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Abstract

Does community management improve the conditions of local natural resources? With 104 randomly sampled forests in the Middle Hills of Nepal, we address this question. Forest conditions were evaluated by aerial-photo analysis and forest inventory. We find that co-management systems, which are the forest users groups registered at the local forest offices, contributed to increase tree regeneration. In the case of Nepal, the official support from the forest offices enhanced the functions of community management. However, community management systems without any external support are not ineffective. Our analysis suggests that they reduced the incidents of forest fire and grazing activity.

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

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, participatory approach was in fashion.[1] In forest policies, community management was promoted by many governments and international donor agencies (e.g. FAO 1989). The fad has passed. Several studies have pointed out the problems in community-forest management systems (e.g., Brett 2003, Campbell et al. 2001, Graner 1997). The World Bank became cautious about too much emphasis on the role of local-level organizations (World Bank 2004. p. A-6). Without promising alternatives, however, much funds and human resources are still being devoted to community-forest projects.

Along with the participatory practices, there appeared flourishing literature on community management of local natural resources; Bardhan (2000), Ostrom (2000), Paul (2005), Sethi and Somanathan (1996), White and Runge (1994), to name a few. The cases of voluntary cooperation (or "NO" *tragedy of commons*) stimulated the curiosity of social scientists. 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 on resource conditions. One should note that emergence and survival of community management do not necessarily conserve the local natural resources. For example, formation of a community management system may be for symbolizing the community identity, not for resource management (Baland and Platteau 1996, pp. 191-192). For the resource conditions of natural forests, in particular, there are few empirical studies on the impacts of community management systems. Considering the fund and human resources allocated to the community-forest projects, 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 many types of forests on varied geographical conditions. The users of these forests are heterogeneous both in ethnic composition and in social characteristics. Above all, the most notable information in the Middle Hills' data is the variation in forest management system. Our data contains the cases of both community management and co-management of local forests. The latter is the community-management

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[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.

groups registered at the local forest offices. These registered users groups obtain official title of forest use right and can receive various support from the forest offices. With the growing importance of co-management systems in local natural resource management, a comparison between community and co-management systems is of special interest (Baland and Platteau 1996, Ch. 13, Ligon and Narain 1999).

Besides the comparison between community and co-management systems, our work is different from the extant studies in three aspects. First, our data set is not confined to a specific area or project. It contains 104 randomly-sampled forests throughout the Middle Hills (Fig. 1). Our extensive survey will provide a reference point for detailed area-specific analyses such as Gautam et al. (2003), Jackson et al. (1998), and Schweik (2000). Second, we measured the resource conditions of all the sampled forests. It is difficult to measure the resource conditions of natural forests. This is the main reason why few studies have statistically evaluated the impacts of management systems on forest conditions. The exceptional pioneering studies use the subjective indices of overall forest conditions judged by foresters: e.g., Heltberg (2001) and Varughese and Ostrom (2001). One of the contributions of this paper is to propose a practical procedure to measure the conditions of natural forests. It is a combination of two methods: aerial-photo analysis and forest inventory.

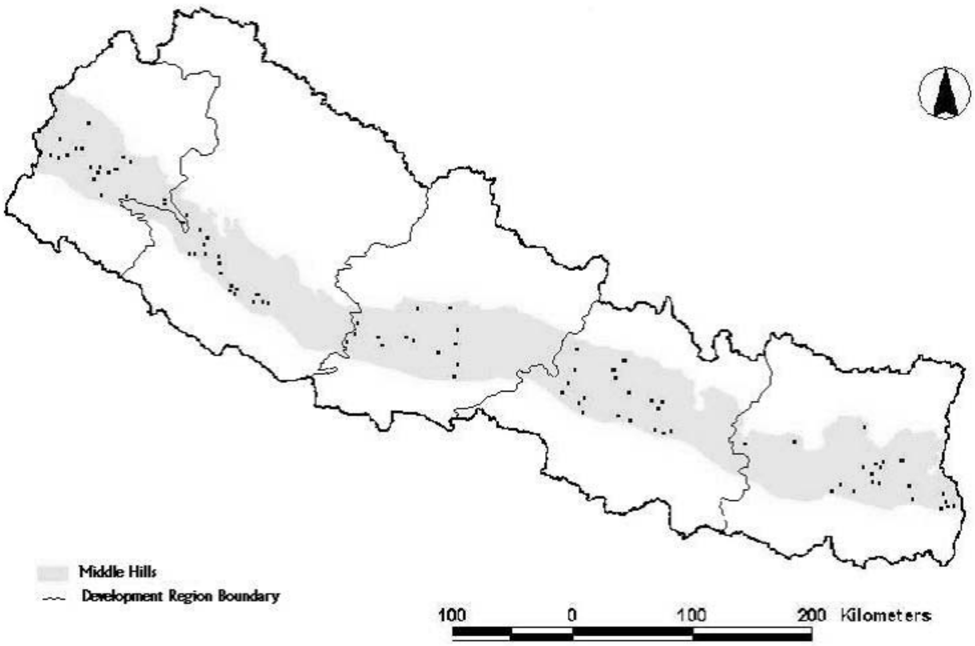
This paper proceeds as follows. Section 2 provides a description of study area and our data set. Section 3 summarizes our findings on the forest conditions in the Middle Hills. In Section 4, we discuss empirical specifications to evaluate the impact of management systems on the changes in forest conditions. 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-shaped country. 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

Figure 1: The Middle Hills and the Samples



(Source) Prepared by the authors

wetter and cooler than the western part. The most notable geography of Nepal is her drastic altitudinal variation roughly within the 150 km band from southern Terai plain, lying as low as 60 to 300 meters altitude, to northern Himalayan mountains. The wide variation in altitude and precipitation bring Nepal extensive range of flora from tropical deciduous forest to tundra vegetation.

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 stands, the Middle Hills has rugged geography filled with continuous hills. It contains river valleys as low elevation as 300 meter, and the areas along ridges as high elevation as 3,000 meter. The Middle Hills had been 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 (CBS 1998, Ch.22).[2] Even with significant out-migration, more than 40% of 22 million population of Nepal 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. Later we will examine the impacts of out-migration and heterogeneous ethnic population on forest resource management.

Due to its rugged geographical conditions, 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. Man power, that is porters, has been the main means of transportation. 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 (CBS 1996, pp. 38-39).

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

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

of forests.

2.2 History of Forest Management Systems

From 1846 to 1950, Nepal was under the feudal regime governed by the *Rana* family. In this period, the local officials appointed by the Rana government controlled timber harvesting. The forest products other than timber were usually left open access (ICIMOD 1999). In 1950, the Rana regime was overthrown. 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 Forest Department. Some researchers considered the nationalization as the main cause of deforestation by arguing that it destroyed traditional forest management systems. Gilmour and Fisher (1991, p.12) cast doubt on this view. They argue that with insufficient number of forest officers and limited means of transportation, the nationalization policy was ineffective in many parts of the country. According to our field interviews with elderly forest users, 36 out of 104 randomly-sampled forests experienced massive tree cutting at the time of nationalization. Twenty-five out of these 36 forests are located near market towns or along motorable roads.

Political upheavals and the accelerated population growth through the improved medical conditions gradually intensified the population pressure on forest resources. Responding to forest-resource shortages, there emerged community management systems of forest resources. That is, some indigenous groups spontaneously began to manage the forests they utilized, on which the government had legal ownership (Gilmour and Fisher 1991, Ch.1). Partly due to the increasing number of forestry projects supported by international donor agencies, the indigenous management system has spread over the Middle Hills (Negi 1994, Ch.4).

One important note here is that there are a variety of indigenous community-management systems of forests. Some are based on 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 a sample forest in MDR, the due per household is 2 *pathi* (= 4 kg) of grain per year. In many cases of *mana pathi* system, villagers do not form a users group. A sample forest in CDR shows an example other than *mana pathi* system. 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 subsidies from the outside. 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 users 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 trusted the regulation and the management of the forest to the family of local traditional king, whose political authority was lost more than a hundred years ago. There are also the cases where forest-related projects induced the formation of community management system. In a sample forest in WDR, an Australian project prompted the villagers to initiate forest management. In this case, the local members of the Australian project took responsibility of forest management.

Since 1987, the government of Nepal has officially 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-users groups by registering them. One of the conditions for registration is that a users group elects a forest-management committee which takes responsibility of forest-resource management. The current regulation, Forest Act of 1993, further aims to transfer the official use right of forests to the well-functioning users groups.

Thus, currently, there are three major types of forest management systems in the Middle Hills of Nepal. First is the management by the forest-users groups which are already registered at the DFOs or have acquired official use right from the DFOs. This mode corresponds to the co-management system (Baland and Platteau1996, Ch. 13). Second is the management by unregistered users groups. This mode corresponds to the community management system in the theoretical literature. The last is the direct management by the DFOs. The forests under this mode are often left as *de facto* open access.

