observations is 98 after excluding 3 forests which show mixed changes both with improved and deteriorated indices.

Table 2 displays the summary statistics for controls other than the management variables (X_i). They are specified as follows. Population pressure consists of three variables: number of user households per forest area, increase in the number of user households since 1980, and average travel time to forest from the users' settlements. [17] The increase in the

[16] Except for the dummy variables of forest condition in 1978, these variables describe the situation at the period of investigation. We have noticed that they are not good explanatory variables for the emergence of community management more than a decade ago.

[17] There is a conceptual difficulty when defining user households of *de facto* open access forests, because in principle, everyone can have access to such forests. For the 30 forests directly under the control of DFOs, we investigated the number of user households who *regularly* extracted resources

number of user households is a proxy for the population growth rate. In the social survey, we used the first referendum in Nepal in 1980 as the recall point for past variables. Topographic conditions consist of the lowest altitude of the forest area, the average slope, and the ratio of inventory plots facing north. Since the inventory plots were randomly chosen in the forest area, the last variable captures the impacts of sunlight. Two dummy variables, which indicate the average stand size in the 1978 aerial photographs, are included to control for the initial forest condition. The baseline for these two dummy variables is shrub and grass land in 1978.

Column (1) of Table 7 reports the estimated coefficients. Since the dependent variable is a rank dummy, we employ the ordered probit model. Columns (2) to (4) report the marginal effects evaluated in each rank probability. We are primarily concerned with the three management variables listed at the top of Table 7: years under community management, years under co-management, and the dummy for projects. The null hypotheses on these management variables are that they have not contributed to the improvement in forest condition. We therefore implement one-sided tests for the statistical significance of their estimates as well as the conventional two-sided tests.

Among the three management variables, years under community management and the dummy for projects have positive and statistically significant coefficients at the 5% level both in the one-sided and two-sided tests. The marginal effects imply that between 1978 and 1992/96, an additional year of community management and the existence of forest-related projects reduced the number of forests that experienced a deterioration as well as increased those that experienced an improvement. Among the other explanatory variables, the number of user households per forest area, the slope of the forest area, and the dummy for immature forests in 1978 have statistically significant coefficients. All of them work against an improvement in forest condition.

The coefficient of years under co-management is -0.030 with an unexpected negative sign and without any conventional level of statistical significance. As has been noted, years under co-management is likely to be an endogenous variable, which may distort the estimates in columns (1) to (4) of Table 7. Currently, the most legitimate way to tackle this endogeneity is to estimate the joint distribution of changes in forest condition in equation [1] and years under co-management in equation [2] (Wooldridge 2002, 475-478). Both variables are, however, non-linear responses. In particular, years under co-management is a complex duration variable representing the dual decision of user groups: whether and how quickly to apply for registration. It is not practical to estimate such a joint distribution with 98 observations (Cameron and Trivedi 2005, 888-889). We thus turn from estimating the joint likelihood function of equations [1] and [2], and rely on two alternative estimates.

The first alternative is a switching-regression model where the non-linearity in years under co-management is degenerated into a dichotomous dummy. That is, we neglect the user-groups' decision on how quickly to apply for registration, and focus on their decision on whether to register themselves. This is not a bad approach because our sample forests were under co-management for short periods: 3.4 years on average (column (3) of Table 1). Nineteen out of 45 co-

from those forests.

management forests had been under co-management for 2 years or less. Specifically, years under co-management in equation [1] is replaced by a dummy for co-management.

$$\begin{aligned}\text{(Changes in Forest Conditions)}_i \;=\; & \beta_1'\text{(Years under Community Management)}_i \\ & + \beta_2'\text{(Dummy for Co-management)}_i \;+\; \ldots \;+\; \epsilon_i' \qquad [3]\end{aligned}$$

and it is in turn accommodated by the following binary outcome equation.

$$\begin{aligned}\text{(Dummy for Co-management)}_i \;=\; & \alpha_1' \;+\; \alpha_2'\text{(Time to Ranger Office [TR])}_i \;+\; \alpha_3'\text{(Ratio of Sal Trees [SAL])}_i \\ & + \alpha'\text{(All the Other Exogenous Variables)}_i \;+\; \upsilon_i'. \qquad [4]\end{aligned}$$

If any, the unobserved common determinants of changes in forest condition and adoption of co-management system are revealed as the correlation between the error term ϵ_i' and υ_i'. For the identification of the system of equations [3] and [4], along with TR, we find the ratio of Sal trees in the forest stands (SAL in Table 5) to be an appropriate instrument. Refer to the Appendix for the validity of these instrument variables.

The second alternative is to use a standard two-stage least squares (2SLS) for the system of equations [1] and [2]. In this case, we ignore all the non-linearity in changes in forest condition and years under co-management. Angrist (2001) shows that in non-linear frameworks, there are cases where 2SLS is a viable estimation for investigating the causal effect of treatment. To alleviate the heteroskedasticity stemming from the inattention to non-linearity, White-heteroskedasticity consistent standard errors are used for testing the statistical significance of estimated coefficients by 2SLS.

Column (5) of Table 7 shows the endogenous switching ordered-probit estimates of equation [3], where the probit model is applied to switching equation [4]. The dummy for co-management has a positive coefficient of 0.277, but without any conventional level of statistical significance. Years under community management and the dummy for projects have positive coefficients similar to those in column (1), and maintain the 5% level of statistical significance in the appropriate one-sided tests. Note that in this switching-regression specification, we estimate the impact of an additional year of community management and the impact of the existence of co-management. Although over a few years, the latter represents accumulated impact. Thus, both in magnitude and statistical significance, this specification provides leverage to the impact of co-management in comparison with that of community management. The results show that the impact of an additional year of community management maintains its statistical significance in this less favorable specification. The other controls also have estimates similar to those in column (1). In fact, with a p-value of 0.615, a likelihood-ratio test does not reject the null hypothesis that the dummy for co-management is an exogenous variable.

