Do community management and co-management improve natural forest condition?: A case of the Middle Hills in Nepal

Towa Tachibana[1*] Sunit Adhikari[2]

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[1]* Corresponding author, Graduate School of International Cooperation Studies, Kobe University, 2-1 Rokkodai, Nada, Kobe 657-8501, Japan; Tel/Fax: 81-78-803-7154, E-mail: ttachi@kobe-u.ac.jp
[2]School of Resources, Environment and Society, Australian National University

Abstract

Does community management improve the condition of local natural resources? Do interventions and support by official agencies impair or enhance the functions of voluntary communal management? With 102 randomly-sampled natural forests in the Middle Hills of Nepal, we address these questions. Our data contain the cases of government management, community management, and co-management of local forests. Co-management is the management by the user groups receiving official support from local forest agencies. Forest condition was evaluated by the aerial-photo interpretation and forest inventory. We find that, controlling for the possible self-selection into official support, co-management system has contributed to improve tree regeneration. However, community management without any external support also can be effective. Our analysis indicates that such management reduced the incidences of forest fire.

Keywords : community management, co-management, forest inventory, aerial-photo interpretation

1 Introduction

Facing degradation, various policy frameworks have been applied to management of local natural resources such as pasture land, small irrigation, in-shore fishery, and forest. In the past decades, a participatory approach was in fashion.[1] In forest policies, community management was promoted by many governments and international donor agencies (e.g., [9]). The fad has passed. Several studies have pointed out the problems in community forestry programs [4, 5, 14]. The World Bank becomes cautious about too much emphasis on the role of local-level organizations [34, p. A-6]. Without promising alternatives, however, significant funds and human resources are still being devoted to community forestry programs.

Along with the participatory practices, there appeared flourishing literature on communal management of local natural resources (e.g., [3, 24, 26, 28, 33]). The cases of voluntary cooperation stimulated the curiosity of researchers. Thus these studies focus on the factors that facilitate collective action. In contrast, a vital concern in local natural-resource management has not received much attention: impacts of collective action on resource condition. One should note that establishment and survival of community management do not necessarily conserve the local natural resources. For example, formation of a community management system may be motivated by a desire for symbolizing the community identity, not for resource management [1, pp. 191-192]. For the resource condition of natural forests, in particular, there are few empirical studies on the impacts of community management systems. Considering the funds and human resources allocated to the community-forest programs, it is an important task to accumulate such empirical studies. This paper tries to do so by evaluating the forest management systems in the Middle Hills region of Nepal.

Nepal has been known as a leading country of community forest management. The Middle Hills contains several types of forests on varied geographical conditions. The users of these forests are heterogeneous both in ethnic composition and social characteristics. Above all, the most valuable information in the Middle Hills' data is the variation in forest management systems. Our data contain the cases of government management, community management, and co-management of local forests. Co-management is the management by the user groups registered at the local forest offices. The regis-

[1] Participatory approach indicates that a voluntarily organized group of users or a local community is involved in management of local natural resources: from being consulted to being trusted the management.

tered user groups receive various support from official agencies, and can apply for the official use right of forest. With the growing importance of co-management systems in local resource administration, a comparison between community and co-management systems is of special interest [1, 18].

Besides the comparison between community and co-management systems, our work has two major innovations. First, our data set is not confined to a specific area or a project. It contains 102 randomly-sampled forests throughout the Middle Hills (Fig. 1). Our extensive survey will provide background information for the detailed area-specific analyses [8, 11, 16, 27]. Second, we measured the resource condition of all the sampled forests. The main reason why few studies have statistically evaluated the impacts of forest management systems is that it is difficult to measure the resource condition of natural forests. The exceptional pioneering studies adopted the subjective indices of overall forest condition judged by foresters or users [12, 15, 32]. One of the contributions of this paper is to propose a practical procedure to measure the condition of natural forests. It is a combination of two methods: aerial-photo interpretation and forest inventory.

This paper proceeds as follows. Section 2 provides a description of study area and our data set. Section 3 summarizes our findings on the forest condition in the Middle Hills. In Section 4, we discuss empirical specifications to evaluate the impact of management systems on forest condition. Section 5 reports the estimation results. With brief discussions on our field observations, we conclude the paper in Section 6.

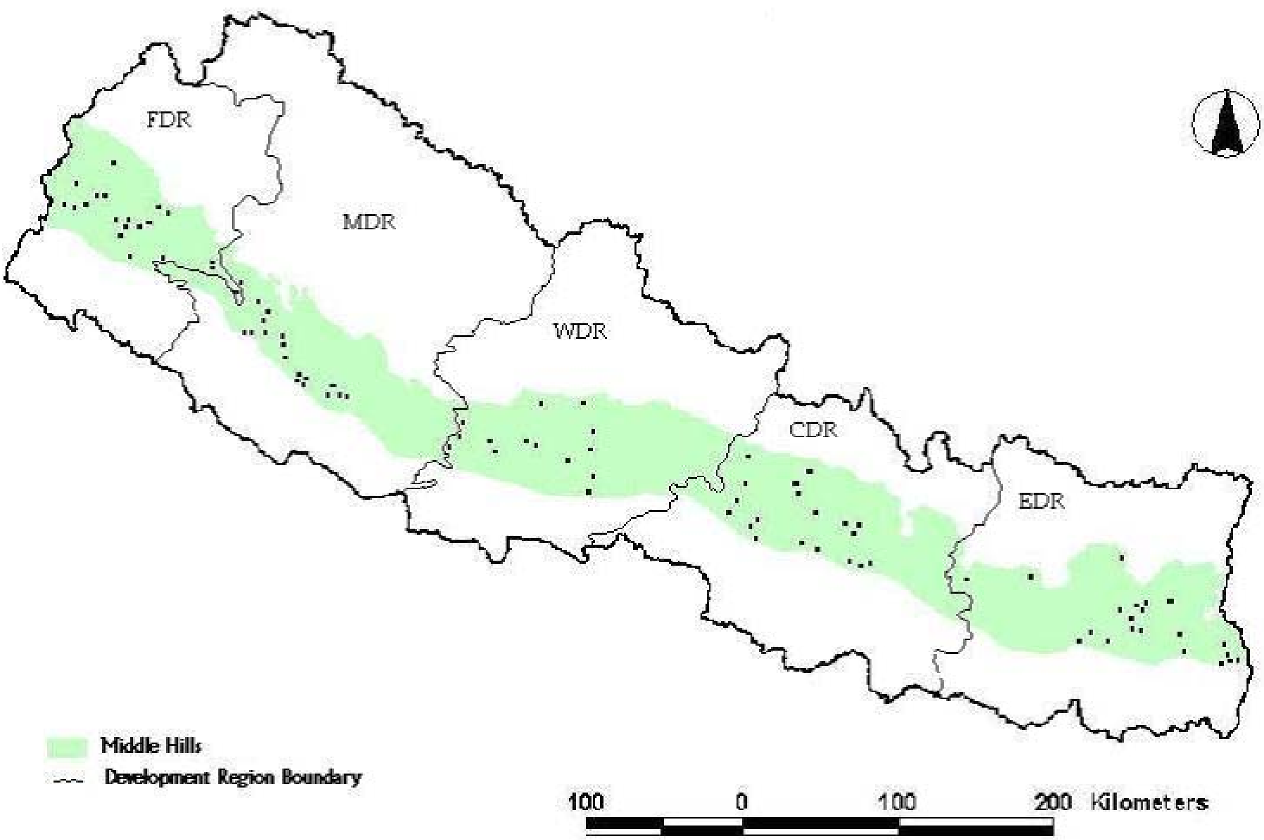
2 Study area and data

2.1 Geography and economy

Nepal has a rectangular shape, where the longer east-to-west side is divided into five development regions: Eastern Development Region (EDR), Central Development Region (CDR), Western Development Region (WDR), Mid-western Development Region (MDR), and Far-western Development Region (FDR). Most of the precipitation is in monsoon season. In general, the eastern part of the country is wetter and cooler than the western part.