To clearly distinguish co-management from community management, we refer to the registered groups as formal forest-users groups and the registered ones as informal forest-users groups. The main difference between the formal and informal forest-users groups is that due to the approval and support from the DFOs, the management committees of formal groups have more authority than those of informal groups. To some extent, however, the formal groups lose flexibility in making management rules and organizations. This is because they have to follow the guidelines set by the DFOs. The actual impacts of these management systems on forest conditions are of our main interest. Table 1 shows the distribution of management systems over our sample forests. In this table, the number of forests is 102.

Table 1: Forest Management System: 102 Forests

	(1) Sample Forests	(2) Managed by Formal Users Group Number	(3) Average Years[a)]	(4) Max Years	(5) Managed by Informal Users Group Number	(6) Average Years	(7) Max Years	(8) Directly under DFOs Number	(9) With Project 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.

Due to the mismatch between forest inventory and the social survey, two forests are deleted from the randomly-sampled 104 forests. Our sample contains many formal users groups, 46% of the samples. This is because we implemented the stratified sampling based on the access to forests.

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. The IFPRI-IOF survey was designed to investigate management activities of forest users (Otsuka and Place 2001). The authors attended the research project 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 patch is considered as two separate 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 administrative units such as ward or village development committee (VDC). Ward is the smallest administrative unit in Nepal. A VDC 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 the two VDCs.

Over the Middle Hills, based on the aerial photos 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 analyses.[3] In the social survey, users of these forests were identified. As was discussed above, if two or more users groups separately used a forest patch, we randomly chose one group and the forest area that group utilized. 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 (Kumar and Hotchkiss 1988). 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

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

to reach a remote forest after leaving vehicle. The sampled forests are 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 are concentrated in the three safer districts out of its six districts.

The stratification based on the remoteness is intended to capture both external pressures on forest resources and external intervention in forest-resource 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 spontaneous management of forests by local communities, or may impede it. In accessible areas, for example, people have more opportunities to move out of the community than in remote areas. Then people in accessible areas may have less incentive to keep the community agreement. 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 (Edmonds 2002). 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 the management of formal users groups. In contrast, in the remote area, merely 22% of the sample forests is under the management of formal users groups.

For the sampled forests, we implemented aerial-photo interpretation and forest inventory. We utilized the two sets of aerial photographs. The first set of photos was taken in 1978. The second set was taken in 1992 in EDR and CDR, and in 1996 in the other three regions.[4] On the aerial photographs, we analyzed forest area, forest-cover type, crown coverage, etc. In addition, we analyzed the land-use classification for the VDCs in which sampled forests are located. 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 the height more than 20 cm. See Appendix for the details of forest inventory. The next section summarizes the results of our measurement.

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[4] 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.

3 Forest Conditions in The Middle Hills

3.1 Tree Species Distribution

In forest inventory, we measured 15,645 stands and identified 149 species over 113 forests.[5] Among the 149 species, 27 species (152 stands) were identified only by local tree names. We could identify neither botanical nor local tree 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. *Shorea robusta* and *Pinus roxburghii* are the two key species in the Middle Hills. The dominant species in number is *S. robusta*, whose local name is Sal. *S. robusta* is a deciduous broadleaf tree. It accounts 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 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 tree stands in the Middle Hills. About tree regeneration, we measured 22,617 saplings and identified 212 species. Among them, 3,896 are the established saplings with DBH: 4 cm $<$ DBH $<$ 10 cm. *S. robusta* is the dominant species in regeneration accounting for 35.3% of all the saplings.

Although the Middle Hills is considered as one topographic zone, it is not sensible to treat it uniform when we work on the tree vegetation. The 1,000 meter altitude line is a rough border between the tropical and the temperate (sub-tropical) forest zone (Shrestha 1989, Ch. 6; Negi 1994, Ch. 3). The wetter eastern part has different flora from the drier western part. We therefore divide sample forests into groups based on the five development regions and on whether the lowest part of the forest is up or below 1,000 meter altitude. Tables 2 and 3 show the species composition in the sub-divided areas in the Middle Hills.

In these tables, following Metz (1997), the leading species are shown in importance percentage: the average of the ratio of stands and the ratio of basal area.[6] A note is that the wetter EDR shows starker differences from the other four regions. In EDR, the importance ratio of *P. roxburghii* is as low as 7% in the higher altitude, while *Schima wallichii* is more common than *S. robusta* in the lower altitude. In

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[5] In the inventory, 3 forests in the aerial-photo analysis were combined into one forest, and there was a forest which was not in the aerial-photo analysis. All of these forests are among the 9 resurvey forests.

[6] Throughout the paper, we do not show biomass. Sharma and Pukkala (1990), 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: Tree Species Distribution: Lower Altitude

		Development Regions				
	Total	Eastern (EDR)	Central (CDR)	Western (WDR)	Mid-western (MDR)	Far-western (FDR)
Forests Measured[a)]	55	7	11	16	11	10
Avg. Lowest Altitude	754	717	773	691	852	745
Avg. Highest Altitude	1090	945	1080	1023	1217	1164
Number of Trees Measured	8274	687	2279	2229	1999	1080
Number of Species Identified	95	44	48	38	34	28
Simpson's Index of Diversity[b)]	0.730	0.832	0.548	0.757	0.578	0.639
Leading Species: 1	*Shorea robusta*	*Schima wallichii*	*S. robusta*	*S. robusta*	*S. robusta*	*Pinus roxburghii*
Importance Ratio (%) [c)]	43.7	32.7	59.1	33.9	56.2	62.4
2	*Pinus roxburghii*	*Shorea robusta*	*P. roxburghii*	*Schima wallichii*	*P. roxburghii*	*S. robusta*
Importance Ratio (%)	21.9	25.0	10.4	32.9	31.7	23.6
3	*Schima wallichii*	*Castanopsis spp.*	*Terminalia alata*	*Castanopsis spp.*	*T. alata*	*T. alata*
Importance Ratio (%)	11.9	6.7	9.5	16.1	1.8	2.6
Number of Saplings Counted	13012	1107	2808	5471	1895	1731
Leading Species: 1	*Shorea robusta*	*S. robusta*	*S. robusta*	*S. robusta*	*S. robusta*	*S. robusta*
Ratio (%)	48.9	36.0	63.5	40.3	59.3	49.5
2	*Castanopsis spp.*	*Castanopsis spp.*	*Terminalia alata*	*Castanopsis spp.*	*Pinus roxburghii*	*P. roxburghii*
Ratio (%)	9.0	13.7	10.1	17.4	9.9	34.0

a) In total, there are 113 forests in the inventory. Refer to footnote 5 in the text.

b) The probability that two randomly selected trees in the area are of the different categories. Defined by 1− (Simpson's Index of Concentration).

c) The average of the ratio of stands and that of basal area.

Table 3: Tree Species Distribution: Higher Altitude

		Development Regions				
	Total	Eastern (EDR)	Central (CDR)	Western (WDR)	Mid-western (MDR)	Far-western (FDR)
Forests Measured	57	12	10	14	9	12
Avg. Lowest Altitude	1456	1577	1442	1299	1446	1537
Avg. Highest Altitude	1867	2046	1846	1710	1844	1908
Number of Stands Measured	7371	775	1164	2659	1455	1318
Number of Species Identified	99	38	38	46	19	37
Simpson's Index of Diversity	0.912	0.876	0.899	0.914	0.813	0.867
Leading Species: 1	*Pinus roxburghii*	*Alnus nepalensis*	*P. roxburghii*	*P. roxburghii*	*P. roxburghii*	*P. roxburghii*
Importance Ratio (%)	23.5	22.9	25.6	16.4	35.1	30.6
2	*R. arboreum*[b)]	*Castanopsis spp.*	*Shorea robusta*	*Schima wallichii*	*R. arboreum*	*Pinus wallichiana*
Importance Ratio (%)	11.9	13.2	16.6	13.7	21.3	19.1
3	*Shorea robusta*	*R. arboreum*[b)]	*R. arboreum*	*R. arboreum*	*S. robusta*	*Quercus spp.*
Importance Ratio (%)	8.6	10.5	11.8	11.6	13.7	16.0
Number of Saplings Counted	9605	899	1885	4101	667	2053
Leading Species: 1	*Shorea robusta*	*Alnus nepalensis*	*S. robusta*	*S. robusta*	*S. robusta*	*Pinus roxburghii*
Ratio (%)	16.8	16.8	17.3	20.0	24.7	17.2
2	*Schima wallichii*	*R. arboreum*[b)]	*Eurya acuminata*	*Castanopsis spp.*	*Quercus spp.*	*Pinus wallichiana*
Ratio (%)	7.5	14.1	9.8	12.9	20.4	15.6

a) See the notes in Table 2.

b) Rhododendron arboreum.

contrast, in the drier FDR, pine trees (*Pinus spp.*) account for more than 60% of the stands in the lower altitude.