Column (6) of Table 7 reports the 2SLS estimates of equation [1]. Except for years under co-management, all the variables have qualitatively similar estimates to those of the ordered probit. One difference is that for many controls, the 2SLS coefficients are about half the magnitude of the ordered-probit estimates. Years under co-management has a positive coefficient, but without any conventional level of statistical significance. The dummy for projects maintains its statistical significance at the 5% level, while years under community management has lost some of its statistical significance to the marginal 10% level in the one-sided test. Similar to the case of the endogenous switching ordered-probit estimates, however, the Hausman test does not reject the exogeneity of years under co-management. In the OLS estimates, which are not shown, years under community management has a positive coefficient with a 5% level of statistical significance in the one-sided test.

Taken together, we can conclude that community management and projects in forest areas contributed to the recovery of forest condition, from 1978 to 1992/96, detected by the aerial photographs. The co-management arrangement, on the other hand, did not have an impact on this recovery. Since these aerial photographs are in a fairly small scale of 1:42,000, our estimates imply that community management and projects produced a remarkable improvement in forest condition. The examples are the conversion of shrub land into sparse forest, poor forest into matured forest, and mono-species forest into diversified forest.

Conversely, with this coarse dependent variable constructed from small-scale aerial photographs, we may have missed the contribution of co-management. This in turn might have lowered the power of endogeneity tests for the co-management arrangement. Furthermore, as was discussed in section 3, the aerial photographs were taken in 1992 in the eastern part of Nepal. The period up to 1992 may be too short to evaluate the impacts of the co-management system in the eastern part. We address these concerns with the plot-wise regeneration rate.

Regeneration rate

Table 8 displays the estimation results of equation [1], where the dependent variable is the regeneration rate measured in 3,777 plots over 101 forests. From 3,793 plots in Table 4, we dropped 16 plots with missing information in the corresponding covariates. The main estimation method is a random effects model based on an analogy between plural plots in a forest and panel data.[18] Our hope is that the possibility of omitted-variable bias is reduced by the forest-specific unobserved components in the random effects model.

Many of the independent variables are the same as those for the changes in forest condition detected by the aerial-photo analysis. There are, however, two differences. First, we dropped the 3 variables in Table 7: the increase in the number of user households since 1980 and the two dummy variables for the average stand size in 1978. The regeneration rate indicates upcoming changes in forest subject to the initial exogenous conditions, which can be captured by the measurements of forest inventory. We thus dropped the 3 variables standing for the past trend of population growth and the forest condition of nearly 20 years ago. Second, to control for differences in vegetation, we included the logarithm

[18] We cannot estimate a fixed effects model because the variables of main interest, management indices, are forest-wise variables.

of basal area and the ratio of pine trees in each plot. Regeneration can be affected both by the density and the species of current stands.

Column (1) of Table 8 shows the OLS estimates of equation [1] with the standard errors corrected by the forest-wise clustering of measured plots. Column (2) reports the random effects estimates. The Breusch-Pagan test favors these two estimates over the pooled regression by firmly rejecting the null hypothesis of i.i.d. errors. All the coefficients in columns (1) and (2) share the same sign. Among the three management variables, only years under co-management has a statistically significant estimate. In the cluster-robust OLS in column (1), years under co-management has a positive coefficient with a 5% level of statistical significance in the one-sided test. In the random-effect estimation in column (2), however, its statistical significance goes down to the marginal 10% level.

Columns (3) and (4) of Table 8 show the 2SLS estimates in the random-effect specification *a la* Balestra and Varadharajan-Krishnakumar (1987).[19] As is discussed in the Appendix, for years under co-management up to 1998, there is doubt about the validity of SOC (in Table 2) as a good instrument. Column (4) therefore reports the IV estimate with TR (in Table 2) as the sole instrument. Instrumenting for years under co-management has a pronounced effect. The estimated coefficients for years under co-management are 0.418 and 0.373, respectively. These are four times greater than without instrumenting. In addition, these coefficients are statistically significant at the 1% level in the appropriate one-sided test. In contrast to the case of Table 7, the Hausman specification test rejects the null hypothesis of no endogeneity in years under co-management.

For a robustness check, column (5) of Table 8 lists the forest-wise estimates with the averaged variables over the plots. The forest-wise estimates are qualitatively and quantitatively similar to the plot-wise estimates. In particular, the estimated coefficient for years under co-management is 0.440 with a 1% level of statistical significance in the one-sided test. Taken together, our estimates indicate that the co-management arrangement improved regeneration in the sampled forests.

The results also indicate that denser stands (Log of Basal Area) and a higher ratio of pine trees work against regeneration. North-facing plots, on the other hand, provide favorable conditions for regeneration. The first two findings are intuitive. The second one statistically confirmed the allegation in the previous section that pine trees tend to dry the forest floor and lead to less regeneration. The last finding, more regeneration in north-facing plots, seems odd at first glance. This is, however, partially consistent with a finding of Agrawal and Chhatre (2006) who report a positive correlation between north-facing slopes and general forest condition in the Indian Himalaya area. Their explanation is that the north-facing slopes in the area are moister than the south-facing slopes, and assist in vegetative growth. Our interpretation focusing on regeneration is that less human activities, such as grazing, in north-facing plots facilitate tree regeneration. In the Middle Hills of Nepal, forest users often avoid north-facing slopes where leeches thrive in wet conditions. Above all, the statistically significant estimates of basal area, ratio of pine trees, and the aspect of plots elicit

[19] The first stage equation [2] is estimated by OLS. Applying non-linear models such as a Poisson regression did not make much differences.

the importance to control for topographic and vegetation factors in the evaluation of the impact of management systems on forest condition.