The Middle Hills is a physiographic zone extending over the average altitude range between 700 and 2,000 meters (Fig. 1). It occupies about 30% of the country. As its name indicates, the Middle

Figure 1: The Middle Hills and the sample forests



(Source) Prepared by the authors

Hills has rugged geography filled with continuous hills. It contains river valleys as low in elevation as 300 meter, and the areas along ridges as high as 3,000 meter. The Middle Hills was the economic and cultural center of Nepal. After the eradication of malaria in the 1960s, Terai plain lying along the Indian border has emerged as agricultural and industrial center. Since then, there has been an internal migration flow from the mountain and hill zones to Terai [7, Ch. 22].[2] Even with significant out-migration, more than 40% of the 22 million population of Nepal still lived in hill zone in the 1990s. Indo-Aryan origins tied to Hindu caste has been the majority in the Middle-Hills' population. There are, however, many groups of Tibetan-Mongoloid origins: Limbu, Rai, Tamang, Gurung, etc.

Due to its rugged geographical condition, both land productivity and access to market are limited in the Middle Hills. Most of the farms are on terraced slopes with poor irrigation facilities. Motorable roads are not many. Even now, there are many villages from where it takes a few days walk over hilly trails to reach the nearest market town. These factors make more than 90% of the Middle Hills' population rural, and have made subsistence farming with limited use of purchased inputs as the main economic activity. People depend on forests for their agricultural inputs such as fodder and leaf-litter for animal bedding and composting. Moreover, more than 90% of the family collects firewood as their main fuel for heat and cooking [6, pp. 38-39].

It is this users' dependence on minor non-timber forest products (NTFP) that leads to the possibility of efficient community-management systems of forests. In natural forests on rugged terrain, it costs much for individuals or local officials to protect these NTFPs. Under such economic and physical conditions, community or co-management system may be more efficient than private and government management of forests.

2.2 History of forest management system

In 1950, the hundred-year long feudal regime was overthrown in Nepal. As an attempt to replace local feudal systems, the new government promulgated the Private Forest Nationalization Act in 1957, which aimed to bring all the forest area under the control of the government. With insufficient number of forest officers and limited means of transportation, however, the nationalization policy was ineffective in many parts of the country [13, p. 12].

[2] Mountain and hill zones are topographical areas in official statistics. Hill zone includes the Middle Hills.

Subsequent political upheavals and the accelerated population growth gradually intensified the population pressure on forest resources. Responding to forest-resource shortages, there emerged community management system of forest resources. That is, some indigenous groups spontaneously began to manage the forests they utilized, on which the government had legal ownership [13, Ch. 1]. In addition, traditional forest-management systems were brought once again to the fore. Partly through the increasing number of forestry projects supported by international donor agencies, the indigenous management system has spread over the Middle Hills [22, Ch. 4].[3]

One important note here is that there are a variety of indigenous management systems. For these systems, an image of well-defined rules and decision-making mechanism is sometimes misleading. Some of the indigenous forest-management systems are simply the ongoing traditional systems. The most noted in the literature is *mana pathi* system, which is often observed in the western part of Nepal. In this system, the villagers hire forest guards and pay them in grain. In many cases of *mana pathi* system, users neither form a management committee nor have general meetings. A sample forest in CDR shows an example other than ongoing traditional systems. In this case, as early as 1986, the villagers were aware of the shortage of forest products, and made up their own regulations. Furthermore, the villagers planted trees without any external subsidies. In fact, our aerial-photo analysis confirmed that this forest was in the condition of shrub land in 1978, and recovered to a broad-leaf forest in 1992. The users of this forest, however, did not form a user group. They trusted a local administrative leader to operate their own regulations. Another sample forest in WDR demonstrates a more extreme case. The users of this forest have trusted the management to the family of local traditional king, whose political authority was lost more than one hundred years ago. In the field survey, we paid special attention to identify any types of indigenous management system.

Since 1987, the government of Nepal has promoted the communal management of forest resources. Since 1991, upon satisfying several conditions, the district forest offices (DFOs) officially approve the activities of well-functioning forest-user groups by registering them. One of the prerequisites for registration is that a user group elects a management committee which takes responsibility of forest-resource management. The current regulation, the Forest Act of 1993, further aims to transfer

[3]It is this spreading process that could generate the cases of community management whose purpose was not necessarily for conserving forest resource. Initiation of community management might be motivated by a desire for supports from NGO, etc.

the official use right of forests to the well-functioning registered groups.

Thus, currently, there are three major types of forest management system in Nepal. First is the management by the user groups which are registered at the DFOs. Some of these groups have already acquired official use right of forests. To the registered user groups, the DFOs must provide various supports, notably technical advices. To clearly identify the involvement of local forest officials, we hereafter refer to the registered user groups as formal user groups, and the management by them as co-management [1, Ch. 13]. Second is the management by the unregistered user groups: indigenous management. We refer to these unregistered user groups as informal user groups, and the management by them as community management. The last is the direct management by the DFOs. The forests under this mode are often left as *de facto* open access.

The main difference between the formal and informal user groups is that due to the approval and support from the DFO, management committees of the formal groups have more authority than those of the informal groups. To some extent, however, the formal user groups lose flexibility in making management decisions. This is because they have to follow the guidelines set by the DFO.[4] Table 1 shows the distribution of the three management systems over our sample forests.[5] Our sample contains many cases of co-management: 46% of the samples. This is because we implemented the stratified random sampling of forests based on the access to local market and motorable roads.

2.3 Survey design

The data set was constructed jointly by International Food Policy Research Institute (IFPRI) and Institute of Forestry (IOF) of Tribhuvan University, Nepal [25]. The authors attended the survey from its initial phase. The major part of the survey was conducted between 1997 and 2000. Some data clarifications on forest management were done in 2001.

The unit of data collection is forest defined by the 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. It also merits to be noted that the forests were sampled regardless of administrative boundaries. In the Middle Hills, it is not uncommon that a forest patch lies over two or three adminis-

[4] In addition to elect a management committee, the guidelines require the user groups to include female members in the committee, to implement pruning of forest in regular interval, etc.

[5] In Table 1, the number of forests is 102. Due to the mismatch between forest inventory and the social survey, two forests are deleted from the randomly-sampled 104 forests.

Table 1: Forest management system: 102 Forests

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Co-management (Manged by Formal User Group)			Community Management (Managed by Informal User Group)			Directly under DFOs	With Project
	Sample Forests	Number	Average Years[a)]	Max Years	Number	Average Years	Max Years	Number	Number
Middle Hills	102	46 (45.1%) [b)]	3.3 [1.6][c)]	7	26 (25.5%)	10.1 [9.7]	43	30 (29.4%)	17 (16.7%)
by Development Regions									
Eastern (EDR)	19	11 (57.9%)	4.1 [1.6]	7	2 (10.5%)	2.5 [0.7]	3	6 (31.6%)	5 (26.3%)
Central (CDR)	20	8 (40.0%)	2.4 [0.7]	4	5 (25.0%)	16.0 [16.6]	43	7 (35.0%)	4 (20.0%)
Western (WDR)	22	10 (45.5%)	3.1 [1.8]	7	7 (31.8%)	8.4 [5.0]	17	5 (22.7%)	3 (13.6%)
Mid-western (MDR)	20	8 (40.0%)	3.0 [1.5]	5	6 (30.0%)	11.7 [6.9]	21	6 (30.0%)	4 (20.0%)
Far-western (FDR)	21	9 (42.9%)	3.8 [1.8]	6	6 (28.6%)	8.0 [10.1]	28	6 (28.6%)	1 (4.8%)
by Access									
Forests in Accesible Area	52	35 (67.3%)	3.3 [1.6]	7	12 (23.1%)	10.9 [11.5]	43	5 (9.6%)	11 (21.2%)
Forests in Remote Area	50	11 (22.0%)	3.3 [1.9]	7	14 (28.0%)	9.4 [8.3]	28	25 (50.0%)	6 (12.0%)

a) Indicate the years under the management system mentioned above.
b) Numbers in parentheses are the ratio to the forests surveyed in each region (column (1)).
c) Numbers in bracket are the standard errors.

trative units such as ward or village development committee (VDC). A VDC usually consists of nine wards. A ward is usually consists of several settlements called *tol*. The size of *tol* varies: from a few households to more than 100 households. In our sample, 27 forests lie over more than one ward, and 3 forests lie over two VDCs.