3.2 Forest Resource Conditions

Table 4 summarizes the results of forest inventory with respect to the conditions of stands. This table does not contain the 9 resurvey forests in WDR, because we did not record the number of measured plots in these resurvey forests. Total number of forests in this table is 104, and the total number of stands is 14,418.

An indicator of forest-resource condition is the number of big stands per hectare in the forests. We adopt the two criteria for big stands. First is the trees with DBH ≥ 35 cm and the height ≥ 13 m, and the second is the trees with DBH ≥ 55 cm and the height ≥ 13 m. The first criterion is set at the average tree size in the little disturbed forests in the Middle Hills analyzed by Metz (1997). There are 1,571 stands that satisfy the first criterion, which account for 10.9% of all the measured stands. Twenty-two forests have no trees satisfying the first criterion. The second criterion is simply the middle of tree-size classification between DBH = 10 cm and more than 100 cm. There are only 302 stands that satisfy the second criterion, which account for 2.1% of all the measured stands. Fifty forests have no trees satisfying the second criterion.

Another indicator of forest-resource condition is the volume of trees suitable for timber, firewood, and fodder. The latter two are the representative NTFPs. Tree species suitable for timber, firewood, and fodder are taken from Negi (1994, pp. 99-135). *S. robusta*, whose local name is Sal, is suitable for all the three uses, and has been considered as the most valuable tree in the Middle Hills (Storrs and Storrs 1998, pp. 264-267; Negi 1994, Chs. 5-7). *Pinus spp.* and *Quercus spp.* are the other examples of species suitable for timber. *Quercus spp.* and *Terminalia spp.* are those for firewood, and *Albzzia spp.* and *Terminalia spp.* are those for fodder.

The first three rows of Table 4 show 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 conditions for all the three forest resources: timber, firewood, and fodder. The forests in FDR, however, are in the best condition in terms of the big stands in both criterion I and II, 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

Table 4: Resource Conditions: 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	Average[b)]	365.8	259.2	476.9	454.8	402.6	241.7
Stands	Max[c)]	1101.7	511.1	1101.7	1009.5	560.2	520.8
per hectare	Min	14.3	84.8	65.0	140.0	227.8	14.3
Number of	Average	39.9	21.5	34.3	19.9	56.1	56.6
Big Stands I	Max	168.0	107.1	161.7	71.1	168.0	113.4
(DBH ≥ 35 cm, Height ≥ 13 m)	Min	0.0	0.0	0.0	0.0	0.0	0.0
per hectare							
Number of	Average	7.7	5.3	4.4	3.7	10.4	12.2
Big Stands II	Max	71.4	71.4	25.0	12.3	34.0	40.3
(DBH ≥ 55 cm, Height ≥ 13 m)	Min	0.0	0.0	0.0	0.0	0.0	0.0
per hectare							
Stem Volume	Average	138.6	92.9	130.7	117.5	167.5	162.6
(m^3 per hectare)	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	Average	109.4	35.2	110.0	60.0	153.8	152.9
Good for Timber	Max	348.4	155.6	348.4	203.9	223.8	309.6
(m^3 per hectare)	Min	0.0	0.0	0.2	0.0	0.0	0.2
Stem Volume	Average	44.4	18.3	76.9	23.9	73.5	27.1
Good for Firewood	Max	314.1	91.7	242.7	120.8	314.1	106.4
(m^3 per hectare)	Min	0.0	0.0	0.0	0.0	0.0	0.0
Stem Volume	Average	55.3	36.8	85.9	38.0	83.2	33.4
Good for Fodder	Max	303.5	94.9	242.2	191.2	303.5	153.2
(m^3 per hectare)	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 based on the number of measured plots in each development region.

c) Max and Min is about the average in each sample forest.

Table 5: Resource Conditions: 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
A	Number of Saplings per Plot	Average	109.7	88.9	162.5	131.9	74.7	95.4
		Max	448.7	188.8	342.0	448.7	187.5	231.6
		Min	0.0[b] (7.6)[c]	25.0	0.0[b] (33.3)[c]	14.7	16.7	7.6
B	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 town area.

c) The value except for the plantation forest explained in b).

there are a lot of pine trees (*Pinus spp.*) in FDR and MDR (Tables 2 and 3). A major species suitable for timber is pine tree, which usually has large stand and is dominant in the drier MDR and FDR.

Table 5 summarizes the results on regeneration of saplings. Block A of Table 5 shows the simple counts of saplings per plot. The forests in EDR, MDR and FDR have much smaller number of saplings than those in WDR and CDR. We can get a clearer picture when we weight the saplings by their sizes. For example, established saplings, 4 cm < DBH < 10 cm, are given higher weight than the smaller saplings. Block B of Table 5 shows that the forests in MDR and FDR have much poorer regeneration 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 6 summarizes the qualitative observations by the enumerators about human impacts. These indices also show the stark differences among the five development regions. Compared to the other three regions, MDR and FDR have higher incidence of fire and the lower collection of leaf litter. The plots with seasonal fire incidents account for 11.3% of all the plots in MDR, and 19.8% of those in FDR. In contrast, the corresponding number in EDR is 2.1%. Frequent fire incidences suggest more shifting-

Table 6: Human Impacts

		(1)	(2)	(3)	(4)	(5)	(6)
			by Development Region				
		Total	EDR	CDR	WDR	MDR	FDR
Number of plots evaluated		2,539[a)]	142	372	686	567	772[b)]
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
Grazing	None (%)	37.8	59.9	41.1	40.4	40.2	28.2
	Moderately (%)	44.4	28.9	48.1	56.0	48.0	32.5
	Heavily (%)	17.8	11.3	10.8	3.6	11.8	39.2
Lopping	None (%)	54.0	59.9	30.6	48.4	73.9	54.7
	Moderately (%)	39.9	29.6	67.2	46.6	18.3	38.3
	Heavily (%)	6.1	10.6	2.2	5.0	7.8	7.0
Leaf Litter Collection	None (%)	57.3	73.9	39.2	61.5	73.9	46.8
	Occasionaly (%)	34.7	12.0	33.9	29.2	24.7	51.5
	Frequently (%)	8.1	14.1	26.9	9.3	1.4	1.7

a) This is the number of plots where the intensity of grazing was evaluated. In several plots in FDR, the other human impacts were not evaluated. Refer to b).

b) This is the number of plots where the intensity of grazing was evaluated. The number of plots where fire was evaluated is 771, that of lopping is 770, and of leaf litter is 769.

cultivation and less patrol in forests. The plots with frequent collection of leaf litter accounts for 1.4% of all the plots in MDR, and 1.7% of those in FDR. The average of the Middle Hills is 8.1%. These stark differences are also mainly due to the dominance of pine trees in MDR and FDR. Pine leaves cannot be utilized for fodder. Since the fallen leaves of pine trees are slippery, users often intentionally put fire on these leaves to avoid accidents of livestock and people. In terms of grazing, the forests in FDR are more heavily grazed than those in the other regions. This reflects the fact that there are large-scale cattle raisings in FDR.

3.3 Landscape and its Intertemporal Changes

Although forest inventory reveals the detailed resource conditions, what it shows are static images. To investigate the intertemporal changes in forest conditions, the two sets of aerial photographs are utilized. The aerial photos we analyzed cover 279,958 hectare, which amounts to 6.5% of the total area of the Middle Hills. The area under the analysis includes 94 village development committees (VDC) over 31 districts. Table 7 compares the land-cover changes among the five development regions, and between the accessible and the remote area. Here, shrub land is defined as the area of which more than 50% is covered by the trees lower than 10 m height. Grassland is included in the classification of non-agricultural land, which is not shown. Table 7 provides a clear view of the landscape in Nepal. On average, the ratio of forest area is higher in MDR (45.2%) and FDR (56.4%) than in the other three regions. As expected, the ratio of forest area is higher in the remote area (45.3%) than in the accessible area (35.7%).

The intertemporal changes in the forest-land ratio are, however, negligible both among the five development regions and between the accessible and remote area. In spite of repeated denials from academics, there still remain popular accounts that the human-caused loss of Himalayan-forests cover has raised threats of flood to the people in Bangladesh and India (e.g. Rischard 2002, Ch. 10). Our analysis confirms that there have been no significant changes in forest area in the Middle Hills of Nepal from the late 1970s to the late 1990s. Coupled with the analysis by Metz (1991), who compares the forest cover between 1964-65 and 1978-79 aerial photographs, the forest area in the Middle Hills has not decreased since the 1960s.[7]

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[7] Metz (1991) argued that in the Middle Hills, almost all the arable land had been developed before 1950.