Potential Mechanisms of Positive Impacts

The estimation results revealed the positive impacts of community management and forest-related projects on changes in forest condition, which were so sizable that they could be detected using small-scale aerial photographs. Although co-management did not have such a large impact, we found that it enhanced the regeneration of saplings within a few years. Then how did these improvements in forest condition happen? Here we focus on the general function of community management, co-management, and forest-related projects.

First, why did community management have a positive impact in the Middle Hills of Nepal? Can we recommend the community management of forests to other countries? Here we need to recall the socio-economic condition of the study area. Because of the rugged geography, the majority of the population in the Middle Hills has been engaged in subsistence agriculture relying on fodder and leaf-litter collected from forests. In addition, their main energy source has been firewood. It is this users' dependence on small non-timber forest products (NTFPs) that leads to the possibility of effective community-based management. For individuals and local officials, it is extremely costly to protect these small NTFPs. This is because, first, harvesting of such small NTFPs is barely visible in natural forests. Second, it is almost impossible to make a connection between those small NTFPs carried out from a forest and the place of their extraction. These small NTFPs are homogeneous, and do not leave a clear trace of extraction. Imagine how difficult it is to ascertain the harvesting place of dry and fallen branches collected for firewood in a forest.

Thus, in areas where users expect small NTFPs from forests, community-based management is likely to function effectively due to its low cost for forest protection. The empirical results in the paper provide supportive evidence on this view.[20] Following the same logic, in areas where people expect large forest products such as timber, community management does not necessarily function better than private or government management. Extraction and transportation of timber is relatively visible. It is easy to make a connection between harvested timber and its extraction place through stumpage. Without the advantage of low protection cost, it will be hard for community management to match the incentive mechanism of private property or the administrative authority of local officials.

In fact, Sakurai et al. (2004) shows that in a district in Inner Terai of Nepal, private plantations enjoy more intensive care in pruning and thinning than community plantations, while the latter are less costly in protecting planted areas than the former. Inner Terai, where timber becomes the main forest product, is located at a lower altitude than the Middle Hills with milder slopes. The results of Sakurai et al. (2004) indicate that the low protection cost in community-based management is fairly robust even in mildly sloped areas, and also suggest that community management does not provide appropriate incentives for timber production. Taken together, our results support the recommendation of

[20] We thank Dr. Takeshi Sakurai who clarified this view at the initiation of the research project.

community management for areas (not necessarily in Nepal) where people expect forests to produce small NTFPs, but not necessarily in other areas.

Second, how did community management and 17 projects exert a positive impact on changes in forest condition? As has been emphasized, the positive impact was so substantial that it was identified on small-scale aerial photographs. In the study area, there are two human-related factors which can cause such a substantial change in forests: tree planting and fire. From the survey, we know that only 7 informal user groups conducted tree planting. Seven groups cannot represent the average positive impact of the 59 cases of community management. For the cases of the projects, we estimated the ordered probit model for equation [1] with a dummy for 5 projects that did not involve tree planting. Its coefficient completely lost statistical significance. Although the small number of projects prevents us from making a firm conclusion, this estimate suggests that tree planting is one channel through which forest-related projects improved forest condition.

Forest fire often destroys large parts of forest areas. Frequent fire incidence indicates a greater practice of shifting-cultivation, a higher frequency of careless fire use, and less patrols in the forest area. To examine the importance of fire prevention in the function of community management, we estimated equation [1] with the forest-wise average of the fire index in Table 6 as the dependent variable. The forest-wise average is constructed so that a higher value indicates a smaller incidence of forest fire. For the independent variables, we tried two specifications. One is the same set of independent variables as for the changes in forest condition detected in aerial photographs, and the other is the same set as for the regeneration rate. Since two sample forests did not record a fire index in their plots, our sample here is 96 forests for the former specification, and 99 forests for the latter.

The estimation results are summarized in column (7) of Table 7 and column (6) of Table 8. Assuming that the forest-wise average of the plot-wise rank dummy is an appropriate continuous variable, 2SLS generates consistent estimates. In column (7) of Table 7, the coefficient of years under community management is 0.015 with a 1% level of statistical significance in the one-sided test, while that in column (6) of Table 8 is 0.017 with a 1% level of significance in both one-sided and two-sided tests. The goodness of fit for the specification in Table 7 is, however, very low. In both estimates, the dummy for projects has positive coefficients, but their statistical significance levels are a marginal 10% in the one-sided test. The Hausman tests do not reject the null hypothesis of exogeneity for years under co-management, and OLS generates similar estimates for either specification.

In sum, we can conclude that reducing forest fire is a vital channel through which community management substantially improved forest condition. For suppressing bold activities such as shifting cultivation and careless use of fire in forests, an unofficial agreement among users seems to be sufficient. Other than management variables, the higher ratio of pine trees increased fire incidence with a 1% level of statistical significance. This is because, as we noted in the previous section, to protect livestock from accidents, users sometimes place fire on slippery pine needles on the forest floor.

Lastly, how did co-management arrangements improve the regeneration of saplings? Our intensive field interviews suggest that registration of a user group usually enhances the authority of its management committee. Authorized forest committees often succeed in persuading the users to follow technical advice from the DFOs, which recommends rotational use of a forest area. In fact, 24 out of 45 formal user groups in our data restrict the collection period for dead and dry branches. Since dead and dry branches is the least protected forest resource in the Middle Hills, such restriction indicates the closing of a forest area for some period. The rotational use of a forest area is a mechanism that may raise regeneration under co-management arrangements.