Over the Middle Hills, based on the aerial photographs in 1992/96, we have randomly sampled 104 forest patches with the area more than 10 hectare. The minimum forest size of 10 hectare was necessary to apply the aerial-photo interpretation.[6] In the social survey, users of these forests were identified. In randomly sampled forests, 53 forests were chosen from the accessible area, and the other 51 were chosen from the remote area. Remoteness is defined by the distance from local markets and motorable roads. Specifically, the remote forests are at least 15 km away from district capitals, which are usually main local markets, and 10 km away from motorable all-season roads. In most cases, it is about one-day trek to reach a remote forest after leaving vehicle. The sampled forests were selected from all the districts in each development region except for the case of MDR. Due to the disturbances by the Maoist rebels, the sampled forests in MDR were concentrated in the three safer districts out of its six districts. In addition to these randomly sampled forests, we re-surveyed the nine forests in WDR that were studied by an IFPRI team in the early 1980s [17].

The stratification based on the remoteness is intended to capture external pressures on forest resources and management system. The forests along motorable roads and near local markets are more likely to be exposed to the demand for firewood and timber from the urban sector. Such external stress may facilitate the management of forests by local communities, or may impede it. Another external pressure of our interest is the intervention by the DFOs. Due to budget and human resource constraint, the DFOs have mainly assisted the management of forests accessible from the major roads [8]. The last two rows of Table 1 clearly demonstrate the effects of DFOs' intervention. In the accessible area, 67% of the sample forests is already under co-management. In contrast, in the remote area, merely 22% of the sample forests is under co-management.

For the sampled forests, we implemented aerial-photo interpretation and forest inventory. We utilized the two sets of aerial photographs.[7] The first set of photos was taken in 1978. The second set

[6]One sampled forest happened to be with the area less than 10 ha: 7.5 ha.

[7]The aerial photographs were taken at a fairly small scale of 1:42,000 or 1:50,000, but with relatively good quality with approximately 65% fore and aft overlaps and 30-40% lateral overlaps.

was taken in 1992 in EDR and CDR, and in 1996 in the other three regions. On the aerial photographs, we 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 sampled plots. In addition, the number of saplings, the impact of human activities (fire, grazing, etc) were recorded. Here the saplings are defined as the ones with DBH less than 10 cm and with the height 20 cm and above. Refer to the appendix for the details of forest inventory. The next section summarizes the results of our measurement.

3 Forest condition in the Middle Hills

3.1 Tree species

In the forest inventory, we measured 15,645 stands and identified 149 species over 113 forests.[8] Among the 149 species, 27 species (152 stands) were identified only by local tree names. We could identify neither botanical nor local names of the 13 stands, which were classified into one genus: miscellaneous. The Simpson's index of tree-species diversity, which is the probability that two randomly selected stands in the Middle Hills are of different species, is 0.857. About regeneration, we measured 22,617 saplings and identified 212 species. Among them, 3,896 are the established saplings with DBH 4 cm and above.

A detailed analysis on the tree distribution requires another paper. For the current analysis, all we need is to comprehend the two key species in the Middle Hills: *Shorea robusta* and *Pinus roxburghii*. *S. robusta* is a deciduous broadleaf species whose local name is *Sal*. It is the dominant tree species in number, accounting for 30% of all the measured stands. In terms of size, however, *P. roxburghii* is the dominant species in the Middle Hills. *P. roxburghii* is a kind of pine, which is a coniferous tree. It accounts for 18% of all the measured stands, but 27.4% of all the basal area and 37.5% of all the stem volume. Both in number and size, the sum of *S. robusta* and *P. roxburghii* accounts for about 50% of the measured stands. In the Middle Hills, *S. robusta* has been considered as the most valuable tree because it provides good timber, firewood, fodder, and leaf litter ([22, Chs. 5-7], [31, pp. 264-267]). In contrast, pine trees, including *P. roxburghii*, have not been appreciated much. Pine trees are good

[8] In the inventory, three out of the 9 resurvey forests were combined into one forest. In addition, there was one resurvey forest which was not in the aerial-photo analysis.

for timber, but their needle-like leaves are of no use for the subsistence agriculture.

Although the Middle Hills is considered as one topographic zone, it is not sensible to treat it as uniform when we work on forest condition. The wetter eastern part has different flora from the drier western part. For example, pine trees (*Pinus spp.*) are more dominant in FDR and MDR. In the following description, we therefore divide sample forests into groups corresponding to the five development regions.

3.2 Forest resource condition

Table 2 summarizes the results of forest inventory with respect to the stand condition. Total number of forests in this table is 104, and the total number of stands is 14,418.[9] An indicator of forest-resource condition is the number of big stands per hectare in the forests.[10] The criterion for big stands is set at the average tree size in the little disturbed forests in the Middle Hills analyzed by Metz [20]: the stands with DBH $\geq$ 35 cm and the height $\geq$ 13 m. There are 1,571 stands that satisfy this criterion, which account for 10.9% of all the measured trees. Twenty-two forests have no stands satisfying this criterion. Another indicator of forest-resource condition is the stem volume suitable for timber, firewood, and fodder. The latter two are the representative non-timber forest product (NTFP). As was explained above, *S. robusta* (*Sal*) is suitable for all the three uses.

The first row of Table 2 shows that the forests in EDR and FDR have significantly fewer stands per hectare than the other three regions: 259.2 and 241.7, respectively. The forests in EDR are in poor condition for all the three forest resources: timber, firewood, and fodder. The forests in FDR, however, are in the best condition in terms of the number of big stands, and second to the forests in MDR in terms of stem volume per hectare and stem volume good for timber. This reflects the fact that there are a lot of pine trees (*Pinus spp.*) in FDR and MDR. A major species suitable for timber is pine tree, which usually has large stand and is dominant in the drier MDR and FDR.

Table 3 summarizes the results on regeneration, which is the weighted counts of saplings per plot. Established saplings (4 cm $\leq$ DBH $<$ 10 cm) are, for example, given higher weight than the smaller saplings. Table 3 clearly indicates that the forests in MDR and FDR have much poorer regeneration

[9]Table 2 does not contain the 9 resurvey forests in WDR, because we did not record the number of measured plots in the resurvey forests.

[10]We do not show biomass. Sharma and Pukkala [29], who provide the tree volume equations in Nepal, caution that their biomass-prediction equations are inaccurate because these equations are based on the measurements outside of Nepal.

Table 2: Resource condition: Stands

		(1)	(2)	(3)	(4)	(5)	(6)
			by Development Region				
		Total	EDR	CDR	WDR	MDR	FDR
Number of Forests Measured		104[a)]	19	21	22	20	22
Plots Measured		3941	564	722	805	858	992
Number of Stands per hectare	Average[b)]	365.8	259.2	476.9	454.8	402.6	241.7
	Max[c)]	1101.7	511.1	1101.7	1009.5	560.2	520.8
	Min	14.3	84.8	65.0	140.0	227.8	14.3
Number of Big Stands[d)] per hectare	Average	39.9	21.5	34.3	19.9	56.1	56.6
	Max	168.0	107.1	161.7	71.1	168.0	113.4
	Min	0.0	0.0	0.0	0.0	0.0	0.0
Stem Volume (m^3 per hectare)	Average	138.6	92.9	130.7	117.5	167.5	162.6
	Max	421.1	413.0	421.1	302.7	335.8	324.8
	Min	0.4	21.6	3.2	17.8	59.1	0.4
Stem Volume Good for Timber[e)] (m^3 per hectare)	Average	109.4	35.2	110.0	60.0	153.8	152.9
	Max	348.4	155.6	348.4	203.9	223.8	309.6
	Min	0.0	0.0	0.2	0.0	0.0	0.2
Stem Volume Good for Firewood (m^3 per hectare)	Average	44.4	18.3	76.9	23.9	73.5	27.1
	Max	314.1	91.7	242.7	120.8	314.1	106.4
	Min	0.0	0.0	0.0	0.0	0.0	0.0
Stem Volume Good for Fodder (m^3 per hectare)	Average	55.3	36.8	85.9	38.0	83.2	33.4
	Max	303.5	94.9	242.2	191.2	303.5	153.2
	Min	0.0	0.0	0.0	0.0	0.0	0.2

a) The sample forests do not include the resurvey forests in WDR. See the text.
b) Calculated from all the measured plots in each development region.
c) Max and Min is about the average in each sample forest.
d) The trees with DBH ≥ 35 cm, and height ≥ 13 m.
e) Species suitable for timber, firewood, and fodder are taken from Negi [22, pp. 99-135].

than the other three regions. This is again because of the dominance of pine (*Pinus spp.*) trees in MDR and FDR. Since pine trees make drier soil cover beneath them, there is generally less regeneration under pine trees.