Table 7: Changes in Land Cover in the Middle Hills: from 1978 to 1992-96

	(1)	(2)	(3)	(4)	(5)	(6)
			Land Cover Ratio to Total VDC Area			
	Coverage	Year of Aerial-photos	Forest (%)	Shrub (%)	Forest and Shrub (%)	Agricultural Land (%)
Middle Hills	94 VDCs [a]					
	(31 districts)	1978	41.1	11.8	53.0	36.2
	279,958 ha	1992	41.2	10.6	51.9	35.8
by Development Region						
EDR	18 VDCs					
	(8 districts)	1978	31.4	14.5	45.9	37.2
	57,389 ha	1992	30.8	9.5	40.3	42.6
CDR	18 VDCs					
	(6 districts)	1978	31.6	19.5	51.2	39.9
	47,836 ha	1992	33.8	14.7	48.5	41.4
WDR	26 VDCs					
	(10 districts)	1978	36.9	10.4	47.3	42.7
	63,693 ha	1996	37.0	10.6	47.6	39.1
MDR	14 VDCs					
	(3 districts)[b]	1978	45.4	6.6	52.1	37.9
	40,575 ha	1996	45.2	10.1	55.3	32.5
FDR	18 VDCs					
	(4 districts)	1978	56.9	8.6	65.6	26.1
	70,465 ha	1996	56.4	9.0	65.4	25.3
by Access						
Accessible Area	47 VDCs	1978	35.0	12.9	47.9	43.7
		1992/96	35.7	12.4	48.1	42.9
Remote Area	47 VDCs	1978	45.7	11.0	56.7	30.7
		1992/96	45.3	9.3	54.6	30.5

a) Number of Village Development Committee (VDC), districts, and the area analyzed.

b) The survey covers 3 out of 6 districts in the region. See the text.

Table 8: Changes in Forest Conditions: Aerial-photo Analysis

	(1) Sample Forests	(2) Improved[a)]	(3) No Change	(4) Degraded	(5) Mixed[b)]	(6) Year of Photos	(7) Shrub[c)]
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 increased species. See the text.
b) Forest with both improved and degraded indices.
c) Here shrub cover includes grassland. Note the difference from Table 7.

3.4 Intertemporal Changes in Forest Condition

The analysis on the land-cover changes shows no significant loss of forest area: deforestation. Metz (1991) reported that, however, between 1964 and 1978, there was a significant degradation in forest conditions in the Middle Hills. Have the forests in the Middle Hills continuously degraded after 1978, or did they begin to recover? To address this question, between the 1978 and 1992/96 aerial photographs, we compare the sample forests in crown-cover density, maturity class of stands, and major species. Table 8 shows the intertemporal changes in resource conditions 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 tree species. The degraded forests are those with decreases in such indices. There are, however, complicated cases where improved indices and degraded indices coexist. For example, a forest with decreased maturity index has increased crown-cover index. These cases are classified as "mixed". Furthermore, in the case of tree species, we make one exception for *Sal* (*S. robusta*) trees. As was noted above, *Sal* has been considered as the most valuable tree in the Middle Hills. When a forest changes from *Sal* dominant to *Sal* cum other tree species dominant, we consider that the forest is degraded.

With noting the possibly large errors in aerial-photo interpretation, three interesting features stand out in Table 8. First, forest-resource conditions show significant intertemporal changes. More than 55% of sample forests experienced changes in their resource conditions (column (2), (4), and (5)). Second and the most importantly, at least partially, the trend of forest-resource degradation between 1964 and 1978 was reversed. Since 1978, nearly one-third of sample forests experienced improvement in their resource conditions (column (2) of Table 8). Lastly, there were more cases of improvement in the accessible area than in the remote area. 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.[8]

4 Empirical Specification

4.1 Specific Empirical Questions

The aerial-photo analysis in Table 8 suggests that 30% of sample forests experienced some improvement in their resource conditions between 1978 and 1992/96. An imperative question is to what extent the community management, summarized in Table 1, contributed to this improvement. A related question is to what extent the formal approval and support from the local forest offices enhanced the effectiveness of community management. This question is about the differences between co-management and community management. The reference point is the forests under the direct control of district forest offices (DFOs). Many of them are often under *de facto* open access. Hereafter, the number of forests under the analyses is 102 in Table 1, all of which are randomly sampled forests.

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[8] One more observation is that there were less cases of forest improvement in WDR. In fact, five forests with improved conditions in WDR are all the resurvey forests, not randomly sampled forests. We do not have clear explanation for it.

Another management factor which may affect forest-resource conditions is forest-related projects. According to column (9) of Table 1, 17 sample forests have or had forest-related projects. There are several types in these 17 projects. A major type is tree planting project by local forest offices or by local and international NGOs. The other major type is that international and bilateral donor agencies provide technical assistance to forest users groups. In general, these projects exert more direct intervention in the forest management than the orthodox community-forest approach. We try to quantify the impacts of these projects on intertemporal changes in forest conditions.

4.2 Indices of Forest Resource Conditions

To assess the impacts of management systems, we employ three indices of forest conditions. The first is the intertemporal changes in forest conditions detected in the aerial-photo analysis in Table 8. The second is the regeneration rate in Table 5. The last is the observations of human impacts in Table 6: fire, grazing, lopping practices, and leaf litter collections. Each index has advantages and disadvantages.

The advantage of the first index, the changes in forest conditions detected in the aerial-photo analysis, is that it is made from the observations in different years. This index really 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 8). 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, the aerial photographs may be too rough to capture the impacts of management systems on forest conditions.[9]

The other indices, regeneration rate of trees and the four human-impact indicators, are made from forest inventory. Our interpretation is that the regeneration rate and the four human-impact indicators reveal the direction of upcoming changes in forest conditions, so that we can use them as proxies for intertemporal changes in forest conditions. Since these indices were measured at many plots in each forest, they reveal more detailed forest-resource conditions than the aerial-photo analysis. Furthermore, we can compare the results of forest-wise regression analyses with those of the plot-wise regression 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 conditions at the time of forest measurement.

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[9] With a fairly small scale of 1:50,000, the aerial-photo interpretation merely compares crown coverage, tree maturity (size), and the major species in the forests.

An advantage specific to the human-impact indicators is that they directly evaluated the intensity of resource extraction by the users. We can assess the differences between the articulated regulations and the real use of forests. A specific disadvantage of the human-impact indicators is that, these observations are subjective which may be different among the enumerators.

4.3 Specification of Regression Equations

In the empirical analyses to evaluate the effects of management systems on forest conditions, we need to deal with the three complications. The first complication is due to the fact that forest vegetation is a stock variable. It usually takes several years to improve forest conditions. In the empirical analyses, we thus should note that there are little immediate impacts from current forest-management activities to current forest conditions. 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 users groups would have relatively high prospect of improvement in their conditions whether or not there are users groups. An example is that an unknown factor, such as a strong leadership in local government, prompts both the formation of users groups and the improvement in forest conditions. If this is the case, simple regression analyses overestimate the impacts of forest-management systems on forest conditions. The last complication is mainly related to the analyses with the four human-impact indicators in Table 6. A certain level of human impacts does not necessarily mean bad management. Users groups usually make the harvesting rules specific to each NTFP based on resource conditions. For example, there are cases that lopping branches for fodder collection is completely prohibited while the grazing in the forest is not at all restricted.

To deal with the first complication, as the main indices for management systems, we adopt the number of years under informal and formal management systems (columns 3 and 6 of Table 1). In other words, as the main management indices, we do not use dichotomous dummy variables. In addition to circumvent the first complication, the duration of informal management systems is less likely to be affected by the local administrative factors, which may have hidden impact on forest conditions. The main specification for our empirical analyses is:

$$\begin{aligned}\text{Changes in Forest Conditions } = {} & \beta_1 + \beta_2(\text{Population Pressure}) \\ & + \beta_3(\text{Topographic Conditions}) + \beta_4(\text{Vegetation Conditions}) \\ & + \beta_5(\text{Dummy for Project}) \\ & + \beta_6(\text{Years under the Management by Informal Users Group}) \\ & + \beta_7(\text{Years under the Management by Formal Users Group}).\end{aligned} \tag{1}$$

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 projects, we control for population pressure, topographic conditions, and vegetation conditions.

About the impacts of formal management systems, however, there remains a possibility that sample self-selection bias is significant. Recall that the DFOs are in charge of registering users groups. Many years under formal management system suggest that the DFO in that area has been eager to implement the community-forest program. Such DFOs are expected to implement other forest-management activities efficiently. Moreover, the years under the formal management systems is not so long, and is similar to a dichotomous dummy variable. The registration scheme of users groups was officially introduced in 1991. If any, the sample forests are under the formal management systems for short years: 1.47 years on average and 3.33 years among the forests under the formal management systems. In addition to equation (1), we thus estimate two-step specification to examine the endogeneity of formal management system.[10] Over all, the second specification is:

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[10] The treatment index in equation (1) is a count variable: the years under the formal management systems. The period under the formal management is generally short, and there is no widely received method to cope with the count-variable treatment. We thus use the dummy variable in the second specification.

$$
\begin{aligned}
\text{Changes in Forest Conditions } = {} & \beta'_1 + \beta'_2(\text{Population Pressure}) \\
& + \beta'_3(\text{Topographic Conditions}) + \beta'_4(\text{Vegetation Conditions}) \\
& + \beta'_5(\text{Dummy for Project}) \\
& + \beta'_6(\text{Years under the Management by Informal Users Group}) \\
& + \beta'_7(\text{Dummy for Formal Users Group}),
\end{aligned} \tag{2}
$$

where the possible endogeneity of the dummy for formal users groups is considered in the following first-step estimation:

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

To cope with the third complication, we use the regulation indices specific to each NTFP as well as the years of or dummy for each management system.