V. Conclusions

With 101 randomly sampled forests in the Middle Hills of Nepal, this paper examines the effects of community-based management on changes in forest-resource condition. We combine forest measurement data, aerial-photo interpretation, and a social survey. As far as we know, this paper is a rare attempt to measure the impact differentials between indigenous community management and co-management with some involvement of official agencies. The main findings can be summarized as follows.

First, community management without systematic external support exerted a positive impact on changes in forest condition. This positive impact was so substantial that it could be identified on small-scale aerial photographs. Reduction in forest fire seems to be the major channel of this community-management contribution. Second, co-management improved the regeneration of saplings within a short period. This is likely to be the result of rotational use of the forest area. The management committees authorized under co-management arrangements often succeeded in persuading the users to practice a rotational use of the forest. In the future, one can expect a higher biomass in forests that are under co-management. This may become visible in aerial photographs. This expectation is, however, subject to the assumption that there will be proper silvicultural management for the growth of saplings. Lastly, along with community management, projects in the forest area brought substantial improvement in forest condition. Our analysis suggests that tree planting was a major channel through which projects exerted this positive impact.

The second finding on regeneration may require additional notes. It suggests that official intervention can improve the function of voluntary management of local natural resources by users. Several cautions are necessary, however. First, in the case of Nepal, interventions by government agencies are mainly in the form of standardization of management rules, technical assistance, and inter-group intermediation. None of these are as intensive as the co-management exercises in other countries. The official registration of user groups is like providing a clear property right over the forest to the users. Our regression results, therefore, cannot provide a comment on the impacts of *intensive* government intervention in community management. Second, we have a maximum of 7 years of co-management in our data. The evaluation of longer consequences is necessary for obtaining a firm policy implication on the effect of government intervention. Above all, we found that community management without external support functioned well in improving natural forests. Under the condition that users expect small NTFPs from their forest, one should be careful to venture into official intervention. [21]

The paper also provides two methodological contributions. First, we show that careful field research identifying various indigenous management activities is the starting point for evaluating the impact of community-based management. Our field research identified the cases of community management without well-defined decision-making mechanisms, and excluded the 2 cases of fake community management. Our estimates in Table 7 are, for example, in a good sense not perfectly robust. When we regard these 2 fake cases as community management, the statistical significance of the ordered-probit estimate of years under community management goes down to the marginal 10% level. In these 2 cases, mainly for political reasons, one or a few community leaders declared the initiation of community management of the forest. But they were merely nominal from the beginning and no management activities were implemented for 8 and 14 years, respectively. Second, we clearly show that it is necessary to control for geographic and vegetation conditions when evaluating the differential impact of natural-resource management systems. Our estimates indicate that, for example, the ratio of pine trees is an important determinant of regeneration and forest fire.

A major remaining task is to balance the impacts of various extraction rules set by user groups on forest condition. Such analysis requires careful classification of indigenous management rules. We reserve this issue for future research.

[21] In policy formation, one should also consider the impacts of co-management other than those on resource condition. Mani Nepal, Alok K. Bohara and Robert P. Berrens (2007) provide favorable evidence for co-management by finding its external impact on tree planting on private land. Graner (1997) provides negative evidence that user groups sometimes exclude socially weak users.

Appendix: Validity of Instruments

We have tested many variables as instruments for the evolution of co-management: the registration of user groups at the district forest office (DFO). Examples are the number of local administration units (ward) to which users belong, the ethnic diversity of users, the ratio of households with out-migrant members, etc. Among them, we chose three variables as instruments. The main one consistently utilized in all the IV estimates is travel time from sample forests to the nearest ranger office (TR). The other two are an index of social capital (SOC) and the ratio of Sal stands in the forest (SAL). The summary statistics of these variables are collected in Table 2.

In the system of equations [1] and [2], the instrument variables need to satisfy the following three conditions. i) They are closely correlated with years under co-management. ii) They do not directly affect the dependent variable of equation [1]. iii) They are not correlated with the error term of equation [1]: ϵ_i. The first criterion requires the valid instruments to have statistically significant coefficients in the linear projection of years under co-management onto all the exogenous variables. Columns (1) to (3) of Table A1 show such linear projections, while column (4) displays that of the dummy for co-management. In column (1): to be consistent with the aerial photographs, years under co-management in the eastern part of Nepal is counted up to 1992. It is counted up to 1996 in the other part of the country.

Throughout columns (1) to (4), TR has negative coefficients with 1%-levels of statistical significance. As the lower block of column (3) of Table 1 indicates, the DFOs have mainly assisted the user groups of easily accessible forests. Thus, TR is an important determinant of years under co-management as well as the dummy for co-management.

SOC has a positive coefficient at the 10%-level of statistical significance in column (1) of Table A1. SOC is the participation rate of forest users in community activities other than forest management. These community activities often accompany some involvement with government agencies and NGOs, and are expected to facilitate an early application for the co-management arrangement. The statistical significance of SOC coefficient is, however, lost in columns (2) and (3). Comparison between column (2) and (3) suggests that the reduction in the statistical significance is mainly due to the under-evaluation of years under co-management in the eastern part of Nepal. On average, the more developed eastern part has a higher SOC (0.78) than the western part (0.70). SOC seems to have a stronger impact in the western-part of the country where it is scarcer. Although the F-test supports the joint statistical significance of TR and SOC in column (3), we make some reservation for the validity of SOC as a good instrument.

In column (4), SAL has a positive coefficient with a 10% level of statistical significance. As noted in section 3, Sal has been the most valuable tree for forest users in the Middle Hills. In our field interviews, several user groups listed protection of Sal resources as the main reason to register their groups.