Table 4 summarizes the qualitative evaluations on fire incident in measured plots. Frequent fire incidences indicate more shifting-cultivation, more careless use, and less patrol in forests. This index also shows a stark difference among the five development regions. Compared to the other three regions, MDR and FDR have higher incidence of fire. The plots with seasonal fire incidences account for 11.3% of all the plots in MDR, and 19.8% of those in FDR. In contrast, the corresponding numbers in the other three regions are 2.1% and below. Again, this stark difference is mainly due to the dominance of pine trees in MDR and FDR. Since the fallen leaves of pine trees are slippery, users often intentionally put fire on these fallen leaves to avoid accidents of livestock and people.

3.3 Intertemporal changes in forest condition

Although forest inventory reveals the detailed resource condition, what it shows are static images, not intertemporal changes. By comparing the 1964-65 and the 1978 aerial photographs, Metz [19] found that there was a significant degradation in forest condition in the Middle Hills. Have the forests in the Middle Hills continuously degraded after 1978, or did they begin to recover?[11] To address this question, between the 1978 and 1992/96 aerial photographs, we compare each sample forest in its crown-cover density, maturity class of stands, and major species. Table 5 shows the intertemporal changes in resource condition in 113 forests, 104 randomly sample forests as well as the 9 resurvey forests.

Here the improved forests are, *ceteris paribus*, those with improved index in crown cover, stands' maturity, or the number of major tree species. The degraded forests are those with deterioration in such indices. There are, however, complicated cases where improved and deteriorated indices coexist. These cases are classified as "mixed". For the number of major tree species, we make one exception for *Sal* (*S. robusta*) trees. Since *Sal* has been considered as the most valuable tree in the Middle Hills, we consider that a forest is degraded when it changes from *Sal* dominant to *Sal* cum other tree species

[11]The main thesis of Metz [19] 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.

Table 3: Resource condition: Regeneration

		(1)	(2)	(3)	(4)	(5)	(6)
			by Development Region				
		Total	EDR	CDR	WDR	MDR	FDR
Number of Plots		3941	564	722	805	858	992
Weighted[a)] Sum of Saplings per Plot	Average	40.9	44.3	57.2	43.7	27.8	36.0
	Max	145.9	118.9	145.9	116.7	64.8	88.6
	Min	0.0[b)] (3.4)[c)]	13.7	0.0[b)] (20.4)[c)]	5.7	5.1	3.4

a) Weight: 1 for Established, 0.5 for Woody, 0.3 for Whippy, 0.1 for Sub-whippy.
b) This is the value of the plantation forest in a town area.
c) The value except for the plantation forest explained in b).

Table 4: Fire incidences

		(1)	(2)	(3)	(4)	(5)	(6)
			by Development Region				
		Total	EDR	CDR	WDR	MDR	FDR
Number of plots evaluated		2,538	142	372	686	567	771
Fire	None (%)	58.2	76.1	89.5	66.6	56.8	33.2
	Occasionally (%)	32.9	21.8	10.5	32.2	31.9	47.1
	Seasonally (%)	8.9	2.1	0.0	1.2	11.3	19.8

Table 5: Changes in forest condition: Aerial-photo analysis

	(1) Sample Forests	(2) Improved[a)]	(3) No Change	(4) Degraded	(5) Mixed[b)]	(6) Year of Photos	(7) Shrub
Middle Hills	113	34	50	25	4	1978	11
		(30.1%)	(44.2%)	(22.1%)	(3.5%)	1992/96	7
by Developement Regions							
EDR	19	4	7	7	1	1978	0
		(21.1%)	(36.8%)	(36.8%)	(5.3%)	1992	0
CDR	21	9	7	4	1	1978	6
		(42.9%)	(33.3%)	(19.0%)	(4.8%)	1992	1
WDR	31	5	17	8	1	1978	3
		(16.1%)	(54.8%)	(25.8%)	(3.2%)	1996	4
MDR	20	8	9	3	0	1978	0
		(40.0%)	(45.0%)	(15.0%)	(0.0%)	1996	1
FDR	22	8	10	3	1	1978	2
		(36.4%)	(45.5%)	(13.6%)	(4.5%)	1996	1
by Access							
Forests in	62	23	26	12	1	1978	9
Accessible Area		(37.1%)	(41.9%)	(19.4%)	(1.6%)	1992/96	5
Forests in	51	11	24	13	3	1978	2
Remote Area		(21.6%)	(47.1%)	(25.5%)	(5.9%)	1992/96	2

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

dominant.

With noting the possibly large errors in aerial-photo interpretation, three interesting features stand out in Table 5. First, forest-resource condition shows significant intertemporal changes. More than 55% of sample forests experienced changes in their resource condition (column (2), (4), and (5)). Second and most importantly, the trend of forest-resource degradation between 1964 and 1978 was partially reversed. Since 1978, nearly one-third of sample forests experienced improvement in their resource condition (column (2) of Table 5). Lastly, there were more cases of improvement in the accessible area than in the remote area. Those four shrub lands in 1978, which regenerated into forests in 1992/96, are all located in the accessible area (column (7)). This observation suggests that population pressure may not be the main cause of forest-resource degradation.

4 Empirical specification

The aerial-photo analysis in Table 5 suggests that 30% of sample forests experienced some improvement after 1978. Our main question is to what extent the community and the co-management systems, summarized in Table 1, contributed to this improvement. Another management factor which may affect forest-resource condition is forest-related projects. Column (9) of Table 1 shows that seventeen sample forests have or had forest-related projects. There are several types in these projects. A major type is tree planting project by local forest offices or by local and international NGOs. Another major type is technical assistance to forest user groups by international or bilateral donor agencies. In general, these projects exert more direct intervention in forest management than the co-management system. In addition to the community and co-management systems, we try to quantify the impacts of these projects on the changes in forest condition. Hereafter, the number of forests under the analyses is 102 in Table 1, all of which are randomly sampled forests.

4.1 Indices of Forest Resource Condition

We employ three indices of forest condition. The first is the intertemporal changes detected in the aerial-photo analysis in Table 5. The second is the regeneration rate in Table 3. The last is the intensity of fire incidences in Table 4.[12] Each index has advantages and disadvantages.

The advantage of the first index, the changes in forest condition detected in the aerial-photo interpretation, is that it is made from the observations in different years. This index actually measures intertemporal changes. The major disadvantage of this index is that in EDR and CDR, aerial-photographs were taken in 1992 (column (6) of Table 5). The period up to 1992 may be too short to evaluate the impacts of co-management system, which was officially introduced in 1991. Besides this disadvantage, with a fairly small scale of 1:50,000, the aerial photographs may be too rough to capture the impacts of management systems on forest condition.

The other two indices, regeneration rate and fire intensity, are made from the forest inventory. Our interpretation is that these two indices reveal the upcoming changes in forest condition, so that we can use them as proxies for intertemporal changes. Since these indices were measured at many plots in each forest, they reveal more detailed forest-resource condition than the aerial photographs. Furthermore, we can compare the results of forest-wise analyses with those of the plot-wise analyses, where forest-wise data is obtained by averaging plot-wise data over each forest. The major disadvantage of these plot-wise indicators is that, strictly speaking, they show static condition at the time of forest measurement. A disadvantage specific to the fire-incidence indicator is that it is a subjective evaluation which may be different among the enumerators.

4.2 Specification of regression equations

There are two complications in statistically evaluating the impacts of management systems on forest condition. The first complication is due to the fact that forest vegetation is a stock variable. It usually takes several years to improve forest condition. In the empirical analyses, we should note that there are little immediate impacts from the current forest-management activities to the current forest condition. The second complication is treatment effects. Simple regression analyses on the impacts of management systems are likely to suffer from self-selection bias of samples. More specifically, there is a possibility that forests with user groups would have relatively high prospect of improvement in their condition whether or not there are user groups. An example is that an unknown factor, such as a strong leadership in local government, prompts both the formation of user groups and the improve-

[12] This paper does not report the analyses on NTFP extractions. Since users groups usually make extraction rules specific to each NTFP, we used rule-based management indicator in such analyses.

ment in forest condition. If this is the case, simple regression analyses overestimate the impacts of forest-management systems on forest condition.