4.4 Determinants of Forest-management Systems

We start with equation (3), which is on the initiation of co-management systems (formal users groups). We also estimate equation (3) with the emergence of informal management systems and forest-related projects as its dependent variables. This is to examine the treatment effects in these management variables. Table 9 reports the estimation results.

The explanatory variables we considered are as follows.[11] 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 to which users belong, ethnic diversity of users,

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[11] Refer to Bardhan (2000) for a detailed discussion on the explanatory variables for the formation of community-management systems.

Table 9: Formation of Management Systems: 102 Forests

	(1)	(2)	(3)	(4)	(5)
Dependent Variable (Y)	Rank Dummy$^{a)}$	Dummy for Formal Management	Dummy for Informal 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	0: 76.7	0: 80.4	0: 100.0	0: 97.4	0: 98.8
Correctly	1: 15.4	1: 78.3	1: 3.8	1: 11.5	1: 5.9
Predicted Y	2: 87.0				
Log-likelihood	-80.250	-45.904	-54.938	-51.736	-40.508
Pseudo R-squared$^{b)}$	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.

b) The measure poposed by Mcfadden. Refer to Wooldridge (2001, p. 465).

and the ratio of user households whose members are working outside as seasonal or permanent migrants. Except for ethnic diversity of users, these variables are expected to have negative coefficients.[12] There is a conceptual difficulty to define the number of user households in *de facto* open access forests. It can be huge because everyone can have access to these forests. In the social survey on the open access forests, we investigated the number of user households who *regularly* extract resources from those forests. For the number of local administration unit from which users come from, we use the number of ward. Ethnic diversity is the Simpson index of diversity for castes and ethnic groups of the user households.

Traveling time from the nearest ranger office is to assess the impact of intervention by DFOs. We expect negative and substantial coefficient 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, as was discussed above, users in the Middle Hills consider *Sal* as the most valuable trees. 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.[13] As an explanatory variable for forest-related projects, we also tried formal and informal forest-management systems. They are not statistically significant and are dropped.

Column (1) of Table 9 shows the ordered probit analysis with dependent variable 0 for the forests under the direct control of the DFOs, 1 for the forests under the management of informal users groups, and 2 for the forests under formal users groups. We adopt this ranking because an application by existing informal users group is required to register it as a formal users group. Column (2) shows the probit estimate with dummy dependent variable for the formal users groups. These two estimates 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 users groups which were easily accessible from their offices. Higher ratio of *Sal* trees and relatively good initial condition of forests induce the initiation of co-management systems. These results imply that either the users or the DFOs registered the groups mainly to protect the rich forest resources, not to rehabilitate the degraded forests. An unexpected result

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[12] For possible non-monotonic relationships between heterogeneity of users and the function of community management, refer to Varughese and Ostrom (2001) and Baland and Platteau (1997).

[13] As an indicator of social capital, we tried the ratio of forest users attending the community activities other than forest management.

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 users groups.

Columns (3) and (4) of Table 9 show the probit estimates for informal management systems. Among the various specifications, column (4) shows the best result in terms of the percent of correctly predicted dependent variable: a measure of goodness of fit. Since the goodness of fit is so low, we can conclude that informal management systems emerged randomly regardless of exogenous conditions. This finding is consistent with the variety of forms in informal management systems, which we discussed in Section 2. Another possible explanation is that the registrations of users groups have been so systematic along with the exogenous conditions, so that the remaining non-registered groups seem to be random.

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 assigned to forests randomly. An important result here is that we do not have to consider the treatment effects of informal management systems and forest-related projects.

We have also implemented probit estimations on the existence of specific harvesting rules to each NTFP. If formal users group set any restrictions on the collection of NTFP, the dependent dummy takes one. The results are in Table 10. The predicted values from Tables 9 and 10 are utilized in the estimations of equation (2) to cope with the possible endogeneity in formal-groups dummies.

5 Impacts of Management Systems

5.1 Effects on Changes Detected in Aerial-Photo Analysis

Table 11 reports the estimation results of equation (1) and (2), where the dependent variable is the changes in forest conditions detected by aerial-photo interpretation. Since three sample forests have mixed indices of intertemporal changes (Table 8), the number of observations is 99.[14] 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

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[14] Among the four forests with mixed indices in Table 8, one is a resurvey forest in WDR.

Table 10: Probit Analyses on Rules in Formal Management System: 102 Forests

Dependent Variable (Y)	(1) Dummy for Dead Branches	(2) Dummy for Grazing	(3) Dummy for Fodder	(4) Dummy for Leaf Litter
Constant	0.071	-3.057	-2.456	-3.423**
	(1.569)	(1.704)	(1.552)	(1.602)
Log of Forest	-0.264	-0.244	0.211	-0.109
Area	(0.175)	(0.167)	(0.157)	(0.161)
Log of Number	0.241	0.963***	0.305	0.650**
of Housholds	(0.271)	(0.333)	(0.301)	(0.306)
Number of Wards	-0.152	-0.127	-0.085	-0.077
Users Belong	(0.139)	(0.133)	(0.123)	(0.125)
Ethnic	1.356	-1.775*	-1.062	0.765
Diversity	(0.916)	(0.998)	(0.903)	(0.972)
Log of Time to	-0.335**	-0.394***	-0.209	-0.107
Ranger Office	(0.140)	(0.149)	(0.140)	(0.133)
Ratio of	1.604***	1.309***	2.038***	1.153**
Sal	(0.548)	(0.607)	(0.557)	(0.551)
Immature Forest	-0.273	0.861*	0.250	-0.490
in 1978	(0.458)	(0.520)	(0.527)	(0.466)
Mature Forest	0.807*	1.047**	0.523	0.642
in 1978	(0.438)	(0.484)	(0.439)	(0.452)
Percent Correctly	0: 92.9	0: 93.6	0: 93.6	0: 94.9
Predicted Y	1: 65.6	1: 45.8	1: 37.5	1: 43.5
Log-likelihood	-41.148	-39.175	-42.483	-40.877
Pseudo R-squared	0.35	0.30	0.24	0.25

Refer to the notes of Table 9.

Table 11: Determinants of Forest-Condition Changes in Aerial Photos: 99 Forests

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (Y)	Rank Dummy: 0 = Deteriorated, 1 = No Significant Changes, 2 = Improved					
Estimator	Ordered Probit					IV
	Coefficient	Marginal Effect in				
		Y = 0	Y = 1	Y = 2	Coeff.	Coeff.
Constant	1.571				1.711	1.784
	(2.33)				(2.386)	(1.494)
Households per Forest	-0.041**	0.011**	0.002	-0.013	-0.040**	-0.02**
Area (per ha)	(0.018)	(0.005)	(0.003)	(0.021)	(0.018)	(0.01)
Growth Rate of	0.739	-0.199	-0.038	0.237	0.748	0.346
Housholds	(0.712)	(0.192)	(0.065)	(0.492)	(0.705)	(0.378)
Log of Time to	0.215	-0.058	-0.011	0.069	0.212	0.089
Forest (minutes)	(0.191)	(0.052)	(0.018)	(0.133)	(0.19)	(0.108)
Log of Lowest	0.142	-0.038	-0.007	0.046	0.126	0.038
Altitude (meter)	(0.324)	(0.087)	(0.02)	(0.17)	(0.329)	(0.194)
Average Slope	-0.046**	0.012**	0.002	-0.015	-0.047**	-0.027**
	(0.019)	(0.005)	(0.003)	(0.023)	(0.019)	(0.011)
Dummy for Immature	-1.563***	0.236***	0.328***	-0.564	-1.562***	-0.746***
Forest in 1978	(0.434)	(0.039)	(0.049)	(0.725)	(0.435)	(0.208)
Dummy for Mature	-0.326	0.096***	0.002	-0.097	-0.321	-0.160
Forest in 1978	(0.332)	(0.028)	(0.023)	(0.774)	(0.333)	(0.185)
Management Variables						
Dummy for	0.619$^{*}_{++}$	-0.136$^{**}_{++}$	-0.085$^{***}_{+++}$	0.220	0.619$^{**}_{++}$	0.297$^{*}_{++}$
Project	(0.344)	(0.067)	(0.014)	(0.695)	(0.343)	(0.177)
Years under Informal	0.011	-0.003	-0.001	0.003	0.011	0.006
Management	(0.016)	(0.004)	(0.001)	(0.008)	(0.016)	(0.009)
Years under Formal	-0.016	0.004	0.001	-0.005		
Management$^{a)}$	(0.073)	(0.02)	(0.004)	(0.023)		
Dummy for Formal					-0.095	-0.145
Management					(0.271)	(0.338)
Threshold	1.544***				1.544***	
Parameter$^{b)}$	(0.187)				(0.187)	
Percent of	0: 30.4				0: 30.4	
Correctly	1: 85.4				1: 85.4	
Predicted Y	2: 42.9				2: 42.9	
Log-likelihood	-90.222				-90.185	
R-squared$^{c)}$	0.13				0.13	0.14

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) Adjusted to the years when the aerial-photos were taken. See text.

b) Threshold between 1 and 2 in dependent variable.

c) Pseudo R^2 for columns (1) and (2), and adjusted R^2 for columns (6). Refer to b) in Table (9).

settlements (*tol*) where users live.[15] Topographic conditions consist of the log of the lowest altitude of forest, average slope, and the ratio of sample plots facing to north in forest inventory. Two dummy variables indicating the average tree sizes in the 1978 aerial photographs are included to control for both vegetation characteristics and initial conditions.