The credibility of our instruments turns on the second criterion of whether TR, SOC, and SAL do not directly affect changes in forest condition. Considering the patrol activities by rangers, it seems unreasonable to assume that TR does not directly affect changes in forest condition. Here we should recall the economic and geographic conditions of the study area. Due to limited transportation, the major cause of forest degradation in the Middle Hills has not been commercial logging, but the overuse of small NTFPs such as fodder and firewood by users. Forest patrol by rangers has not been effective in arresting the over-harvesting of small NTFPs. In fact, this ineffectiveness of rangers' patrols is the main reason why the government of Nepal adopted a community-based approach to forest management. To the difficulties faced by rangers in conducting intensive forest patrols, poor views in forests on the rugged geography makes little difference between nearby and remote forests. We thus can exclude TR from equation [1].

SOC consists of community activities such as drinking water management, women development, and village school building. None of these have a direct influence on changes in forest condition. Since Sal is a broad-leaved tree, SAL surely causes smaller stands and a higher crown cover in forests than conifer trees such as pine. Almost all the broad-leaved tree species, however, will generate smaller stems and higher crown cover than conifer trees. In our data, two other broad-leaved species, *Schima wallichi* and *Quercus* species, account for nearly 15% of the total stands. Compared with these two broad-leaved species, Sal does not have a specific size or crown coverage. In the data set, the average stem volume of Sal trees is 0.283 cubic meter, while that of *Schima wallichi* is 0.263 and of *Quercus* species is 0.319. We thus would not expect SAL to have a significant direct influence on changes in forest condition measured by stand size and crown coverage.

To check the third criterion, we implemented Sargan's test for overidentification in the forest-wise linear regressions. The null hypothesis is that instrumental variables are uncorrelated with ϵ_i. The results are listed in Tables 7 and 8. We cannot reject the null hypotheses at any ordinary level of statistical significance.

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Table 1: FOREST MANAGEMENT SYSTEM

	(1)	(2)	(3)	(4)	(5)
	Community-based Management			Directly	
	Community Management	Including the Ones Already Registered[a)]	Co-management	under the DFOs[b)]	With Project
101 Sample Forests					
Number of Observations	26	59	45	30	17
Ratio[c)]	[25.5%]	[58.4%]	[44.6%]	[29.7%]	[16.8%]
Average Years[d)]	10.1	8.1	3.4		
(Std. Dev.)	(9.7)	(7.8)	(1.6)		
Max Years[d)]	43	43	7		
By Access					
51 Forests in Accessible Area					
Number of Observations	12	40	34	5	11
Ratio[c)]	[23.1%]	[78.8%]	[66.7%]	[9.8%]	[21.6%]
Average Years[d)]	10.9	7.5	3.4		
(Std. Dev.)	(11.5)	(7.6)	(1.5)		
Max Years	43	43	7		
50 Forests in Remote Area					
Number of Observations	14	19	11	25	6
Ratio[c)]	[28.0%]	[38.0%]	[22.0%]	[50.0%]	[12.0%]
Average Years[d)]	9.4	9.2	3.3		
(Std. Dev.)	(8.3)	(8.5)	(1.9)		
Max Years	28	28	7		

a) Including the forests currently under co-management with more-than-a-year-long period of community management. For example, if a user group registered itself 8 years after its initiation, 8 years is counted in "Average Years" of this column.

b) Including 2 forests under the non-functioning user groups.

c) Ratio to the total number of observations in each access classification.

d) Count of the years under the management arrangement indicated by the column.

Table 2: SUMMARY STATISTICS

Variables	101 Sample Forests Mean and (Std. Dev.)	51 Accessible Forests Mean and (Std. Dev.)	50 Remote Forests Mean and (Std. Dev.)
Population Pressure			
Number of User	183.80	214.00	153.00
Households (HHs)	(163.19)	(179.07)	(140.41)
Increase in User HHs	0.26	0.33	0.19
since 1980[a,b]	(0.18)	(0.20)	(0.13)
Time to	34.50	23.37	45.86
Forest (minute)[b]	(27.84)	(18.96)	(30.90)
Topographic Condition			
Forest Area	115.75	76.39	155.90
(hectare)	(210.22)	(81.68)	(283.06)
Lowest	1127.59	970.35	1287.98
Altitude (meter)	(427.24)	(397.19)	(399.44)
Average Slope	0.51	0.51	0.52
(radian)	(0.10)	(0.10)	(0.09)
Ratio of Plots	38.69	35.00	42.45
Facing North[c]	(33.77)	(31.23)	(36.11)
Vegetation Condition			
Basal Area	16.52	15.21	17.86
per hectare (m^2)	(9.64)	(9.62)	(9.56)
Number of Immature Forest in 1978	69	33	36
Number of Matured Forest in 1978	19	7	12
Other Variables			
TR: Time to Ranger	191.65	67.88	317.90
Office (minute)	(208.84)	(59.91)	(230.51)
SOC: Social Capital	0.73	0.73	0.74
in the Users (%)[d]	(0.35)	(0.37)	(0.34)
Number of Wards	2.49	2.10	2.88
Users Belong	(1.58)	(1.37)	(1.69)
Ethnic Diversity	0.50	0.60	0.40
of Users[e]	(0.23)	(0.17)	(0.24)
Ratio of HHs with Out-	0.20	0.15	0.26
migrant Members[f]	(0.35)	(0.18)	(0.46)

a) { (HHs in 1998) − (HHs in 1980) } / (HHs in 1998). We chose this denominator because some settlements did not exist in 1980.

b) Weighted average over the settlements having access to the forest. The weight is the current number of HHs in the settlements.

c) Include the plots facing the north side: north, northwest and northeast.

d) Ratio of HHs attending community activities other than forest management.

e) The Simpson index of diversity for castes and ethnic groups among the user HHs.

f) Ratio of HHs some of whose members stay and work outside of the district.