To deal with the first complication, as the main indices of management systems, we adopt the number of years under community and co-management systems (columns 3 and 6 of Table 1). In other words, we do not use dichotomous dummy variables as the main management indices. The benchmark specification for our empirical analyses is:

$$\begin{aligned}\text{Changes in Forest Conditions} = \beta_1 &+ \beta_2(\text{Population Pressure}) \\ &+ \beta_3(\text{Topographic Condition}) + \beta_4(\text{Vegetation Condition}) \\ &+ \beta_5(\text{Dummy for Project}) \\ &+ \beta_6(\text{Years under Community Management}) \\ &+ \beta_7(\text{Years under Co-management}).\end{aligned} \quad (1)$$

Here, β's are parameters. In this specification, what we measure is not the impact of the presence of each management system, but the impact of additional year-long management of each system. Other than management systems and forest-related projects, we control for population pressure, topographic condition, and vegetation condition.

About the impacts of the co-management system, in particular, the second complication, sample self-selection bias, can be significant. Recall that the DFOs are in charge of registering forest user groups. Many years under co-management suggests that the DFO in that area has been eager to implement the community forest program. Such DFOs are expected to implement the other forest-management activities efficiently. Moreover, the years under co-management is not so long, and is similar to a dichotomous dummy variable. The registration scheme of user groups was officially introduced in 1991. If any, the sample forests are under co-management for short years: 1.47 years on average and 3.33 years among the forests under co-management. In addition to equation (1), we thus estimate two-step specification to accommodate the possible endogeneity in co-management. The main body of the second specification simply replaces the last term of the first specification with a dummy:

$$\begin{aligned}\text{Changes in Forest Conditions } =& \beta'_1 + \beta'_2(\text{Population Pressure}) \cdots \\ &+ \beta'_7(\text{Dummy for Co-management}).\end{aligned} \tag{2}$$

The possible endogeneity in the dummy for co-management is considered in the following first-step estimation:

$$\begin{aligned}\text{Dummy for Co-management } =& \alpha_1 + \alpha_2(\text{Forest Area}) + \alpha_3(\text{Social Factors}) \\ &+ \alpha_4(\text{Access from District Forest Office}) \\ &+ \alpha_5(\text{Ratio of Sal Trees}) \\ &+ \alpha_6(\text{Forest Condition in 1978}).\end{aligned} \tag{3}$$

4.3 Determinants of forest-management system

We start the estimation with equation (3), which is on the emergence of co-management (formal user groups). We also estimate equation (3) with the dummy for community management and that for forest-related projects as its dependent variables. This is to examine the treatment effects in these management variables. Table 6 reports the estimation results.

The explanatory variables we considered are as follows. Forest area is expected to have negative impact on the formation of management systems. As social factors, we test four variables: the number of user households, the number of local administration units (ward) to which users belong, ethnic diversity of users, and the ratio of user households whose members are working outside as seasonal or permanent migrants.[13] Except for ethnic diversity of users, these variables are expected to have negative coefficients.[14] Ethnic diversity is measured by the Simpson index of diversity for castes and ethnic groups among the user households.

Access from the district forest office (DFO) to the sample forests is measured by the traveling

[13]There is a conceptual difficulty to define the number of user households in *de facto* open access forests, because in principle, everyone can have access to such forests. In the social survey on the open access forests, we investigated the number of user households who *regularly* extracted resources from those forests.

[14]For possible non-monotonic relationships between heterogeneity of users and the function of community management, refer to Varughese and Ostrom [32].

Table 6: Formation of management systems: 102 Forests

	(1)	(2)	(3)	(4)	(5)
Dependent Variable (Y)	Rank Dummy$^{a)}$	Dummy for Co-management	Dummy for Community Management		Dummy for Project
Estimator	Ordered Probit	Probit	Probit	Probit	Probit
Constant	1.378	0.317	-0.997	0.538	-3.225**
	(1.269)	(1.512)	(1.369)	(1.416)	(1.542)
Log of Forest	-0.207	-0.192	-0.013	-0.005	-0.107
Area (ha)	(0.128)	(0.152)	(0.142)	(0.144)	(0.179)
Log of Number	0.533**	0.616**	-0.191	-0.517**	0.538*
of Housholds	(0.239)	(0.292)	(0.247)	(0.251)	(0.283)
No. of Wards	-0.196*	-0.185	0.004		-0.414**
Users Belong	(0.114)	(0.135)	(0.114)		(0.168)
Ethnic	-0.067	-0.667	0.965	1.311*	0.496
Diversity	(0.645)	(0.794)	(0.732)	(0.787)	(0.884)
Ratio of Households				-2.059**	
Working Outside				(1.005)	
Log of Time to Ranger	-0.428***	-0.482***	0.226*	0.268**	0.171
Office (Min.)	(0.123)	(0.145)	(0.132)	(0.127)	(0.153)
Ratio of	1.521***	1.530***	-0.287		0.376
Sal	(0.485)	(0.557)	(0.498)		(0.555)
Immature Forest	-0.442	-0.304	-0.183	-0.320	-0.171
in 1978	(0.449)	(0.507)	(0.469)	(0.481)	(0.503)
Mature Forest	0.927***	0.940**	0.014	0.242	0.315
in 1978	(0.351)	(0.413)	(0.378)	(0.383)	(0.463)
Percent of Correctly Predicted Y	0: 76.7 1: 15.4 2: 87.0	0: 80.4 1: 78.3	0: 100.0 1: 3.8	0: 97.4 1: 11.5	0: 98.8 1: 5.9
Log-likelihood	-80.250	-45.904	-54.938	-51.736	-40.508
Pseudo R-squared	0.26	0.35	0.05	0.11	0.12

Numbers in parentheses are standard errors. Marginal effects are not reported.
*, **, and *** indicate statistically significant at 10, 5, and 1 percent level.
a) 0 = Under DFOs, 1 = Informal Management, and 2 = Formal Management. Refer to the text.

time from the nearest ranger office. We expect negative and substantial coefficients on this variable based on the observations in the last two rows of Table 1. We include the ratio of *Sal* (*S. robusta*) stands in sample forests because *Sal* is the most appreciated tree in the Middle Hills. We control for the initial condition of forests by the two dummy variables indicating the average tree size detected in the aerial photographs in 1978. The baseline for these dummy variables is the shrub and grass land in 1978. Other variables such as the index for social capital and the squared value of number of user households are not statistically significant in any estimates, and are dropped.

Column (1) of Table 6 shows the ordered probit analysis with dependent variable 0 for the forests under the direct control of the DFOs, 1 for those under community management, and 2 for those under co-management. We adopt this ranking because an application by existing informal user group is required to register it as a formal user group. Column (2) shows the probit estimate with the dummy dependent variable for co-management. Column (1) and (2) show similar results. Time to ranger office has negative coefficients, which are statistically significant at the 1% level. We reconfirm that the DFOs assisted the user groups which were easily accessible from their offices. Higher ratio of *Sal* trees and relatively good initial condition of forests induced the initiation of co-management systems. These results imply that users registered a group mainly for protecting the rich forest resources. An unexpected result is positive and statistically significant coefficients on the number of user households. The large number of users did not hinder collective actions. A possible explanation is that the DFOs might have mainly assisted the relatively big user groups.

Columns (3) and (4) of Table 6 show the probit estimates for the community management. Among the various specifications, column (4) shows the best result in terms of the goodness of fit, which is measured by the percent of correctly predicted dependent variable. Since the goodness of fit is so low, we can conclude that regardless of exogenous conditions informal user groups emerged and survived. This finding is consistent with the variety of forms and history of indigenous management systems, which we discussed in Section 2. Column (5) shows the probit estimate for forest-related projects. Due to the small number of forests with projects (17 forests), the regression has little predictive power. We can consider that the external projects have been randomly assigned to forests. Based on these estimates, we do not consider the treatment effects in community management and forest-related projects.