Column (1) of Table 11 reports the estimates of equation (1). Since the dependent variable is a rank dummy (Table 8), we adopt ordered probit model. Columns (2) to (4) report the marginal effect evaluated in each cell probability. We are primarily concerned with the three management variables, dummy for projects, years under informal users group, and years under formal users group. The null hypotheses on these management variables are that they did not contribute to the improvement in forest conditions. Therefore we implement one-sided test for the statistical significance of their estimated coefficients as well as conventional two-sided test. 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 conditions.

Without considering the treatment effect in the dummy for formal management, column (5) shows the ordered probit estimate of equation (2). Column (6) reports the estimate of instrumental variable (IV) method, in which the predicted value of column (2) of Table 9 is used as the instrumental variable for the dummy for the formal management. In IV estimation, a mere rank dummy is regarded as a meaningful continuous dependent variable. The IV estimation with the first-stage probit is, however, a widely-accepted method to resolve treatment effect.[16] Except for the size of coefficients, columns (5) and (6) of Table 11 show qualitatively similar results. In the IV estimate considering the treatment effect, the dummy for project has a statistically significant estimate 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 conditions, which was sizeable enough to be identified by aerial photographs.

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[15] The annual increase in the number of households is a proxy for population growth rate. In the social survey, we use the first referendum in Nepal in 1980 as a reference point for the number of households in the past.

[16] We also tried two-step ordered probit estimation in which the predicted values of equation (3) are inserted for the dummy for formal management. The coefficient on dummy for project maintains its statistical significance at the 5 % level in one-sided test.

5.2 Regeneration Rate

Table 12 reports the regression results on the regeneration rate weighted by the size of saplings (Block B of Table 5). Many of the independent variables are the same as that of Table 11. There are, however, two differences. First, we drop three independent variables in Table 11: the annual increase in the number of user households and the two dummy variables for the average tree size in 1978. As was discussed above, 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 changes and the forest conditions in 1978. Second, as for vegetation-condition variables, we include log of basal area and the ratio of pine trees in the forests. Regeneration can be affected both by the density and the type of current vegetation. As was discussed in Section 3.2, there are usually less regeneration in the floor of pine trees.

Column (1) of Table 12 shows the OLS estimates of equation (1). Among the three management variables, years under formal management has statistically significant coefficient at the 5% level in the 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 considers the treatment effect in the dummy for formal management. In either estimate, dummy for formal management has statistically significant coefficient at the 1% level both in one-sided and two-sided tests.[17] Other than the formal management systems, the higher ratio of pine trees in forests reduced regeneration. An interesting observation is that columns (2) and (3) of Table 12 suggest that north-facing plots had higher regeneration.

We can examine the robustness of these forest-wise estimates by plot-wise regressions, whose results are collected in Table 13. In our data set, we can utilize the regeneration measurement in 3,777 plots over 101 forests. One sample forest in Table 12 is dropped from all the plot-wise analyses hereafter due to the missing information of the aspect of each plot. Column (1) of Table 13 shows the OLS estimate of equation (1) with plot-wise data. Although many coefficients are statistically significant, OLS may not be an appropriate estimator because plots in a same forest are likely to share some kind of characteristics.

To deal with this forest-wise effect in plot-wise data, we adopt two methods. First method is to correct covariance matrix of OLS estimate by clustering the sample plots by forests. Corrected result is shown in

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[17] We also estimated equation (2) with replacing years under informal management by a dummy for informal management. Such replacement did not generate any significant changes.

Table 12: Determinants of Forest-wise Regeneration Rate: 102 Forests

	(1)	(2)	(3)
Dependent Variable (Y)	Regeneration Rate Weighted by Size of Saplings		
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 to 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 Informal Management	0.015	0.012	0.012
	(0.013)	(0.013)	(0.012)
Years under Formal Management	0.112$^{*}_{++}$		
	(0.060)		
Dummy for Formal 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.

Table 13: 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					
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	0.044^{***}	0.044	0.015	0.039	0.013	0.008
Area (per ha)	(0.006)	(0.032)	(0.016)	(0.029)	(0.016)	(0.016)
Log of Time to	0.215^{***}	0.215	0.141	0.284^{**}	0.239	0.380^{**}
Forest (minutes)	(0.044)	(0.142)	(0.163)	(0.129)	(0.160)	(0.176)
Log of Lowest	-0.354^{***}	-0.354	-0.528^{**}	-0.239	-0.423	-0.306
Altitude (meter)	(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	0.331^{***}	0.331^{**}	0.170^{***}	0.357^{**}	0.171^{***}	0.174^{***}
to North	(0.059)	(0.144)	(0.062)	(0.140)	(0.062)	(0.062)
Log of Basal Area	-0.194^{***}	-0.194	-0.360^{***}	-0.197	-0.359^{***}	-0.359^{***}
in Plot	(0.050)	(0.129)	(0.055)	(0.138)	(0.055)	(0.055)
Ratio of Pine	-0.833^{***}	-0.833^{***}	-0.785^{***}	-0.813^{***}	-0.784^{***}	-0.782^{***}
Trees	(0.069)	(0.166)	(0.087)	(0.160)	(0.087)	(0.087)
Management Variables						
Dummy for	0.267^{***}_{+++}	0.267	0.338	0.221	0.312	0.246
Project	(0.085)	(0.337)	(0.287)	(0.313)	(0.276)	(0.279)
Years under Informal	0.015^{***}_{+++}	0.015	0.012	0.014	0.013	0.017
Management	(0.004)	(0.012)	(0.014)	(0.012)	(0.014)	(0.014)
Years under Formal	0.102^{***}_{+++}	0.102^{*}_{++}	0.092^{*}_{++}			
Management	(0.016)	(0.056)	(0.056)			
Dummy for Formal				0.752^{***}_{+++}	0.736^{***}_{+++}	1.375^{***}_{+++}
Management				(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) Large value of Lagrange-multiplier test indicates that panel specification is prefered to OLS.

column (2), where the statistical significance of many coefficients vanished. The positive impact of years under formal management is, however, still significant at the 5% level in one-sided test. Second method is to apply a random-effect model based on an analogy of plural plots in a forest with panel data. Its result is shown in column (3). Huge value of the Lagrange-multiplier test static indicates that panel specification is preferred to OLS. Again, the positive impact of years under formal management keeps its significance at the 5% level in one-sided test. Coupled with the results of forest-wise analyses (column (1) of Table 12), we can conclude that additional year under the formalized users groups improved regeneration rate.

Columns (4) to (6) of Table 13 show the estimation results of equation (2) with plot-wise regeneration data. The estimators in column (4) and (5) do not consider the treatment effect in the dummy for formal management, whereas the estimator in column (6) corrected treatment effect by instrumental variable (IV) method proposed by Balestra and Varadharajan-Krishnakumar (1987). From column (4) to (6), dummy for formal-management system has statistically significant coefficients both in one-sided and two-sided test. The correction of treatment effect raises the impact of formal-management dummy on regeneration rate: 0.736 in column (5) to 1.375 in column (6). This observation is consistent with the ones in Table 12. Combined with the forest-wise analyses, we can conclude that the existence of authorized users groups (formal management) contributed to improve tree regeneration in forests.

Other than the impact of formal-management systems, the results of plot-wise analyses generally support the forest-wise analyses in Table 12. An example is that north-facing plots attained higher regeneration rate in Table 13. 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 14 shows the forest-wise analyses on fire index, whereas Table 15 summarizes the plot-wise analyses. Since two sample forests have no record of fire-index observations, we have 100 samples for forest-wise analyses, and 2,443 plots over 99 forests for plot-wise analyses. The dependent variable is constructed as its higher value indicates the less incidents of forest fire.