Table 3: CHANGES IN FOREST CONDITION: AERIAL-PHOTO INTERPRETATION

	(1) Sample Forests	(2) Improved[a)]	(3) No Change	(4) Degraded	(5) Mixed[b)]	Years of Photo	(6) Shrub
Middle Hills	101	28	48	22	3	1978	11
		(27.7%)	(47.5%)	(21.8%)	(3.0%)	1992/96	7
by Access							
Forests in	51	17	24	9	1	1978	9
Accessible Area		(33.3%)	(47.1%)	(17.6%)	(2.0%)	1992/96	5
Forests in	50	11	24	13	2	1978	2
Remote Area		(22.0%)	(48.0%)	(26.0%)	(4.0%)	1992/96	2

a) Improved in crown cover, maturity, or number of tree species.
b) Forest with both improved and deteriorated indices.

Table 4: REGENERATION

	101 Sample Forests	by Access	51 Forests in Accessible Area	50 Forests in Remote Area
Number of Plots Measured	3,793		1,750	2,043
	Mean (Std. Dev.)		Mean (Std. Dev.)	Mean (Std. Dev.)
Weighted Sum of Saplings per Plot[a,b)]	1.60 (1.78)		1.80 (1.76)	1.42 (1.78)

a) The area of plot for regeneration counting is 4 square meter.
b) Weight: 1 for Established, 0.5 for Woody, 0.3 for Whippy, and 0.1 for Sub-whippy Saplings.

Table 5: TREE SPECIES IN SAMPLE FORESTS

	(1) Stands	(2)	(3)	(4) DBH[a]	(5)	(6) Stem Volume	(7)
	Number Measured	(SAL) Ratio of Sal	Ratio of Pine[b]	Ratio of Sal	Ratio of Pine[b]	Ratio of Sal	Ratio of Pine[b]
101 Sample Forests	13,776	31.8%	20.5%	28.0%	26.5%	23.8%	43.2%
by Access							
In the 51 Accessible Forests	6,212	52.2%	16.1%	46.2%	21.4%	40.6%	31.6%
In the 50 Remote Forests	7,564	15.0%	24.1%	14.0%	30.4%	12.7%	50.9%

a) Diameter at Breast Height.
b) Includes the three pine species. Refer to footnote (13) in the text.

Table 6: FIRE INCIDENCE

	Number of Plots Evaluated	None	Occasionally	Seasonally
101 Sample Forests	2,448	1,386 (56.6%)	835 (34.1%)	227 (9.3%)
By Access				
51 Forests in Accessible Area	882	581 (65.9%)	296 (33.6%)	5 (0.6%)
50 Forests in Remote Area	1,566	805 (51.4%)	539 (34.4%)	222 (14.2%)

Table 7: DETERMINANTS OF CHANGES IN FOREST CONDITION IN AERIAL PHOTOS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample	98 Forests						96 Forests
Dependent Variable (Y)	Rank Dummy from Table 3: 0 = Deteriorated, 1 = No Significant Changes, 2 = Improved						Fire Index in Table 6
Estimator	Ordered Probit				FIML[a)]	2SLS	2SLS
Excluded Variables[b)]					TR & SAL	TR & SOC	TR & SOC
	Coefficient	Marginal Effect in Y = 0	Y = 1	Y = 2	Coeff.	Coeff.	Coeff.
Management Variables							
Years under Community Management	0.036^{**}_{++}	-0.009^{**}_{++}	-0.002	0.012^{**}_{++}	0.033^{*}_{++}	0.018_{+}	0.015^{**}_{+++}
	(0.018)	(0.005)	(0.002)	(0.006)	(0.019)	(0.011)	(0.006)
Years under Co-Management	-0.030	0.008	0.002	-0.010		0.046	-0.034
	(0.075)	(0.019)	(0.005)	(0.024)		(0.126)	(0.094)
Dummy for Co-Management					0.277		
					(0.765)		
Dummy for Project	0.757^{**}_{++}	-0.149^{***}_{+++}	-0.124	0.273^{**}_{++}	0.719^{*}_{++}	0.329^{**}_{++}	0.246_{+}
	(0.358)	(0.055)	(0.095)	-0.137	(0.370)	(0.150)	(0.150)
Other Controls							
Households per Forest Area (per ha)	-0.045^{**}	0.011^{**}	0.003	-0.014^{**}	-0.048^{**}	-0.024^{***}	0.011
	(0.019)	(0.005)	(0.003)	(0.006)	(0.019)	(0.008)	(0.009)
Increase in User HHs since 1980	0.665	-0.170	-0.043	0.213	0.738	0.401	0.459
	(0.724)	(0.186)	(0.060)	(0.233)	(0.718)	(0.385)	(0.316)
Log of Time to Forest (minutes)	0.287	-0.074	-0.019	0.092	0.318	0.157	-0.045
	(0.199)	(0.052)	(0.020)	(0.064)	(0.204)	(0.109)	(0.090)
Log of Lowest Altitude (meter)	0.095	-0.024	-0.006	0.031	0.175	0.068	0.100
	(0.329)	(0.084)	(0.022)	(0.106)	(0.372)	(0.156)	(0.174)
Log of Average Slope	-1.133^{**}	0.290^{**}	0.074	-0.364^{**}	-1.036^{**}	-0.566^{*}	0.094
	(0.461)	(0.121)	(0.069)	(0.149)	(0.504)	(0.294)	(0.200)
Ratio of Plots Facing the North	-0.149	0.038	0.010	-0.048	-0.079	-0.039	0.145
	(0.373)	(0.096)	(0.026)	(0.120)	(0.391)	(0.219)	(0.183)
Dummy for Immature Forest in 1978	-1.585^{***}	0.222^{***}	0.349^{***}	-0.571^{***}	-1.635^{***}	-0.761^{***}	0.007
	(0.444)	(0.047)	(0.124)	(0.135)	(0.448)	(0.175)	(0.151)
Dummy for Mature Forest in 1978	-0.388	0.110	0.003	-0.114	-0.415	-0.208	-0.249
	(0.337)	(0.105)	(0.026)	(0.090)	(0.340)	(0.192)	(0.183)
Cut Point (or Const.)						2.400	0.515
for 0 in Y	-4.174				-3.121		
for 1 in Y	-2.574				-1.545		
Log-likelihood	-86.85				-133.01		
R-squared[c)]	0.15					0.15	-0.02
p-value Endogeneity Test[d)]					0.615	0.634	0.460
p-value Overidentifying Restrictions[e)]						0.641	0.751