5 Results

5.1 Effects on changes detected in the aerial-photo analysis

Table 7 reports the estimation results of equation (1) and (2), where the dependent variable is the changes in forest condition detected by aerial-photo interpretation (Table 5). Since three sample forests have mixed indices of intertemporal changes, the number of observations is 99.[15]

Population pressure consists of three variables: the number of households per forest area, the annual increase in the number of households between 1980 and 1998/1999, and the average traveling time to forests from the settlements (*tol*) where users live. The annual increase in the number of households is a proxy for population growth rate. In the social survey, we used the first referendum in Nepal in 1980 as the recall point for the number of households in the past. Topographic condition consists of the log of the lowest altitude of forest and average slope. Two dummy variables, which indicate the average tree sizes in the 1978 aerial photographs, are included to control for both vegetation characteristics and initial forest condition.

Column (1) of Table 7 reports the estimates of equation (1). Since the dependent variable is a rank dummy (Table 5), we adopt ordered probit model. Columns (2) to (4) report the marginal effect evaluated in each rank probability. We are primarily concerned with the three management variables, dummy for projects, years under community management, and years under co-management. The null hypotheses on these management variables are that they did not contribute to the improvement in forest condition. Therefore, as well as conventional two-sided test, we implement one-sided test for the statistical significance of their estimated coefficients. Among the management variables, only dummy for projects has a statistically significant estimate: at the 5% level in one-sided test, and the 10% level in two-sided test. The marginal effects imply that forest-related projects reduced the number of forests which experienced either deterioration or no significant changes between 1978 and 1992/96. Among the other explanatory variables, the number of user households per forest area, steeper slope in forest area, and the dummy for immature forests in 1978 work against the improvement in forest condition.

Column (5) shows the two-step ordered probit estimate of equation (2), where the predicted value

[15] Among the four forests with mixed indices in Table 5, one is a resurvey forest in WDR.

Table 7: Determinants of forest-Condition changes in aerial photos: 99 forests

	(1)	(2)	(3)	(4)	(5)
Dependent Variable (Y)	Rank Dummy: 0 = Deteriorated, 1 = No Significant Changes, 2 = Improved				
Specification	Equation (1)				Eqn. (2)
Estimator	Ordered Probit				Two-Step Ordered Pro.
		Marginal Effect in			
	Coefficient	Y = 0	Y = 1	Y = 2	Coeff.[a)]
Constant	1.571				1.873
	(2.330)				(2.549)
Households per Forest	-0.041**	0.011**	0.002	-0.013	-0.040**
Area (per ha)	(0.018)	(0.005)	(0.003)	(0.021)	(0.019)
Growth Rate of	0.739	-0.199	-0.038	0.237	0.840
Housholds	(0.712)	(0.192)	(0.065)	(0.492)	(0.741)
Log of Time to	0.215	-0.058	-0.011	0.069	0.191
Forest (minutes)	(0.191)	(0.052)	(0.018)	(0.133)	(0.206)
Log of Lowest	0.142	-0.038	-0.007	0.046	0.113
Altitude (meter)	(0.324)	(0.087)	(0.02)	(0.17)	(0.338)
Average Slope	-0.046**	0.012**	0.002	-0.015	-0.046**
	(0.019)	(0.005)	(0.003)	(0.023)	(0.020)
Dummy for Immature	-1.563***	0.236***	0.328***	-0.564	-1.545***
Forest in 1978	(0.434)	(0.039)	(0.049)	(0.725)	(0.489)
Dummy for Mature	-0.326	0.096***	0.002	-0.097	-0.302
Forest in 1978	(0.332)	(0.028)	(0.023)	(0.774)	(0.341)
Management Variables					
Dummy for	0.619*++	-0.136**++	-0.085***+++	0.220	0.618*++
Project	(0.344)	(0.067)	(0.014)	(0.695)	(0.355)
Years under Community	0.011	-0.003	-0.001	0.003	0.012
Management	(0.016)	(0.004)	(0.001)	(0.008)	(0.017)
Years under Co-	-0.016	0.004	0.001	-0.005	
management	(0.073)	(0.02)	(0.004)	(0.023)	
Dummy for Co-					-0.270
management[b)]					(0.720)
Threshold	1.544***				1.547***
Parameter[c)]	(0.187)				(0.188)
Percent of	0: 30.4				0: 21.7
Correctly	1: 85.4				1: 85.4
Predicted Y	2: 42.9				2: 39.3
Log-likelihood	-90.222				-90.176
Pseudo R-squared	0.13				0.13

Numbers in parentheses are standard errors.
*, **, and *** indicate statistically significant at 10, 5, and 1 percent level (two-sided test).
+, ++, and +++ indicate statistically significant at 10, 5, and 1 percent level (one-sided test).
a) The asymptotic covariance matrix is corrected with the method of Murphy and Topel [21].
b) For the estimation in column (5), the predicted value from equation (3) is inserted.
c) Threshold between 1 and 2 in the dependent variable.

of equation (3), column (2) of Table 6, is inserted for the dummy for co-management. The coefficient on dummy for project maintains its statistical significance at the 5% level in one-sided test. We can conclude that only the forest-related projects had positive impacts on the changes in forest condition, which was sizeable enough to be identified by aerial photographs. These sizeable impacts of the projects were likely to be the results of tree planting activities.

5.2 Regeneration rate

Table 8 reports the regression results on the regeneration rate weighted by the size of saplings (Table 3). Many of the independent variables are the same as that of Table 7. There are, however, three differences. First, we drop three independent variables in Table 7: the annual increase in the number of households and the two dummy variables for the average tree size in 1978. Regeneration rate is considered to indicate the upcoming path of forest-condition changes expected at the time of forest measurement. We thus drop the independent variables which show the past trend of population growth and the forest condition in 1978. Second, to topographic variables, we add the ratio of sample plots in the forest inventory facing the north. This is to consider the effects of sunshine on regeneration. Lastly, as vegetation variables, we include the log of basal area and the ratio of pine trees in the forests. Regeneration can be affected both by the density and the species of current vegetation. Recall that there is usually less regeneration in the floor of pine trees.

Column (1) of Table 8 shows the OLS estimates of equation (1). Among the three management variables, years under co-management has statistically significant coefficient at the 5% level in appropriate one-sided test, while at the 10% level in two-sided test. Column (2) reports the OLS estimate of equation (2), while column (3) shows the IV estimate that accommodates the treatment effects in the dummy for co-management. The instrument is the predicted value of equation (3). In either estimate, dummy for co-management has statistically significant coefficient at the 1% level both in one-sided and two-sided test.

In all the estimates, the higher ratio of pine trees in forests reduced regeneration. This indicates the importance to control for vegetation in empirical studies on forest-resource management systems. An interesting observation is that columns (2) and (3) of Table 8 suggest that the forests with many north-facing plots had higher regeneration.

Table 8: Determinants of forest-wise regeneration rate: 102 Forests

	(1)	(2)	(3)
Dependent Variable (Y)	Regeneration Rate Weighted by Size of Saplings		
Specification	Equation (1)	Eqn. (2)	
Estimator[a)]	OLS	OLS	IV
Constant	4.152**	2.714	1.541
	(2.027)	(2.009)	(2.122)
Households per Forest Area (per ha)	0.041*	0.037	0.032
	(0.024)	(0.023)	(0.023)
Log of Time to Forest (minutes)	0.158	0.218	0.290*
	(0.169)	(0.163)	(0.167)
Log of Lowest Altitude (meter)	-0.350	-0.224	-0.136
	(0.271)	(0.263)	(0.262)
Average Slope	-1.533	-1.231	-0.979
	(1.304)	(1.255)	(1.228)
Ratio of Plots Facing the North	0.518	0.616*	0.732**
	(0.345)	(0.332)	(0.332)
Log of Basal Area in Forest (/ha)	-0.097	-0.093	-0.107
	(0.146)	(0.140)	(0.136)
Ratio of Pine Trees	-0.787**	-0.759**	-0.732**
	(0.340)	(0.327)	(0.316)
Management Variables			
Dummy for Project	0.228	0.202	0.099
	(0.322)	(0.304)	(0.304)
Years under Community Management	0.015	0.012	0.012
	(0.013)	(0.013)	(0.012)
Years under Co-management	0.112*++		
	(0.060)		
Dummy for Co-management		0.791***+++	1.276***+++
		(0.232)	(0.418)
Adjusted R-squared[b)]	0.11	0.18	0.14
Correlation between Predicted and Observed Y	0.35	0.43	0.42

*, **, and *** indicate statistically significant at 10, 5, and 1 percent level (two-sided test).
+, ++, and +++ indicate statistically significant at 10, 5, and 1 percent level (one-sided test).
a) All the estimaters are weighted by the number of measured plots in each forest.
b) In weighted regressions, R^2 is not necessarily a valid measure. We thus report correlation between predicted and observed Y.