The independent variables are the same as those in the 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

Table 14: Determinants of Forest-wise Fire Index: 100 Forests

	(1)	(2)	(3)
Dependent Variable (Y)	Fire Index of Forest Averaged over Plots Between 0 (= every year) to 2 (= No fire for past 5 years)		
Estimator[a)]	OLS	OLS	IV
Constant	1.080	0.525	0.696
	(0.890)	(0.911)	(1.034)
Households per Forest	0.023^{**}	0.021^{**}	0.021^{**}
Area (per ha)	(0.01)	(0.010)	(0.009)
Log of Time to	-0.080	-0.048	-0.059
Forest (minutes)	(0.081)	(0.080)	(0.085)
Log of Lowest	0.097	0.129	0.118
Altitude (meter)	(0.123)	(0.121)	(0.120)
Average Slope	-0.198	0.07	0.018
	(0.646)	(0.643)	(0.632)
Ratio of Plots Facing	0.451^{***}	0.486^{***}	0.469^{***}
to North	(0.170)	(0.165)	(0.166)
Basal Area per Forest	-0.403	-0.323	-0.321
Area (per ha)	(0.561)	(0.545)	(0.515)
Ratio of Pine	-0.676^{***}	-0.640^{***}	-0.654^{***}
Trees	(0.144)	(0.142)	(0.142)
Management Variables			
Dummy for	0.278^{*}_{++}	0.286^{*}_{++}	0.297^{**}_{++}
Project	(0.160)	(0.150)	(0.146)
Years under Informal	0.007	0.007_{+}	0.007_{+}
Management	(0.006)	(0.005)	(0.005)
Years under Formal	0.041_{+}		
Management	(0.031)		
Dummy for Formal		0.289^{**}_{+++}	0.238
Management		(0.120)	(0.206)
Adjusted R-squared	0.33	0.36	0.36
Correlation between Predicted and Observed Y[b)]	0.41	0.41	0.41

*, **, 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) Refer to footnote b) of Table 12.

Table 15: 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)					
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 to 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 Informal 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 Formal Management	0.037^{***}_{+++}	0.037_{+}	0.024			
	(0.007)	(0.028)	(0.028)			
Dummy for Formal 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 note in Table 13.

level (Table 6). In the forest-wise analyses, the dependent variable is a simple average of this plot-wise ranking in each forest. We consider this average as a meaningful continuous variable, and apply OLS estimators. A questionable case is the estimators for plot-wise analyses where we apply OLS again. That is, we consider 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 probabilities of the observations in a group. In our data set, each forest contains many measured plots. For example, a sample forest has 86 plots where fire index was recorded, which requires 86 multiplication of probabilities in the likelihood function. Consequently, the estimates of ordered-probit random effect models are unstable. Thus, with noting its problems, we applied OLS for the plot-wise rank variables.[18]

Column (1) of Table 14 reports the estimates of equation (1) with forest-wise data, while columns (1) to (3) of Table 15 show the corresponding estimates with plot-wise data. In forest-wise analysis, dummy for project and years under formal management lessen the incidence of forest fire. The statistical support for the latter is, however, weak: at the 10% level in one-sided test. In fact, in the plot-wise analysis with random-effect specification (column (3) of Table 15), neither dummy for project nor years under formal management has statistically significant coefficient. In contrast, years under informal management reduce the incidents of forest fire.

Column (2) and (3) of Table 14 report the OLS and IV estimate of equation (2) with forest-wise data. Columns (4) to (6) of Table 15 show the corresponding estimate with plot-wise data. In the OLS estimates with forest-wide data, all the three management variables contribute to decrease the incidents of forest fire, although the statistical support for years under informal management is weak (column (2) of Table 14). In the IV estimate with forest-wise data, however, the statistical significance of dummy for formal management disappears (column (3) of Table 14). In the plot-wise analyses, the statistical significance of both dummy for project and that for formal management disappear (column (6) of Table 15). In contrast, years under informal management has positive coefficient which is statistically significant both in one-sided and two-sided test. Overall, what we can surely conclude about forest fire is that informal users groups contributed to reduce it.

Other than the management variables, the ratio of pine trees has negative and statistically significant

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[18] A justification of using OLS is that in the field survey, the same inventory teams were dispatched to the five development regions in turn. We can expect fairly consistent evaluation in the differences in ranks of human impacts indices.

coefficients in all the estimates. This is because the users sometimes intentionally put fire on pine forests due to the reasons we discussed in Section 3.2. In forest-wise analyses in Table 14, the number of households per forest area reduced forest fire. In random-effect analyses in plot-wise data, this positive effect loses its statistical significance. We have a similar finding about the effect of north-facing plots.

5.4 Grazing and the Other Indices

Table 16 shows the forest-wise analyses on grazing index, whereas Table 17 summarizes the corresponding plot-wise analyses. Since four sample forests do not have record of grazing index, there are 98 samples in forest-wise analyses and 2,444 plots over 97 forests in plot-wise analyses. The dependent variable is constructed as its higher value indicates less grazing activities in forests. The independent variables are all the same as those in the analyses on regeneration rate and fire index except for one. As discussed above, users groups often put specific restrictions to grazing. As well as the indices of formal and informal users groups, we thus try regulation index which is specific to grazing.

Column (1) of Table 16 reports the forest-wise OLS estimate of equation (1) with years under informal or formal management, while column (4) shows the OLS estimate with years of grazing regulation imposed by users groups. Column (1) and (4) of Table 17 show the corresponding random-effect estimates with the plot-wise data. In either specification of management index, in forest-wise analyses, dummy for project lessen grazing intensity. The years of grazing regulation by informal users group also reduce forest-wise grazing intensity (column (4) of Table 16). The statistical support for this grazing-regulation index is, however, weak: 10% level in one-sided test. In plot-wise analyses, both dummy for project and indices for informal management moderate the grazing intensity. In particular, years of grazing regulation imposed by informal users groups has statistically significant coefficient at the 5% level in one-sided test (column (4) of Table 17).

Column (3) and (6) of Table 16 summarize the IV estimation of equation (2) with the forest-wise data, while column (3) and (6) of Table 17 show the corresponding random-effect estimates with the plot-wise data. In both forest-wise and plot-wise analyses, dummy for project has positive and statistically significant coefficients. In plot-wise estimations, although their statistical significance is at the 10% level in one-sided test, both years of informal management and years of grazing regulation by informal users groups lessen grazing intensity.

Table 16: Determinants of Forest-wise Grazing: 98 Forests

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (Y)	Grazing Index of Forest Averaged over Plots Between 0 (= Heavily Grazed) to 2 (= Not Grazed)					
Estimator$^{a)}$	OLS	OLS	IV	OLS	OLS	IV
Constant	-0.083	0.054	0.446	-0.281	-0.389	-1.084
	(1.006)	(1.052)	(1.199)	(0.964)	(0.968)	(1.091)
Households per Forest	-0.004	-0.003	-0.002	-0.004	-0.005	-0.005
Area (per ha)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Log of Time to	-0.012	-0.017	-0.044	0.021	0.021	0.020
Forest (minutes)	(0.091)	(0.093)	(0.099)	(0.087)	(0.087)	(0.088)
Log of Lowest	0.205	0.199	0.173	0.218	0.233*	0.306**
Altitude (meter)	(0.139)	(0.139)	(0.139)	(0.137)	(0.137)	(0.147)
Average Slope	-0.392	-0.509	-0.627	-0.46	-0.458	-0.217
	(0.731)	(0.743)	(0.731)	(0.723)	(0.728)	(0.751)
Ratio of Plots Facing	-0.007	-0.006	-0.045	-0.022	0.005	0.196
to North	(0.192)	(0.191)	(0.192)	(0.192)	(0.194)	(0.237)
Basal Area per Forest	1.199*	1.135*	1.138*	1.347**	1.278*	0.981
Area (per ha)	(0.635)	(0.630)	(0.596)	(0.646)	(0.645)	(0.681)
Ratio of Pine	-0.579***	-0.584***	-0.616***	-0.558***	-0.558***	-0.589***
Trees	(0.163)	(0.164)	(0.164)	(0.158)	(0.159)	(0.16)
Management Variables						
Dummy for	0.520$^{***}_{+++}$	0.495$^{***}_{+++}$	0.521$^{***}_{+++}$	0.425$^{**}_{+++}$	0.425$^{**}_{+++}$	0.401$^{**}_{++}$
Project	(0.181)	(0.173)	(0.170)	(0.173)	(0.174)	(0.176)
Years under Informal	0.005	0.006	0.005			
Management	(0.006)	(0.006)	(0.006)			
Years under Formal	-0.032					
Management	(0.035)					
Dummy for Formal		-0.135	-0.253			
Management		(0.139)	(0.24)			
Years of Informal Regulation				0.026$_{+}$	0.025$_{+}$	0.005
on Grazing				(0.017)	(0.018)	(0.023)
Years of Formal Regulation				-0.049		
on Grazing				(0.051)		
Dummy for Formal Regulation					-0.074	0.486
on Grazing					(0.165)	(0.435)
Adjusted R-squared	0.21	0.21	0.20	0.21	0.21	0.10
Correlation between Predicted and Observed Y$^{b)}$	0.38	0.37	0.37	0.38	0.39	0.37

*, **, 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) Refer to footnote b) of Table 12.