Numbers in parentheses are standard errors (SE). For columns (6) and (7), we list White's heteroskedasticity-robust SE.
*, **, and *** indicate statistically significant at the 10, 5, and 1% level (+ for one-sided test).
a) Full information maximum likelihood estimation of endogenous-switching ordered probit.
b) TR: travel time to the nearest ranger office, SAL: ratio of Sal trees in forest, SOC: index of social capital.
c) Pseudo R^2 in column (1), and adjusted R^2 in columns (6) and (7).
d) The null hypotheses are no endogeneity. Likelihood ratio test for column (5), and regression-based Hausman test (Wooldridge 2002, 119) for columns (6) and (7).
e) Sargan's test based on R^2 times number of observations following $\chi^2(1)$.

Table 8: DETERMINANTS OF REGENERATION RATE

	(1)	(2)	(3)	(4)	(5)	(6)
Sample	3,777 Plots over 101 Forests				101 Forests	99 Forests
Dependent Variable	Regeneration in Each Plot in Table 4:				Averaged Regeneration in Table 4	Averaged Fire Index in Table 6
Estimator	OLS Clustering[a)]	Random Effect (RE)	2SLS RE	2SLS RE	2SLS	2SLS
Instruments[b)]			TR & SOC	TR	TR & SOC	TR & SOC
Management Variables						
Years under Community	0.015	0.013	0.019	0.018	0.012	0.017^{***}_{+++}
Management	(0.012)	(0.015)	(0.015)	(0.015)	(0.014)	(0.006)
Years under Co-	0.097^{*}_{++}	0.087_{+}	0.418^{***}_{+++}	0.373^{**}_{+++}	0.440^{**}_{+++}	-0.001
management	(0.057)	(0.056)	(0.147)	(0.149)	(0.174)	(0.072)
Dummy for	0.305	0.341	0.063	0.101	0.025	0.228_{+}
Project	(0.351)	(0.293)	(0.316)	(0.316)	(0.432)	(0.150)
Other Controls[c)]						
Households per Forest	0.043	0.015	0.000	0.002	-0.002	0.014**
Area (per ha)	(0.032)	(0.016)	(0.017)	(0.017)	(0.025)	(0.006)
Log of Time to	0.223	0.144	0.360*	0.330*	0.230	-0.001
Forest (minutes)	(0.144)	(0.164)	(0.187)	(0.187)	(0.248)	(0.077)
Log of Lowest	-0.345	-0.521**	-0.430	-0.443*	-0.360	0.070
Altitude (meter)	(0.298)	(0.266)	(0.269)	(0.269)	(0.362)	(0.131)
Slope‡	-0.666	-0.345**	-0.341***	-0.342**	-1.465	0.271
(radian)	(0.420)	(0.172)	(0.172)	(0.172)	(1.414)	(0.513)
Dummy for Plots	0.323**	0.169***	0.177***	0.176***	0.801*	0.186
Facing the North‡	(0.142)	(0.062)	(0.062)	(0.062)	(0.420)	(0.171)
Log of Basal	-0.194	-0.360***	-0.360***	-0.360***	-0.138	0.254
Area‡	(0.129)	(0.055)	(0.056)	(0.055)	(0.138)	(0.586)
Ratio of Pine	-0.846***	-0.787***	-0.784***	-0.784***	-0.753**	-0.582***
Trees‡	(0.163)	(0.087)	(0.087)	(0.087)	(0.351)	(0.172)
Constant	3.449*	5.114***	3.347	3.587*	3.704	0.847
	(2.019)	(1.904)	(2.043)	(2.046)	(2.425)	(0.979)
F test	38.65***	19.34***	15.72***	16.63***	2.07**	2.25**
p-value of Hausman test[d)]			0.014	0.038	0.025	0.844
p-value Overidentifying Restrictions[e)]					0.240	0.958

Standard errors are shown in parentheses. For the forest-wise specifications in columns (5) and (6), they are White's heteroskedasticity-robust standard errors.

*, **, and *** indicate statistically significant at the 10, 5, and 1% level (+ for one-sided test).

a) Covariance matrix of OLS is corrected by clustering of plots in each forest.

b) TR: time to ranger office, SOC: index of social capital (Table 2).

c) For columns (5) and (6), independent variables with ‡ are averaged in each forest.

d) Regression-based Hausman test with the null hypothesis of no endogeneity in years under co-management (Wooldridge 2002, 119).

e) Sargan's test based on R^2 following $\chi^2(1)$.