We can examine the robustness of these forest-wise estimates by plot-wise regressions, whose results are collected in Table 9. In our data set, we can utilize the regeneration measurement in 3,777 plots over 101 forests. One sample forest in Table 8 is dropped from all the plot-wise analyses due to the missing information of the aspect of each plot. Column (1) of Table 9 shows the pooled regression of equation (1) with plot-wise data. Although many coefficients are statistically significant, the OLS may not be an appropriate estimator because plots in a forest are likely to share some kind of characteristics.

To deal with this forest-wise effect in plot-wise data, we adopt two methods. The first method is to correct the covariance matrix of the OLS estimates by clustering the sample plots by forests. The corrected result is shown in column (2), where the statistical significance of many coefficients are lost. The positive impact of years under co-management is, however, still significant at the 5% level in one-sided test. The second method is to apply a random-effect model based on an analogy between plural plots in a forest and panel data. Its result is shown in column (3). Huge value of the Lagrange-multiplier test static indicates that panel specification is preferred to the OLS (pooled regression). Even in the random-effect specification, the positive impact of years under co-management keeps its statistical significance at the 5% level in one-sided test. Coupled with the results of forest-wise analyses (column (1) of Table 8), we can conclude that an additional year under co-management improved regeneration rate.

Columns (4) to (6) of Table 9 show the estimation results of equation (2) with plot-wise regeneration data. The estimators in column (4) and (5) do not consider the treatment effects in the dummy for co-management, whereas the estimator in column (6) accommodates the treatment effects by the instrumental variable (IV) method for panel specification [2]. The instrument is the predicted value of equation (3). From column (4) to (6), dummy for co-management has statistically significant coefficients both in one-sided and two-sided test. The correction of treatment effects raises the impact of co-management dummy on regeneration rate: 0.736 in column (5) to 1.375 in column (6). These results are consistent with the ones in Table 8. Combined with the forest-wise analyses, we can conclude that the existence of the registered user groups (co-management) contributed to improve tree regeneration in forests.

Other than the impact of co-management systems, the results of plot-wise analyses in Table 9

Table 9: Determinants of plot-wise regeneration: 3,777 plots in 101 forests

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (Y)	Regeneration Rate Weighted by Size of Saplings					
Specification	Equation (1)			Equation (2)		
Estimator	OLS	OLS Clustering[a)]	Random Effect (R.E.)	OLS Clust.	R.E.	IV of R.E.
Constant	3.525^{***}	3.525^{*}	5.166^{***}	2.294	3.920^{**}	2.370
	(0.501)	(2.032)	(1.894)	(1.834)	(1.875)	(2.044)
Households per Forest Area (per ha)	0.044^{***}	0.044	0.015	0.039	0.013	0.008
	(0.006)	(0.032)	(0.016)	(0.029)	(0.016)	(0.016)
Log of Time to Forest (minutes)	0.215^{***}	0.215	0.141	0.284^{**}	0.239	0.380^{**}
	(0.044)	(0.142)	(0.163)	(0.129)	(0.160)	(0.176)
Log of Lowest Altitude (meter)	-0.354^{***}	-0.354	-0.528^{**}	-0.239	-0.423	-0.306
	(0.070)	(0.300)	(0.265)	(0.274)	(0.258)	(0.265)
Slope	-0.666^{***}	-0.666	-0.345^{**}	-0.584	-0.346^{**}	-0.343^{**}
	(0.181)	(0.423)	(0.171)	(0.408)	(0.171)	(0.172)
Dummy for Plots Facing the North	0.331^{***}	0.331^{**}	0.170^{***}	0.357^{**}	0.171^{***}	0.174^{***}
	(0.059)	(0.144)	(0.062)	(0.140)	(0.062)	(0.062)
Log of Basal Area in Plot	-0.194^{***}	-0.194	-0.360^{***}	-0.197	-0.359^{***}	-0.359^{***}
	(0.050)	(0.129)	(0.055)	(0.138)	(0.055)	(0.055)
Ratio of Pine Trees	-0.833^{***}	-0.833^{***}	-0.785^{***}	-0.813^{***}	-0.784^{***}	-0.782^{***}
	(0.069)	(0.166)	(0.087)	(0.160)	(0.087)	(0.087)
Management Variables						
Dummy for Project	0.267^{***}_{+++}	0.267	0.338	0.221	0.312	0.246
	(0.085)	(0.337)	(0.287)	(0.313)	(0.276)	(0.279)
Years under Community Management	0.015^{***}_{+++}	0.015	0.012	0.014	0.013	0.017
	(0.004)	(0.012)	(0.014)	(0.012)	(0.014)	(0.014)
Years under Co-management	0.102^{***}_{+++}	0.102^{*}_{++}	0.092^{*}_{++}			
	(0.016)	(0.056)	(0.056)			
Dummy for Co-management				0.752^{***}_{+++}	0.736^{***}_{+++}	1.375^{***}_{+++}
				(0.231)	(0.219)	(0.397)
F-test	38.610	38.610		49.650		19.620
σ_e [b)]			1.909		1.909	
σ_u [c)]			0.992		0.916	
Lagrange-multiplier Test[d)]			5665.8^{***}		5118.0^{***}	

*, **, and *** indicate statistically significant at 10, 5, and 1 percent level (two-sided test).
+, ++, and +++ indicate statistically significant at 10, 5, and 1 percent level (one-sided test).
a) Covariance matrix of OLS is corrected by plot clustering by forest.
b) σ_e is the estimated variance of plot-wise heterogeneity.
c) σ_u is the estimated variance of forest-specific heterogeneity.
d) Breusch and Pagan's LM test statistics with the null hypothesis $\sigma_u^2 = 0$.

generally support the results of forest-wise analyses in Table 8. An example is that north-facing plots attained higher regeneration rate. This may seem to be odd at first glance. An explanation is that less human activities in north-facing plots improved tree regeneration there. In the Middle Hills, forest users often avoid north-facing plots where leech thrives in the wet condition.

5.3 Fire Index

Table 10 summarizes the results of plot-wise analyses on fire index. The forest-wise analyses obtain qualitatively similar results to these plot-wise analyses, and are not reported. Since two sample forests have no record of fire-index observations, our sample now is 2,443 plots over 99 forests. The dependent variable is constructed as its higher value indicates the less incidences of forest fire.

The independent variables are the same as those in the plot-wise analyses on regeneration rate. Here, we need to discuss the dependent variable and the estimators. Fire index was recorded as a rank variable at the plot level (Table 4). We apply linear regression to this rank variable, which means that we consider a mere ranking as a meaningful continuous variable. An obvious choice is ordered probit or logit model. In discrete choice models, however, the likelihood function of random-effect specification includes the product of the densities for each group. In our data set, each forest contains many measured plots. For example, a sample forest has 86 plots, which requires 86 multiplications of probabilities in the likelihood function. Consequently, the estimates of ordered-probit random effect models are unstable. Thus, with noting its problems, we applied the OLS for the plot-wise rank variables.

Columns (1) to (3) of Table 10 show the estimates of equation (1). Dummy for project and years under co-management have statistically significant positive coefficients in columns (1) and (2). Their significance, however, vanish in the random-effect specification in column (3). In contrast, even in the random-effect specification, years under community management keeps its statistical significance to reduce the incidences of forest fire.