Table 17: Determinants of Plot-wise Grazing: 2,444 plots in 97 Forests

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable (Y)	Lopping Index Between 0 (Hevily Grazed) to 2 (not Grazed)					
Estimator$^{a)}$	Random Effect (R.E.)	R.E.	IV of R.E.	R.E.	R.E.	IV of R.E.
Constant	1.352	1.349	1.078	1.101	1.018	0.603
	(1.044)	(1.077)	(1.245)	(1.024)	(1.035)	(1.098)
Households per Forest Area (per ha)	-0.004	-0.004	-0.004	-0.006	-0.005	-0.006
	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)
Log of Time to Forest (minutes)	0.008	0.008	0.028	0.030	0.034	0.060
	(0.087)	(0.089)	(0.101)	(0.086)	(0.086)	(0.089)
Log of Lowest Altitude (meter)	-0.078	-0.078	-0.054	-0.053	-0.044	-0.003
	(0.145)	(0.147)	(0.157)	(0.144)	(0.145)	(0.149)
Slope	0.617^{***}	0.617^{***}	0.617^{***}	0.617^{***}	0.616^{***}	0.615^{***}
	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)	(0.068)
Dummy for Plots Facing to North	-0.018	-0.018	-0.018	-0.017	-0.017	-0.016
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Log of Basal Area in Plot	0.011	0.011	0.011	0.011	0.011	0.010
	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
Ratio of Pine Trees	0.079^{**}	0.079^{**}	0.079^{**}	0.080^{**}	0.080^{**}	0.079^{**}
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Management Variables						
Dummy for Project	0.325^{**}_{++}	0.322^{**}_{++}	0.306^{*}_{++}	0.262_{+}	0.251_{+}	0.210_{+}
	(0.163)	(0.162)	(0.165)	(0.163)	(0.164)	(0.168)
Years under Informal Management	0.011_{+}	0.011_{+}	0.012_{+}			
	(0.008)	(0.008)	(0.008)			
Years under Formal Management	-0.007					
	(0.032)					
Dummy for Formal Management		-0.019	0.072			
		(0.127)	(0.246)			
Years under Informal Mgt. on Grazing				0.030^{*}_{++}	0.027^{*}_{++}	0.022_{+}
				(0.016)	(0.016)	(0.017)
Years under Formal Mgt. on Grazing				0.035		
				(0.040)		
Dummy for Formal Mgt. on Grazing					0.148	0.410_{+}
					(0.140)	(0.272)
σ_e	0.185	0.185		0.185	0.185	
σ_u	0.269	0.269		0.269	0.271	
Lagrange Multiplier Test	18918.2^{***}	18943.6^{***}		17889.2^{***}	18554.2^{***}	

*, **, 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).
Refer to the notes in Table 13.

Other than the management variables, the ratio of pine trees has statistically significant coefficients in all the estimates. For this variable, there is a puzzling discrepancy between Table 16 and Table 17. In the forest-wise analyses, the ratio of pine trees have negative coefficients (Table 16). That is, the forests with more pine trees were grazed more intensively. This finding is counterintuitive because pine leaves are not suitable for fodder and there is less grass under pine trees. In fact, in plot-wise analyses, the ratio of pine trees has positive and statistically significant coefficients (Table 17). That is, the plots with more pine stands were grazed less intensively. An interpretation of this discrepancy is that forest areas with many pine trees are attached less importance by users who mainly utilize minor NTFPs such as firewood and fodder. Thus, on such forest areas, the control by any management systems are less strict, which results in more grazing on the plots other than pine plots.

We do not report the results with lopping and leaf-litter collection indices because no management variables are statistically significant there.

6 Conclusion

With more than one-hundred randomly sampled forests, the paper examined the effects of community (informal users group) and co-management (formal users group) on forest-resource conditions in the Middle Hills of Nepal. The results can be summarized as follows. First, since 1978, the degradation trend of forest conditions in the Middle Hills has been partially reversed. According to the aerial-photo analyses, nearly one-third of sampled forests experienced some improvement in their resource conditions. Second, forest-related projects (ex. tree-planting projects) had positive impacts on forest conditions that can be identified in the aerial photographs. Third, the co-management system (formal users groups), which is the users groups registered at the local forest offices, contributed to increase tree regeneration. Lastly, community (informal) management systems reduced the incidents of forest fire. In addition, the informal management systems seem to have lessened grazing activity. The statistical supports for the impacts on grazing intensity are, however, weak.

The above-mentioned third finding about regeneration suggests that official support for community management, co-management, will improve the forest conditions in the long run. Our field observations suggest that registration of a users group often enhances the authority of its management committee. With enhanced authority, the formal users groups sometimes close all or part of the forest for several years. This closing of forests is likely to have resulted in improved regeneration. Our analyses, however, also suggest that co-management is not necessarily a prerequisite for the effective regulations on shifting cultivation (forest fire) and grazing. For suppressing such bold activities in forests, unauthorized agreement among the users seems to be sufficient.

Four field observations are worth to be noted. First, community management of forest had a tendency to affect the management of nearby forests. Initiation of community management implies severer restrictions to the use of forest resources by the outsiders. Those who were under stricter restrictions or were excluded from the use of some forest tended 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 conditions 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, a plaintive field observation, which we could not quantify, was the effects of 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 conditions of natural forests. It is a combination of aerial-photo analysis and forest inventory. Ideally, by utilizing GPS (Global Positioning System), we should fix the locations 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.

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Appendix: Method of Forest Inventory

We first discuss sampling of plots, and then explain measurement method. Usually sampling intensity in forest inventory should be determined based on the variance of the variable of interest.In planted forests, it is mostly timber stock per specified area. Here we encountered two difficulties. First, we would like to evaluate the conditions of natural forests, on which people depend for multiple resources: timber, firewood, leaf litter, fodder, place for grazing, medical plants, etc. Thus we are interested in several variables: not only timber volume but also diversity of tree species, regeneration rate, trace of fire and grazing, etc. For forests in the Middle Hills of Nepal, there were no published data sets describing the variances of these multiple indicators. Second, our budget did not allow us to measure small preliminary samples to determine the variances of variables in each forest.

To circumvent these problems, we have made simplifying assumptions. First, we set up a conceptual variable of our interest: *forest-resource condition*. This is because, as stated above, our purpose is to evaluate natural forests in terms of their potential production of multiple resources. Second, we assume that the forest-resource condition, the conceptual variable of our interest, can take only two values: good or bad. We make this assumption because there is no widely-accepted composite index that summarizes the potential production of various forest resources. Third, we assume that a forest consists of units, each of which bears either good or bad forest-resource condition. For simplicity, we adopt one hectare of squared area as the unit. That is, we implicitly assume that a continuous forest area of one hectare usually has uniform forest-resource condition. Thus a forest with the area of one hundred hectare consists of one hundred units, which are the population to be investigated in our inventory.

The most drastic simplifying assumption is that we can make precise inference about the forest-resource condition of a unit by measuring one percent of its area. In other words, we assumed that we could gain precise information about forest-resource condition of one-hectare unit by measuring a plot with 100 square meters. Lastly, we applied the following common formula to determine the sampling intensity.

$$n = \left[\frac{N}{\left(\frac{e}{1.96}\right)^2 * \frac{N-1}{0.25} + 1} \right] + 1, \tag{4}$$

where n is the number of sampled plots of 100 square meters, 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, as is usual, we set the population ratio of good forest-resource conditions at 50%, which makes the possible error largest. Due to budget constraint, we set possible error e at 10%.

Table 18: Number of Sample Plots under $e = 0.10$

N	10	25	100	220	380	440
n	10	21	50	68	77	79

With these simplifying assumptions, we derived sample size for each forest under investigation. Admittedly the measurement intensity of 0.5 to 1% 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 official forest inventories in Nepal.[19] In each forest, based on field observation, 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.

In the sampled plots, we recorded the names of species, diameter at breast height (DBH: about 1.37 m from the ground) and height of all the stands with DBH ≥ 10 cm. DBH was measured for all the stands. We measured at least two to three trees with different height in a plot. 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 more than 20 cm. 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, and sub-whippy.

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[19] See, for example, Forest Research and Survey Center and Forest Resource Information System Project (1994), which reports the forest inventory in a district located in Siwalik area. The measurement intensity was about 0.4% of accessible forests (defined by the slope) and 0.1% of total forest are of the district.

We refer to Shrestha (1989), Storrs and Storrs (1998), and Nepal-Australia Community Forestry Project (1994) to find out botanical names of measured trees.

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