Table A1: INSTRUMENT VARIABLE

Dependent Variable	(1) Years under Co-management (up to 1992 for eastern part)[a]	(2) (up to 1998)	(3)	(4) Dummy for Co-management	(5) Years under Community Management	(6) Dummy for Project
Used in	Table 7		Table 8	Table 7		
Sample Forests	98	98	101	98	101	101
Candidates for Instrument						
Log of Time to Ranger Office (TR)	-0.379**	-0.681***	-0.696***	-0.116***	-1.340*	0.021
	(0149)	(0.162)	(0.144)	(0.037)	(0.706)	(0.034)
Social Capital (SOC)	0.705*	0.414	0.503		1.110	0.084
	(0.354)	(0.443)	(0.461)		(2.326)	(0.094)
Ratio of *Sal* (SAL)				0.294*	0.022	
				(0.164)	(0.032)	
Ethnic Diversity					-1.383	0.099
					(3.526)	(0.183)
Ratio of Households with Out-migrant Members					0.116	-0.014*
					(0.158)	(0.008)
Other Exogenous Variables						
Years under Community Management	-0.001	-0.032	-0.031	0.002		-0.001
	(0.024)	(0.024)	(0.021)	(0.006)		(0.004)
Years under Co-management					-0.545	0.031
					(0.436)	(0.024)
Dummy for Project	0.229	0.810	0.613	0.101	-0.341	
	(0.449)	(0.550)	(0.534)	(0.114)	(1.418)	
Immature Forest in 1978	0.765	0.636		0.221	0.081	0.012
	(0.506)	(0.510)		(0.168)	(2.126)	(0.139)
Mature Forest in 1978	0.206	0.690		0.149	0.560	-0.043
	(0.512)	(0.499)		(0.122)	(2.842)	(0.097)
Exogenous Variables in Table 7[b]	○	○		○		
Exogenous Variables in Table 8[b]			○		○	○
F-test on the Coefficients of	TR & SOC 3.93**	TR & SOC 8.13***	TR & SOC 9.78***	TR & SAL 5.23***		

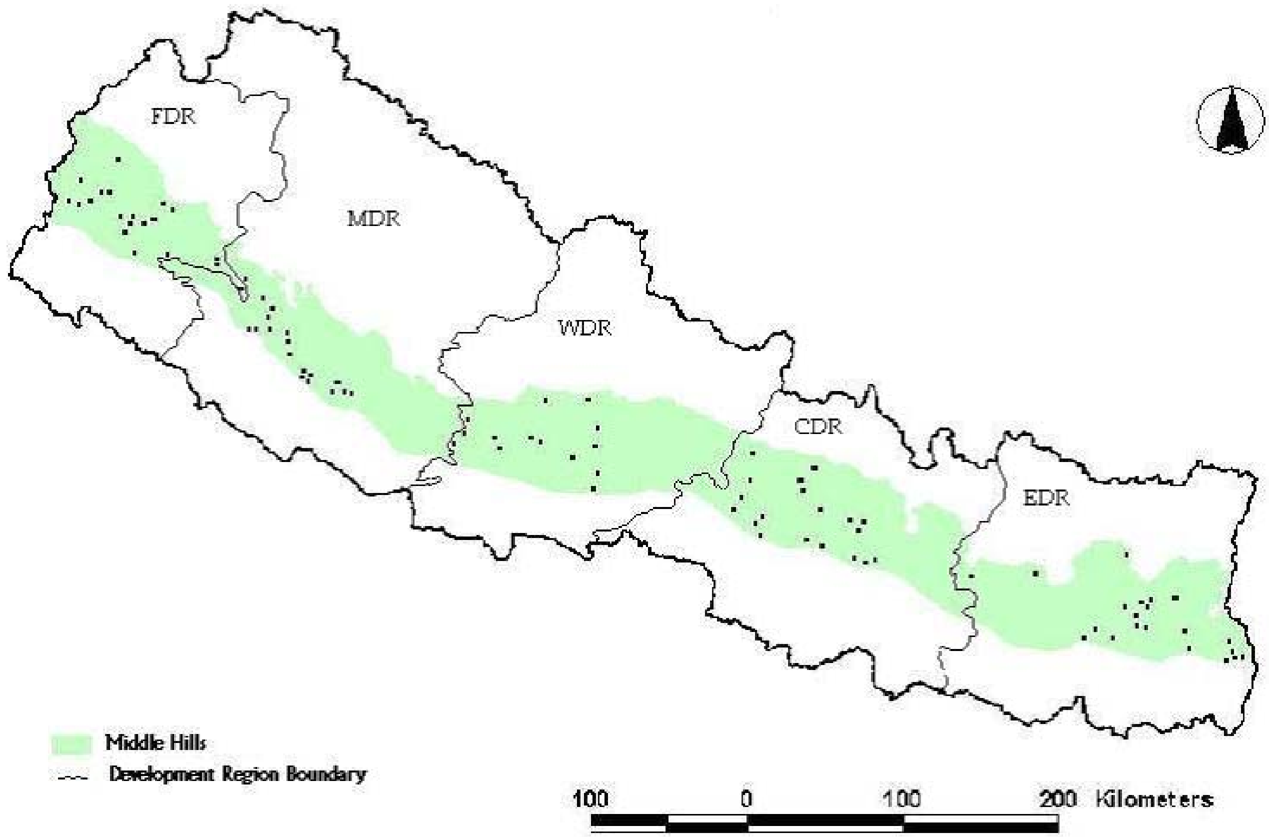
White's heteroskedasticity-robust standard errors are listed in parentheses.

*, **, and *** indicate statistical significance at the 10, 5, and 1 percent level.

a) This is to make consistent with the shooting year of the aerial photographs. In the eastern part of Nepal, the aerial photographs were taken in 1992. Refer to the text.

b) ○ indicates that all the exogenous variables in the referred table are included.

Figure 1: THE MIDDLE HILLS AND THE SAMPLE FORESTS



EDR: Eastern Development Region
CDR: Central Development Region
WDR: Western Development Region
MDR: Mid-western Development Region
FDR: Far-western Development Region

(Source) Prepared by the authors