Columns (4) to (6) of Table 10 show the OLS and IV estimate of equation (2). In the IV estimation, we use the predicted value of equation (3) as the instrument. In the IV estimation of the random-effect specification, the statistical significance of both dummy for project and that for co-management disappear (column (6)). In contrast, years under community management has positive coefficient

Table 10: Determinants of Plot-wise fire index: 2,443 plots in 99 Forests

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (Y)	Fire Index Between 0 (Seasonally) to 2 (No Fire)					
	Equation (1)			Equation (2)		
Estimator[a)]	OLS	OLS Clustering	Random Effect (R.E.)	OLS Clust.	R.E.	IV of R.E.
Constant	0.949***	0.949	1.438	0.445	1.209	1.163
	(0.218)	(1.194)	(0.910)	(1.12)	(0.917)	(1.037)
Households per Forest Area (per ha)	0.022***	0.022***	0.010	0.019***	0.010	0.010
	(0.002)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
Log of Time to Forest (minutes)	-0.051**	-0.051	0.004	-0.019	0.021	0.025
	(0.020)	(0.084)	(0.077)	(0.082)	(0.077)	(0.086)
Log of Lowest Altitude (meter)	0.070**	0.070	0.001	0.115	0.021	0.025
	(0.029)	(0.161)	(0.126)	(0.150)	(0.125)	(0.132)
Slope	0.052	0.052	0.019	0.107	0.019	0.019
	(0.078)	(0171)	(0.054)	(0.163)	(0.054)	(0.054)
Dummy for Plots Facing the North	0.169***	0.169*	0.029	0.185**	0.030	0.030
	(0.025)	(0.090)	(0.019)	(0.089)	(0.019)	(0.019)
Log of Basal Area in Plot	0.083***	0.083	-0.007	0.080	-0.007	-0.007
	(0.021)	(0.064)	(0.017)	(0.063)	(0.017)	(0.017)
Ratio of Pine Trees	-0.483***	-0.483***	-0.199***	-0.465***	-0.199***	-0.199***
	(0.027)	(0.110)	(0.025)	(0.107)	(0.025)	(0.025)
Management Variables						
Dummy for Project	0.246***+++	0.246**++	0.166	0.248**++	0.165	0.163
	(0.039)	(0.121)	(0.139)	(0.107)	(0.136)	(0.138)
Years under Community Management	0.010***+++	0.010+	0.013*++	0.010	0.013**++	0.013**++
	(0.001)	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)
Years under Co-Management	0.037***+++	0.037+	0.024			
	(0.007)	(0.028)	(0.028)			
Dummy for Co-management				0.274***+++	0.150+	0.166
				(0.122)	(0.107)	(0.201)
F-test	82.14***	82.14***		90.65***		
σ_e [b)]			0.116		0.116	
σ_u [c)]			0.211		0.203	
Lagrange-multiplier Test[d)]			19065.8***		17933.6***	

*, **, and *** indicate statistically significant at 10, 5, and 1 percent level (two-sided test).
+, ++, and +++ indicate statistically significant at 10, 5, and 1 percent level (one-sided test).
a) All the estimaters are weighted by the number of measured plots in each forest.
b), c), d) Refer to the notes in Table 9.

which is statistically significant both in one-sided and two-sided test. Overall, what we can conclude about forest fire is that informal user groups (community management) contributed to reduce it.

Other than the management variables, the ratio of pine trees has negative and statistically significant coefficients in all the estimates. This is because the users sometimes intentionally put fire on pine forests due to the reason we discussed in Section 3.2.

6 Conclusion

With more than 100 randomly sampled forests, the paper examined the effects of community management (by informal user groups) and co-management (by formal user groups) on forest-resource condition in the Middle Hills of Nepal. The results can be summarized as follows. First, since 1978, the degradation trend of forest condition in the Middle Hills has been partially reversed. According to the aerial-photo analyses, nearly one-third of the sampled forests experienced some improvement in their resource condition. Second, forest-related projects had sizeable positive impacts on forest condition that could be identified in the aerial photographs. Third, the co-management system contributed to improve tree regeneration. Lastly, community management systems reduced the incidences of forest fire.

The third finding about regeneration indicates that official support for community management (that is, co-management) will improve the forest condition in the long run. Our field observations suggest that registration of a user group often enhances the authority of its management committee. With enhanced authority, the formal user groups sometimes close all or part of the forest for several years. This closing of forests is likely to have resulted in improved regeneration. The interventions by official agencies, mainly in the form of technical assistance and authorization, enhanced the functions of voluntary communal management. Our analyses, however, also suggest that co-management is not necessarily a prerequisite for the effective regulations on shifting cultivation and careless fire in the forests. For suppressing such bold activities in forests, unofficial agreement among the users seems to be sufficient.

Four field observations are worth noting. First, community management of a forest tended to influence the management of nearby forests. Initiation of community management implies severer restrictions to the use of a forest by the outsiders. Those who are under stricter restrictions or are excluded from the use of some forest tend to initiate the protection of their own forest. Second, we observed several cases of voluntary division of community forest. The divisions were by ethnic groups or by settlements (*tol*). It may be a path to the privatization of forest area. Third, we observed the cases that forest-resource condition altered the life style of users. In a sample forest in CDR, for example, users abandoned the tradition of making local cheese (Khuwa), which resulted in the less consumption of firewood. Lastly, an unfortunate field observation, which we could not quantify, was the effects of the Maoist rebels. We observed several cases that people gave up forest-resource extraction to avoid the Maoist rebels.

One of the innovations in this study is to propose and implement a practical method for evaluating the resource condition of natural forests. It is a combination of aerial-photo interpretation and forest inventory. Ideally, by utilizing the global positioning system (GPS), we should fix the positions of inventory plots. By doing that, we can measure the same plots every, for example, ten years. This is a task of our future research.

Appendix: Method of forest inventory

Sampling of inventory plots

Usually sampling intensity for forest inventory is determined based on the variance of the variable of interest: for example, timber stock per hectare in plantation area. Here we encountered two difficulties. First, our purpose was to evaluate the condition of natural forests, from where people extracted multiple resources: timber, firewood, leaf litter, fodder, place for grazing, medical plants, etc. Thus we were interested in several variables such as timber volume, crown cover, and diversity in tree species. For the forests in the Middle Hills of Nepal, there was no published data describing the variances of such multiple variables. Second, our budget did not allow us to measure small preliminary samples in each forest to determine the variances of these variables.

To circumvent these difficulties, we made simplifying assumptions. First, we set up a conceptual variable of our interest: *forest-resource condition*. This variable was assumed to capture the potential of a forest in producing the multiple resources that users extracted. Second, we assumed that the forest-resource condition could take only two values: good or bad. We made this assumption because there was no widely-accepted composite index for summarizing the condition of multiple forest resources. Third, we assumed that a forest consisted of units, each of which bore either good or bad forest-resource condition. We adopted one hectare of squared area as the unit. For example, a forest with the area of 100 hectare consisted of 100 units, which was the population for the sampling of our inventory.

Fourth and the most drastic assumption was that by measuring one percent of the unit, we could make satisfactory precise inference about its forest-resource condition. That is, to evaluate the forest-resource condition of a unit, we measured a sample plot with the area of 100 square meters. Lastly, we applied the following common formula to determine the sample size.

$$n = \left[\frac{N}{\left(\frac{e}{1.96}\right)^2 * \frac{N-1}{0.25} + 1} \right] + 1,$$

where n is the number of sample plots, N is the forest area in hectare, [ ] is the Gauss sign which indicates the largest integer not exceeding the numbers in it. In this formula, we set the population ratio of good forest-resource condition at 50%, which made the possible variance largest. Due to the budget constraint, we set the target precision e at 10%. Examples of sample size are shown in the table below.

Table 11: Number of sample plots under $e = 0.10$

Forest Area in hectare (N)	10	25	100	220	380	440
Number of plots (n)	10	21	50	68	77	79

Admittedly, our measurement intensity, one % and below of the total forest area, is low. We, however, should note that our measurement intensities are, in general, higher than those adopted by the previous forest inventories in Nepal.[16] In each forest, based on field observations, the forest area was stratified by tree species and stand size. The cruising lines were set in each stratum crossing various topographical conditions. Sampled plots were set on specified intervals on these lines.

[16] See, for example, [10], which reports the official forest inventory in a district in Nepal. Their measurement intensity was about 0.4% of accessible forests (defined by the slope), and 0.1% of the total forest area.

Measurement method

In the sampled plots, we recorded the species, diameter at breast height (DBH: about 1.37 m from the ground) and height of all the stands with DBH 10 cm and above. DBH was measured for all the stands. In a plot, we measured the height of at least two to three stands. The heights of the other stands were estimated based on these measured trees. At the center of each sample plot, we set a nested plot of 4 square meters. In it, we counted the number of saplings and seedlings with DBH less than 10 cm and the height 20 cm and above. Based on the size and age, these saplings and seedlings were categorized as established (4 cm ≤ DBH < 10 cm), woody (height ≥ 1 m or 1 cm ≤ DBH < 4 cm), whippy (less than 1 m height), and sub-whippy (less than 30 cm height). We refer to [23, 30, 31] to find out the botanical names of measured stands.

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